User's Guide

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on behalf of the
Sea Launch Limited Partnership

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ABBREVIATIONS AND ACRONYMS

ACS	assembly and command ship
ARS	anomaly resolution system
AST	U.S. Department of Transportation Office of the Associate Administrator for Commercial Space Transportation
BR9DM	Zenit-3SL telemetry system
CARF	central altitude reservation function
CCAM	contamination and collision avoidance maneuver
C_3	velocity squared at infinity
CCTV	closed-circuit television
CDR	critical design review
CIS	Commonwealth of Independent States
CLA	coupled loads analysis
CPSP	customer prelaunch safety package
EGSE	electrical ground support equipment
EMC	electromagnetic compatibility
EMI	electromagnetic interference
EPTME	encapsulated payload transportation mechanical equipment
EPTV	encapsulated payload transport vehicle
FAA/AST	U.S. Department of Transportation Office of the Associate Administrator for Commercial Space Transportation
FMH	free molecular heating
FONSI	finding of no significant impact
GEO	geosynchronous Earth orbit
GORR	ground operations readiness review
GPS	global positioning system
GSE	ground support equipment
GTO	geosynchronous transfer orbit
h_a	height of apogee
h_p	height of perigee
HP	Home Port
ICD	interface control document
I/F	interface
ILV	integrated launch vehicle
IPT	integrated product team
IS	interface skirt
ISPS	interface skirt and payload structure
LAN	local area network
LCC	launch control center

LEO	low Earth orbit
LOX	liquid oxygen
LP	launch platform
LRR	launch readiness review
LV	launch vehicle
MD	mission director
MDR	mission dress rehearsal
MECO1	main engine cutoff number 1
MEO	medium Earth orbit
MES1	main engine start number 1
MMDS	mission management display system
MRR	mission readiness review
NIMA	National Imagery and Mapping Agency
OASPL	overall sound pressure level
PDR	preliminary design review
PLF	payload fairing
PLU	payload unit
PPF	payload processing facility
RF	radio frequency
RH	relative humidity
S&MA	safety and mission assurance
SBA	strongback assembly
S/C; SC	spacecraft
SCA	spacecraft adapter
SL	Sea Launch
SLS	Sea Launch system
TDRSS	Tracking and Data Relay Satellite System
TIM	technical interchange meeting
TM	technical manual
WX	weather
XFR	transfer

1. 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.
- The assembly and command ship.
- Spacecraft and launch vehicle processing facilities.
- Tracking and communications assets.

Sea Launch Standard Offerings and Options (appendix B) describes the hardware, launch services, facilities, support services, and optional services provided by the Sea Launch Limited Partnership.

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

Advantages

Our marine-based operations concept provides a number of advantages over traditional 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 desired azimuth, largely unconstrained by terrain overflight considerations. Launching at sea permits equatorial or near-equatorial launch of geosynchronous satellites, which improves the mass-to-orbit capability by eliminating costly plane change maneuvers.

The Sea Launch system is compatible with both a “ship and shoot” approach to spacecraft processing and the traditional method of post-transportation spacecraft testing.

The Sea Launch system accomplishes launch vehicle tracking, telemetry, and command through the use of the assembly and command ship Tracking and Data Relay Satellite System (TDRSS), and existing ground stations within Russia and the Commonwealth of Independent States (CIS) territorial limits.

Timeline

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

Sea Launch is dedicated to reducing the time required for integrating and launching spacecraft. Deviations from the standard 18- and 12-month flows may be accommodated on a case-by-case basis. Similarly, the standard mission cycle time is 60 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 the Sea Launch system should complete the user questionnaire (appendix A) and return it to the address indicated in the appendix. On contract signature, Sea Launch will use the information in the user questionnaire to begin the integration process.

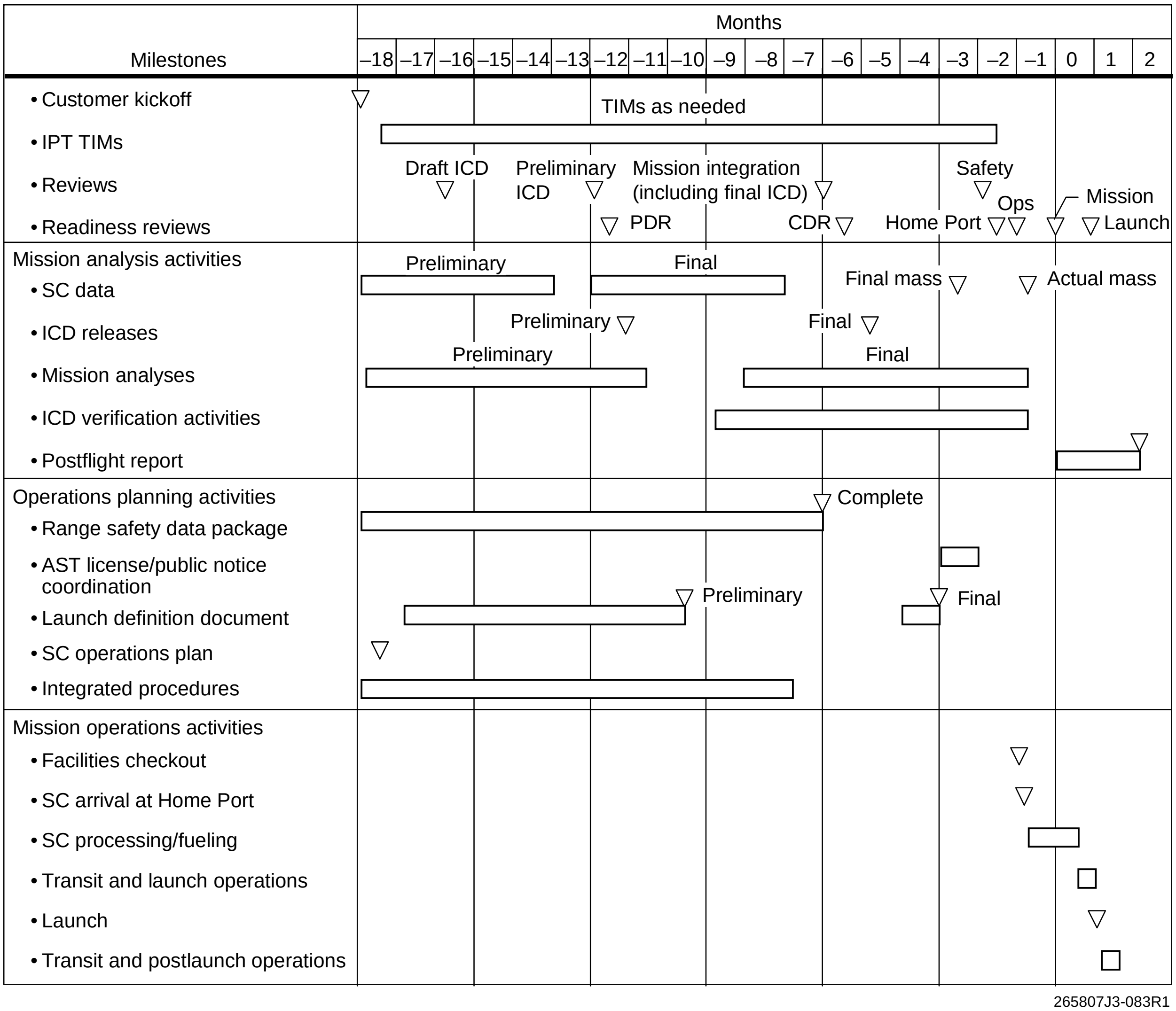

Figure 1-1. Generic Integration Timeline

1.2 Sea Launch Organization

Overview

The Sea Launch system is owned by the Sea Launch Limited Partnership. The partners are

- Boeing Commercial Space Company.
- RSC Energia.
- KB Yuzhnoye/PO Yuzhmash.
- Anglo-Norwegian Kvaerner Group.
- The general partner, Sea Launch Company, LLC.

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

The Boeing, Energia, KB 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. Each partner is also a supplier to the venture, capitalizing on the strengths of these industry leaders.

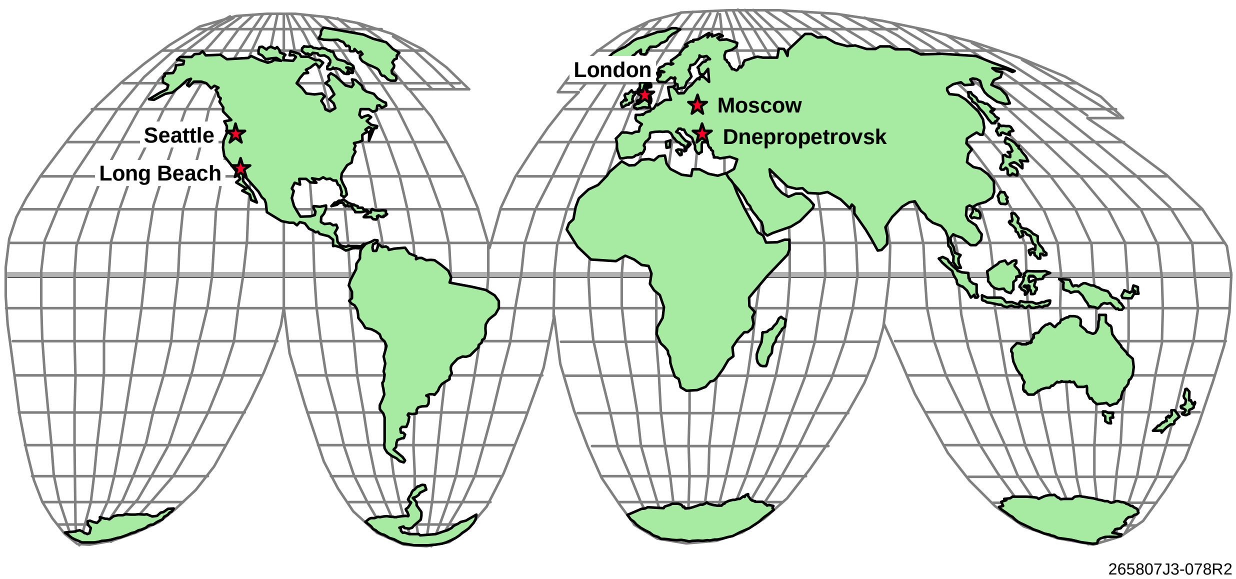

Figure 1-2. Sea Launch Partner Locations

Sea Launch Company

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

- Managing the overall project.
- Business management.
- Supplier management.
- Marketing and sales.
- Insurance and financing.
- Chief engineer

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 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 the Sea Launch project. Boeing responsibilities include

- Designing and manufacturing the payload fairing (fig. 1-3) and adapter.
- Developing and operating the Home Port facility.
- Integrating the spacecraft with the payload unit and the Sea Launch system.
- 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 legendary experience in space exploration and launch system integration to the Sea Launch project. Energia is a joint stock company established under the laws of the Russian Federation, with its principal place of business in Korolev (near Moscow), Russia. Energia has the overall responsibility for

- Developing and qualifying the Block DM-SL design modifications.
- Manufacturing the Block DM-SL upper stage (see fig. 1-4).
- Developing and operating the automated ground support equipment.
- Integrating the Block DM-SL with Zenit-2S and launch support equipment.
- Planning and designing the CIS portion of the launch operations.
- Developing flight design documentation for the flight of the upper stage.
- Performing launch operations and range services.

Figure 1-4. Block DM-SL

KB Yuzhnoye/PO Yuzhmash

KB Yuzhnoye/PO Yuzhmash, the leading Ukrainian aerospace organizations, are established under the laws of Ukraine, with their principal place of business in Dnepropetrovsk, Ukraine. They are also a contractor to the Sea Launch Company, LDC, and as the principal designers of ballistic missiles and launch vehicles for the former Soviet Union, have conducted hundreds of successful launches.

KB Yuzhnoye/PO Yuzhmash design and manufacture the Zenit 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

- Developing and qualifying Zenit-2S design modifications.
- 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 have been made to allow the basic Zenit design to meet Sea Launch's unique requirements. For example, the base of the launch vehicle has been stiffened to provide greater structural strength required to allow integration of the Block DM on a dynamic launch platform.

Figure 1-5. Zenit Launch Vehicle

Anglo-Norwegian Kvaerner Group

The Anglo-Norwegian Kvaerner Group of 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.

Kvaerner is also a contractor to the Sea Launch Company and is responsible for

- Designing and modifying the assembly and command ship (see fig. 1-6).
- Designing and modifying 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

2. VEHICLE DESCRIPTION

Overview

The Zenit-3SL is a liquid propellant launch vehicle (LV) 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.

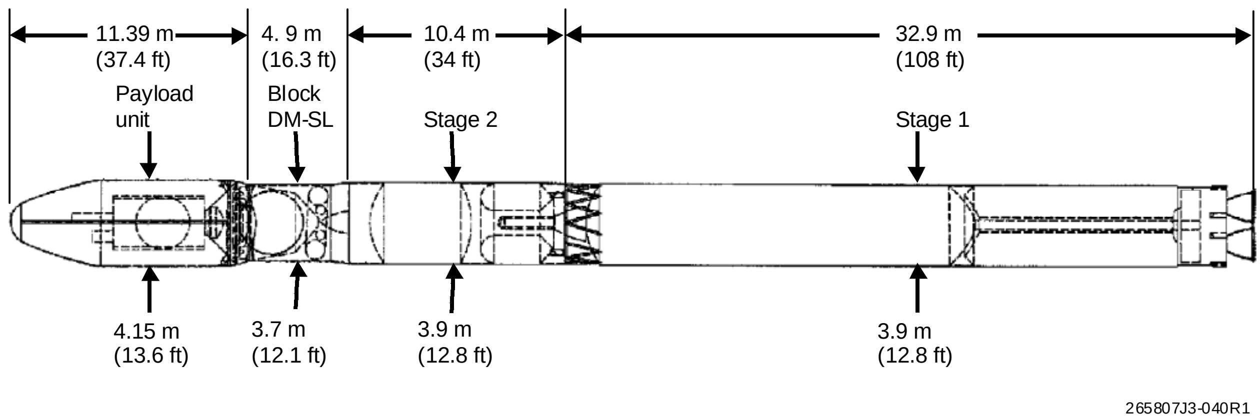

Figure 2-1. Zenit-3SL Launch Vehicle

Design

The original two-stage Zenit was designed by KB 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 June 2000, the Zenit two-stage vehicle has completed 30 missions in 34 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 an existing design developed by RSC Energia. It has a long and successful history as the fourth stage of the Proton LV.

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 184 successful missions as of July 2000. Primary missions have been geosynchronous transfer orbit (GTO); geosynchronous orbit (GEO); 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.

Flight success ratios

Table 2-1 lists flight success ratios for each of the three Zenit-3SL stages as of May 2000.

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

- Extensive testing performed when changes 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	42 of 44 (95.4%)	98.4%
Zenit Stage 2	1985	30 of 34 (88.2%)	94.3%
Block DM	1974	184 of 190 (96.8%)	98.2%

Payload accommodation (PLA)

The PLA is a new development hardware item, but the design is based on launch experience that extends back over three decades. The PLA 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 (see 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 LV. 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 (LOX) and kerosene (see fig. 2-3). It provides an impressive 1.6 million lb of thrust at liftoff and is one of the most powerful engines developed in the world. The LOX tank is positioned above the kerosene tank and the lower dome of the LOX tank is located in the concave top of the kerosene tank. A single turbo pump feeds four thrust chambers. Four differentially gimbaled thrust nozzles provide directional control during Stage 1 flight.

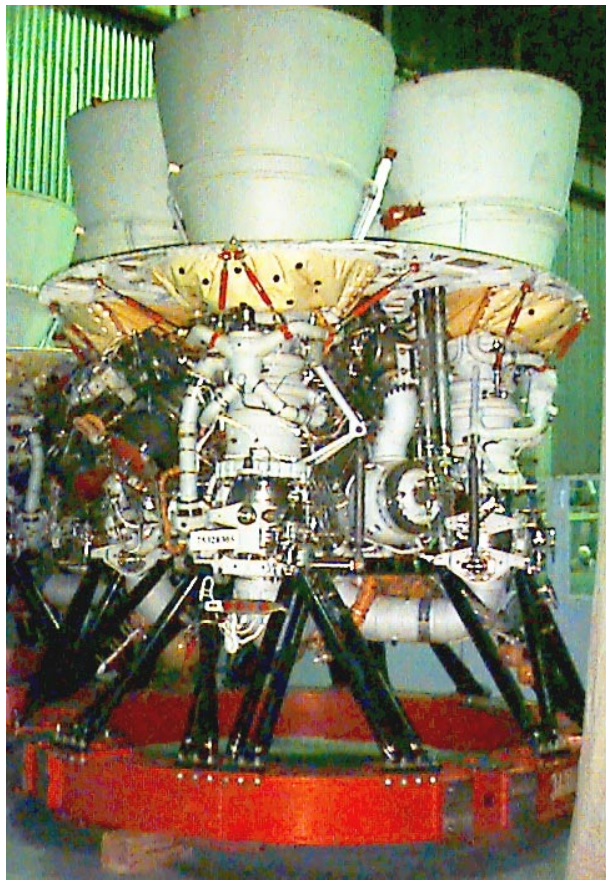

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Figure 2-3. RD-171 Stage 1 Engine

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)	353,870 kg (782,000 lb)	92,473 kg (200,000 lb)
Thrust (sea level)	737,700 kg (1.63 million lb)	Not applicable
Thrust (vacuum)	803,900 kg (1.77 million lb)	95,100 kg (209,700 lb)
Fuel (kerosene)	89,855 kg (194,900 lb)	23,006 kg (50,000 lb)
Oxidizer (LOX)	235,546 kg (512,700 lb)	58,848 kg (129,000 lb)

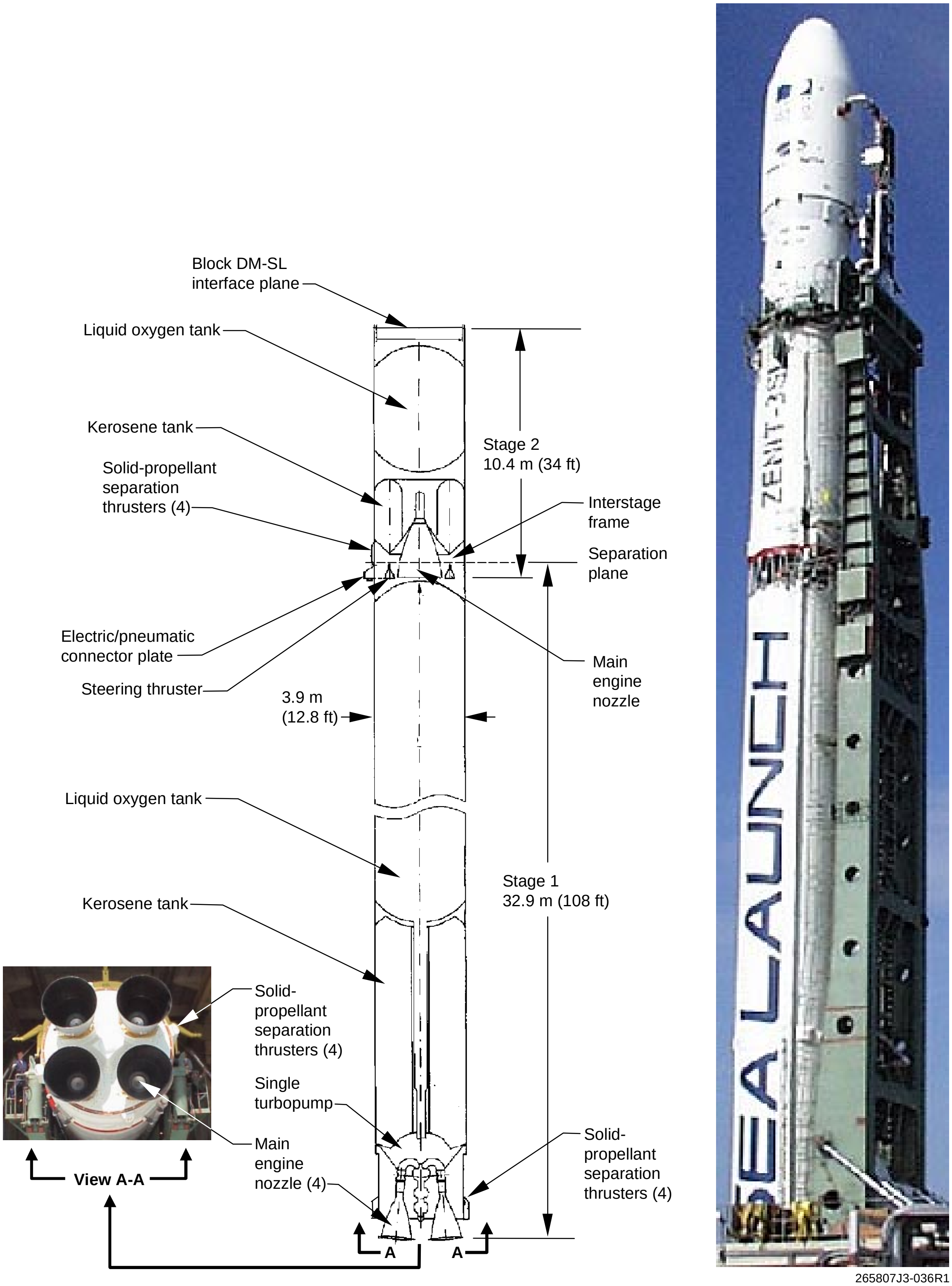

Figure 2-4. Zenit Stage 1 and Stage 2 Configuration

2.2 Zenit Stage 2

Stage 2 primary structure

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

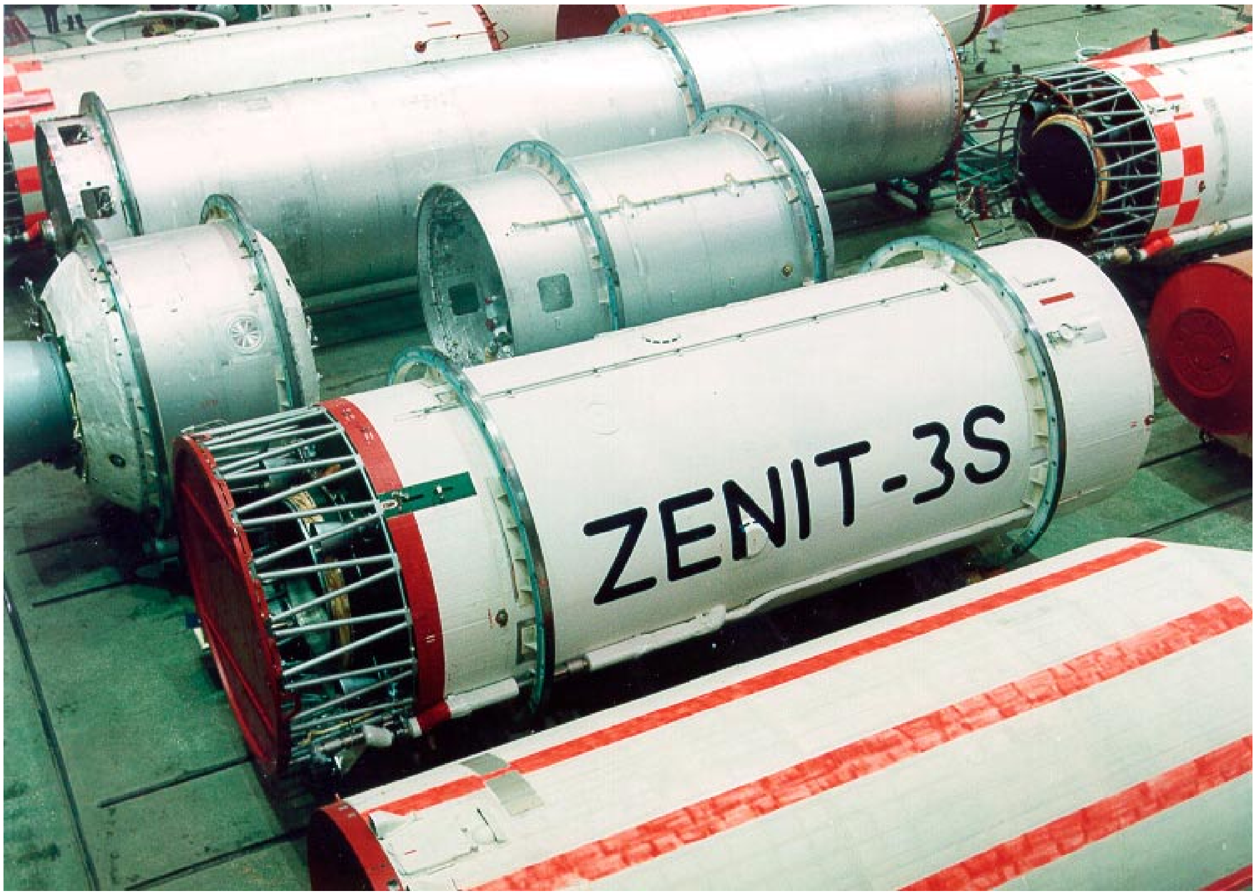

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Figure 2-5. Stage 2, Zenit-3SL

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 turbo-pump feeding four gimbaling thrusters. The RD-8 produces 8100 kg (17,900 lb) of thrust.

2.3 Block DM-SL—Upper Stage

Configuration

The Block DM-SL is a restartable upper stage capable of restarting up to four 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 turbo pump. 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)

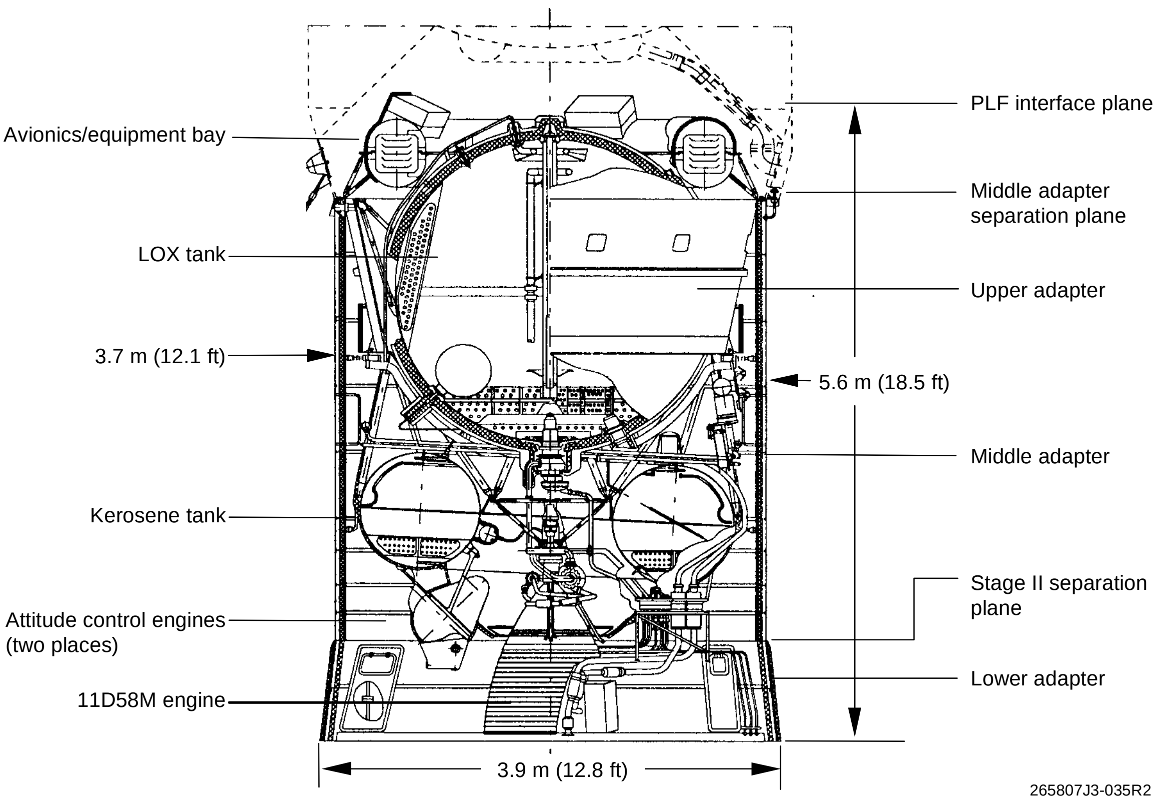

Figure 2-6. Block DM-SL

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 (N_2O_4) and monomethylhydrazine (MMH).

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]	18,600 kg (38,000 lb)
Thrust (vacuum)	8,000 kg (17,600 lb)
Fuel (kerosene)	4,200 kg (9,500 lb)
Oxidizer (LOX)	10,400 kg (22,800 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 adapter.

2.4 Payload Unit

Components and construction

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

The payload accommodation consists of the spacecraft adapter, payload structure, interface skirt (IS), payload fairing, and flight avionics and instrumentation. Figure 2-7 shows the arrangement of the major payload accommodation components. The construction is aluminum honeycomb/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 at the Home Port.

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

Future 5 m capability

Sea Launch is assessing customer interest in a 5 m diameter payload unit. If sufficient interest exists, Sea Launch will offer this capability to our customers in the 2002 to 2003 timeframe. 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 PLU operations, as well as similar avionics and structural interfaces.

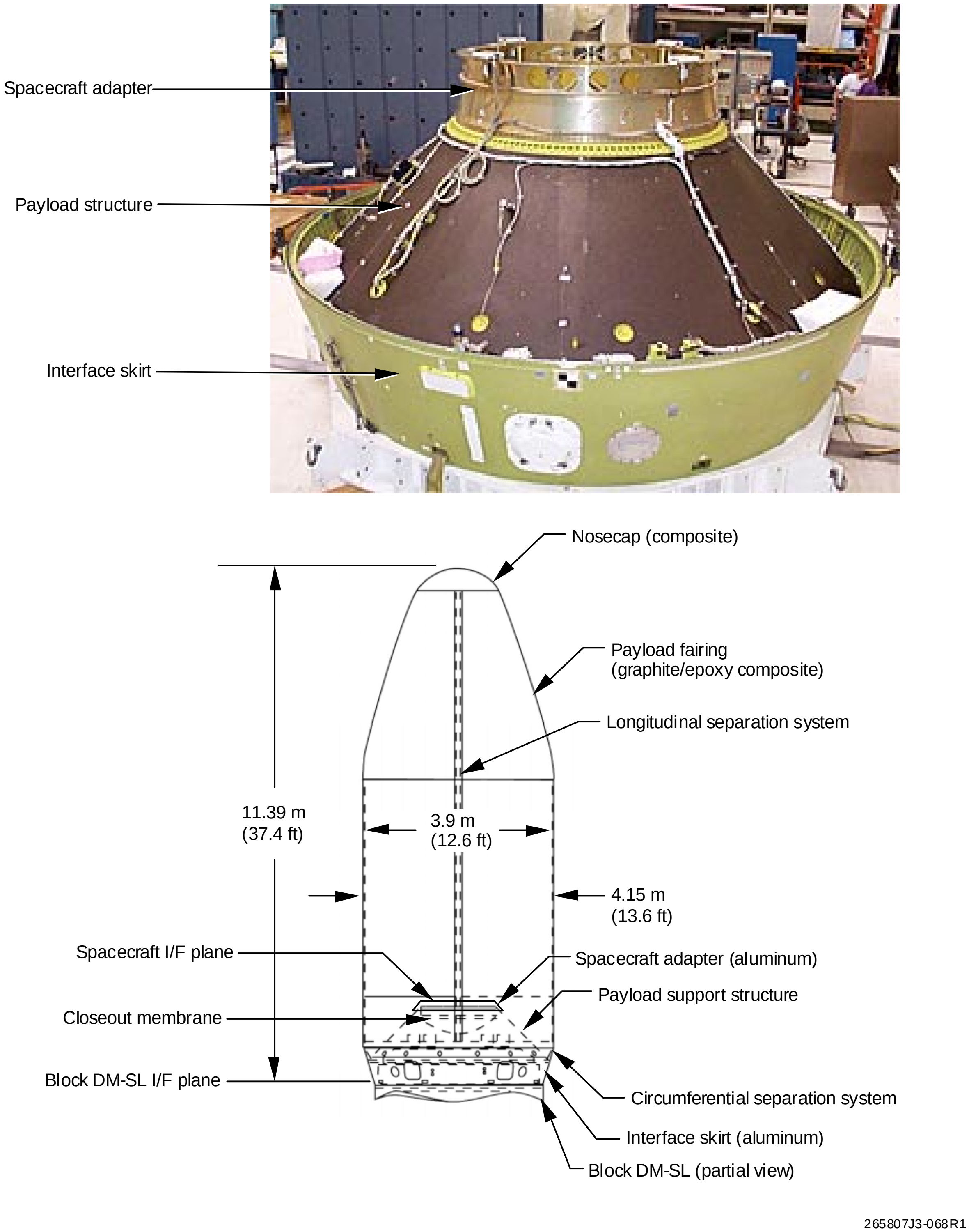

Figure 2-7. Sea Launch Payload Unit

Payload fairing The payload fairing provides environmental protection for the spacecraft from encapsulation through launch and ascent. It can accommodate a wide range of payloads.

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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 (see sec. 7, fig. 7-1).

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 (FMH) never exceeds spacecraft requirements. The customer can tailor the time of payload fairing jettison (and associated maximum FMH). The thermal environments are described in section 5.

Interface skirt (IS)

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

The IS is constructed of aluminum with integral stiffeners (see fig. 2-9). The IS is 0.81 m (2.6 ft) long and accommodates the transition from a 3.715 m (12.2 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 (SCA)

The SCA 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 (PS)

The PS 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 PS allow airflow out of the payload unit, and prevents 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.

3. PERFORMANCE

Overview

The Zenit-3SL can deliver spacecraft to a wide variety of orbits, including geosynchronous transfer orbit (GTO), medium Earth orbits (MEO), highly elliptical orbits, and Earth escape. Current capability to a standard GTO orbit (defined in sec. 3.3) is 5250 kg. Various performance-enhancing changes will be implemented to increase standard GTO payload capability to 5700 kg for future missions. Data presented in this section is for a generic mission only. Please contact Sea Launch for a performance quote specific to your mission requirements and launch date.

Characteristics of performance are covered in sections 3.1 through 3.6, including

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

Trajectory design process

Trajectory design is part of overall mission analysis process described more fully in section 4. On behalf of Sea Launch, BCSC flight design engineers work with the spacecraft customer to optimize the mission design and orbit at spacecraft separation, based on the customer's mission objectives. BCSC then provides the preliminary trajectory to the CIS partners and coordinates all customer requirements with them. Yuzhnoye and Energia generate the final trajectory and BCSC verifies that all spacecraft requirements are met. The CIS partners then generate the mission data load and verify it using Monte Carlo simulations with flight software and vehicle hardware. These simulations provide the final injection accuracy and verification of the propellant flight performance reserve.

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 points, weather, and vessel transit times. For nonequatorial missions that drive range safety concerns (e.g., an island located along the ascent groundtrack) an alternate launch site may be selected.

Site benefits

Because the site is located on the equator, no plane change maneuvers are required to reach an orbital inclination of 0 deg. Currently, the payload capability for the standard GTO mission is 5250 kg. In terms of spacecraft mass in final orbit, this would be equivalent to approximately 6000 kg of payload capability if launched from Cape Canaveral, because the spacecraft does not need to perform a plane change maneuver during the geosynchronous Earth orbit circularization burn. Also, a wide range of mission inclinations are possible because of the absence of land and major shipping lanes.

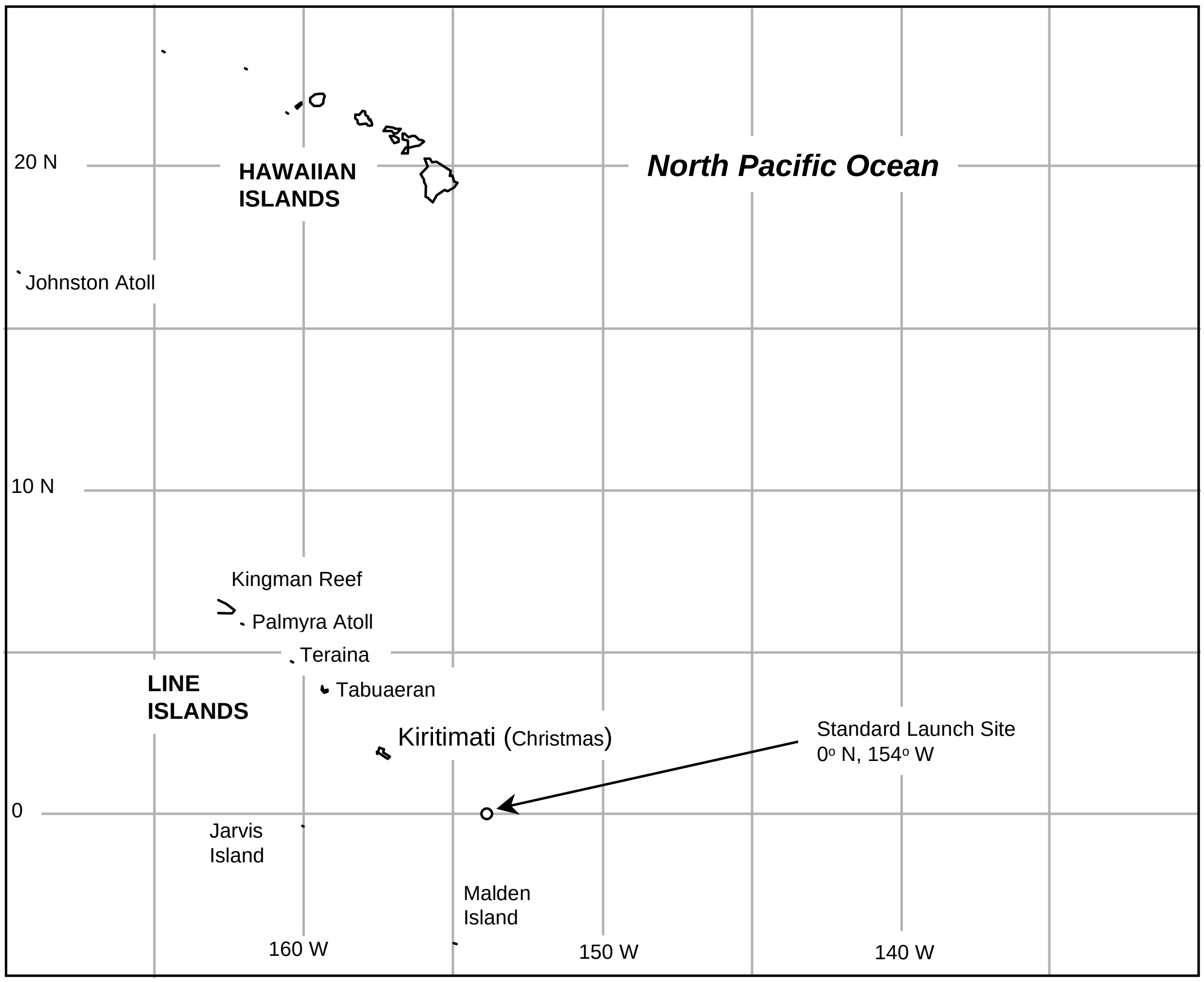

Figure 3-1. Standard Launch Site Location

3.2 Ascent Trajectory

Stage 1 flight

The Zenit Stage 1 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 to limit the maximum axial acceleration.

Stage 2 flight

The Zenit Stage 2 main and vernier engines provide the thrust for the next 6.2 min flight. Stage 2 vernier ignites prior to Stage 1 separation. The vernier engine operates alone for the initial 5 sec and final 75 sec of Stage 2 operation. The payload fairing is jettisoned 1 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 10.7 min of powered flight. Depending on mission requirements, the Block DM-SL performs one to five burns. For multiple burn missions, the initial burn establishes a stable parking or phasing orbit.

Flight timeline Table 3-1 lists the times when the main flight events occur.

Table 3-1. Typical Flight Timeline—GTO Mission

Time, Sec	Event
0	Liftoff
8	Begin pitchover
10 to 20	Roll to launch azimuth
63	Maximum dynamic pressure
109	Maximum axial acceleration
109 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
206	Payload fairing jettison
421 to 441	Stage 2 main engine throttle to 85%
441	Stage 2 main engine shutdown
516	Stage 2 vernier engine shutdown
517	Stage 2 separation
518	Block DM-SL middle adaptor jettison
527	Block DM-SL engine ignition
1,169	Block DM-SL engine shutdown
1,669	Spacecraft separation

Flight profile Figure 3-2 illustrates a typical GTO flight profile with key trajectory events and parameters labeled.

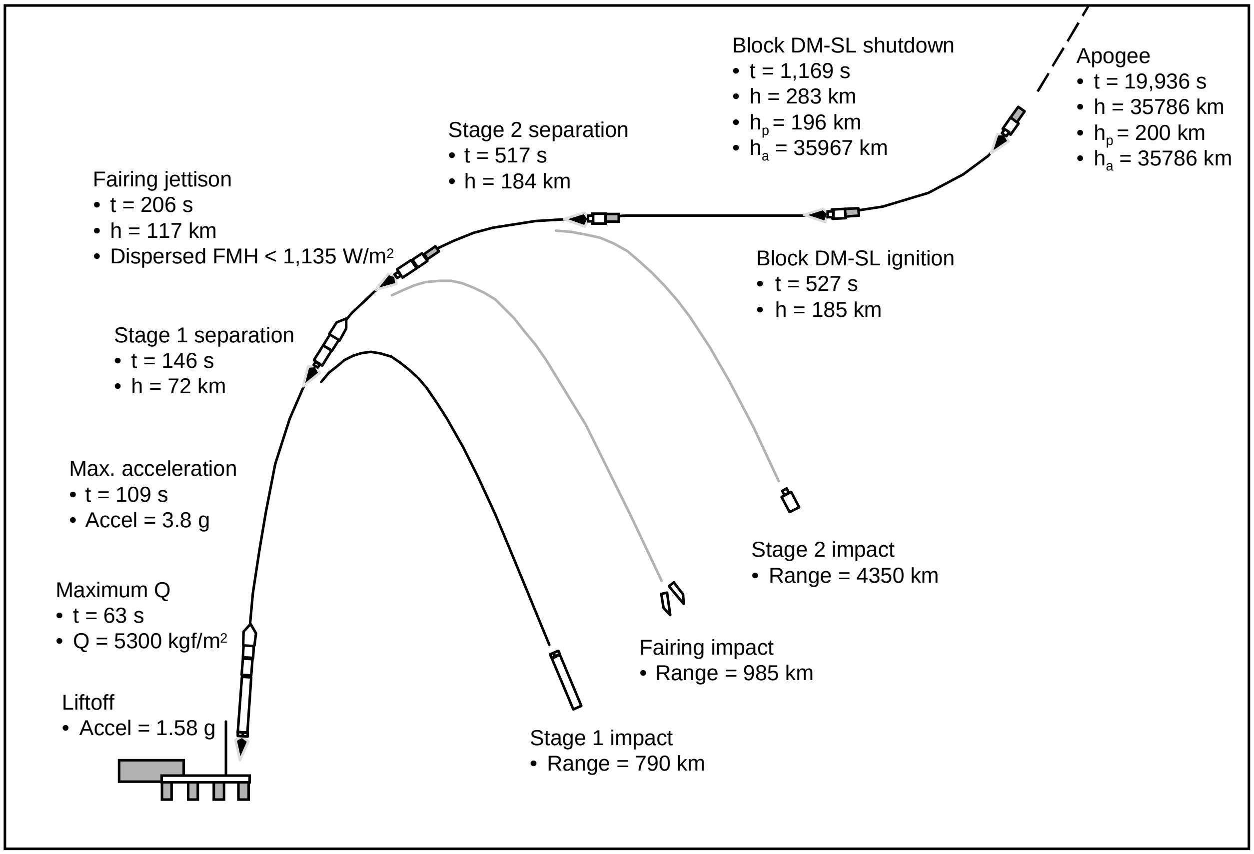

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Figure 3-2. Typical Flight Profile—GTO Mission

Groundtrack Figure 3-3 shows the ascent groundtrack, including nominal stage impact points and ascent trajectory parameters as a function of typical down range position.

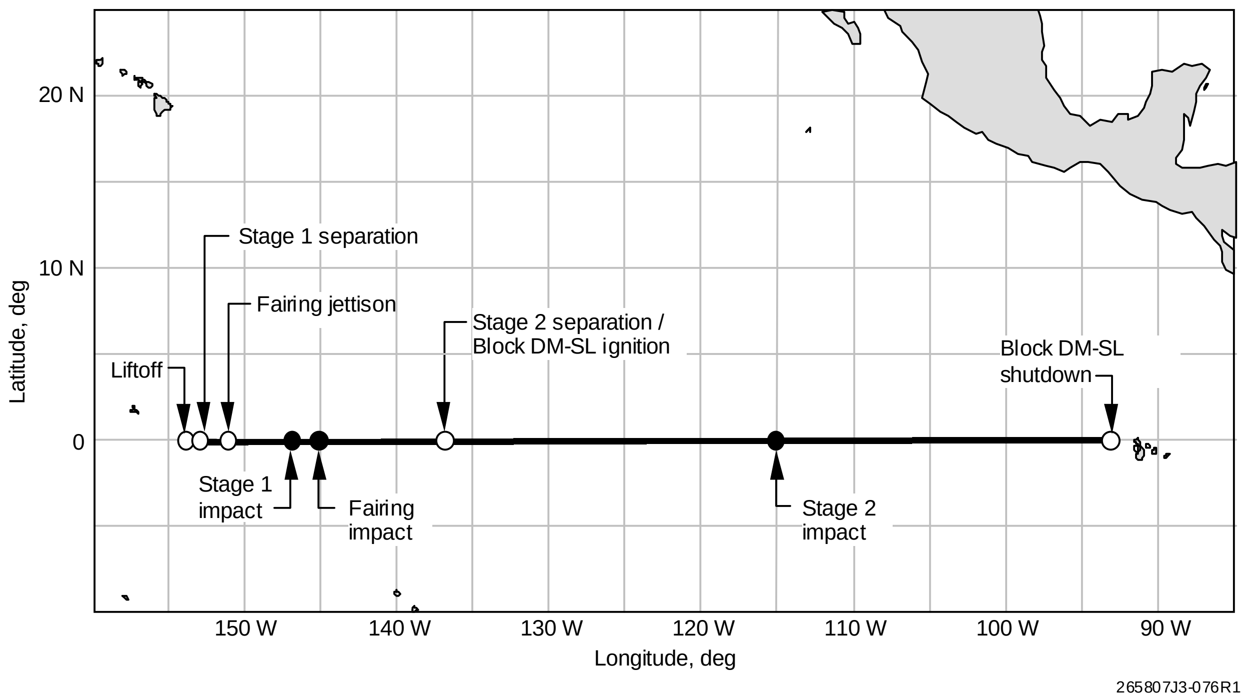

Figure 3-3. Typical Groundtrack—GTO Mission

3.3 Payload Capability

Ground rules

This section describes payload capability for geosynchronous transfer orbit, circular and elliptical orbits, and high-energy and escape orbits.

Performance data is provided based on the following generic set of ground rules:

- Payload capability is defined as mass of the separated spacecraft, assuming a 100 kg spacecraft adapter.
- Sufficient flight performance reserves are maintained to reach the specified orbit with a confidence level of at least 2.3σ.
- At the time of fairing jettison, the free molecular heating (FMH) is less than 1,135 W/m^2 with a confidence level greater than 3σ.
- Orbital altitudes are specified with respect to an Earth radius of 6378 km.

Injection schemes (see fig. 3-4) with one or two Block DM-SL burns are typically used. Structural limitations or mission-unique requirements, such as those requiring an additional burn, may reduce payload capability. See section 6 for more detail on structural limitations.

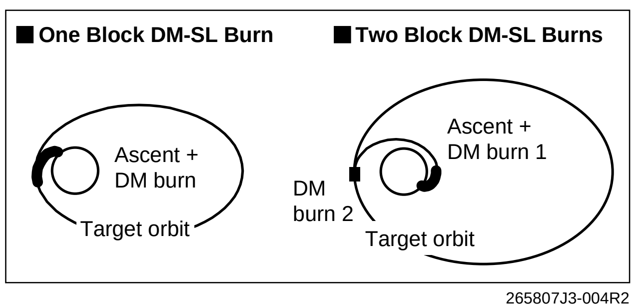

Figure 3-4. Block DM-SL One or Two Burns

Geosynchronous transfer orbit

The Zenit-3SL can deliver large satellites to a variety of GTOs. For maxium payload mass a standard GTO uses a single Block DM-SL burn and is defined by table 3-2 at the time of first apogee passage.

Table 3-2. Single Block DM-SL Burn Standard GTO Parameters

Orbital Parameter	Value at First Apogee Passage
Perigee altitude	200 km
Apogee altitude	35,786 km
Inclination	0 deg

GTO parametric performance

In addition to the standard GTO mission, the Zenit-3SL can deliver the spacecraft to orbits with lofted perigees and sub- or supersynchronous apogees. For missions with perigee altitudes less than 250 km, a single Block DM-SL burn provides optimum performance. For perigee altitudes above 250 km, two Block DM-SL burns provide optimum performance. The maximum payload capability for a range of typical GTO perigees and apogees is shown in figures 3-5 and 3-6.

Sea Launch can provide a range of argument of perigee and longitude of apogee values without a performance penalty for GTOs with perigee altitudes in the 250 to 2100 km range. This is due to the characteristics of the injection scheme typically used for this perigee range.

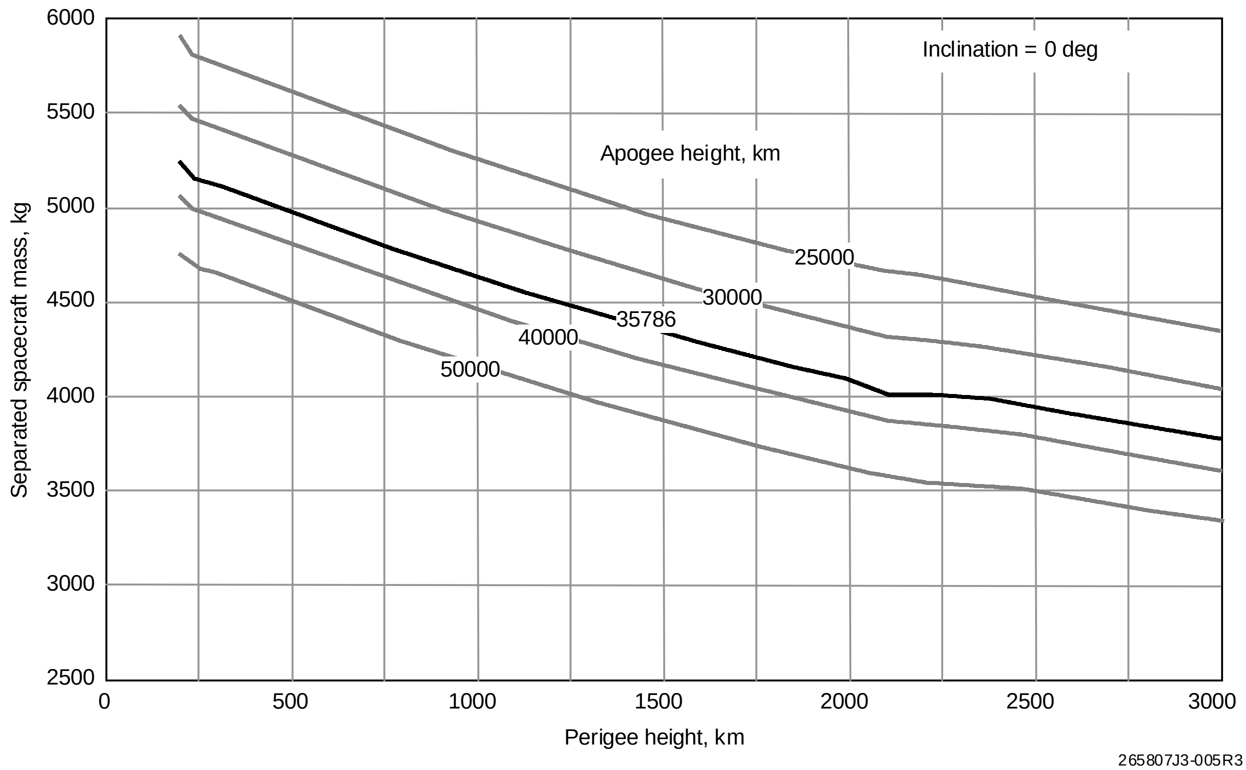

Figure 3-5. GTO Payload Capability—Lower Perigees

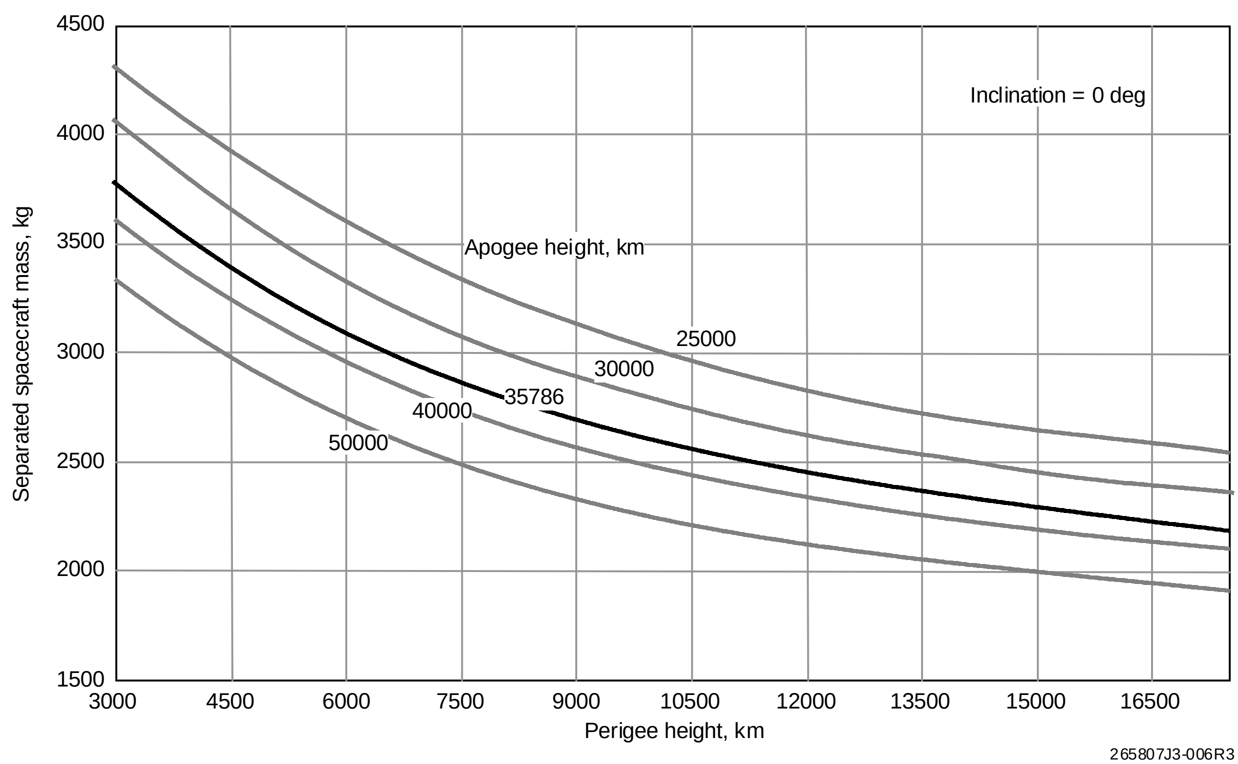

Figure 3-6. GTO Payload Capability—Higher Perigees

Circular and elliptical orbits

Figures 3-7 and 3-8 illustrate the Zenit-3SL payload capability for a range of circular and elliptical orbital altitudes and inclinations. For the nonzero inclinations, southeastern launch azimuths are typically used to avoid flight/impact point passage over highly populated areas in North America.

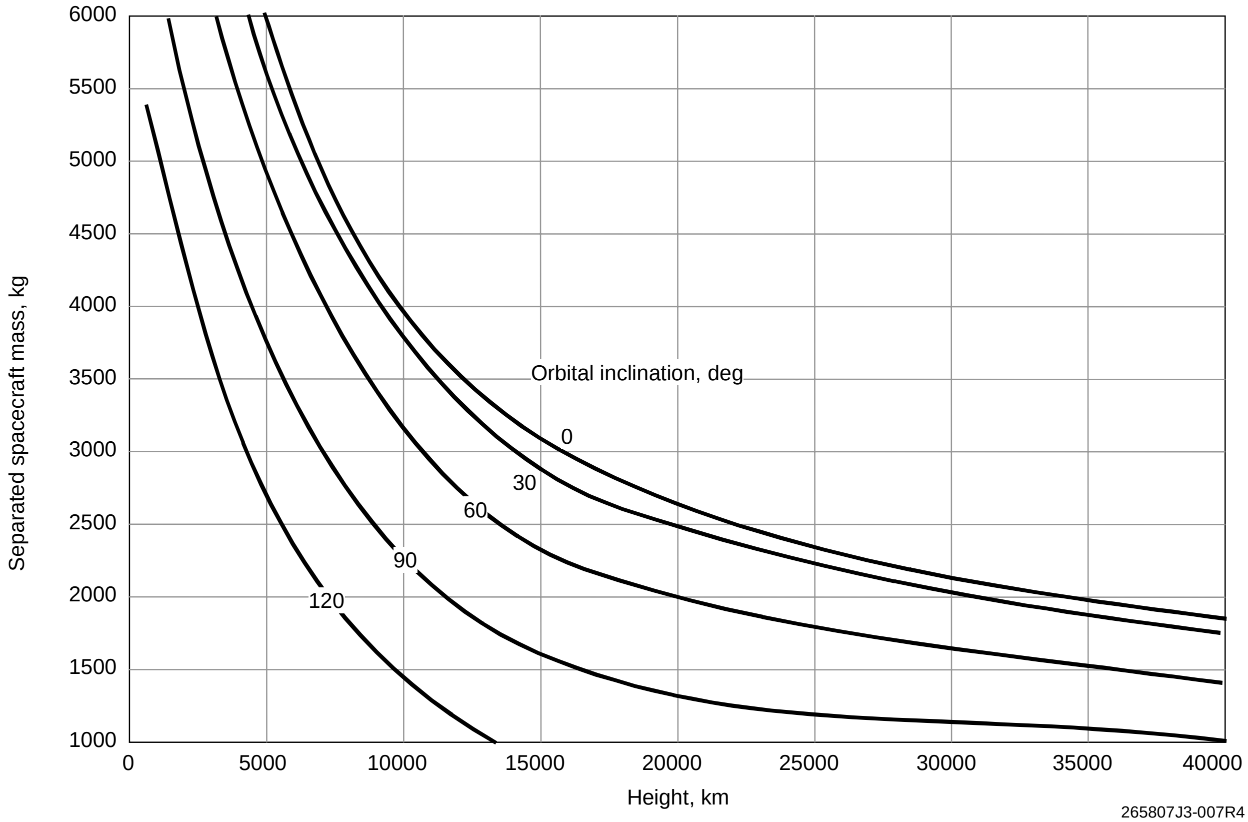

Figure 3-7. Circular Orbit Payload Capability

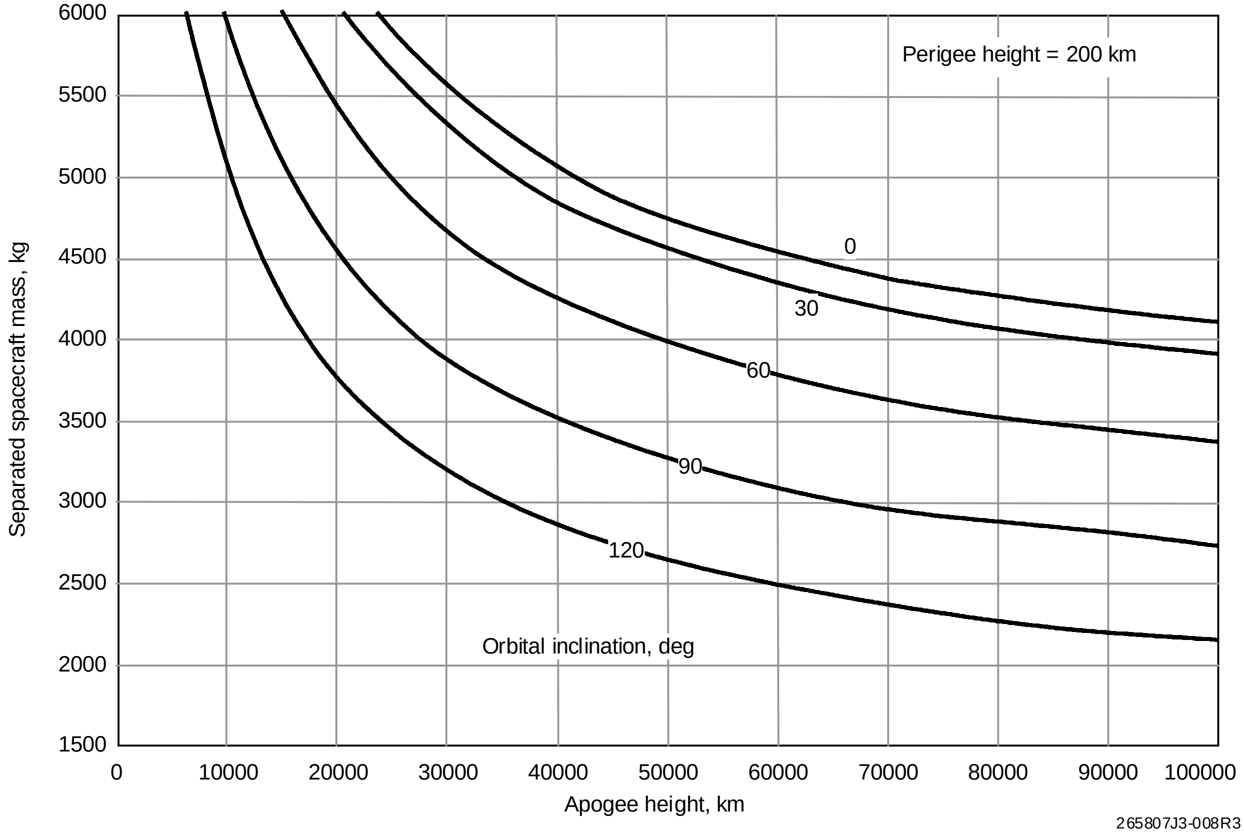

Figure 3-8. Elliptical Orbit Payload Capability

High-energy and escape orbits

Figure 3-9 illustrates the Zenit-3SL payload capability for a range of high-energy and escape orbits as a function of C_3, the velocity squared at infinity.

Note: There is no performance penalty for targeting a declination lower than the maximum declination.

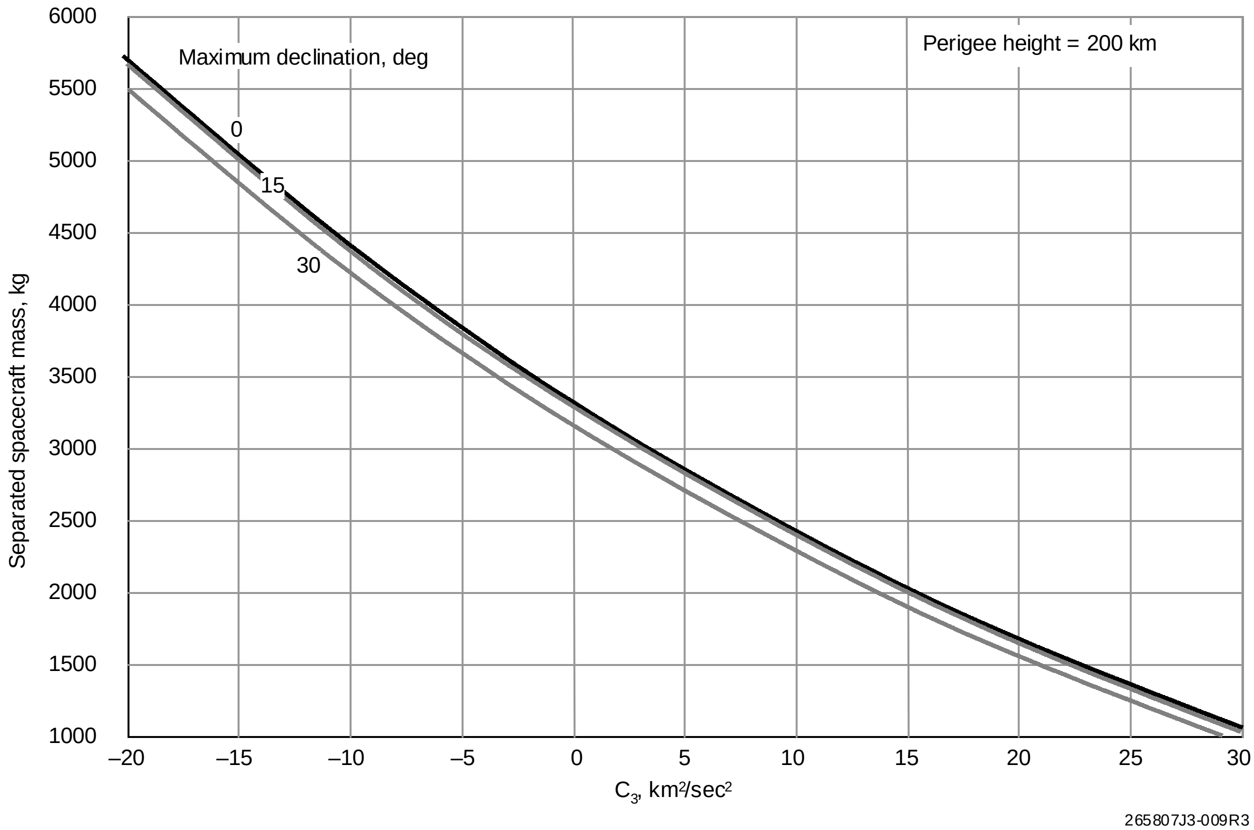

Figure 3-9. High-Energy and Escape Orbit Payload Capability

3.4 Coast Phase Attitude

Three-axis pointing

The Block DM-SL can accommodate preferred three-axis attitude pointing (including sun pointing) while coasting between Block DM-SL main engine burns. Attitude and attitude rate accuracy depend heavily on spacecraft mass properties. Preliminary attitude and attitude rate are assumed to be ±3 deg and ±0.25 deg/sec in all three axes (2.3σ).

Roll maneuvers

Continuous rolls for spacecraft thermal control and battery charging are supported. For a roll rate of 5 deg/sec, the roll-axis pointing accuracy is ±4 deg and the attitude rate accuracy is ±0.2 deg/sec in all three axes (2.3σ).

3.5 Spacecraft Separation

Separation event

Spacecraft separation typically occurs 500 sec 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 (CCAM), which prevents future contact with the spacecraft. The Block DM-SL then vents all residual propellant and gasses and depletes any remaining charge in its batteries.

Separation capabilities

The separation system provides a relative velocity between the Block DM-SL and the spacecraft of at least 0.3 m/sec. The Block DM-SL attitude control system can provide a longitudinal spin rate if desired. The separation springs can provide a straight pushoff or a small transverse angular rate.

Attitude and attitude rate accuracy depend heavily on spacecraft mass properties and spin rate, but for preliminary purposes may be assumed to be ±2.5 deg and ±0.6 deg/sec in all three axes for a nonspinning separation (2.3σ).

Injection accuracy

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

Table 3-3. Standard GTO Injection Accuracy (2.3σ)

Orbital Parameter	Injection Accuracy
Perigee height	± 10 km
Apogee height	± 80 km
Inclination	± 0.25 deg
RAAN	± 0.25 deg (nonzero inclinations)
Argument of perigee	±0.25 deg (nonzero inclinations)

3.6 Future Performance Capability

Planned performance growth

Various Zenit-3SL mass reductions and performance enhancements will be implemented during the next few years. This will increase the standard GTO mission payload capability from 5250 kg to 5500 kg. In addition, a higher performance Block DM-SL fuel will be available as an option which will increase the performance to 5700 kg. Table 3-4 shows a timeline of the planned performance enhancements for the standard GTO mission. As an added convenience, the parametric performance curves in section 3.3 are presented in figures 3-10 through 3-14 with multiple axes to represent a preliminary performance estimate as a function of launch date for a range of missions.

Table 3-4. Estimate of Additional Future Performance Capability as a Function of Launch Date

Launch Date	Payload Capability to Standard GTO	Additional Performance Capability
Current	5250 kg	
Late 2001	5400 kg	+ 150 kg
Early 2002	5500 kg	+ 250 kg
Mid 2002 **Note:** This additional performance increase will only be available as an extra cost option.	5700 kg	+ 450 kg

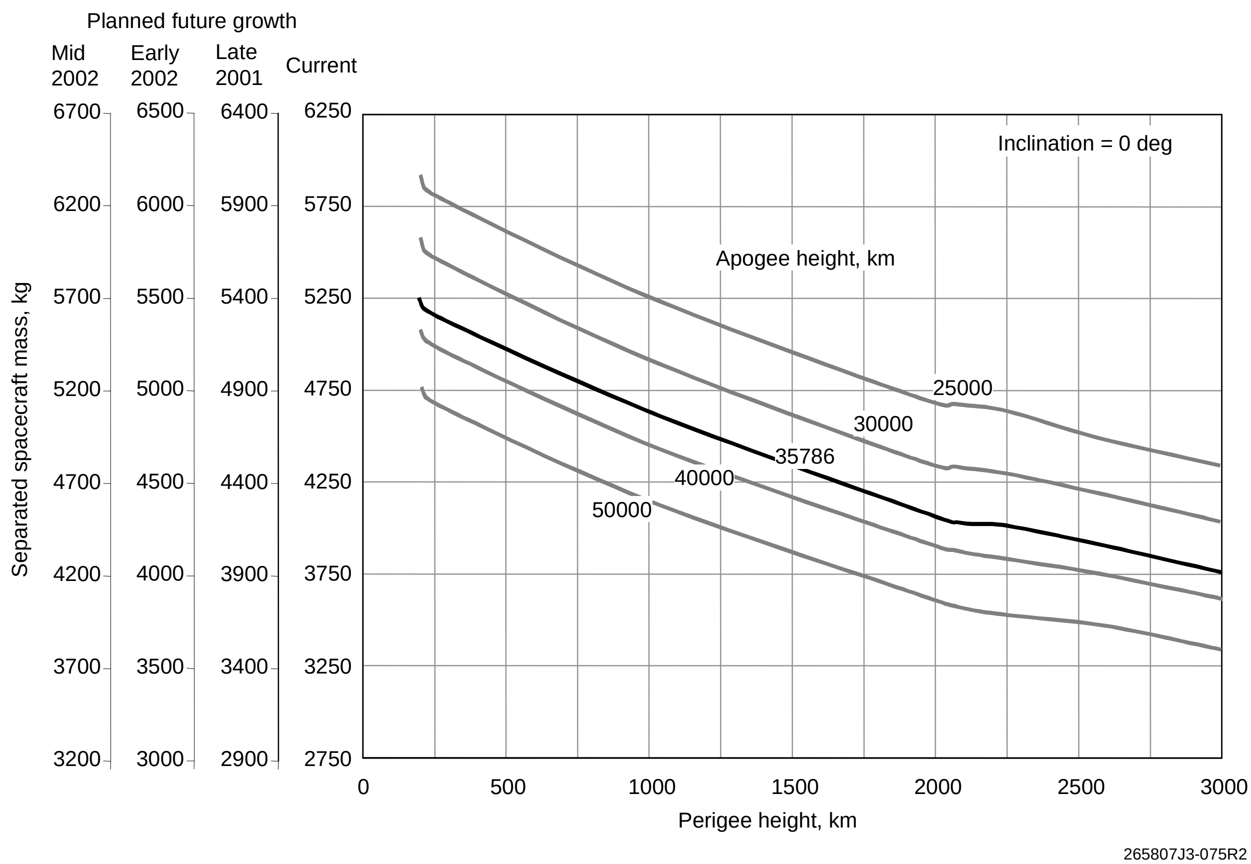

Figure 3-10. Future GTO Payload Capability Estimate—Lower Perigees

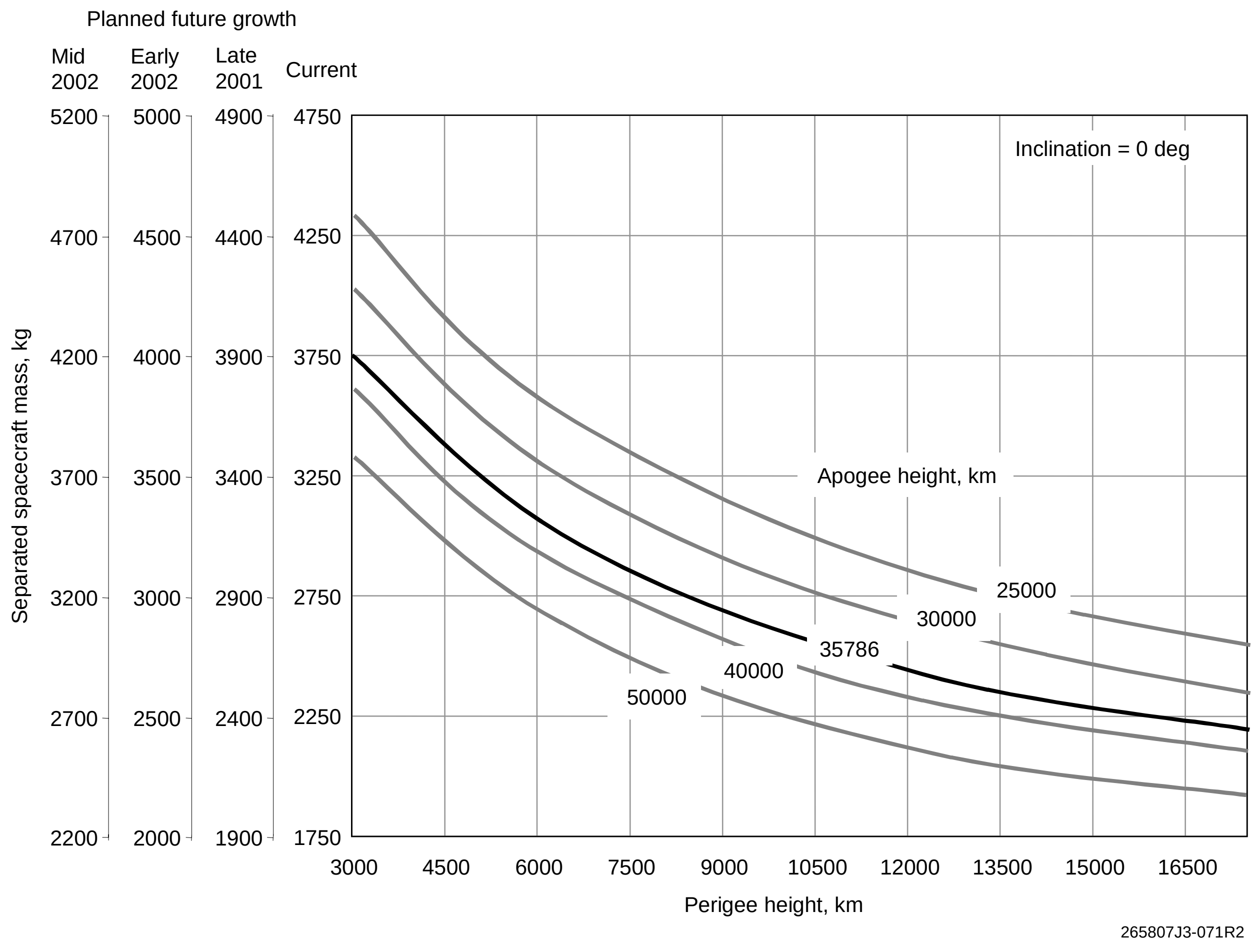

Figure 3-11. Future GTO Payload Capability Estimate—Higher Perigees

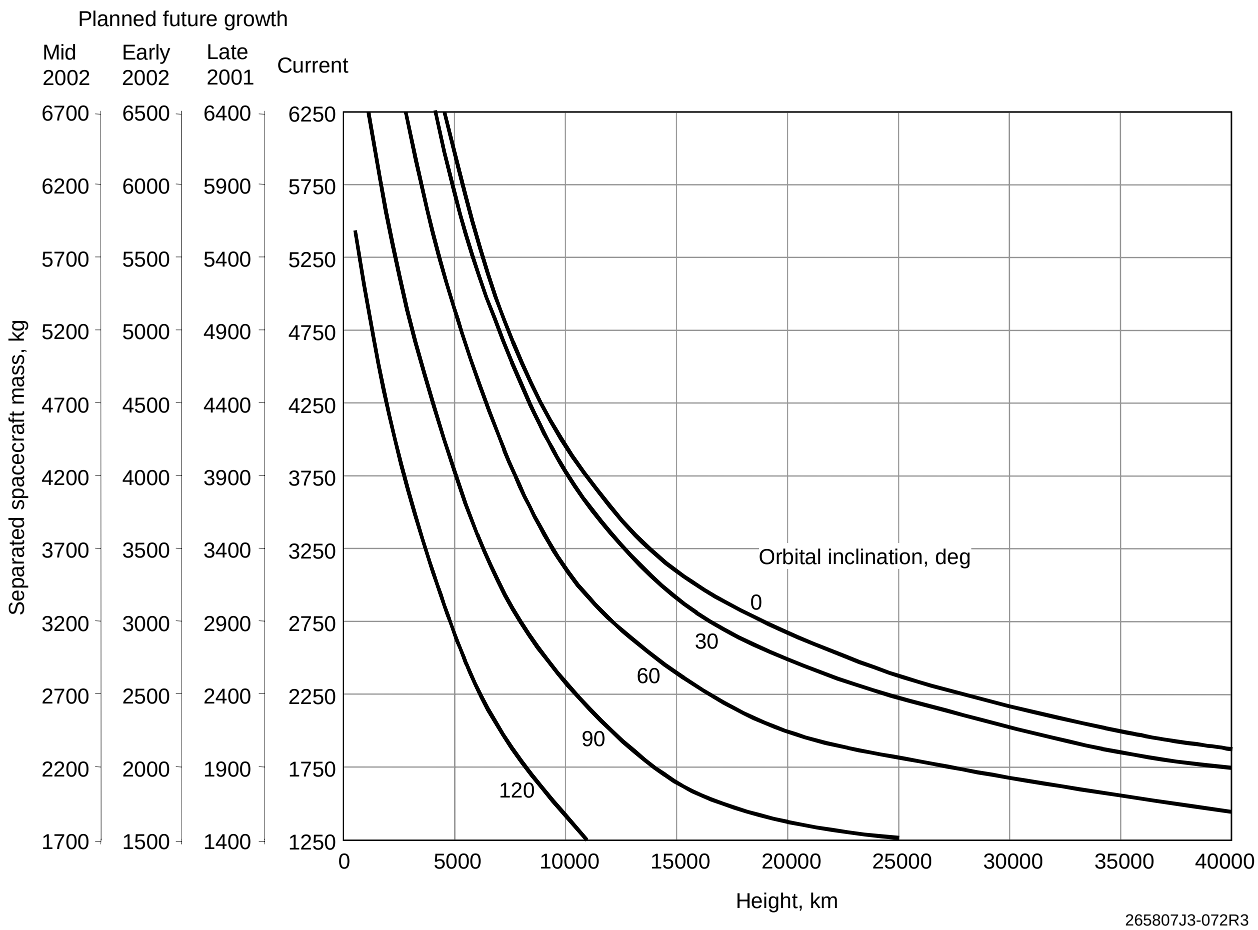

Figure 3-12. Future Circular Orbit Payload Capability Estimate

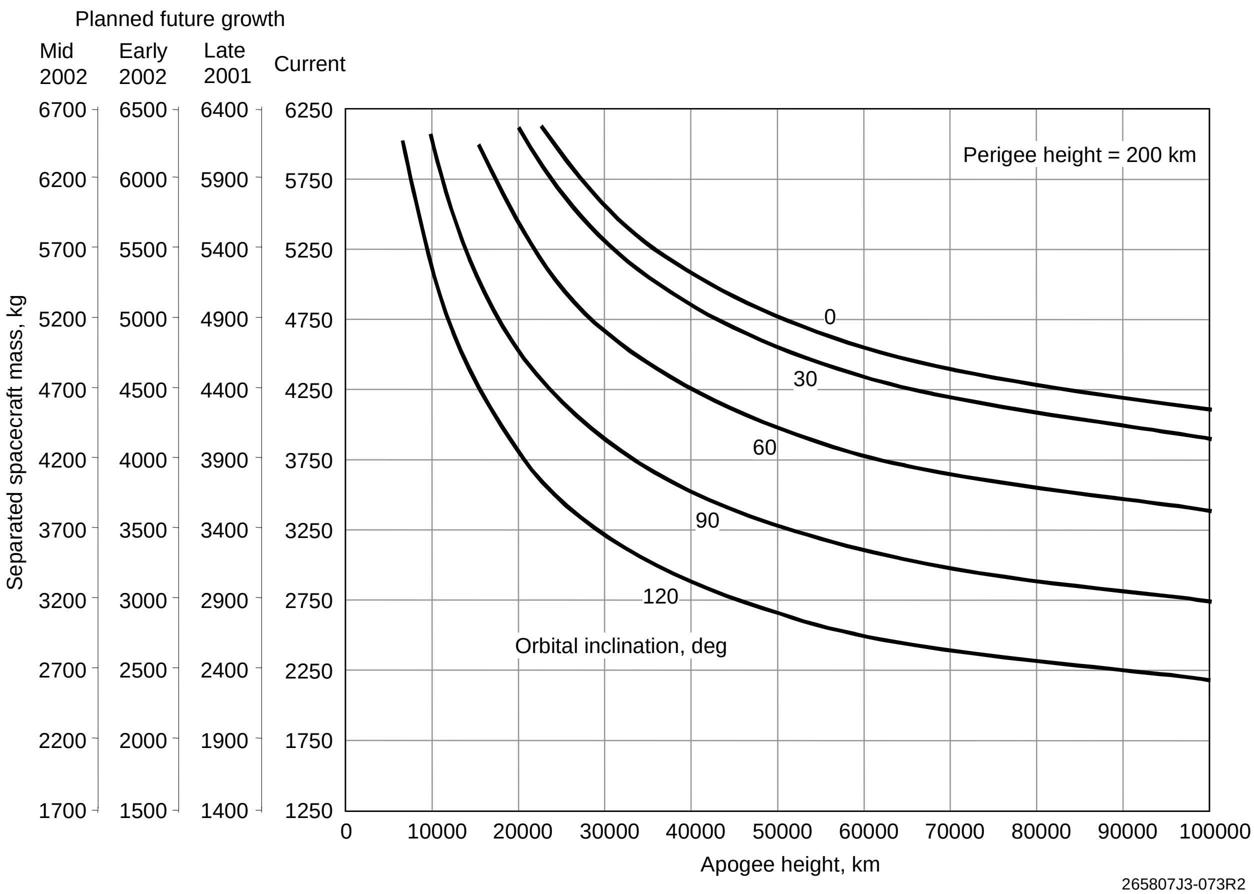

Figure 3-13. Future Elliptical Orbit Payload Capability Estimate

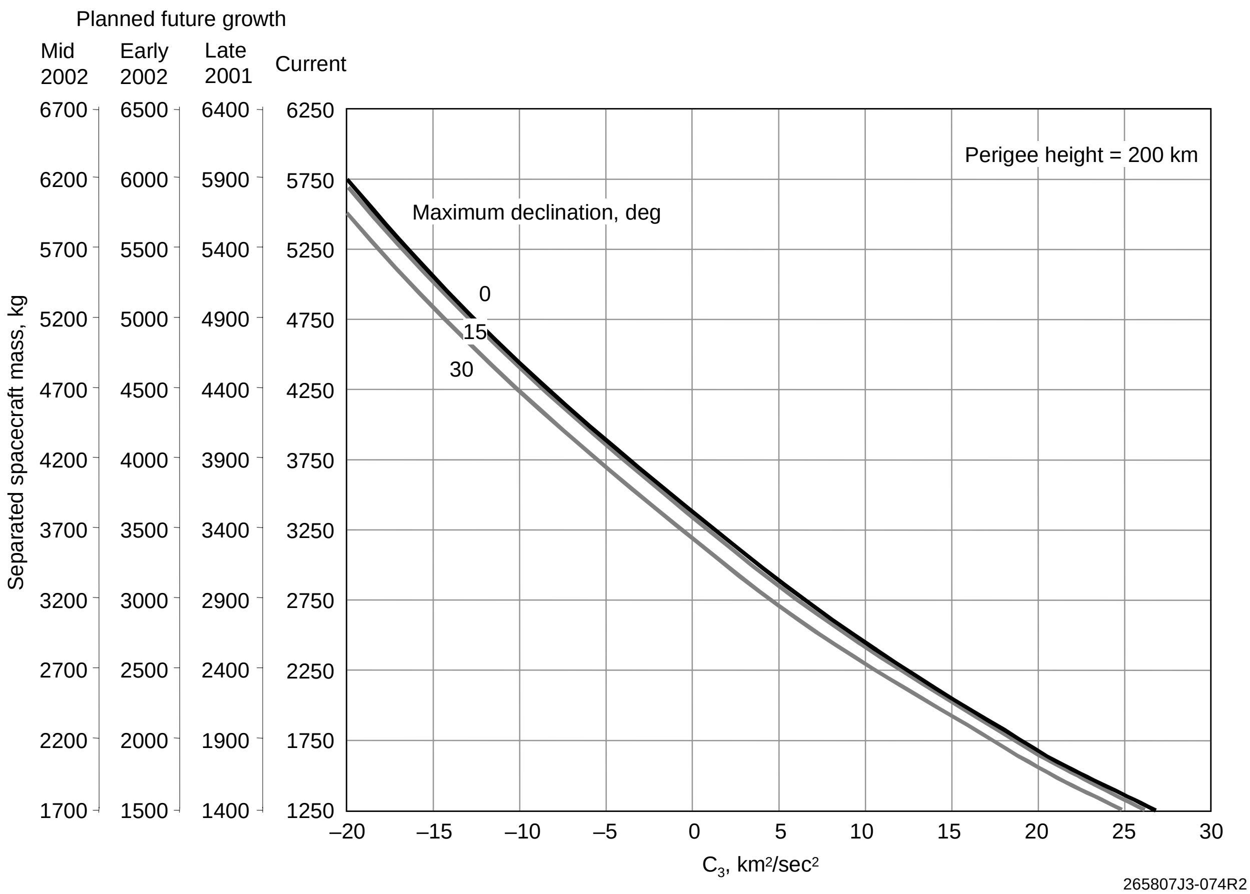

Figure 3-14. Future High-Energy and Escape Orbit Payload Capability Estimate

4. 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.

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 both for the planning phase and during the launch campaign.

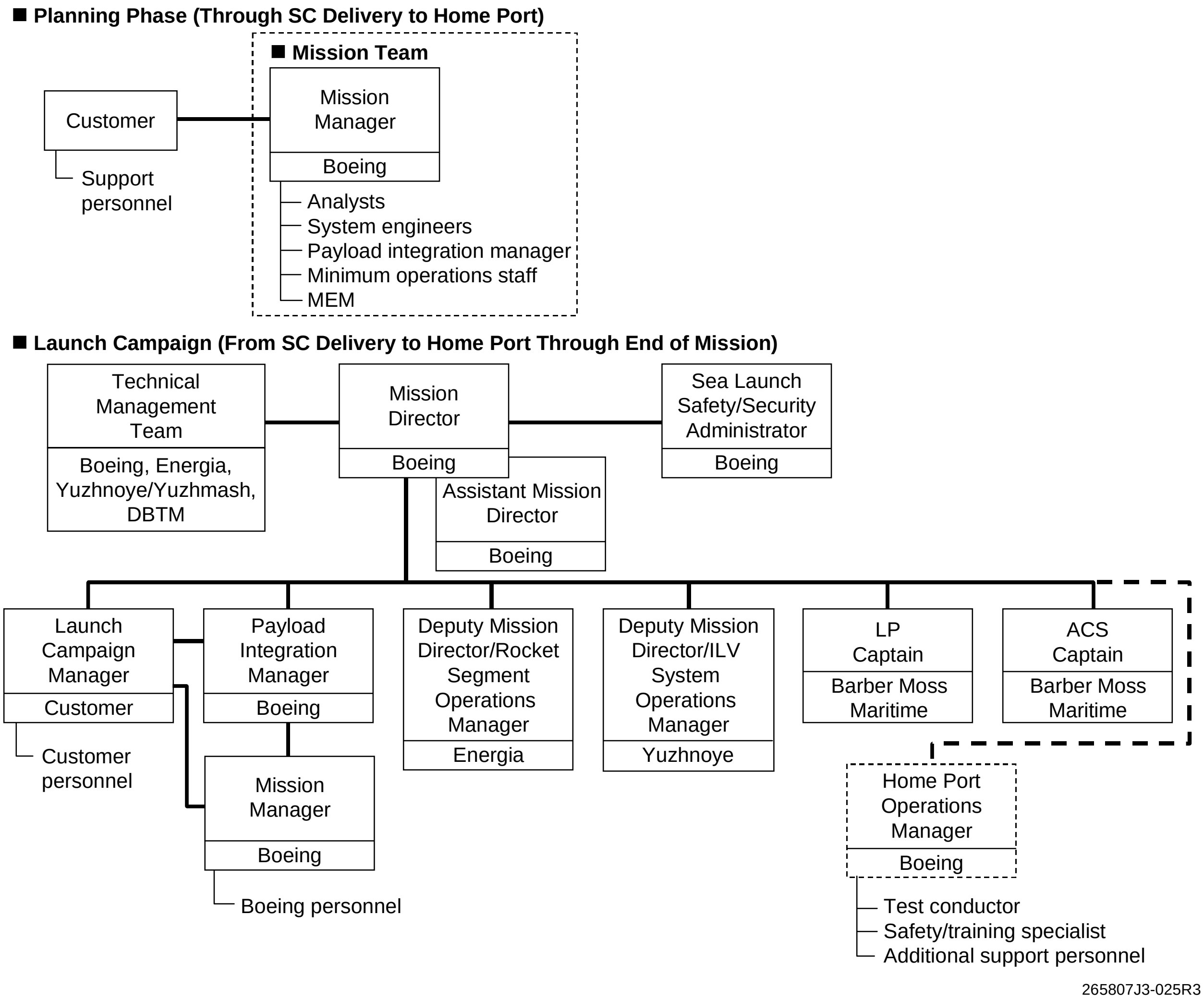

Figure 4-1. Management Structure

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. During the planning phase, up to the time of spacecraft delivery to the Home Port, the mission manager leads a mission team comprised of 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 the Home Port, the focus changes from analytical integration to the physical integration of the spacecraft and the conduct of the launch campaign. Mission teams roles and responsibilities are shown in table 4-1.

Table 4-1. Mission Team Roles and Responsibilities

Title	Role and Responsibilities
Customer launch campaign manager	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 spacecraft provider representative, designated the launch campaign manager, and other customer personnel as required.
Mission manager	• Primary customer interface. • Leads the mission analysis team.
Payload integration manager	• Leads the physical integration team. • Responsible for all operations at the 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 the Home Port. • Supports the mission director in spacecraft processing operations.

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

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

Operations planning will also address 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 operations 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.

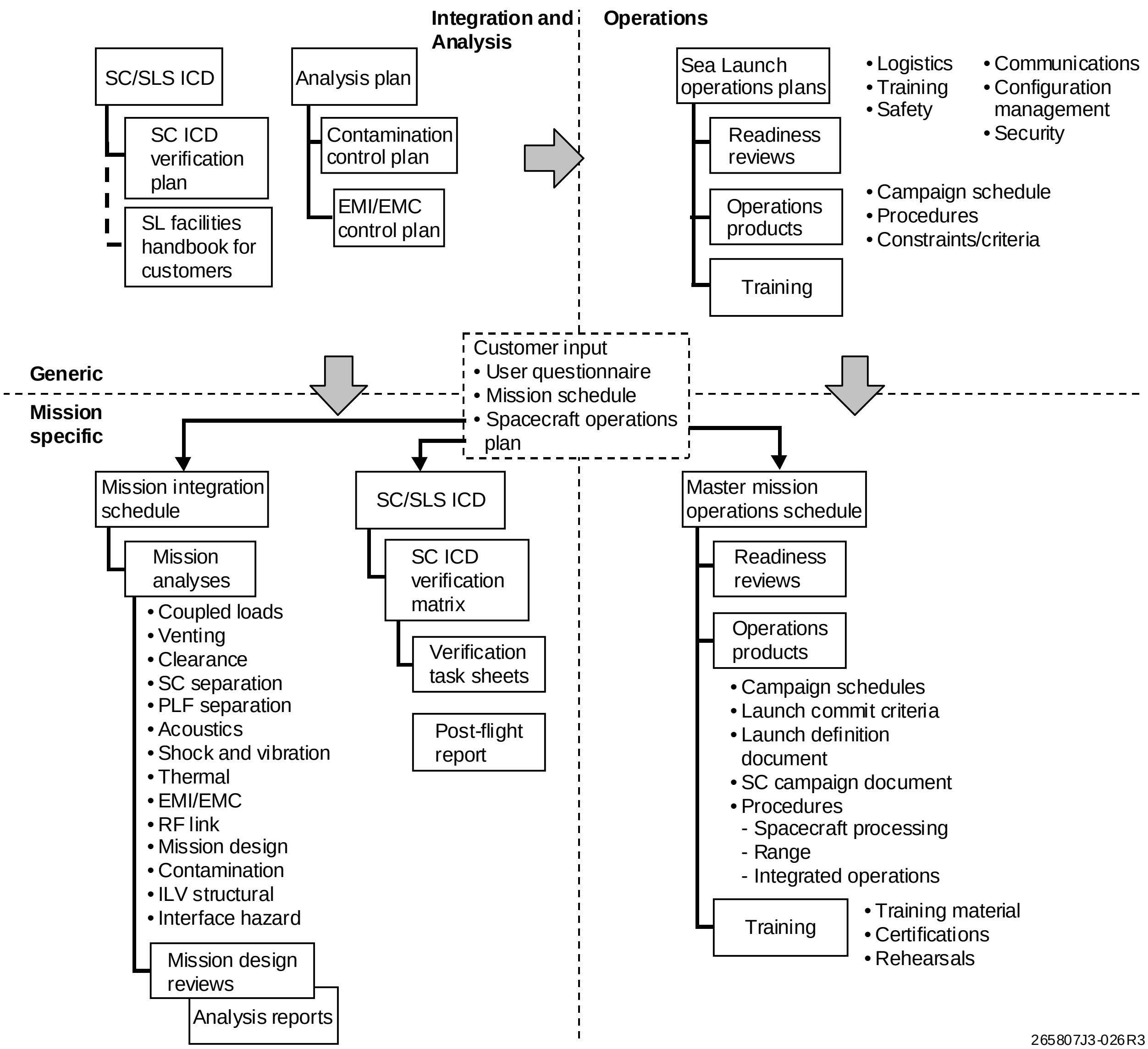

Figure 4-2. Mission Documentation and Related Products

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 control plan.

These generic documents provide the basis for the mission-specific interface control document:

- Generic spacecraft to Sea Launch system interface control document (ICD).
- Spacecraft interface control document verification plan.

The interface control document allows the customer to define unique interfaces between its 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 (appendix 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.
- Tailored version of the spacecraft/Sea Launch system ICD.
- Verification matrix.
- Mission design and analysis reports.

The mission-specific operations documentation consists of

- Spacecraft ICD.
- Spacecraft ICD verification matrix.
- Spacecraft campaign document.
- Tailored operations procedures.
- Launch commit criteria.
- Master countdown procedure.
- Training materials.
- Postflight report.

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.

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

- General operations flow.
- Schedule of customer reviews.
- Overall training and rehearsal requirements.
- Integrated schedules for processing and launch operations.
- Hardware need dates.
- Spacecraft integration milestones.
- Key Home Port, assembly and command ship, and launch platform events.

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.
- EMI and EMC.
- Orbit and trajectory details.
- Separation clearances.

Operations plan

The operations plan defines the detailed plans and processes for all Sea Launch operations activities. This includes

- 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.)

The generic interface control document template will be modified and expanded to define the needs and accommodations of the specific mission, thus creating a mission-specific interface control document.

Spacecraft verification matrix

A spacecraft verification matrix defines the process by which the interface control document requirements and functions are verified prior to 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. 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.

These environments include

- 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 ends 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	1569	6086	21842	1.0E+08

Note:

- Vertical loads are in addition to gravity: g (vertical) = 1.0 ± load (g).
- Environment covers 3 trips (1.5 round trips) between Home Port and equatorial launch site.
- Loads act uniformly along the length of the spacecraft.
- The dynamic loads act in all directions simultaneously.

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Pitch and roll

Table 5-2 gives the maximum pitch and roll motions during transport between Home Port and the launch site. Launch platform loads apply to spacecraft and GSE while ASC loads only apply to GSE.

The quasi-static load factors for ocean transport in figure 5-1 account for launch platform motions.

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

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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 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 acceleration levels are shown for the spacecraft center of gravity. The accelerations can act simultaneously in the horizontal and vertical directions. The magnitude of the vector sum of the horizontal load factors for the two orthogonal horizontal directions is 0.5 g. The accelerations in figure 5-1 apply when the integrated launch vehicle is vertical or horizontal and while it is being erected or lowered.

The orientation of the spacecraft when the Zenit-3SL is horizontal or vertical is shown in figures 5-2 and 5-3, respectively.

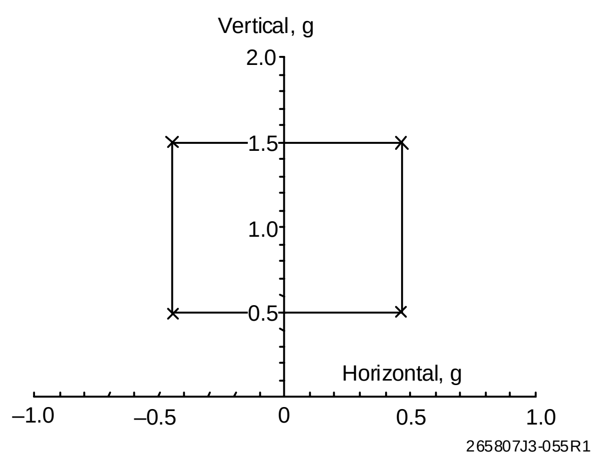

Figure 5-1. Transportation and Handling Limit Load Factors

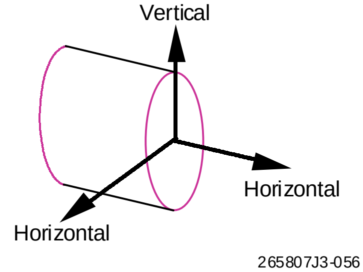

Figure 5-2. Integrated Launch Vehicle Horizontal

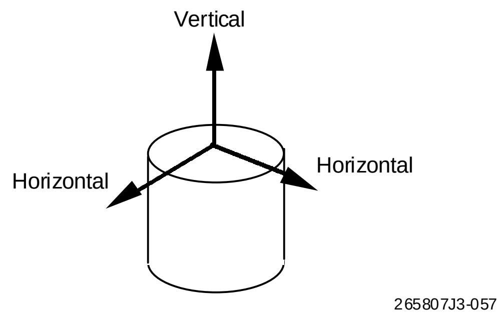

Figure 5-3. Integrated Launch Vehicle Vertical

CLA 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 (CLA). Sea Launch performs a CLA 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 can then be 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 envelope 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 CLA has been performed. Lateral load factors ranging from 1.5 to 2.5 g have been calculated for spacecraft having unique mass and/or stiffness properties.

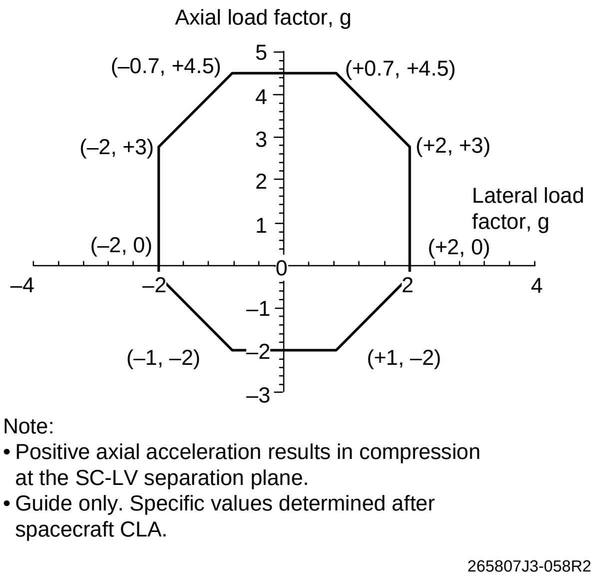

Figure 5-4. Typical Quasi-Static Load Factors for Flight

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 CLA 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.

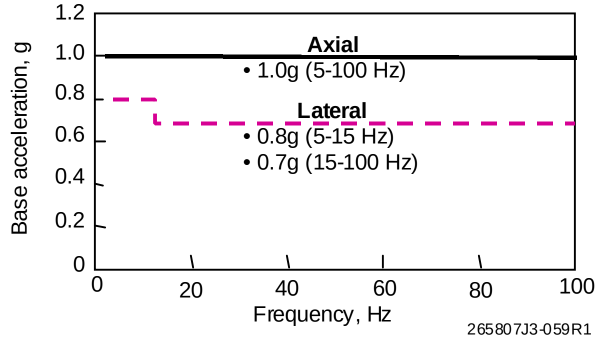

Figure 5-5. Sinusoidal Vibration at the Spacecraft Interface

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.

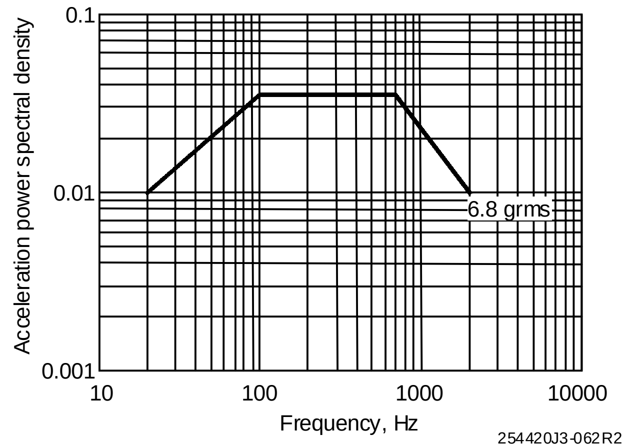

Figure 5-6. Random Vibration Environment During Flight

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 having 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 can also be provided after clocking and fill effects for a specific space-craft are determined.

The compliance requirements of the spacecraft to the internal acoustic environment are given in section 6.

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)

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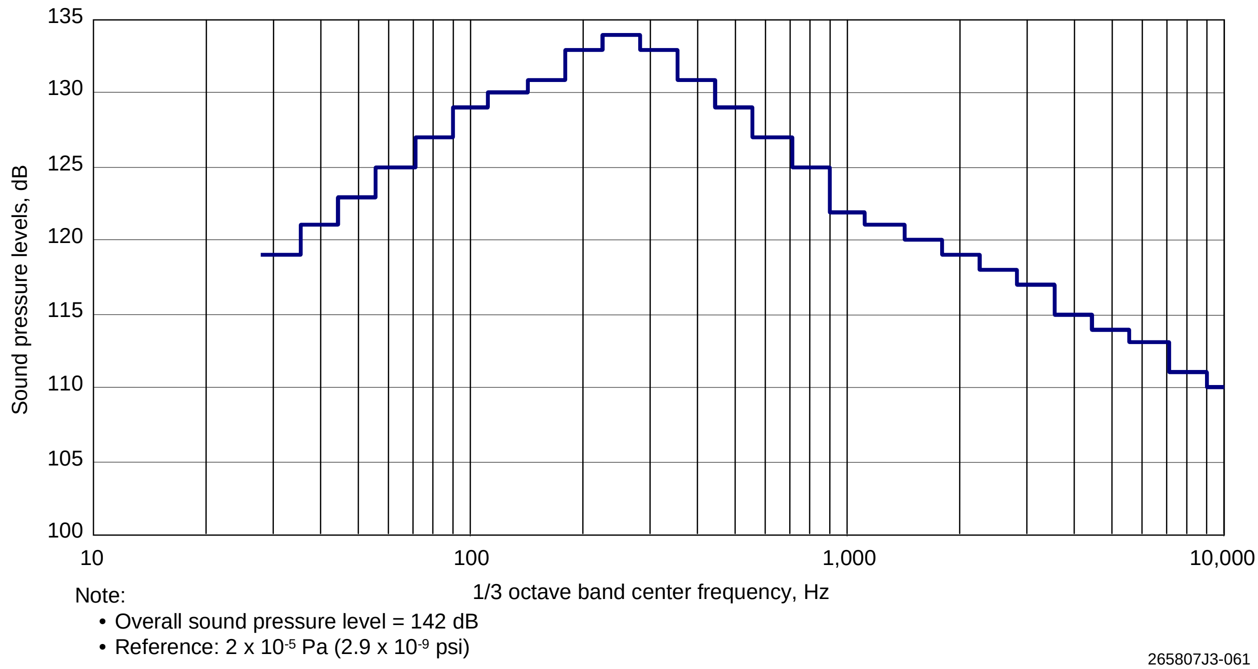


Figure 5-7. Acoustic Environment During Flight

5.5 Shock

Maximum shock at spacecraft separation

The maximum shock at the spacecraft interface occurs at the moment of spacecraft separation. Other shock inputs are well within this envelope and do not require additional consideration.

Shock levels for the three adapters currently offered

Shock environments are provided for the three spacecraft adapters currently available.

- SCA1194 has a diameter of 1194 mm and a Marmon clamp separation system.
- SCA1666 has a diameter of 1666 mm and a Marmon clamp separation system.
- SCA702 and SCA702GEM have diameters of 1664 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. Additional or increased-strength adapters will be evaluated depending on customer requirements.

SCA1194 The shock spectrum shown in figure 5-8 represents the maximum expected shock environment for the spacecraft adapter having a diameter of the 1194 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.

The strength capability of the SCA1194 spacecraft adapter with this clampband tension is given in section 6.1.

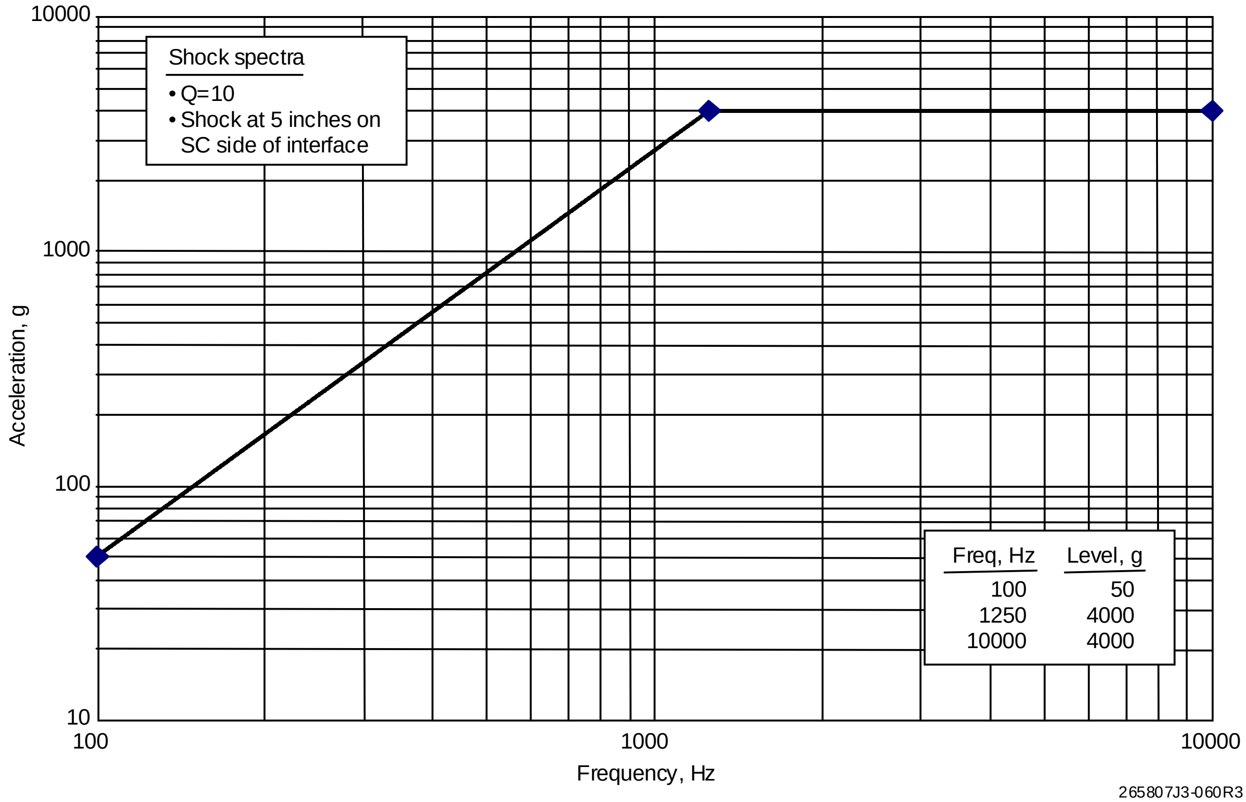


Figure 5-8. Separation Shock for SCA1194 Spacecraft Adapter

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.

The strength capability of the SCA1666 spacecraft adapter with this clampband tension is given in section 6.1.

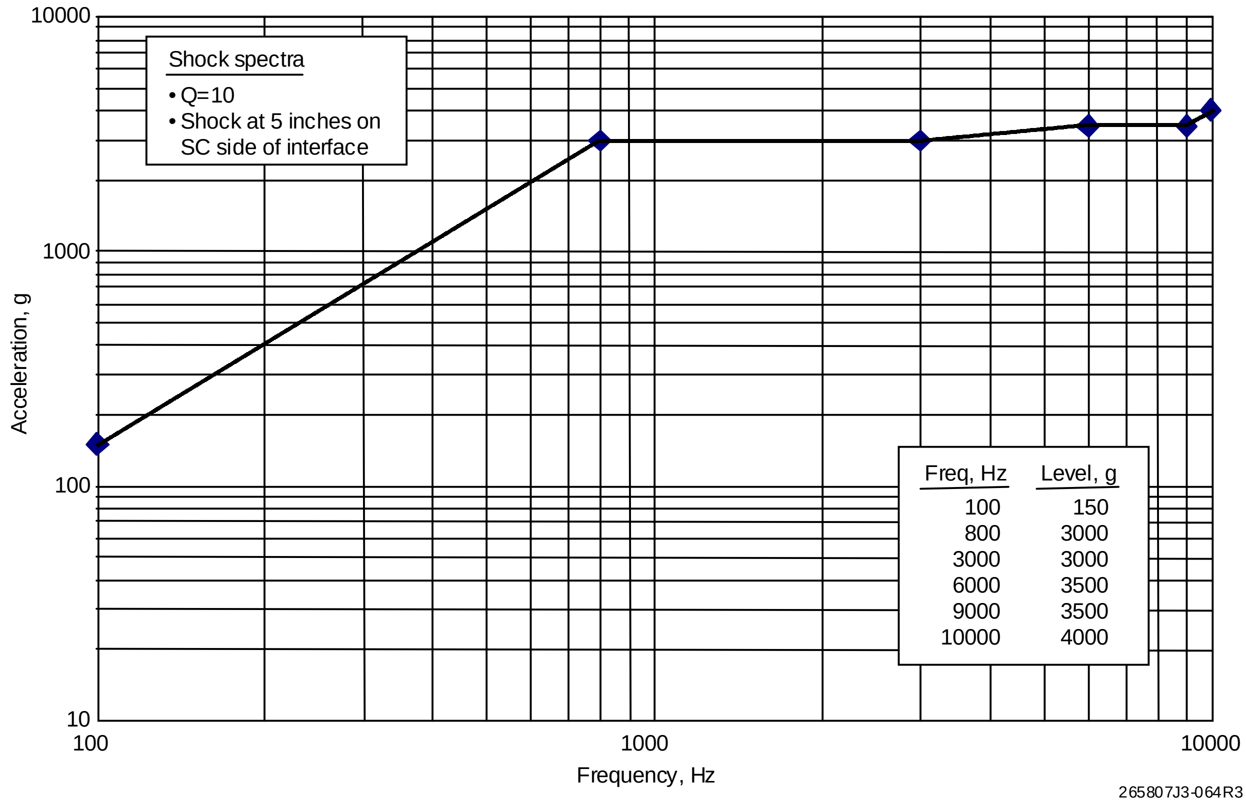


Figure 5-9. Separation Shock for SCA1666 Spacecraft Adapter

SCA702 and SCA702GEM

The Sea Launch system-generated separation shock spectrum using the SCA702 and SCA702GEM 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.

The strength capabilities of the SCA702 and SCA702GEM spacecraft adapters are given in section 6.1.

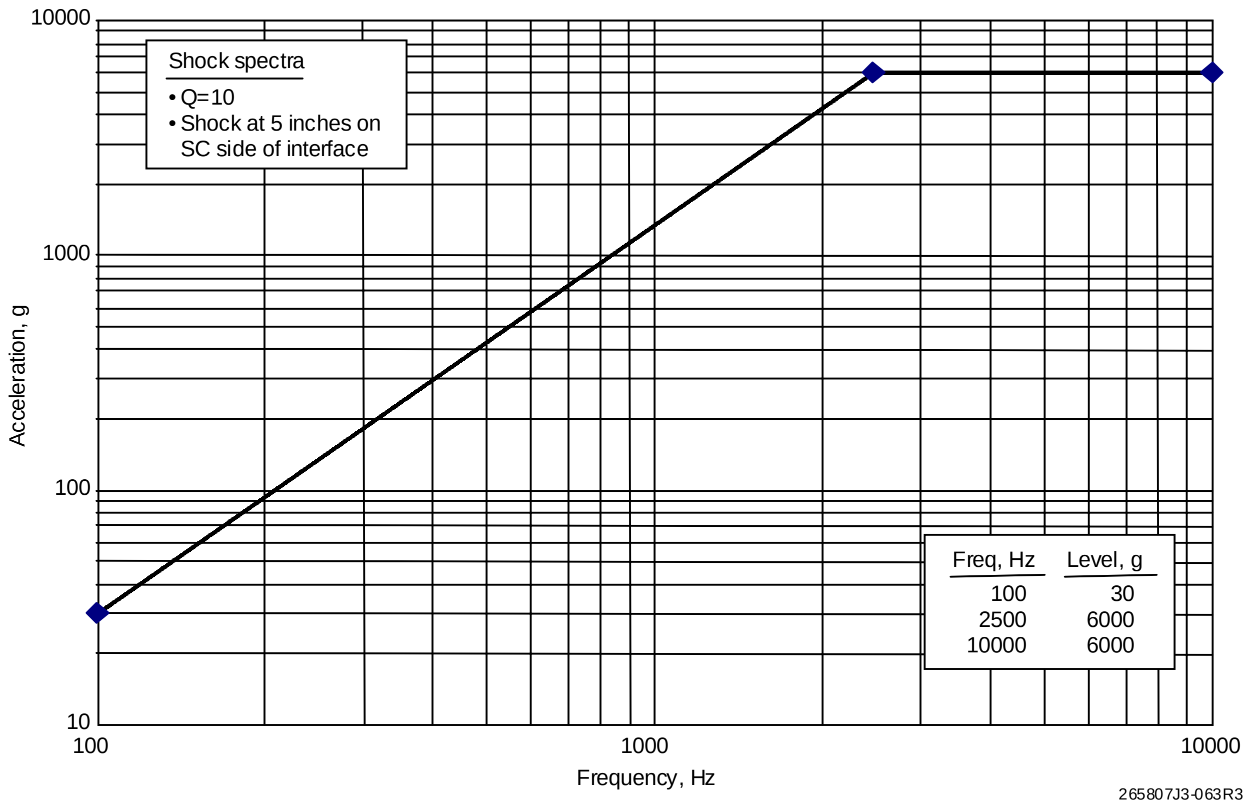


Figure 5-10. Separation Shock for SCA702 and SCA702GEM Spacecraft Adapters

5.6 Electromagnetic Environment

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 of the payload processing facility (see fig. 5-11).
- The Home Port pier (see 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.

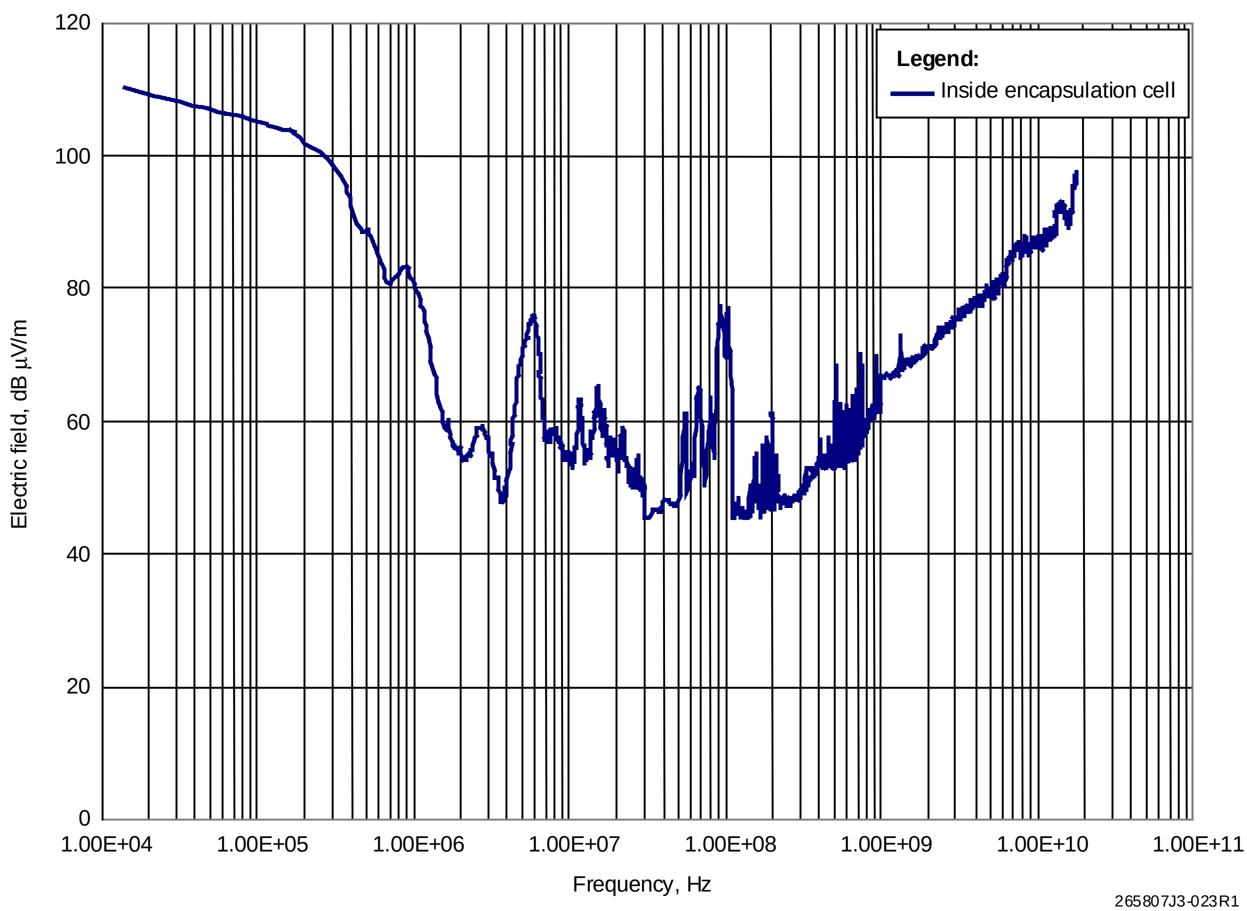
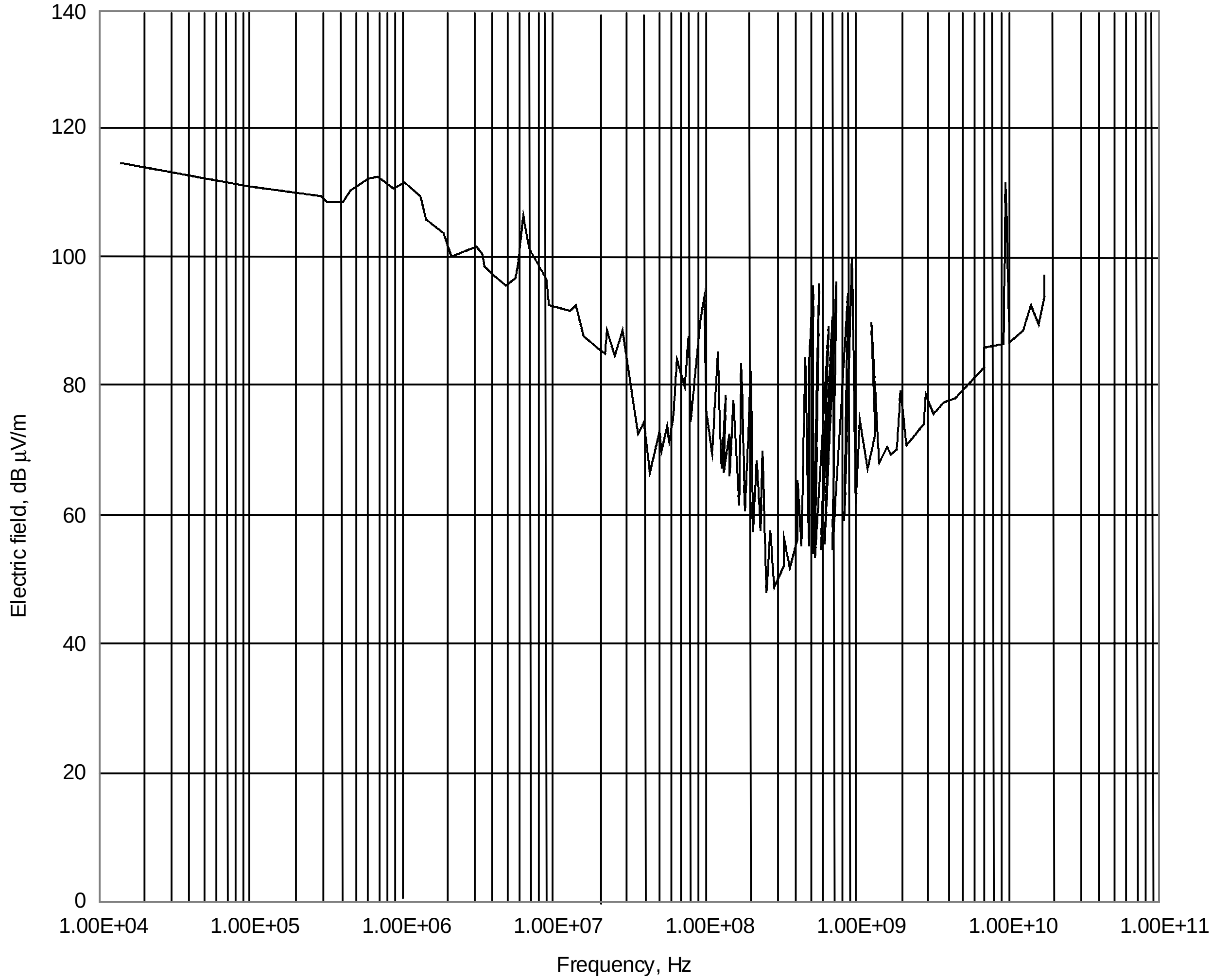


Figure 5-11. Typical Electromagnetic Environment in Payload Processing Facility—Encapsulation Cell



Note: 200 mark on pier; 10.0 KHz to 18.0 GHz.

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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.

- 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 BR-9 DM systems are located on the interface skirt. The Kvant system transmits at 922.76 MHz and the BR-9 DM transmits at 166 MHz.
- The payload unit telemetry system transmits at 2272.5 MHz using several antennas that are mounted on the interface skirt.

The in-flight electromagnetic environment, produced by the launch vehicle transmitters, is illustrated in figure 5-13.

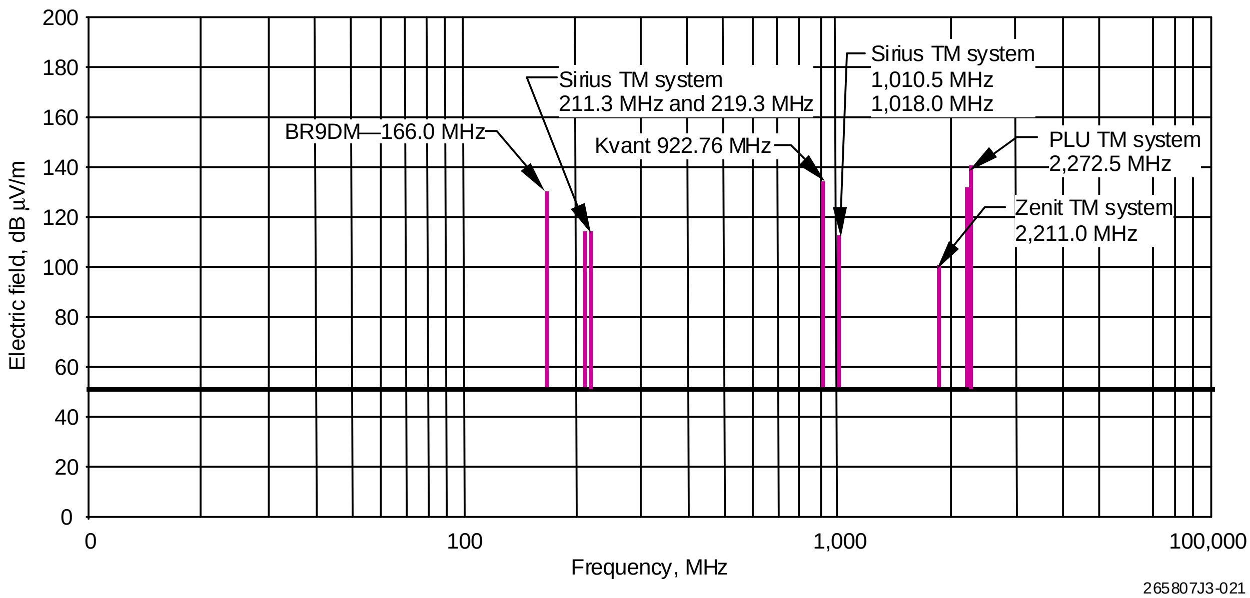

Figure 5-13. In-Flight Electromagnetic Environment

Electromagnetic environment

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

Table 5-4. Sea Launch RF 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
6265.5	126
6273.0	131
7194.5	77
7355.5	117
7494.5	117
7655.5	77
9200.0	92
9410.0	131
9500.0	59

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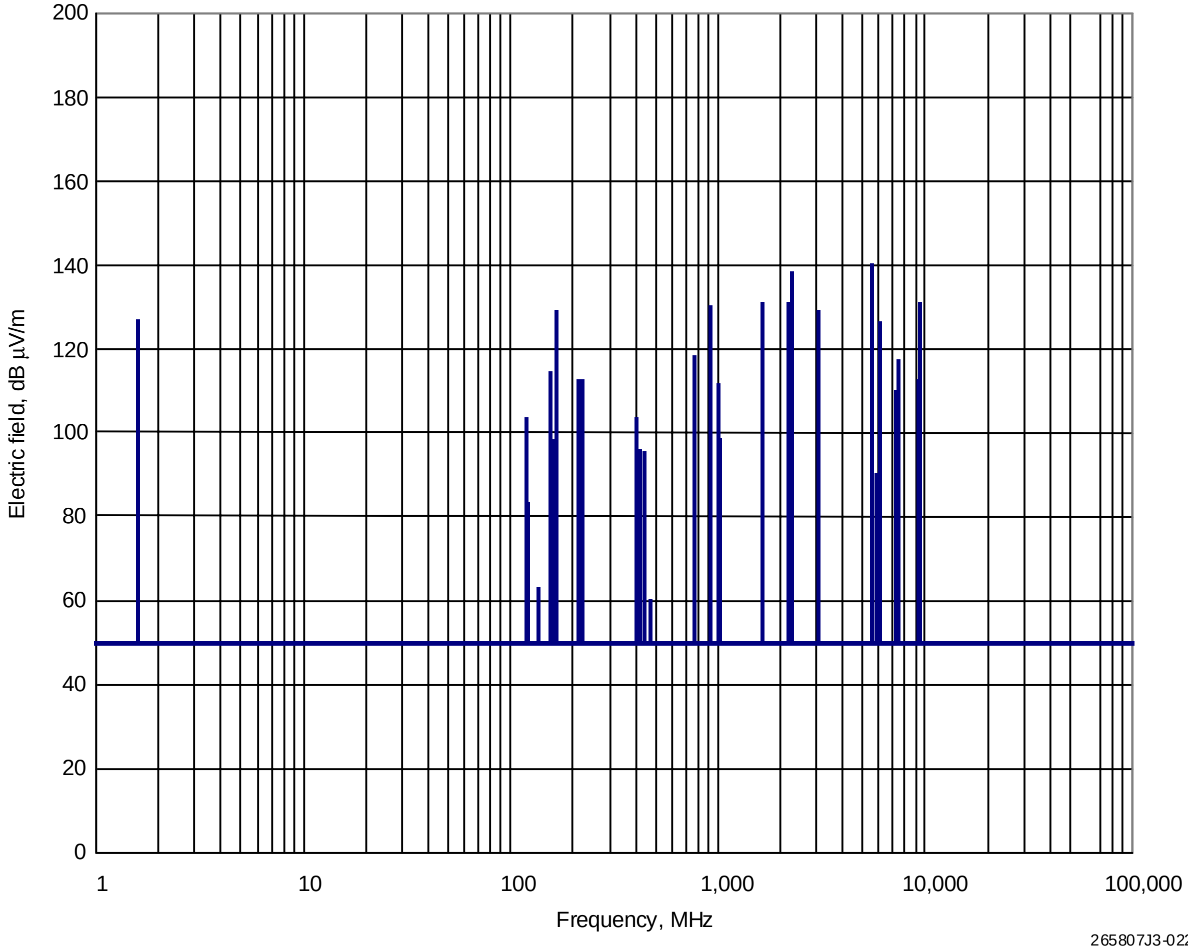

Figure 5-14. Sea Launch RF Environment

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 prior to PLF encapsulation.
- Operations after PLF encapsulation, including ILV integration, transportation to the launch site, and prelaunch preparations.
- Liftoff, ascent, and in-flight operations.

Ground processing and transportation–first phase

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

During operations phases in the Home Port PPF, prior to encapsulation by the PLF, 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 maximum variance of 1.7°C (3°F).

Table 5-5. PPF 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%

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Ground processing and transporta-tion–second phase

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

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

PLU environmental control system inlet conditions and control capabilities are summarized in table 5-6. All air conditioning systems maintain positive pressure inside the PLF to prevent air-transported contaminants from entering the PLF. Air quality is maintained by providing purge air that has been high efficiency particulate air (HEPA) filtered to class-5,000 maximum per FED-STD-209E.

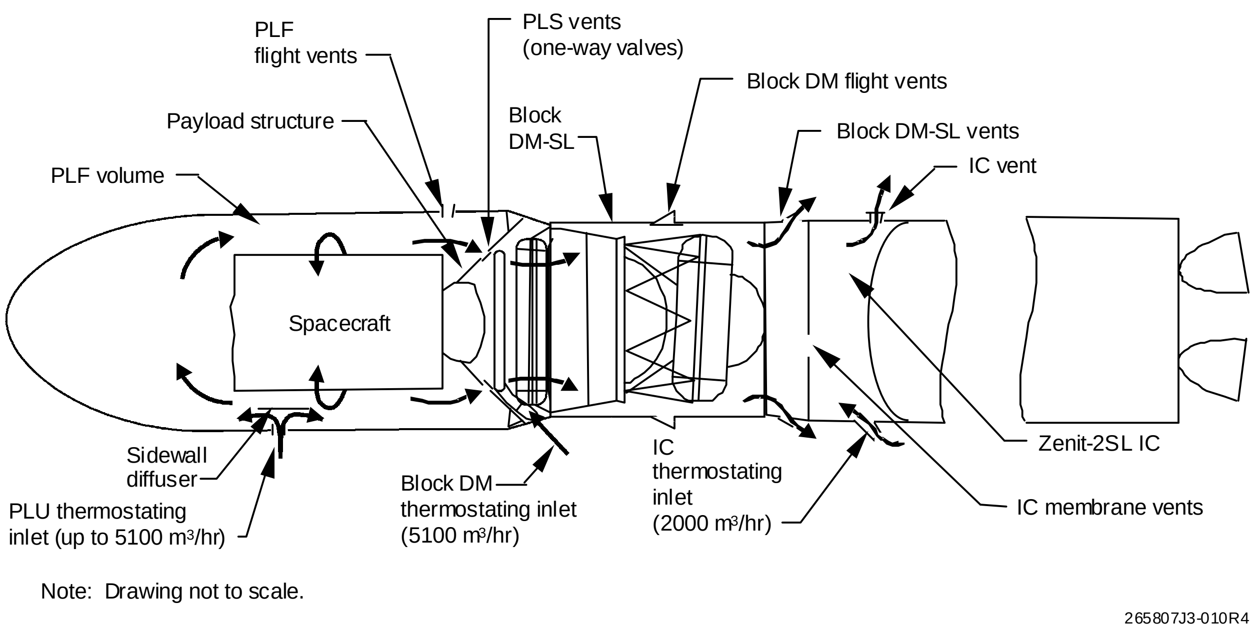

Figure 5-15. Payload Unit Air Conditioning Venting Scheme

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, prior to transfer into hangar	10–25°C (50–77°F)	0–60%	18.1–100 kg/min (40–220 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 (not selectable)	0–60%	>18 kg/min • (not selectable)

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.
(2) Relative humidity controlled to 30–60% if access to spacecraft in PLF 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).

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Ground processing and transportation–third phase

The Sea Launch PLF, 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 PLF 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.

Predicted maximum internal PLF surface temperatures during the ascent period, which conservatively bound Sea Launch flight measurements, are presented in figure 5-16. Predicted peak temperatures of acoustic blanket inner surfaces (which comprise 62% of the PLF area) remain below 85°C. At the time of fairing jettison, over 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 PLF inner surfaces generally have surface emittances ranging from e=0.64 for surfaces covered with acoustic damping material to e=0.83 for noninsulated inner walls.

The SLS accommodates user-specified limitations on aerodynamic heat loads during periods after PLF jettison as constraints on the design of the ascent trajectory and on the time of fairing jettison. Maximum 3σ dispersed free molecular heatloads 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 FMH rate falls below 1135 W/m^2 (360 Btu/hr ft^2), or a value adjusted to meet specific mission requirements. PLF jettison will generally occur at a nominal altitude of approximately 117,000m (384,000 ft) at times ranging from 196 to 219 seconds following liftoff. Delaying time of fairing jettison or raising parking orbit perigee altitude to achieve a reduction in FMH, however, will have a negative effect on LV performance. Dispersed FMH profiles for typical ascent trajectories are shown in figure 5-17.

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

The Block DM-SL flight, as indicated in sections 3.5 and 3.7, is designed to accommodate preferred attitude pointing, continuous rolls, maneuvers, and orientations during coast and preseparation phases that satisfy spacecraft thermal control, battery charging, solar exposure, and other customer-specified attitude or exposure requirements.

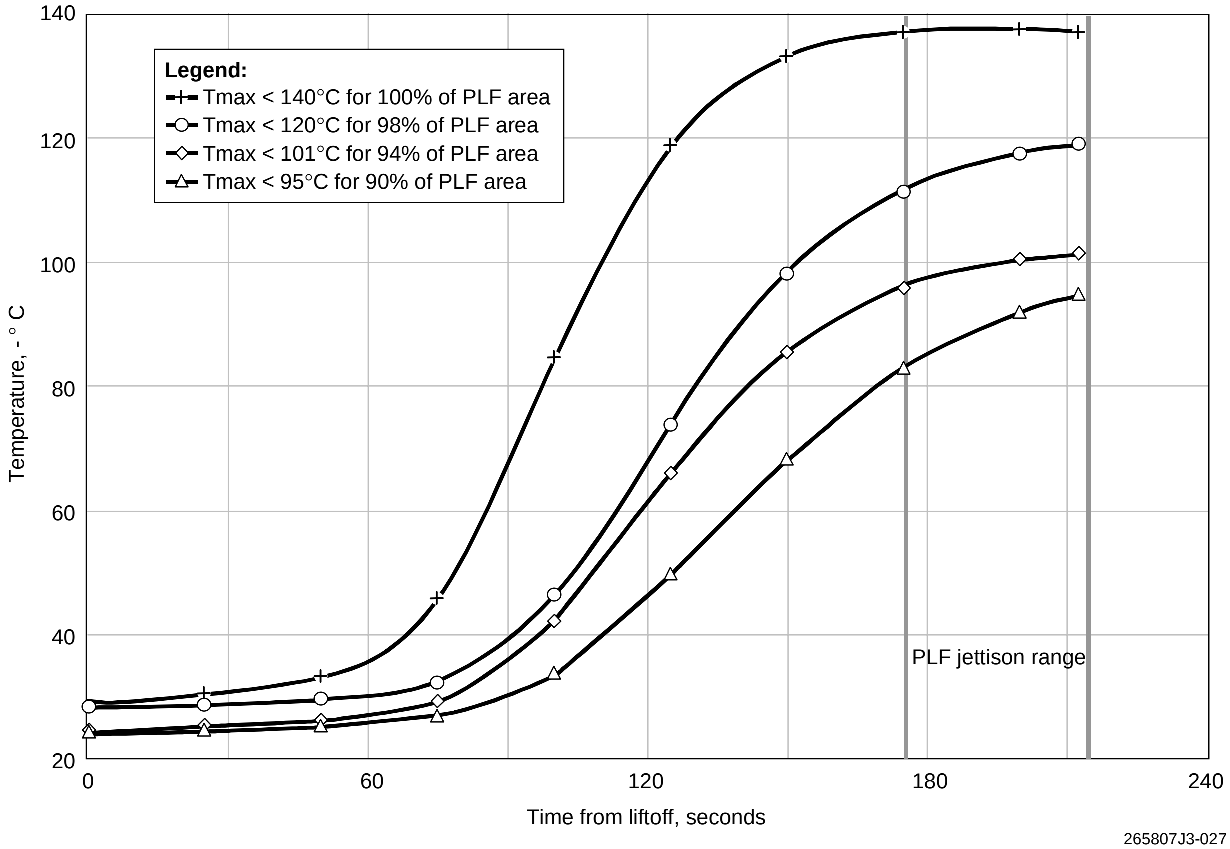

Figure 5-16. Maximum Internal PLF Surface Temperatures

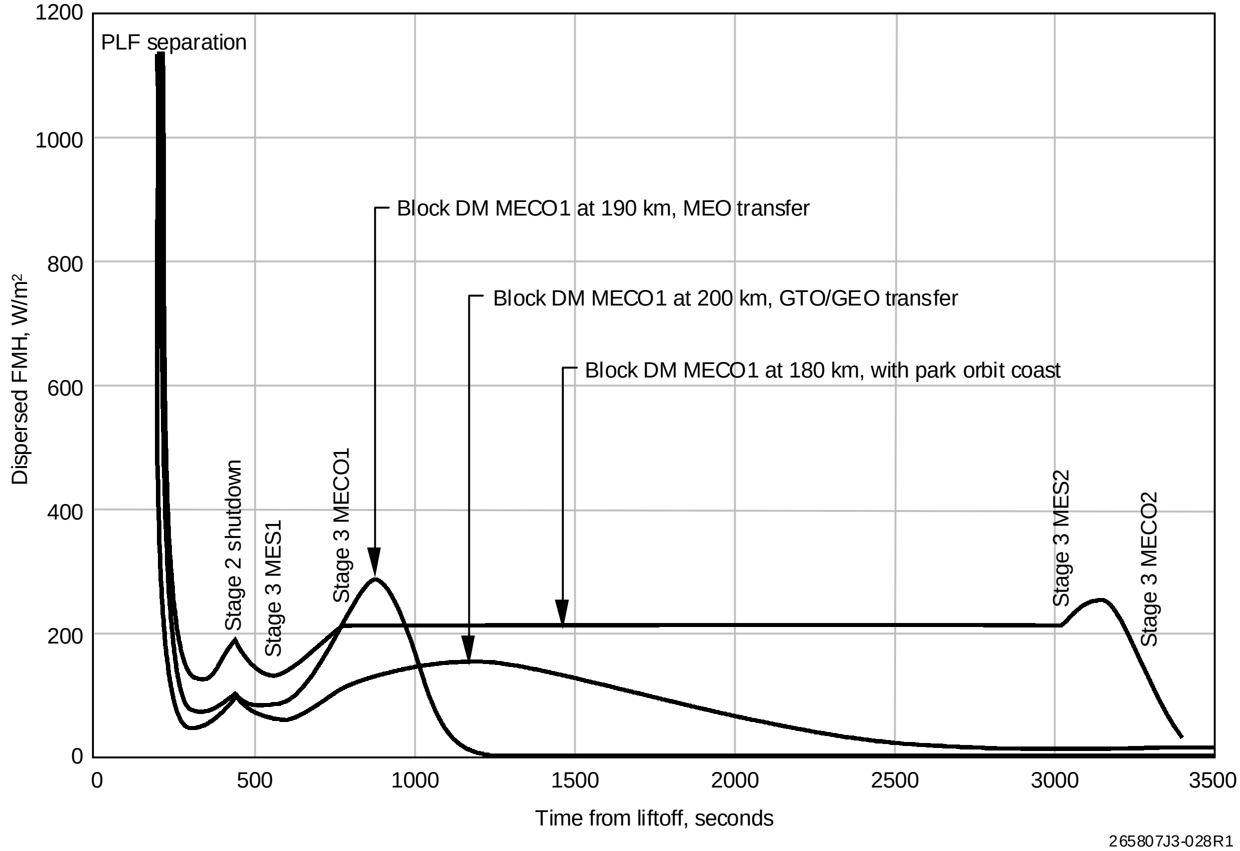

Figure 5-17. Free Molecular Heating Environments

5.8 Payload Unit Ascent Venting

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

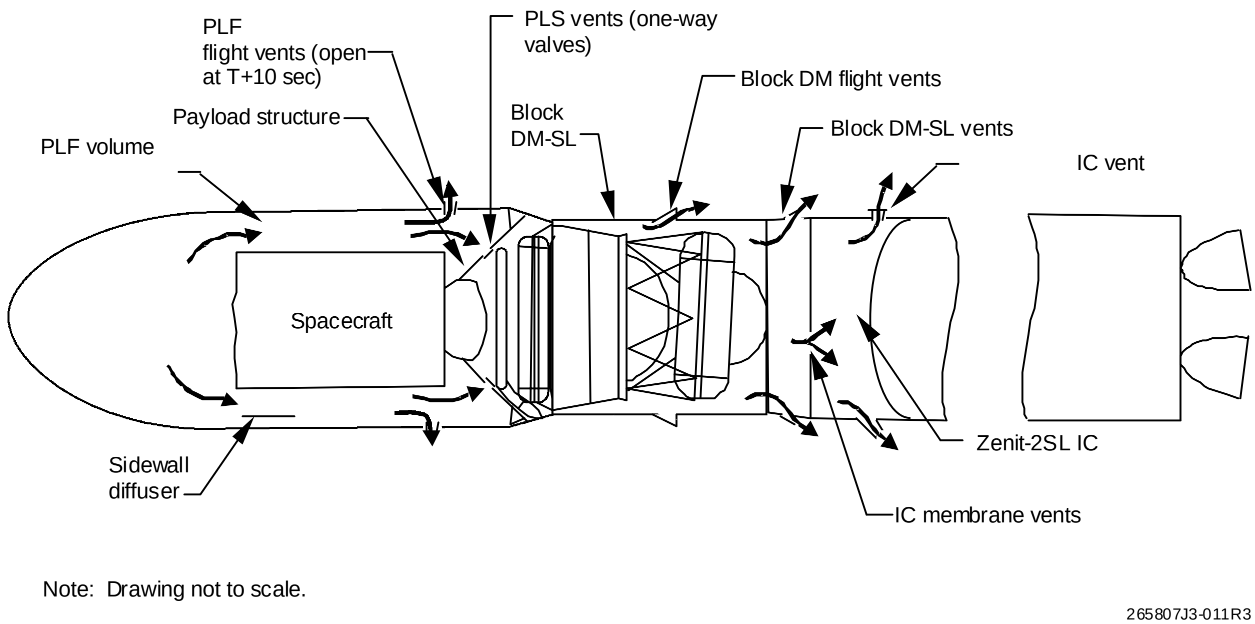

Figure 5-18. Payload Unit Ascent Venting Scheme

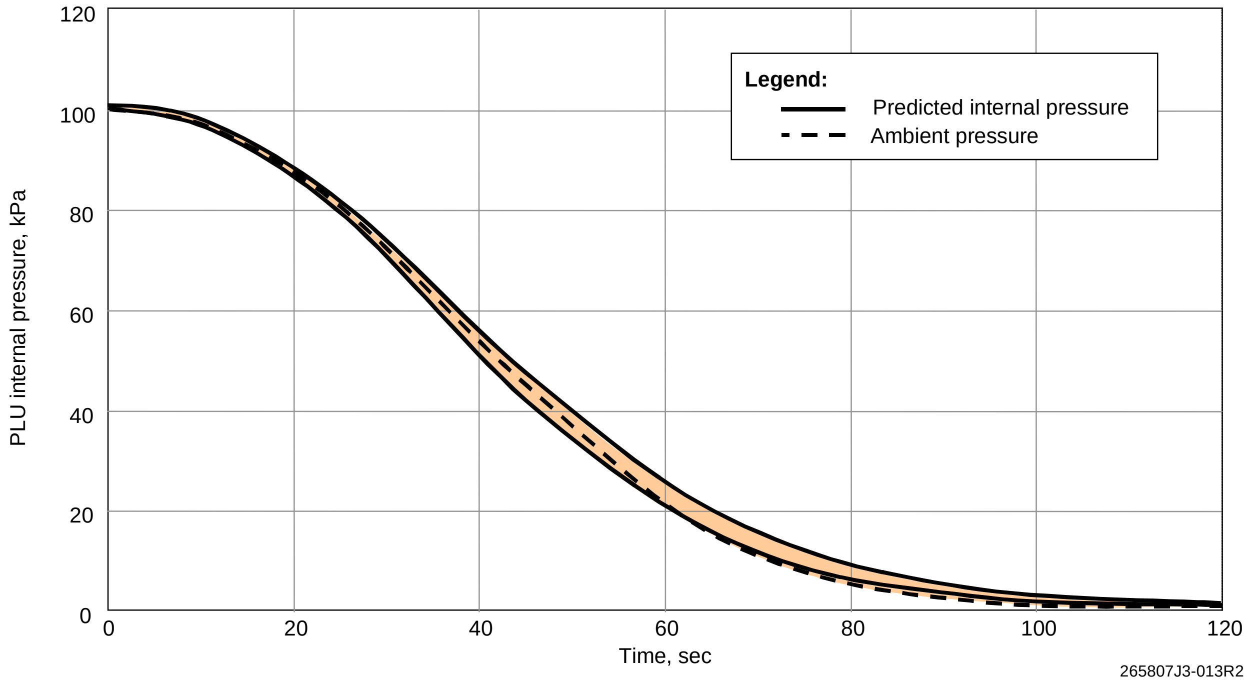

Figure 5-19. Payload Fairing Internal Pressure During Ascent

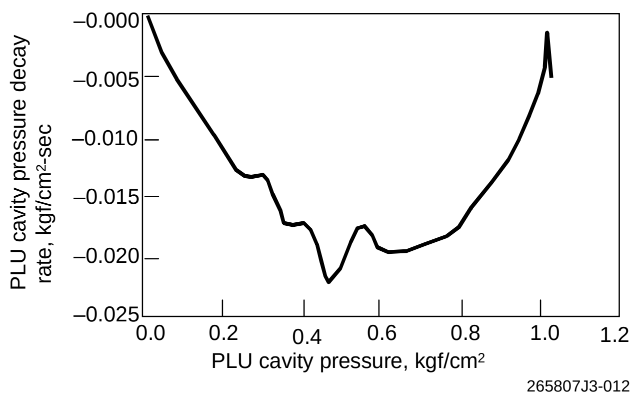

Figure 5-20. Typical Peak Ascent Depressurization

5.9 Contamination

Overview

Contamination of the spacecraft by the launch vehicle is addressed in all phases of the mission. These include:

- 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) clean room environments, including spacecraft standalone testing, payload accommodation preparations, and spacecraft encapsulation.
- After encapsulation, 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 manufacturing 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 receive its final cleaning before shipment.

Precision cleaning process during ground processing

Precision cleaning of the payload fairing 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 and bagged, and placed in a separate container.

Extensive testing has proven cleaning processes can achieve molecular cleanliness levels below 11 mg/m^2 (1.0 mg/ft^2) and particulate levels below 0.5% obscuration. Cleanliness verification is performed by periodic visual inspection, with direct surface sampling available as a mission-unique service.

Flight hardware processing during ground processing

Upon arrival at Home Port the payload accommodation hardware is unbagged in the payload processing facility cleanroom, and a receiving inspection performed. The payload accommodation is inspected and recleaned 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 will also be provided. If necessary, a mission-specific annex to the Home Port control plan is generated to incorporate any unique spacecraft contamination control processing requirements.

Purge air quality during ground processing

After encapsulation, the payload fairing air purge defines the spacecraft environment. This is HEPA filtered and delivered at a nominal cleanliness of class 1,000 (per FED-STD-209E). Purge air is provided from the time the payload unit leaves the payload processing facility through liftoff or launch abort, described in section 5.

The purge air quality is monitored with an airborne particle counter near the payload fairing inlet. Monitoring is discontinued only during the hoist of the integrated launch vehicle from the assembly and command ship to the launch platform, and after erection of the integrated launch vehicle on the launch pad.

Helium exposure during ground processing

Helium concentration in the spacecraft environment is a concern to some customers. The primary source of helium in the Sea Launch system is venting and leakage from the Block DM-SL, with the highest concentration occurring prior to Block DM-SL liquid oxygen load on the launch pad. Payload fairing positive pressure, provided by the purge airflow through the payload structure one-way vent valves, is an effective barrier to helium leakage from the Block DM-SL cavity.

Spacecraft access at sea during ground processing

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 phases is minimized by proper hardware design and flight design. Flight hardware design considerations include cleanability, selection of low-outgassing materials, venting design, and containment of pyrotechnics. Flight design considerations include minimization of thruster plume impingement and exposure to materials outgassing during separation maneuvers.

Payload unit materials outgassing

The payload unit is constructed from low-outgassing materials, 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 contamination analysis.

Spacecraft isolation

The spacecraft is completely isolated from view of any Block DM-SL materials by a closeout membrane and one-way vent valves in the payload structure. These vent valves open to allow purge air to flow aft through the payload fairing and out through the payload structure, then spring closed in flight, preventing any particulate or molecular contamination from the Block DM-SL cavity to enter the spacecraft environment.

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

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 pyro-containment tube, which expands to break a structural aluminum flange and release the two halves of the payload fairing. The aluminum particles generated by the breaking of the flange have been characterized by extensive testing and represent a minimal contamination risk.

Spacecraft adapter separation systems consist of standard clampband or separation bolt designs, which feature containment of pyrotechnics and debris.

Plume impingement

Significant plume impingement is avoided, even in a vacuum environment, by structurally shielding the spacecraft from the Zenit-3SL thrusters, all of which are optimally oriented to minimize the plume impingement effects. The only Zenit-3SL plumes which impinge on spacecraft surfaces are the Stage 2 separation rockets (see retrorocket plumes section) and the Block DM-SL bi-propellant attitude control thrusters (see contamination and collision avoidance maneuver section).

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 to the spacecraft, and prevents any impingement of high-velocity particles on the spacecraft. A small amount of solid lead is contained in the solid fuel as a burn stabilizer.

An extensive set of plume analyses and surface effects tests were conducted, which show that the small deposition of lead will have minimal effect on spacecraft optical, electrical, and radio frequency properties. This data is defined in the general contamination analysis report.

Contamination and collision avoidance maneuver (CCAM)

After spacecraft separation, the Block DM-SL performs a CCAM 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 CCAM design, including maximum Block DM-SL tip-off angle, and minimum separation distance from the spacecraft before major CCAM 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 design.

6. SPACECRAFT DESIGN CONSIDERATIONS

Overview

This section contains spacecraft design guides to assist with your 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 your spacecraft exceeds the design guides described below or requires a unique qualification approach. Sea Launch will work with you to achieve launch vehicle compatibility.

The coordinate system used by Sea Launch for the Zenit-3SL and its components are shown in figure 6-1.

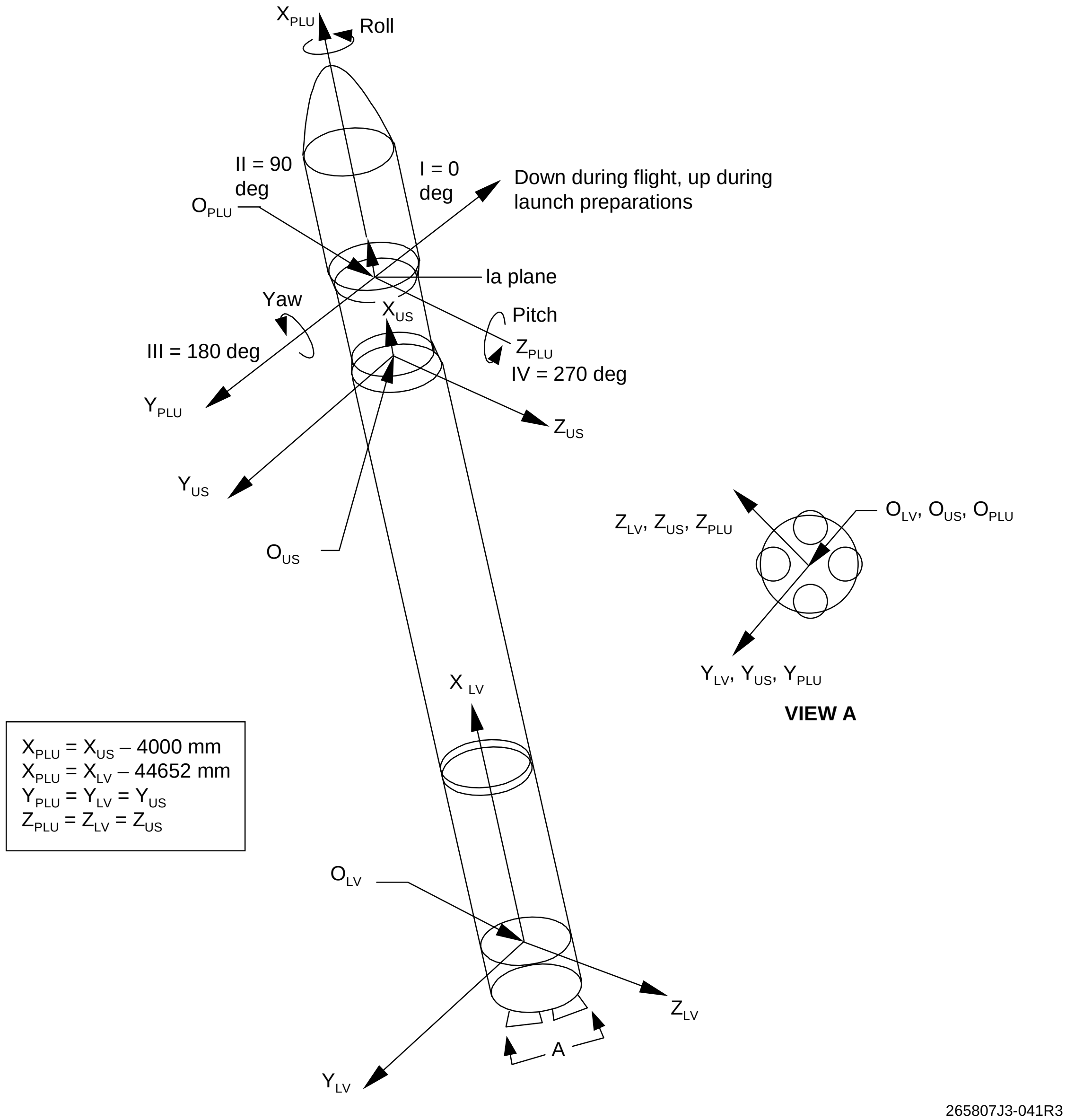

Figure 6-1. Zenit-3SL Coordinate System

6.1 Mass and Center of Gravity (CG) Limits

Definitive compatibility requiring multiple verification activities

Several verification activities must be done to demonstrate Zenit-3SL compatibility with a specific spacecraft having a given mass and CG. 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.

Current Zenit-3SL structural capability

The Zenit-3SL launch vehicle can structurally accommodate spacecraft with a wide range of mass and CG for each of the three spacecraft adapters currently offered by Sea Launch.

Table 6-1 provides the expected spacecraft mass and CG limits for the Zenit-3SL using a standard spacecraft adapter when the lateral load factor on the spacecraft is 2.0 g or less and the load distribution at the spacecraft interface is ideal.

Definitive compatibility of a spacecraft with the Zenit-3SL requires all verification activities outlined above. In particular, peaking load calculations must be performed when the load distribution at the spacecraft interface is not ideal.

Table 6-1. Expected Spacecraft Mass and CG Limits Using Standard-Offering SCA

SC mass, kg	Spacecraft CG, m		
	SCA 1194 with 0% peaking	SCA 1666 with 0% peaking	SCA 702
3830	2.50	—	—
4100	2.33	—	—
4200	2.28	2.61	2.51
4300	2.23	2.54	2.45
4400	2.18	2.46	2.39
4500	2.13	2.40	2.34
4600	2.08	2.33	2.29
4700	2.04	2.27	2.24
4800	1.99	2.21	2.19
4900	1.95	2.15	2.15
5000	1.91	2.09	2.10
5100	1.88	2.04	2.06
5200	1.84	1.99	2.02
5300	1.81	1.94	1.99
5400	1.77	1.89	1.95
5500	1.74	1.85	1.91
5600	1.71	1.80	1.88
5700	1.68	1.76	1.85
5800	1.65	1.72	1.81
5900	1.62	1.68	1.78
6000	1.60	1.64	1.75
6100	1.57	1.60	1.72

Full Zenit-3SL structural capability

If the spacecraft adapters are strengthened and/or requalified, the full Zenit-3SL structural capability is realized. Spacecraft with a higher CG for a given mass are then permitted.

Table 6-2 provides the expected spacecraft mass and CG limits for the Zenit-3SL using strengthened spacecraft adapters when the lateral load factor on the spacecraft is 2.0 g or less. Conservative analyses were used to construct the mass and CG limits (table 6-2). Spacecraft with a higher CG for a given mass may be acceptable on further analysis.

Table 6-2. Expected Spacecraft Mass and CG Limits Using Upgraded SCA

SC mass, kg	Spacecraft CG, m		
	SCA 1194	SCA 1666	SCA 702
4800	2.54	2.41	2.41
4900	2.49	2.36	2.36
5000	2.44	2.31	2.31
5100	2.39	2.27	2.26
5200	2.35	2.22	2.22
5300	2.30	2.18	2.18
5400	2.26	2.14	2.14
5500	2.22	2.10	2.10
5600	2.18	2.06	2.06
5700	2.14	2.03	2.03
5800	2.10	1.99	1.99
5900	2.07	1.96	1.96
6000	2.03	1.93	1.93
6100	2.00	1.89	1.89

Spacecraft mass and CG limits

Figures 6-2 through 6-4 graphically represent the results in tables 6-1 and 6-2 for each of the three spacecraft adapters. These figures show the expected spacecraft mass and CG limits for each of the spacecraft adapters currently available. The CG limits for a given spacecraft mass depend on the amount of peaking at the spacecraft interface for clampband adapters. Curves are provided for 0%, 30%, and 60% peaking.

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

Spacecraft with mass and CG values outside the designated acceptable region may also be acceptable on further analysis.

The longitudinal CG 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 PLU x-axis station X_{PLU} = 2.10 m (6.9 ft). Similarly, the SCA1194 spacecraft adapter separation plane is at X_{PLU} = 1.97 m (6.4 ft).

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

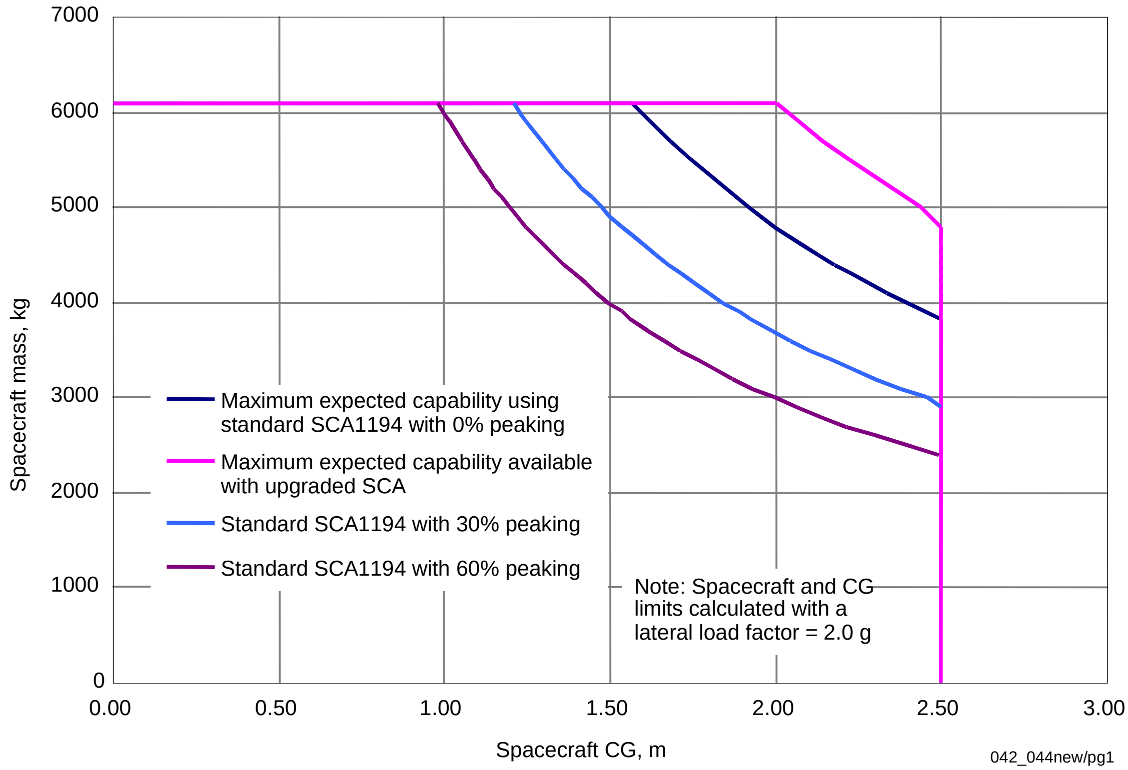

Figure 6-2. Expected Spacecraft Mass and CG Limits With SCA1194 Spacecraft Adapter

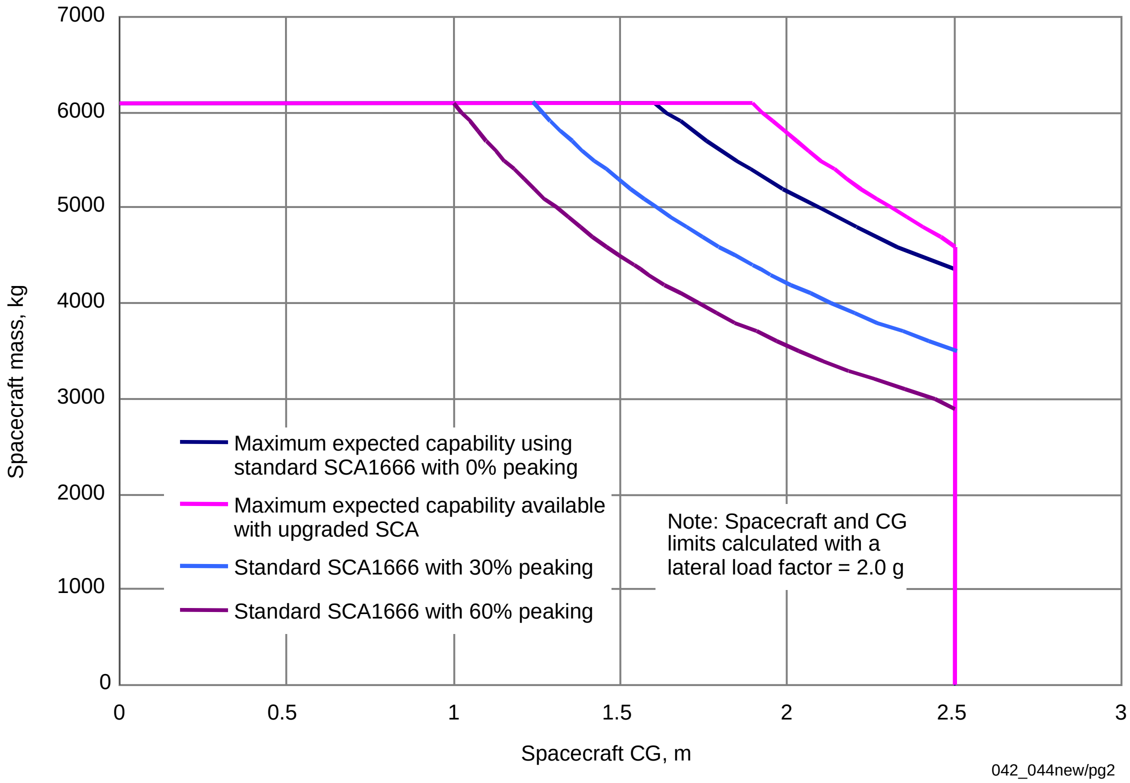

Figure 6-3. Expected Spacecraft Mass and CG Limits With SCA1666 Spacecraft Adapter

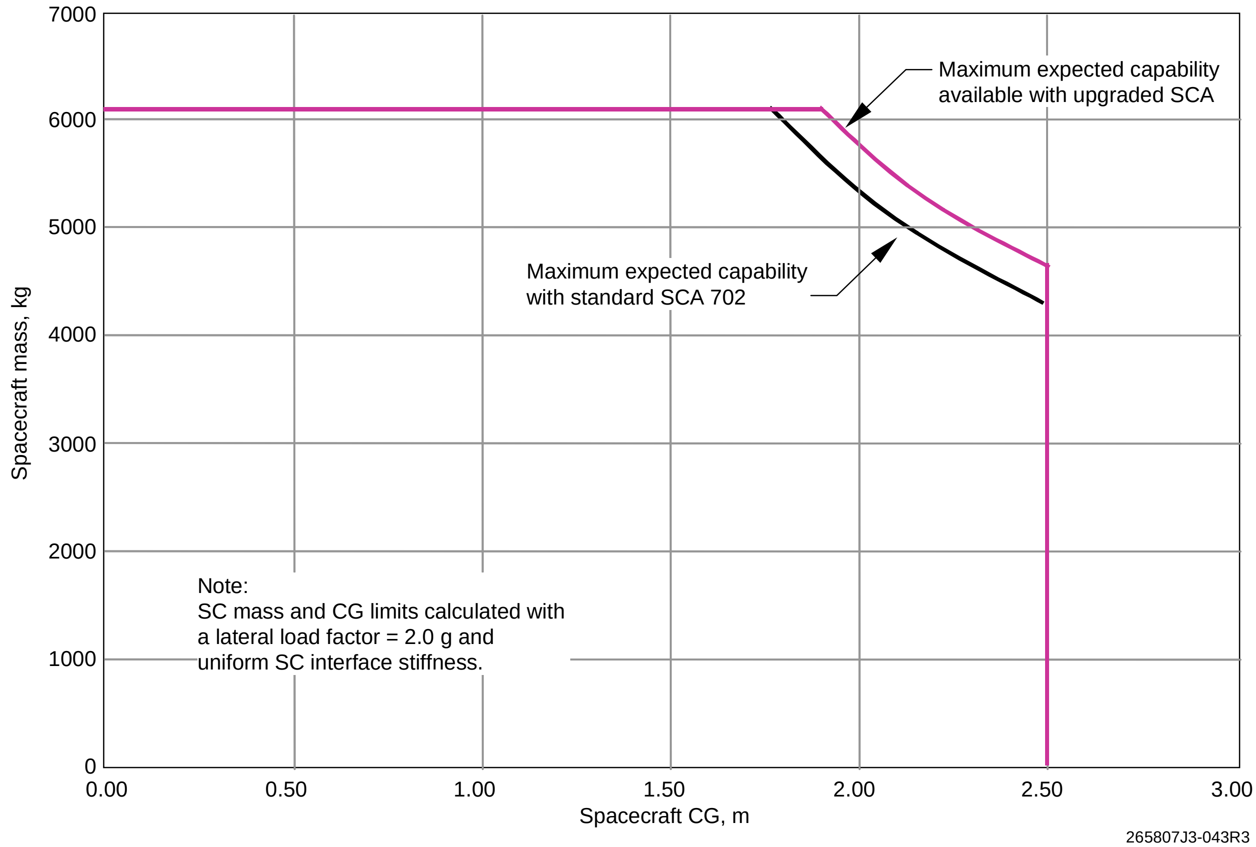

Figure 6-4. Expected Spacecraft Mass and CG Limits With SCA702 and SCA702GEM Spacecraft Adapters

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 (RF) impingement on launch vehicle (LV)

To avoid electromagnetic interference with LV systems, spacecraft electrical field radiation impingement on the LV must not exceed the levels shown in figure 6-5. Spacecraft RF system characteristics will be necessary for integrated analysis and for the required FCC special temporary authority (STA) license, which is necessary for Home Port RF testing.

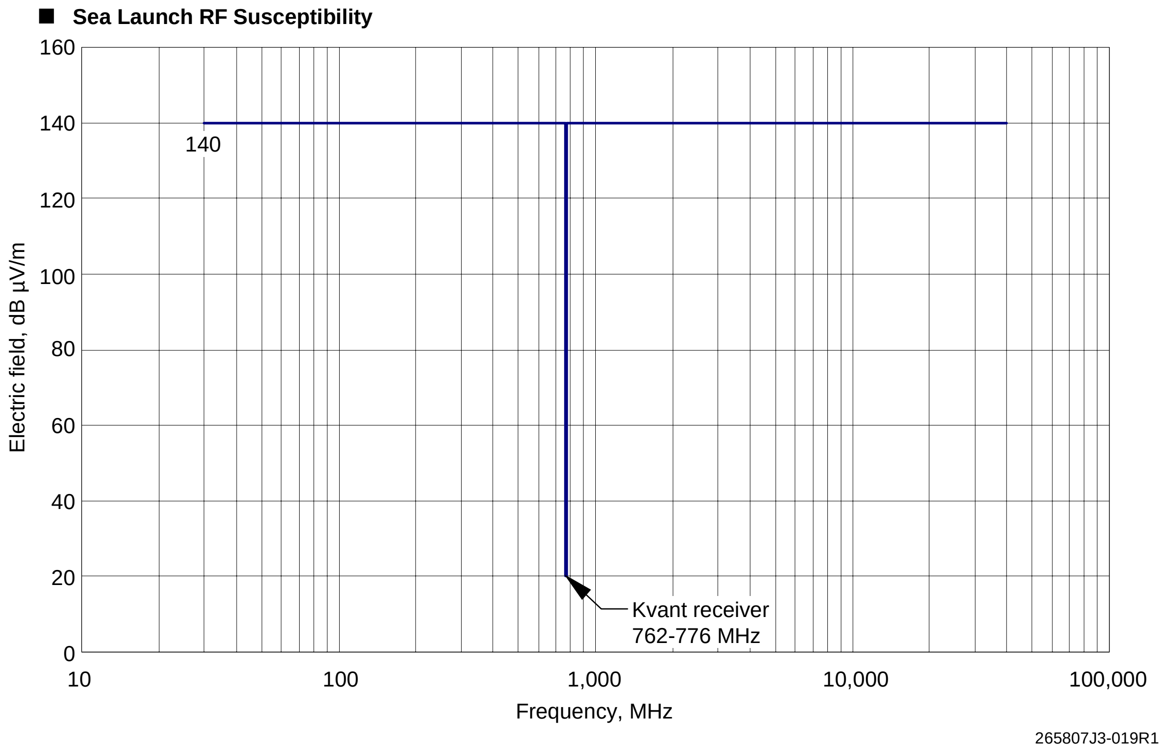

Figure 6-5. Maximum Spacecraft Intentional Electrical Field Radiation Impingement on LV

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.

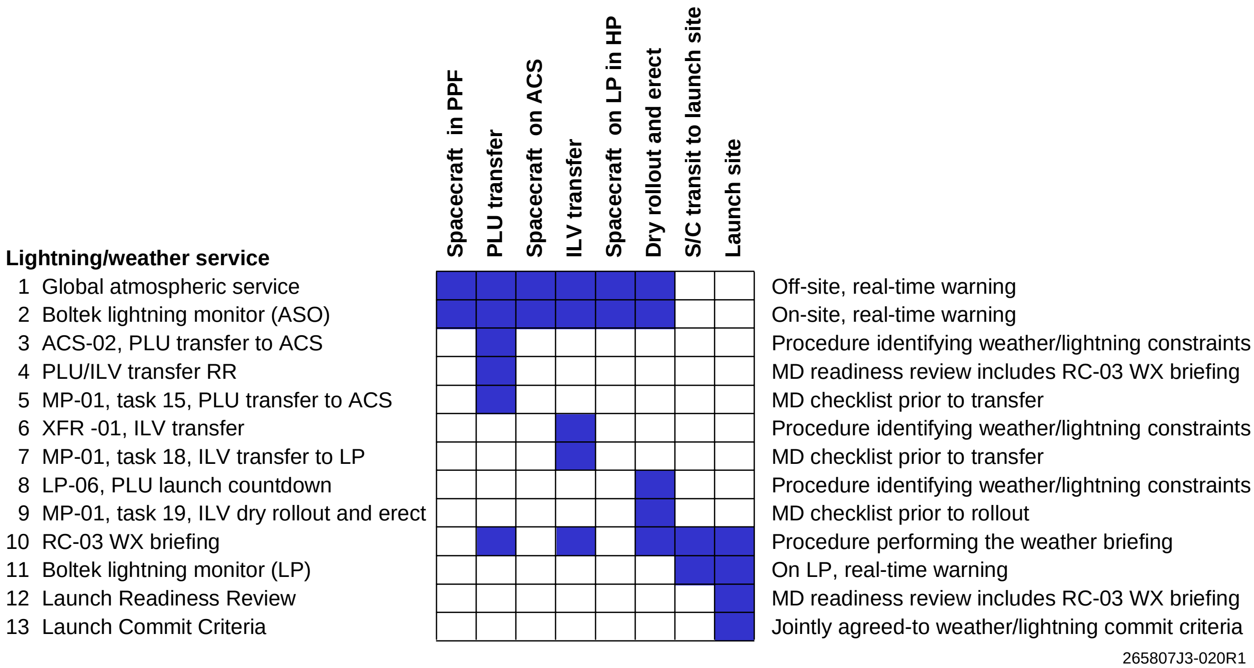

Figure 6-6. Lightning and Weather Services Used to Determine or Forecast Lightning During Launch Campaign

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RF 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 RF transmitters can produce RF hazard levels in areas within the antenna's main beams. These RF hazard locations have been identified along with the RF hazard conditions. Safety personnel have identified the RF hazard areas as controlled-access areas. Safety training is discussed in section 11.

Electromagnetic interference(EMI)/ electromagnetic compatibility (EMC) test report

The spacecraft contractor will be requested to provide Sea Launch with component and subsystem- and equipment-level EMI/EMC 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 below 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 6-3. Note that the minimum ultimate factor of safety shown is 1.3. Moreover, for qualification or proof tests, an ultimate factor of safety equal to 1.25 on limit loads may be acceptable for selected structural components having a flight heritage or when a model uncertainty factor no less than 1.05 is used to determine limit load.

Table 6-3. Factors of Safety and Test Options

Test option	Factors of safety		Test level	Test success criteria
	Yield	Ultimate		
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

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Test-verified model required for final CLA

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 6-3. Limit loads for the transient flight events are calculated by Sea Launch in a coupled loads analysis (CLA) 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 CLA 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 (section 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 CLA 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 6-3. 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 6-3 must be demonstrated.

Sine vibration testing

The sine vibration test levels for qualification, proto-qualification, proof, and acceptance are given in table 6-4. 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 previously flown 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 6-3 must be demonstrated.

Notching may be employed 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 CLAs and provided by Sea Launch. The test factor levels depend on the test options chosen and are given in table 6-3.

Table 6-4. 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	1.25 g	1.25 g	1.1 g	1.0 g
Lateral	5 to 15 Hz	1.0 g	1.0 g	0.9 g	0.8 g
	15 to 100 Hz	0.9 g	0.9 g	0.8 g	0.7 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 are required for every mission. The acoustic margins and duration for qualification, proto-qualification, and acceptance tests are found in table 6-5.

Table 6-5. 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 processing facility. These tests include both electrical and mechanical mates (see fig. 6-7).

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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 will be through the PLF 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 aboard 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. 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. Sea Launch payload fairing accommodates the spacecraft static envelope, as shown in figure 7-1.

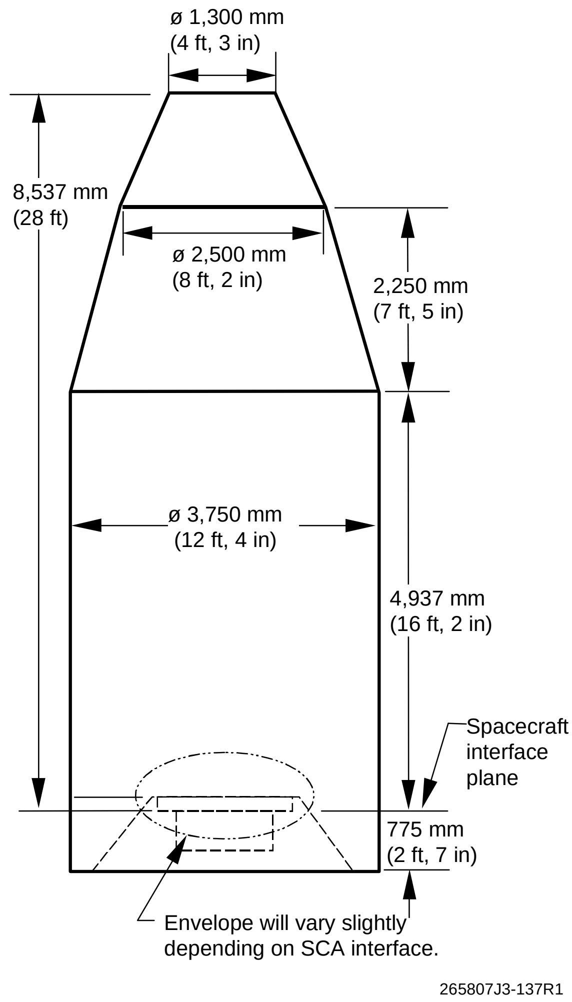

Figure 7-1. Spacecraft Static Envelope

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 7-2 shows the zones on the fairing surface where doors may be located.

- 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.

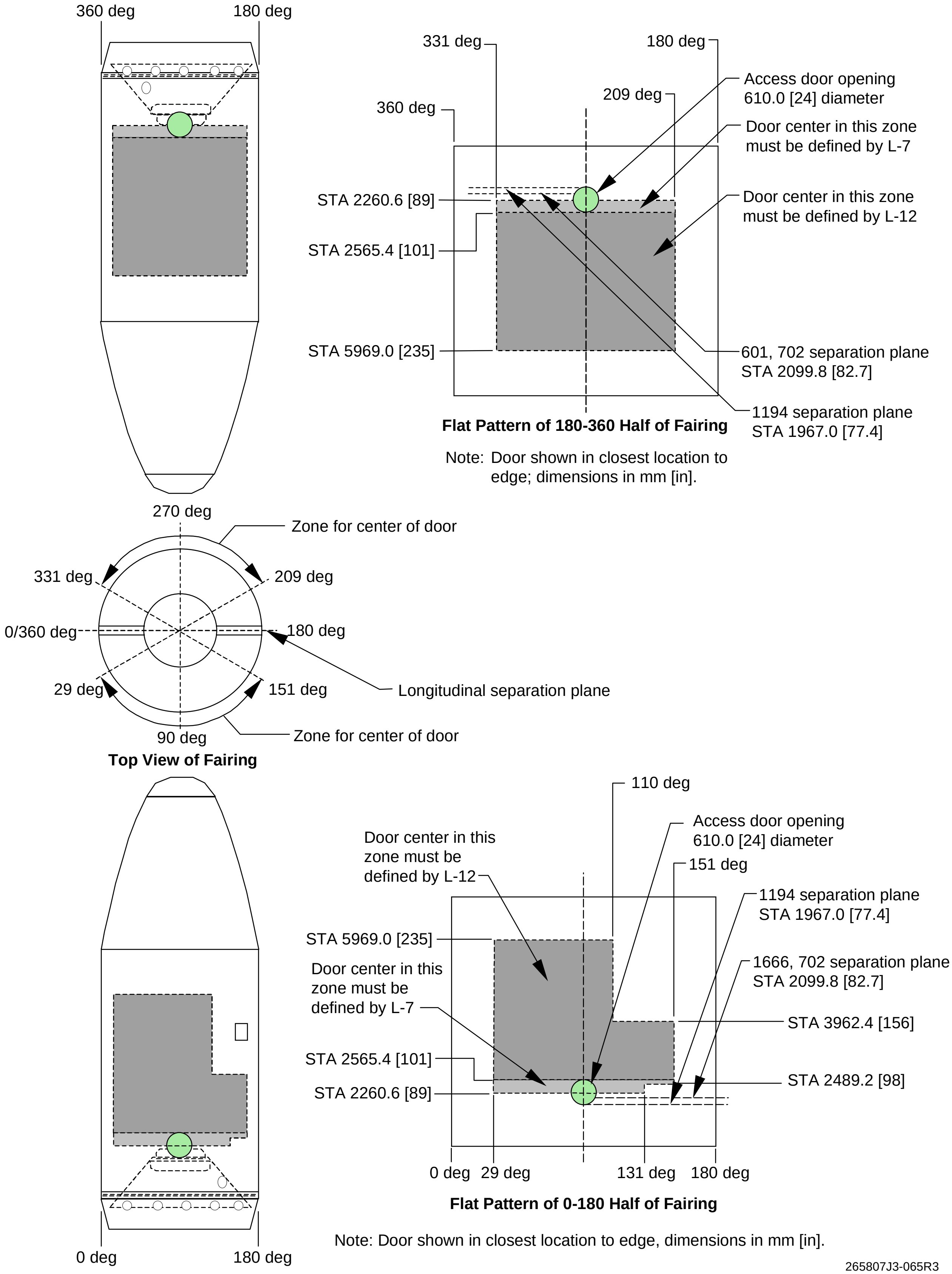

Figure 7-2. Payload Fairing Locations for Access Doors

Spacecraft adapter (SCA) and payload structure (PS)

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

SCA1666

The SCA1666 has a diameter of 1666 mm at the spacecraft interface and utilizes a Marmon clamp separation system. This adapter accommodates the HS601-type spacecraft. Six pushoff springs are used during separation to impart an initial delta velocity with respect to the launch vehicle. The SCA 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 which participate in the spacecraft separation dynamics. The major elements of this clampband type adapter are shown in figure 7-3.

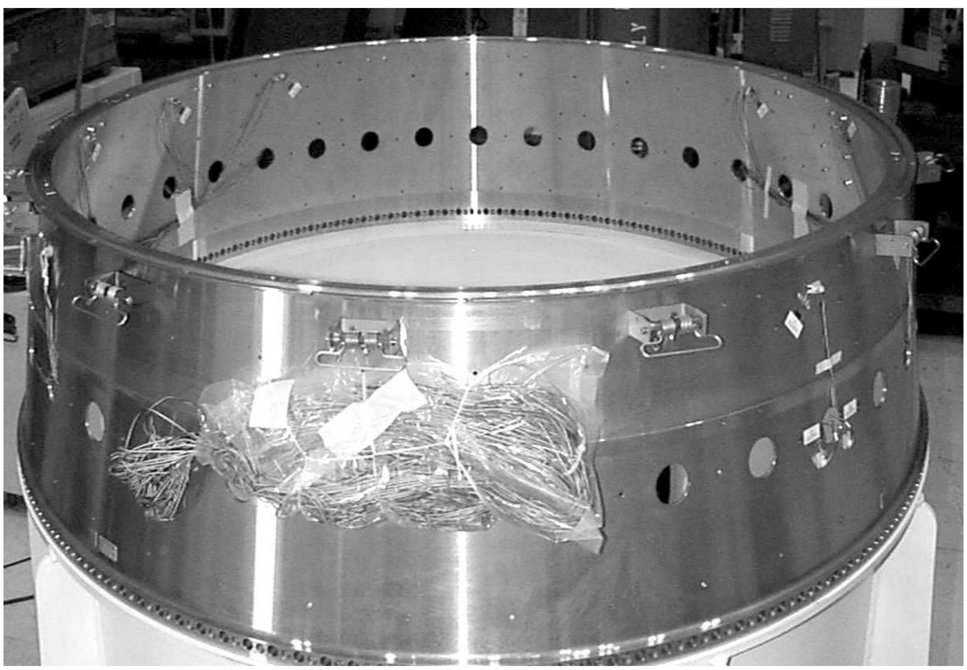

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Figure 7-3. SCA1666 Spacecraft Adapter

SCA702 and SCA702GEM

The SCA702 has a diameter of 1664 mm at the spacecraft interface and is attached to the spacecraft using four bolts. This adapter accommodates the HS702-type spacecraft. 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 (see fig. 7-4).

The SCA702GEM is an SCA702 with minor modifications to account for slightly different geometry at the spacecraft interface.

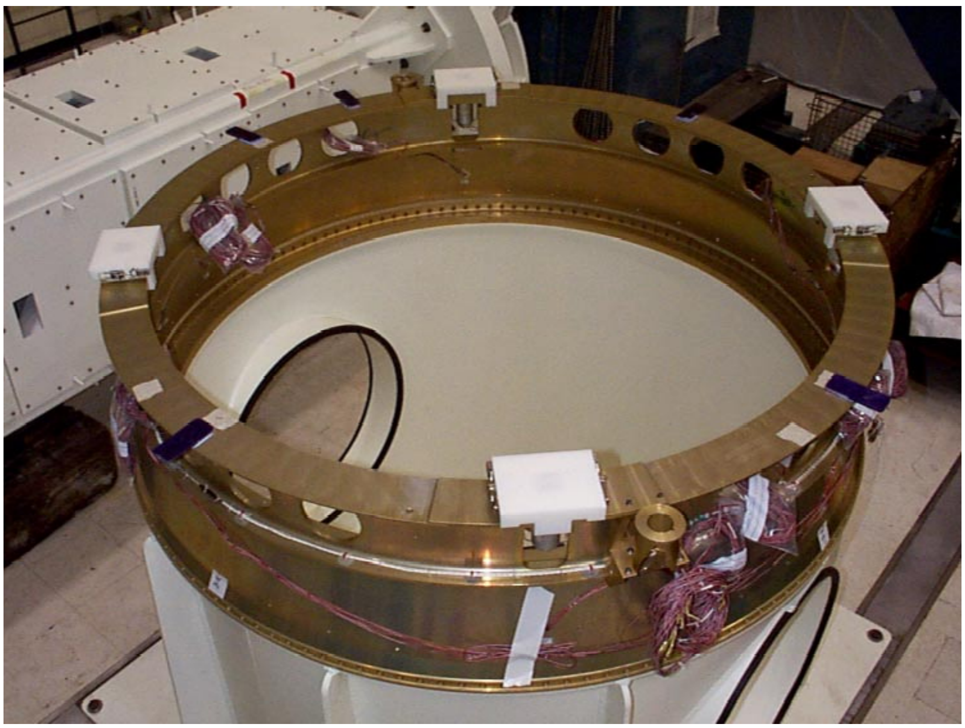

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Figure 7-4. SCA702 Spacecraft Adapter

SCA1194

The SCA1194 has a diameter of 1194 mm at the spacecraft interface and utilizes a Marmon clamp separation system. 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 7-5.

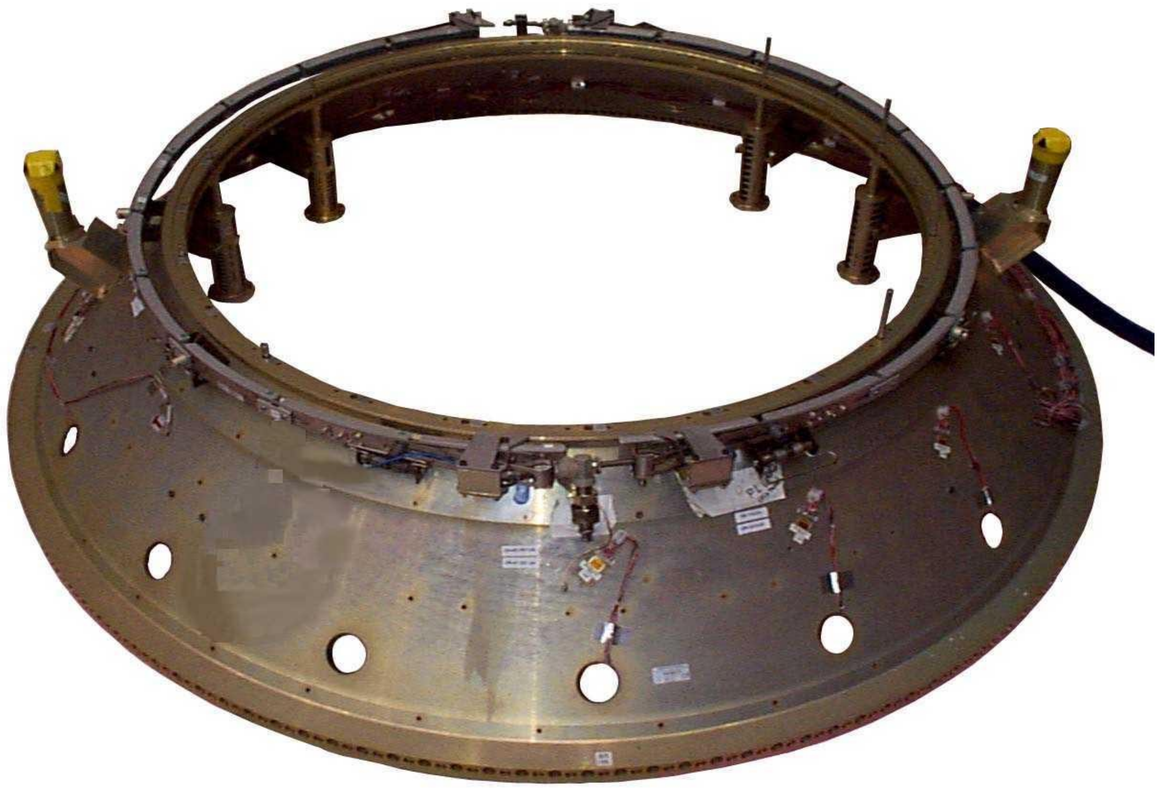

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Figure 7-5. SCA1194 Spacecraft Adapter

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 MIL-C-26482 series connectors (61 pins) or two MIL-C-81703 series connectors (37 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 during integration check out and during transit to the launch site.

- At approximately L-8 hr the interface skirt umbilical is disconnected.
- The T-0 umbilical remains connected until liftoff.

Table 7-1 and figure 7-6 depict umbilical configuration during spacecraft encapsulation, integrated launch vehicle integration, transit phase, and on-pad operations.

Available umbilical functions

Table 7-1. Umbilical Configurations

Umbilical cable path	Signal	power
Interface skirt before L-8 hrs	• 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 • Up to 20 amps 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 • Up to 20 A and 105 V dc for external spacecraft power

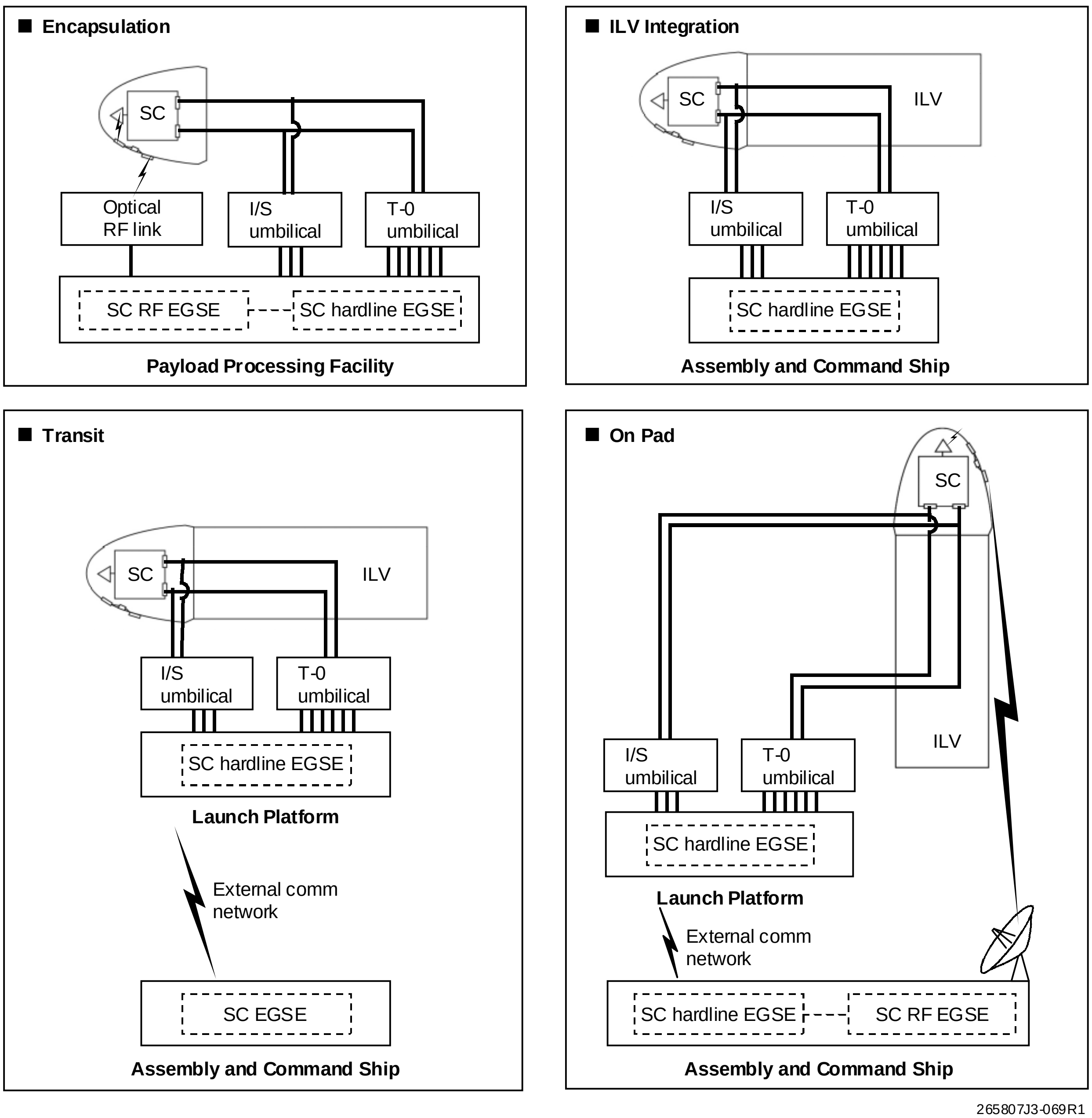


Figure 7-6. Umbilical and RF Configurations During Launch Processing Flow

Radio frequency link (rerad)

A direct RF link to the spacecraft is provided by a reradiation system depicted in figure 7-6. This RF link supports spacecraft telemetry and command communications to spacecraft electrical ground support equipment (EGSE) in the payload processing facility (PPF) and between the ACS and the LP when the integrated launch vehicle is erect at the launch site.

This system is undergoing evaluation relative to customer needs. Upgrade options will be addressed for possible future implementation.

External communications network

The external communications network provides worldwide connectivity in support of Sea Launch operations, including links between the ACS and LP. This network provides RS422 and/or Ethernet connectivity for spacecraft and customer use. During transit and at the launch site, the link will be available by INTELSAT relay. When vessel position permits, the link will be available directly by RF line of sight. The capabilities of this network include

- Spacecraft command and telemetry hard-line links that will use the external communications network between vessels. This is shown in figure 7-7.
- Sea Launch–provided communications connectivity using the Brewster, WA, 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 SC factory. Sea Launch can also provide an Internet connection, to which the customer would have worldwide access.

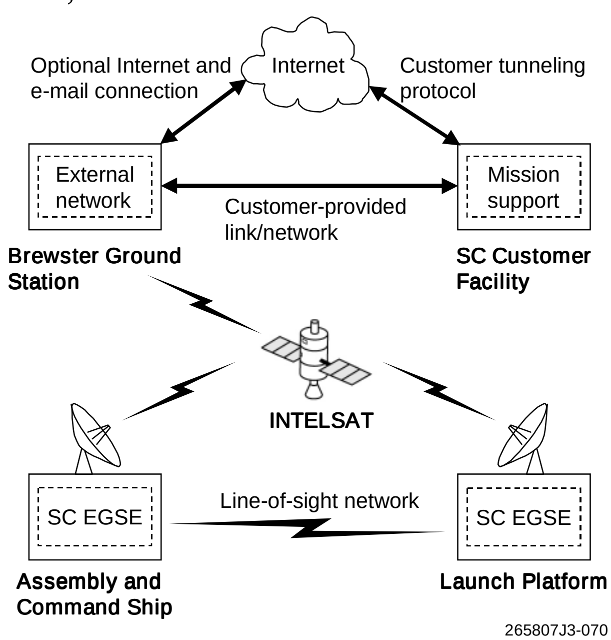


Figure 7-7. Sea Launch External Communications Network

Available in-flight interfaces

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

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

<table>
<tr><th>Interface</th><th>Description</th><th></th></tr>
<tr><td>Serial PCM telemetry</td><td>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.</td><td rowspan="3">Provided postflight</td></tr>
<tr><td>Analog telemetry</td><td>Four launch vehicle analog telemetry channels are available for spacecraft use. These channels will accommodate data input at ≥ 400 samples per sec.</td></tr>
<tr><td>Digital telemetry</td><td>The launch vehicle telemetry system will accept up to eight discrete (bi-level) inputs from the spacecraft.</td></tr>
<tr><td>In-flight commands</td><td>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.</td><td rowspan="2">Provided real time</td></tr>
<tr><td>Separation breakwires</td><td>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 connectors pin allocations.</td></tr>
</table>

Electrical power

Both at the Home Port and on the vessels, Sea Launch provides customer EGSE 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 EGSE to facility ground.

Electrical bonding

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

8. SPACECRAFT INTEGRATION AND LAUNCH OPERATIONS

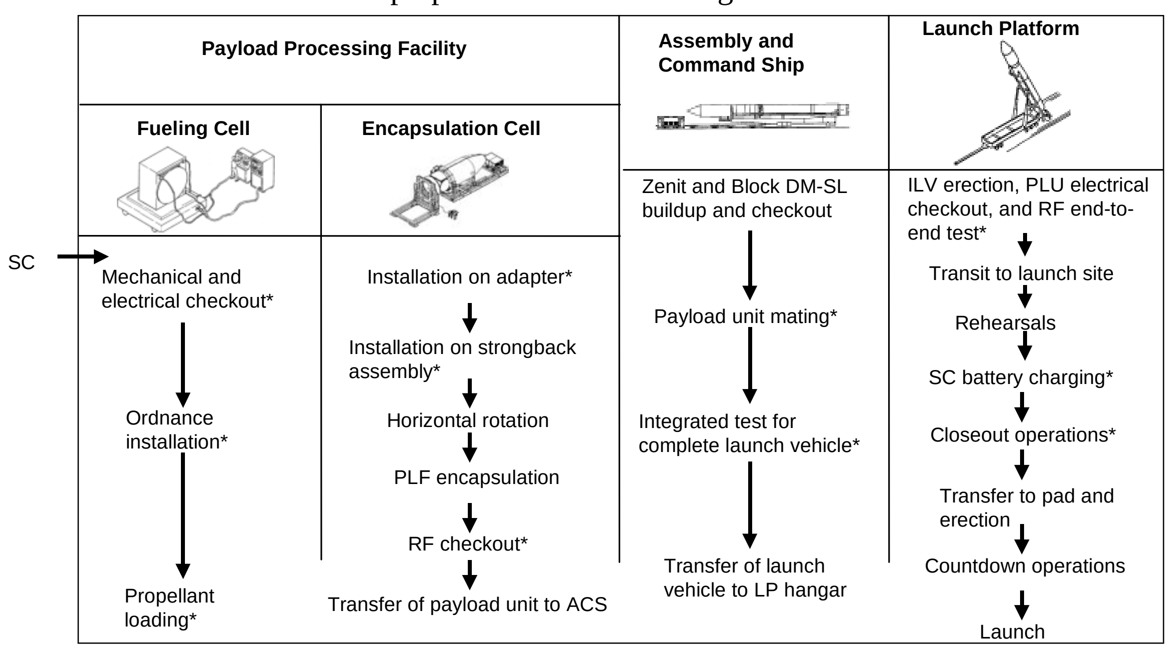
Overview

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 (PPF). This phase starts with the delivery of the spacecraft to Sea Launch at Home Port and includes final processing of the spacecraft, standalone tests, ordnance installation, fueling, and encapsulation with the payload fairing.
- Phase II takes place on the assembly and command ship (ACS). This includes mating the encapsulated spacecraft to the Zenit-3SL launch vehicle and integrated testing.
- Phase III takes place on the launch platform (LP). While still in port, the integrated launch vehicle (ILV) is erected and electrical checkout and RF end-to-end tests are conducted. The LP then transports the ILV to the equator. Rehearsals are conducted while in 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 nominal 60-day processing schedule is shown in figure 8-2. Standard deviations from the 60 day schedule may be accommodated on a case-by-case basis. Communication and power service to the spacecraft during integration and launch preparation 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 2 wk)		–
SC stand-alone operations (notional 2 wk)	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	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 d
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 d
ACS returned from previous launch		–
Block DM stand-alone operations	10 hr/d, 6 d/wk	20
Zenit stand-alone operations	10 hr/d, 6 d/wk	7
Block DM mate to Zenit, interface checks	10 hr/d, 6 d/wk	3

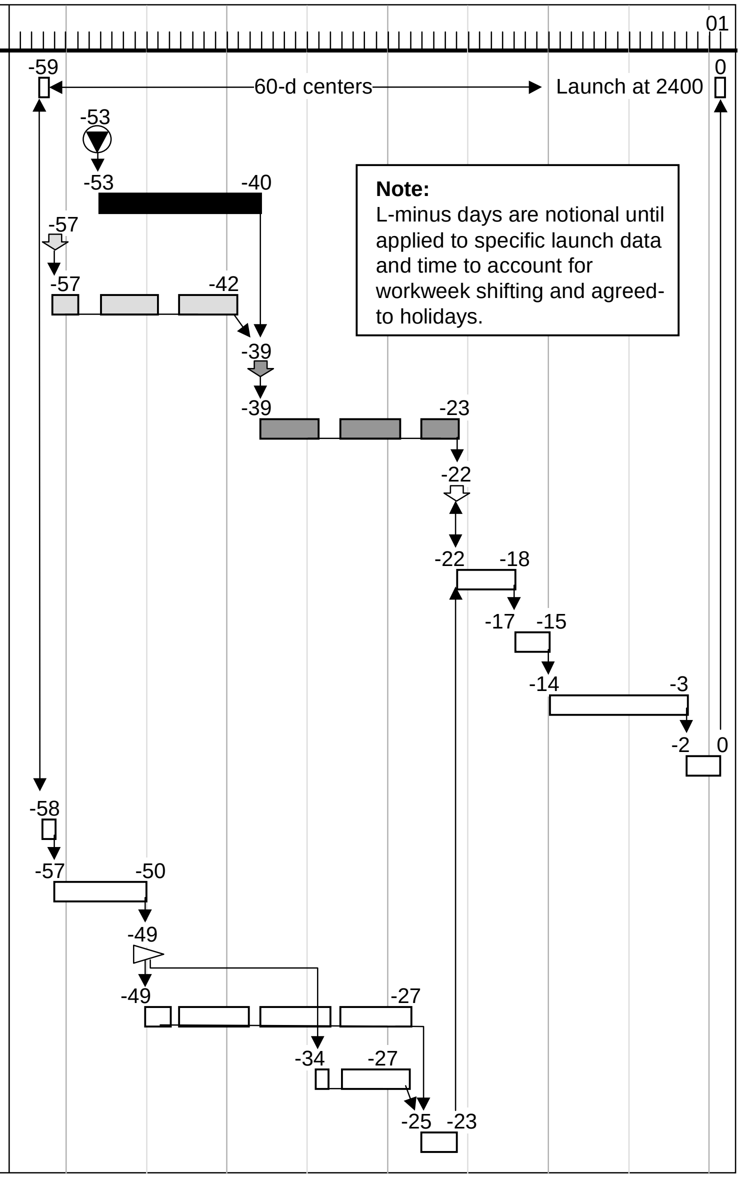

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Figure 8-2. Nominal 60-Day Processing Schedule

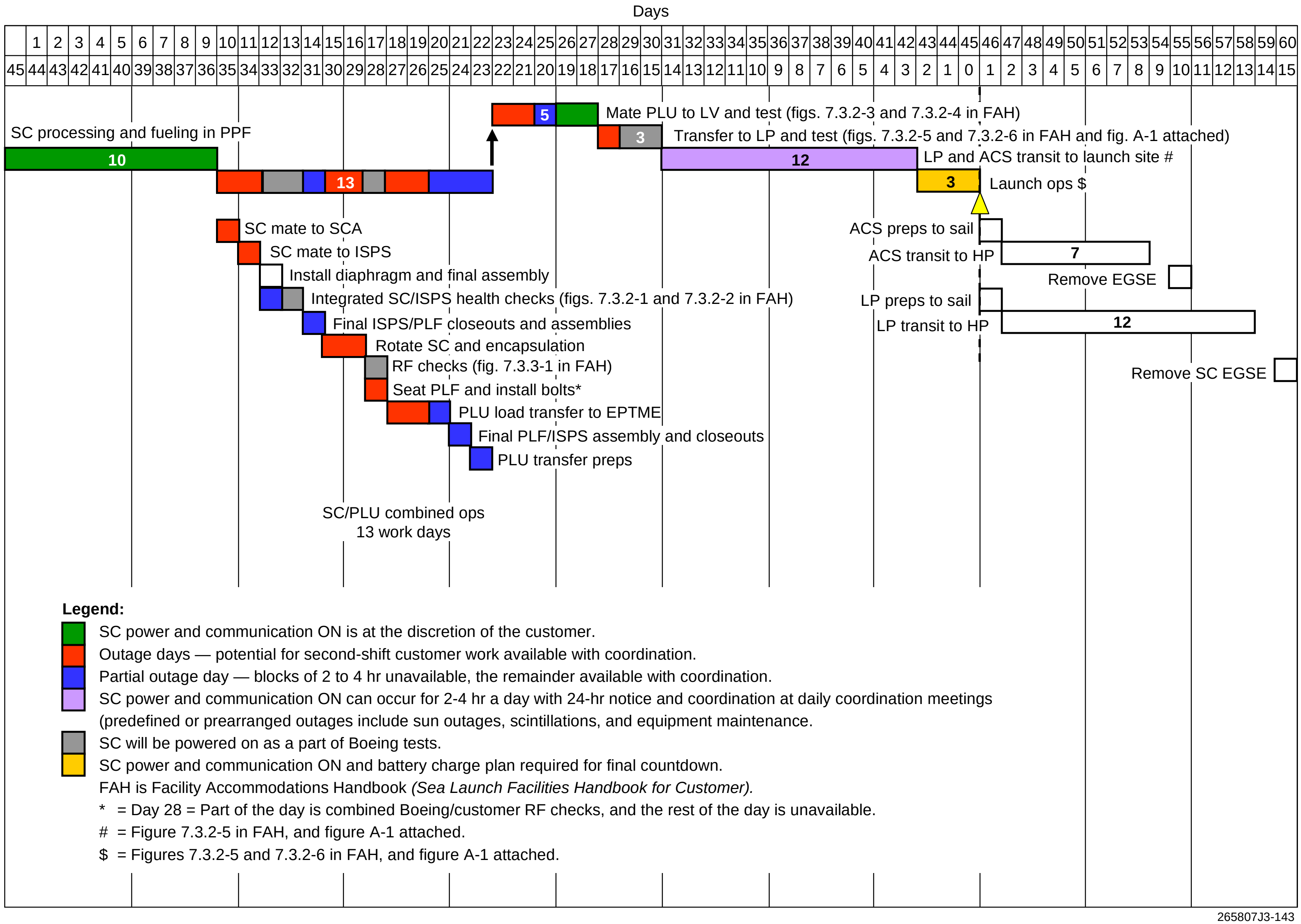

Figure 8-3. Campaign Timeline

8.1 Phase I—Spacecraft Processing in the PPF

Spacecraft delivery

Payload processing begins with delivery of the spacecraft to the Sea Launch Home Port complex in Long Beach, California. Delivery takes place at the common airlock cell in the payload processing facility (see 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 and fueling cells.

Spacecraft processing

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

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

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Figure 8-5. Fit Check on Adapter Support Stand

Facilities

Astrotech provides facility support services while the spacecraft is in the PPF. 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 (ISPS) also arrive at the PPF and are unloaded in the common airlock cell.

Strongback assembly (SBA)

An SBA is used for rotation of the spacecraft from horizontal to vertical for encapsulation (see fig. 8-6 and 8-7).

- Boeing personnel move the ISPS into the encapsulation cell and place it on the SBA.
- Once spacecraft standalone 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 ISPS on the SBA (see fig. 8-8).
- All systems are fully tested before mating and all mechanical and electrical interfaces are verified by established procedures.

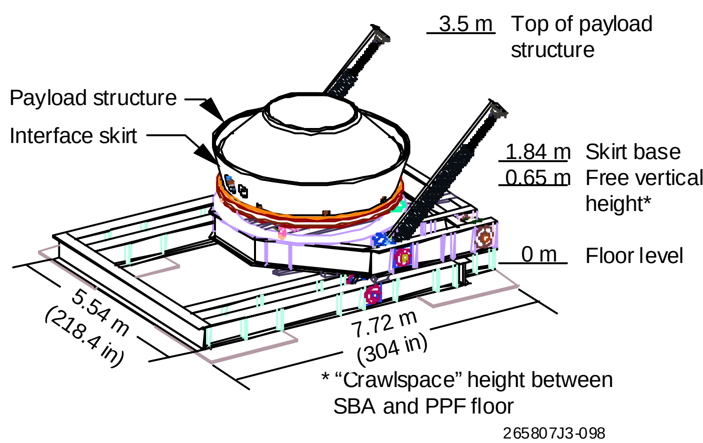

Figure 8-6. SBA Vertical Mating Position

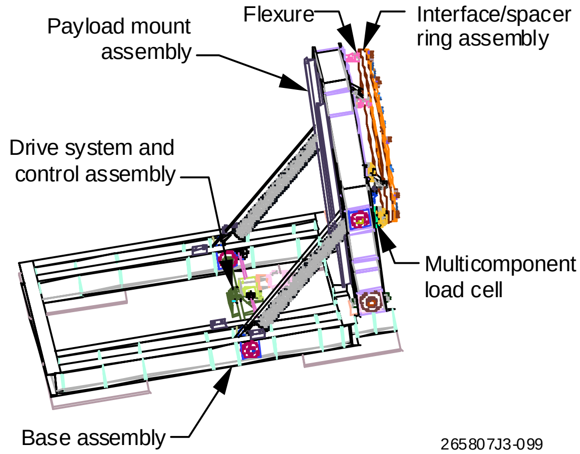

Figure 8-7. SBA Horizontal Raised Position

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Figure 8-8. SBA Rotating to Horizontal With Pathfinder Structure

Encapsulation

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

Alignments are meticulously inspected and the EPTME slides the payload fairing over the spacecraft and mates with the ISPS.

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Figure 8-9. EPTME With Encapsulated DemoSat Spacecraft

Payload unit

The encapsulated spacecraft, adapter, ISPS, 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 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 ACS to provide access for maintenance and to support mating to the Block DM.

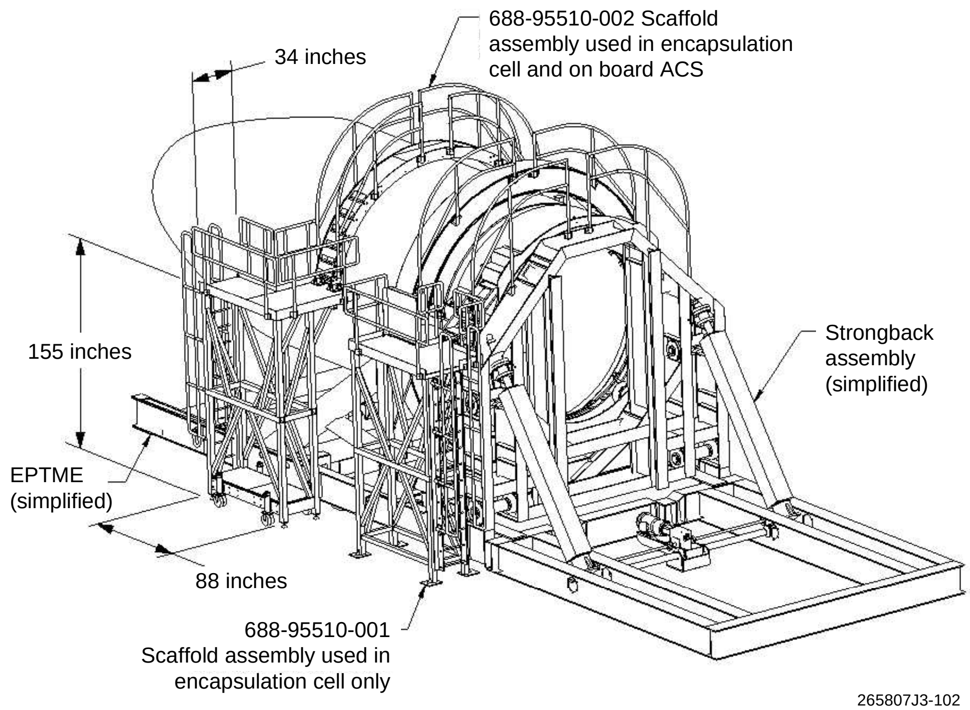

Figure 8-10. Scaffolding Around Encapsulated Spacecraft

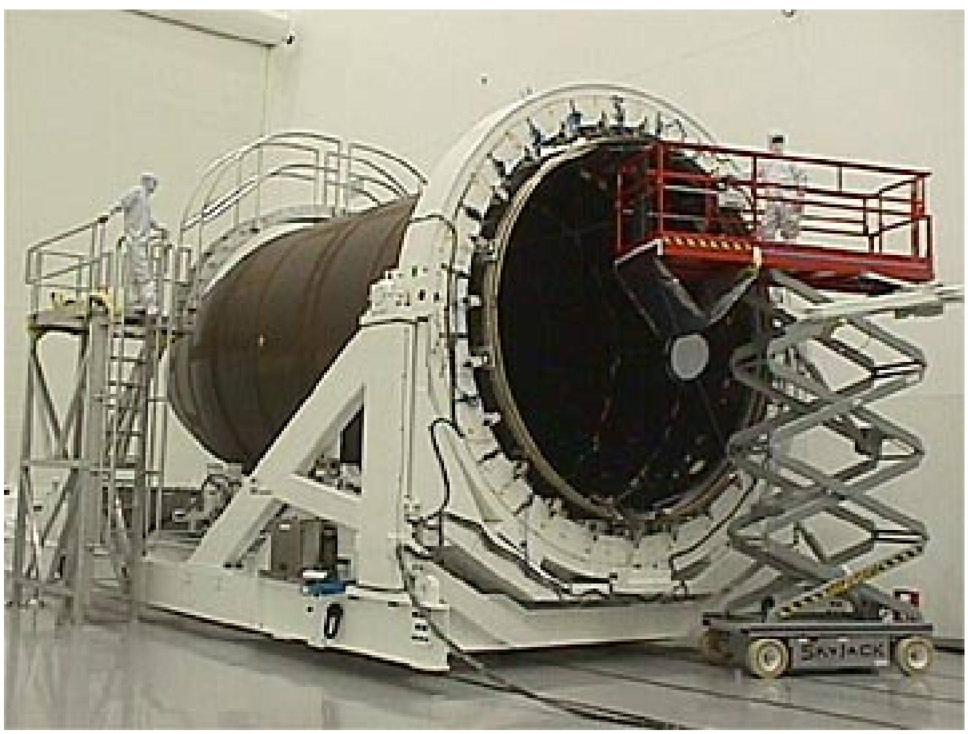

Figure 8-11. Access to Encapsulated Spacecraft

Encapsulated payload transport vehicle (EPTV)

The integrated payload unit is loaded onto an EPTV for transportation to the ACS.

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

Transport from PPF to ACS

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 ACS.

Figure 8-14 shows the payload unit driving onto the stern ramp of the ACS.

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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 ACS 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 LV and Integrated Testing on the ACS

Zenit processing prior to spacecraft mating

Zenit-3SL launch vehicle processing is performed on the ACS while the spacecraft is still in the payload processing facility (see fig. 8-15). At the pier, complete systems for loading fuels, compressed gasses, 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 onto 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 (see fig. 8-16).

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 ACS 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 ILV is fully checked out.

Transfer to the launch platform

The ACS is repositioned around the pier for transfer of the ILV from the ACS to the LP.

The ILV is rolled out of the ACS processing bay by a ship rail system. Cranes are used to lift the ILV up into the LP for placement in the hangar. Clean conditioned air is provided throughout this operation.

Figure 8-17 shows the ILV ready for lifting from the ACS.

Figure 8-18 shows the ILV 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 LP

Transit Transit for the ACS (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 knots).

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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 ILV is supported on the transporter/erector in the launch platform hangar (see fig. 8-21).

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 ACS.

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 are conducted before the ACS arrives at the launch site, including the mission dress rehearsal (MDR). Participation of customer launch personnel on board the ACS, spacecraft tracking and communication systems personnel, and the spacecraft control center is encouraged.

The MDR simulates prelaunch and postlaunch operations up through spacecraft separation and completion of the Block DM-SL CCAM. 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 lowered to its semi-submersible launch draft position of 22.5 m. Platform positioning and orientation are maintained using global positioning system (GPS) inputs to a dynamic positioning system of thrusters on board the platform. 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; most of the waves in the launch regions 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 (see fig. 8-22).

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Figure 8-22. Launch Operations at the Launch Site

Link bridge operations

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

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

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Launch readiness review (LRR)

An LRR 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.

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 ACS, the connecting bridge is stowed, and the ACS is repositioned 6.5 km away.

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

From this point on, the launch platform is under remote operations control from the ACS. 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 hr 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 ILV 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 hold down 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 (see fig. 8-24).

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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 ACS (see fig. 8-25). During all phases of launch processing and flight, the launch control center has ultimate responsibility and authority for all decisions and commands affecting the integrated launch vehicle. Internal communications on both the ACS and launch platform include closed-circuit television (CCTV), telephone, intercom, public address, data communications and computing systems, a line-of-sight system, a countdown clock system, and a mission management display system (MMDS). 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

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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

- Delay of launch operations.
- Invocation of 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 is provided by Sea Launch using assets on board the ACS and the launch platform through the tracking and data relay satellite system (TDRSS).

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

Line-of-sight telemetry coverage is continued through payload fairing jettison. TDRSS telemetry is routed through the central communication node in Brewster, WA.

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 since there are no other launches competing for Sea Launch assets at the same time.

Weather

The ACS 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 ACS while at sea.

Other

- A helicopter is provided to support mission operations. Both the ACS 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, WA, and Eik, Norway.

Zenit-3SL flight operations

Zenit first- and second-stage flight operations are completely automatic. A mission event timeline is included in section 3, table 3-1 of this user's guide.

All Stage 1 and 2 events occur within the view of the ACS. The spent stages fall in 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 CIS 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 LP 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 prior to the second burn of the main engine. Burn program options include, but are not limited to, one- or two-impulse insertion GTO and multiple burns (up to a maximum of five) to medium Earth orbit (MEO) or planetary escape.

Following spacecraft insertion into the target orbit, the Block DM-SL separates from the spacecraft and performs a CCAM. 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 (PLF jettison, engine burns, spacecraft separation, etc.).

An injection report is delivered within 50 min of spacecraft separation. The injection report documents the state vector of the Block DM-SL just prior to 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 the 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. 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. The 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 (ACS) and launch platform (LP) 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 the Home Port.

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

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

- Home Port facilities.
- The ACS.
- The LP.

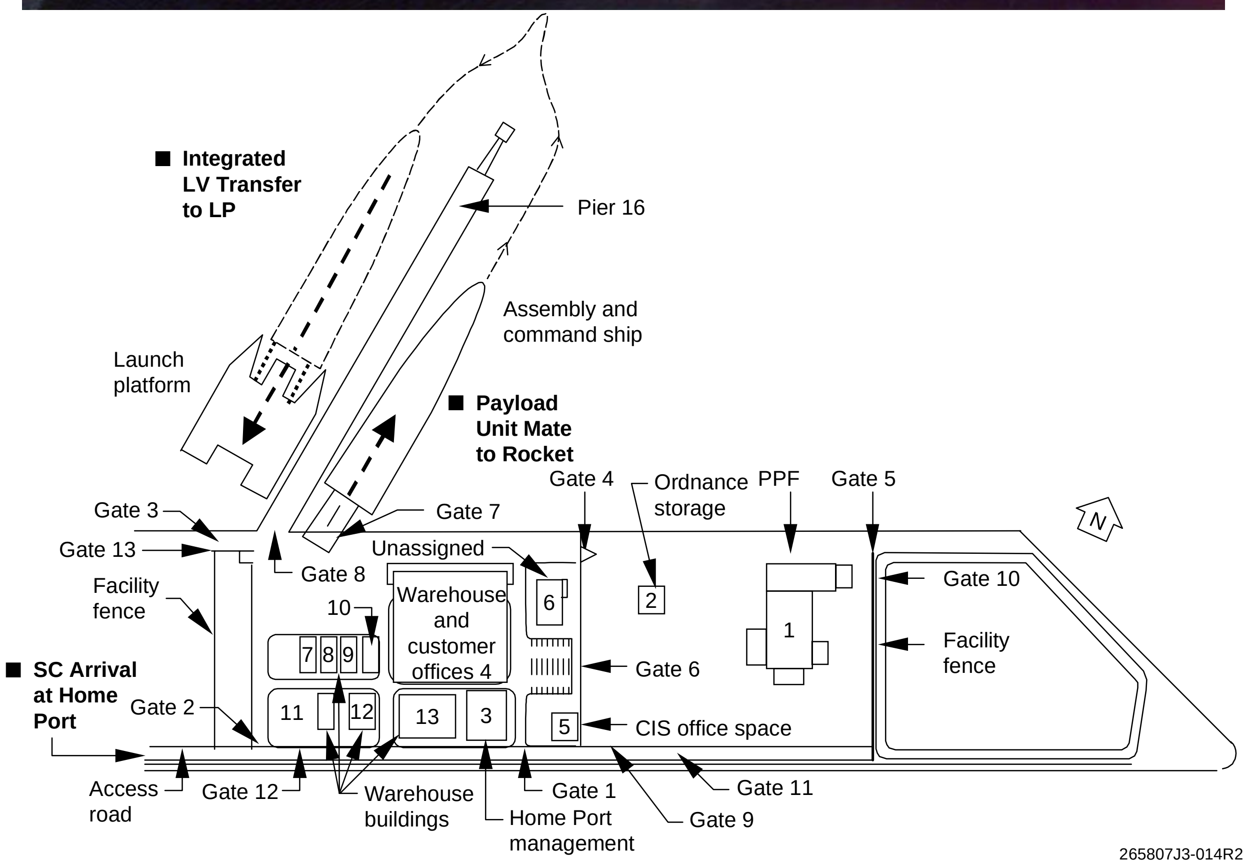

Figure 9-1. Sea Launch Home Port Complex

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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 the 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 (PPF) (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 PPF can support the processing campaigns of two customers concurrently. The PPF is separated from the rest of the complex by an interior fence with controlled access during hazardous spacecraft operations.

The PPF 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.

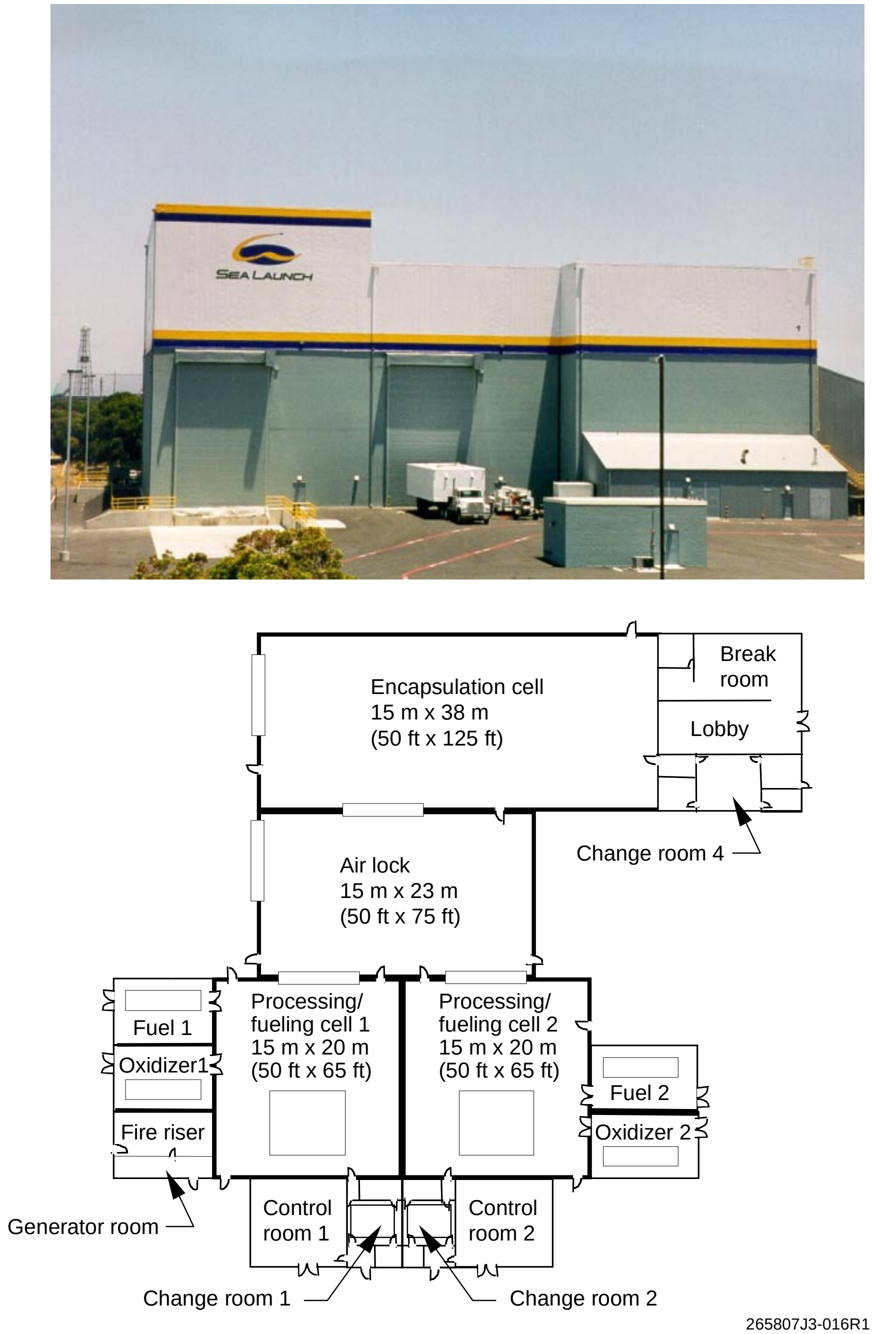

Figure 9-4. Payload Processing Facility—Interior and Exterior Views

Processing and fueling cells

The processing and fueling cells have been designed to facilitate on-site electrical testing, spacecraft fueling, and final assembly before encapsulation of the spacecraft into the payload fairing. Spacecraft providers will be 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 sets of 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 and the interface skirt and 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 PPF 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 PPF at the 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 control or monitor their operations in the PPF remotely.

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


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

Transportation services

When customer equipment destined for the 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 space-craft between Home Port facilities.

9.2 Assembly and Command Ship

Functions and characteristics

The ACS (fig. 9-6) performs four functions for Sea Launch operations:

- It serves as the facility for assembly, processing, and checkout of the launch vehicle.
- It houses the launch control center (LCC), which monitors and controls all operations at the launch site.
- It acts as the base for tracking the initial ascent of the launch vehicle.
- It provides accommodations for the marine and launch crews during transit to and from the launch site.

The ACS 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 ACS include

- A rocket assembly compartment.
- The LCC.
- An LCC viewing room.
- Helicopter capability.
- Spacecraft contractor and customer work areas.
- Spacecraft contractor and customer accommodations.

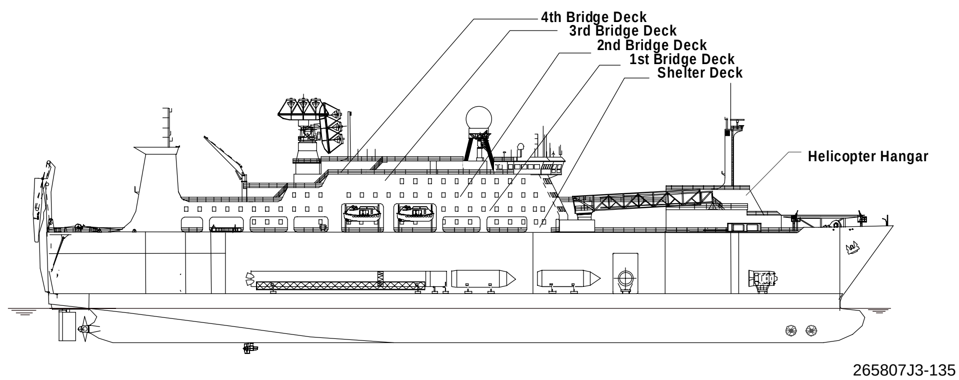

Figure 9-6. Assembly and Command Ship

Rocket assembly compartment

The rocket assembly compartment (fig. 9-7), which is located on the main deck of the ACS, hosts the final assembly and processing of the launch vehicle. This activity is conducted while the vessels are at the 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 PPF, the encapsulated payload is transferred into the rocket assembly compartment, where it is integrated with the Zenit-2S and Block DM.

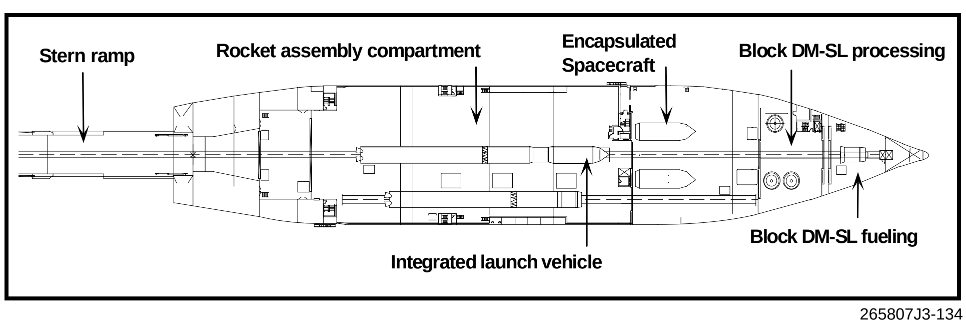

Figure 9-7. Launch Vehicle Processing—Main Deck

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 (see fig. 9-8). Environmental conditioning and monitoring of the encapsulated spacecraft is provided after encapsulation through launch.

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Figure 9-8. Launch Vehicle Transfer From Assembly and Command Ship to Launch Platform in the Home Port

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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 ACS shelter deck, as shown in figure 9-9. Layout of the console and display features of the room is shown in figure 9-10.

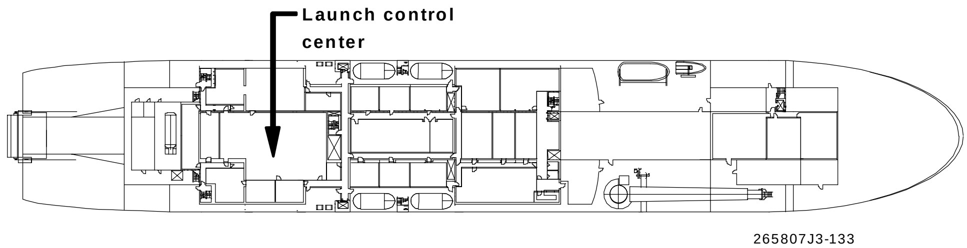

Figure 9-9. Launch Vehicle Control Center—Shelter Deck

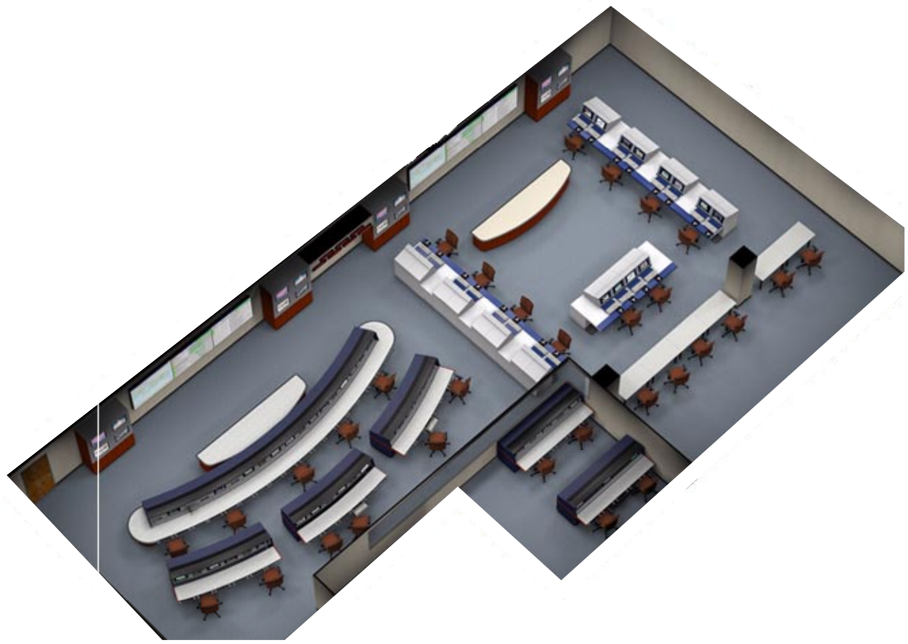

Figure 9-10. Assembly and Command Ship Launch Control Center

Mission management and display system (MMDS)

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

The MMDS receives and processes information from the shipboard weather equipment, marine systems, closed-circuit television (CCTV), 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 ACS.

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

Data management network connection is provided by a local area network allowing 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 VIPs, allows observation of the launch control center, and provides access to the communications networks and phone 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 (GSE) rooms, office areas, conference rooms, individual offices, and storage rooms.

The GSE rooms provide space for the equipment necessary to control and monitor the spacecraft during mission operations. The GSE is loaded to the deck area just behind each room, using the ship's overhead cranes.

The GSE rooms contain

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

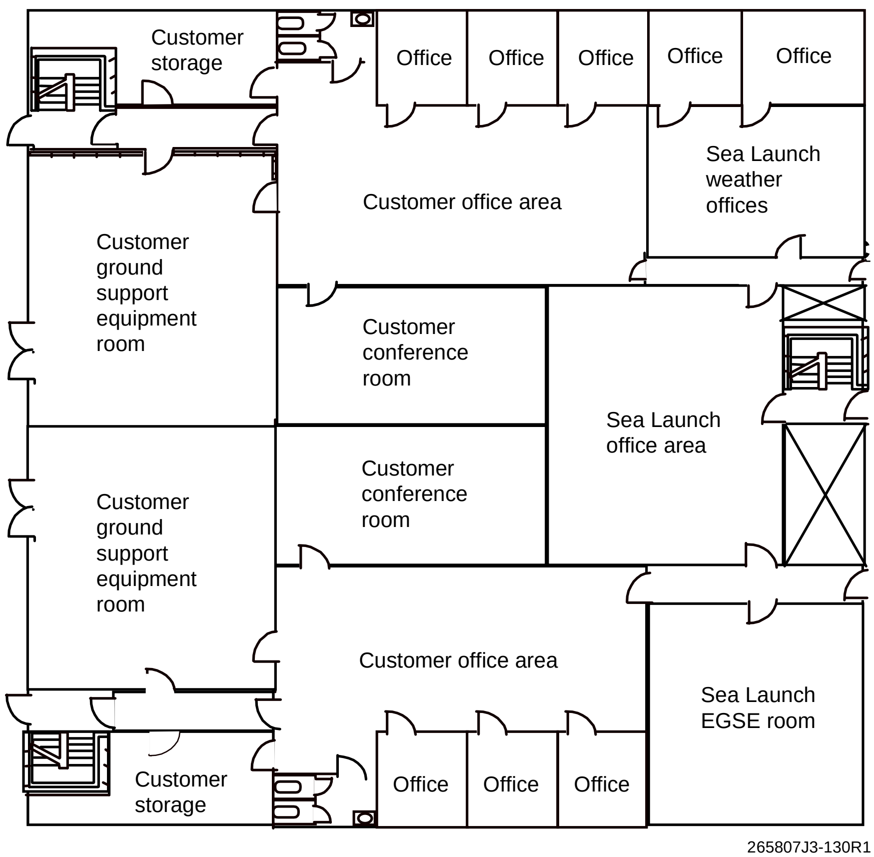

Figure 9-12. Spacecraft Contractor Work Area on First Bridge Deck

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 is 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.

COMSAT services

Telephones, fax machines, teleconferencing, and data links are provided from the ACS to customer home locations through commercial COMSAT services (see fig. 9-13). Radio frequency links between the ACS and the launch platform allow communications with the spacecraft in the hangar and on the launch pad, and between spacecraft GSE rooms on the ACS and 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 (see fig. 9-14). The ACS has accommodations for a total of 15 customer and spacecraft contractor personnel (see fig. 9-15). Crewmembers assigned to the ACS 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. This extra bunk serves as a temporary berth for launch platform crewmembers that have transferred to the ACS during final launch preparations.

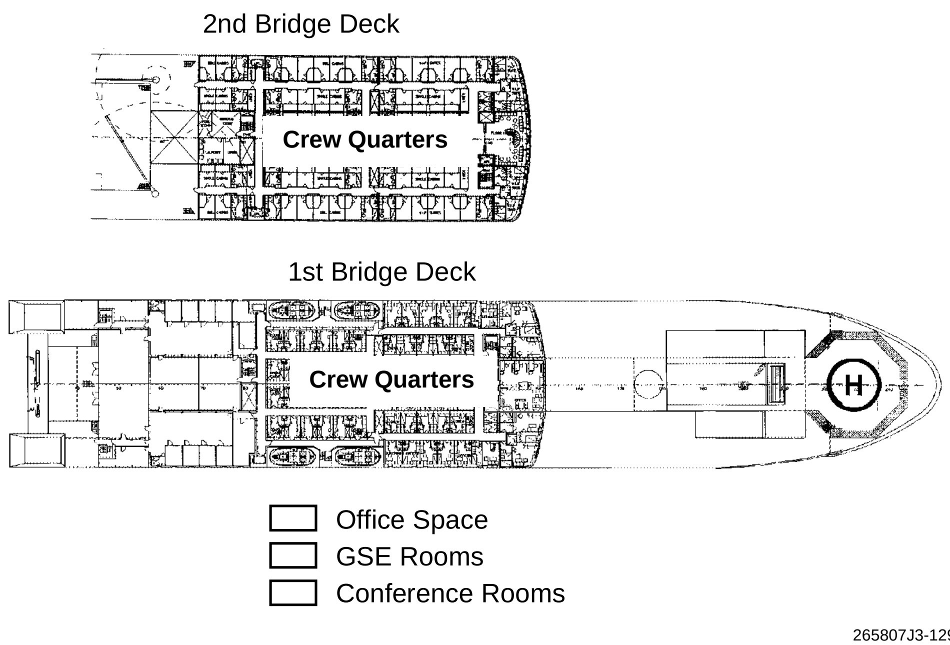

Figure 9-14. Spacecraft Customer Accommodations

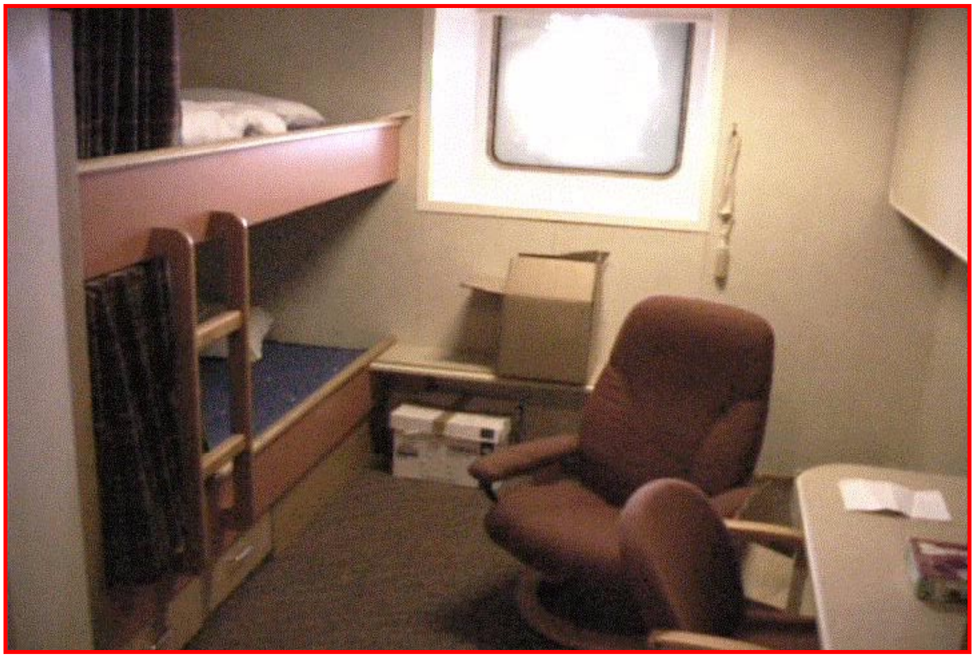

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Figure 9-15. Assembly and Command Ship Cabin Accommodations

Dining, recreation, and medical

The ACS 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 (see fig. 9-16).

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

A first aid clinic is also provided and the ACS marine crew includes a doctor.

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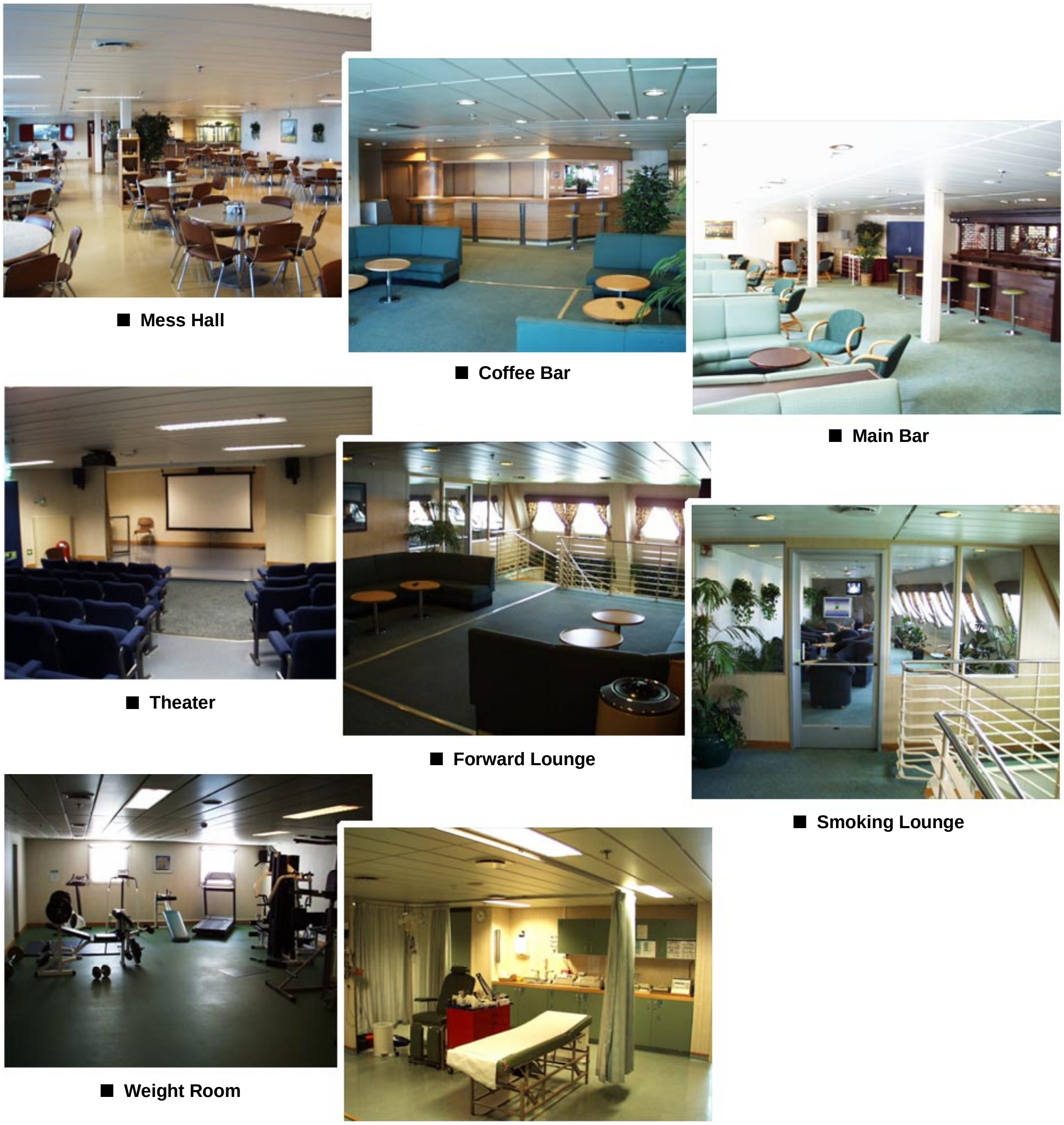
Figure 9-16. Main Cafeteria



■ Mess Hall

■ Coffee Bar

■ Main Bar

■ 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 the launch operations (see fig. 9-18). The launch platform transports the integrated launch vehicle to the enclosed launch 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 ACS using a link bridge between the vessels or by helicopter. Launch platform station keeping and launch operations are conducted from the ACS through redundant radio frequency links between the vessels.

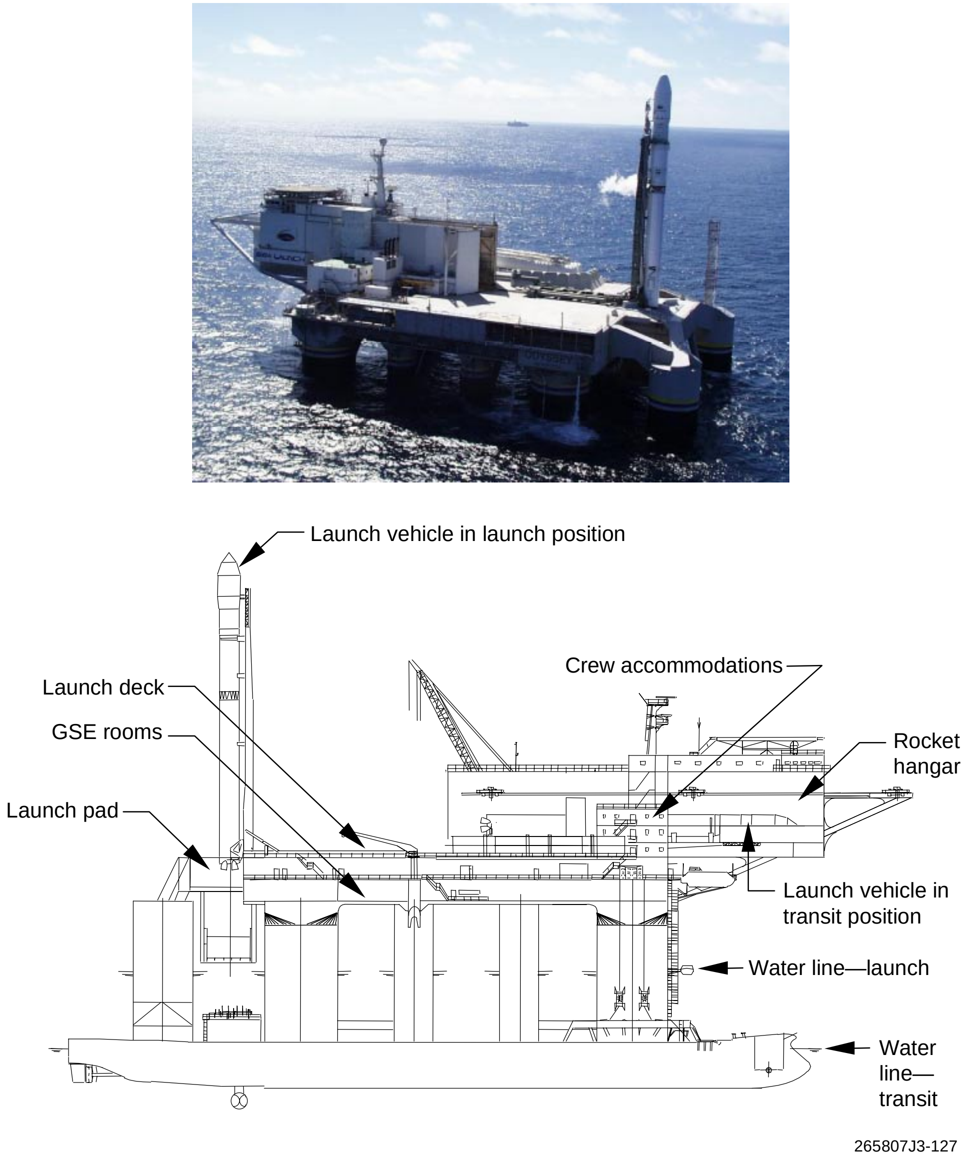

Figure 9-18. Launch Platform During Final Countdown

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 GSE, 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 will be allocated either individual or shared cabins.

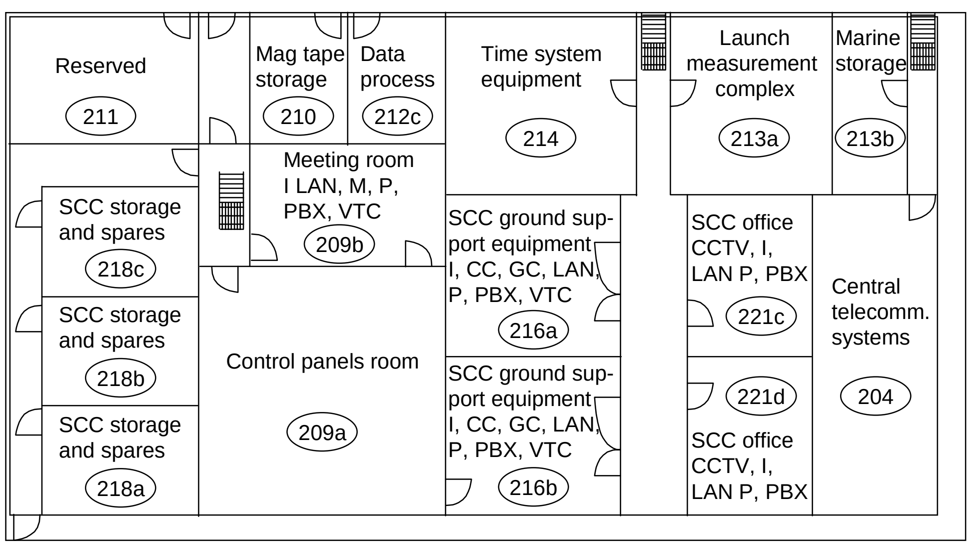

Figure 9-19. Spacecraft Contractor Work Areas on Launch Platform, 38500 Deck Level

Communications and access

Telephones, fax machines, teleconferencing, and data links are provided on the launch platform. Radio frequency links allow communication between the ACS 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 ACS and 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 the transit to and from the launch site. Regular meals are served by the Sea Launch catering staff in the dining hall. In addition, there is a small self-serve dining area to provide food and beverage service.

A first aid clinic is also provided and the launch platform marine crew includes a doctor.

10. 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 are distributed between the assembly and command ship and launch platform. This system includes CCTVs, telephones, intercom, public address, video teleconferencing, and vessel-to-vessel communications (also known as the line-of-sight [LOS] system).

This system links with the external communication system that provides a worldwide network that interconnects the various segments of the Sea Launch program (see fig. 10-1). The external communication system includes INTELSAT and two ground stations. The ground stations are located in Brewster, Washington, and Eik, Norway, and provide the primary distribution gateways to the other communication nodes. Customers can connect to the Sea Launch communication network through the convenient Brewster site. The INTELSAT system ties in with the ACS and launch platform PABX systems to provide telephone connectivity. Additionally, critical telephone capability can be ensured by INMARSAT (see fig. 9-13).

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Figure 10-1. ACS INTELSAT Earth Terminal

Weather systems The ACS has a self-contained weather station with the central office located on the first bridge deck (see 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 (see 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 MMDS.

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Figure 10-2. ACS Weather Office

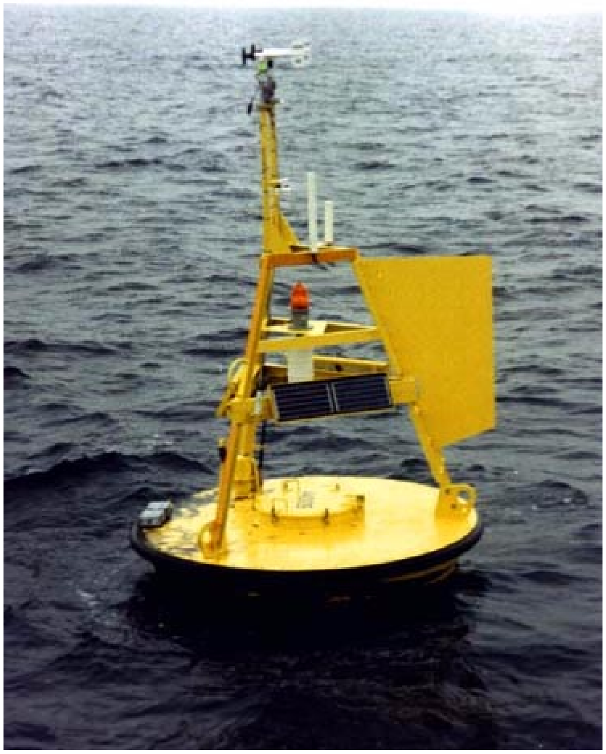

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Figure 10-3. On-Site Meteorological Buoy

Helicopter operations

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

265807J3-085

Figure 10-4. Sea Launch Bell 230 Helicopter

Photographic services

The Sea Launch photo-optical measurement system has several components on the ACS 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 ACS, an optical tracking system is provided (see 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 will also be available on both vessels and at Home Port to support flight hardware closeouts, configuration documentation, or other photographic requirements.

265807J3-088

Figure 10-5. Optical Tracker

External agency coordination

Mission Operations 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:

- Federal Aviation Administration (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 LOS telemetry systems for the initial flight phase, as well as the TDRSS for later phases. The LOS system, which includes the Proton antenna and the S-band system, is located on the ACS (see fig. 10-6 and 10-7). Other telemetry assets include Russian ground tracking stations and the Energia Moscow control center. The following subsections apply to launch vehicle and payload unit telemetry reception and routing.

265807J3-140

Figure 10-6. Assembly and Command Ship Proton Tracking Antenna

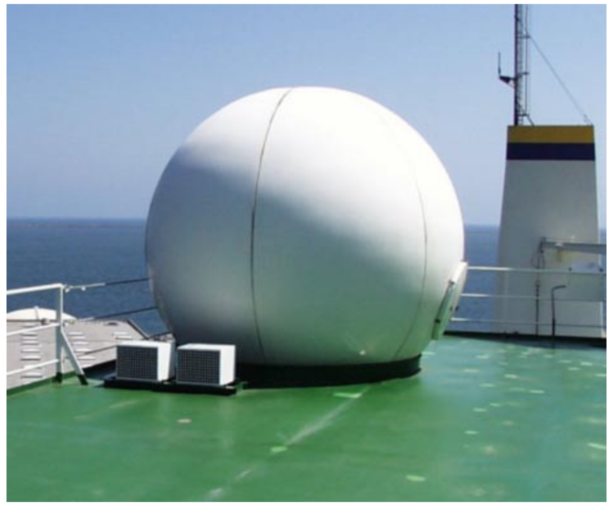

Figure 10-7. S-Band System Radome

Flight vehicle line of sight coverage

Zenit and Block DM data are both received on board the ACS from shortly before liftoff until approximately 7 or 8 min into the flight by the Proton antenna complex. This data is sent first to ACS 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 (see fig. 10-7). The S-band system is capable of relaying very large amounts of data and its duration is from shortly after liftoff until payload fairing separation, which occurs approximately 3 min into the flight. At this time the PLU telemetry system begins to deliver telemetry data through TDRSS.

Tracking and data relay satellite system (TDRSS)

Sea Launch uses a unique dual telemetry stream with the TDRSS. Telemetry is simultaneously received from the Zenit stages, the Block DM upper stage, and the payload unit during certain portions of the flight. The Block DM upper stage and payload unit data are combined, but the Zenit data is sent to a separate TDRSS receiver. Zenit data is received shortly after liftoff at approximately 9 sec, and continues until Zenit Stage 2/Block DM 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 ACS. The data is also recorded at White Sands and at Brewster for later playback to the KB Yuzhnoye design center.

When the payload fairing separates, the payload unit transmitter shifts from sending high-rate payload accommodation data by LOS to sending combined payload unit/Block DM by TDRSS. The combined data is again routed from White Sands to Brewster, where it is separated into Block DM and payload unit data and then sent on to the ACS. 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 PLU data. Simultaneously, Brewster routes Block DM data to the Energia Moscow control center. TDRSS coverage continues until after playback of the recorded Block DM 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 TDRSS coverage, Russian tracking facilities may be brought on line. For low-inclination trajectories, the Block DM-SL will not be within LOS of the Russian tracking facilities until it obtains sufficient altitude. When the Block DM-SL is within LOS 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 ACS 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 ACS has ultimate responsibility and authority for all decisions and commands affecting the launch vehicle, Block DM-SL, and the spacecraft.

11. 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 (S&MA) director and licensing by the U.S. Department of Transportation Office of the Associate Administrator for Commercial Space Transportation (FAA/AST).

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 employed both by 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 S&MA director.

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

11.1 Safety Integration Approach

Sea Launch employs a three-phase approach in defining data required and in conducting reviews for new launch customers or the first launch in a series of launch missions. Follow-on missions employing 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 is identified in chapter 3 of the *Sea Launch Safety Regulations Manual*, Boeing document D688-10024-1.

Customer responsibilities

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

Sea Launch responsibilities

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

Safety and readiness reviews

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

A mission readiness review (MRR) is conducted before vessels leave Home Port for the launch site. A launch readiness review (LRR) 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 MRR and LRR will be recorded and final disposition completed and agreed to by the mission director before beginning operations.

A depiction of the Sea Launch phased safety integration process and data development and reviews is shown in figure 11-1.

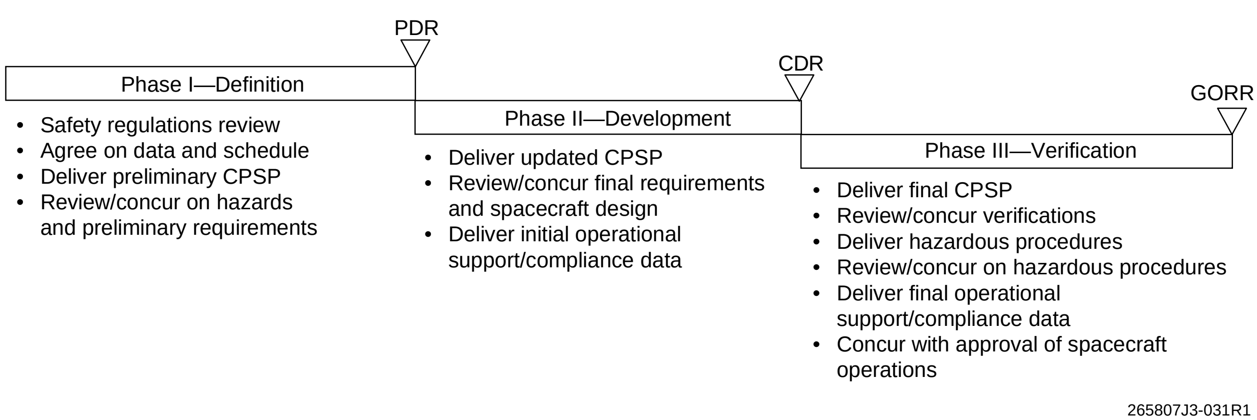

Figure 11-1. Sea Launch Safety Integration Process

11.2 Safety Assessment Phases

These are the three safety assessment phases required by Sea Launch:

- Definition phase.
- Development phase.
- Verification phase.

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

Phase I—definition

The responsibilities of the customer during the definition phase are:

- Review the Sea Launch safety regulations and identify applicability and tailoring necessary.
- Coordinate with Sea Launch to define requirements unique to the customer and agree on final definition of safety data deliverables and review and approval 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:

- Coordinate tailored customer safety requirements, safety data deliverables, and review and approval schedules.
- Review the customer prelaunch safety package (CPSP) 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 PDR.

Phase II—development

The customer responsibilities during the development phase are:

- Submit updated CPSP 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 employed for spacecraft processing and for hazard mitigation. Include preliminary identification of procedures to be employed at Home Port and aboard 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 upon.

This phase is anticipated to conclude at the mission CDR.

Phase III—verification

Customer responsibilities for the verification phase are:

- 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 mission GORR and must be completed prior to the start of spacecraft processing at Sea Launch facilities.

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

11.3 Launch Licensing and Flight Safety

Authority and licensing

Sea Launch supports safety evaluation and obtains licensing by the FAA/AST.

Currently, Sea Launch must apply for a launch-specific license for each launch. After demonstrating the repeatability and reliability of the operations concept, Sea Launch will obtain a launch operator license for similar missions, which will allow activities without applying for launch-specific licenses each time.

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 casualty probabilities remain within program FAA guidelines should a flight failure occur.
- Spacecraft ownership and operator, final orbit, and licensing for radio frequency transmissions.
- Hazardous materials aboard 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. Spacecraft hazardous materials are considered impacts on the environment should a launch failure occur. The FAA/AST has conducted an environmental assessment to cover the entire scope of Sea Launch operations and a finding of no significant impact (FONSI) has been issued. Spacecraft environmental characteristics must not compromise the terms of the FONSI.

Sea Launch complies with FAA/AST requirements to minimize orbital debris by a contamination and collision avoidance maneuver (CCAM) of the orbiting upper stage (Block DM-SL). The CCAM moves the stage away from the spacecraft a safe distance to a disposal orbit. At the completion of the CCAM, all upper-stage 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 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 (CARF).
- United States Space Command (through NASA).
- National Imagery and Mapping Agency (NIMA).

After the launch license is issued and the vessels sail for the launch operations, FAA/AST representatives accompany the launch team aboard 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 are the requirements to ensure safety of personnel and equipment in preparing and launching the spacecraft.

The customer responsibilities for activities that take place in Sea Launch facilities and on Sea Launch vessels are:

- 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 in the Sea Launch facility.

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. 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 past experience has shown 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 reliability of the Zenit-3SL compares favorably with that of other existing launch vehicles. The average flight success ratio of comparable launch vehicles is 93%.

The reliability of the Zenit-3SL is 93.7% and encompasses the implementation of fixes for previous failures in the Block DM and Zenit stages. The Block DM and Zenit first and second stages all have minor modifications to adapt them to use by Sea Launch.

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 93.7% for the Zenit-3SL.

Reliability subsystems and components

Zenit-3SL reliability is enhanced by using 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 (ARS)

The Sea Launch ARS, 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 ARS is in place to acquire and assess failure history, criticality, and effectiveness of changes, and as a database from which recommendations can be validated. The ARS 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 as the system matures (see fig. 12-1).

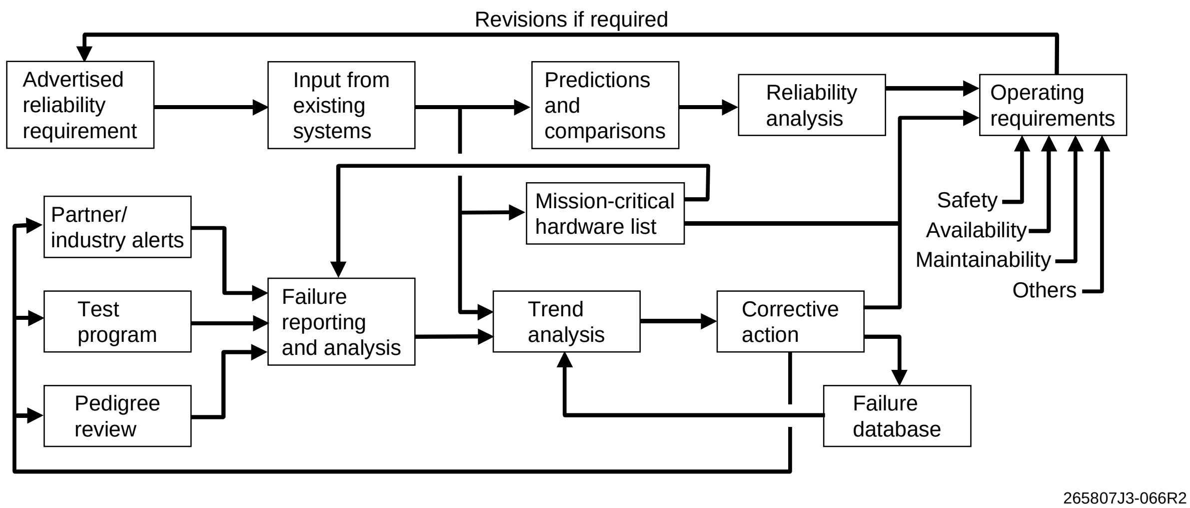

Figure 12-1. Anomaly Resolution System

User Questionnaire

When completed, this questionnaire provides the Boeing Commercial Space Company, acting on behalf of the Sea Launch Limited Partnership, 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 Commercial Space Company

SEA LAUNCH PROGRAM

PO Box 3999, MS 6E-60

Seattle, WASHINGTON 98124-2499

USA
(Attention: Ms. Amy Buhrig)

Boeing Commercial Space Company 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 Limited Partnership without your expressed written permission.

For further information contact:

Ms. Amy Buhrig

Phone: 425-393-1884

Fax: 425-393-1050

User Questionnaire

Spacecraft Physical Characteristics	SI Units		English Units	
Maximum height above I/F plane	______	mm	______	in
Spacecraft protrusions below I/F 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-m^2	______	slg-ft^2
Iyy	______	kg-m^2	______	slg-ft^2
Izz	______	kg-m^2	______	slg-ft^2
Ixy	______	kg-m^2	______	slg-ft^2
Ixz	______	kg-m^2	______	slg-ft^2
Iyz	______	kg-m^2	______	slg-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 tip-off rate	______	deg/sec		
Minimum tip-off 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 (EIRP)	**(dBW)**
Maximum	-
Nominal	
Minimum	
Antenna gain (referenced to boresight)	(dB)
0	
±10°	
±20°	
±30°	
±40°	
±60°	
±80°	
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 SC Antenna	(dBW/m^2)
Maximum	
Nominal	
Minimum	
Antenna gain (refers to boresight)	
0°	
±10°	
±20°	
±30°	
±40°	
±60°	
±80°	
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 ____________________

RS 422 ____________________

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/m^2	________ W/ft^2
Following PLF jettison	________ W/m^2	________ W/ft^2
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 (continued)

Standard facility services provided at the 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 (continued)

ACS (PLU/LV integration)

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

Describe spacecraft access requirements on 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 (continued)

LP (transit, prelaunch, launch operations)

Describe spacecraft access requirements on 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, % obscuration, NVR wipe, etc.)?

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

If yes, indicate allocations:

	Molecular ($\mu g/cm^2$)	Particulate (% 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 lists the basic hardware items and associated services that will be provided for a Sea Launch mission.

Payload accommodations

- PLF with up to two access doors and a customer logo.
- SCA with compatible mechanical interfaces and separation system. Current standard offering SCA are SCA1194, SCA1666, SCA702, and SCA702GEM. Inquire with Sea Launch for adapters not listed.

Launch vehicle

- Zenit-2S two-stage booster with tailored flight software.
- Block DM-SL upper stage with tailored flight software.

Electrical interfaces

RF interfaces

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

Hard-line interfaces

- 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 breakwires as needed.

Environmental controls

Sea Launch will maintain spacecraft environments within the limits specified in the spacecraft/SLS ICD while the spacecraft is in the PPF and encapsulated in the PLU.

Interface test

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

STANDARD-OFFERING LAUNCH SERVICES

The following sections list the basic launch services to be 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

- Customer kickoff meeting.
- Preliminary ICD review.
- Mission integration review (including final ICD 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 PLA).
- Payload/ILV transfer readiness review (ready to integrate PLU to LV).
- 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.
- EMI/EMC 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/SLS ICD.
- Spacecraft campaign document (SCD).
- 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.
- ILV 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.
- EMC 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/PLA 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/SLS ICD.

Separation state vector

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

Transportation

- Assistance to the customer for obtaining ground transportation for the spacecraft and support equipment from any Los Angeles area airport or seaport to the Sea Launch 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

- Fit check—a spacecraft-to-spacecraft adapter fit check conducted at the Home Port.
- Spacecraft checkout and fueling.
- Encapsulation.
- PLU checkout.
- PLU / LV integration.
- ILV integrated test.
- Transfer of the ILV to the LP.
- PLU and spacecraft RF end-to-end test.

Transit activities

- Transportation of the ILV, GSE, and customer launch support personnel to and from the launch site (on board the ACS and LP).
- Operational rehearsals.
- Monitor 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)

- The Home Port facilities are described in detail in the Sea Launch facilities handbook for customers. Facilities at the 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 PPF.

HP facilities	• Processing and fueling cell. • Control room. • Remote control room. • Offices. • Conference room. • Storage.
HP communications	• Intercom. • Spacecraft command and telemetry cabling. • CCTV monitors and cameras. • Telephone. • Launch video. • Countdown net. • Hand-held 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)

ACS capabilities are described in detail in the Sea Launch facilities handbook for customers.

ACS facilities

- Customer GSE 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 LP evacuation.
- Six seats in the launch control center; each console can accommodate two people.
- Two seats in VIP 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 ACS and between the ACS and LP when they are in proximity:

- Intercom (including countdown net).
- CCTV 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 LAN (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 different areas of the ship.
- The facilities have 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.
- Medical clinic (staffed by a medical doctor).
- Photocopier and facsimile machine.

Launch platform (LP)

LP capabilities are described in detail in the Sea Launch facilities handbook for customers.

LP facilities

- Customer GSE 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 LP and between the ACS and LP when they are in proximity:

- Intercom (including countdown net).
- CCTV 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 LAN (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 will control access to different areas of the ship.
- The facilities have 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.
- Medical clinic (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 (RS 422).
- RF link (rerad) capability to the ACS launch vehicle assembly room and the LP 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 phone calls (from phones, facsimile machines, and teleconferencing facilities).
- Access to Internet service provider.
- Bandwidth exceeding 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 final 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 NVR 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 depending on availability.
- Use of any facilities beyond the time frame allocated to the customer may be negotiated depending on availability.