Epsilon Launch Vehicle

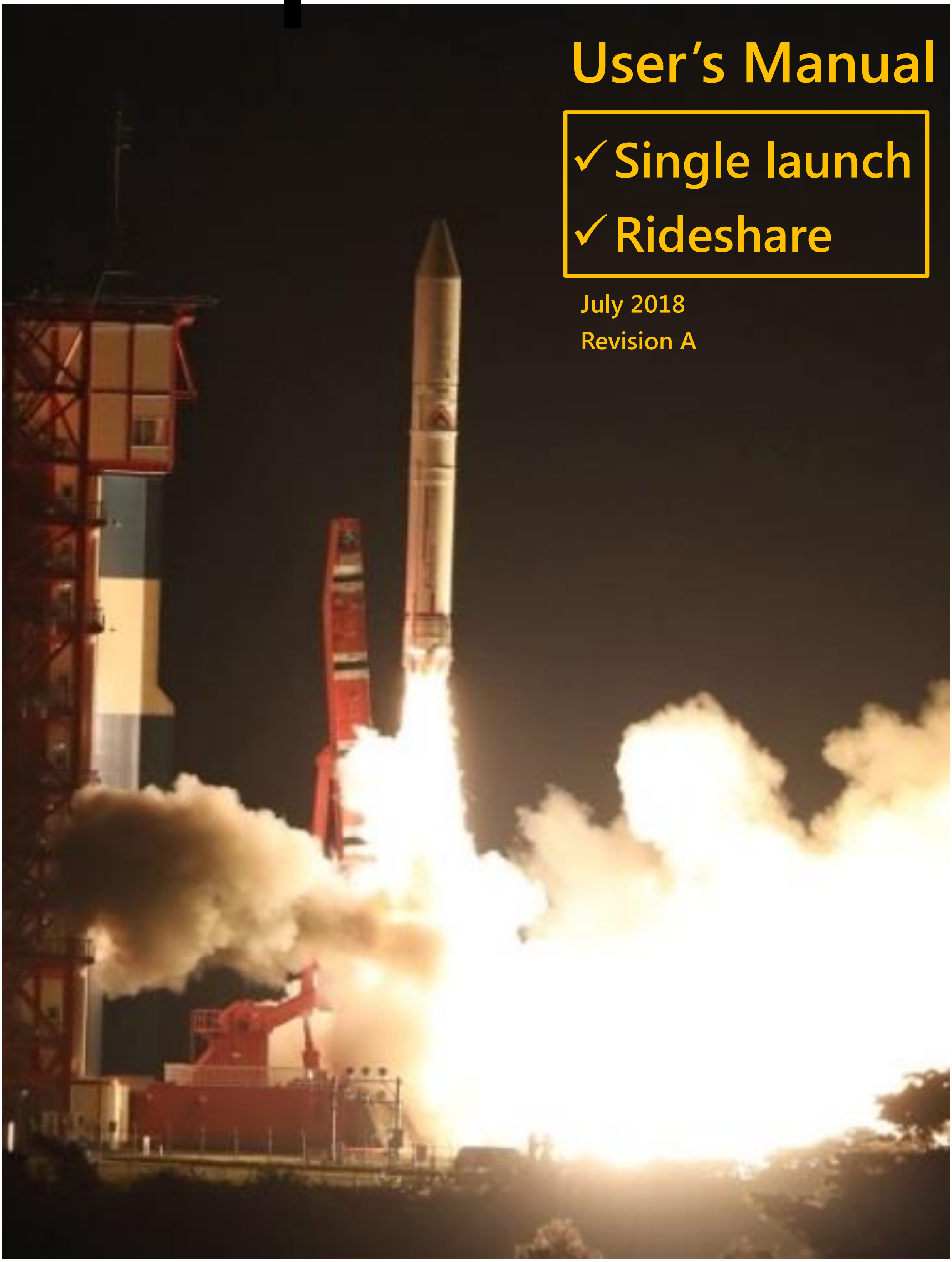
User's Manual

✓ Single launch

✓ Rideshare

July 2018

Revision A



JAXA

Japan Aerospace Exploration Agency

Preface

This document is prepared to provide customers with technical information on the Epsilon Launch Vehicle, its launch services including optional ones, and related facilities and equipment for the purpose of customers' planning.

Configuration control sheet

Date	Revision number	Change Description
February, 2016	First Edition	NC
July, 2018	Second Edition	- Addition of multiple payload launch function - Amendment to interface information on PL

Contents

Glossary

ACS : Attitude Control System
AT : Acceptance Test
CB : Clean Booth
CCAM : Collision and Contamination Avoidance Maneuver
C.G. : Center of Gravity
CLA : Coupled Load Analysis
CR : Clean Room
ECC : Epsilon Control Center (ECC)
EGSE : Electrical Ground Support Equipment
ESC : Epsilon Support Center (ESC)
ESMS : Epsilon Satellite Mounting Structure
E-SSOD : Epsilon Small Satellite Orbital Deployer
FEM : Finite Element Model
FM : Flight Model
FMA : Final Mission Analysis
GSE : Ground Support Equipment
HTPB : Hydroxyl terminated polybutadiene
ICD : Interface Control Document
IRD : Interface Requirement Document
ISAS : Institute of Space and Astronautical Science
ISO : International Organization for Standardization
JAXA : Japan Aerospace eXploration Agency
JEM : Japanese Experiment Module
JOP : Joint Operation Plan
J-SSOD : JEM Small Satellite Orbital Deployer
LEO : Low Earth Orbit
LSP : Launch Service Provider
LV : Launch Vehicle
MLI : Multi Layer Insulation
OIS : Operational Inter-communication System
PAF : Payload Attach Fitting
PBS : Post Boost Stage
PFM : Protoflight Model
PL : PayLoad
PLF : PayLoad Fairing
QT : Qualification Test
RCS : Reaction Control System
RF : Radio Frequency
S/C : SpaceCraft
SMSJ : Solid Motor Side Jet
SOW : Statement Of Work
SPL : Sound Pressure Level
SRB : Solid Rocket Booster

SRM	: Solid Rocket Motor
SSO	: Sun Synchronous Orbit
TNSC	: TaNegashima Space Center
TVC	: Thrust Vector Control
USC	: Uchinoura Space Center

1. Introduction

1.1. Purpose of the User's Manual

This User's Manual is intended to provide customers (Customer) with basic information on the Epsilon Launch Vehicle (LV) and its launch operations at the Uchinoura Space Center (USC).

The contents encompass the followings:

- The Epsilon Launch Vehicle description;
- Launch performance and typical mission profiles;
- LV's environmental conditions and corresponding requirements for Payload (PL) design and verification;
- Description of interfaces between PL and LV;
- PL preparation and ground operations performed at USC;
- Mission Management including a mission integration and support services for Customer.

1.2. Epsilon LV Outline

The Epsilon LV is a next-generation solid propellant rocket, which is developed in a Japanese national program led by JAXA. After the completion of the development, it has been positioned as a Japanese flagship LV. It plays a key role in securing Japan's autonomous capability to launch small satellites for observation and scientific missions. It can also offer effective launch opportunities to small satellites for commercial missions.

Epsilon is a highly-reliable vehicle for space transportation fully reflecting Japanese rocket technology long accumulated through many vehicle programs such as a former M-V and currently operated H-IIA/B LV (Figure 1-1). Epsilon offers user-friendly launch services with newly incorporated technologies, such as next-generation ground support / check-out systems, highly accurate orbit injection system, advanced built-in PL vibration-suppression system, and multi-satellite mounting structure.

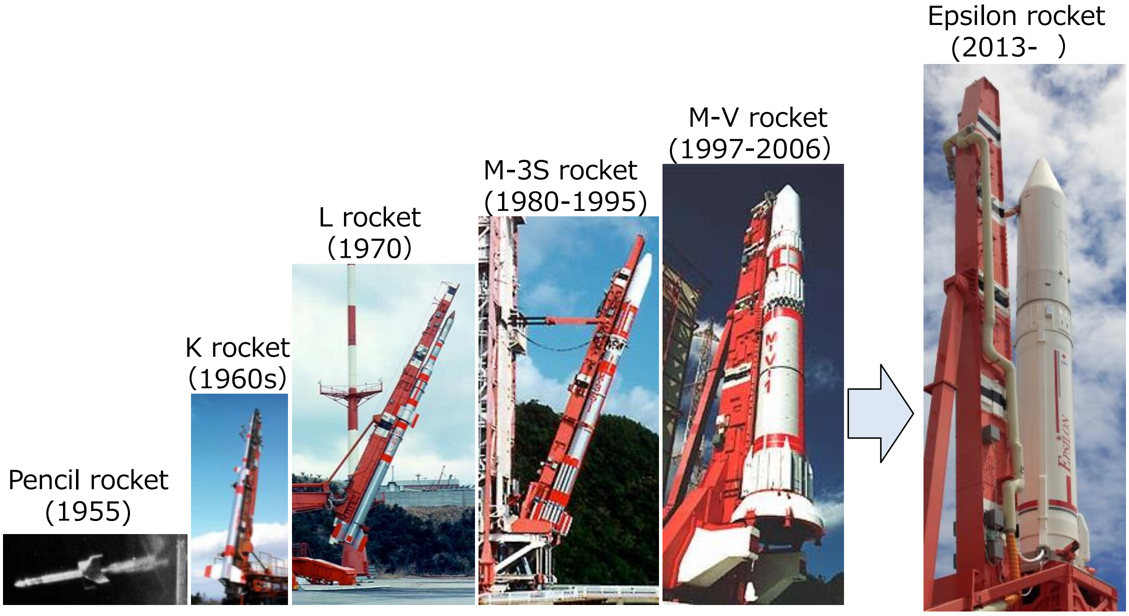


Figure 1-1 Genealogy up to Epsilon LV

1.3. Epsilon Technology Heritage and Enhancement

Epsilon builds on the heritage of successful M-V and H-IIA/B technologies as shown in Figure 1-2.

Since its first flight (Epsilon-1), Epsilon's launch capability has been steadily enhanced (Figure 1-3) and verified by Epsilon-2 and Epsilon-3. From the next flight, Epsilon-4, onward, the LV will have the ability of multiple-payload launch (in this document, multiple payload launch is called "multi launch" or "multiple launch") (Figure 1-4). Epsilon has been evolving in response to users' demand.

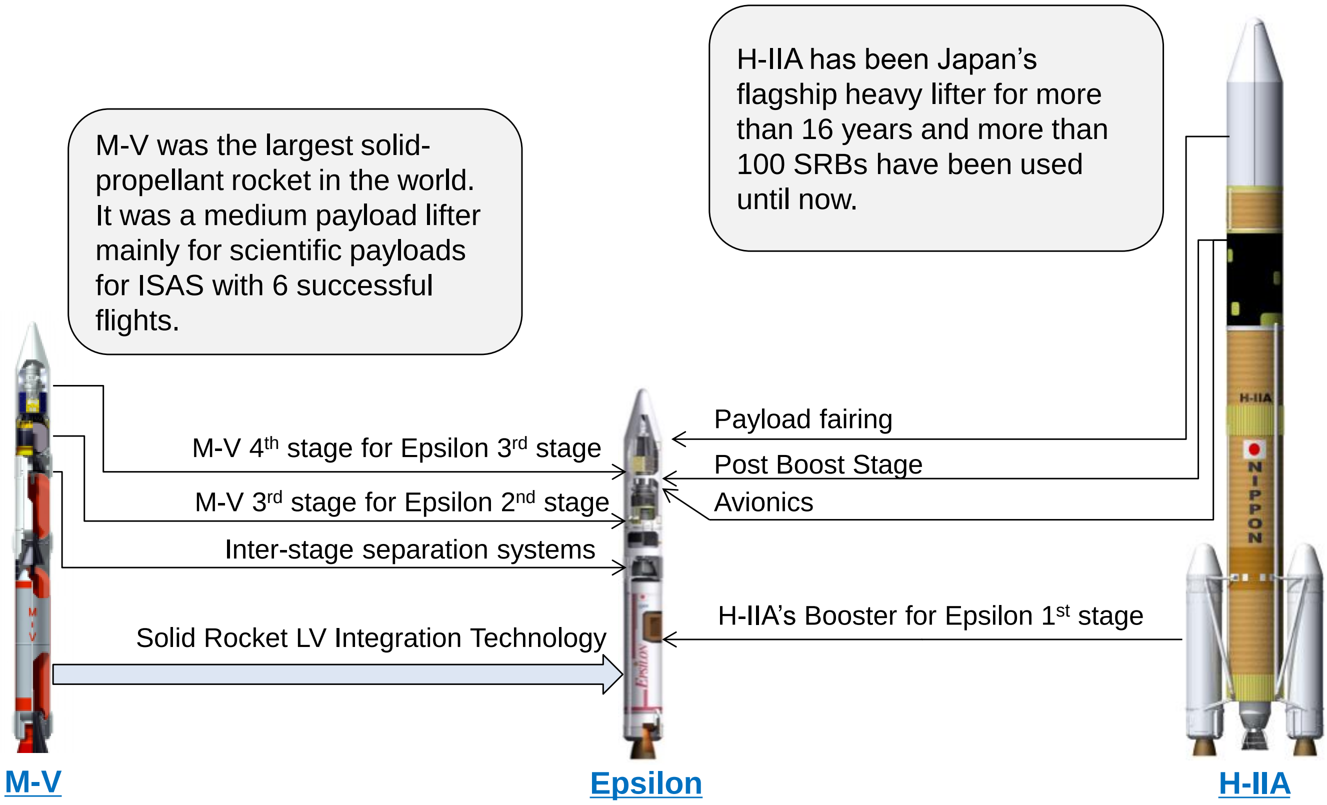


Figure 1-2 Epsilon LV Heritage

The enlarged 2nd solid motor is exposed from the fairing to carry a payload with more mass and volume.

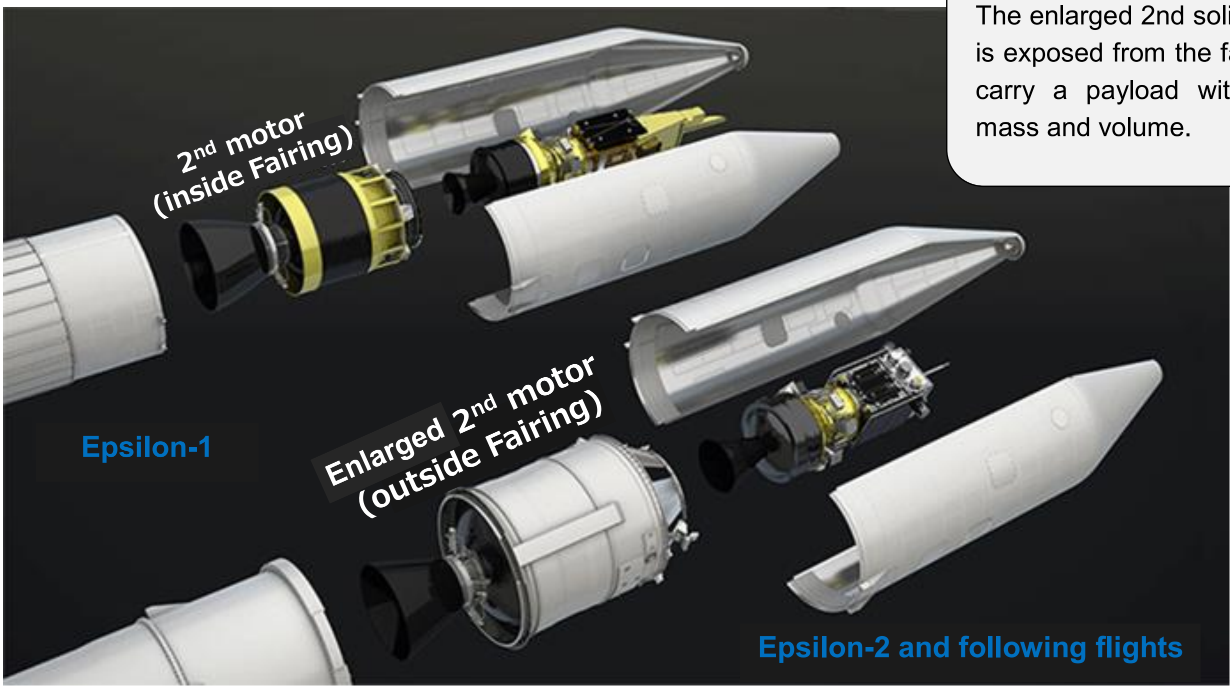


Figure 1-3 Epsilon's Launch Capability Enhancement

The microsatellite separation uses 8-inch Lightband® made by PSC (Planetary Systems Corporation), which has a proven track record of having been used for many satellites.

The newly developed CubeSat deployer (E-SSOD) is based on J-SSOD, a proven deployer installed on JEM of the International Space Station.

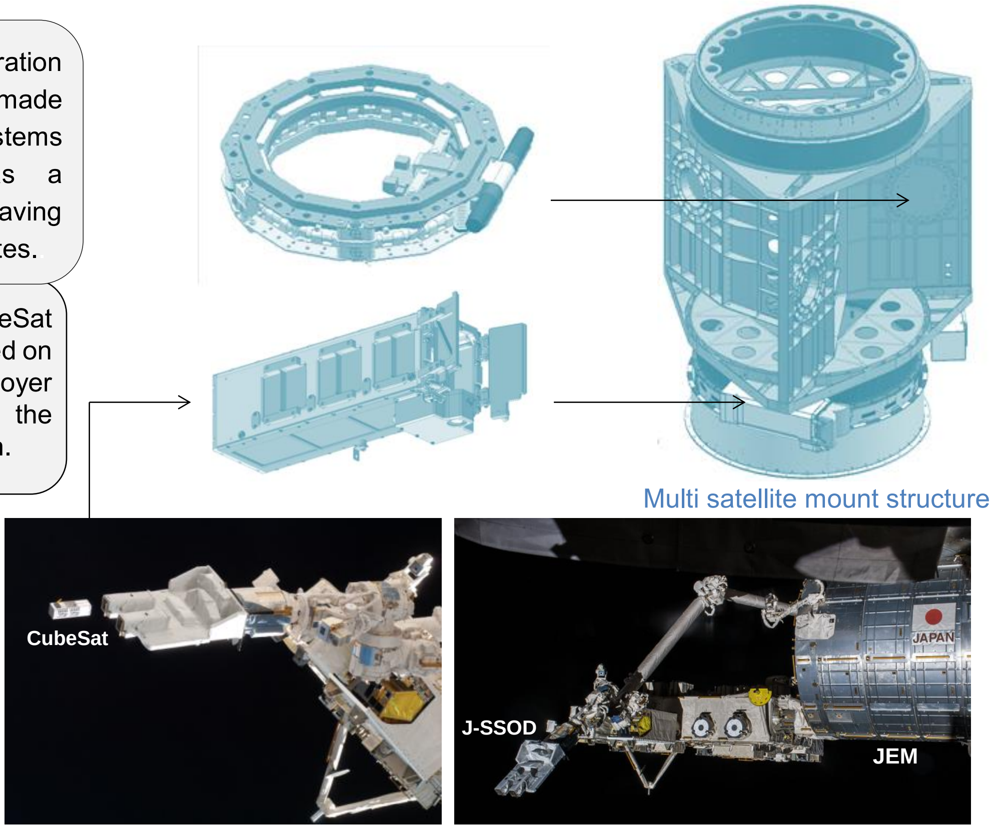


Figure 1-4 Systems for Multiple Payload Launch

1.4. History of Epsilon LV

The Epsilon LV's launch history is shown in Figure 1-5.

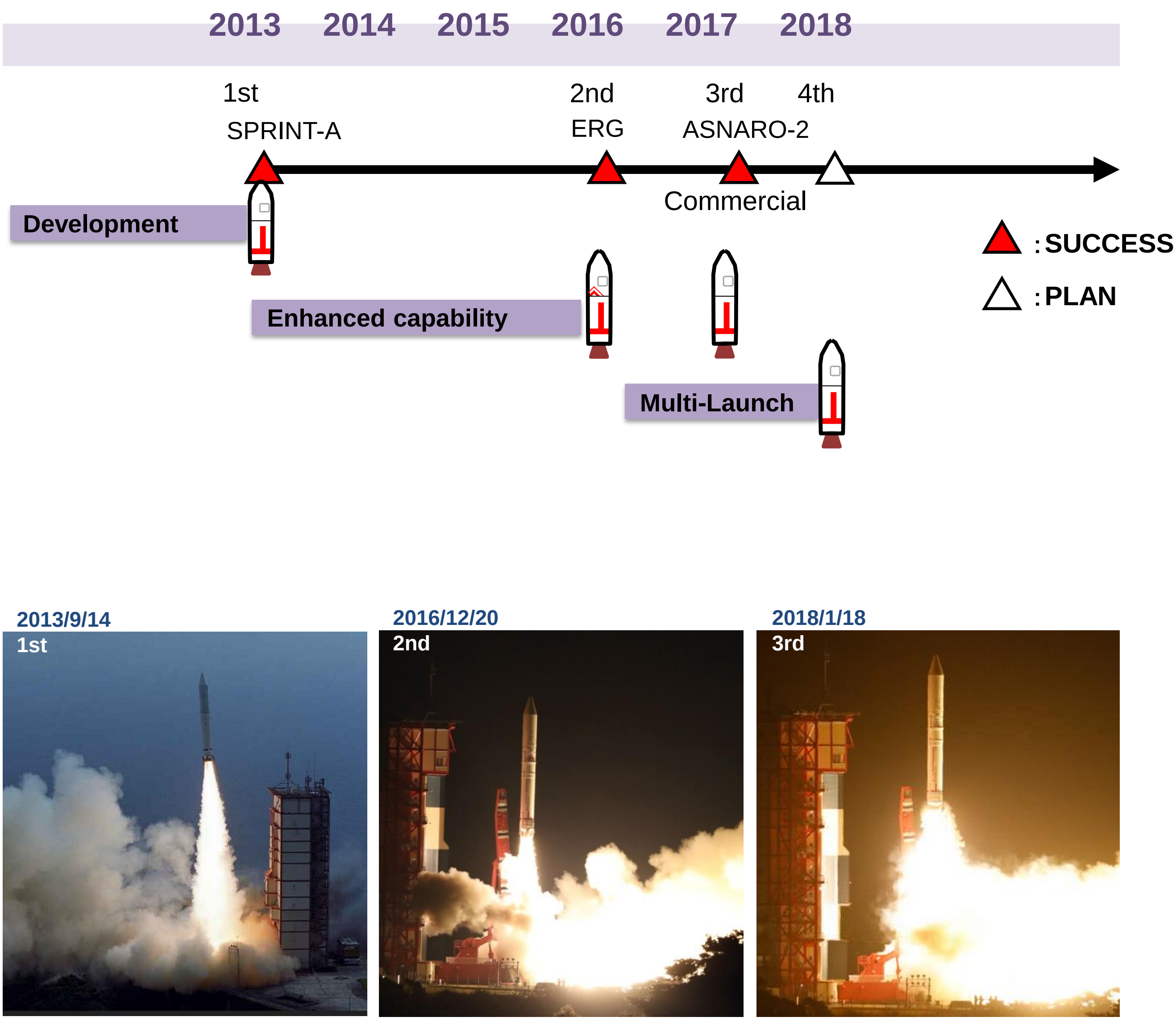


Figure 1-5 Launch History

1.5. Mission Management

Mission Management, together with Safety Supervision, is provided to Customer by Epsilon Launch Service Provider (LSP). A Program Director is assigned as a single point of contact with Customer.

The Mission Management Scheme is depicted in Figure 1-6.

The details of a standard Mission Management are explained in Chapter 6.

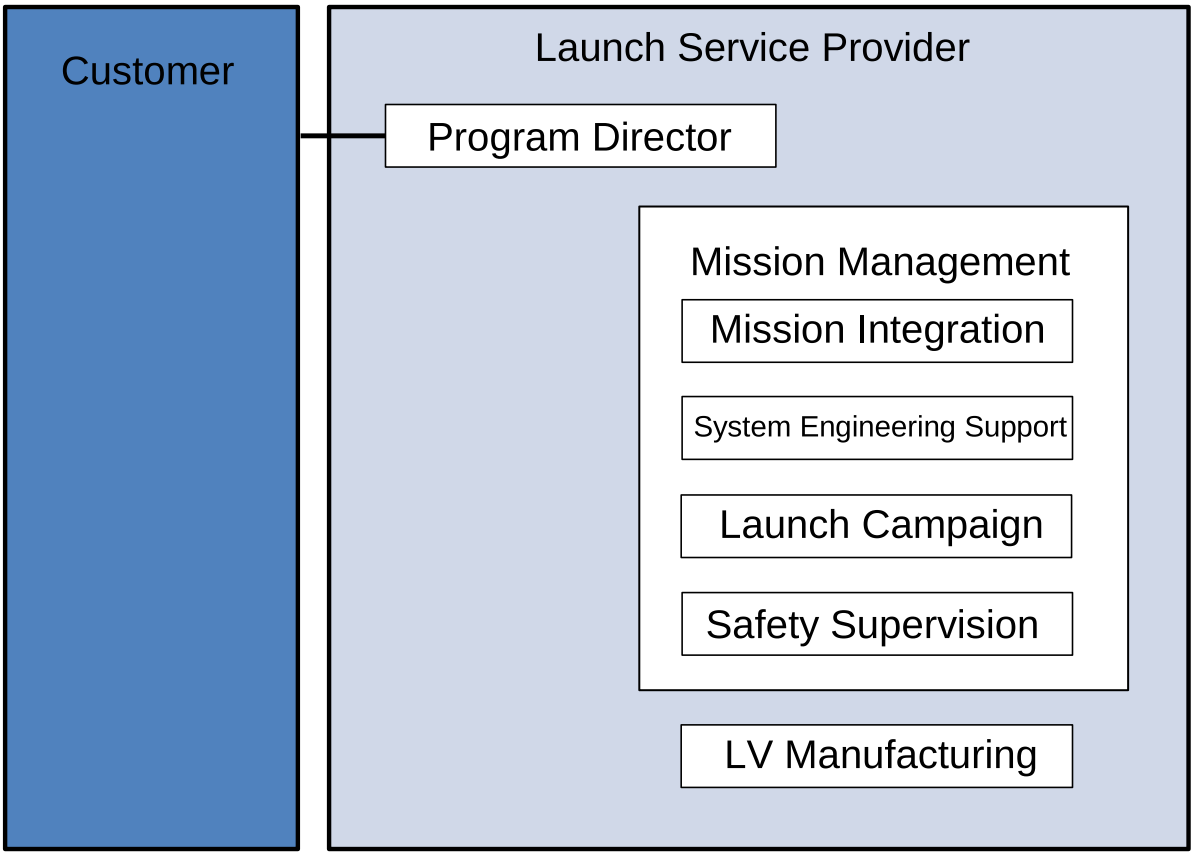


Figure 1-6 Mission Management

2. Vehicle Overview

2.1. Epsilon LV General Data

Epsilon, a three-stage solid propellant launch vehicle, offers a basic configuration and an optional configuration with PBS (Post-Boost Stage), which enhances its orbit injection accuracy. This optional configuration can mount additional structures on the third stage to provide small satellites with a rideshare option. Table 2-1 shows the difference between the specifications of these configurations.

Figure 2-1 shows the exploded view of Epsilon's configurations with and without PBS, and Table 2-2 shows Epsilon's general specifications.

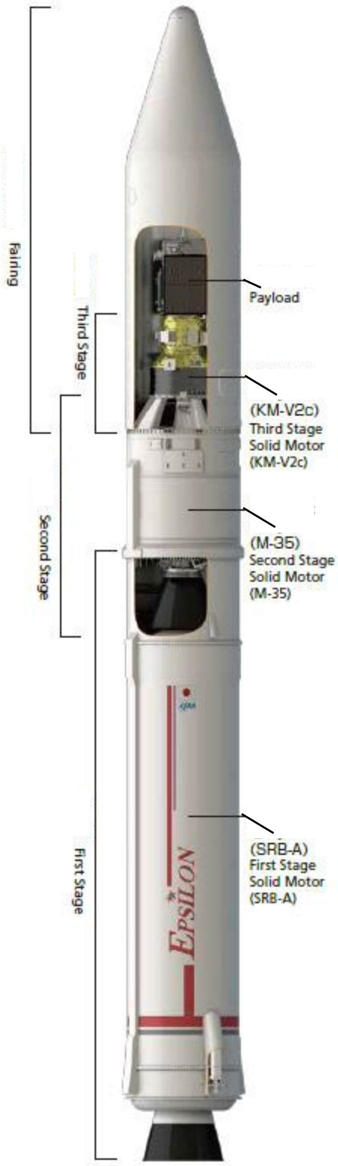


Table 2-1 Difference between specifications of Epsilon's configurations

Device		Basic configuration (Without PBS)	Optional configuration (With PBS)	
			Single Launch	Multi Launch
Payload Separation System	PAF-937M	1	1	1
	Lightband®	-	-	3
	CubeSat Deployer（E-SSOD）	-	-	2
Damper		✔	✔	✔
PBS		-	✔	✔

✔: Installed

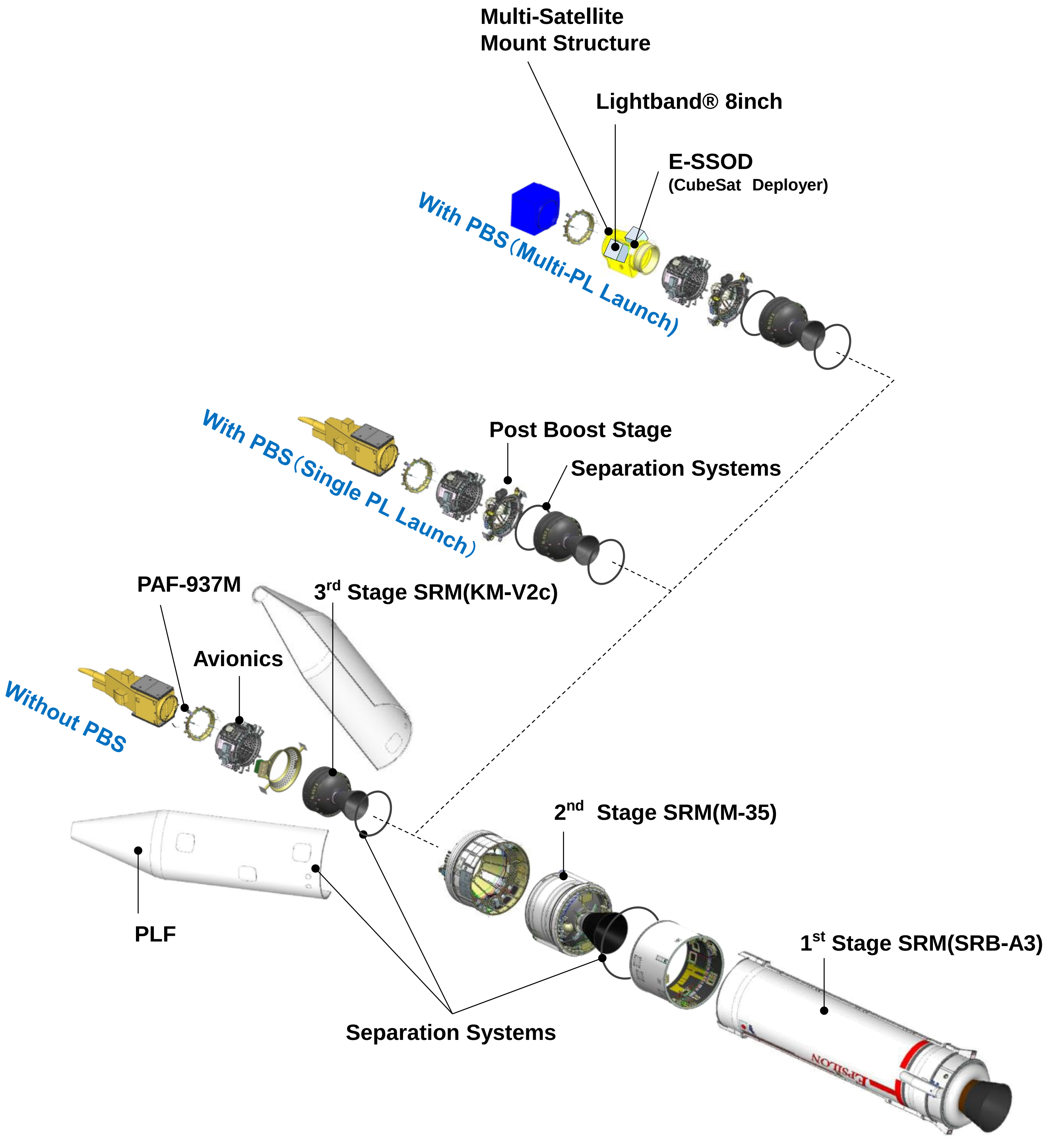


Figure 2-1 Epsilon Configurations

Table 2-1 Epsilon Specifications

Overall					
Length [m]	26				
Diameter [m]	2.6				
Total Weight [ton]	96				
Stages					
Items	**1st stage SRB-A3**	**2nd stage M-35**	**3rd stage KM-V2c**	**PBS*1**	**PLF**
Length [m]	11.7	4.3	2.3	1.2	11.1
Diameter [m]	2.6	2.6	1.4	1.5	2.6
Weight [ton]	75.0	17.0	3.3	0.1	1.0
Propellant [ton]	66.3	15.0	2.5	0.1	-
Thrust [kN]	2,271	372	99.8	0.4	-
Burn time [s]	116	140	90	1100	-
Propellant	Solid HTPB	Solid HTPB	Solid HTPB	Hydrazine	-
Isp [s]	284	300	301	215	-
Control	TVC SMSJ (Solid Thruster)	TVC RCS (Thruster)	Spin	Thruster	-

*1: only for the optional configuration

Assembling 1st motor

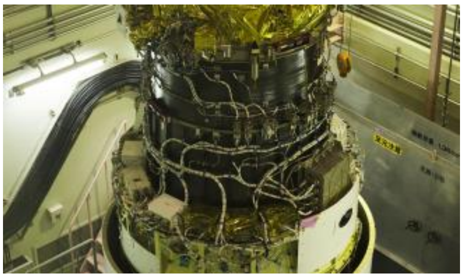
(1) First Stage (SRB-A3)

The first stage is a solid propellant motor slightly modified an H-II A/B's solid rocket booster SRB-A3. The motor case is made of filament-wound monolithic composite materials, the same as that of the second and third stages. The propellant is HTPB composite, also the same as that of the second and third stages. The nozzle is gimballed by electromechanical thrust vector control (TVC) units.

Combustion test of 2nd motor

(2) Second Stage (M-35)

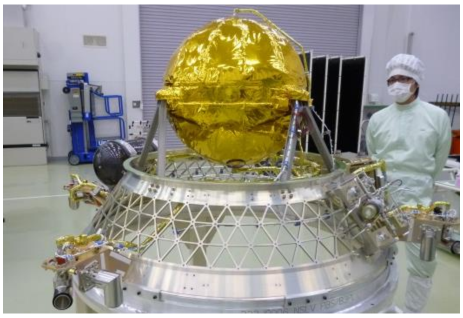
The first Epsilon's second stage motor (M-34c) was developed based on the third stage of MV Rocket. The motor was then improved into the current M-35, whose performance was demonstrated by Epsilon-2. M-35 has 1.4 times the propellant mass of M-34c, increasing Epsilon's launch capability.



3rd stage

(3) Third Stage (KM-V2c)

The third stage KM-V2c is a partially modified fourth stage of MV (KM-V2).



PBS

(4) Post Boost Stage (PBS) (option)

The newly developed PBS, based on the monopropellant reaction control system (RCS) of H-II A/B, enhances orbit injection accuracy.


PLF

(5) PL Fairing (PLF)

The PLF employs the proven track record technology of H-II A/B PLF. It has aluminum-skin, aluminum-honeycomb-sandwich structure and incorporates the clamshell separation system. Several access doors and one RF transparent window can be installed on the PLF to provide access to a satellite inside after encapsulation.


Separation test

(6) Separation Systems

Epsilon has 4 separation systems, each of which has a Marman clamp band and redundant system. It also has Marman clamp band catchers to prevent a separated band from colliding with rocket structures or satellites.

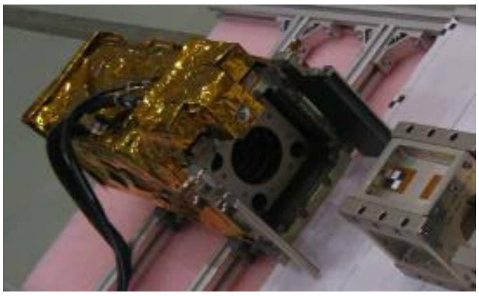
While stages are separated by using pyrotechnics, the satellite is released by a non-pyrotechnic device in order to reduce a shock to the satellite in case of PL (Single Launch) / small satellite (Multi Launch).


Multi-satellite mount structure

(7) Multi-satellite mount structure

The multi-satellite mount structure, now under development, will be demonstrated on Epsilon-4. This structure can mount up to 3 Micro satellites with a small satellite being installed atop. Its separation system uses a proven-record 8-inch Lightband®.

Lightband® 8-inch size


CubeSat Deployer (E-SSOD)

(8) CubeSat deployer (E-SSOD)

Two CubeSat deployers can be bound on the multi-satellite mount structure and each can accommodate one 3U CubeSat at most. It uses the time-proven technology of J-SSOD, a deployer now in operation on the International Space Station.

2.2. Coordinate System

Figure 2-2 shows the coordinate system of LV. The station (STA) at the top of FL in this figure indicates the origin of x-axis, values of which increases toward lower stages.

Table 2-3 shows the standard coordinate system of each PL. This coordinate system is used for environment conditions and mechanical interfaces in this document.

The details of standard coordinate systems of Micro satellite and CubeSat are shown in the Appendix-B and Appendix-C, respectively.

Table 2-3 PL coordinate (standard)

Payload	coordinate	origin
PL (Single Launch)	Figure 2-2	The center of the separation plane
Small satellite (Multi Launch)		
Micro satellite (Multi Launch, Lightband®)	Figure 2-3	The center of the upper ring contact surface of Lightband®
1U to 3U CubeSat	Figure 2-3	The geometry center of the CubeSat shape

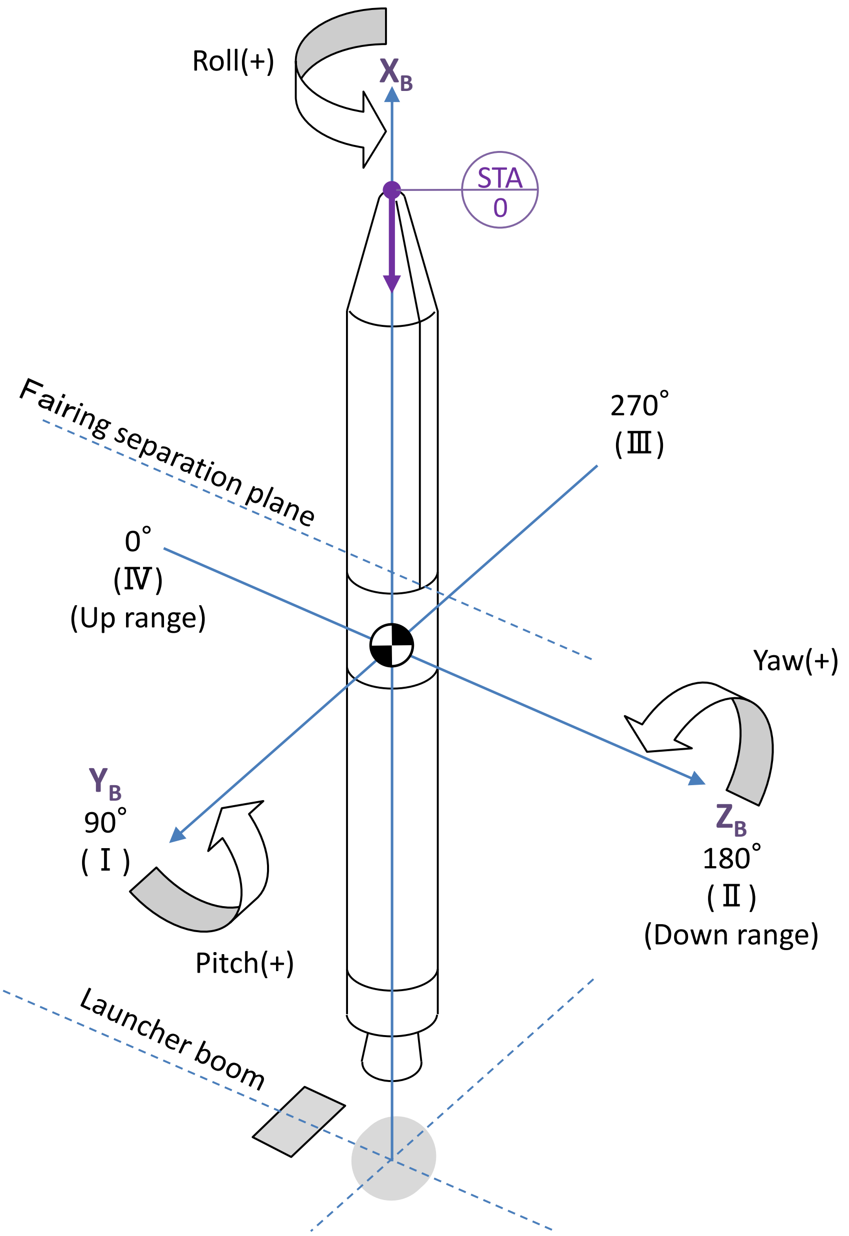
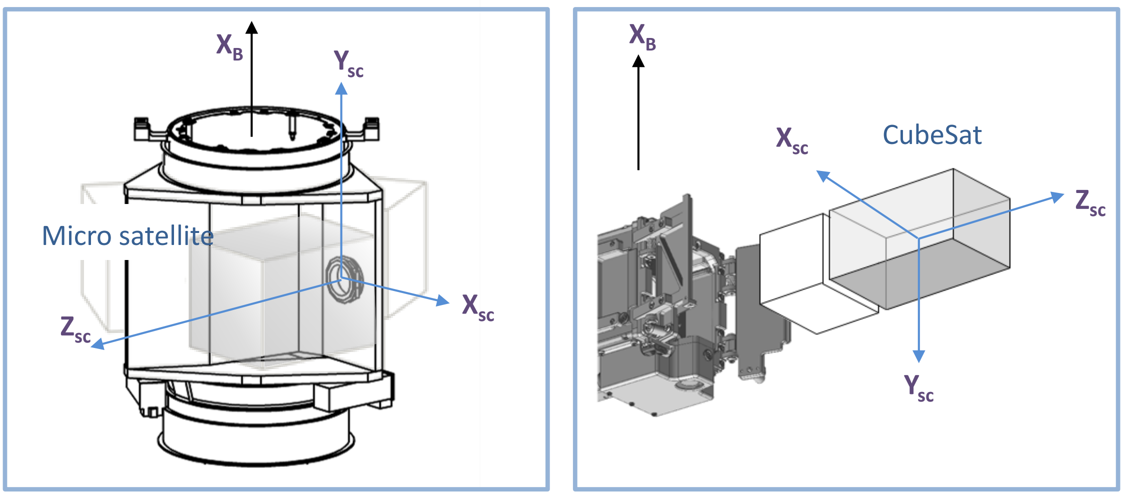


Figure 2-2 Coordinate system of LV



X_{SC},Y_{SC},Z_{SC} : Satellite Axis (standard)

Figure 2-3 Coordinate system of PLs in Multi-Launch (standard)

3. General Performance Information

3.1. Introduction

This section provides the information necessary to make preliminary performance assessments of the Epsilon LV. The following paragraphs present Epsilon's typical performance, typical injection accuracy, mission duration, separation conditions and collision avoidance maneuver.

The data provided here cover a wide range of missions for sun-synchronous orbits (SSO), and low circular or elliptical orbits (LEO), etc.

Performance data presented in this document are for assumed reference missions; therefore, actual performance will be fully optimized based upon Customer's specific mission data.

3.2. Definition of Launch Capability

Epsilon launch capability in this section is defined based upon the following conditions:

(1) PL lift mass is without Payload Attach Fitting (PAF), and
(2) Launch from USC with applicable range safety operations.

3.3. Typical Mission Profile

The typical event sequences are shown as below:

Basic configuration (Without PBS) : Figure 3-1
Optional configuration (With PBS) : Figure 3-2

Typical mission profiles are shown as Table 3-1.

Table 3-1 Typical Mission Profiles

		Path	Altitude	Velocity	Acceleration
SSO Optional configuration (With PBS)	Single Launch	Figure 3-3	Figure 3-5	Figure 3-7	Figure 3-8
	Multi Launch	Figure 3-4	Figure 3-5 & Figure 3-6		
LEO Basic configuration (Without PBS)		Figure 3-9	Figure 3-10	Figure 3-11	Figure 3-12

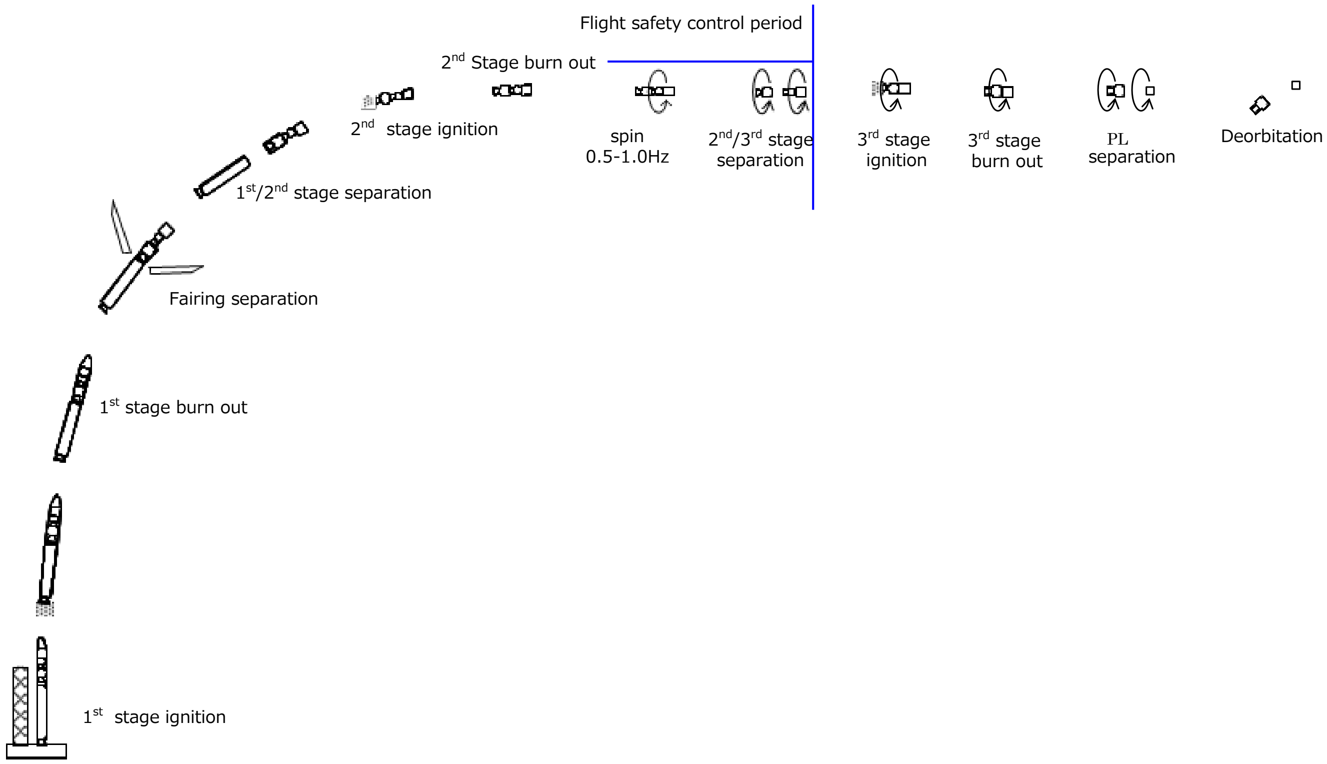


Figure 3-1 Event Sequence: Nominal Mission Profile (without PBS)

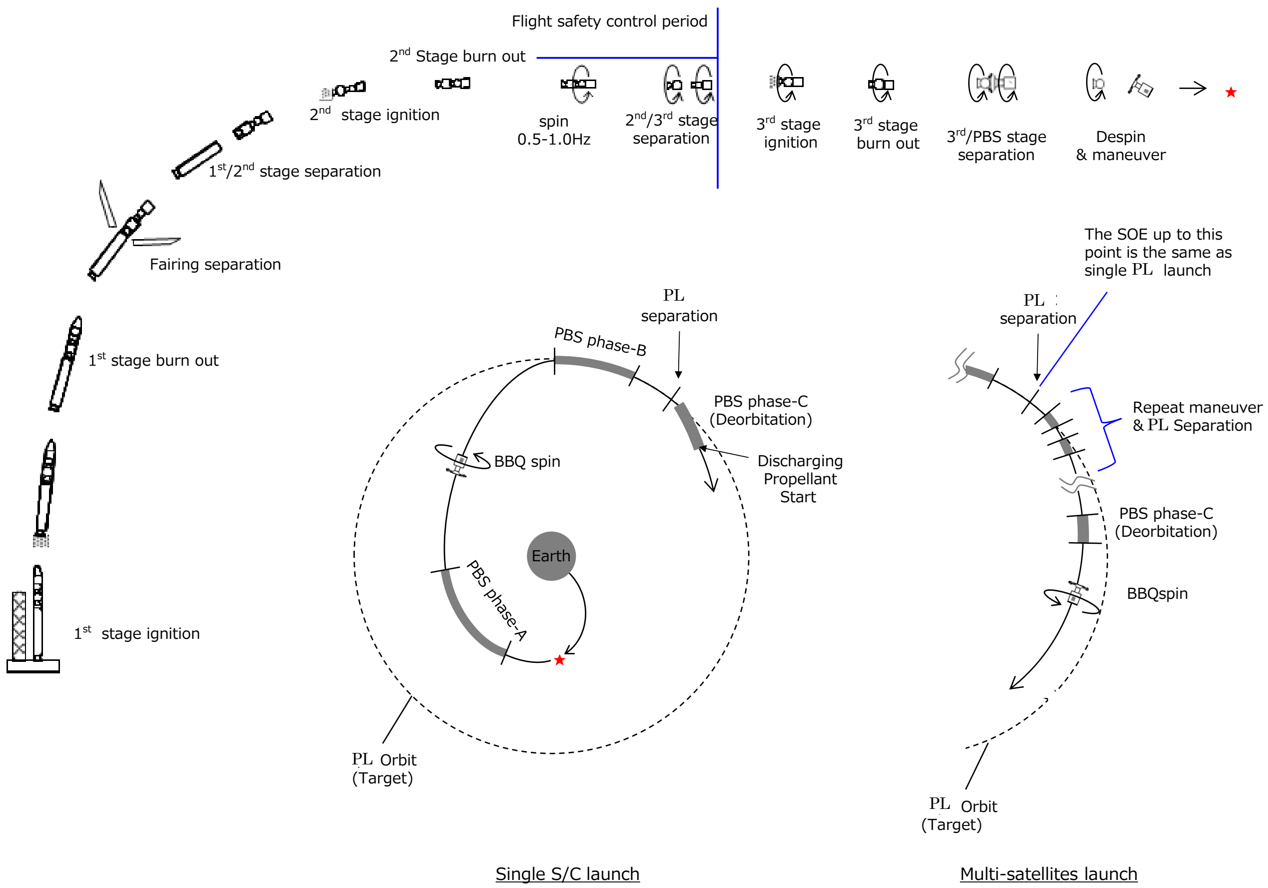


Figure 3-2 Event Sequence: Nominal Mission Profile (with PBS)

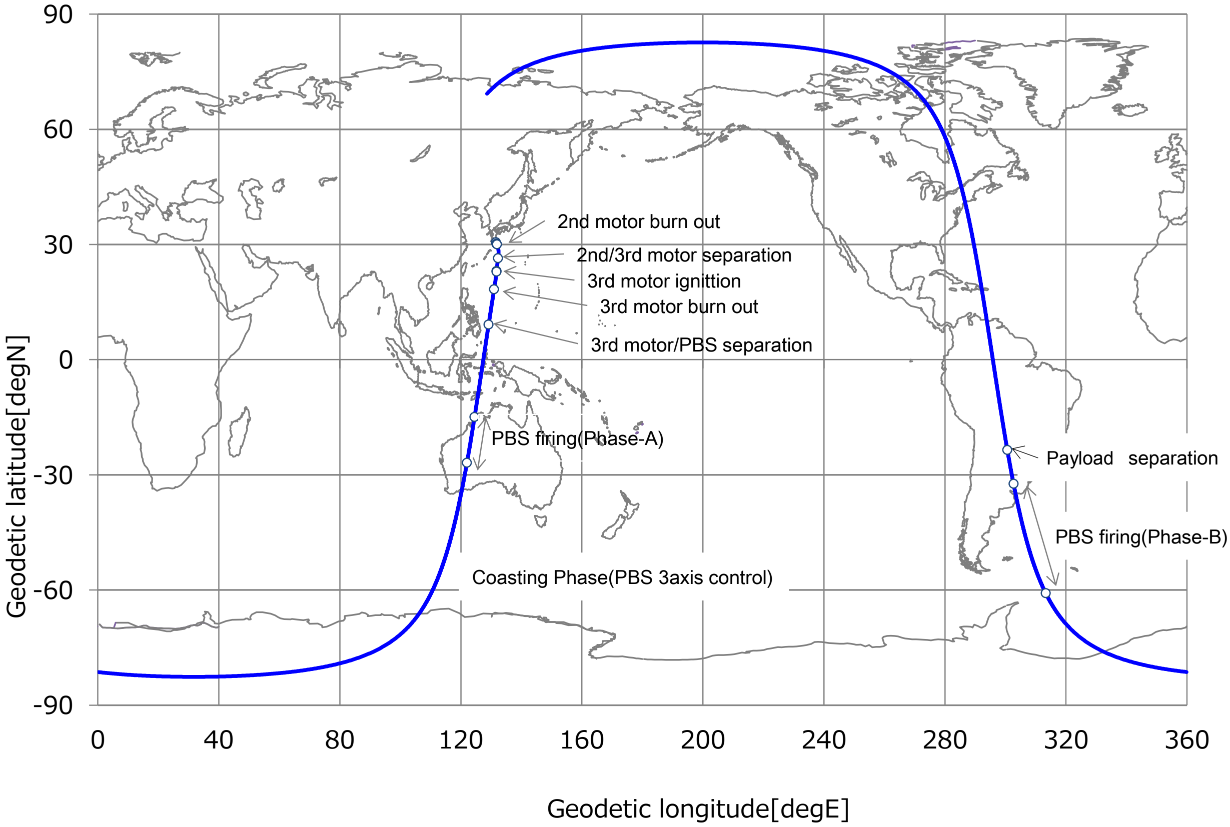


Figure 3-3 Nominal ground path for SSO Mission (with PBS, single launch)

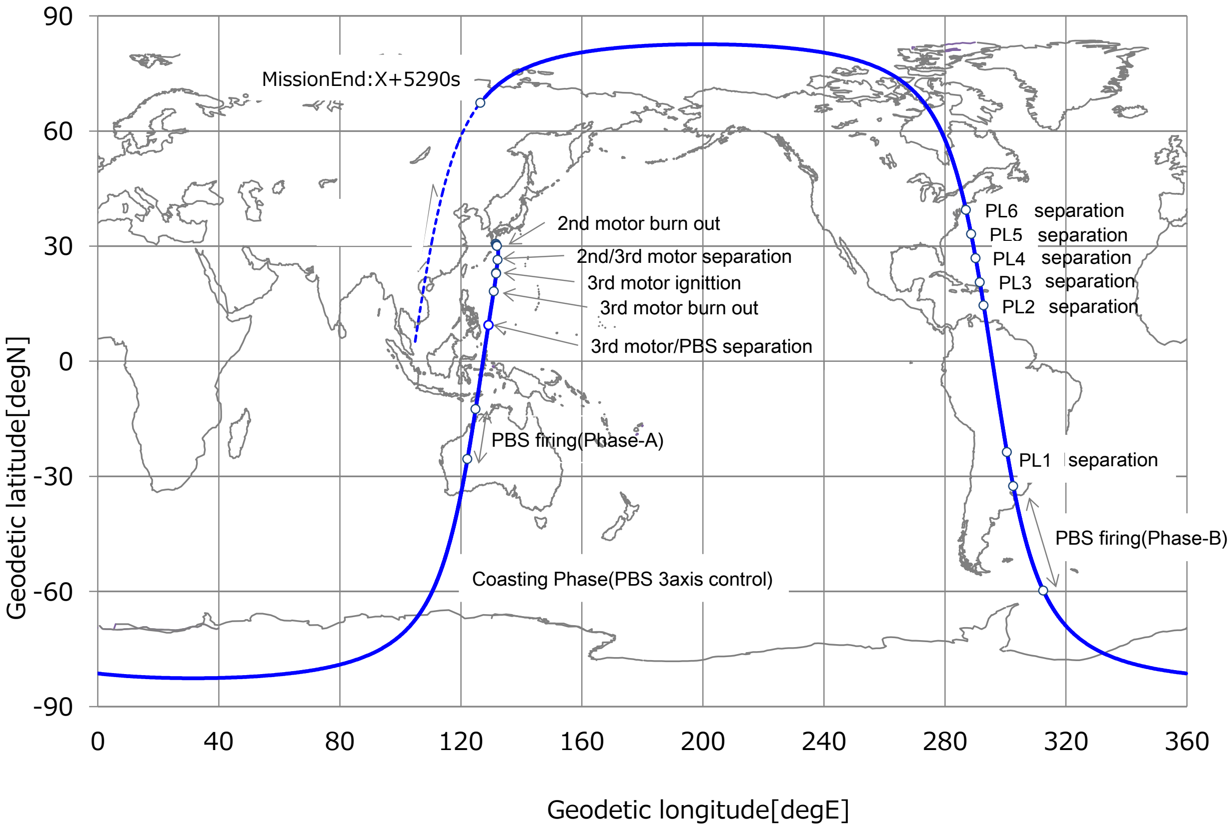


Figure 3-4 Nominal ground path for SSO Mission (with PBS, multi launch)

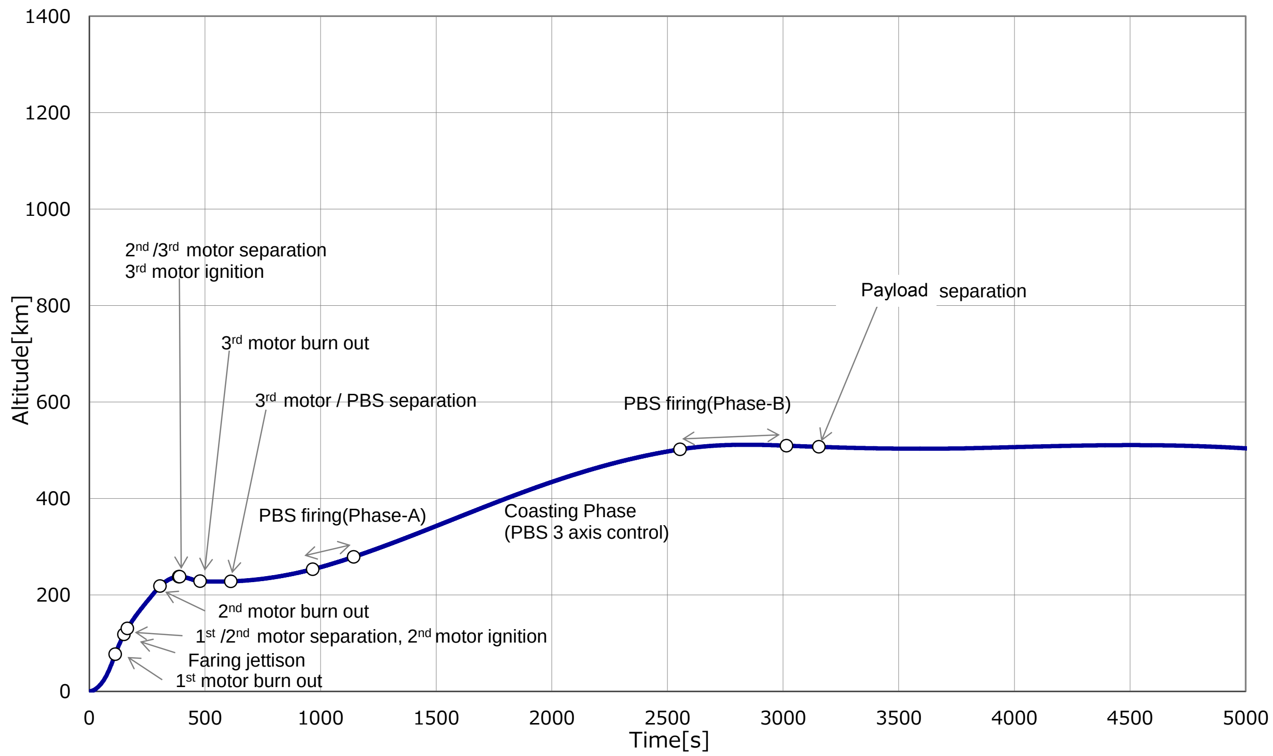
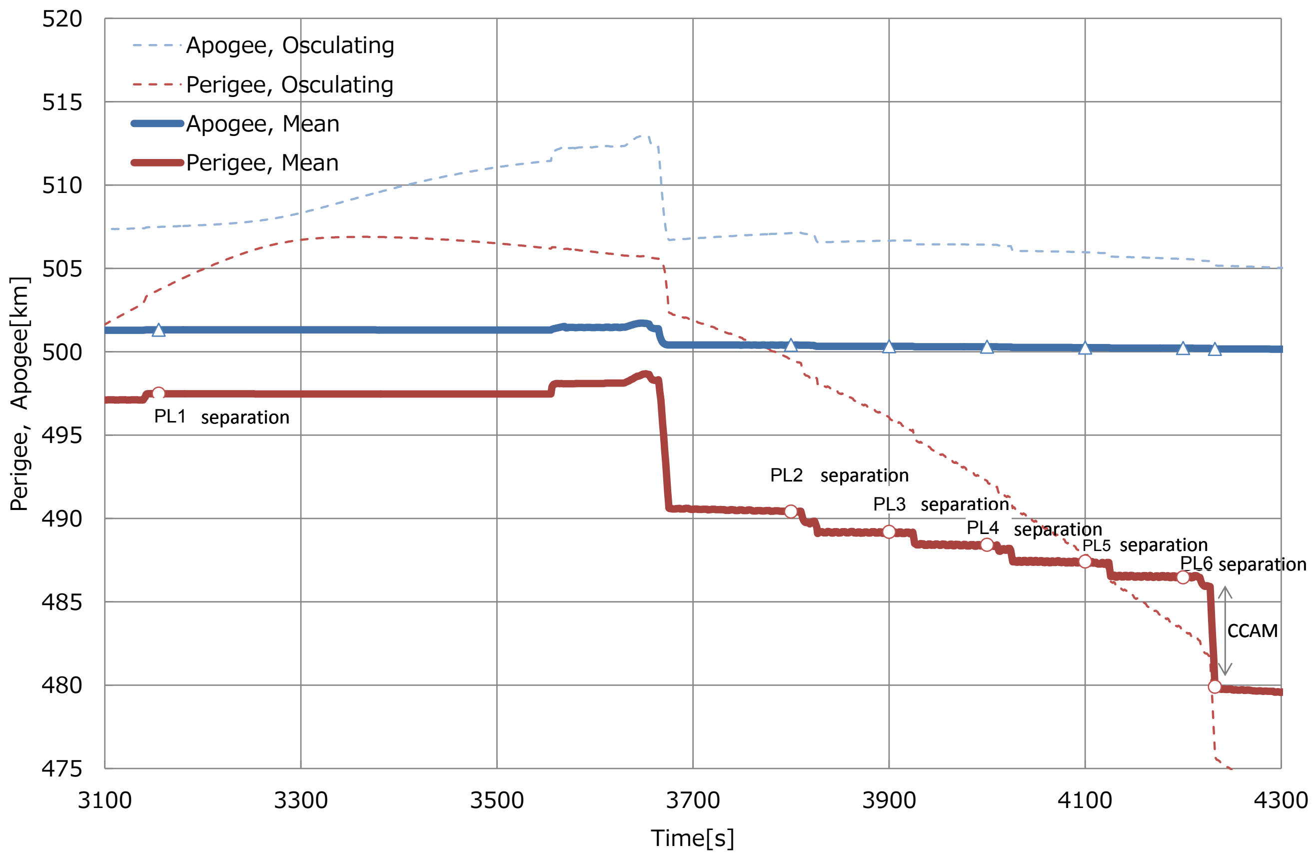


Figure 3-5 Nominal altitude for SSO Mission (with PBS)



※Altitude until PL1 separation is the same as Figure 3-5

Figure 3-6 Nominal altitude for SSO Mission (with PBS, multi launch)

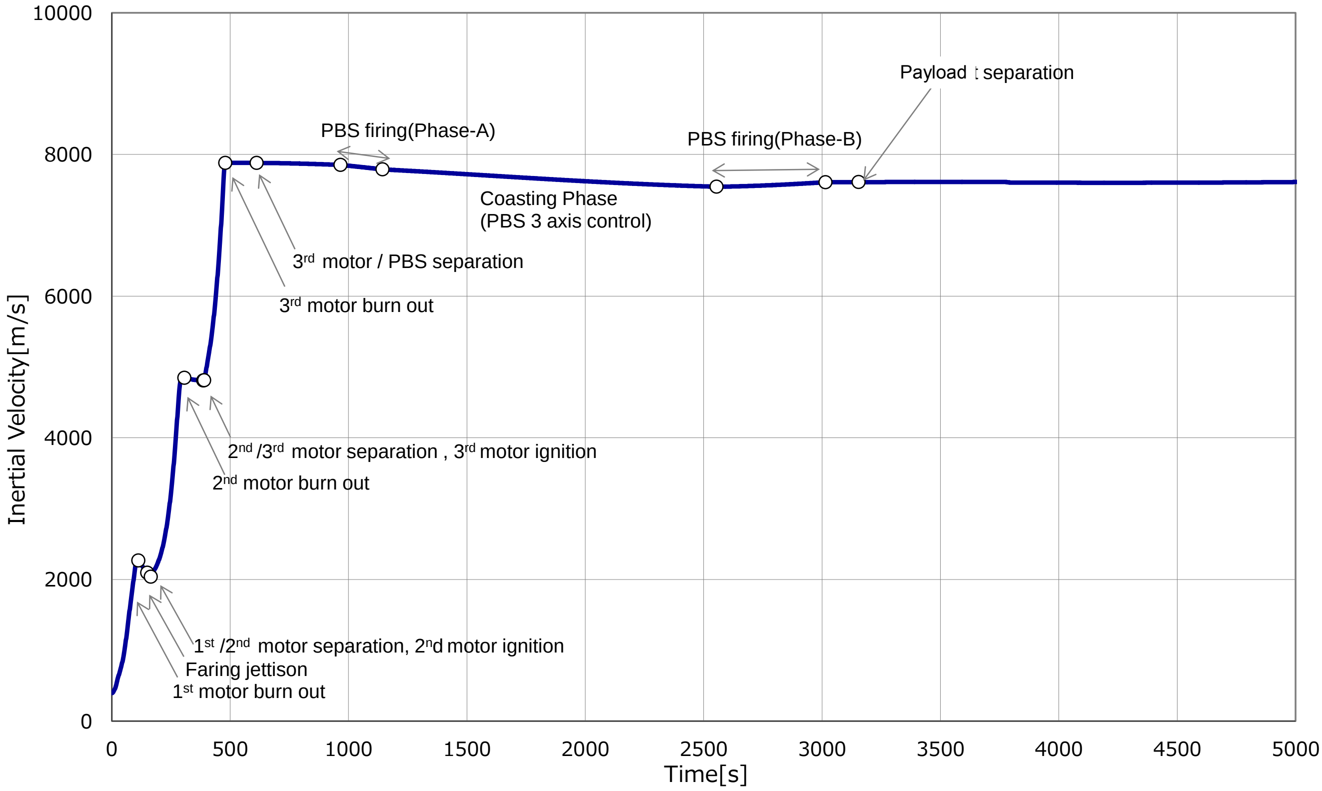


Figure 3-7 Nominal velocity for SSO mission (with PBS)

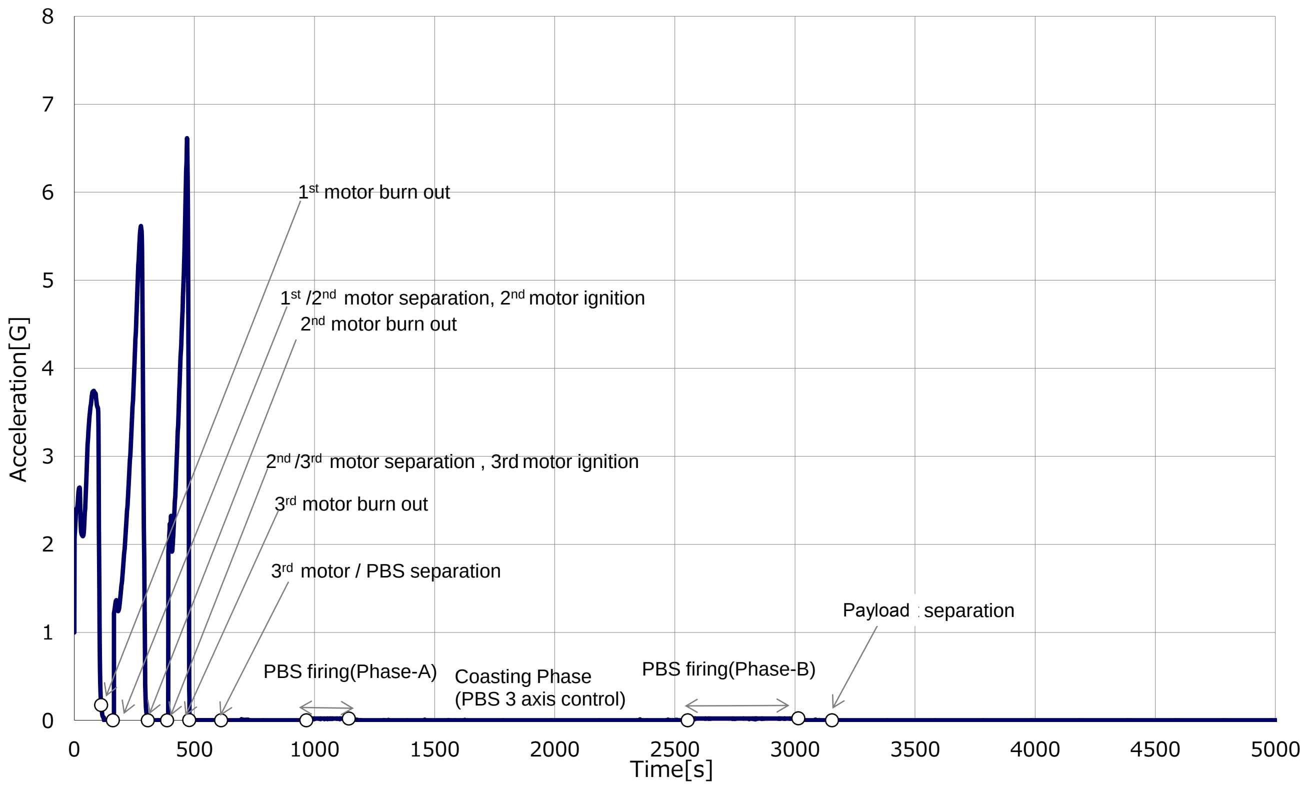


Figure 3-8 Nominal acceleration for SSO mission (with PBS)

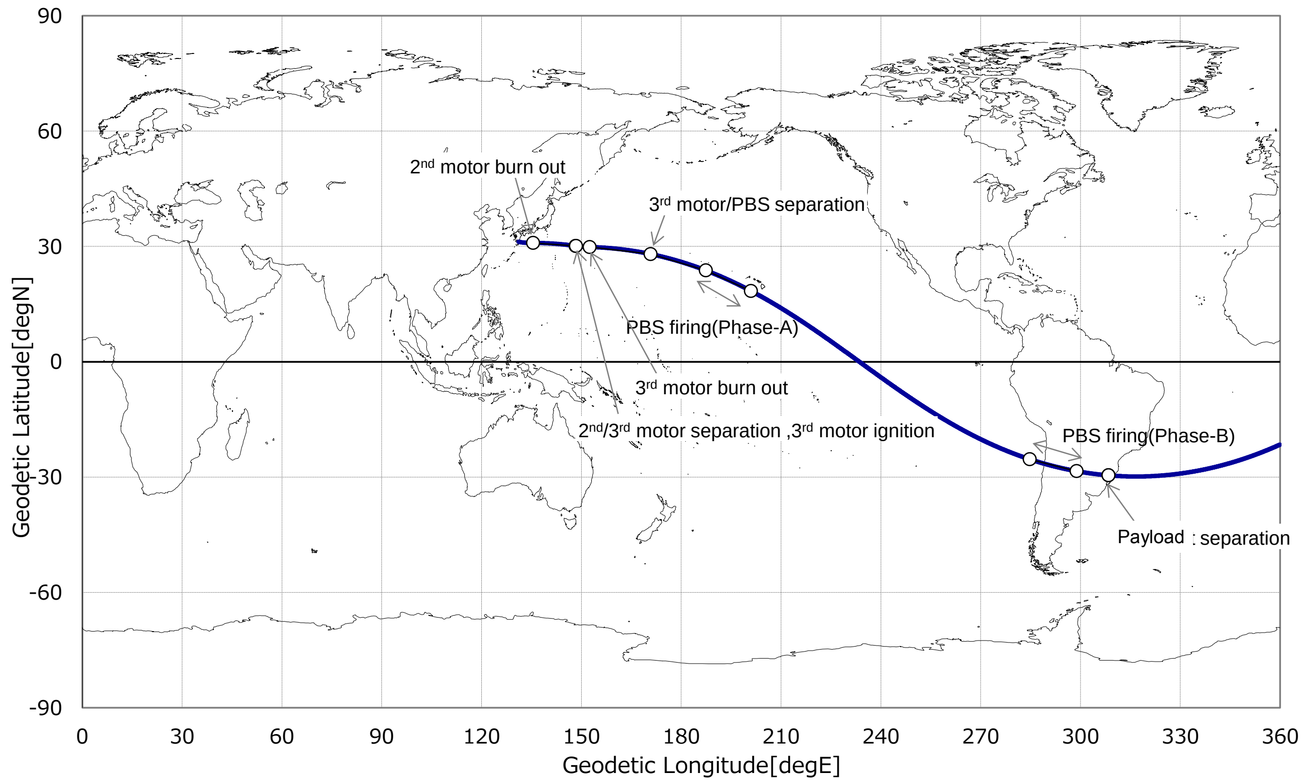


Figure 3-9 Nominal ground path for LEO Mission (with PBS)

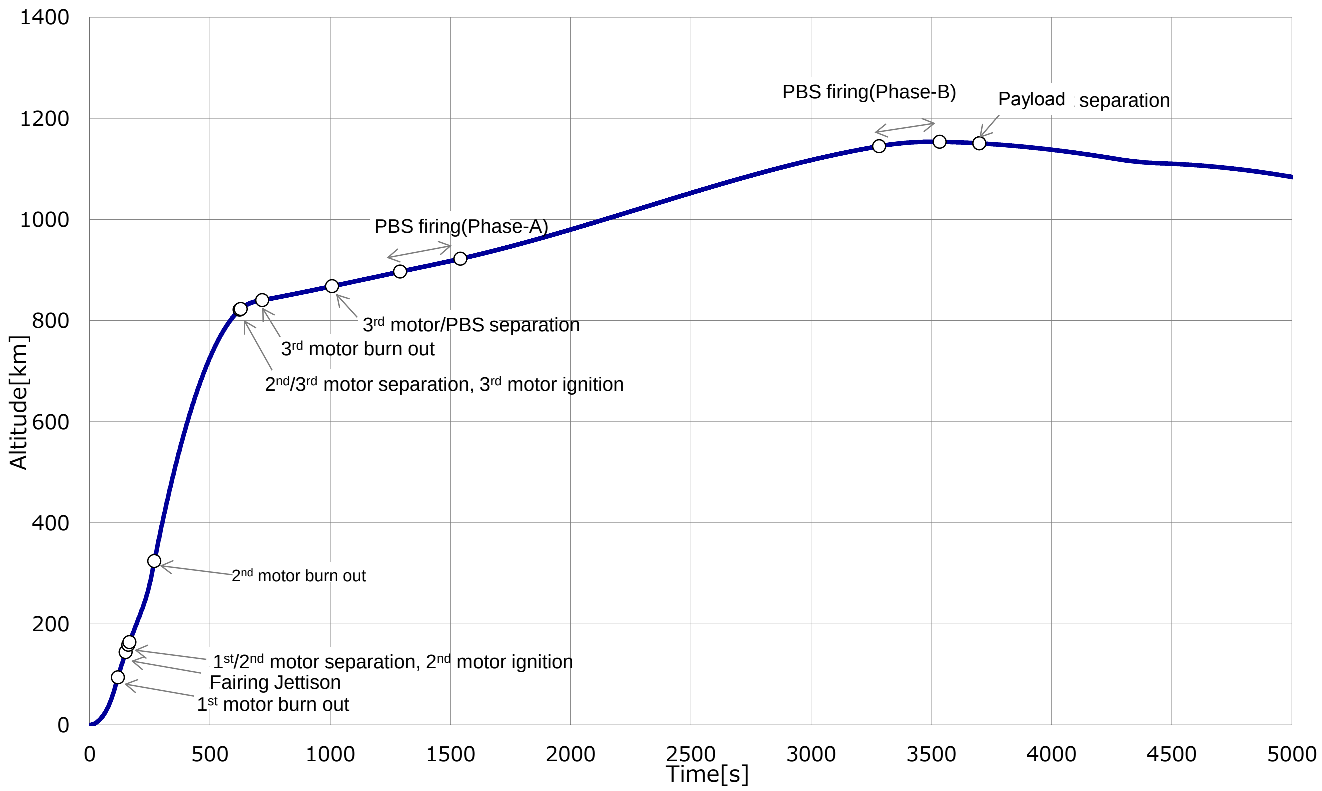


Figure 3-10 Nominal altitude for LEO Mission (with PBS)

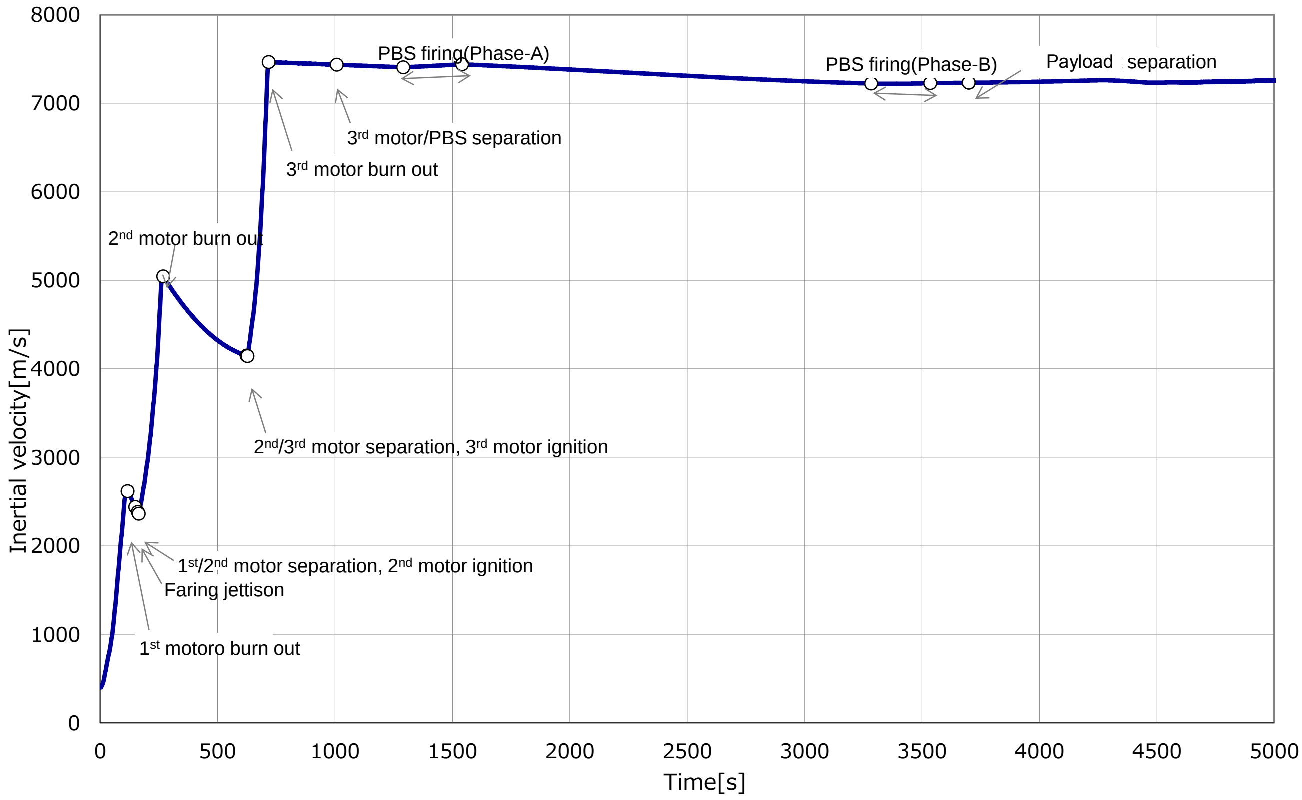


Figure 3-11 Nominal velocity for LEO mission (with PBS)

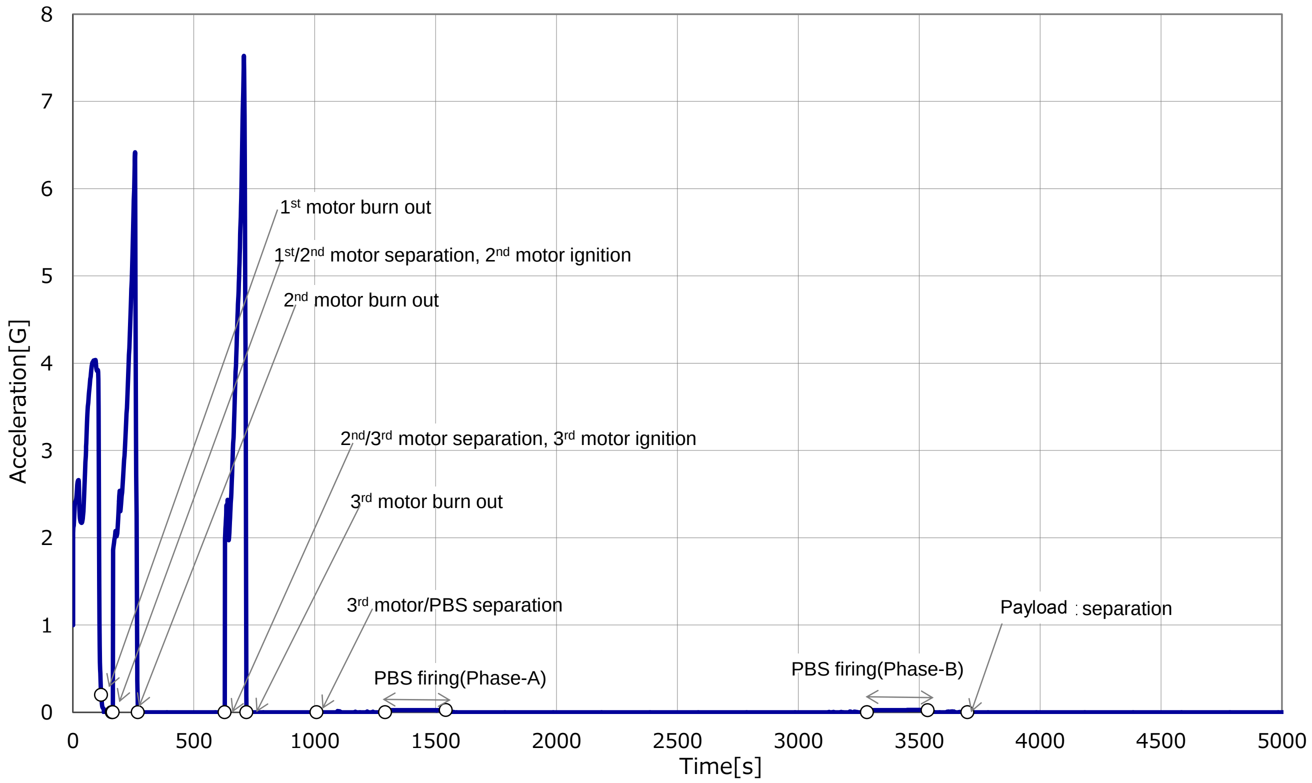


Figure 3-12 Nominal acceleration for LEO mission (with PBS)

3.4. Launch Capability

The launch capability of each configuration is shown in Figure 3-13 and Figure 3-14.

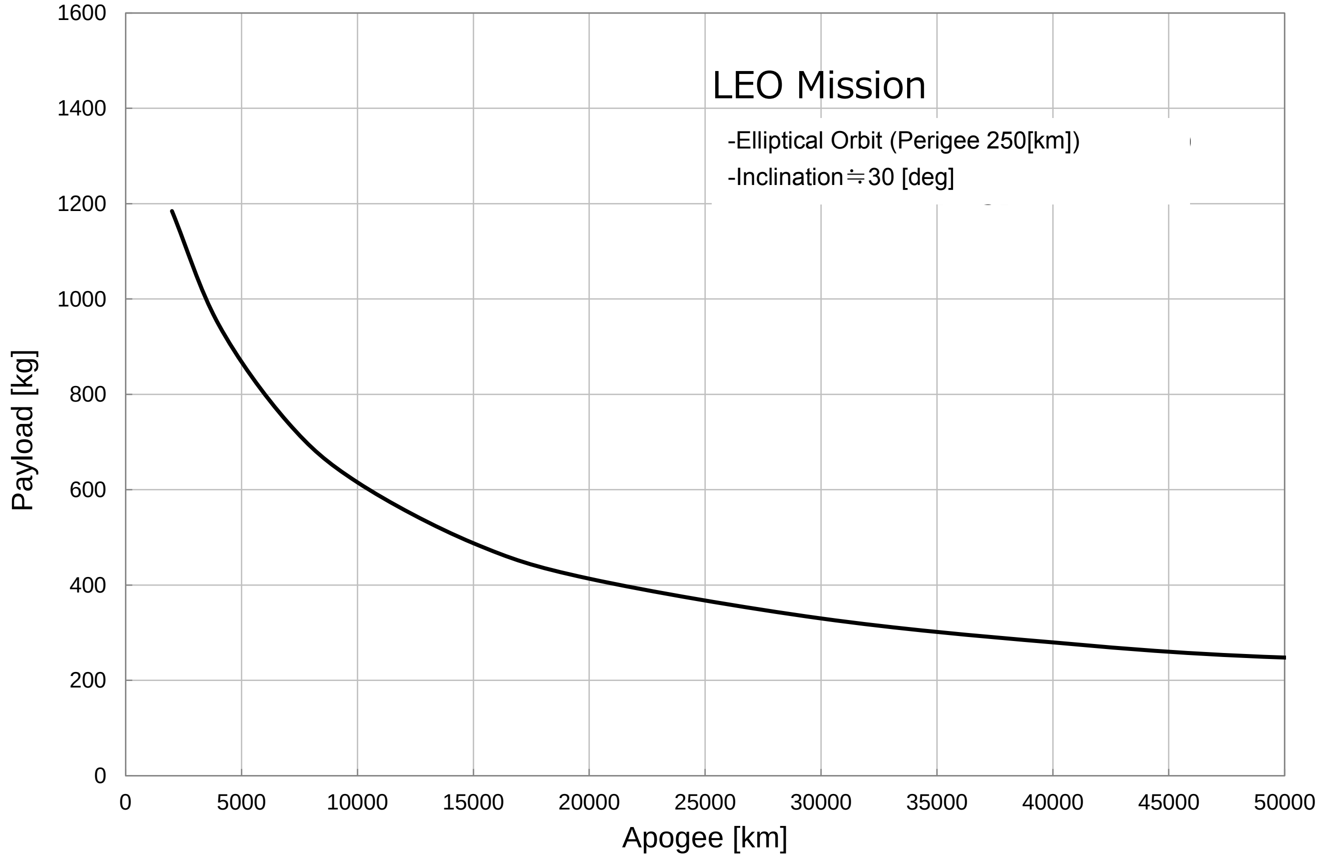
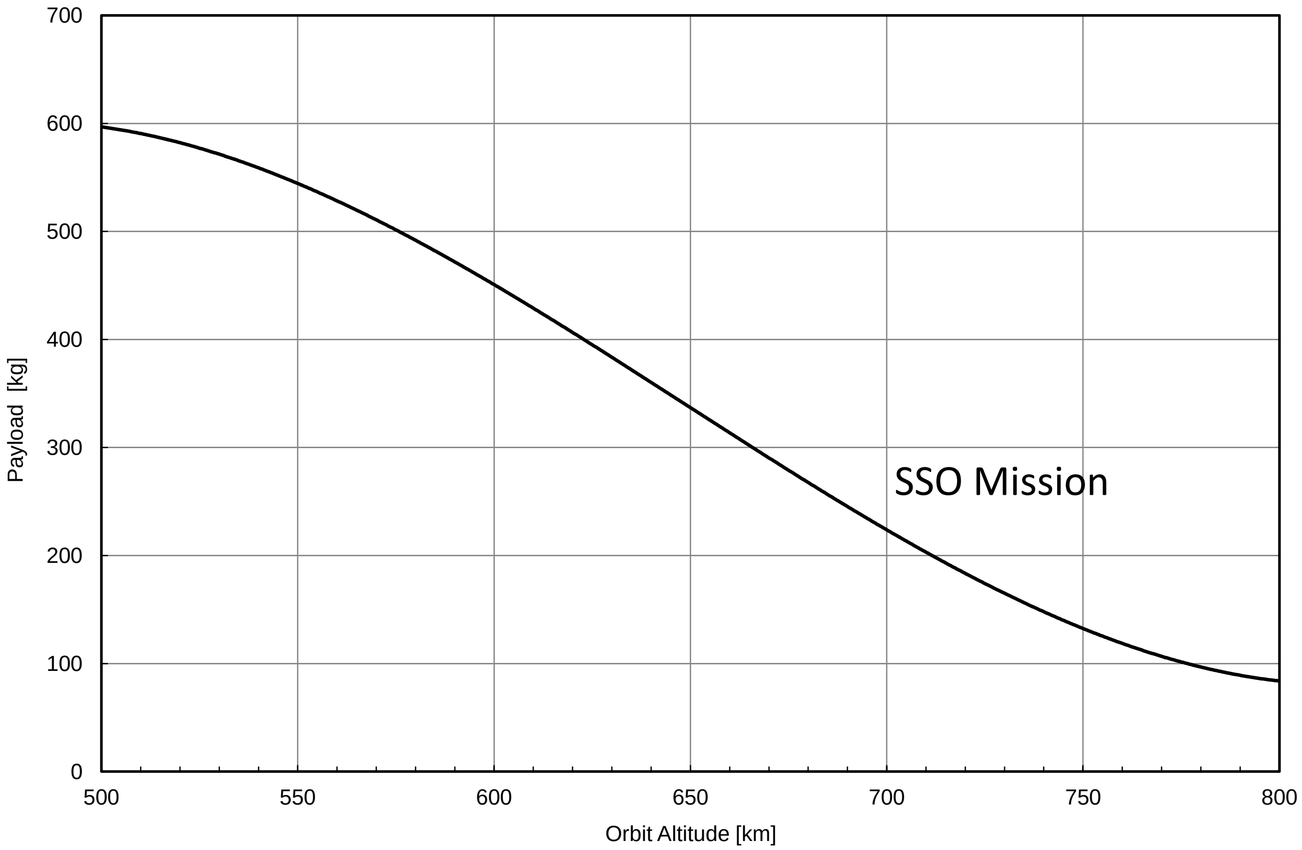


Figure 3-13 Launch Capability (Basic Configuration (without PBS))



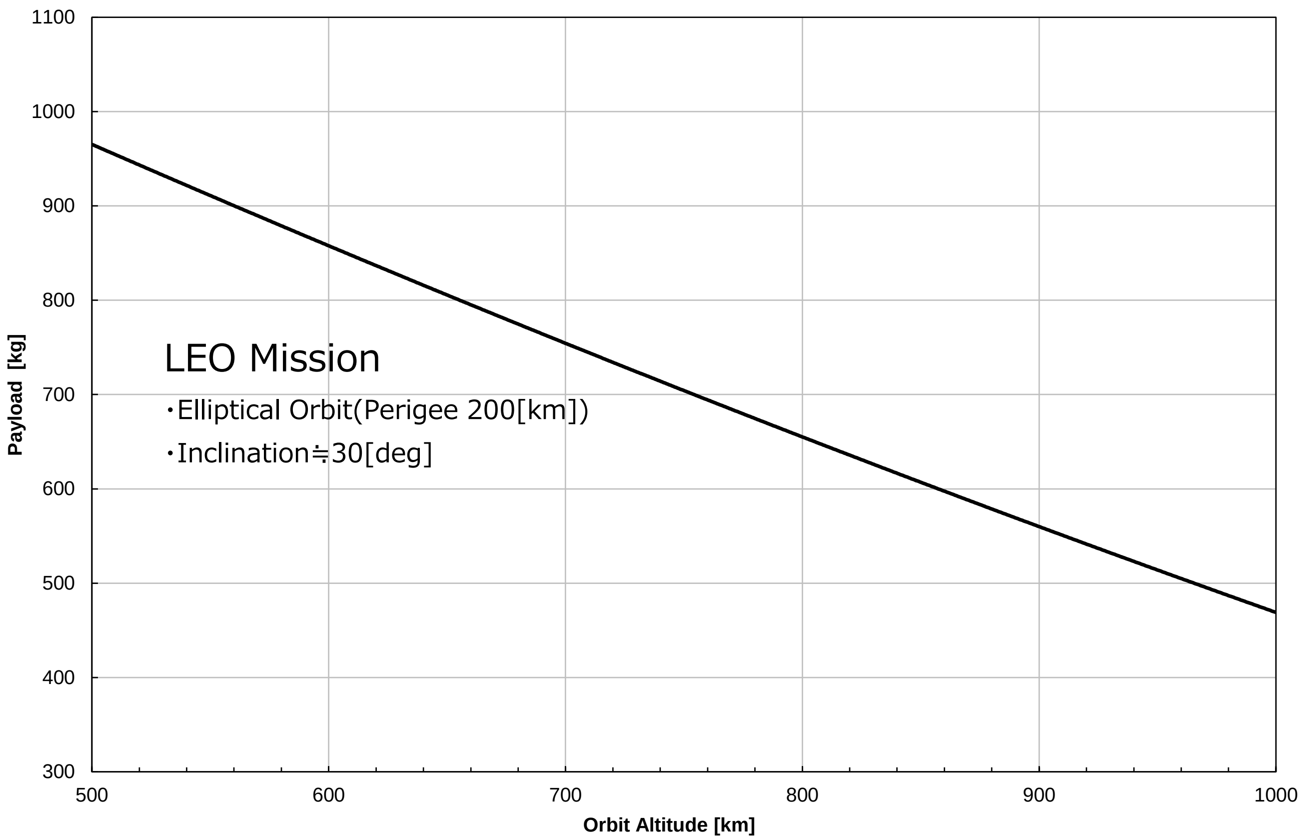


Figure 3-14 Launch Capability (Optional Configuration (with PBS))

3.5. Injection Accuracy

Each injection accuracy (3σ) for LEO and SSO is shown in Table 3-2.
Table 3-3 shows flight results.

Table 3-2 Injection accuracy

Configuration/Orbit		Perigee Altitude [km]	Apogee Altitude [km]	Orbital Inclination [deg]
Optional configuration (with PBS)	LEO (500 km Circular Orbit, Inclination 30.5 deg)	±10	±10	±0.1
	SSO (500 km Circular Orbit, Inclination 97.4 deg)	±10	±10	±0.2
Basic configuration (without PBS)	LEO (Perigee 250 km, Apogee 500 km, Inclination 31.0 deg)	±25	±100	±2.0
	Elliptical (Perigee 250 km, Apogee 30700 km, Inclination 31.0 deg)	±25	±2000	±2.0

Table 3-3 Flight results

Configuration		Perigee Altitude [km]	Apogee Altitude [km]	Orbital Inclination [deg]
Optional configuration (with PBS)	SSO (approximately 500 km Circular Orbit)	+1.46	+1.64	-0.03

3.6. Mission Duration

Epsilon’ mission duration from lift-off through PL separation for the final orbit depends on the specific orbital parameters and the ground station visibility conditions at the time of PL separation.

Critical mission events including PL separation are executed within fields of view of tracking stations. This allows each station to receive near-real-time information on relevant flight events, orbital parameter on-board estimation and separation conditions.

(In multi launch, whether or not PLs except the first separated PL, Small satellite or, in some cases, one of Micro satellites, are separated within the fields of view is determined based on advance arrangements.)

A typical mission duration is about 60 minutes in the configuration with PBS and about 15 minutes in the configuration without PBS. Actual mission duration will be determined in the detailed mission analysis.

3.7. Launch Window

Launch windows are set based on Customer’s requirements and other conditions.

Once the windows are fixed, any change of launch windows must be coordinated in timely manner in consideration of availability of alternative windows.

3.8. Separation Conditions

PL separation is defined as a state of the mechanical fitting between PL and LV being separated.

3.8.1. PL Separation Condition Outline

(1) LV collision avoidance maneuver after PL separation

LV shall maneuver into a lower orbit to avoid collision or contact with PL.

(2) PL operation

Each PL's sequence of events, such as activation of propulsion system, deployment of solar paddle and emission of radio frequency, is determined in an Interface Control Document (ICD) prepared for each PL.

For multi-payload launch, any PL other than the Small satellite shall be released in cold launch method in principle and be allowed to start their event sequence after 200 seconds from the separation.

(3) PL separation order in multiple PL launch

PL separation order in multiple PL launch is decided by agreement between Customer and Program Director.

3.8.2. Altitude Control in PL Separation

The attitude control process in PL separation is defined for each PL.

PL is separated by the spin separation in the basic configuration without PBS, and PL in single launch and Small satellite in multi launch are separated by the spin separation or the 3-axis stabilization in the optional configuration with PBS.

The actual pointing accuracy is defined by the results of each PL's mission analysis.

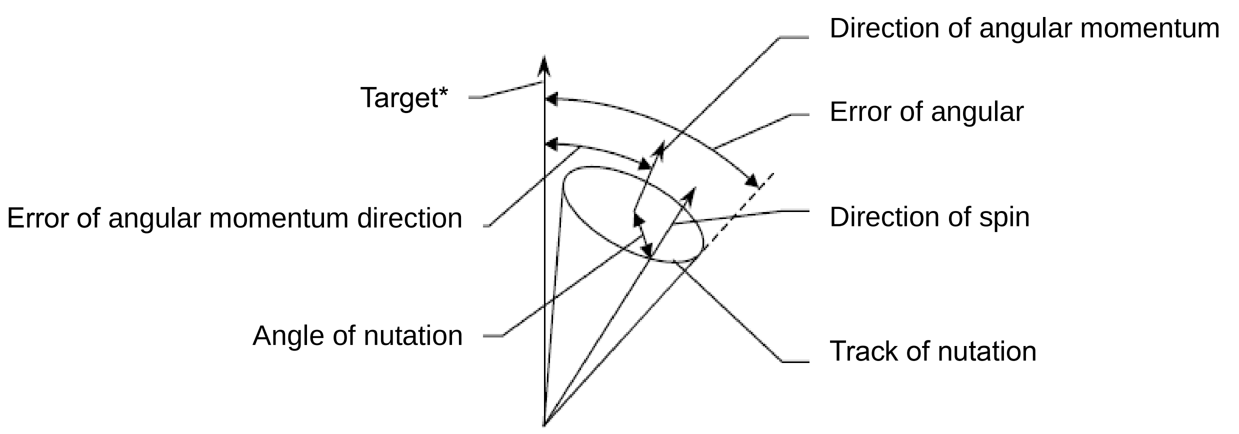
The standard pointing accuracies just before PL separation with 3-axis stabilization by PBS are shown in Table 3-4, and those with spin separation in Table 3-5.

Table 3-4 Standard separation condition (3-axis stabilization)

<table>
<tr><th rowspan="2">Payload</th><th rowspan="2">Pointing error
[deg]</th><th colspan="2">Angular velocity error
[deg/s]</th><th rowspan="2">Separation
velocity [m/s]</th></tr>
<tr><th>Roll</th><th>Pitch/Yaw</th></tr>
<tr><td>PL (single launch)</td><td>±3
(For 600 kg PL)</td><td>±2</td><td>±1</td><td>0.5±0.1</td></tr>
<tr><td>Small satellite
(multi launch)</td><td>±3
(For 200 kg Small satellite
to be first separated)</td><td>±5</td><td>±5</td><td>0.5±0.1</td></tr>
<tr><td rowspan="2">Micro satellite
(multi launch)</td><td>N/A</td><td>±7</td><td>±7</td><td>0.2 to 0.6</td></tr>
<tr><td colspan="3">See Chapter 4.2.2.1 for detail. The center of gravity (CG) of the satellite greatly influences its separation rate.</td><td></td></tr>
<tr><td>Single CubeSat in a deployer (E-SSOD)</td><td colspan="3">To be defined in ICD for each PL.
Details are described in Appendix-C.</td><td rowspan="2">1.1 to 1.7
(For one 3U
weighing 4.5 kg)</td></tr>
<tr><td>2 or 3 CubeSats in a deployer (E-SSOD)</td><td colspan="3">When two or three CubeSats are housed in a deployer, spring plungers installed on the CubeSats will push each other and produce its separation rate. Details of the spring plunger are described in Appendix-C.</td></tr>
</table>

Table 3-5 Standard separation condition (spin separation)

Payload	PBS	Separation condition	Precondition
PL (single launch)	Optional configuration (With PBS)	Error of angular: 30 [deg] or less	Spin rate: 10 [deg/s] Separation velocity: 0.5 [m/s]
Small satellite (multi-launch)			
PL (single launch)	Basic configuration (Without PBS)	Error of angular: 30 [deg] or less	Spin rate: 360 [deg/s] Separation velocity: 2.0 [m/s]



*: In a basic configuration without PBS, target is the direction of LV velocity vector at the time of orbital injection.

Figure 3-15 Definition of the attitude angle

4. PL Accommodation

4.1. PL Fairing (PLF)

PLF protects PLs from the external environment during the accelerated flight in the atmosphere. It consists of two halves of aluminum hull with aluminum honeycomb core sandwich structure.

The separation bolt system is used for PLF separation; PLF is opened like a clamshell by jettison springs over jettison hinges along its rim.

4.1.1. PL Usable Volume

Figure 4-1 shows PLF dynamic envelope, or PL usable volume, in single launch.

PL usable volume is defined as a volume that accommodates a static PL on a Payload Attach Fitting (PAF) or other connecting devices, PL manufacturing tolerances, thermal blankets and other appendices, and allows for PL's dynamic displacement to be caused during flight under the condition that the six degrees of freedom of both PL and PAF or other connecting devices are fixed.

No multilayer insulation (MLI) shall be installed near PAF which connects PL and LV.

As for multi launch, see each section in Appendix as shown below:

- Small satellite — Appendix-A PAF-937M I/F
- Microsatellite — Appendix-B Lightband® I/F
- CubeSat — Appendix-C E-SSOD I/F

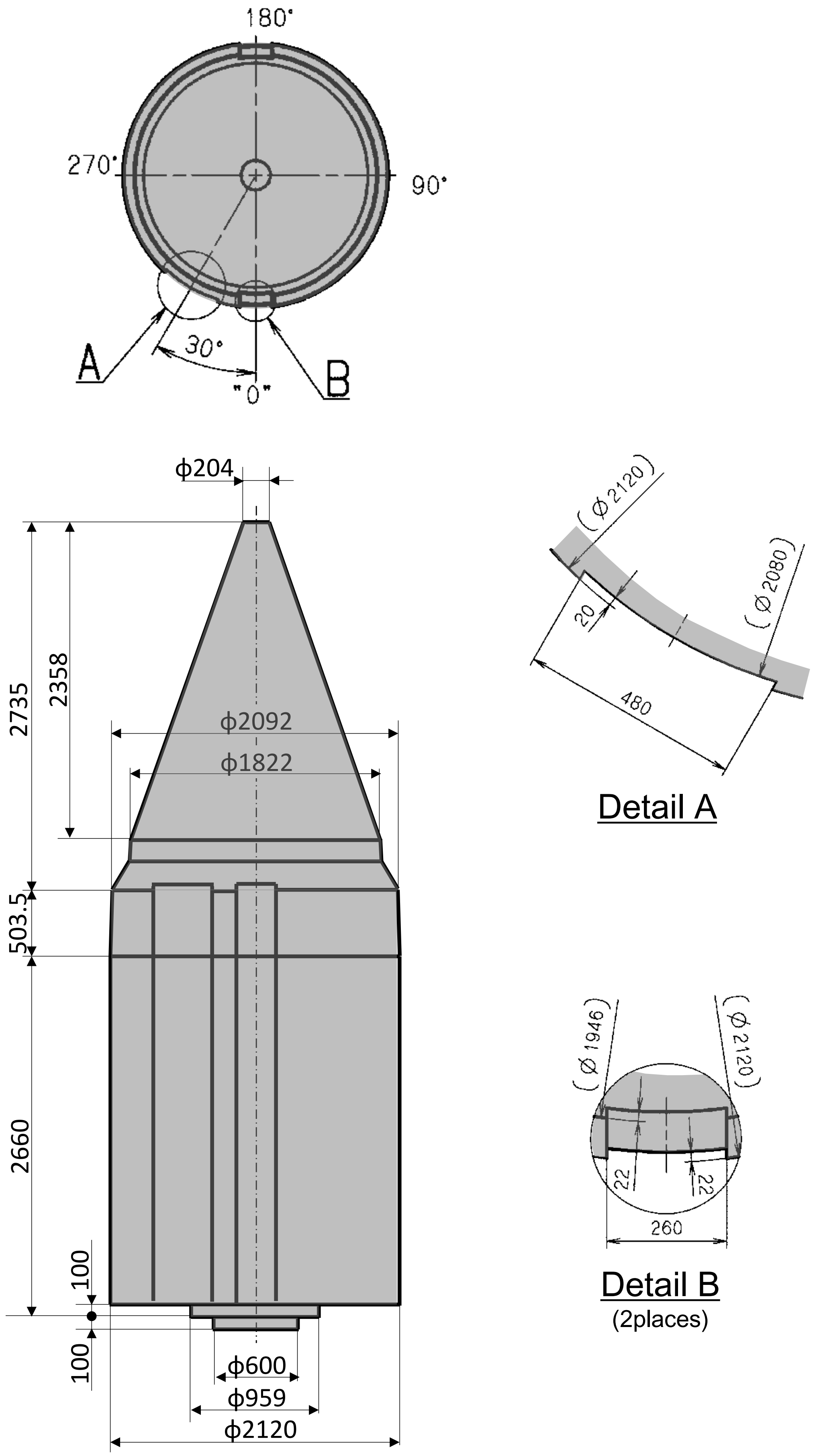


Figure 4-1 PL Usable Volume (single launch)

4.1.2. Access Doors / Radio Frequency (RF) Window

(1) Access doors

Access doors, several to be set on PFL for access to PL in single launch or Small satellite in multi launch, have three types as below. Their available locations are shown in Figures 4.1.2-2, 4.1.2-3, and 4.1.2-4.

Refer to Appendix-E for details because access doors may not be approachable in some cases due to the positional relation of pillars and floor in the M Assemble Tower. For the interference caused by opening and closing doors, contact your Program Director.

- Square with 600 mm x 600 mm: (1 place in standard)
- Circle with a diameter of 180 mm: (2 places in standard)
- Circle with a diameter of 350 mm: (None in standard)

*: These dimensions indicate values on the developed outside panel of PL with a diameter of 2570 mm.

*: Restrictions on distances between each openings of doors and a window are shown on the figures.

(2) RF transparent window

A RF transparent window, only one to be set on PFL for RF link interface with PL in single launch or Small satellite in multi launch, has one type as below. Its available locations are shown in Figure 4.1.2-5. If PL in single launch or Small satellite in multi launch needs RF link tests before launch, consider the direction of the pick-up antenna in USC (See Appendix-D).

- Circle with a diameter of 400 mm: 1 place

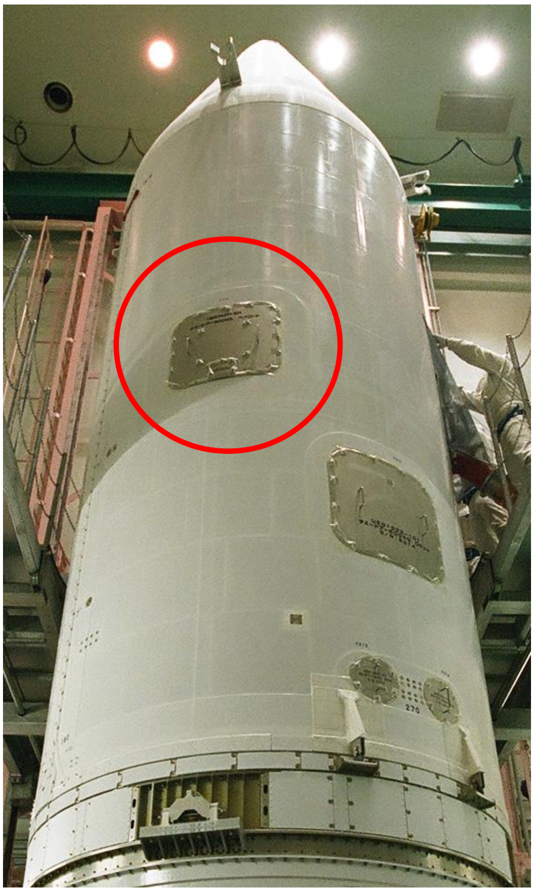


Figure 4.1.2-1 PFL access door

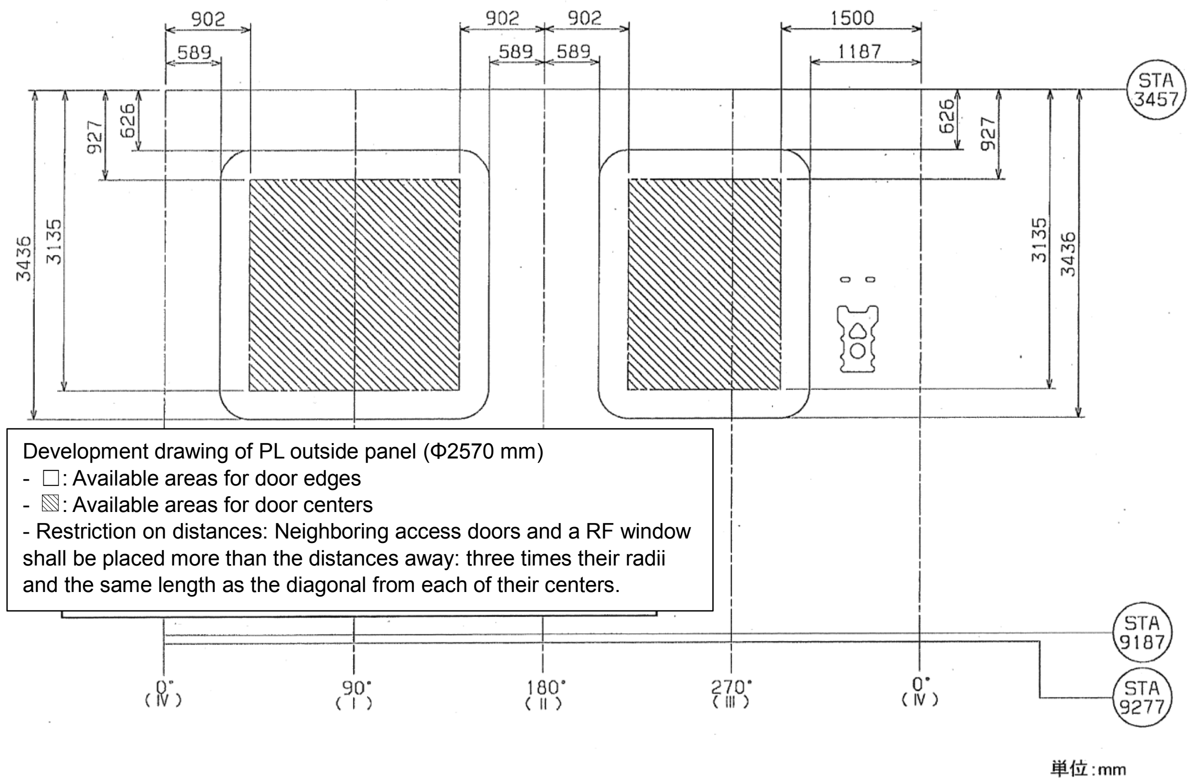


Figure 4.1.2-2　Access door (Square 600 mm)

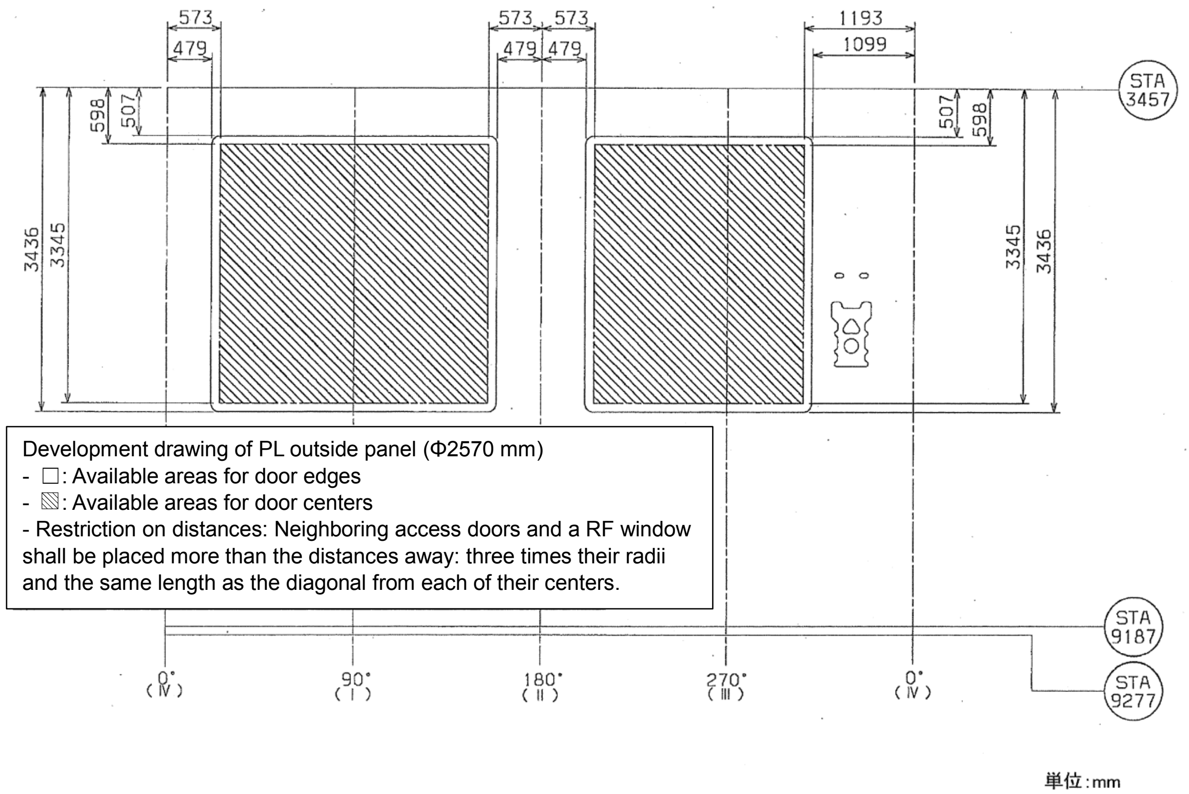


Figure 4.1.2-3　Access door (Φ180 mm)

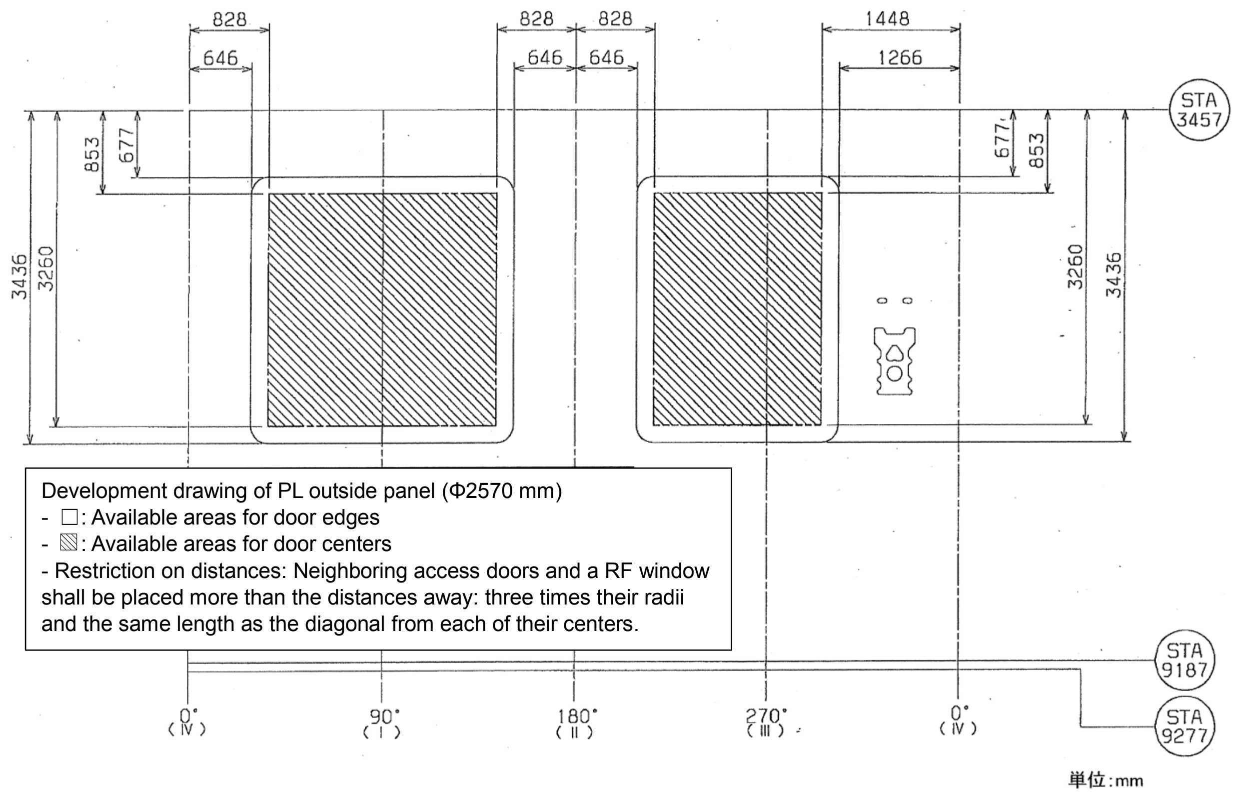


Figure 4.1.2-4 Access door (Φ350 mm)

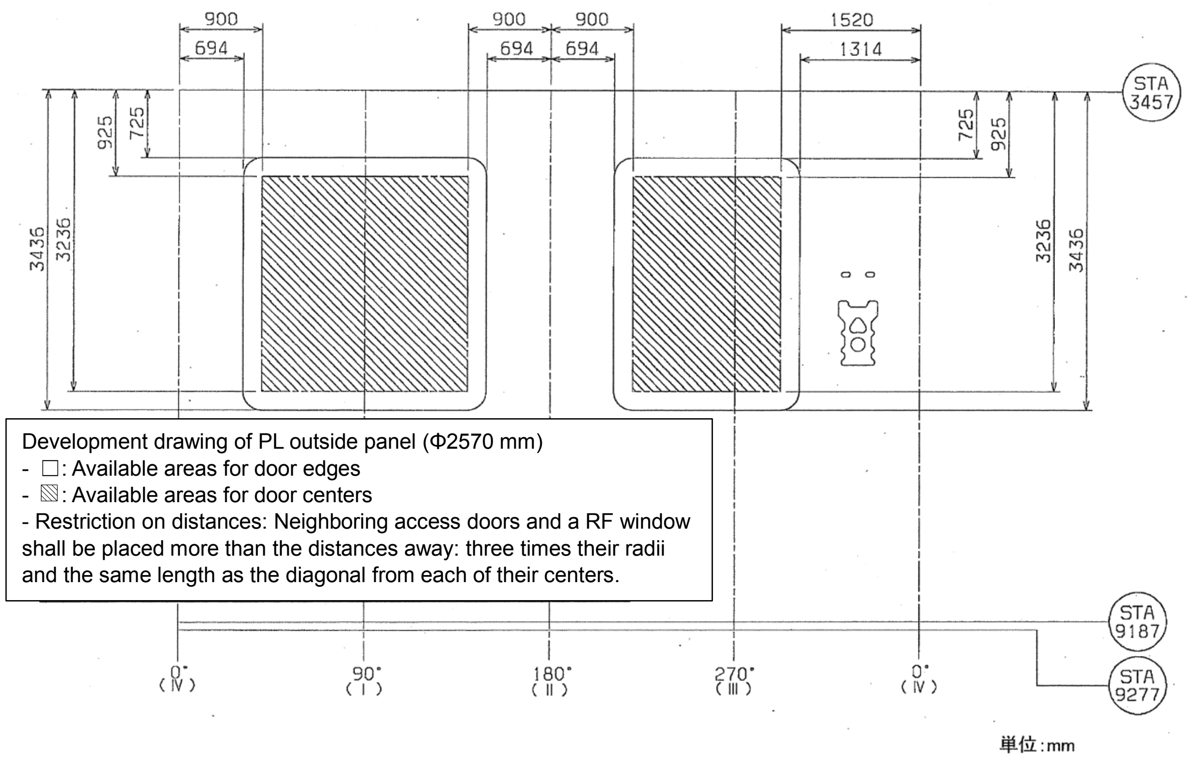


Figure 4.1.2-5 RF transparent window (Φ400 mm)

4.2. PL Requirements

4.2.1. PL Mass

The mass of each PL is limited as shown in Table 4.2.1-1.

Table 4.2.1-1 PL Mass

PL		Mass
PL (single launch)		See Chapter 3.4
Small satellite (multi launch)		170 - 200 kg
Micro satellite (multi launch)		40 - 65 kg
CubeSat	1U size	0.13 - 1.5 kg
	2U size	0.26 - 3.0 kg
	3U size	0.39 - 4.5 kg

4.2.2. Static Unbalance

PL static unbalance, or C.G. allowance, is limited as shown in Table. 4.2.2-1.

Table 4.2.2-1 PL Center of Gravity (C.G.)

PL	C.G.	
	Separation plane	height
PL (single launch)	0 ± 15 mm	Figure 4.2.2-1
Small satellite (multi launch)	0 ± 15 mm	570 mm or less
Micro satellite (multi launch)	See Chapter 4.2.2.1	
1U to 3U CubeSat	Within a sphere of 20 mm radius from the geometric center of each CubeSat	

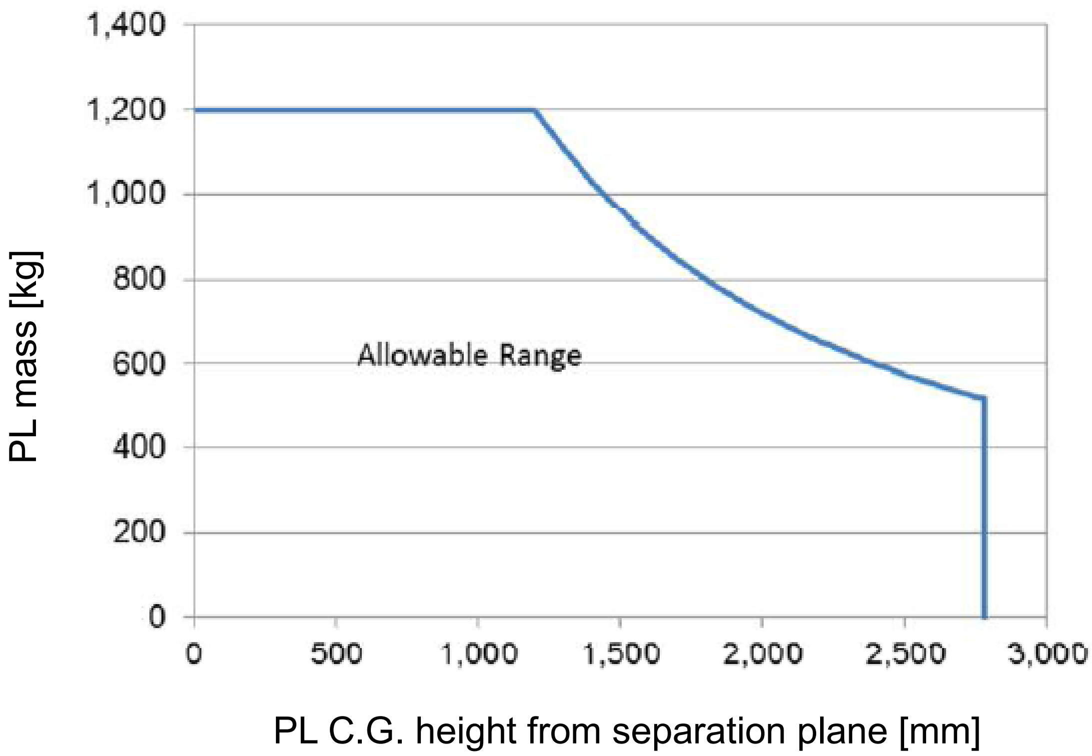


Figure 4.2.2-1 Allowable range of PL mass and C.G. in single launch

4.2.2.1. Limit of CG of Micro satellite

C.G. of a Micro satellite shall be limited as described in (1) and (2) as follows.

(1) C.G. of Xsc, Ysc

C.G. of a Micro satellite on the axes of Xsc and Ysc shall be limited to either (A) or (B) as below. If C.G. lies in B, notify your Program Director of its C.G. and mass at least 7 months before the launch. If a Micro satellite is difficult to satisfy these C.G. limitations, contact your Program Director

(A) The C.G. shall be limited within 5 mm (0 ± 5 mm) from the origin.

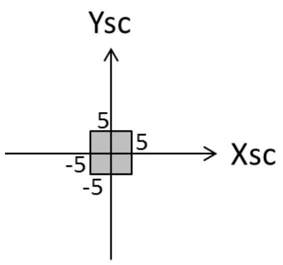


Figure 4.2.2-2 Limit of C.G. (Xsc, Ysc) of Micro satellite (A)

(B) The nominal C.G. (± 5 mm) shall be limited within 15 mm (0 ± 15 mm) from the origin.

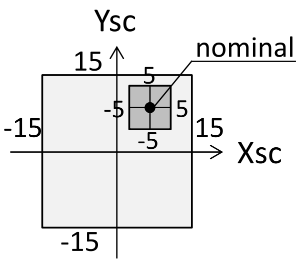


Figure 4.2.2-3 Limit of C.G. (Xsc, Ysc) of Micro satellite (B)

(2) C.G. of Zsc

C.G. of a Micro satellite on the axis of Zsc shall be within the allowable range shown in Figure 4.2.2-4 and their nominals shall be ± 15 mm. As this limitation may be changed according to mass characteristics of other rideshare satellites, the details are defined in your ICD.

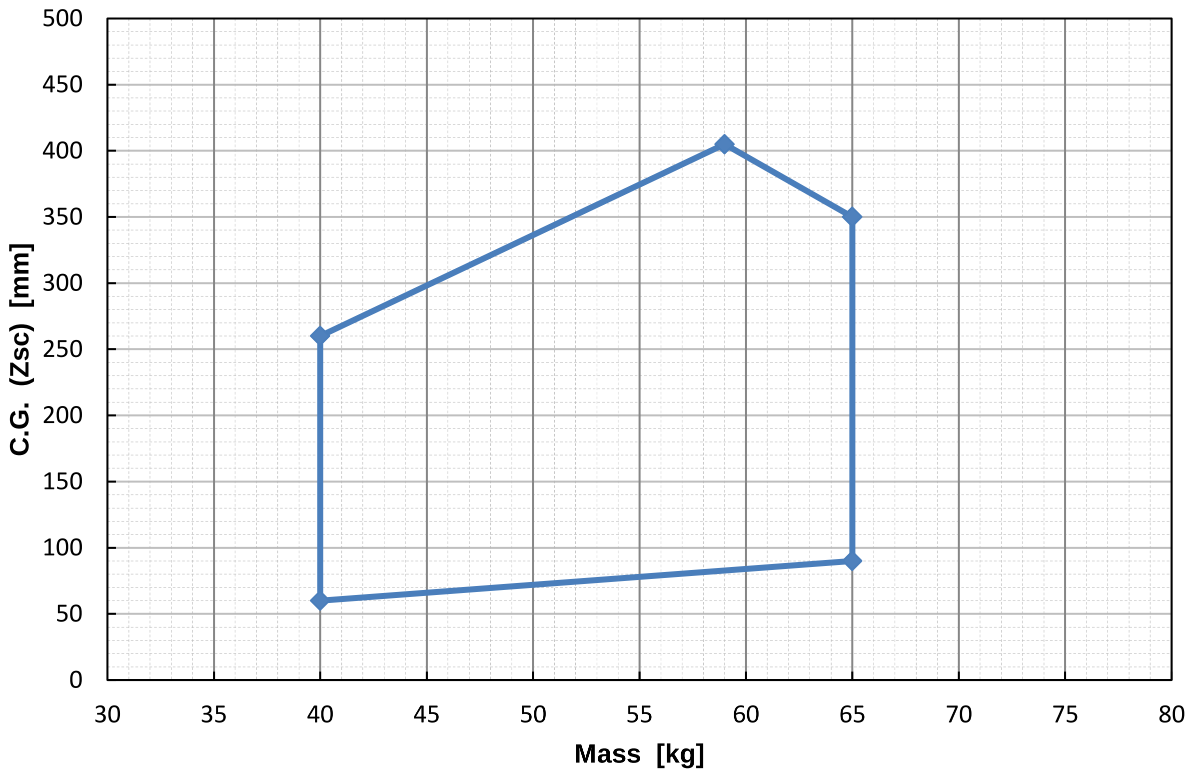


Figure 4.2.2-4 Limit of C.G. (Zsc) of Micro satellite and the mass

4.2.3. Stiffness of PL

To prevent dynamic coupling with LV, PL shall be designed to have an appropriate structural stiffness which meets the following requirements in Table 4.2.3-1.

The natural frequencies of PL tightly cantilevered on the interface of a standard adapter shall meet the requirements in Table 4.2.3-1:

If these requirements cannot be satisfied, some measures, such as CLA, can be provided to confirm the stiffness. Contact your Program Manager for details.

Table 4.2.3-1(1/2) Stiffness

Payload	frequencies		
	Y_B	Z_B	X_B
PL (single launch)	≥ 30 [Hz]		≥ 45 [Hz]
Small satellite (multi launch)			

Table 4.2.3-1(2/2) Stiffness

Payload	frequencies		
	X_{sc}	Y_{sc}	Z_{sc}
Micro satellite (multi launch)	≥ 40 [Hz]		≥ 80 [Hz]
1U to 3U CubeSat*	≥ 113 [Hz]		

*: CubeSat's minimum natural frequency shall satisfy this requirement on condition that all ends of the four rails of the CubeSat are tightly fixed.

4.3. Mechanical Interfaces

Mechanical interfaces with PAF or other connecting devices are described as follows.

･PL (single launch)	Appendix-A PAF-937M I/F
･Small satellite (multi launch)	Appendix-A PAF-937M I/F
･Micro satellite (multi launch)	Appendix-B Lightband® I/F
･CubeSat	Appendix-C E-SSOD I/F

4.4. Electrical Interfaces

4.4.1. Separation Connector / Umbilical Connector

Table 4.4.1-1 shows the number and availability of the separation connectors and umbilical connectors for each PL.

The umbilical connectors are available for PL in single launch and Small satellite in multi launch.

Table 4.4.1-1 Separation Connector and Umbilical Connectors

<table>
<tr><th>PL</th><th>Separation Connector (Connection between PL and PAF)</th><th>LV Umbilical Connector(Connection between PL and LV avionics devices)</th><th>Facilities Umbilical Connector (Connection between PL and ground facilities)</th></tr>
<tr><td>PL (single launch)</td><td rowspan="2">2 Lines
See Appendix-A</td><td rowspan="2">N/A (standard) /
Available (option)
See Chapter 4.4.2</td><td rowspan="2">Available
See Appendix-D</td></tr>
<tr><td>Small satellite (multi launch)</td></tr>
<tr><td>Micro satellite (multi launch)</td><td>2 Lines
See Appendix-B</td><td>N/A</td><td>N/A</td></tr>
<tr><td>CubeSat</td><td>N/A</td><td>N/A</td><td>N/A</td></tr>
</table>

4.4.2. Electrical Functions for PL

For PL in single launch and Small satellite in multi launch, electrical command as shown below can be provided as optional via the separation connectors and LV umbilical connector during flight :

(1) Command channels : 4 ch max
(2) Command Signal : 28 [V] discrete
(3) Output Voltage : 24 – 34 [V]
(4) Output Current : 0.35 [A] max @High, 1.5 [mA] max @ Low
(5) Output duration : 100 +/-10 [ms]
(6) Purpose : per PL requirement.
(7) Grounding : Command Return is grounded on the side of LV. (PL shall be isolated.)

4.4.3. Telemetry Transmission and Power Supply to PL

Monitoring, sending commands to, and power supply to PL in single launch or Small satellite in multi launch are available during launch operation on ground via separation connectors and umbilical connectors.

During flight, neither telemetry transmission nor power supply via LV is provided.

4.4.4. PL Battery Life

If any on-board battery of PL cannot be charged via LV (i.e. Micro satellites and CubeSats in multi launch, and PL without umbilical lines due to its specifications), such PL is recommended to have a sufficient battery life span in consideration of a period between PL mating and launch. The timing of PL mating with LV is decided for each PL.

4.4.5. Separation Switches

4.4.5.1. LV Separation Switches and Transmission of Separation Status

The specifications of LV separation switches for each PL are described in Table 4.4.5-1.

The separation status of PL in single launch or Small satellite in multi launch will be given to Customer by LSP.

The separation status of Micro satellites and CubeSats in multi launch will be provided according to their ICDs.

Table 4.4.5-1 Separation switches (LV)

PL	number	detail
PL (single launch)	2	See Appendix-A
Small satellite (multi launch)	2	
Micro satellite (multi launch)	2 for each satellite	See Appendix-B
CubeSat (multi launch)	2 for each E-SSOD	—

4.4.5.2. PL Separation Switch

The standard specifications of PL separation switches for each PL are described in Table 4.4.5-2. If needed, contact your Program Director.

Table 4.4.5-2 Separation switches (PL)

PL	number	detail
PL (single launch)	2	Appendix-A
Small satellite (multi launch)	2	
Micro satellite (multi launch)	2	Appendix-B
CubeSat (multi launch)	4 at max.	Appendix-C

4.4.6. Bonding and Shielding

4.4.6.1. Bonding

PL shall be electrically connected with PAF at a resistance of 1 ohm or less through electrical connection at PL separation plane. The coatings on PL separation plane of PAF is described in Appendix-A and Appendix-B.

PL is required to expose part of its inner metal, or bonding point, with a diameter of 10 mm or more so as to be measured for bonding resistance.

CubeSat, especially, shall have its bonding point on the side of an access door in case it should need to be handled after being installed in E-SSOD.

4.4.6.2. Shielding

(1) Power Line

Shields of power umbilical lines are grounded on the side of the ground facilities and floated on the side of PL. (The boundary of both sides is at the connecting point of PL and LV .)

(2) Signal Line

Shields of signal umbilical lines are grounded on both sides of the ground facilities and LV. (The boundary of both sides is at the connecting point of the ground facilities and LV in PFL.)

Shields of PL and LV are electrically connected at PL separation plane on PAF.

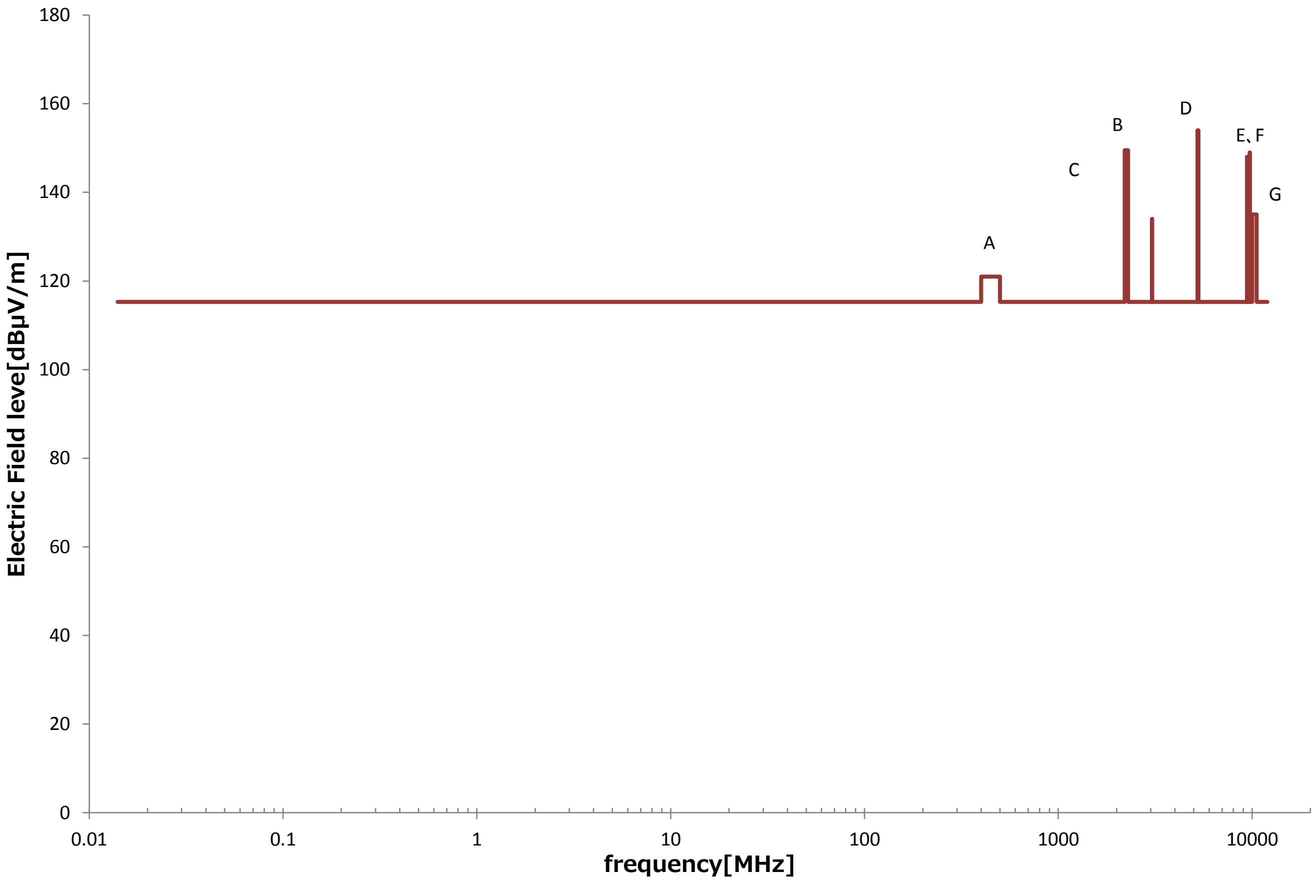
The further information on the umbilical line shields is described in Appendix-D.

4.4.7. Electromagnetic Environment

4.4.7.1. Electromagnetic Environment From LV

The levels of electrical-field (E-Field) at PL separation plane generated by emissions from on-board RF equipment and USC facilities are shown in Figure 4.4.7-1.

Radio properties of launch facilities in and around USC are shown in Table 4.4.7-1.



Frequency (MHz)	Electrical Field Level (dBμV/m)	Reference Character
400 - 500	121	A
2200 - 2290	150	B
3050	134	C
5230 - 5790	154	D
9410	148	E
9730 - 9740	149	F
10000 - 10550	135	G

*1 Electrical field level at other frequencies (14 kHz – 10 GHz) is 116 dBμV/m.

*2 For micro satellite in multi launch, electrical field may exceed these electric field levels at frequencies more than 10 MHz for a very short time (less than 0.5 sec. during separation).

Figure 4.4.7-1 Levels of Electrical-Field Generated by LV and Facilities

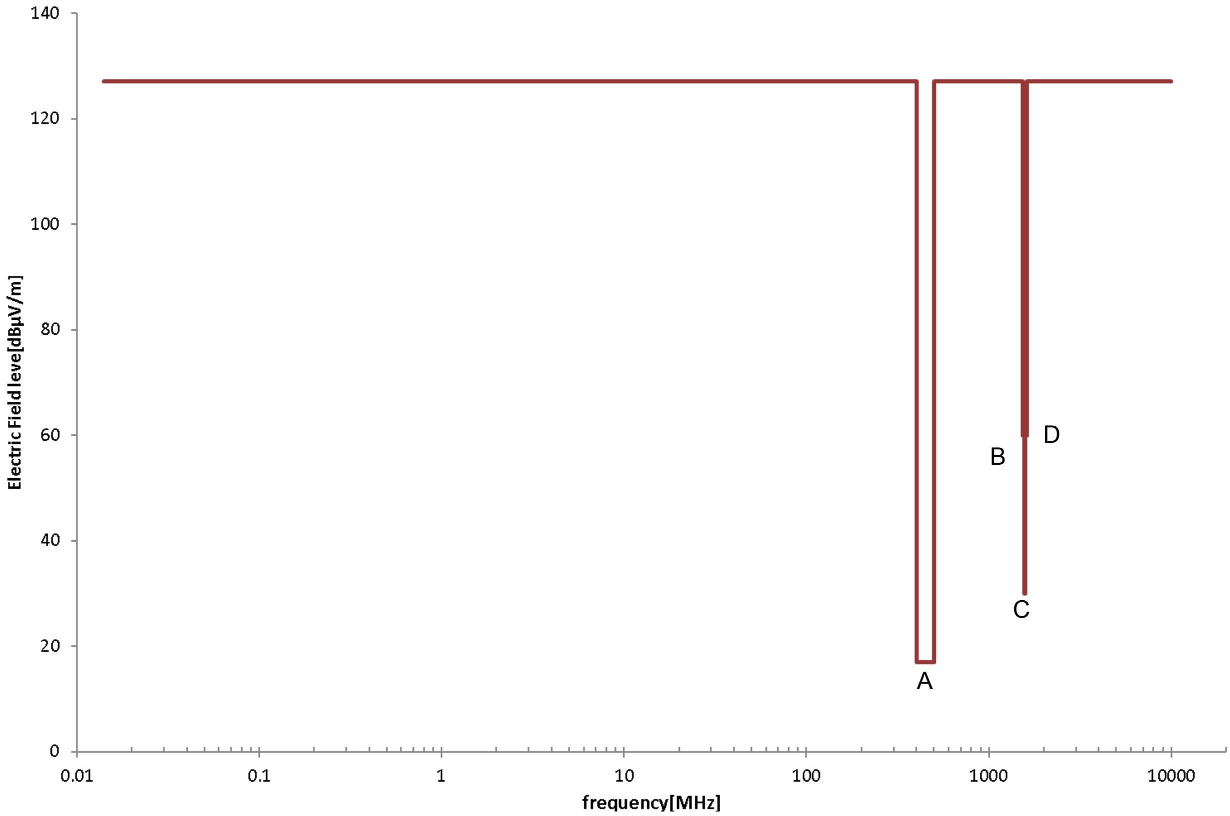
Table 4.4.7-1 Radio properties of launch facilities in and around USC

Facility	1	2	3	4	5
Transmit Frequency	10000-10250 [MHz] 10500-10550 [MHz]	9740 [MHz]	9730 [MHz]	9410 [MHz]	3050 [MHz]
Transmit Power	55.1 [dBm]	50 [kW]	25 [kW]	25 [kW]	30 [kW]

4.4.7.2. PL RF Emissions

PL shall not emit E-Field beyond the levels at PL separation plane given in Figure 4.4.7-2.

Micro satellites and CubeSats, which are in principle released in cold launch method, shall not emit any E-Field.



Frequency (MHz)	Electrical Field Level (dBμV/m)	Reference Character
400～500	17	A
1530～1565	60	B
1565～1585	30	C
1585～1620	60	D

*Electrical field level at other frequencies (14 kHz – 10 GHz) is 127 dBμV/m.

Figure 4.4.7-2 Maximum Electrical-Field Levels Acceptable to LV at PL separation plane

4.4.8. Communication Link to PL

Specifications of radio frequencies for communication link with PL are determined after a specific mission is assigned.

(1) RF telemetry and command link

RF telemetry and command links are provided between PL and its EGSE. The links are available during a period from PL operation on ground through just before liftoff.

The links are not available to Micro satellites and CubeSats in multi launch.

4.5. PL Environment

4.5.1. Mechanical Environment

4.5.1.1. Steady State Acceleration

Steady state acceleration is shown in Table 4.5.1-1.

These figures show the upper limit of the acceleration during the entire duration from the start of PL launch operation on ground through the end of PL separation.

Table 4.5.1-1 Steady State Acceleration (At PL C.G., except for PL on ground)

		Longitudinal	Lateral	note
On Ground		-9.8±19.6 [m/s^2]	±9.8 [m/s^2]	- Acceleration applied to a point where PL is hanged by a standard crane of USC. - Acceleration applied to the PL/LV connecting point by LV operations after PL is mated with LV.
In Flight	1st Stage	22.4±11.2 [m/s^2]	24.5 [m/s^2]	- Acceleration applied by response to a gust at maximum dynamic pressure during 1st stage flight. - Sign-equivalent vibration is also added to in 1st stage flight
	2nd Stage	60 [m/s^2] (Basic Configuration) 55 [m/s^2] (Optional Configuration)	9.8 [m/s^2]	- Acceleration applied by motor thrust during 2nd stage flight.
	3rd Stage	98 [m/s^2] (Basic Configuration) 66 [m/s^2] (Optional Configuration)	9.8 [m/s^2] Spin Rate (on the roll axis): to 360 [deg/s]	- Acceleration applied by motor thrust during 3rd stage flight.
	Spin up Phase	-	Spin Rate (on the roll axis): to 360 [deg/s] Spin Rate Acceleration (on the roll axis): to 90 [deg/s^2]	- Acceleration applied by spin up to stabilize 3rd stage spin before 2nd/3rd stage separation. - Direction of rotation is clockwise on the roll axis of LV coordinate system (Xb)

4.5.1.2. Sine-Equivalent Vibration

Sine-equivalent vibration is shown in Table 4.5.1-2.

Table 4.5.1-2 Sine-Equivalent Vibration*1

	Longitudinal		Lateral	
	Frequency [Hz]	**Amplitude $[(m/s^2)_{0\text{-}p}]$ at PL separation plane**	**Frequency [Hz]**	**Amplitude $[(m/s^2)_{0\text{-}p}]$ at PL C.G.**
Single Launch	43 - 53	8.0 (Basic Configuration) 4.9 (Optional Configuration)	20 - 100	3.0
	53 - 57	4.9		
	Sweep Rate: 0.2 [oct/min]		Sweep Rate: 4 [oct/min]	
	All axes			
	Frequency [Hz]	**Amplitude $[(m/s^2)_{0\text{-}p}]$ at PL separation plane**		
Multi launch	43 - 53	9.8		
	53 - 57	4.9		
	Sweep Rate: 0.2 [oct/min]			

*1 AT level

4.5.1.3. Random Vibration Environment

Random vibration environment is shown in Table 4.5.1-3.

Table 4.5.1-3 Random Vibration Environment

PL (single launch) Small satellite (multi launch)	N/A: Random vibration environment of Small Satellite is covered by the section below, 4.5.1.4. Acoustic Vibration Environment.
Micro satellite (multi launch)	Figure 4.5.1-1, Table 4.5.1-4 All values are at the upper plane of Lightband® upper ring.
CubeSat (multi launch)	Figure 4.5.1-2, Table 4.5.1-5 All values are at installation plane on E-SSOD.

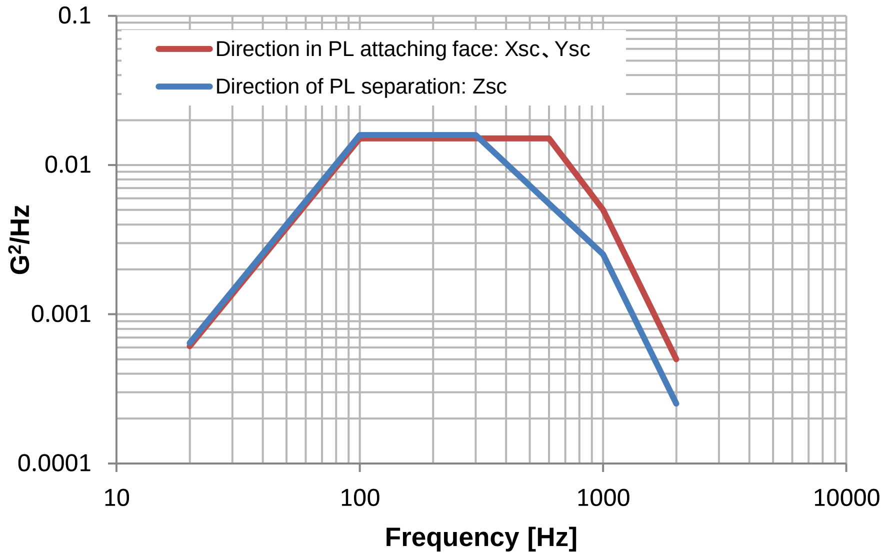
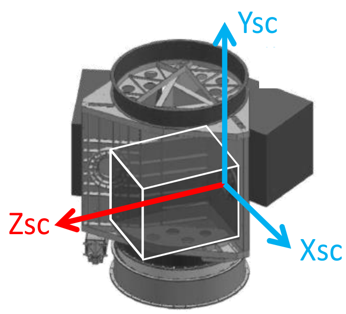


Figure 4.5.1-1 Randam Vibration Environment of Micro Satellite

Table 4.5.1-4 Randam Vibration Environment of Micro Satellite

Xsc, Ysc	20 -	100 [Hz] :	6 [dB/oct]		
	100 -	600 [Hz] :	1.45 $[(m/s^2)^2/Hz]$	$(0.0151\ [G^2/Hz])$	
	600 -	1000 [Hz] :	-6.5 [dB/oct]		
		1000 [Hz] :	0.481 $[(m/s^2)^2/Hz]$	$(0.005\ [G^2/Hz])$	
	1000 -	2000 [Hz] :	-10 [dB/oct]		
	30 sec	O.A. :	35.3 $[(m/s^2)rms]$	(3.6 [Grms])	
Zsc	20 -	100 [Hz] :	6 [dB/oct]		
	100 -	300 [Hz] :	1.53 $[(m/s^2)^2/Hz]$	$(0.0159\ [G^2/Hz])$	
	300 -	1000 [Hz] :	-4.6 [dB/oct]		
		1000 [Hz] :	0.242 $[(m/s^2)^2/Hz]$	$(0.00252\ [G^2/Hz])$	
	1000 -	2000 [Hz] :	-10 [dB/oct]		
	30 sec	O.A. :	29.4 $[(m/s^2)rms]$	(3.0 [Grms])	

*1 AT level



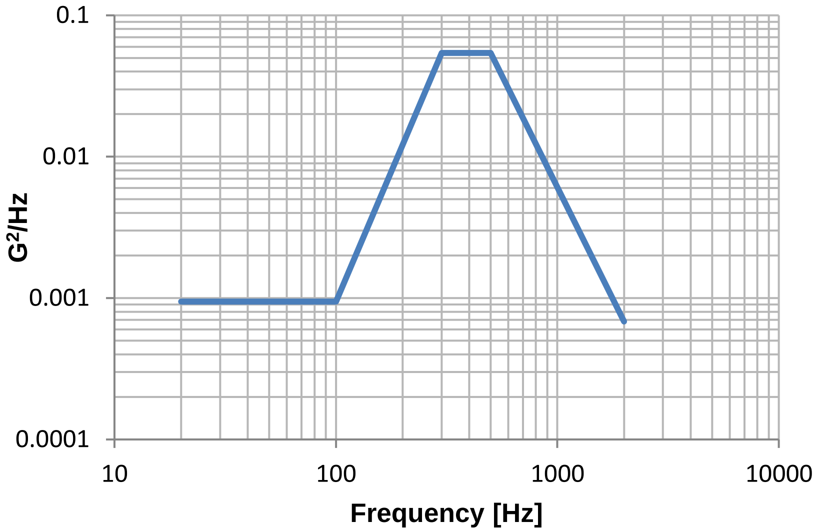


Figure 4.5.1-2 Random Vibration Environment of CubeSat

Table 4.5.1-5 Random Vibration Environment of CubeSat

All axes	20 -	100 [Hz]:	0.0908 [$(m/s^2)^2$/Hz]	(0.000944 [G^2/Hz])
	100 -	300 [Hz]:	11.1 [dB/oct]	
	300 -	500 [Hz]:	5.21 [$(m/s^2)^2$/Hz]	(0.0542 [G^2/Hz])
	500 -	2000 [Hz]:	-9.5 [dB/oct]	
	30 sec	O.A. :	50.0 [(m/s^2) rms]	(5.1 [Grms])

*1 AT level

4.5.1.4. Acoustic Vibration Environment

Acoustic vibration environment is shown in Table 4.5.1-6. This environment is not applicable to Micro satellites and CubeSats.

This environment covers the acoustic vibrations induced by 1st stage motor during liftoff and by pressure fluctuations during flight in the atmosphere.

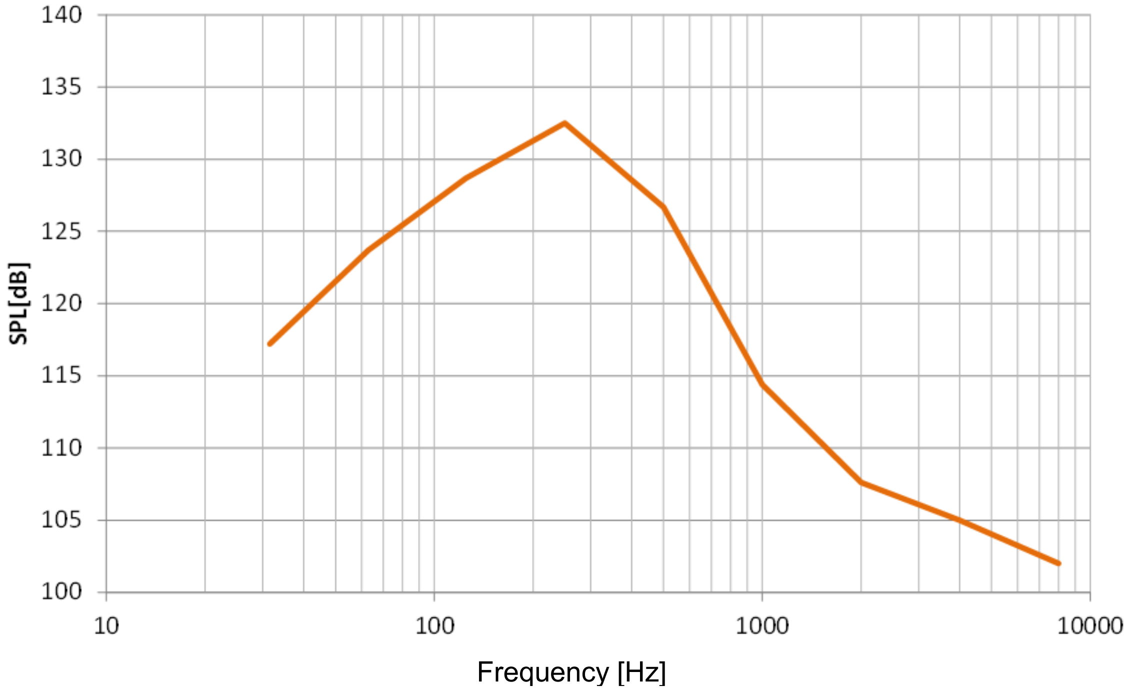


Figure 4.5.1-3 Acoustic Vibration Environment

Table 4.5.1-6 Acoustic Vibration Environment

Frequency [Hz]	SPL [dB]
31.5	117.2
63.0	123.7
125	128.7
250	132.5
500	126.7
1000	114.4
2000	107.6
4000	105.0
8000	102.0
O.A. 135.0dB	30 [seconds]

*1 : AT level

*2 : 0 dB = 2 x 10^{-5} Pa

4.5.1.5. Shock Environment

Shock environment is defined for each PL because it depends on PL mass characteristics and annular stiffness of PL back frame.

For reference, a standard shock environment is shown in Table 4.5.1-7. All the values are based on the time of PL separation and applied to both in axial and radial directions. Shock levels are shock response spectra (SRS) with a Q factor of 10.

Table 4.5.1-7 Standard Shock Environment

PL mass	Frequency	Shock Level (AT)	note
170 - 1200 [kg]	50 - 1000 [Hz]	10 [dB/oct]	Figure 4.5.1-4
	1000 - 4000 [Hz]	9810 [m/s^2](1000 [G])	
40 - 65 [kg] (Micro Satellite)	100 - 1000 [Hz]	7.8 [dB/oct]	Figure 4.5.1-5 (at Lightband® upper ring)
	1000 - 4000 [Hz]	4952 [m/s^2] (505 [G])	
CubeSat	100 - 1000 [Hz]	8.28 [dB/oct]	Figure 4.5.1-6 (at installation plane on E-SSOD)
	1000 - 4000 [Hz]	4067 [m/s^2] (415 [G])	

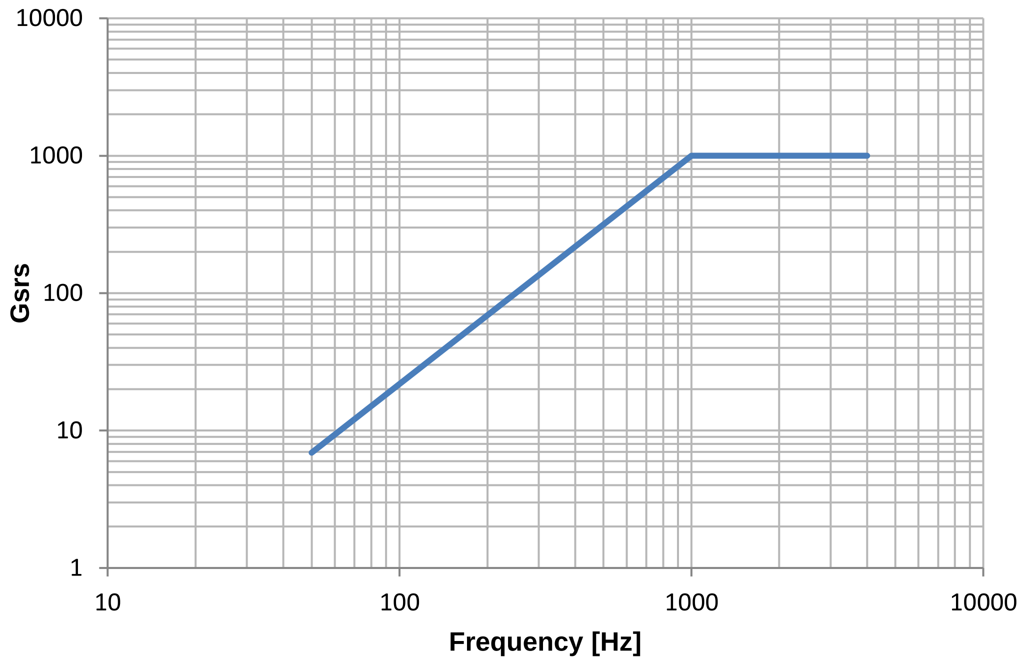


Figure 4.5.1-4 Standard Shock Environment of 170-1200 kg PL

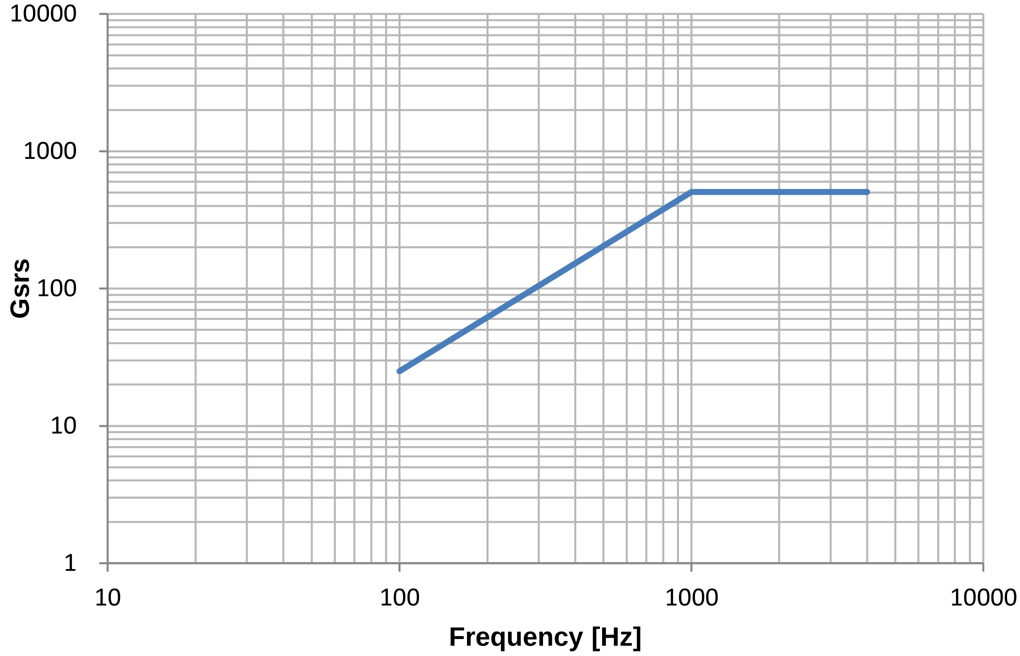


Figure 4.5.1-5 Standard Shock Environment of 40-60 kg PL

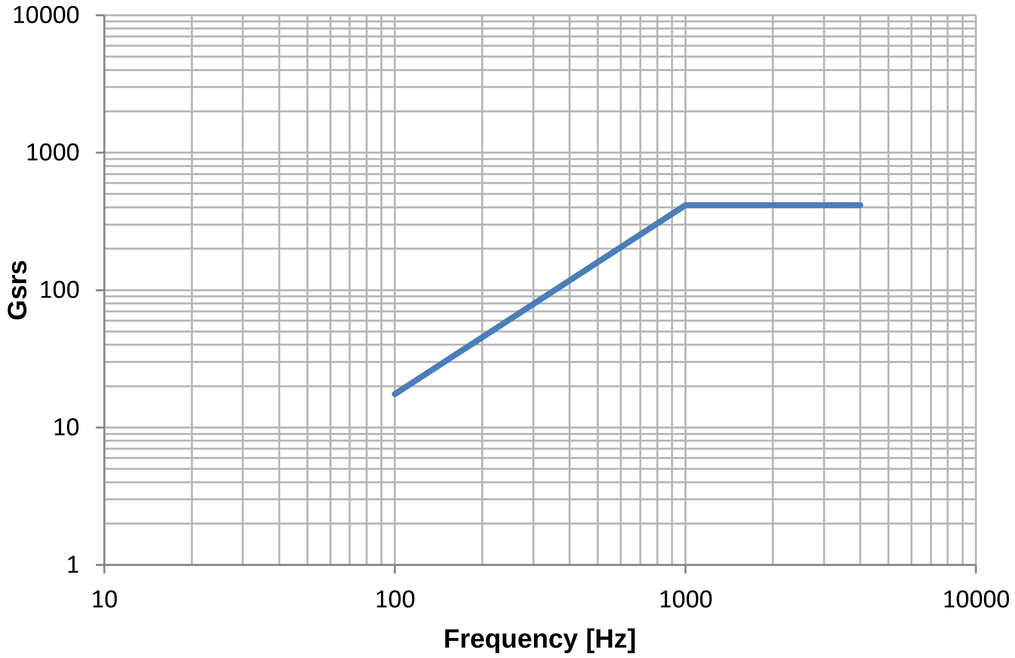


Figure 4.5.1-6 Standard Shock Environment of CubeSat

4.5.1.6. Static Pressure inside PLF

The depressurization rate inside PLF during flight does not exceed 5.0 [kPa/s.]

A typical pressure profile inside PLF is shown in Figure 4.5.1-7. A typical depressurization rate profile inside PLF is shown in Figure 4.5.1-8

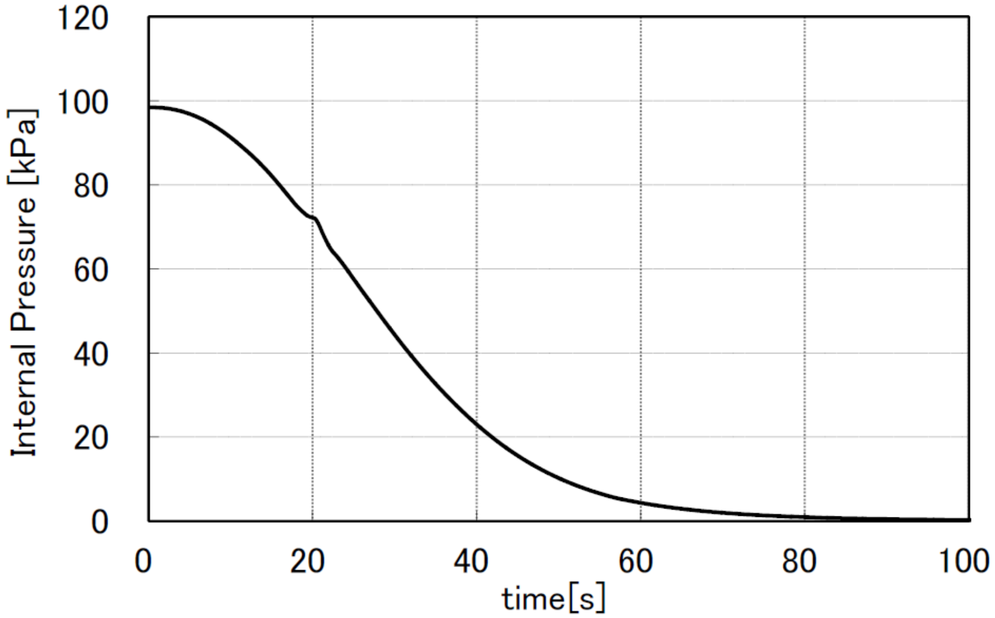


Figure 4.5.1-7 Typical Pressure Profile inside PLF

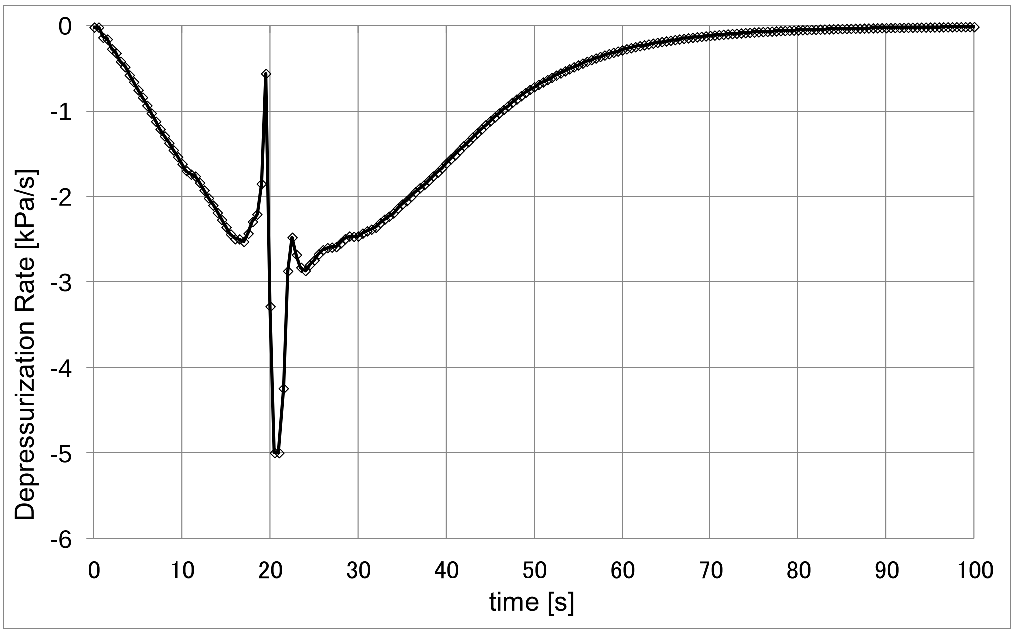


Figure 4.5.1-8 Typical Depressurization Rate Profile inside PLF

4.5.2. Temperature and Humidity Environment

4.5.2.1. Temperature and Humidity Environment on Ground

Temperature and humidity environment on ground for PLs is defined in each ICD based on PL thermal characteristics and launch season.

For reference, temperature and humidity environment on ground is shown in Table 4.5.2-1

Configuration of the air-conditioning system on the launch pad is shown in Figure 4.5.2-1.

Table 4.5.2-1 Temperature and Humidity Environment on Ground of Standard PL

Location		M Assembly Building: Clean room	M Assembly Building: In Container	M Assembly Building: Clean Booth	M Assembly Building: In PLF	M Assembly Tower				On Launch Pad
Task		PL Assembly	Transfer to Clean Booth	Assembly with LV Upper Stage	Transfer into M Assembly Tower	LV Upper Stage VOS	LV Assembly: without umbilical AC	LV Assembly: with umbilical AC	Launch pad roll out	Launch
Condition	Air Conditioner (AC)	Building AC	N/A	Building AC	Umbilical AC	N/A	Building AC	Umbilical AC		
	Fluid	Air	not controlled	Air	Air	not controlled	Air	Air		
	Flow rate [Sm3/min]	N/A		N/A	28		N/A	20-28		
	Temperature [℃]	21-25		20-25	8-27 *1		15-25	8-27 *1		
	Humidity [%]	40-50		40-50	40-50		50-60	40-50		40-50 *2
	Cleanliness Class	100,000		100,000	5000		100,000	5000		

*1 Temperature control accuracy is ±2℃.

*2 Air conditioning without humidification is available at Customer's request.

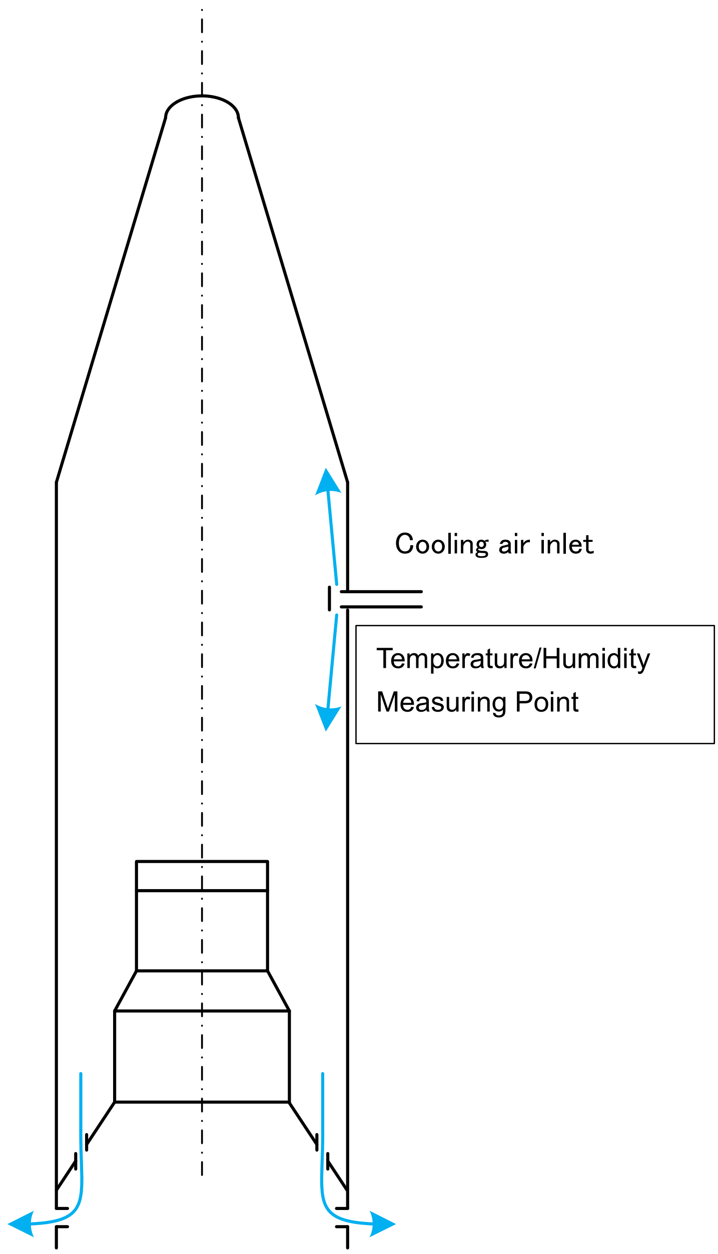


Figure 4.5.2-1 Configuration of the air-conditioning system on the launch pad (and in M Assembly Building as option)

4.5.2.2. Thermal Environment in Flight

Thermal environment in each phase during flight depends on heat factors as Table 4.5.2-2. CubeSats are not affected by these heat factors because they are inside E-SSODs.

Table 4.5.2-2 Heat Factor for PL

✔:exist、—:not exist

Flight Phase	heat factor	detail	PL (Single Launch)	Multi Launch		
				Small satellite	Micro satellite	Cube Sat
Lift off - Fairing separation	Radiation from PLF inner surface	4.5.2.2.1	✔	✔	✔	—
Fairing separation - PL separation	Aerothermal heat flux	4.5.2.2.2 (1)	✔	✔	✔	—
	Sunlight radiation	4.5.2.2.2 (2)	✔	✔	✔	—
	Earth infrared radiation		✔	✔	✔	—
	Earth albedo radiation		✔	✔	✔	—
3rd stage motor ignition - PL separation	Radiation by 3rd motor plume	4.5.2.2.2 (3)	✔	✔	✔	—
Lift off - PL separation	Heat conduction with Lightband®	Lightband® temperature tolerance: between -24 and +56℃	—	—	✔	—

4.5.2.2.1. Before PLF Jettison

The thermal flux density radiated by PLF is less than 1,000 [W/m^2]

4.5.2.2.2. After PLF Jettisoning

(1) Aerothermal Heat Flux

Aerothermal heat flux of free molecular flow is less than 1,135 [W/m^2].

For reference, the result of an aerothermal heat flux of free molecular flow in a nominal flight course of a standard SSO mission is shown in Figure 4.5.2-3.

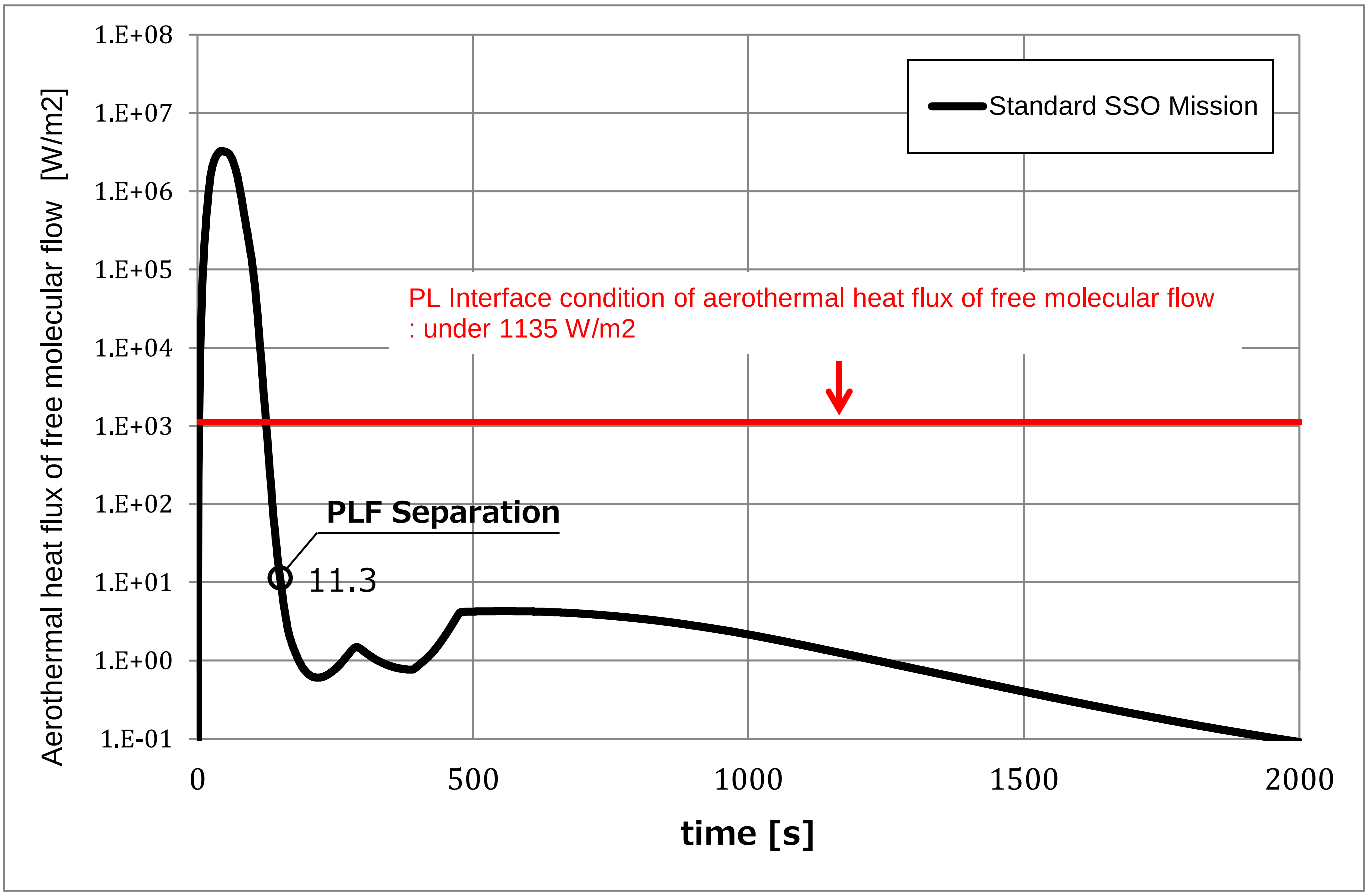


Figure 4.5.2-3 Result of Aerothermal Heat Flux of Free Molecular Flow in Nominal Flight Course of Standard SSO Mission

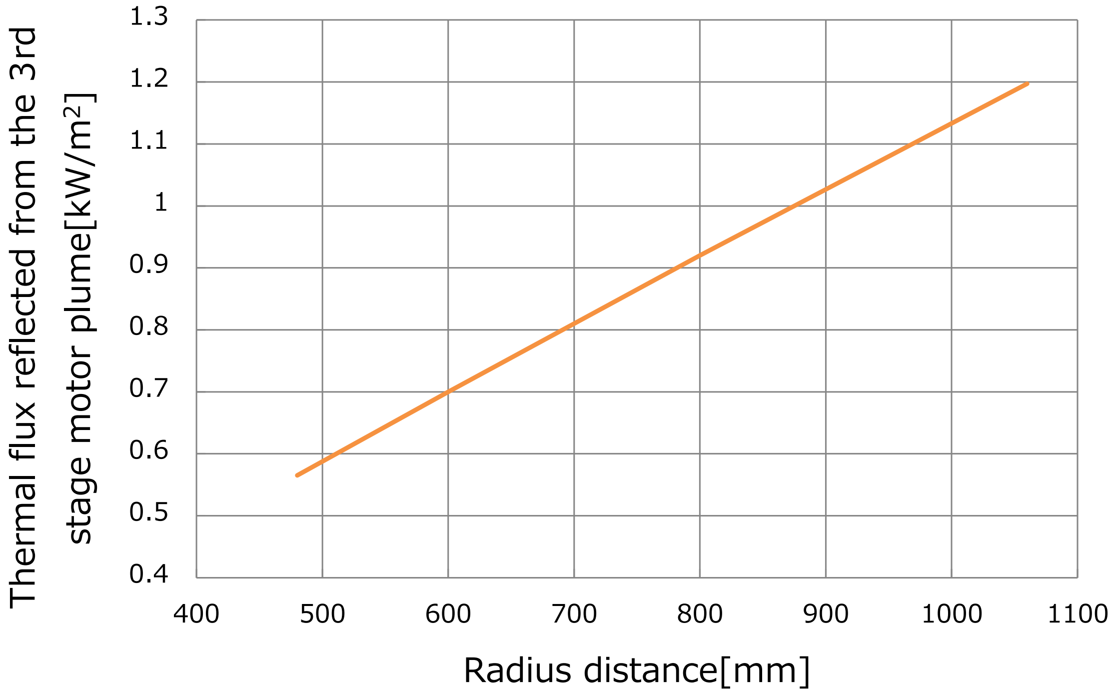
(2) Radiation by Sunlight, Earth Infrared Radiation and Earth Albedo

Sunlight direction profile will be presented if needed after Mission Analysis.

(3) Thermal Flux from the Motor Plume

Thermal flux coming from 1st, 2nd, and PBS stages is negligibly small. Thermal impingement on PL external surface caused by 3rd stage is shown in Figure 4.5.2-4.

Heat area of Micro satellite in multi launch is shown in Figure 4.5.2-5.



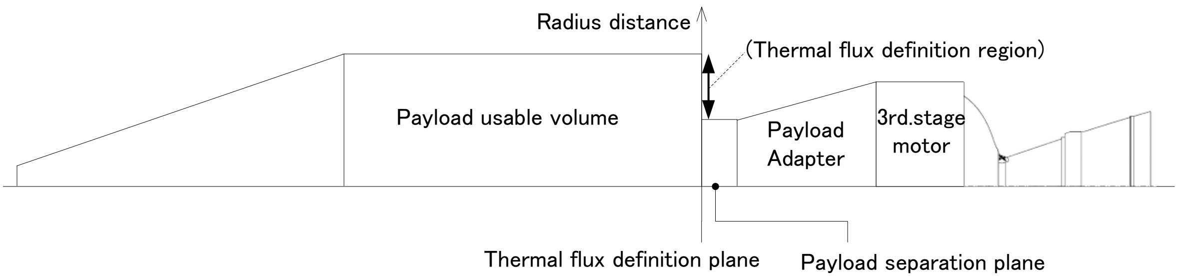


Figure 4.5.2-4 (1/2) Thermal Flux from 3rd Motor Plume

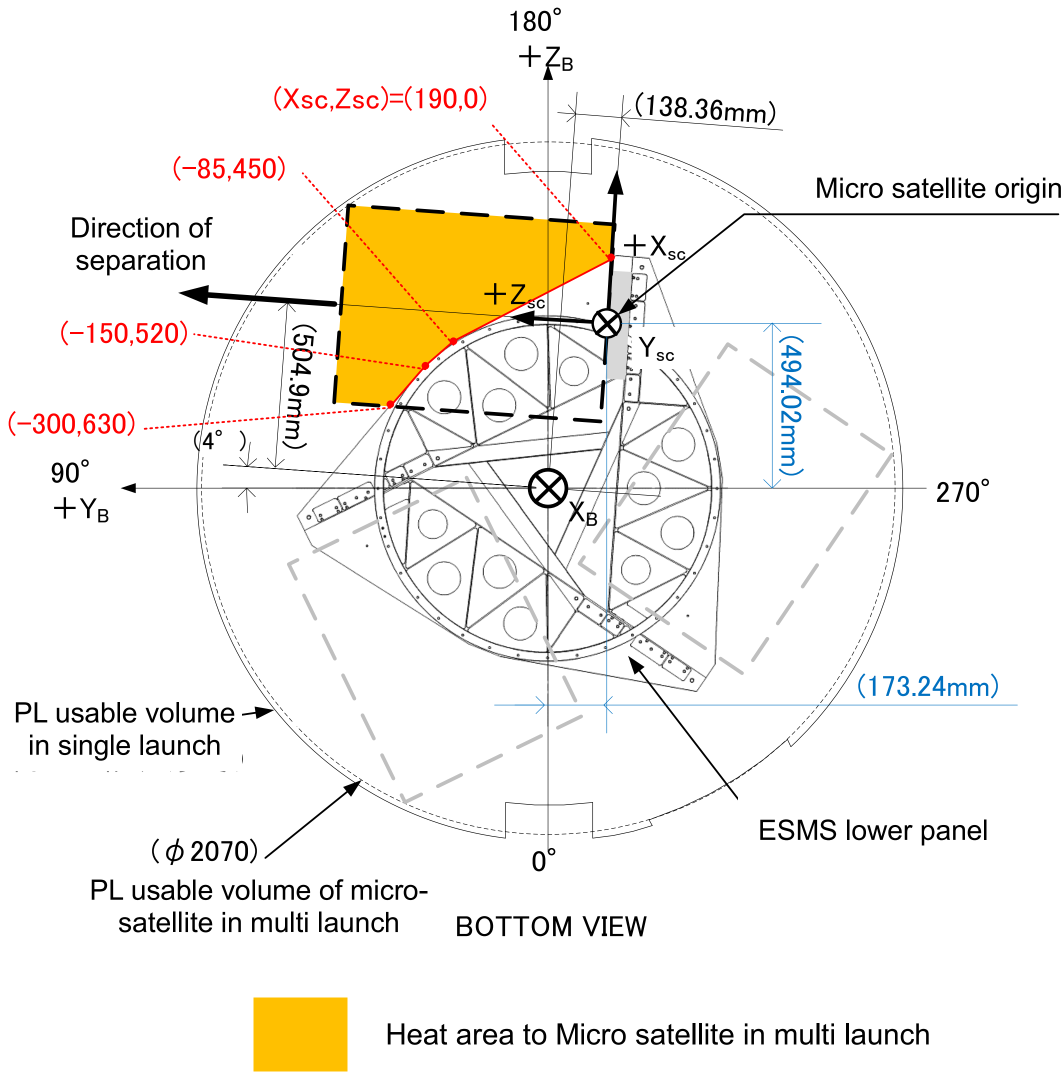


Figure 4.5.2-5 Thermal Flux from 3rd Motor Plume

4.5.3. Cleanliness Environment

4.5.3.1. Cleanliness

Cleanliness Environment is shown in Table 4.5.3-1.

Table 4.5.3-1 Cleanliness Environment

Task	Location	Cleanliness class
PL Assembly	Clean Room	100,000
Transfer to Clean Booth	(In transfer container)	not controlled
Assembly with LV upper stages	Clean Booth	100,000
Transfer into M Assembly Tower	(Encapsulated) in PLF	5,000*1
until Lift off	(Encapsulated) in PLF	5,000*1

*1: Property of conditioning air at PLF inlet

4.5.3.2. Contamination

The maximum organic contamination on PL surface is kept below the following values:

From being carried in M Assembly Building to encapsulation : 2 [mg/m^2 per week]
From encapsulation through separation : 4 [mg/m^2]
After 3rd stage separation : To be defined in each ICD. CubeSats are not affected by contamination because they are in each E-SSOD.

4.6. PL Compatibility Verification Requirements

4.6.1. Verification Logic

PL structure and its on-board equipment shall have the capability of withstanding expected maximum LV ground and flight environments. PL compatibility shall be verified through tests as shown in Table 4.6-1.

Table 4.6-1 PL Verification Logic

PL Development approach	Static	Sine-equivalent dynamics	Random vibration	Acoustic	Shock
Structure Test Model	Qualification Test (QT)	QT	Covered by acoustic test	QT	Shock Test and Analysis
Protoflight Model (PFM)	QT or by heritage*1	PFM Test*2		PFM Test*2	Shock Test and Analysis or by heritage*1
Flight Model (FM)	by heritage*1	AT		AT	by heritage*1

*1: If qualification is claimed by heritage, the representativeness of the structure test model with respect of the actual flight must be demonstrated.
*2: PFM approach means QT levels with AT duration / sweep rate.

4.6.1.1. Dummy Case for Vibration Tests of CubeSats

A dummy case is available for vibration tests of CubeSats.
Details are shown in Appendix-C.

4.6.2. Safety Factor

PL qualification and acceptance test levels are determined based on safety factors given in Table 4.6-2. PL shall have enough margins for these safety factors.

Table 4.6-2 Test Factors and Duration

PL Tests	Qualification		Protoflight		Acceptance	
	Safety factors	Duration	Safety factors	Duration	Safety factors	Duration
Static	1.25×Limit	×2	1.25×Limit	×1	1.0×Limit	×1
Sine-Equivalent Dynamics	1.25×Limit		1.25×Limit		1.0×Limit	
Random Vibration	Covered by acoustic					
Acoustic	Limit +3 [dB]	120 [s]	Limit +3 [dB]	30 [s]	Limit Level	30 [s]
Shock	Limit +3 [dB]	2 times	Limit +3 [dB]	1 time	Limit Level	1 time

5. Uchinoura Space Center

5.1. General Overview

5.1.1. Introduction

JAXA owns and operates two space launch sites in Kagoshima Prefecture, which encompasses the southernmost part of Kyushu Island and a chain of small islands stretching to the south. (See Figure 5.1.1-1).

(1) Tanegashima Space Center (TNSC) for Japan’s heavy lifters: H-IIA and H-IIB

(2) Uchinoura Space Center (USC) for Japan’s small lifters: Epsilon LV and sounding rockets SS-520 and others

USC is located in the southeast of Kyushu Island and its nearest airport, Kagoshima International Airport, is two-hour flight from Tokyo. The local time is GMT – 9 h.

USC is the historic place for Japanese space development, from which the first Japanese spacecraft Ohsumi was launched by a solid propellant L-4S Rocket in 1970. Since then, more than 400 solid propellant rockets, including sounding rockets, have been launched from USC.

USC has a clear launch azimuth from the East to the South and comprises the two major areas and facilities: (See Figure 5.1.2-1)

- Launch Complex (Nagatsubo Area)

  Launch Complex, used for pre-launch activities from PL preparation through PL/LV integration, consists of the following facilities:

  - M Assembly Building
  - M Assembly Tower
  - Launching Pad
  - M Control Center

- Mission Control Complex (Miyabaru Area)

  Mission Control Complex is located approximately 2.5 km southwest of Launch Complex. This complex is used mainly for controlling final launch preparation and liftoff and for tracking LV. It consists of the following facilities:

  - Epsilon Control Center
  - Epsilon Support Center

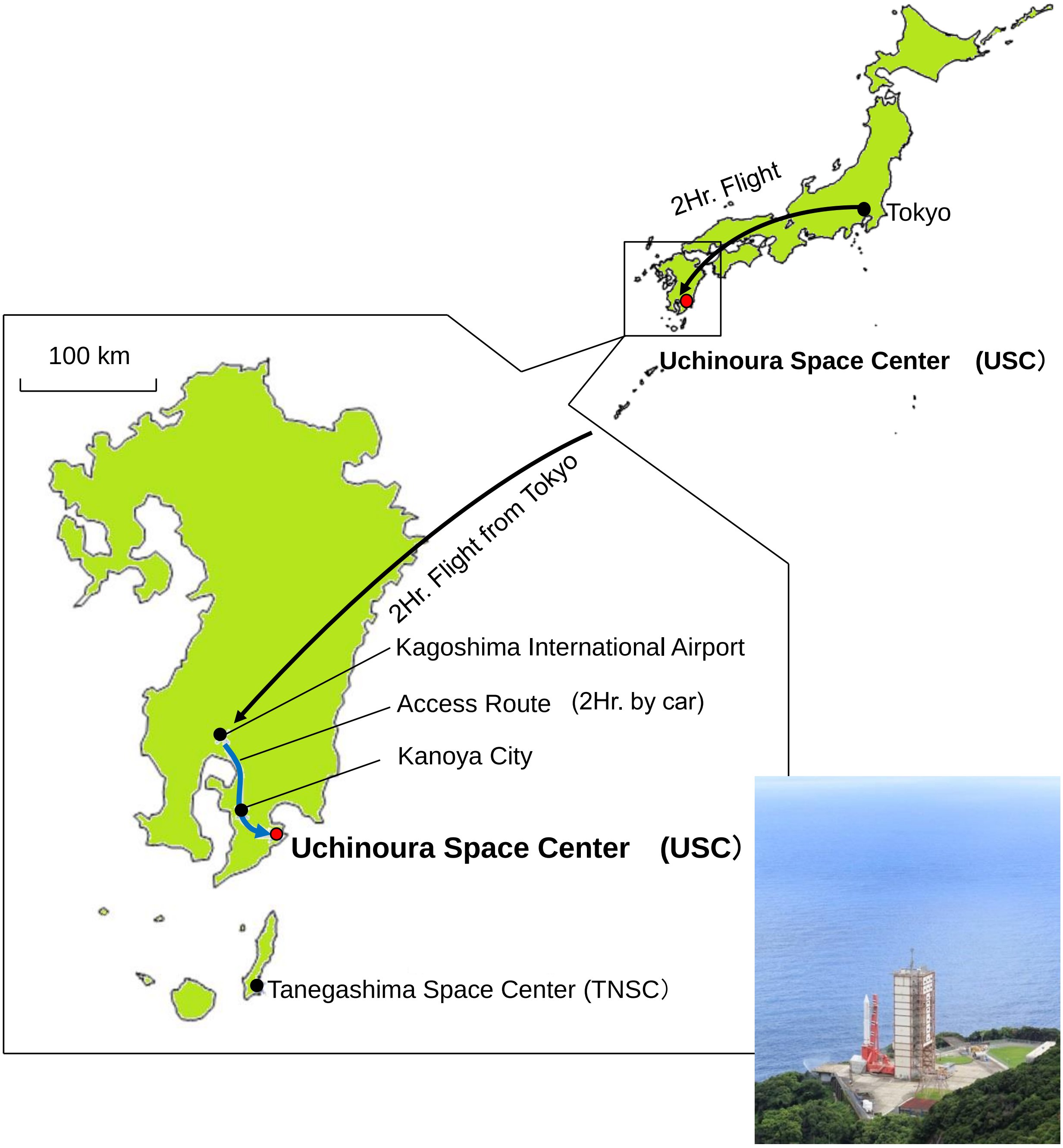


Figure 5.1.1-1 Location of USC and TNSC

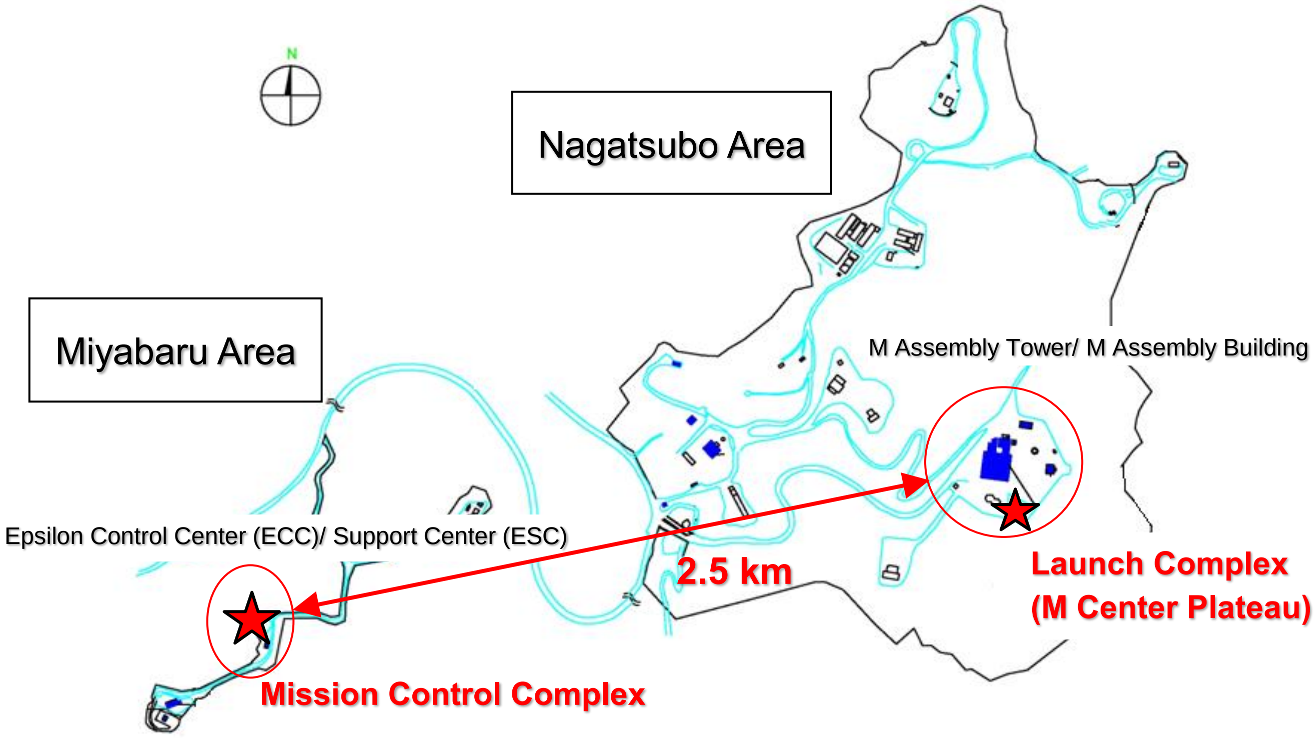


Figure 5.1.1-2 Outline of Uchinoura Space Center (USC)

5.1.2. PL Arrival

(1) Kagoshima International Airport (See Figure 5.1.2-1)

Kagoshima International Airport, the nearest airport to USC, has a 3,000 meter long runway. The airport is connected with USC by a main road (about 110 km long) appropriate for cargo transportation and launch campaign team travel. The customs office is open on a daily basis for cargo import clearance in a bonded area.

Figure 5.1.2-1 Kagoshima International Airport

(2) Shibushi Harbor (See Figure 5.1.2-2)

Shibushi Harbor is located on the coast of Shibushi-Wan Bay on the Ohsumi Peninsula. The distance form this harbor to USC is approximately 40 km on land. This harbor can be used for loading and unloading of heavy and bulky cargos transported by vessel.

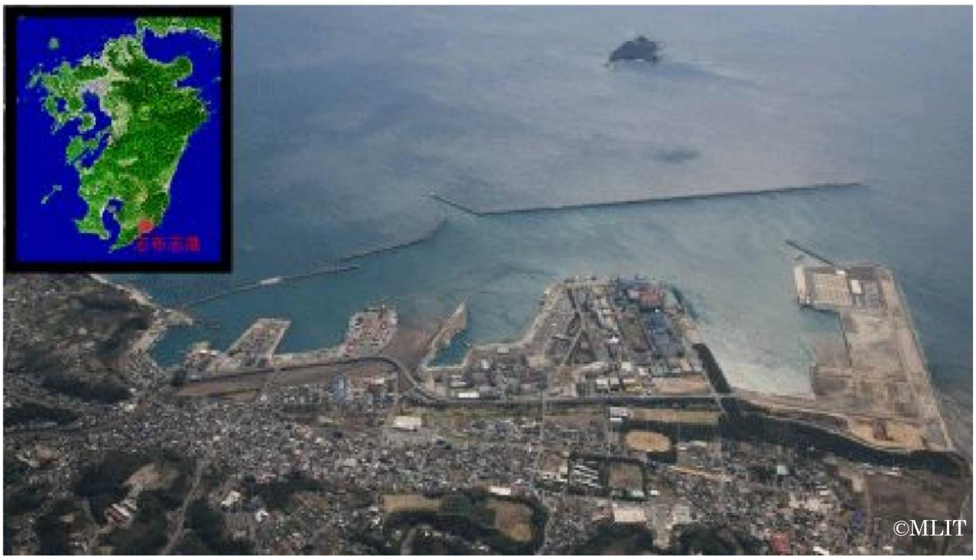


Figure 5.1.2-2 Shibushi Harbor

5.1.3. PL Preparation at USC

PL preparation at USC is mainly performed in Launch Complex (M Center Plateau). (Figure 5.1.3-1)
The complex includes M Assembly Building, M Control Center, M Assembly Tower, and Launching Pad.

M Assembly Building has a Clean Room available for non-hazardous operations for PL. It also has a Clean Booth for hazardous operations such as propellant loading, tank pressurization and pyro installation.
These hazardous operations are remotely monitored from M Control Center where Customer's EGSE for PL can be installed. (During launch time, all staff and operators have to evacuate M Control Center.)
Hazardous materials can be stored in Dangerous Goods Warehouse next to M Assembly Building.
Propellant can be temporarily stored in Clean Booth for temperature stabilization before fueling.

In Clean Booth of M Assembly Building, PL is mated with LV upper stage and encapsulated in PLF. After that, the encapsulated PL is transferred to M Assembly Tower by a dedicated car to be launched on Launching Pad.

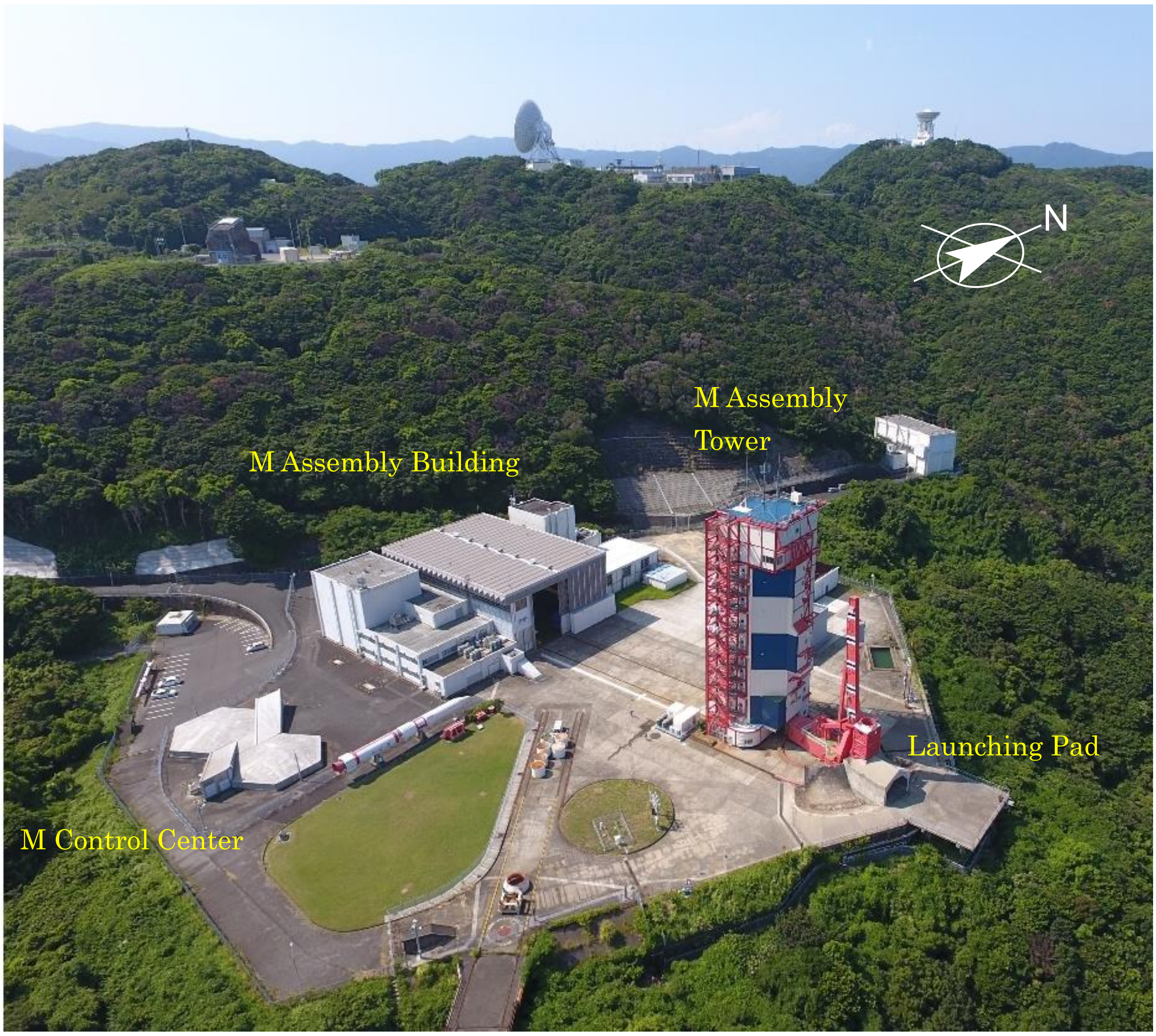


Figure 5.1.3-1 Launch Complex (M Center Plateau) Birds-Eye View

(1) M Assembly Building

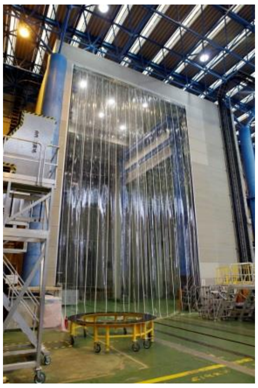
Figure 5.1.3-2 depicts the layout of M Assembly Building, which is composed of the following sections:

1) Assembly Room for LV integration preparation
2) Clean Room (179 m^2) dedicated to PL non-hazardous operations
3) Clean Booth (108 m^2) for PL hazardous operations, such as propellant loading and pyro-installation, and PL/LV mating operation
4) Check-out Room (next to Clean Room) for PL operations for check out

Forklifts are available for loading and unloading PL containers and others.
Equipment for the communication and network in Clean Room and Clean Booth is described in Appendix-D.

PL/LV mating operation is conducted in Clean Booth of M Assembly Building. After being fueled, PL is fixed with Payload Attach Fitting (PAF), then integrated onto LV's 3rd Stage and finally encapsulated inside PLF in vertical position. Encapsulated PL is transferred to M Assembly Tower for integration onto the lower part of LV.

CR



CB Front room

CB

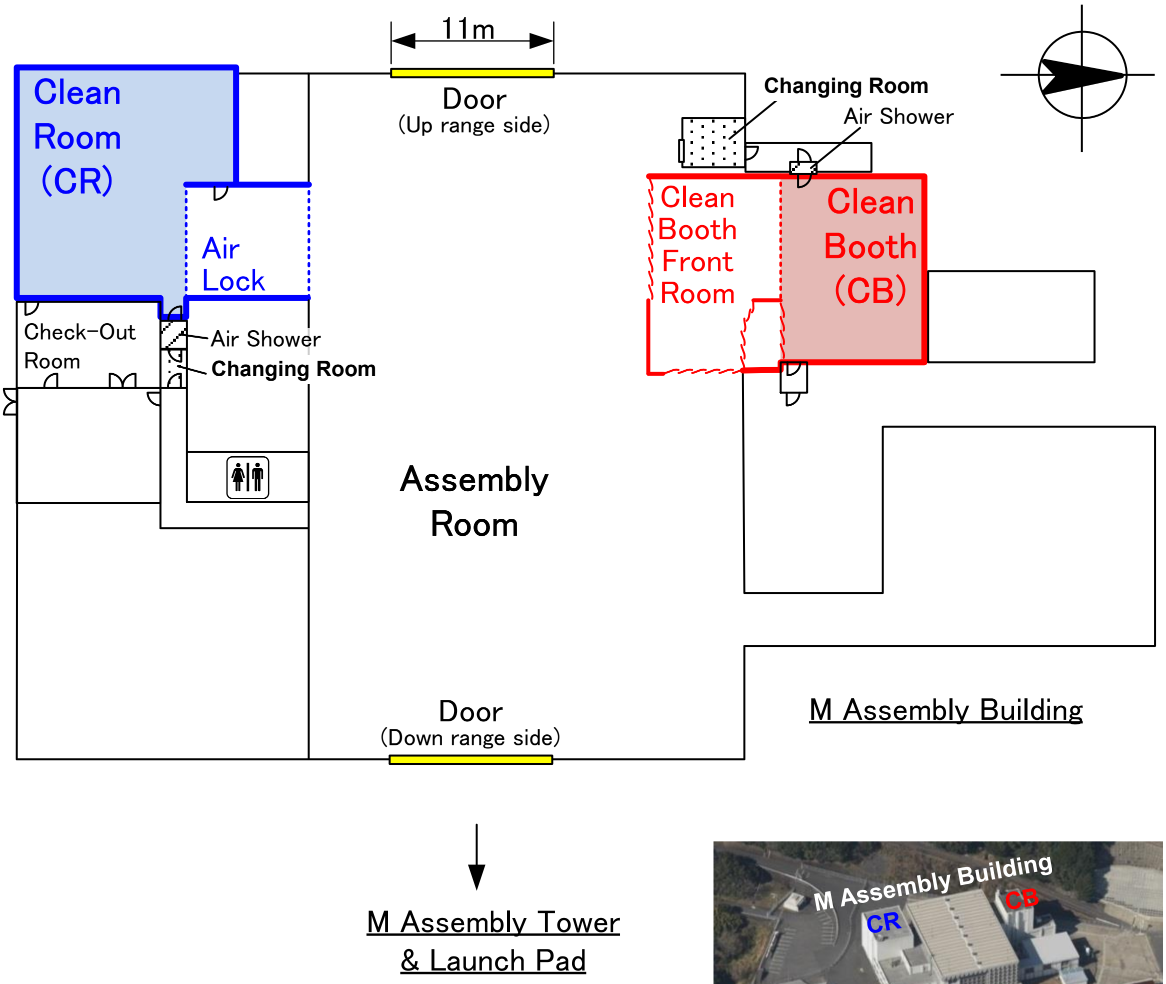


Figure 5.1.3-2 M Assembly Building Layout

(2) M Assembly Tower (See Figure 5.1.3-3)

M Assembly Tower is used for Epsilon LV integration and launch preparations. All stages, including PLF encapsulating PL, are hoisted and stacked on Launching Pad one by one using a travelling ceiling crane installed in M Assembly Tower. Then, facilities umbilical connector is connected, and composite electrical readiness test and launch preparations are performed. The environment in PLF is maintained by a ventilation duct connected between the mast and PLF. Access to PL is available on the 8th and 9th floors through optional access doors installed on PLF.

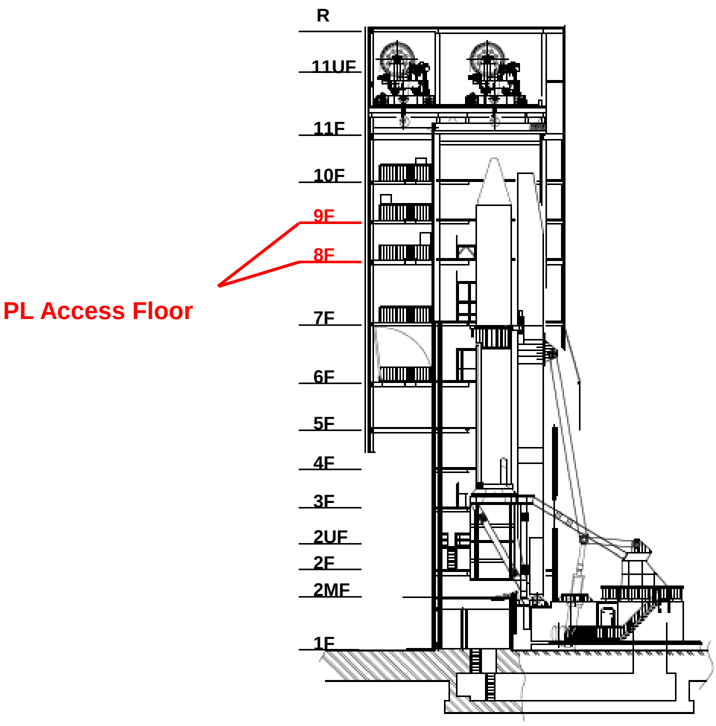


Figure 5.1.3-3 M Assembly Tower

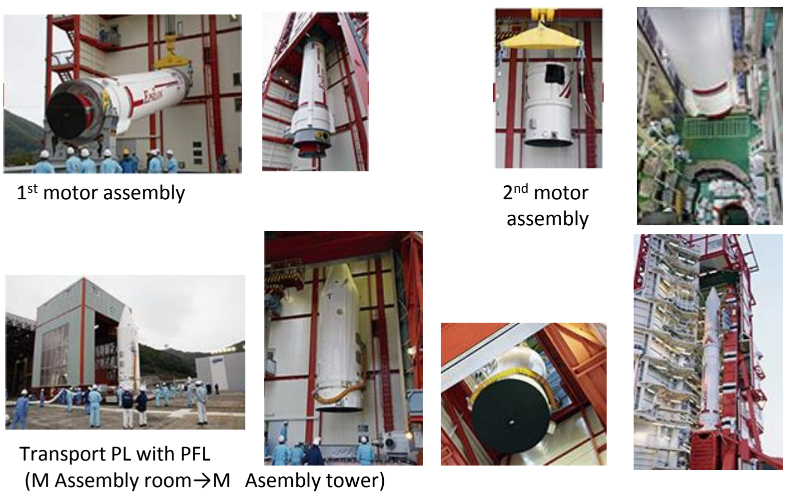


Figure 5.1.3-4 LV Assembly in M Assembly Tower

(3) Launching Pad (See Figure 5.1.3-5)

On a launch day, an Epsilon LV with PL on Launching Pad is rolled out from M Assembly Tower to its launching position for terminal count down. After the final check out followed by terminal count down, lift-off is initiated.

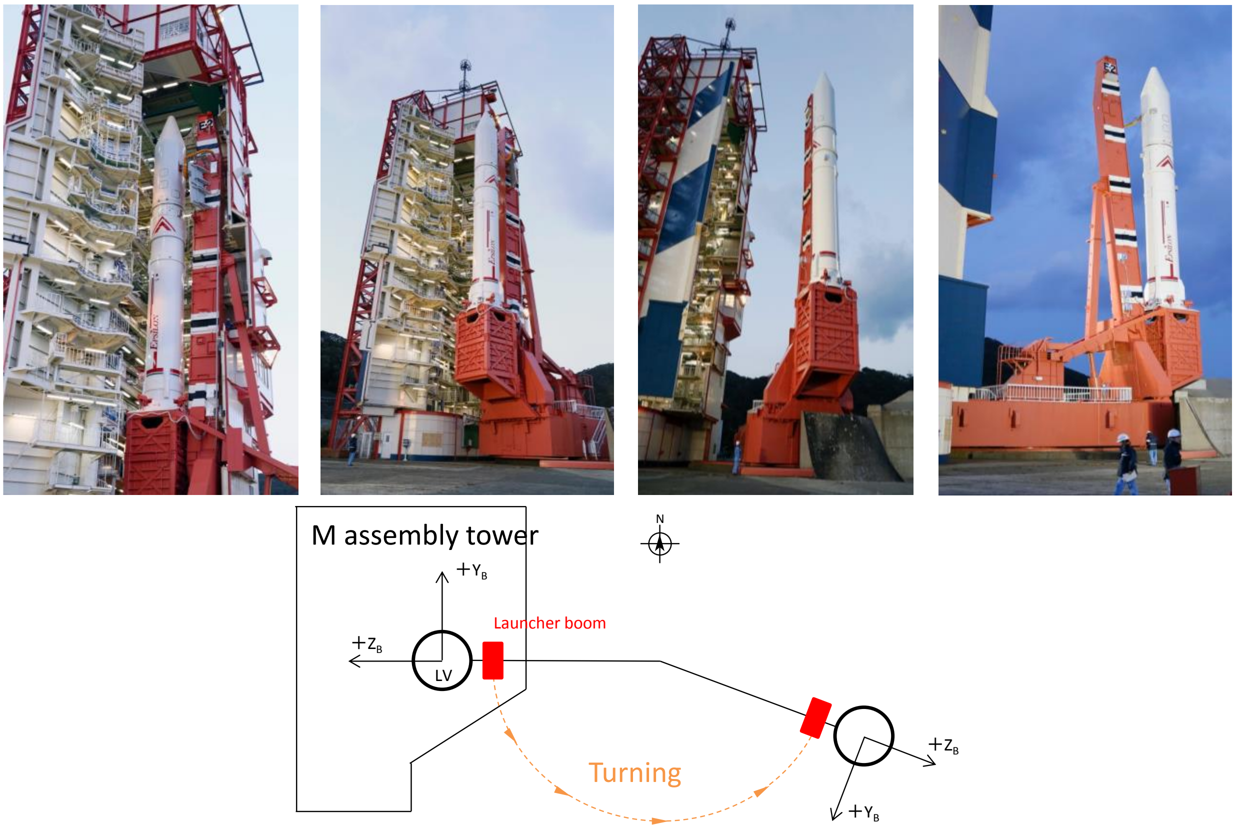


Figure 5.1.3-5 Epsilon LV on Launching Pad

(4) M Control Center

M Control Center, located near M Assembly Building and M Assembly Tower, is available for PL team during PL operations on ground, in addition to PL Control Room described in Chapter 5.1.4.

5.1.4. Facilities for Launch Operation

PL team shall stay in Epsilon Control Center and Epsilon Support Center of Mission Control Complex in Miyabaru Area, during launch preparation and countdown for PL remote operation.

(1) Epsilon Control Center (See Figure 5.1.4-1)

Epsilon Control Center is a two-story building used for administrative operation such as management and coordination of launch preparation and countdown by LV and PL teams.

The Epsilon Control Center is composed mainly of two rooms:

1) PL Control Room dedicated to PL team for PL remote operations, and
2) Launch Control Room (See Figure 5.1.4-2)

This Center is used for the following operations:

1) PL Check-out
2) LV and PL Battery Charging
3) Launch Countdown
4) LV Tracking

Figure 5.1.4-1 Epsilon Control Center

Figure 5.1.4-2 Launch Control Room

(2) Epsilon Support Center (See figure 5.1.4-3)

Epsilon Support Center has office rooms for both LV and PL teams. The building is connected with Epsilon Control Center by a roofed corridor on their 2nd floors. Four office rooms are available for PL team with desks, chairs, and working table, etc.

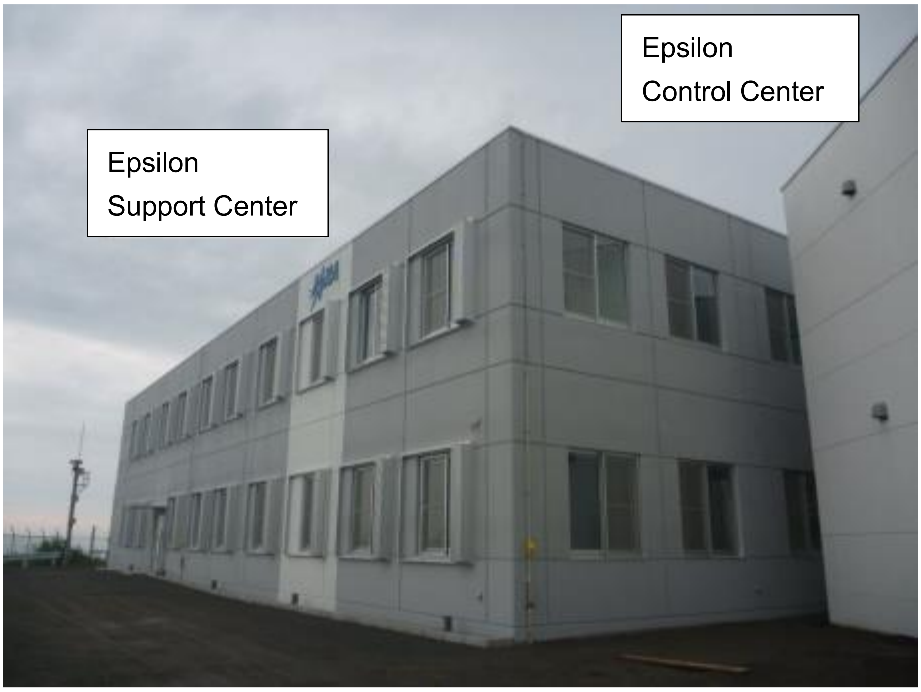


Figure 5.1.4-3 Epsilon Support Center

5.2. General Characteristics of Facilities

5.2.1. Climate Conditions

The average climate conditions at USC are as follows:

・The ambient air temperature varies between: -5[°C] ≤ T ≤ 35[°C]

・The relative humidity varies between: 30[%] ≤ r ≤ 100[%]

5.2.2. Power Supply

The USC's power facilities can supply non-intermittent electrical power of Japanese standard (100[V]/200[V] - 60[Hz]). If electrical power with other specifications is needed, contact your Program Director.

Uninterruptible power-supply system (UPS) is also available. If needed, contact your Program Director.

5.2.3. Communication and Data Network

5.2.3.1. Operational Data Network

Data links are provided between the Customer EGSE and PL during launch preparation. PL data can be also transmitted to the Epsilon Control Center during final countdown.

Telemetry / Telemetry command between Customer’s EGSE and PL are directly transmitted by the followings:

1) RF signals in S-band,
2) Wired link: transmission speed depends on protocols. (up to 64 [kbps] for RS-422)

Dedicated network is provided between PL Control Room and Customer Rooms.
If other data networks are needed, contact your Program Director.

5.2.3.2. Communication Network

The communication networks are available for Customer to communicate inside and outside USC facilities. The Operational Intercommunication System (OIS) is provided during a launch campaign for communications among operators. One channel is allocated for the exclusive use of PL team.

5.2.3.3. Telephone

Personal Handy-phone System (PHS) connecting the outside line are available in USC.

5.2.3.4. Internet

Internet ports are available in Customer’s office rooms of Epsilon Support Center.

5.2.3.5. Standard Time

Standard time signal can be provided as optional services. If needed, contact your Program Director.

5.2.4. Transportation and Handling

PL is transported in two ways as below:

(1) Covered in a dedicated PL Container between Clean Room and Clean Booth,

(2) Encapsulated inside PLF between M Assembly Building and M Assembly Tower.

PL Container's environment is equivalent to that of Clean Room. The Container in Figure 5.2.4-1 is available for Customer use.

Handling equipment including cranes and trolleys is available for Customer to transfer PL and its support equipment inside the facility. Specific handling equipment for PL shall be prepared by Customer. Table 5.2.4-1 shows the cranes' capabilities for PL team handling operations.

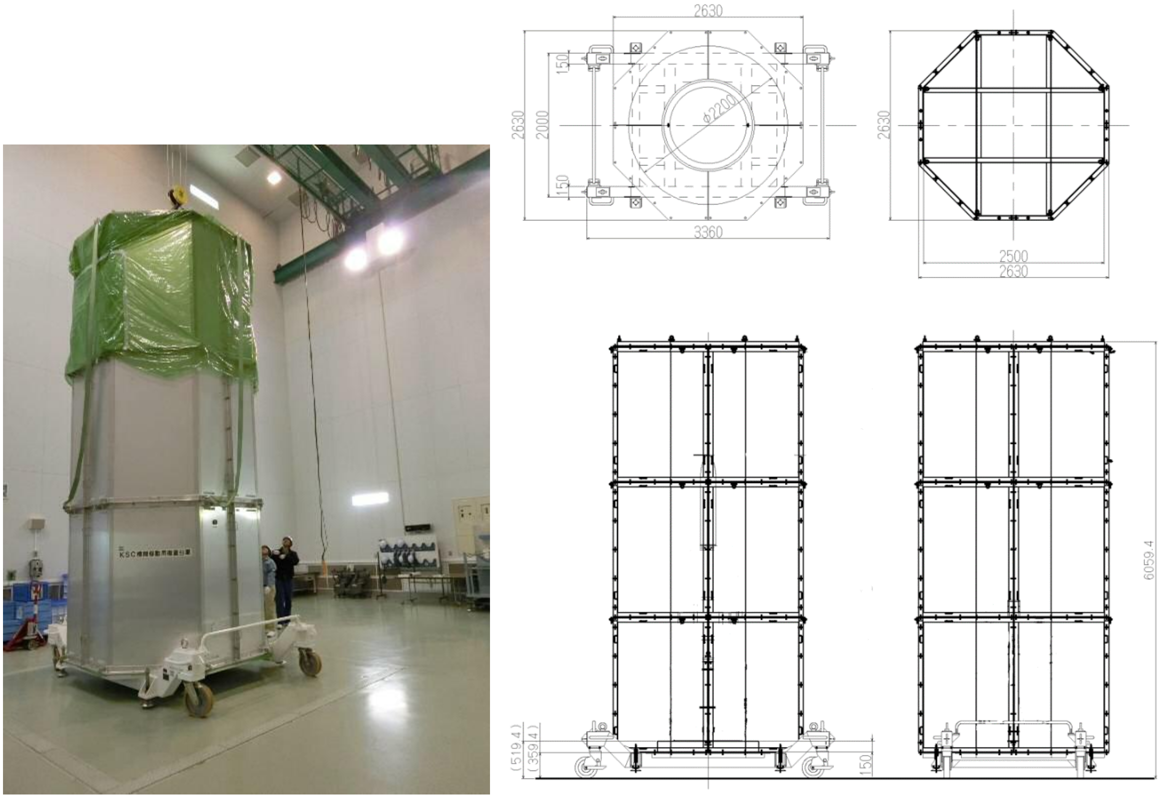


Figure 5.2.4-1 Payload Container between Clean Room and Clean Booth

Table 5.2.4-1 Crane Capability for PL Handling

Facility	Room	Capability	qt.
M Assembly Building	Clean Room	5 [ton]	1
	Clean Booth	2.5 [ton]	2
	Assembly Room	50 [ton]	1

5.2.5. Fluids and Gases

The following fluids and gases with industrial quality standards can be supplied as optional services based upon Customer’s requests.

1) Compressed gas for tools
2) Gaseous nitrogen (GN2)
3) Gaseous Helium (GHe)
4) Liquid Nitrogen (LN2)
5) Ethyl alcohol
6) Isopropyl alcohol (IPA)
7) Demineralized water

The specifications of each fluid and gas are to be determined based upon the specific mission assigned.

Compressed air for breathing and distilled water are available in Clean Booth of M Assembly Building and in M Assembly Tower for hazardous operations.

5.3. Operation Policy

5.3.1. Site Security

JAXA takes security measures compliant with Japanese laws and regulations in USC.

The security measures include the followings, but not limited to,:

(1) During launch operation, access to USC is restricted and the entrances of roads to Nagatsubo and Miyabaru areas are controlled by security staff.

(2) All entrances to facilities for PL preparation are controlled by a dedicated electronic card reader system and limited to authorized personnel with ID cards.

(3) All the offices and integration areas such as Clean Room and Clean Booth of M Assembly Building are locked.

5.3.2. Safety

PL team is required to submit the following data for safety hazard evaluation:

1) Propellants: name/specifications/weight
2) Pyrotechnics: name/specifications/weight
3) High pressure gases: name/specifications/pressure/volume

USC takes basic safety measures, such as keeping fire extinguishers and first-aid kits in place.

Before a launch campaign, all on-site operators of PL team are required to attend a safety training course provided by JAXA.

During launch operations, JAXA's Launch Site Safety Team supervises the prescribed hazardous operations. PL team is required to submit procedures for any operations involving potential danger to the Launch Site Safety Team for approval.

5.3.3. Support for PL Team at USC

LV team offers several optional services to PL team. For details, contact your Program Director.

6. Mission Management

6.1. Outline of Mission Management

LSP provides Mission Management aimed at successful completion of launch services during a contract term. Mission Management covers various activities as listed below:

1) Mission Integration
2) System Engineering Support
3) Launch Campaign
4) Safety Supervision

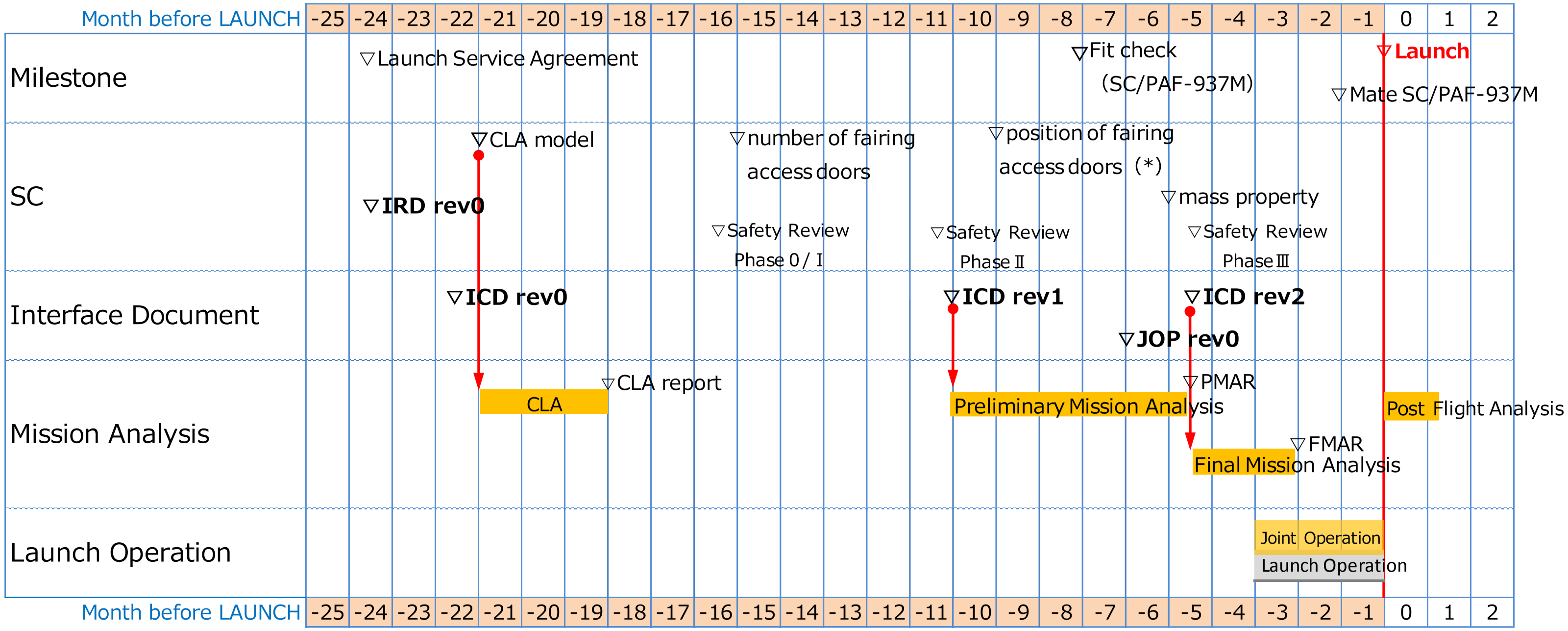
Contractual responsibilities between LSP and Customer are specified in a statement of work (SoW) and technical specifications (ICD and JOP as described in Chapter 6.3.1).

Based on these responsibilities, a program director, representative of LSP, is appointed as a point of contact with Customer and is responsible for contractual and technical coordination throughout the program.

Each activity is described in the following sections.

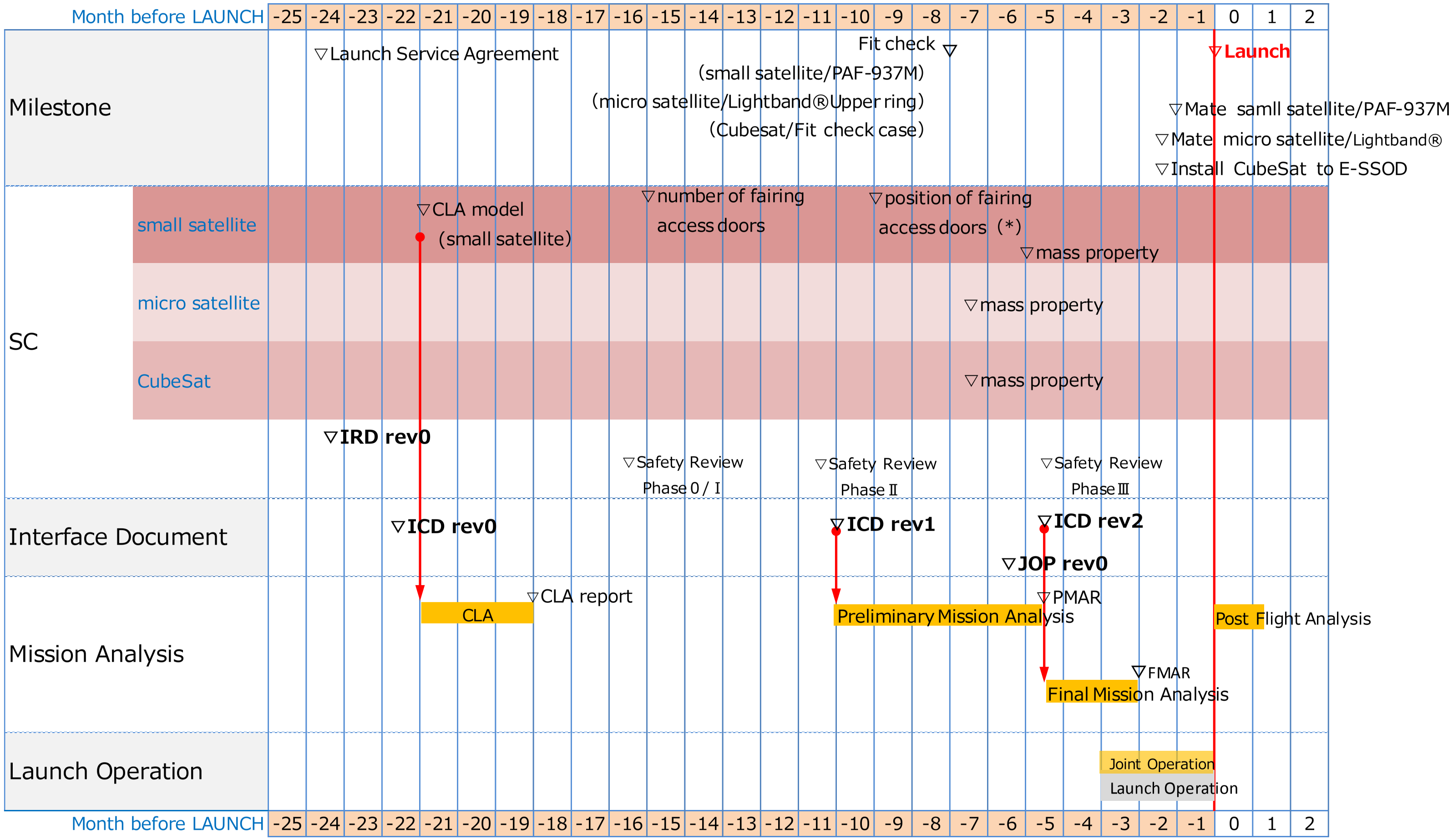
Mission management starts from appointment of program director and ends with submission of Launch Evaluation Report (see section 6.3.5). Launch schedule is determined based on the SoW, ICD and JOP agreed by Customer.

A typical schedule for a mission management until launch day is shown in Figure 6.1-1.



(*)Standard combination of access doors is (□600mm×1,φ180mm×2,RF transparent window×1, see chapter 4.1.2)

Figure 6.1-1(1/2) Typical schedule for mission management until launch day (Single Launch)



(*)Standard combination of access doors is (□600mm×1,φ180mm×2,RF transparent window×1, see chapter 4.1.2)

Figure 6.1-1(1/2) Typical schedule for mission management until launch day (Multi Launch)

6.2. Mission Integration

Mission Integration starts from the Kick-off Meeting and various activities are carried out to integrate Customer's mission into Epsilon launch operations through updating ICD, etc.

Customer shall submit necessary information such as IRD based on ISO standards at the Kick-off Meeting.

LSP will prepare an ICD draft based on Customer's requirements and information. Its typical schedule is shown in Chapter 6.1.

6.3. System Engineering Support

6.3.1. Interface Management

The technical interfaces are controlled by two documents as follows. If needed, other documents can be added. Schedules for preparation of these documents is shown in Chapter 6.1.

Document	Contents
Interface Control Documents (ICD)	Technical interface between PL and LV is defined and mission analysis is performed based on this document. (Typical example) Rev 0: after signing a contract Rev 1: before Preliminary Mission Analysis Rev 2: before Final Mission Analysis
Joint Operation Plan (JOP)	Plan for joint operation of PL Team and LV Team on Launch Site.

6.3.2. Mission Modification

Mission Modification Items, which can be set through interface arrangements between Customer and LSP, are shown in Table 6.3-1.

Table 6.3-1 Mission Modification Items

Items	PL	Items to be modified
PLF Access Doors/ RF Window	PL (Single Launch) Small Satellite (Multi Launch)	Location and number of PLF Access Doors and location of an RF Window
	Micro Satellite (Multi Launch)	N/A (Access doors may be set through arrangements with other rideshare PLs)
	CubeSat (Multi Launch)	N/A
Interface with PAF	PL (Single Launch) Small Satellite (Multi Launch)	Phases of separation switches, separation springs and separation connectors may be changed.
	Micro Satellite (Multi Launch)	Phases of separation switches and separation connectors may be changed.
	CubeSat (Multi Launch)	N/A
PL Crocking Position	PL (Single Launch) Small Satellite (Multi Launch) Micro Satellite (Multi Launch)	Phases of Xsc and Ysc of PL may be changed from standard phases within PL usable volume
	CubeSat (Multi Launch)	PL can be set by rotating on Zsc axis, provided its setting meets the interface requirements described in Chapter 4 and is determined before Preliminary Mission Analysis.
PL Usable Volume	PL (Single Launch) Small Satellite (Multi Launch) Micro Satellite (Multi Launch)	PL Usable Volume may be adjusted as long as PAF and PLF are not affected.
	CubeSat (Multi Launch)	N/A

6.3.3. Mission Analysis

Mission Analysis is conducted to ensure the achievement of the mission objectives and the compatibility of the PL and LV. It generally consists of two phases:

(1) Preliminary Mission Analysis (PMA)
(2) Final Mission Analysis (FMA)

Typical Mission Analyses are shown in Table 6.3-2. These analyses can be selectable according to a mission status through discussion with Customer.

Table 6.3-2 Typical Mission Analyses

Type of Analysis	Preliminary Mission Analysis	Final Mission Analysis
Trajectory Analysis	○	○
Separation Analysis	○	○
Collision Avoidance Analysis	○	○
Contamination Analysis	○	
Thermal Analysis	○	
Coupled Load Analysis (CLA)	○	

6.3.4. PL Design Compatibility Verification

Some tests shown in Table 6.3-3 can be carried out as options to verify the compliance of the mechanical and electrical interfaces between PL and LV and confirm PL environmental condition.

Table 6.3-3 Optional Tests for Compliance Verification

Items	PL	Typical Contents
Fit-Check	PL (Single Launch)	Fit-check can be carried out using a flight model of PAF to: - Verify mechanical interfaces with PAF, separation switches, umbilical connectors and separation springs - Verify electrical interfaces with umbilical connectors and separation switches - Measure pull power of umbilical connecters - Measure bonding
	Small Satellite (Multi Launch)	
	Micro Satellite (Multi Launch)	Fit-check can be carried out using an actual (or equivalent) Lightband® upper ring, or it can be done as part of fit-check of PAF.
	CubeSat (Multi Launch)	- Customer shall confirm fit-check using a Fit-Check Case. * Details of Fit-Check Case are shown in Appendix-D
Separation Test	PL (Single Launch)	If needed, separation tests with PAF are available as an option. For more information, contact your Program Director.
	Small Satellite (Multi Launch)	
Electric Test of Umbilical Line and Separation Connector	PL (Single Launch)	End to End Tests of Umbilical Line and Separation Connector are performed during Launch Preparation.
	Small Satellite (Multi Launch)	
EMC Test	All PL	To be arranged for each PL If needed, contact your Program Director
RF Linkage Test	All PL	To be arranged for each PL If needed, contact your Program Director
Accessibility Test	All PL	To be arranged for each PL If needed, contact your Program Director.

6.3.5. Post-Flight Analysis

Quick-look data for orbit parameters and altitude data are provided to Customer in 15 minutes after PL separation. Mission Evaluation Report based on actual flight data are issued to Customer in one month after the launch.

6.4. Launch Campaign

6.4.1. Launch Campaign Organization

A designated Program Director serves as a liaison with Customer throughout Launch Campaign including Pre-launch and Launch Activities. (See Figure 1-5)

6.4.2. PL Pre-Launch Activities

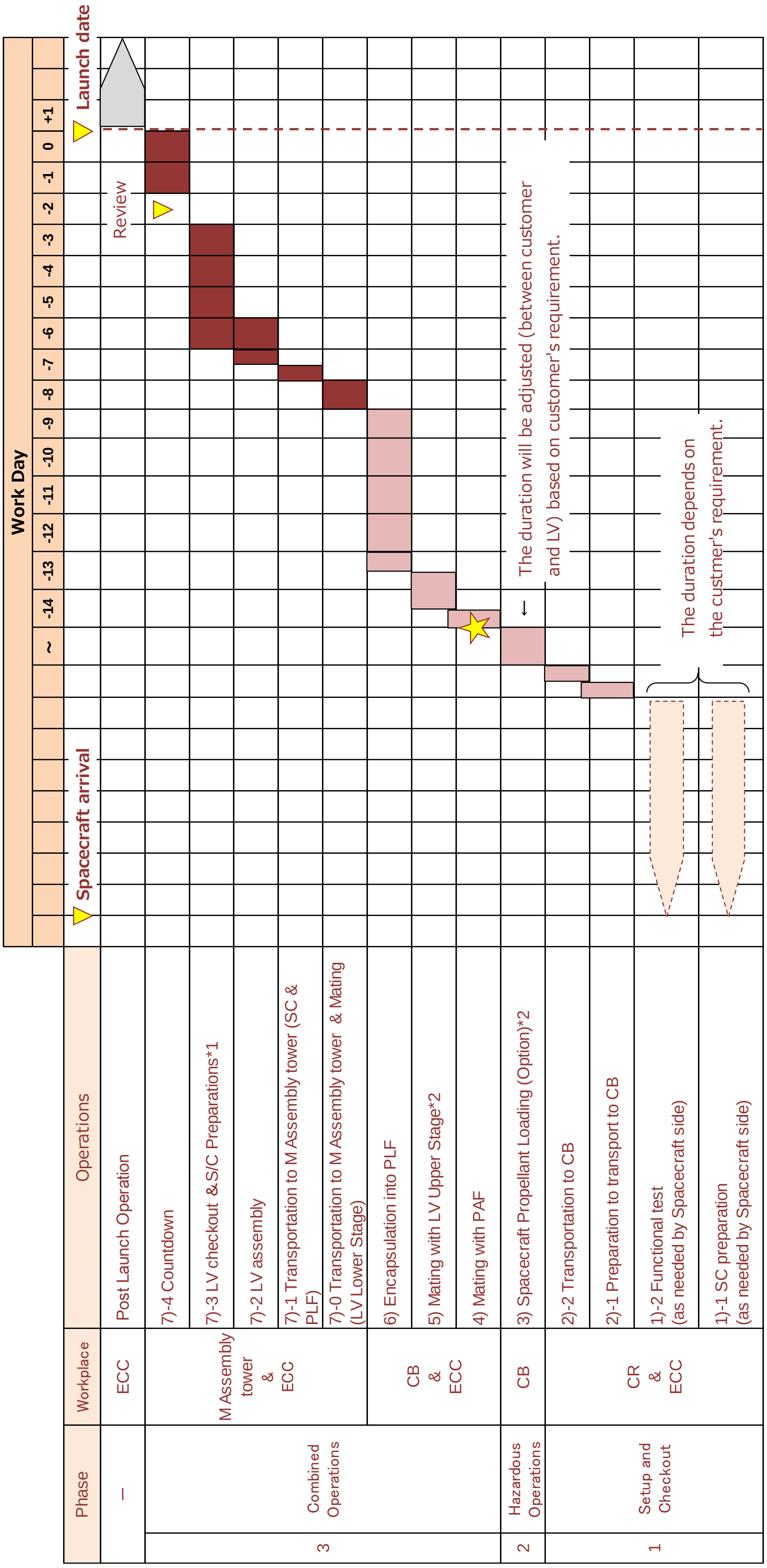
PL Pre-Launch Activities at USC are divided into three phases as follows:

(1) Phase 1. PL Setup and Checkout
- Stand-alone activities of PL

(2) Phase 2. PL Hazardous Operations
- Hazardous operations such as tank pressurization, propellant loading, and pyro installation etc.

(3) Phase 3. Combined Operations with LV
- Joint operations by PL and LV teams such as electrical/radio performance evaluation tests and combined launch rehearsal.

Typical PL Pre-Launch Activities and schedule are shown in Figure 6.4-1.
The specific schedule is arranged and agreed with Customer.



*1 : SC Preparations through the access door on the PFL, and SC check out are available.
In additon, SC test on the launch point outside of M tower is available with additional days.
The details of the test will be adjusted between customer and rocket based on customer's requiest.

*2 : (Option) SC check out is available.

Figure 6.4-1 Typical PL Pre-Launch/Launch Operation Flow

6.4.2.1. Phase 1. PL Setup and Checkout

1) PL Setup and Checkout

1)-1 Setup

・PL inside transportation container is arrived at M Assembly Room and moved to Air Lock Room through the up-range side door. (See Figure 6.4-2)

・PL is unpacked in Air Lock Room and then moved to Clean Room after dust cleaning.

・EGSE can be installed in either Check-out Room of M Assembly Room or M Control Center.

1)-2 Functional Test

・ The following operations are conducted in Clean Room.
  - Visual Inspection
  - Check Out

・ The temperature and humidity in Clean Room are controlled by air conditioners and monitored and recorded continuously.

・ The following analyses can be performed as options:
  - Continuous measurement of organic deposits in Clean Room
  - Continuous monitoring of particle count in Clean Room

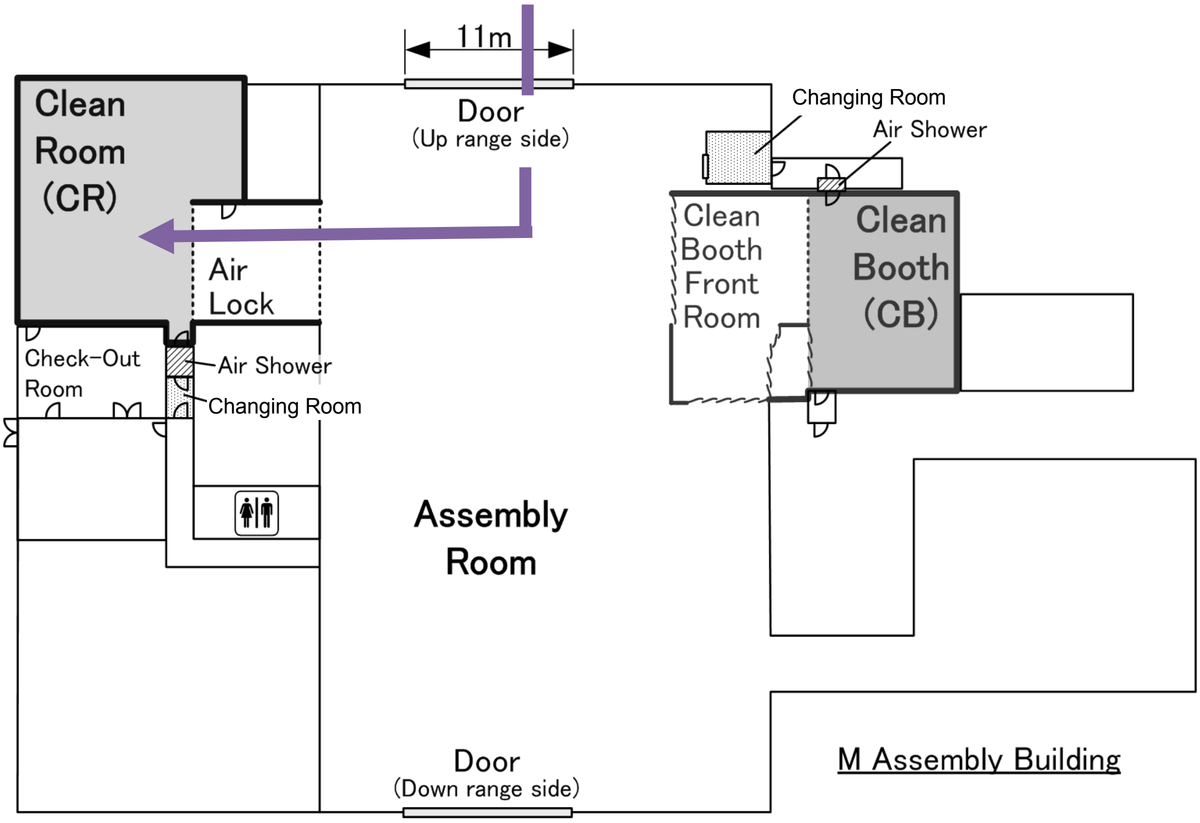


Figure 6.4-2 Transfer Route to Clean Room

6.4.2.2. Phase 2. PL Hazardous Operations

2)-1 Preparation for Transfer to Clean Booth (See Figure 6.4-3)

・PL is mounted on Transfer Cart by PL Team.

・Cart Cover is placed over PL and sealed tightly by LV Team.

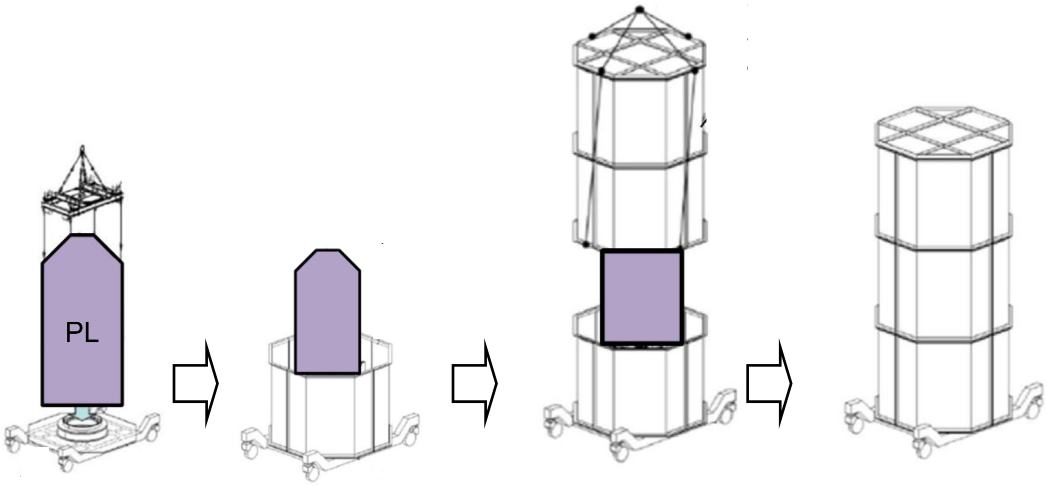


Figure 6.4-3 Preparation for Transfer to Clean Booth

2)-2 Transfer to Clean Booth (See Figure 6-4)

- PL in Transfer Cart is transferred from Clean Room to Clean Booth by LV Team.
- Cart Cover is removed by LV Team.
- LV Team changes the Transfer Cart with one prepared by PL Team.

- The following equipment is available in Clean Booth.
  - Scrubbers
  - SCAPE Suites (protective suites with air supply function), Breathable Air Supply equipment
  - Toxic Gas Detectors
- Temperature and humidity in Clean Booth are monitored and recorded. Continuous monitoring of particle count in Clean Booth is provided as an option.

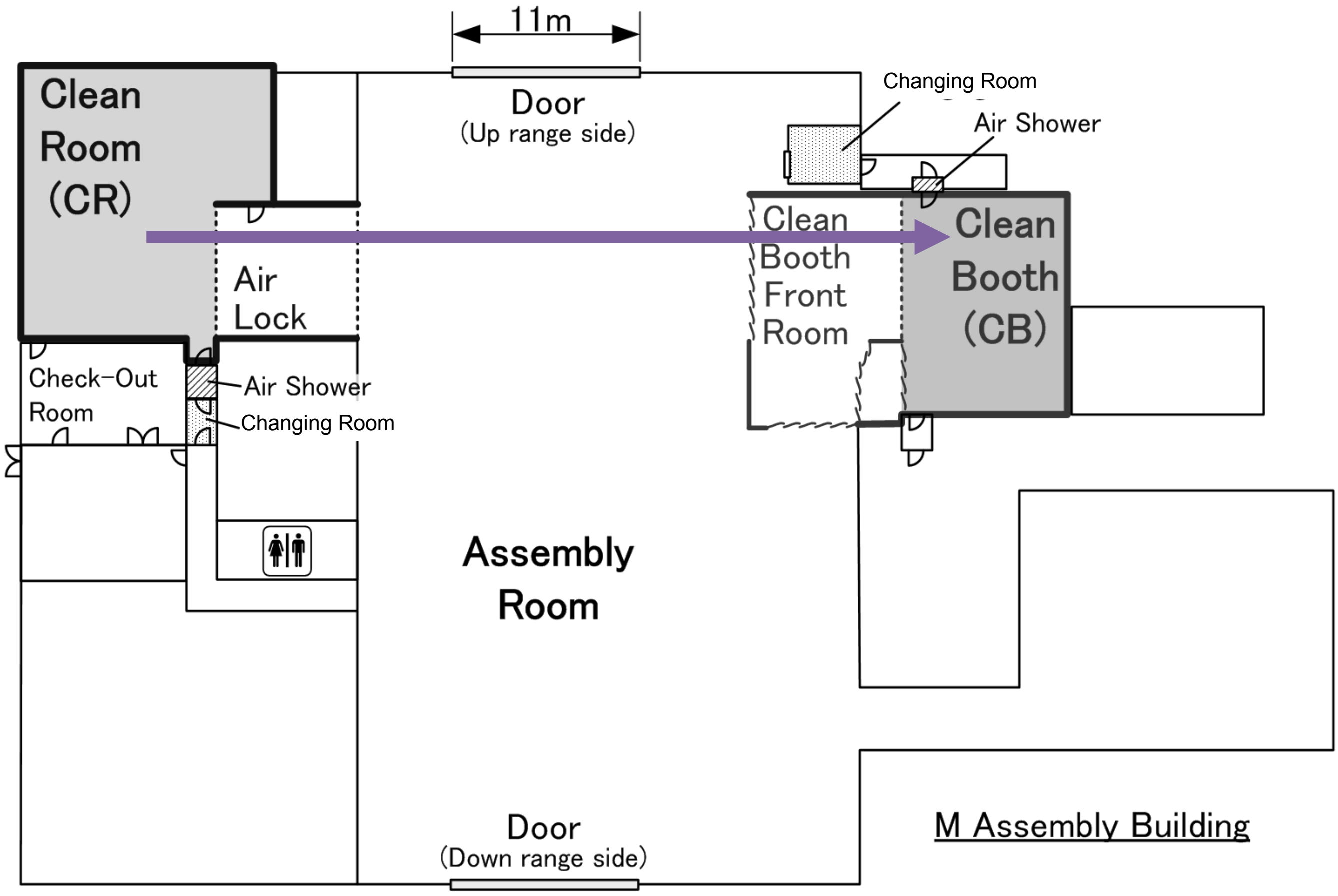


Figure 6-4 Transfer Route from Clean Room to Clean Booth

3) Propellant Loading in Clean Booth

3)-1 Propellant Loading Equipment Setup (by PL Team)

・Fueling Equipment is carried in.

・Fueling Equipment is set up.

3)-2 Propellant Loading (by PL Team)

・Fueling

・Tank Pressurization

・Fueling Equipment Decontamination

・Fueling Equipment is carried out.

6.4.2.3. Phase 3. Combined Operations with LV

4) Mating with PAF (by PL Team and LV Team)

・PL is mated with PAF on a PAF Stand in Clean Booth. (PL Team conducts operations until PL is hoisted over LV Upper Stage, then LV Team takes on subsequent operations.)

5) Mating with Upper Stage of LV (by LV Team)

・PL with PAF is mated with LV Upper Stage mounted on the Upper Stage Dolly.

6) Encapsulation into PLF (by LV Team)

・PL mated with LV Upper Stage is encapsulated in PLF and then ventilation duct is connected to PLF.

Work flows of PL encapsulation in Single Launch and Multi Launch are shown in Figure 6.4-5 and in Figure 6.4-6, respectively.

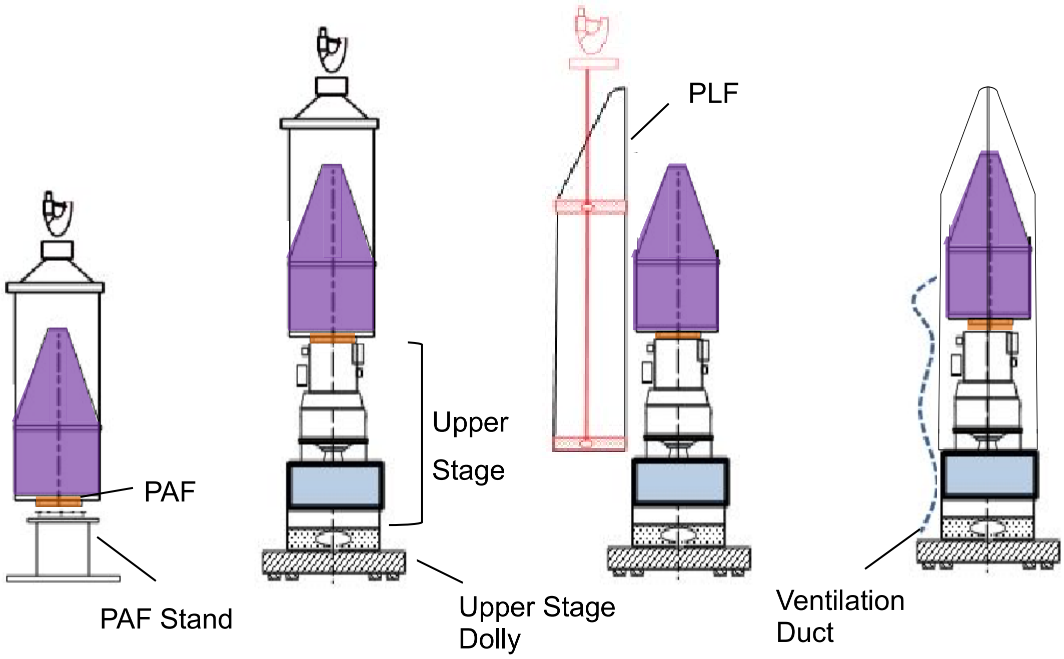


Figure 6.4-5 Encapsulation in PLF (Single Launch)

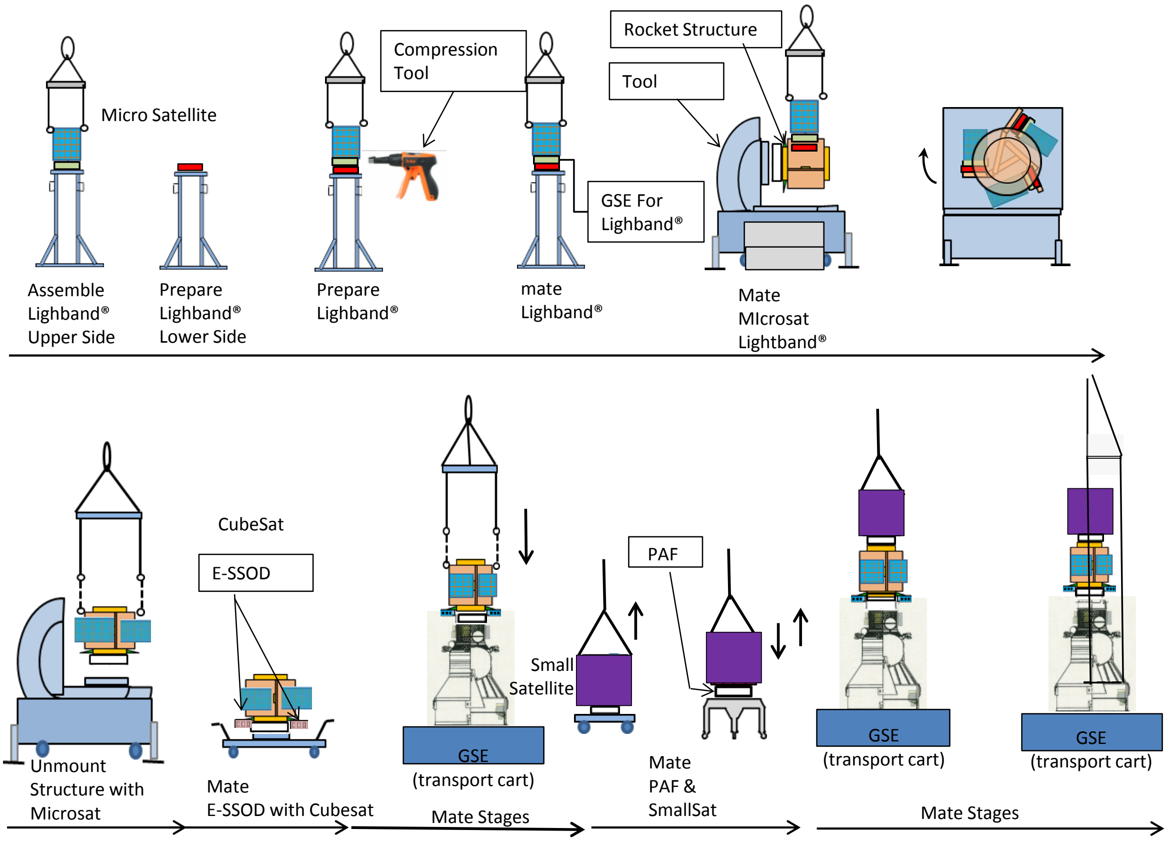


Figure 6.4-6 Encapsulation in PLF (Multi Launch)

7) Vehicle on Stand (by LV Team)

- Epsilon's 1st Stage on Transfer Trailer is moved to M Assembly Tower and hoisted to a vertical position and placed on Launching Pad. (See figure 6.4-7)

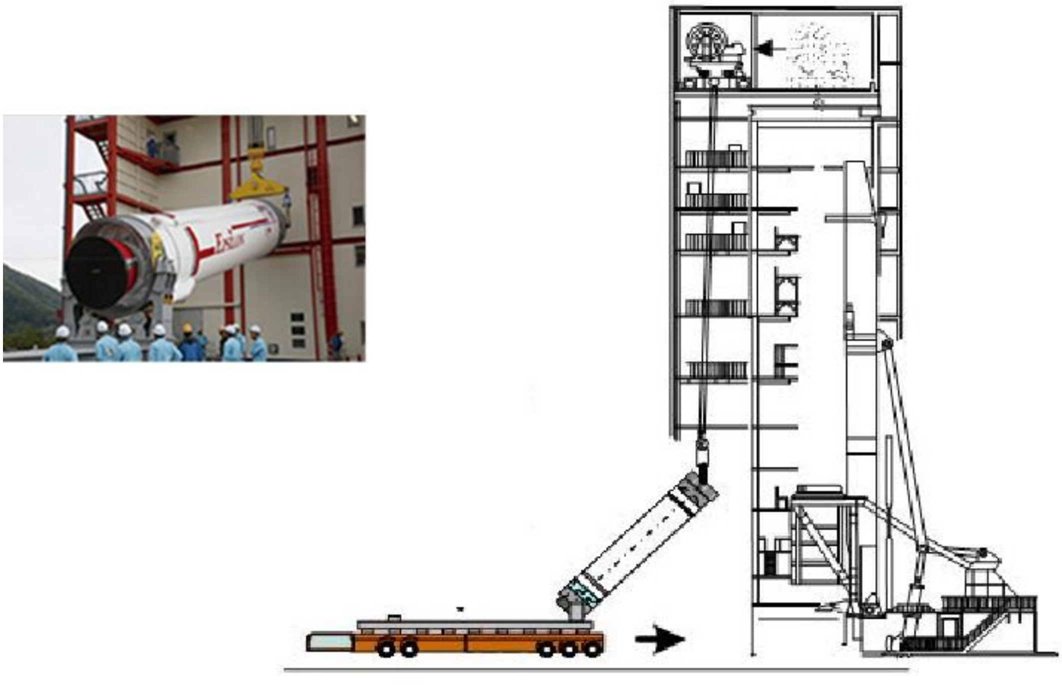


Figure 6.4-7 1st Stage on Stand

- Then, 2nd Stage is hoisted and positioned atop 1st Stage (See figure 6.4-8)

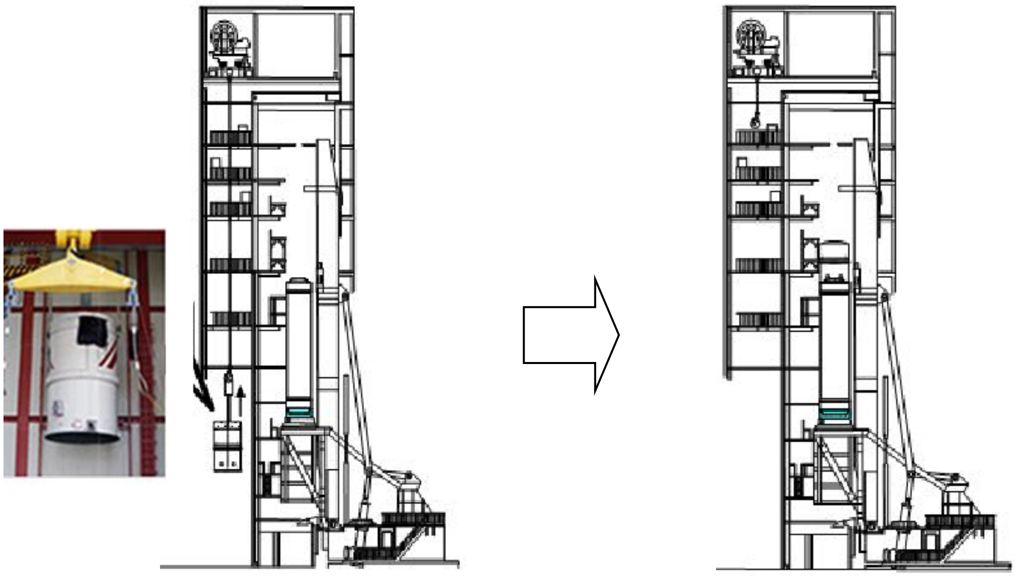


Figure 6.4-8 2nd Stage on 1st Stage

7)-1 Transfer to M Assembly Tower (by LV Team)

- Encapsulated PL on Upper Stage Dolly, together with an air conditioning car, is transported by Crane from Clean Booth to M Assembly Tower through Assembly Room. (See Figure 6.4-9)
- Temperature, humidity and air flow rate inside PLF are regulated by the air conditioning car and continuously monitored and recorded during the transfer.

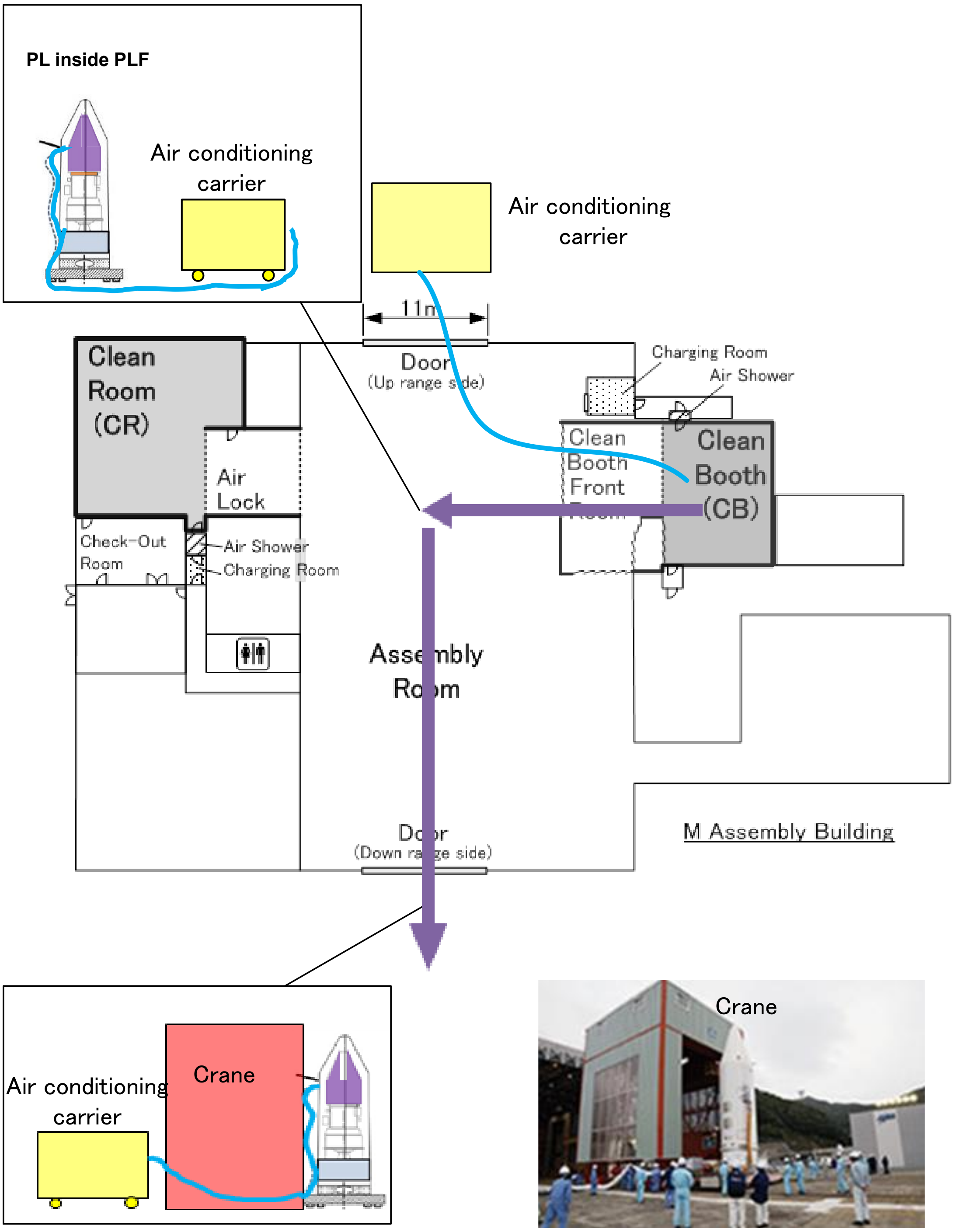


Figure 6.4-9 Transfer to M Assembly Tower

7)-2 Mating with 2nd Stage of LV (by LV Team) (See Figure 6.4-10)

- After arriving in M Assembly Tower, encapsulated PL is unloaded from Upper Stage Dolly and hoisted to the upper floor after the removal of ventilation duct. Then the PL is placed atop 2nd Stage for mating.
- After mating, PL are connected with wire harnesses and ventilation duct.
- After umbilical line is connected, PL checkout can be conducted using EGSE.

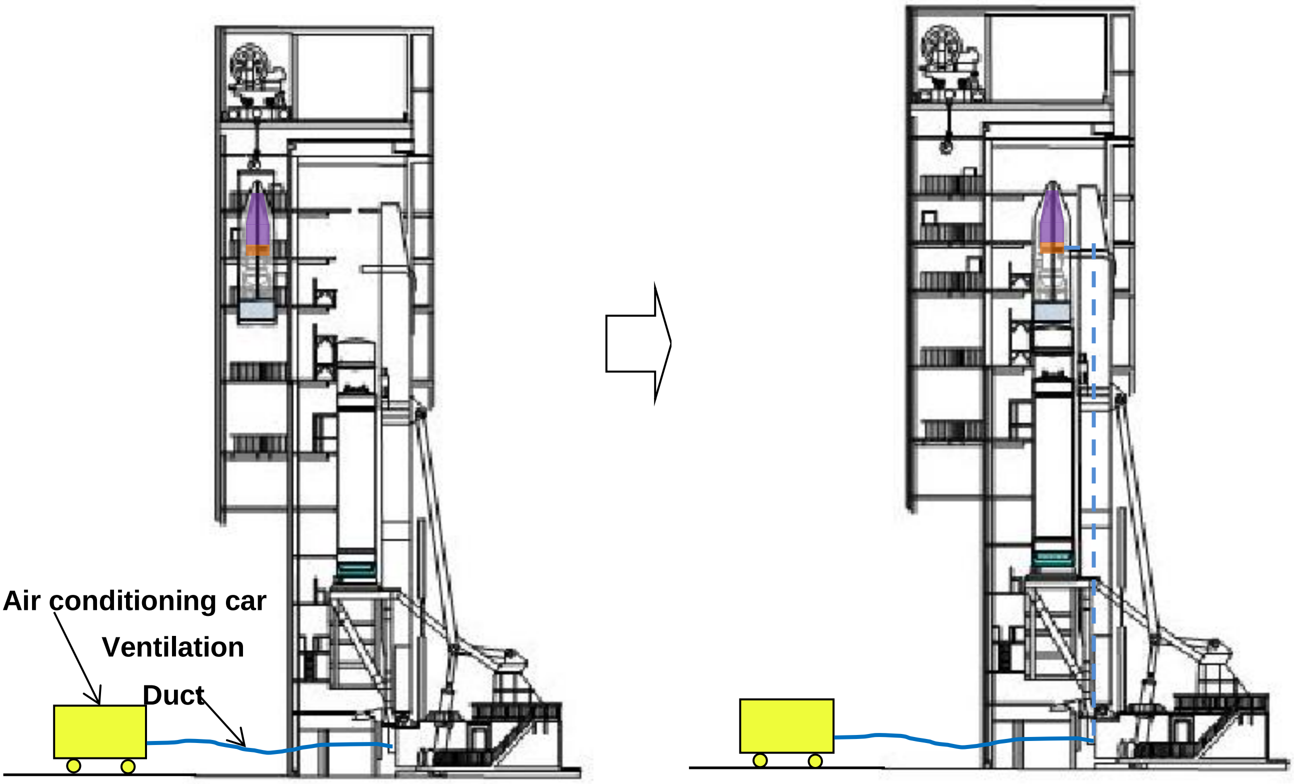


Figure 6.4-10 Mating with 2nd Stage of LV

7)-3 Checkout (by both PL Team and LV Team)

- Combined electrical/radio-electrical readiness tests and launch countdown rehearsal are performed to demonstrate the compatibility between PL, LV and ground facilities.
- For PL in Single Launch and Small Satellite in Multi Launch, PL Checkout and Battery Charge are available before the start of countdown.

7)-4 Countdown (by LV Team)

LV on Launching Pad is rolled out from M Rocket Assembly Tower to its launching position outside and prepared for countdown. (See Figure 6-10)

Countdown is carried out step by step based upon countdown procedures as LV Team confirm a green right of each step.

PL Team can continue to monitor the status of PL and, if needed, can conduct final PL checkout from Epsilon Control Center.

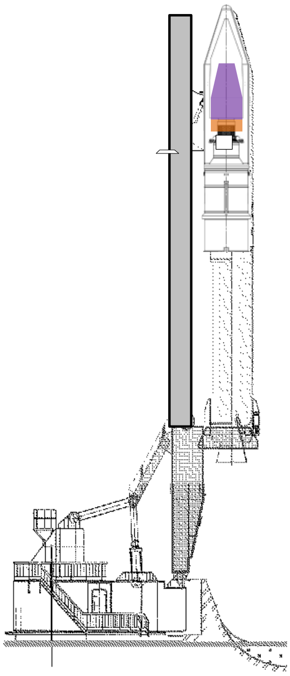


Figure 6.4-11 Final Configuration of Launch Vehicle

8) Tracking Operation (by LV Team)

After a successful liftoff, LV Team tracks LV by downrange stations for range safety operation and monitors critical events during the flight.

6.5. Safety Supervision

JAXA is responsible for the safety of human lives and properties and the protection of the environment during all phases of a Launch Campaign at USC from the arrival and transport of Customer's PL, GSE and materials/components through liftoff and PL separation. Therefore, Customer is required to observe JAXA's safety regulations and PL design and launch operations shall meet the requirements of JMR-002 LAUNCH VEHICLE PAYLOAD SAFETY STANDARD stipulated by JAXA.

Customer is also required to prepare its safety program plan, which is subject to inspection by JAXA safety authority, Launch Site Safety Team.