Proton Launch System Mission Planner’s Guide

SECTION 4

Spacecraft Interfaces

4. SPACECRAFT INTERFACES

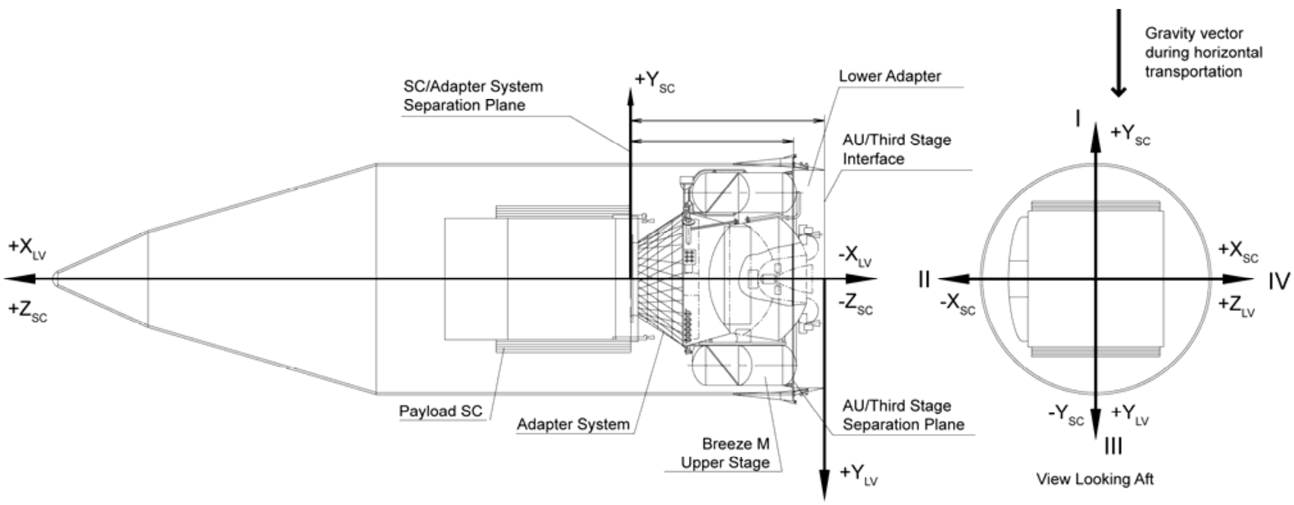
4.1 MECHANICAL INTERFACES

4.1.1 Structural Interfaces

The Spacecraft (SC)-to-Launch Vehicle (LV) structural/mechanical interfaces include a Payload Adapter (PLA) interface ring, a separation system, umbilical connectors, separation switches and bonding straps (if needed). The structural/mechanical interfaces are defined for each Adapter System (AS) in Appendix D of this Proton Mission Planner's Guide.

The LV coordinate system is shown in Figure 4.1.1-1 with a representative SC and its coordinate system.

Figure 4.1.1-1: LV and Typical SC Coordinate System



Notes:

a) SC longitudinal axis is in direction of flight.

b) Two remaining SC axes are in SC separation plane.

c) Proton M ($+X_{LV}$) is longitudinal in direction of flight.

d) Proton M ($+Y_{LV}$) is in direction of gravity vector during horizontal transportation operations.

4.1.2 General SC Structural and Load Requirements

4.1.2.1 Design Criteria

The SC and LV interface structure shall support the SC during the limit load condition without yielding. The clearance between the flanges of the SC and the adapter prior to clampband tensioning shall not exceed 0.6 mm. The geometry of the SC flange is provided in Appendix D for a temperature of 21°C. The surface flatness of the SC interface ring shall be less than 0.3 mm. The coating of the surface of the SC/LV interface structural elements shall be conductive.

4.1.2.2 SC Stiffness

The SC primary structural stiffness shall be such that the minimum fundamental lateral and axial mode frequencies shall be greater than 8.5 Hz and 25 Hz, respectively, as cantilevered from a rigid interface. The SC/LV interface is assumed to behave linearly under all loading conditions.

4.1.2.3 SC Interface Loads

The SC lifting device and structure shall be capable of lifting the SC plus the PLA and the separation system. Maximum adapter, separation system and other mass to be lifted by the SC $\leq$ 220 kg.

Loads affecting the SC at the SC/LV interface include the adapter system springs and the SC/LV electrical umbilical connectors. The adapter system spring forces and the SC/LV electrical umbilical connector forces are provided in Appendix D of this PMPG.

4.1.2.4 SC Mass and Center of Gravity (CG) Offset Requirements

The allowable position of the SC Center of Gravity (CG) relative to the SC/AS separation plane in the longitudinal axis is determined for each type of AS and separation system and are presented in Appendix D.

The SC CG displacement from the LV longitudinal X axis shall not exceed 20 mm in any lateral direction.

4.1.3 Payload Fairing (PLF) Interfaces

This section provides a description of the PLF interfaces, including generic fairing useable volume, allowable access door locations and RF window locations.

4.1.3.1 PLF General Description

For commercial launches with the Breeze M, two PLF lengths are available: 13305 mm (Figure 4.1.3.1-1a and Figure 4.1.3.1-1b) and 15255 mm (Figure 4.1.3.1-2a and Figure 4.1.3.1-2b). The 15255 mm fairing (PLF-BR-15255), which is the standard, and the 13305 mm fairing (PLF-BR-13305) are of similar design.

Specific useable volumes (i.e., volume under PLF useable for SC accommodation) for the two fairing types tailored to individual adapter systems are provided in Appendix E. Specific adapters take into account required adapter clearances for installation and required flight clearances with the adapter structure.

4.1.3.2 PLF Access Door Locations

The bottom part of the PLF accommodates a door for access to the clampband tension-monitoring electrical connectors and may also accommodate doors for access to the SC, in the locations for the two PLF versions shown in Figures 4.1.3.1-1a and 4.1.3.1-1b, 4.1.3.1-2a and 4.1.3.1-2b, respectively. Some mission-unique designs for door locations may be possible in coordination with KhSC. The Customer may use these doors for access to SC-related interface equipment. These access requirements need to be coordinated and agreed upon with ILS in the mission-specific ICD. From the time of fairing encapsulation up to the beginning of LV fueling on the launch pad, coordination with ILS is necessary for scheduling access through these doors.

4.1.3.3 RF Window Locations

Figures 4.1.3.1-1a, 4.1.3.1-1b, 4.1.3.1-2a and 4.1.3.1-2b show the locations of access doors and RF window cutouts for the two PLF versions, respectively.

There are two RF window positions in the PLF to take into account the possible view angles required at each of the two Proton launch pads. When the launch pad is designated, one out of the two windows will be replaced with a RF-opaque cover, leaving one active window for transmission of the SC telemetry and command signal between the SC and Control Room 4102 via the Bunker.

Figure 4.1.3.1-1a: Proton Breeze M PLF-BR-13305 Commercial Fairing General Layout (Sheet 1 of 2)

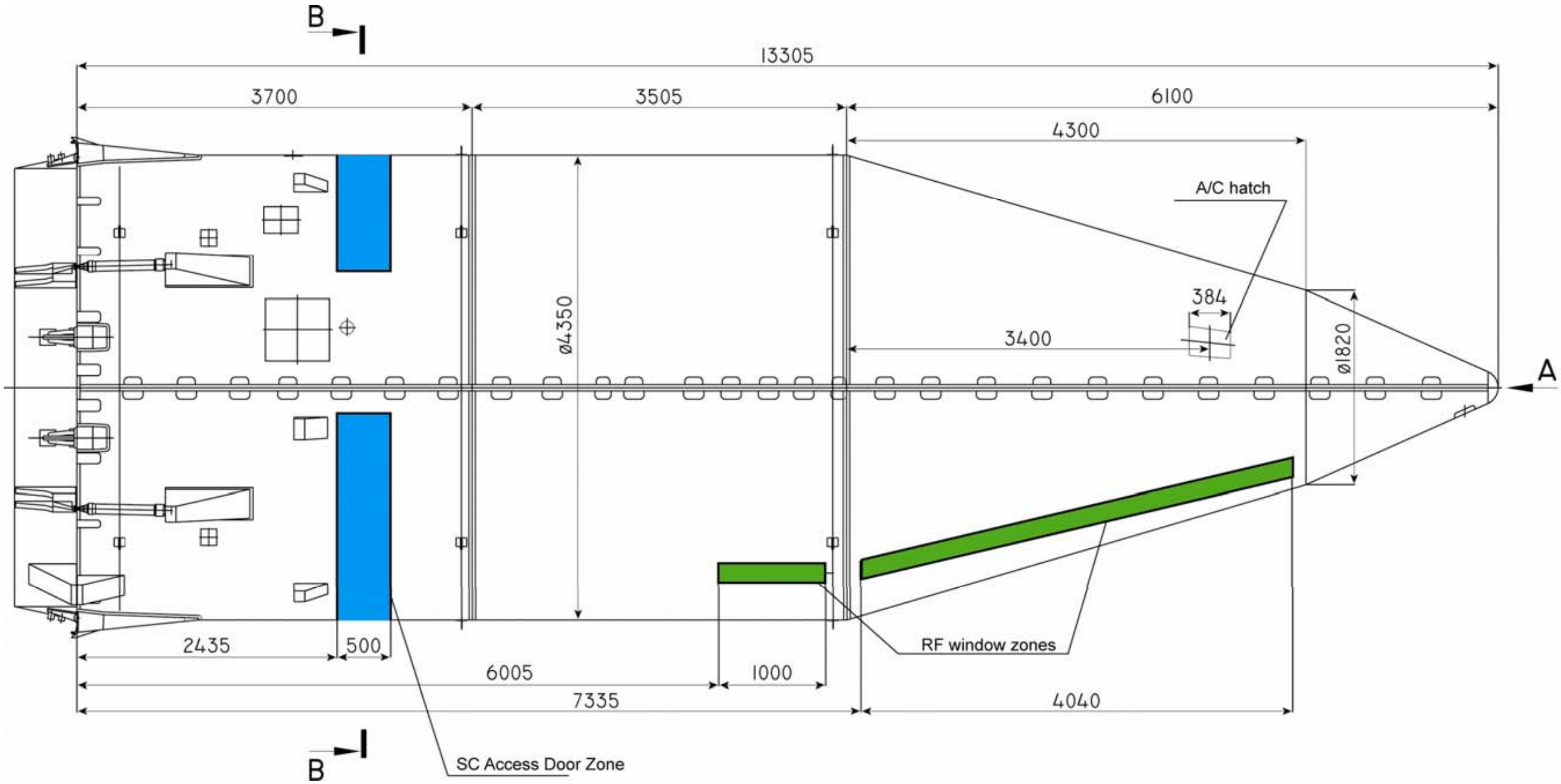


Figure 4.1.3.1-1b: Proton Breeze M PLF-BR-13305 Commercial Fairing General Layout (Sheet 2 of 2)

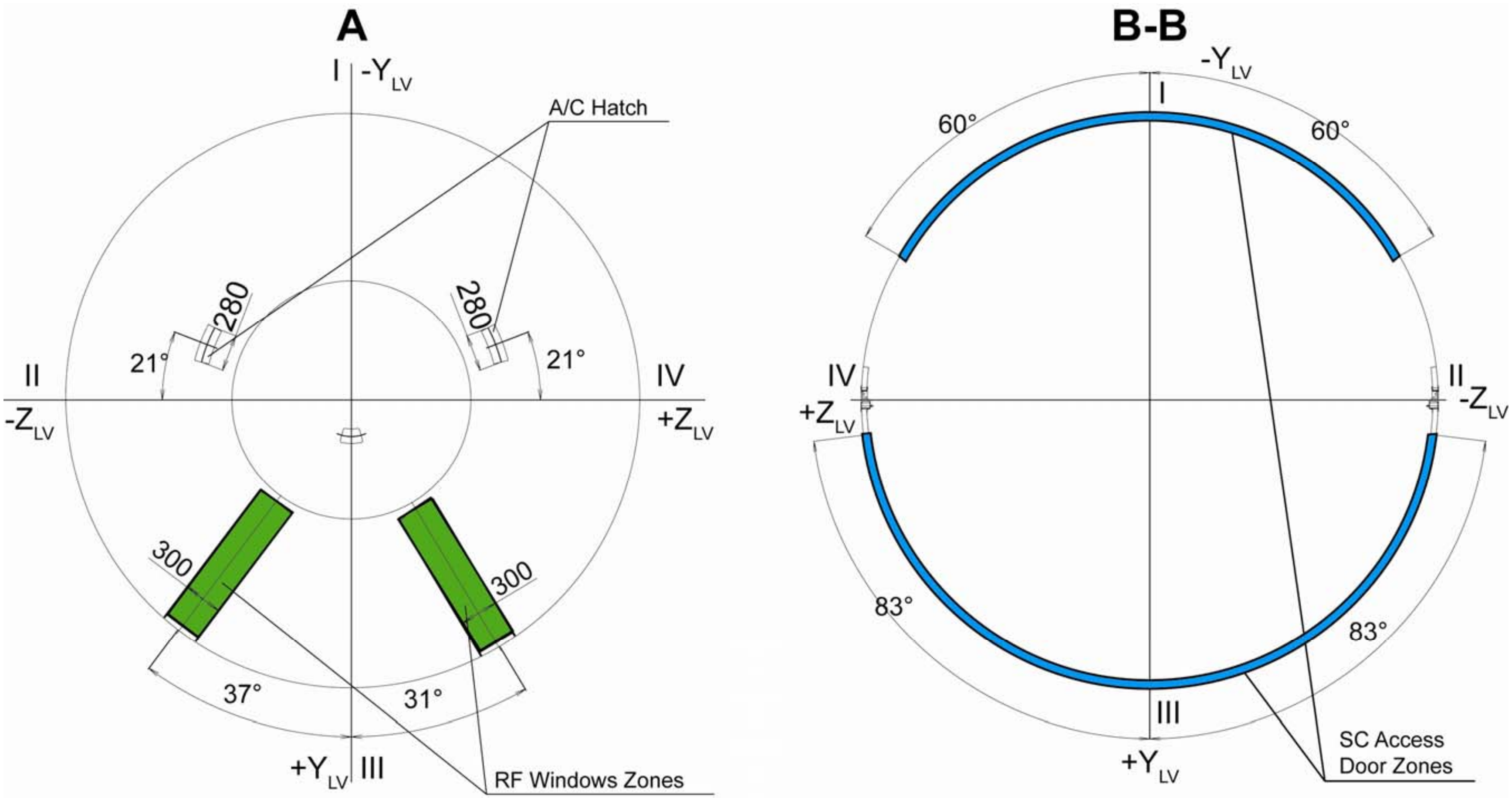


Figure 4.1.3.1-2a: Proton Breeze M PLF-BR-15255 Commercial Fairing General Layout (Sheet 1 of 2)

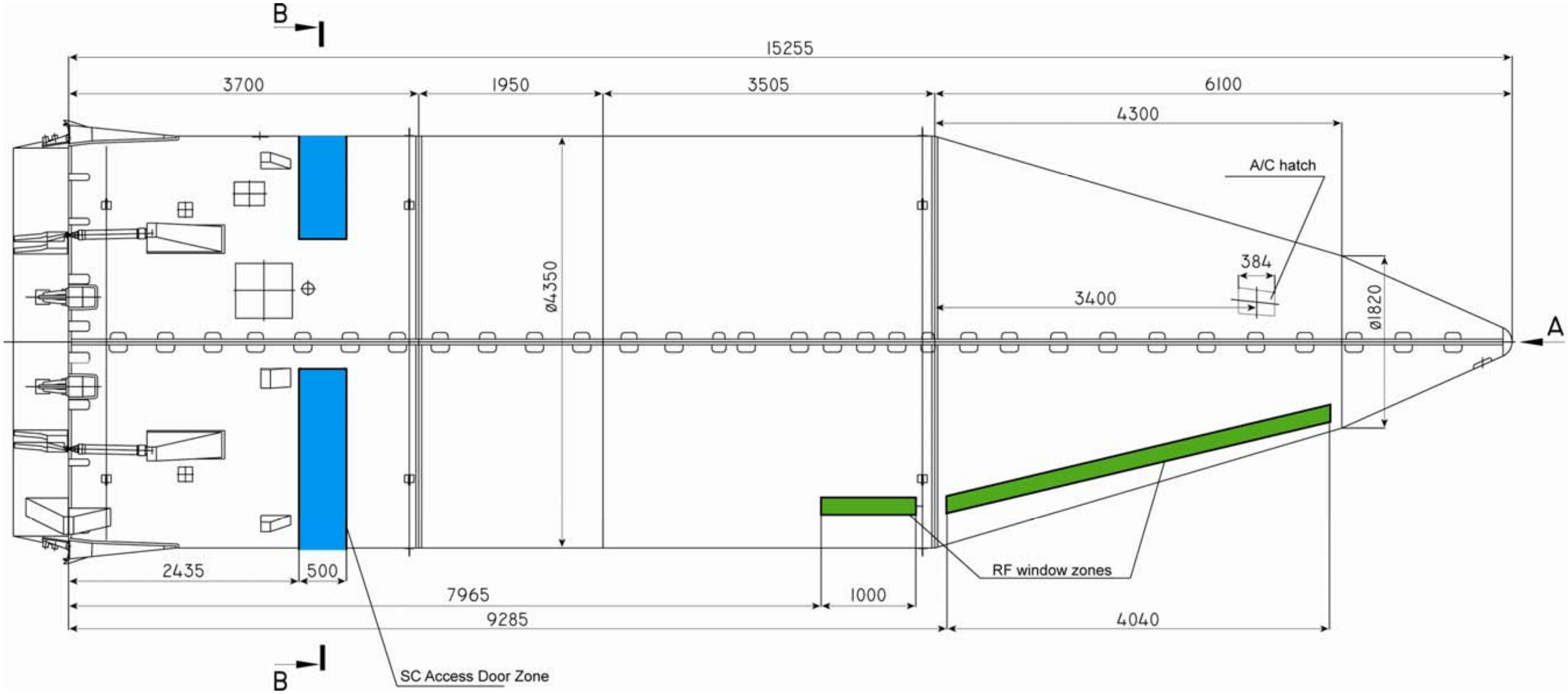
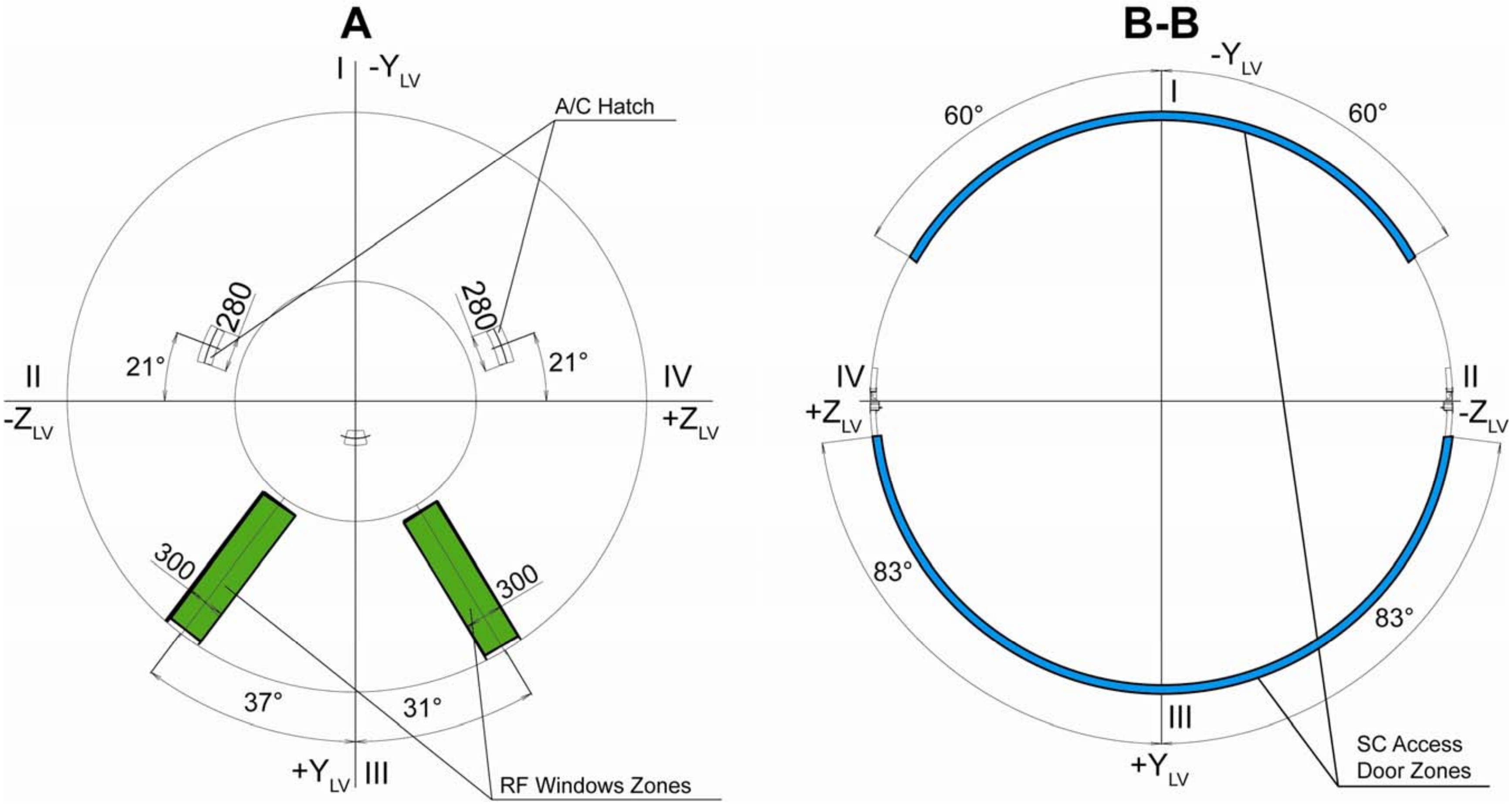


Figure 4.1.3.1-2b: Proton Breeze M PLF-BR-15255 Commercial Fairing General Layout (Sheet 2 of 2)



4.1.4 Adapters

The adapter system links the Breeze M and the SC mechanically and electrically during all phases of combined operation prior to the separation of the SC and Breeze M during flight.

Table 4.1.4-1 lists the available PLA systems used by the Proton LV.

A general view of available adapter systems is shown in Figure 4.1.4-1. A description and drawings of the mechanical interface of available adapter systems are shown in the corresponding sections of Appendix D. Other adapter systems may be developed that include other separation systems, in accordance with the requirements of the SC developer.

Figure 4.1.4-1: Available Adapter Systems

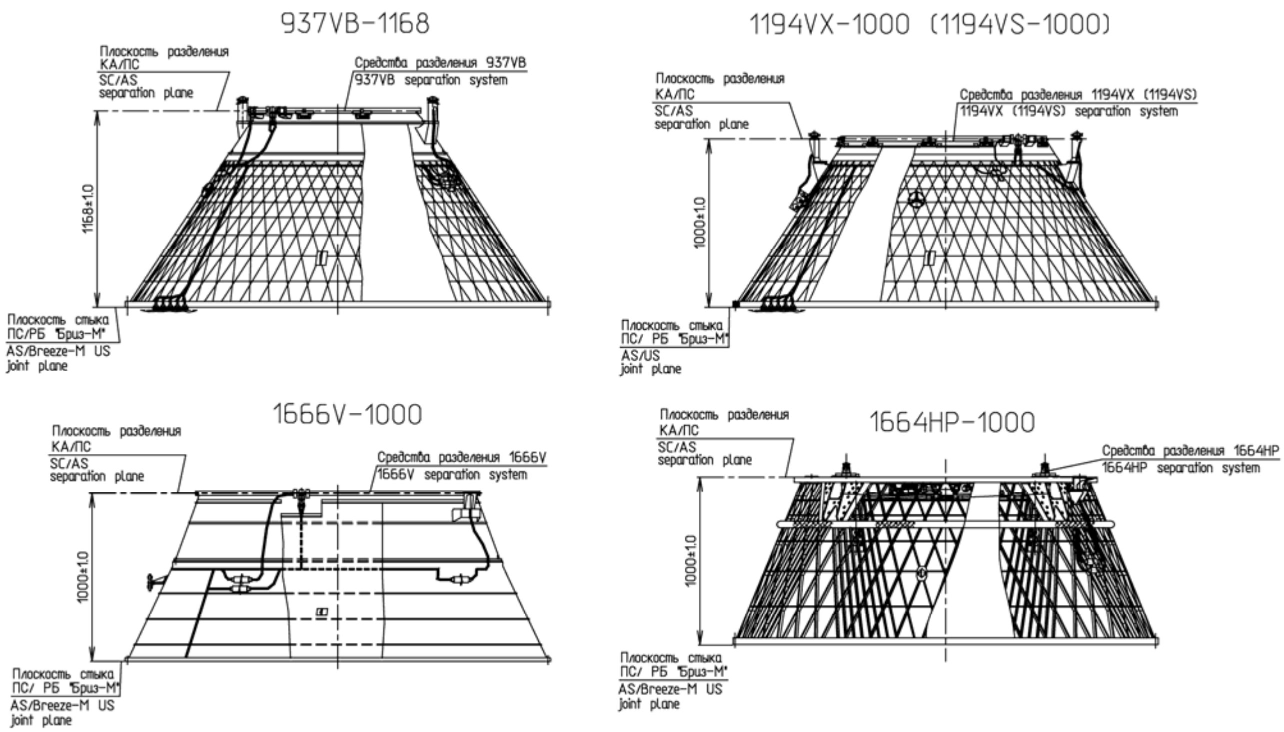


Table 4.1.4-1: Available Proton Adapter Systems

Adapter System	Height (mm)	Mass (kg)	Adapter System Characteristics	Appendix Reference
937VB-1168	1168	120	15 degree ramp angle on the SC side, 9 degree ramp angle on the AS side, 30 kN band tension	D.1
1194VX-1000	1000	110	15 degrees ramp angle on SC side, 9 degrees ramp angle on adapter side, 35 kN to 40 kN band tension	D.2
1194VS-1000	1000	110	15 degree ramp angle on SC side, 9 degrees ramp angle on adapter side, 54 kN band tension	D.2
1666V-1000	1000	155	15 degree ramp angle on the SC side, 11 degree ramp angle on the AS side, 30 kN band tension	D.3
1664HP-1000	1000	120	4 hard-point separation system	D.4

4.1.5 Payload/Adapter Separation Systems

Currently, annular and hard-point separation systems may be used for separation of the SC from the AS.

Annular separation systems of the following reference diameters may be used: 937 mm, 1194 mm, and 1666 mm. If required, a 2624 mm interface may be used. A specific separation system is proposed in each specific case, depending on SC requirements. The separation system can be based on either the traditional pair of pyrotechnically-initiated bolt cutters or a low-shock ClampBand Opening Device (CBOD). The RUAG CBOD system has been flight demonstrated on several launch vehicles, but not yet on Proton. The ground test qualification for use of RUAG CBOD on Proton has been completed. First flight demonstration on Proton is expected in 2010. KhSC is in the process of ground qualification for use on Proton of a CBOD system manufactured by CASA.

A hard-point attachment separation system may be used if the properties and configuration of the SC allow mechanical latches to be installed on the adapter with a pyro actuator or pyro latches (nominal 1664 mm interface). When necessary, a different hard-point interface required by the Customer may be used.

Separation systems have the following typical makeup:

- A separation assembly (see Table 4.1.5-1); a set of push-type actuators
- Umbilical electrical connectors
- Separation verification sensors
- A pneumatic purge fitting (if required)

Alternative separation systems of the annual and hard-point type are shown in Table 4.1.5-1.

Table 4.1.5-1: Mechanical Interface Options for Separation System

#	Interface Diameters (mm)	Separation System Designation	Separation System Manufacturers	Separation System Types
1	937	937VB	RUAG AEROSPACE SWEDEN AB/KhSC	Annular
2		937VS	RUAG AEROSPACE SWEDEN AB/KhSC	Annular
3		937LPSU	EADS CASA Espacio/KhSC	Annular
4	1194	1194VX	RUAG AEROSPACE SWEDEN AB/KhSC	Annular
5		1194VS	RUAG AEROSPACE SWEDEN AB/KhSC	Annular
6		1194LPSU	EADS CASA Espacio/KhSC	Annular
7	1666	1666V	RUAG AEROSPACE SWEDEN AB/KhSC	Annular
8		1666LPSU	EADS CASA Espacio/KHSC	Annular
9		1666S	RUAG AEROSPACE SWEDEN AB/KhSC	Annular
10	1664	1664HP	KhSC	Point attachment

Requirements are levied on the energy of separation system push-type actuators in order to satisfy the Customer's SC separation requirements. A typical example of push spring characteristics is shown in Table 4.1.5-2. The characteristics may be varied based on the requirements of a specific SC. If SC spin is required, push-type actuators with different travel distances may be installed.

Table 4.1.5-2: Push Spring Characteristics

Travel (mm)	Initial Force (N)	Final Force (N)	Nominal Energy of One Push Spring (J)	Nominal Energy of All Push Springs (J)
65	1180.0	100.0	41.0	328.0

4.1.6 GN_2/Dry Air Purge Option

Pursuant to particular contractual arrangements, the Customer can obtain a Gaseous Nitrogen (GN_2)/dry air purge of the SC after PLF encapsulation via special pneumatic fittings at the adapter interface. GN_2 can be provided via Customer-provided gas bottles during operations in the Payload Processing Facility (PPF), Building 92A-50, and on the launch pad up to MST rollback. At this time, the line can be connected to a dry air source running through the LV to provide a dry air purge up to lift-off. Characteristics of this purge system are as follows:

Item	Characteristic
Number of fittings	1
Type fitting	Pneumatic 0.172 inch (4.36 mm) internal diameter, 0.281 inch (7.14 mm) external diameter, 303 CRES material (provided by Customer)
Period of operation	a) Accessible by Customer during payload operations in PPF and on-pad, prior to MST rollback (including during transportation operations, as mutually agreed upon between ILS and Customer) b) Connected to ILS/KhSC dry air source through LV from MST rollback to launch
Operational gas	Gaseous nitrogen (GN_2) or air
Particulate size	<50 microns
Hydrocarbon content	Maximum condensable hydrocarbons - 5.0×10^{-4}% by mass
Helium content	At standard atmosphere concentrations - 5.0×10^{-4}% maximum by volume
Filtration	Preliminary purification and availability of filter at system outlet with mesh of 25 microns to 50 microns
Temperature	-30°C to +30°C
Humidity requirement	Maximum dew point temperature = -55°C
Flow rate at SC/LV interface	450 cm^3/min to 650 cm^3/min
Maximum pressure drop from SC/LV interface through SC	0.048 Pa

For a typical mechanical interface layout, see Appendix D of this Proton Mission Planner's Guide.

4.2 ELECTRICAL INTERFACES

Electrical interfaces include the SC/LV airborne interfaces, Electrical Ground Support Equipment (EGSE) interfaces, and telemetry/command links.

4.2.1 Airborne Interfaces

Electrical umbilical interfaces are used primarily for providing power to the SC from Customer ground power supplies located in the Vault under the launch pad. They are also used for hardline telemetry and command links between the SC and the Customer GSE located in the PPF Control Room 4102 or the launch control Bunker at the pad. Additionally, the Customer has an option to have SC telemetry recorded by the Breeze M telemetry system via these umbilicals.

4.2.1.1 Electrical Connectors

Two 37-pin or 61-pin umbilical connectors are provided at the SC interface with the LV adapter. The connectors are spring-loaded and at separation will disconnect from the adapter. The type of umbilical connector is mutually agreed to between ILS and the Customer.

Appendix D describes the standard adapters and also provides the type, location and mechanical configuration for these connectors.

4.2.1.2 Separation Verification

Two diametrically opposed separation microswitches are provided on the top adapter interface flange. Refer to Appendix D for specific locations and mounting configuration for each specific adapter. At separation, the microswitches will open a circuit and the LV telemetry will detect this as the separation event.

In addition, continuity loops are provided in each umbilical connector on the SC side. At separation, the umbilical connectors will disengage, thereby opening these circuits and providing a redundant indication of separation to the LV telemetry system.

4.2.1.3 Interface Electrical Constraints

All SC and LV electrical interface circuits shall be restricted at least 20 seconds prior to SC separation, such that there is no current flow greater than 100 milliampere per wire during the separation event.

4.2.1.4 Spacecraft Environment Telemetry

Flight events and mechanical and temperature environments during SC orbital insertion are recorded by the Proton M LV third stage and Breeze M telemetry systems with the aid of sensor equipment mounted on the adapter system and fairing.

AS sensors are mounted near the upper flange and record the following:

- High-frequency vibrations in the direction of flight and in the radial direction
- Longitudinal and lateral accelerations
- The AS acoustic environment
- Temperature values in the upper part of the AS

Sensors on the fairing prior to its separation measure:

- Acoustic pressure inside and outside the fairing during first 100 seconds of flight
- Internal static pressures
- Fairing temperature values

Mechanical and temperature environments are measured during LV operation, including high-frequency vibration parameters and acoustic pressure, low-frequency vibration parameters, and AS temperatures, as well as the fairing acoustic pressure and temperature.

After separation from the LV, the Breeze M telemetry system measures AS temperature parameters and records SC separation events. In special cases, it may also measure low-frequency AS vibrations.

Breeze M telemetry system transmission capabilities and data transfer rates are determined by radio coverage conditions, and implement the following modes:

- Direct data transmission with simultaneous recording
- Data recording
- Direct transmission with simultaneous playback of previously recorded data
- Direct transmission of data with redundancy in a time delay mode

Five accelerometers are mounted near the top of the adapter interface flange to record acceleration from lift-off until stage three/four separation. Three accelerometers measure longitudinal loads and two measure lateral loads. Refer to Section 4.2.1.6 for characteristics of these telemetry channels.

4.2.1.5 Pre-Separation "Dry Loop" Commands

The Customer may choose as an optional service up to two primary and two redundant in-flight commands in the form of relay closures for initiating SC commands during flight. The command for closure will be issued after launch and before SC/LV separation. Timing and signal characteristic requirements need to be provided by the Customer no later than at L-12 months. Characteristics of this command are as follows:

Table 4.2.1.5-1: Relay Closure Command Characteristics

Item	Characteristic
Type of relay	Electronic switches on IRF7103 transistors
Actuation time	Any time from launch to SC separation
Pulse duration	0.1 second to 10 minutes
Timing accuracy	± 32 ms
Allowable maximum voltage through relay contact at relay closure	16 Volts
Allowable maximum steady-state current through SC/LV interface contact	1 Ampere

4.2.1.6 LV Telemetry, Command and Power

The LV provides the SC separation command and the power for initiating the separation system. There is no LV power or command lines which pass across the SC separation plane.

Table 4.2.1.6-1 provides a description of the measurement system that is used during ground handling. Table 4.2.1.6-2 provides the characteristics and location of each flight telemetry sensor registering flight events of an example mission. Finally, Figures 4.2.1.6-1 through 4.2.1.6-5 show the locations of each sensor on the LV or ground transportation device.

Table 4.2.1.6-1: Instrumentation Characteristics and Locations for Ground Operations

Accelerations	Accelerometer Location and Measurement Directions	Amplitude Measurement Dynamic Range (g)	Frequency Measurement Range (Hz)
Transport by Rail, SC Mounted in Shipping Container on Shock Pallet	Location: In the area of the attachment of the container on shock pallet to the transport vehicle Longitudinal Vertical Lateral	 1.0 (TBX1) 1.0 (TBY1) 1.0 (TBZ1)	 Up to 50 Hz
Transport by Rail, SC Mounted on Breeze M (Breeze M and Fairing Only)	Support point of Breeze M aft interface ring Longitudinal Vertical Lateral Support point of fairing assembly at cylinder-nose cone transition Longitudinal Vertical Lateral SC-to-PLA separation plane Longitudinal Vertical Lateral	 1.0 (TBX2) 1.0 (TBY2) 1.0 (TBZ2) 1.0 (TBX3) 1.0 (TBY3) 1.0 (TBZ3) ±1.0 (TBX) -1 ±1.0 (TBY) ±1.0 (TBZ)	 Up to 50 Hz Up to 50 Hz Up to 50 Hz
Transport by Rail, SC Mounted on Proton LV Assembly	Support point of Breeze M aft interface ring Longitudinal Vertical Lateral Support point of Proton first stage at aft ring Longitudinal Vertical Lateral SC-to-PLA separation plane Longitudinal Vertical Lateral	 1.0 (TBX4) 1.0 (TBY4) 1.0 (TBZ4) 1.0 (TBX5) 1.0 (TBY5) 1.0 (TBZ5) ±1.0 (TBX) -1 ±1.0 (TBY) ±1.0 (TBZ)	 Up to 50 Hz Up to 50 Hz Up to 50 Hz
Temperature	**Temperature Sensors Location**	**Measurement Range (°C)**	
SC transportation in the shipment container from Yubileiny Airfield to processing facility	Air temperature in the air duct at the container inlet for air conditioning from the air conditioning car	-10 to +40	
All ground operations (after AU integration	Air under PLF around SC Temperature at adapter	-10 to +40 -10 to +40	
At launch pad	Air under PLF around SC Temperature at adapter	-10 to +40 -10 to +40	

Table 4.2.1.6-1: Instrumentation Characteristics and Locations for Ground Operations (Continued)

Humidity	Humidity Sensors Location	Measurement Range
Transportation in Container	Relative humidity inside shipping container	0 - 90%
All Transportation Events	Relative humidity of inlet, exit air from KhSC thermal conditioning car	0 - 80%
Contamination	**Contamination Sensors Location**	**Measurement Range**
All Ground Events	Particulate size at inlet/exit from air conditioning car	0.5 microns/5 microns and higher
All Ground Events	Witness plates (2) located inside PLF	
On-Pad	Access to PLF air supply for manual reading of contamination levels	0.5 microns/5 microns and higher

Table 4.2.1.6-2: Instrumentation Characteristics and Locations for Flight Events (Typical)

Name of Parameter	Parameter Index	Measurement Range	Recording Frequency
ADAPTER SYSTEM			
Parameters Measured Before Separation of Stage III Booster			
Vibration at joint area of SC and AS: Along X-axis In radial direction	 BX-CT BR-CT	 15Hz to 2000 Hz, 10 g 15 Hz to 2000 Hz, 15 g	 8000 Hz 8000 Hz
Vibrations at joint area of SC and AS: Along X axis	 КХ1 - КХ3	 -2 g to +4 g up to 64 Hz	 200 Hz, record at separation of stages: КХ1 - 400 Hz, КХ2, КХ3 - 200 Hz
Vibrations at joint area of SC and AS Along Y-axis Along Z-axis	 KY4 KZ5	 ± 0.6 g up to 32 Hz	 200 Hz, record at separation of stages - 100 Hz
Parameters Measured During 100 s of Flight			
Acoustic pressure at joint area of SC and AS	AB5	30 Hz to 2000 Hz, 120 dB to 155 dB	8000 Hz
Parameters Measured Before Separation of SC			
Separation of SC	ДКР1, ДКР2	Moment of separation of SC	12.5 Hz
Temperature in upper portion of AS structure	TA1-TA4	-10° C to +80° C	0.036 Hz
Temperature in lower portion of AS structure	TA7-TA10	-90° C to +90° C	0.036 Hz
PAYLOAD FAIRING			
Parameters Measured Before Separation of PLF			
Temperature of inner surface of leading-edge	T1	0° C to +150° C	0.3 Hz
Temperature of external surface of outer skin of honeycomb construction	T2 - T7	-40° C to +200° C	0.3 Hz
Temperature of external surface of inner skin of honeycomb construction	T8 - T13	-40° C to +200° C	0.3 Hz
Temperature of panel of LTMCS cooler	T14, T15, T30	-40° C to +100° C	0.3 Hz

Table 4.2.1.6-2: Instrumentation Characteristics and Locations for Flight Events (Typical) (Continued)

Name of Parameter	Parameter Index	Measurement Range	Recording Frequency
Heat insulation temperature	T16 - T19 T28, T29	-40° C to +100° C -40° C to +200° C	0.3 Hz 0.3 Hz
Temperature of medium under PLF	T22, T23	-40° C to +100° C	0.3 Hz
Temperature of heat protection surface	T25, T26 T27	0° C to 600° C -40° C to +200° C	0.3 Hz 0.3 Hz
External static pressure on PLF surface	ДНД1 - ДНД3, ДНД5 - ДНД8 ДНД4	0 mm Hg to 780 mm Hg 0 mm Hg to 400 mm Hg	50 Hz 50 Hz
Internal static pressure	ДВО1 ДВО2, ДВО4 ДВО3 ДВО5	0 mm Hg to 780 mm Hg 0 mm Hg to 250 mm Hg 0 mm Hg to 400 mm Hg 0 mm Hg to 50 mm Hg	50 Hz 50 Hz 50 Hz 50 Hz
Internal static pressure under drain port fairings	ДДО1 - ДДО4	0 mm Hg to 780 mm Hg	50 Hz
Pressure differential	ПНД1 - ПНД4	-50 mm Hg to 50 mm Hg	50 Hz
Angle of turn of doors	УПС1, УПС2	0 mm Hg to 60 deg.	100 Hz
Separation of door connectors	PPC1 - PPC4	Moment of separation of EC strip	100 Hz
Beginning of opening of joint	HPC5 - HPC8	Moment of opening of joint	100 Hz
Parameters Measured During 100 s of Flight			
Acoustic pressure on PLF outside	AH1, AH3, AH7	30 Hz to 2000 Hz, 125 dB to 165 dB	8000 Hz
Acoustic pressure inside PLF	AB2, AB4, AB6, AB8	30 Hz to 2000 Hz, 125 dB to 155 dB	8000 Hz
SPACECRAFT			
Parameters Measured Before Separation of SC			
Separation of SC	OKA1, OKA2	Moment of separation of SC	12.5 Hz

Figure 4.2.1.6-1: Instrumentation During Transportation of SC in Contractor's Container

Rail transportation of SC in SC contractor's container from Yubileiny to SC processing facility (40 - 70 km at ≤ 15 km/hr).

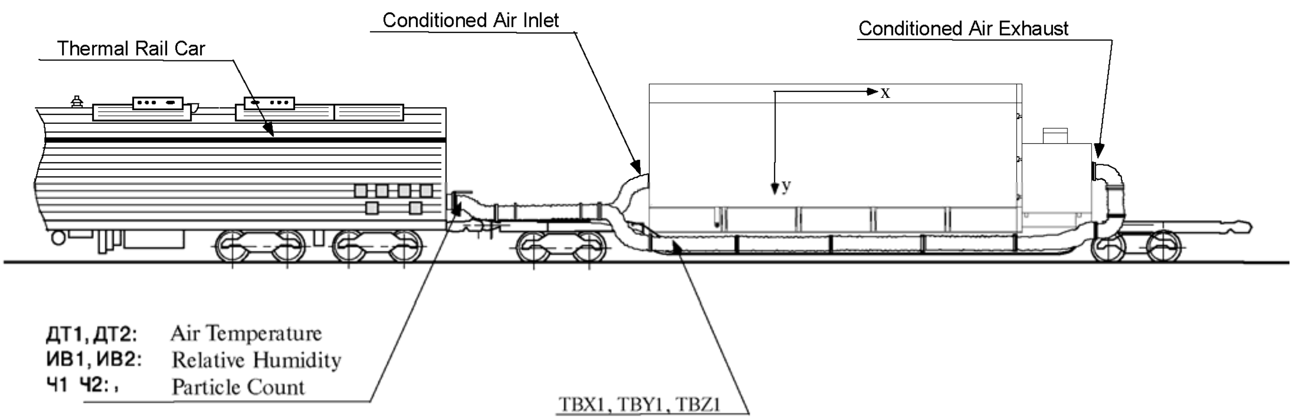


Figure 4.2.1.6-2: Instrumentation During Transportation of AU

Rail transportation of AU from Building 92A-50, Hall 101 to Hall 111.

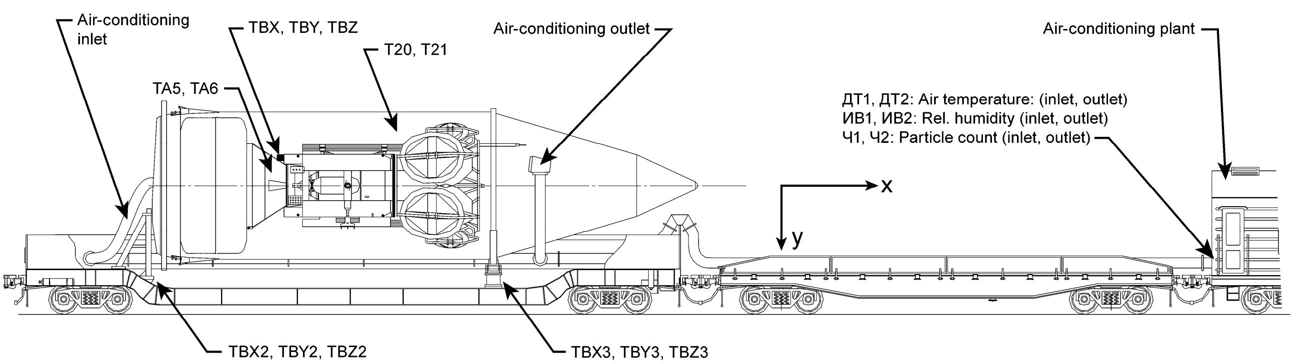


Figure 4.2.1.6-3: Instrumentation During Integration of AU To LV

Temperature, humidity, particle count and witness plate measurements during the AU mate to the LV.

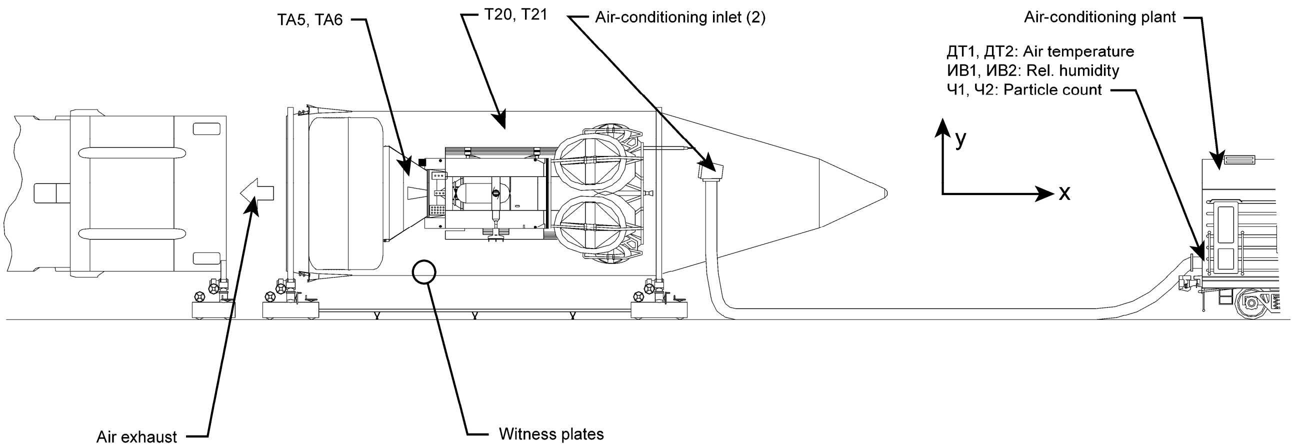


Figure 4.2.1.6-4: Instrumentation During Transportation of Integrated Proton LV

Temperature, humidity, particle count, accelerations and witness plate measurements during transport from Area 95 to the launch pad.

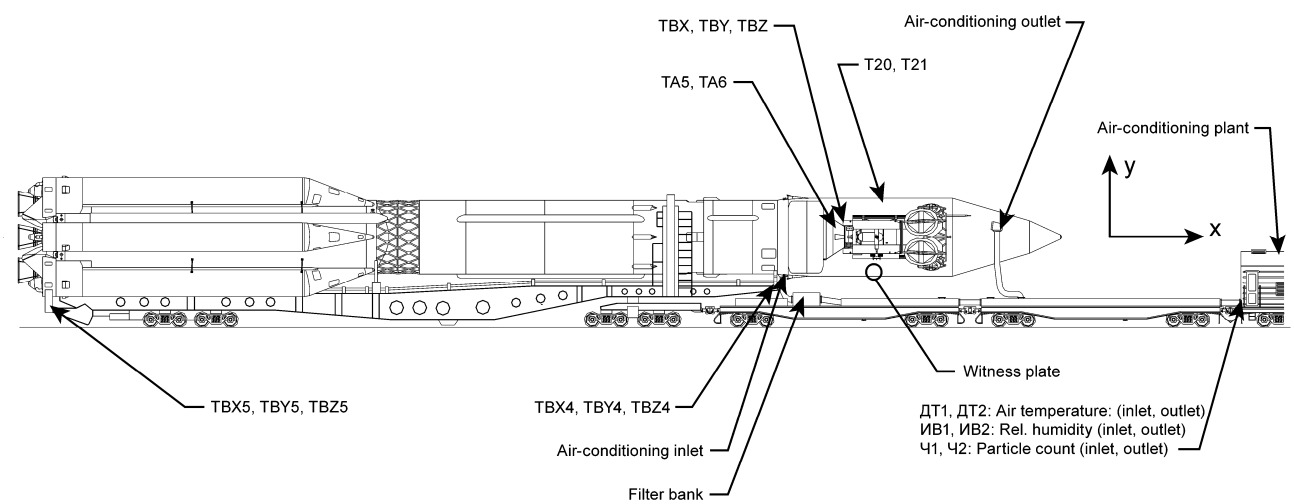
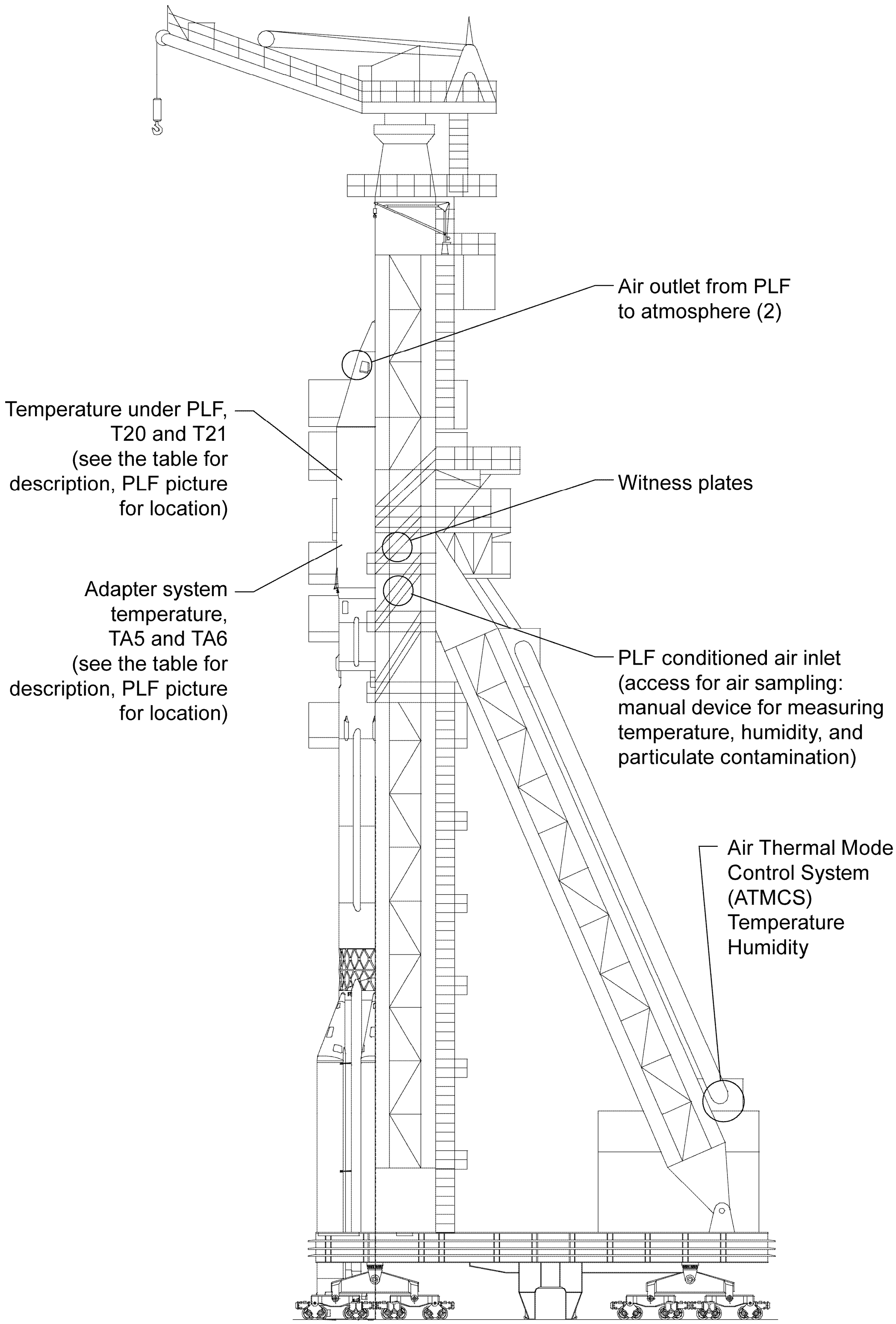


Figure 4.2.1.6-5: Instrumentation During On-Pad Operations

Temperature, humidity, particle count, and witness plate measurements while on the launch pad.



4.2.1.7 Customer-Requested SC Telemetry Recording Through the Breeze M Telemetry System

Upon specific Customer request, SC data may be recorded using the Breeze M telemetry system. Recording capabilities, telemetry volume, and polling frequency shall be determined on a mission-specific basis.

4.2.2 Launch Pad EGSE Interfaces

EGSE electrical interfaces at Pads 24 and 39 are shown in Figures 4.2.2-1 and 4.2.2-2. The two interface connectors described in Section 4.2.1 are wired to a mission-specific wiring harness on the adapter, which is connected to the LV flight umbilical harness running the length of the vehicle to an interface connector Ш06 at the bottom of the first stage. From here, ground cabling connects the umbilical to an interface panel in the Vault under the launch pad, where the Customer electrical interface equipment is located. As can be seen from Figures 4.2.2-1 and 4.2.2-2, there are test access connectors (X9 and X10) on the Breeze M that permit access to the umbilical from the MST up to 8 hours prior to launch. These can be used to interface Customer battery charging power supplies on the MST with the SC. They can also be used to connect with wiring in the MST to provide a parallel path with the flight LV umbilical to reduce overall resistance drop from the SC to Customer GSE for high current power lines.

The launch pad interfaces include connections from the base of the Proton LV (and connections at station 43.85 on the MST, if required) to ground wiring interfacing with SC EGSE. ILS provides all necessary electrical harnesses and cables between the SC/LV In-Flight Disconnects (IFDs) and the SC EGSE interface enables in the Vault and on the MST. Figures 4.2.2-1 and 4.2.2-2 provide block diagrams of the electrical interfaces available between the payload, LV and ground systems.

Figure 4.2.2-1: Electrical Interfaces Between SC and EGSE at Launch Complex 81, Pad 24

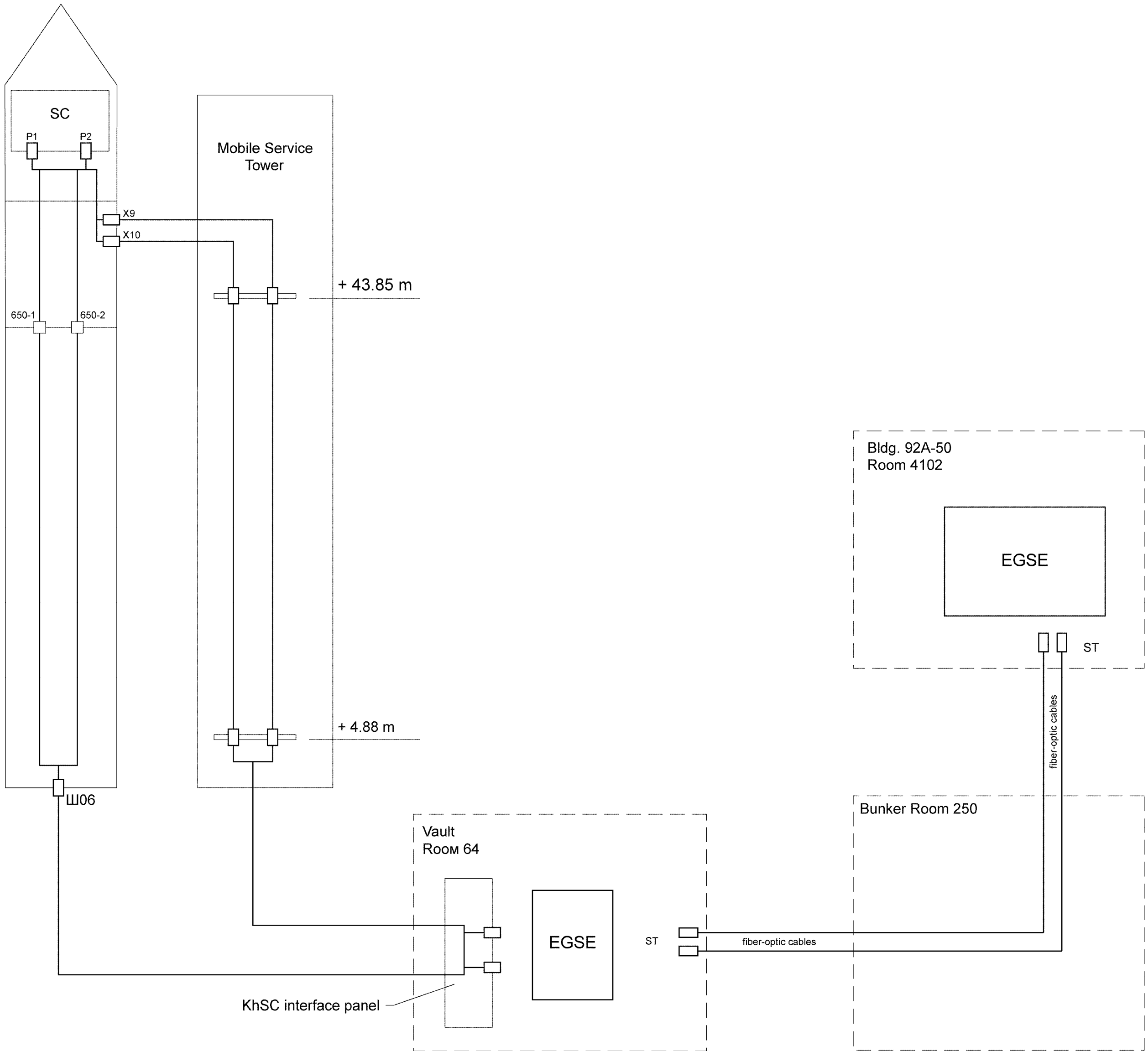
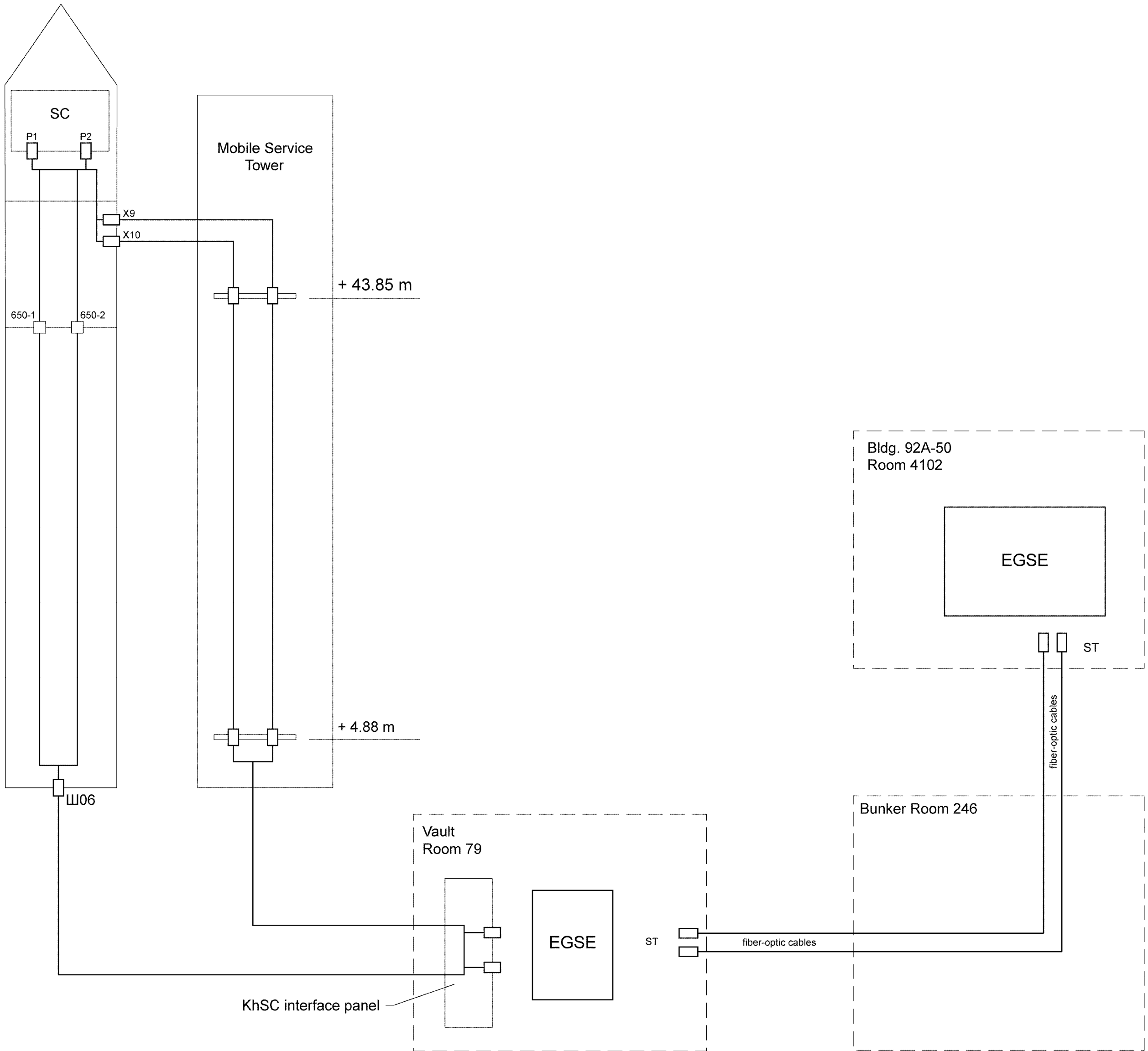


Figure 4.2.2-2: Electrical Interfaces Between SC and EGSE at Launch Area 200, Pad 39



The Proton M transit cable for commercial SC is routed through the Proton M LV stages from bottom connector Ш06 to electrical connectors 650-1 and 650-2 located at the interface between the Proton M LV third stage and the Breeze M.

The Proton M transit cable includes:

Unshielded wires	71 pcs
Shielded wires	19 pcs
Shielded twisted pairs	20 pairs (40 pcs)
Three wires inside a common shield	2 groups (6 pcs)
Cable for transmission of remote control signals	6 pairs (12 ea)
Total conductors	148 + 2 shields

The transit cable has the following parameters:

- I_{min} = 1 milliampere with V_{min} = 1 mV in one contact circuit.
- $I_{operating}$ = 1.5 A per wire.
- V_{max} = 100 V (on SC umbilical connectors), also accounting for voltage peaks taking place at transient processes.
- $I_{\Sigma max}$ = 140 A, is the maximum transit cable current from connectors 650-1 and 650-2, located at the interface on the Proton M LV third stage, to bottom connector Ш06 over a time not to exceed 1000 hours.
- Breeze M and Proton M transit cable have the same configuration.
- The Breeze M transit cable is laid from:
    - Electrical connectors 650-1 and 650-2, located at the interface between the Proton LV third stage and the Breeze M, to the electrical connector, located at the interface between the Breeze M and the AS.
- The shields of single conductors, twisted pairs, and connections using three conductors in Proton LV and Breeze M transit cables are interconnected and linked via electrical connectors to the shields of other cable wiring. Proton M LV transit cable shields connect to pins in bottom electrical connector Ш06. Conductor shields in transit cables are insulated from external cable sheathing, electrical connector housings, and the LV hull.
- The maximum resistance of one line is 2.9 Ohm.
- Wire insulation resistance should not be less than 5 MOhm.
- The LV/AU interface qualification is carried out by using connectors located on the Breeze M.

The external sheathing of onboard cables is current-conducting and is connected to the LV hull.

Signal and power grounds from the SC are passed through the umbilical without connecting them to the LV structure. Likewise, umbilical shield grounds are isolated from the LV structure.

4.2.2.1 Restrictions on EGSE Electrical Interface Parameters

Maximum voltage on SC P1 and P2 umbilical connectors is 100 V.

The Customer should provide means of limiting current in all electrical interfaces between the SC and EGSE in order to prevent damage to LV ground and on-board systems due to a short. SC test equipment should turn off power no longer than 0.2 second after the permissible current level is exceeded by 50%.

Before mating or demating umbilical connectors, the SC and GSE power should be powered off (no current or voltage on the line).

At lift-off, the transit cable should be void of current both on the SC and GSE side, except jumpers in the umbilical connectors.

4.2.2.2 Fiber-Optic Data Transmission System

To provide communication capability to the checkout equipment situated in the technical complex and launch complex areas, KhSC makes available a Fiber-Optic Data Transmission System (FODTS).

A schematic layout of the FODTS at the technical complex and launch complex is shown in Figure 4.2.2.2-1.

Table 4.2.2.2-1 sums up the fiber-optic cable characteristics.

Table 4.2.2.2-2 shows numbers of the fiber-optic cables routed between the technical complex and launch complex facilities.

Reconfiguring of the fiber-optic communication lines is possible by reconnecting (switching over) at patch panels in Room 4124 of Building 92A-50, Room 250 of Building 84-1, and Room 246 of Building 201-1.

The control room (Room 4102) of Building 92A-50 houses the Central Transmitter/Receiver Device (CTRD).

Halls 101 and 111 of Building 92A-50, the Breeze M fueling workstation, Rooms 64 and 76 of Building 81-1, and also Rooms 79 and 82 of Building 200-2 accommodate the Peripheral Transmitter/Receiver Devices (PTRD).

For connection of the CTRD and PTRD, their side panels are provided with ST optical connectors.

Figure 4.2.2.2-1: Schematic Layout of Fiber-Optic Data Transmission System

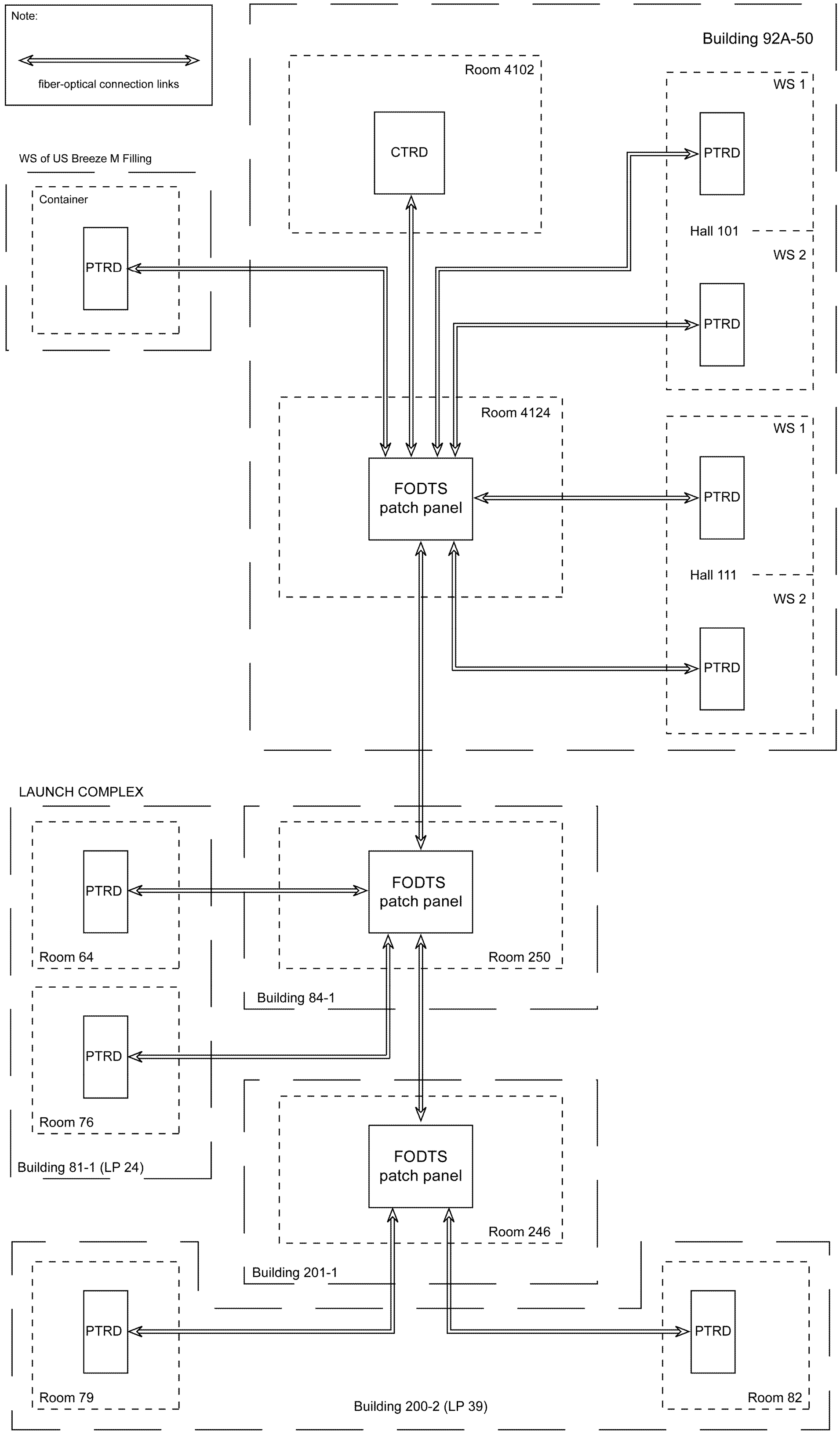


Table 4.2.2.2-1: Characteristics of Fiber-Optic Cables

Characteristics	Values
Fiber type	Single mode, 10/125
Attenuation factor at 1310 nm wavelength	0.4 dB/km
Cable outer diameter	18 mm
Cladding diameter	125 μm ± 2.0 μm
Operating temperature	-40° C to +50° C
Optical connector type	ST

Table 4.2.2.2-2: Numbers of Fiber-Optic Cables Routed Between Technical Complex and Launch Complex Facilities

Where From			Where To			Number of Cables	Number of Fibers in Cables
Device	Building	Room	Device	Building	Room		
CTRD	92A-50	4102	Patch Panel	92A-50	4124	5	6
Patch Panel	92A-50	4124	PTRD	92A-50	101 WS № 1	5	6
			PTRD		101 WS № 2	5	6
			PTRD		111 WS № 1	5	6
			PTRD		111 WS № 2	5	6
			PTRD	Breeze M Fueling Area		2	16
			Patch Panel	84-1	250	2	16
Patch Panel	84-1	250	PTRD	81-1	64	5	6
			PTRD		76	5	6
			Patch Panel	201-1	246	2	16
Patch Panel	201-1	246	PTRD	200-2	79	2	16
			PTRD		82	2	16

4.2.3 Telemetry/Command RF Links

An RF command and telemetry channel will be provided between the SC on the launch pad and SC test equipment in Building 92A-50 Control Room 4102. The RF channel is used for radio transmissions from the time of ILV erection until the lift-off. The SC test equipment should have two RF connectors, of which one is used for telemetry input and the other for command output. Through these connectors, SC test equipment is linked to the KhSC RF channel equipment located in the Bunker and connected to the Bunker roof antenna. With a retracted MST, the signals are transmitted directly between the SC antenna and the Bunker roof antenna. With the MST forward, the signals between the SC antenna and the Bunker antenna are transmitted through a relay on the MST.

Figure 4.2.3-1 shows a general block diagram of the RF link.

KhSC will provide an RF channel in compliance with the Customer's requirements with characteristics similar to one of the five channels presented in Tables 4.2.3-1a, 4.2.3-1b, 4.2.3-1c, 4.2.3-1d and 4.2.3-1e.

In order to ensure compatibility with the KhSC RF channel equipment, the Customer should observe the following requirements:

a) The SC checkout station shall have two physical interfaces; one for commands and the other for telemetry.

b) Total SC test equipment interface impedance should be 50 Ohms.

c) The Customer should provide KhSC with an estimate of signal degradation values for signals passing through a radio transparent window. This degradation will be verified while checking the channel after the SC is encapsulated in the integration facility. The radio channel check at the integration facility shall be performed by using SC Contractor equipment and personnel.

d) The Customer should provide KhSC with SC and radio test equipment per the characteristics in Appendix C.

RF operations are coordinated with the Roscosmos to ensure RF silence as required by pad operations or other reasons. There will be no more than a 20 minute outage of the RF link when the MST crosses the RF line of site during rollback.

Figure 4.2.3-1: SC-to-Building 92A-50 Control Room RF/Electrical Interface Block Diagram

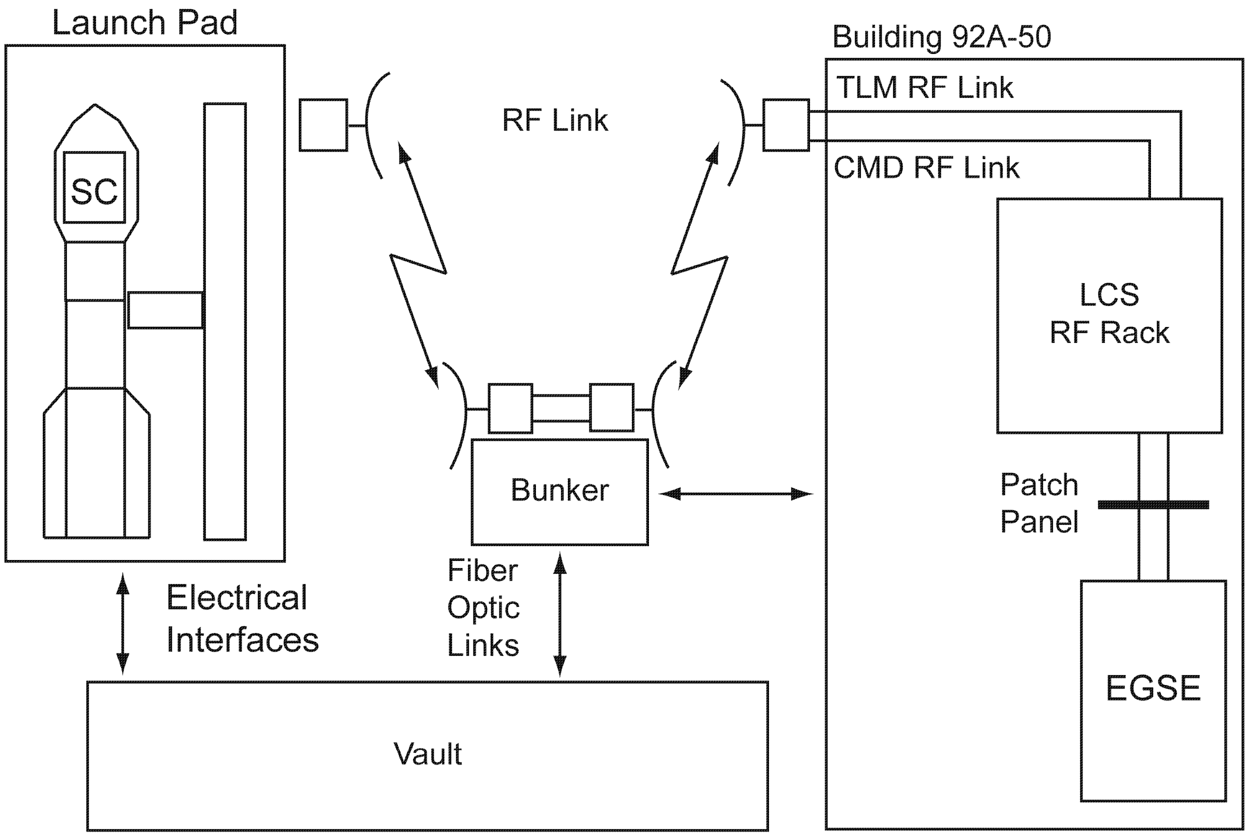


Table 4.2.3-1a: C-Band RF Link Characteristics

Telemetry Link		
Reference	**Value**	**Note**
Frequency range (GHz)	3.95 ± 0.2	
Bandwidth (MHz)	> 250	
Signal polarization	Left-hand circular	
Radio link output signal power		
Maximum (dBm)	-0.0	With MST rolled back
	-6.2	With MST in place
Minimum (dBm)	-30.0	With MST rolled back
	-36.2	With MST in place
Radio link gain factor (dB)	-31.0 ± 5	With MST rolled back
	-42.2 ± 2	With MST in place
Gain factor adjustment limit for radio link input (dB)	30	
Radio link output SNR (dB·Hz)	64	

Command Link		
Reference	**Value**	**Note**
Frequency range (GHz)	6.42 ± 0.05	
Bandwidth (MHz)	> 200	
Signal polarization	Right-hand circular	
Radio link output signal power*		
Maximum (dBW/m^2)	-22.2	With MST rolled back
	-38.6	With MST in place
Minimum (dBW/m^2)	-72.2	With MST rolled back
	-88.6	With MST in place
Radio link gain factor (dB)	-43.2	With MST rolled back
	-38.6	With MST in place
Gain factor adjustment limit for radio link input (dB)	30	
Radio link output SNR (dB·Hz)	70	

*Radio link output signal power means antenna power flux with antenna gain = 0 dB.

Table 4.2.3-1b: Ku-Band RF Link 1 Characteristics

Telemetry Link		
Reference	**Value**	**Note**
Frequency range (GHz)	11.1 ± 0.2	
Bandwidth (MHz)	> 250	
Signal polarization	Linear, vertical	
Radio link output signal power		With SC antenna input signal power of 0 dBW
Maximum (dBm)	-31	With MST rolled back
	-37	With MST in place
Minimum (dBm)	-41	With MST rolled back
	-41	With MST in place
Radio link gain factor (dB)	-78.3 ± 5	With MST rolled back
	-80.0 ± 2	With MST in place
Gain factor adjustment limit for radio link input (dB)	30	
Radio link output SNR (dB·Hz)	118	

Command Link		
Reference	**Value**	**Note**
Frequency range (GHz)	14.0 ± 0.05	
Bandwidth (MHz)	> 200	
Signal polarization	Linear, horizontal	
Radio link output signal power*		With SCS antenna input signal power of 3 dBW
Maximum (dBW/m^2)	-55.5	With MST rolled back
	-61.5	With MST in place
Minimum (dBW/m^2)	-65.5	With MST rolled back
	-65.5	With MST in place
Radio link gain factor (dB)	-78.3	With MST rolled back
	-80.0	With MST in place
Gain factor adjustment limits for radio link input (dB)	from -65 to -41 from -67 to -43	
Radio link output SNR (dB·Hz)	123	

*Radio link output signal power means antenna power flux with antenna gain = 0 dB.

Table 4.2.3-1c: Ku-Band RF Link 2 Characteristics

Telemetry Link		
Reference	**Value**	**Note**
Frequency range (GHz)	12.2 ± 0.2	
Bandwidth (MHz)	> 250	
Signal polarization	Left-hand circular	
Radio link output signal power		With SC antenna input signal power of 0 dBW
Maximum (dBm)	2	With MST rolled back
	-3	With MST in place
Minimum (dBm)	-8	With MST rolled back
	-7	With MST in place
Radio link gain factor (dB)	-35 ± 5	With MST rolled back
	-45 ± 2	With MST in place
Gain factor adjustment limit for radio link input (dB)	30	
Radio link output SNR (dB·Hz)	118	

Command Link		
Reference	**Value**	**Note**
Frequency range (GHz)	14.0 ± 0.05	
Bandwidth (MHz)	> 200	
Signal polarization	Right-hand circular	
Radio link output signal power*		With SCS antenna input signal power of 3 dBW
Maximum (dBW/m^2)	-31	With MST rolled back
	-36	With MST in place
Minimum (dBW/m^2)	-41	With MST rolled back
	-40	With MST in place
Radio link gain factor (dB)	-78.3	With MST rolled back
	-80.0	With MST in place
Gain factor adjustment limits for radio link input (dB)	from -50 to -80 from -52 to -82	
Radio link output SNR (dB·Hz)	123	

*Radio link output signal power means antenna power flux with antenna gain = 0 dB.

Table 4.2.3-1d: Ku-Band RF Link 3 Characteristics

Telemetry Link		
Reference	**Value**	**Note**
Frequency range (GHz)	12.45 ± 0.25	
Bandwidth (MHz)	> 500	
Signal polarization	Linear horizontal	
Radio link output signal power		
Maximum (dBm)	-8.0	With service tower rolled back
	-14.4	With service tower in place
Minimum (dBm)	-44.0	With service tower rolled back
	-49.4	With service tower in place
Radio link gain factor (dB)	-74.0	With service tower rolled back
	-79.4	With service tower in place
Gain factor adjustment limit for radio link input (dB)	30	
Radio link output SNR (dB·Hz)	118	

Command Link		
Reference	**Value**	**Note**
Frequency range (GHz)	17.3 ± 0.05	
Bandwidth (MHz)	> 200	
Signal polarization	Linear vertical	
Radio link output signal power*		
Maximum (dBW/m^2)	-59.0	With service tower rolled back
	-59.1	With service tower in place
Minimum (dBW/m^2)	-89.0	With service tower rolled back
	-89.1	With service tower in place
Radio link gain factor (dB)	-93.0	With service tower rolled back
	-96.0	With service tower in place
Gain factor adjustment limit for radio link input (dB)	30	
Radio link output SNR (dB·Hz)	155	

*Radio link output signal power means antenna power flux with antenna gain = 0 dB.

Table 4.2.3-1e: Ka-Band RF Link Characteristics

Telemetry Link		
Reference	**Value**	**Note**
Frequency range (GHz)	18.3 ± 0.01	
Bandwidth (MHz)	≤ 100.0	
Signal polarization	circular	
Radio link output signal power		
Maximum (dBm)	-11.0	With MST rolled back
	-5.0	With MST in place
Minimum (dBm)	-41.0	With MST rolled back
	-35.0	With MST in place
Radio link gain factor (dB)	-41.0 ± 5.0	With MST rolled back
	-35.0 ± 5.0	With MST in place
Gain factor adjustment limit for radio link input (dB)	≥ 30.0	
Radio link output SNR (dB·Hz)	68.0	

Command Link		
Reference	**Value**	**Note**
Frequency range (GHz)	29.374 ± 0.12	
Bandwidth (MHz)	≤ 100.0	
Signal polarization	any	
Radio link output signal power*		
Maximum (dBW/m^2)	-70.4	With MST rolled back
	-67.4	With MST in place
Minimum (dBW/m^2)	-100.4	With MST rolled back
	-97.4	With MST in place
Radio link gain factor (dB)	-38.0 ± 3.0	With MST rolled back
	-41.0 ± 3.0	With MST in place
Gain factor adjustment limit for radio link input (dB)	≥ 30.0	
Radio link output SNR (dB·Hz)	45.0	

*Radio link output signal power means antenna power flux with antenna gain = 0 dB.

4.2.4 Electrical Grounding

All payload preparation areas used by the SC, as well as launch base facilities used by the SC and SC EGSE, are equipped with earth-referenced steel ground busses with equipment attach points (threaded studs). The resistance between any point on these bars and the building earth ground is less than 4 ohms. The floor surfaces in the payload and hazardous payload processing areas is anti-static and connected to the facility grounding system. The SC contractor shall provide all cables and attachment hardware required to interconnect the SC and support equipment with facility grounds. SC grounding at the launch complex is affected via the serially-bonded adapter, Breeze M, and lower three Proton stages.

4.2.5 Electrical Bonding

The resistance across the SC/adapter separation plane shall not exceed 10 milliohms at a current less than 10 milliamperes, to be measured prior to the installation of separation pyrotechnics. This may be accomplished either by conductive surface contact between the SC and adapter interface ring (1666 adapters) here, the metal structures of the SC and the LV AS are irreversibly disconnected electrically during flight at the umbilical connector housings or by the use of two bonding straps which incorporate a friction contact connector that releases upon SC separation with a separation force of 40 N $\pm$ 5 N (as required by the SC Contractor). The outer surface of the transit cables will be made conductive and electrically joined to the LV body, with resistance not in excess of 1 milliohm.

4.2.6 SC/LV Lightning Protection

All payload preparation areas used by the SC (except the launch complex) will be equipped with a lightning protection system for direct and indirect hits. Augmentation of the standard provisions for any necessary SC individual circuit protection shall be provided by the SC contractor. The launch complex service tower will protect solely against direct lightning hits. Launch constraints preclude launching during a thunderstorm.

4.2.7 Electrostatic Discharge

During the entire flight through SC separation, no electrostatic discharge shall occur from either the LV or the SC surface through the LV-to-SC interface plane.

4.3 FITCHECK OF MECHANICAL/ELECTRICAL INTERFACES

A fitcheck of electrical/mechanical interfaces with the flight adapter and SC is required at the SC manufacturer's facility for first-of-a-kind SC and the first follow-on SC in a series. Details are available in the ILS Fitcheck Release Test Philosophy document.