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VOLATILES INVESTIGATING POLAR EXPLORATION ROVER

VIPER – PROGRAM OF RECORD TECHNICAL INFORMATION TO INFORM PARTNERSHIP PROPOSAL FORMULATION

February 3, 2024

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1 PURPOSE AND SCOPE FOR USE IN PARTNERSHIP PROPOSALS

This document is a reference document to support the Lunar Volatiles Science Partnership and the associated Announcement for Partnership Proposals (AFPP). The AFPP contains broader context on this partnership and how it builds off of the VIPER project, which NASA announced was proposed for cancellation in July, 2024. NASA is seeking a partner to deliver its VIPER rover to the Moon and wants to use this document to provide important interface and technical information that proposals will need.

This document documents and builds upon the technical requirements that the VIPER project developed as part of their initial 'program of record' approach to land on the Moon using a lander procured by the Commercial Lunar Payload Services (CLPS) initiative. VIPER will no longer fly on a CLPS lander and the partnership proposers are expected to have their own landing and science operation approaches for accomplishing a partnership with VIPER. The technical requirements in this document describe VIPER's mission operation concept and needs under the prior program of record, and some may not be applicable.

A proposer to the AFPP may utilize this document to develop their own technical requirements for a Lunar Volatiles Science Partnership approach to deliver the VIPER Surface Segment to the lunar surface, to conduct VIPER's Mission, and to achieve VIPER's science objectives. The types of requirements contained herein include interface definitions with corresponding interface requirements, mission operations requirements across the phases of the mission, and integrated test requirements and test activities between NASA/VIPER and the partner organization. Some of these items illustrate the complexity of choosing a landing site for lunar traverse, how to operate the rover, among other considerations.

Respondents to the AFPP may consider and potentially incorporate relevant technical features from this document as part of their technical proposals, and may make reference to it. If selected for a partnership, the LVSP partner's proposal would then be coordinated into a Cooperative Research and Development Agreement with core technical responsibilities, along with a Technical Implementation Plan (TIP) with critical technical requirements defined based on the partner's proposal. Agreement between NASA and the partner on the TIP and subsequent implementation approaches will help to formalize the approach

Because this document captures requirements from the prior program of record that involves utilization of a CLPS contractor for delivery to the Moon, many of the items in this requirement still utilize the original phrasing of "the Contractor" within this Technical Requirements Document. NASA intends to select a partner for this effort and is not using a formal contract. As appropriate based on their technical approach, the AFPP proposer may interpret such claims as potential applying to "the Partner", or to the organization that will be selected by the AFPP process. Further, for flight hardware interfaces tied to the Partner's landing delivery approach, "the Lander" is specifically cited.

There are TBDs within this document that would likely be very dependent on the LVSP partner's proposed approach for delivering the VIPER rover to the Moon (such as the timing of when VIPER delivery would occur). This document does include the former program of record landing site location, which may be a site of interest for AFPP proposers due to its known ability to support execution of science goals. After Partner selection, there will be additional effort needed to resolve these TBDs.

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3 INTERFACES

The interfaces defined in this document include the Space Segment between the Lander and VIPER Surface Segment, and Ground Segment between the Contractor Mission Operations Center (MOC) and VIPER Missions Operations Center. Interfaces are depicted in Figures 3-1 and 3-2.

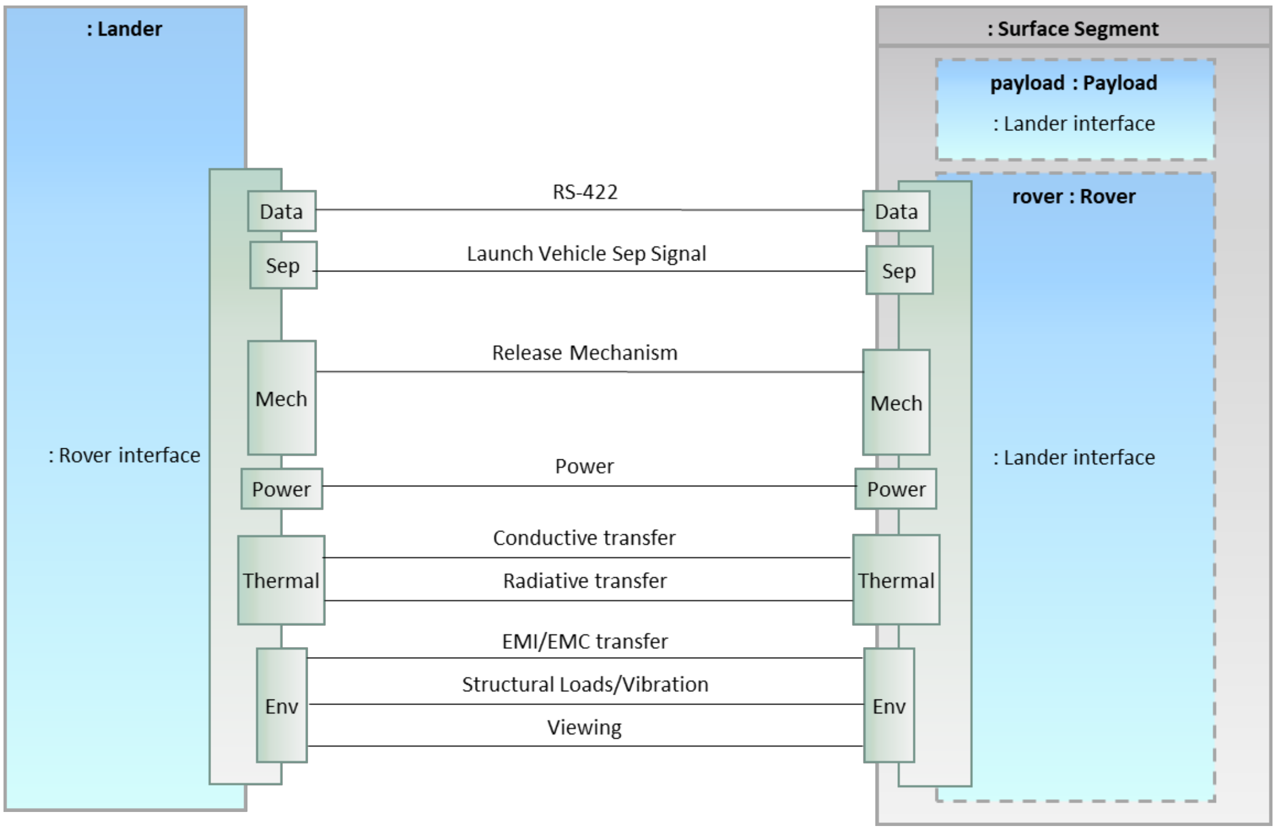


Figure 3-1. Lander-to-VIPER Surface Segment Interface Context Diagram

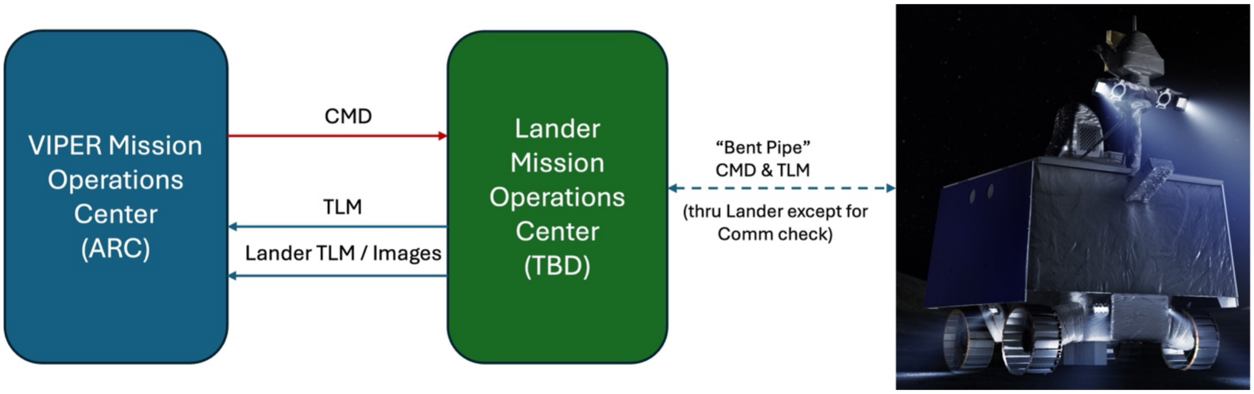


Figure 3-2. Lander-to-VIPER Mission Operations Centers Diagram

4 *LUNAR DELIVERY TASK PERFORMANCE OBJECTIVES*

In support of the VIPER Mission goal to achieve Level 1 Science Requirements, VIPER expects summarized task performance needs will be fulfilled by the Contractor to enable successful delivery of VIPER to the lunar surface. These performance needs form the basis from which the technical requirements defined in Section 5 of this document have been derived.

The Contractor will:

- lead mission planning, reviews, integration, and test activities with VIPER from the start of contract award through delivery of VIPER to the lunar surface;
- provide a delivery service to the lunar surface which satisfies VIPER interface and technical requirements;
- ensure that the Lander and any co-manifested payload will not interfere with VIPER (e.g. physical, EMI/EMC or other operational interferences);
- satisfy contamination and cleanliness requirements;
- participate in mission planning, pathfinding, evaluation, engineering, simulation, ORTs, rehearsals with the VIPER team prior to VIPER hardware delivery to the contractor integration facility;
- accept delivery of VIPER hardware, integrate VIPER with the Lander, and perform integrated flight vehicle testing including end-to-end testing with the Contractor and VIPER mission operations centers;
- define the Lander design and operations approach for VIPER egress to the lunar surface;
- deliver VIPER to the lunar surface on a date and time specified by NASA;
- provide landing location and Lander/VIPER orientation information at landing, and egress path imagery;
- and prior to and after launch, provide trajectory and space vehicle attitude data to enable VIPER to manage thermal, power, and data communications performance, and perform VIPER system checkout during lunar transit prior to landing.

5 TECHINCAL REQUIREMENTS

5.1 SCHEDULE REQUIREMENTS

5.1.1 LUNAR DELIVERY

[1] The Contractor shall deliver VIPER to the lunar surface within a 2-hour window of time that begins on TBD DATE at TBD TIME UTC for a verified traverse that meet VIPER measurement requirements. Final landing start date and time will be determined after contract award.

[2] The Contractor shall guarantee there are multiple launch windows that meet the landing date and times which satisfy the VIPER measurement requirements until successful launch.

5.1.2 INTEGRATION

[3] The Contractor shall accept physical delivery of VIPER and associated Ground Support Equipment (GSE) at the launch site payload processing facility.

VIPER GSE Hardware:

- VIPER Shipping Container (VSC) Base (Footprint: 14' x 14')
- VIPER Shipping Container (VSC) LID (Footprint: 14' x 14')
- Rover Cover (Footprint: 14' x 14')
- SHADE 2-4 (9' x 7' x 10'H)
- SHADE 6 (7' x 7' x 3'H)
- VIPER Dolly (SSMURF)
- 6 Workstations
- Steel Cages
- 3 ESD Carts
- 1 VIPER Ground Power Unit (GPU)
- 1 VIPER RF Rack
- 1 VIPER SSTAN
- 1 Rigging Box
- 2 Tool Chest
- VSC Dollies
- SHADE 6 Cart

[4] The Contractor shall support 10-days business days of VIPER activities upon arrival at the Launch Site Payload Processing Facility prior to Lander Integration.

5.2 LANDING SITE AND LANDER LANDING REQUIREMENTS

[5] The Contractor shall deliver VIPER to the moon at 85.4451243175º south latitude and 30.9437378907º east longitude using the Moon Mean Earth coordinate frame defined by

https://lunar.gsfc.nasa.gov/library/LunCoordWhitePaper-10-08.pdf. Final landing location will be determined after contract award.

[6] The Contractor shall deliver VIPER to the moon within 100 meters of the landing site location that enables a valid VIPER traverse that meets the VIPER measurement plan.

[7] The Lander shall land in an orientation that allows the VIPER solar arrays to be exposed to direct sunlight as shown in Figure 5.2-1.

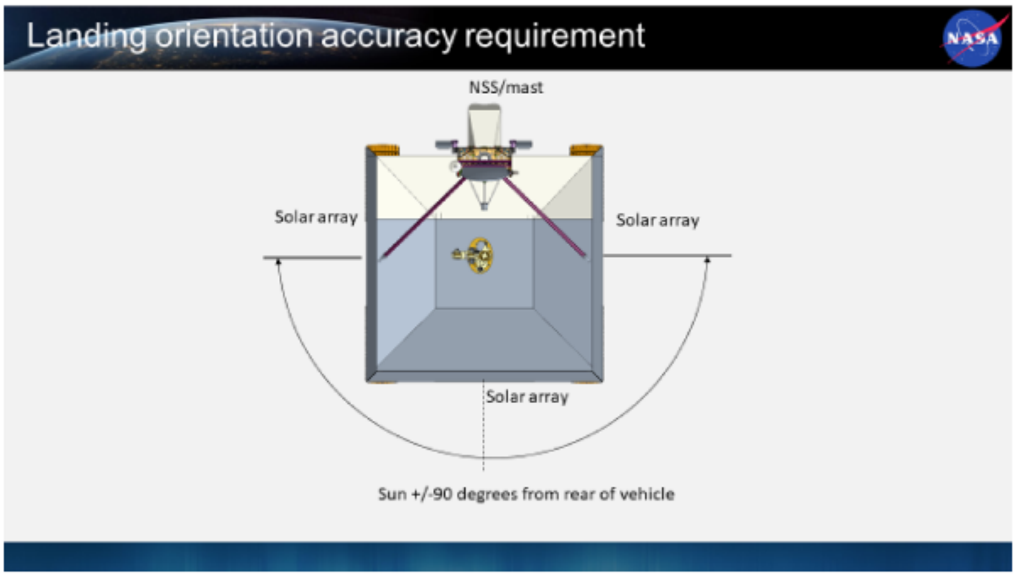


Figure 5.2-1. Landing Orientation Accuracy with respect to Sun

[8] The Lander shall land in an orientation that allows the VIPER high gain antenna to have line of sight to Earth. VIPER HGA position and nominal pointing direction are defined in Section 5.4.1.4 in this document.

[9] The Lander shall land in a location with an effective slope of ≤ 10 degrees. Effective slope is defined as the angle between the local gravity vector and a vector perpendicular to the plane fitted to the terrain circumscribed by the four landing feet of the lander.

[10] The Lander shall land in a location which has an effective slope of ≤ 10 degrees for at least two lengths of the Rover in the egress path past the Lander structure. Rover vehicle length is defined in Section 5.4.1.2 in this document.

[11] The Lander shall land in a location within at least two rover lengths with obstacles ≤ 15 cm in step-height.

[12] If the Contractor uses a Lander ramp design for VIPER egress, the deployed Lander Egress Ramps shall be at an angle no greater than 30 degrees total which includes ramp deformation with rover load (including local terrain slope and lander deck attitude) with respect to Lunar gravity during Rover egress.

[13] Any drop-off at the end of the deployed Lander Egress Ramps shall be no greater than 16 cm.

[14] If the NASA Rover is lowered to the ground via a crane or davit type approach, the NASA Rover most be lowered to within 1 cm of the lunar surface before the NASA Rover is released.

5.3 PAYLOAD PROCESSING / LANDER DO-NO-HARM REQUIREMENTS

5.3.1 NON-INTERFERENCE

[15] The Contractor shall ensure that the Lander or other co-manifested payloads cannot interfere with the VIPER (e.g. physical, EMI/EMC, cleanliness/contamination or other operational interferences) during any mission phase from pre-integration to post-VIPER egress onto the lunar surface.

5.3.2 CONTAMINATION AND CLEANLINESS

[16] The Lander external surfaces shall be visibly clean per IEST-STD-CC1246.

[17] The Lander flight materials shall meet outgassing screening criteria of 0.1% CVCM and 1.0% TML per NASA RP-1124, exceptions must be approved by TBD technical or project management authority.

[18] The Lander shall not contain silicone material due to VIPER's science payloads are sensitive to silicone material outgassed species.

[19] The Contractor shall not exceed the specified TBD particulate contamination requirements during flight, descent and landing, lander surface operations, and lander passivation post-VIPER egress onto the lunar surface. VIPER Project is required to analyze the risk to VIPER external surfaces, optical surfaces, payloads, and sensors for any contaminate degradation resulting from Launch Vehicle/Lander, exhausts plumes, passivation vents, and/or lunar dust from descent/landing.

5.4 INTERFACE REQUIREMENTS

This section defines the interface requirements applicable to the Contractor's system end products, such as the Lander, and includes relevant interface definitions of the VIPER design which correspond to the interface requirement applicable to the Contractor's interfacing system. Wherever possible, this information is arranged as a [Requirement] and additional "Interface Definition" to provide more information about the interface.

5.4.1 SURFACE SEGMENT INTERFACE REQUIREMENTS

5.4.1.1 ENVELOPES

5.4.1.2 STATIC ENVELOPE

[20] The Contractor shall accommodate the mechanical integration of the VIPER Static Envelope, defined in outer vehicle dimensions of 1.7m x 1.7m x 2.5m (base x height), with the Lander.

5.4.1.3 DYNAMIC STAY-IN ENVELOPE

[21] The Contractor shall accommodate the VIPER Dynamic Envelope defined in Figure 5.4-1 for launch, flight, and landing phases of the mission.

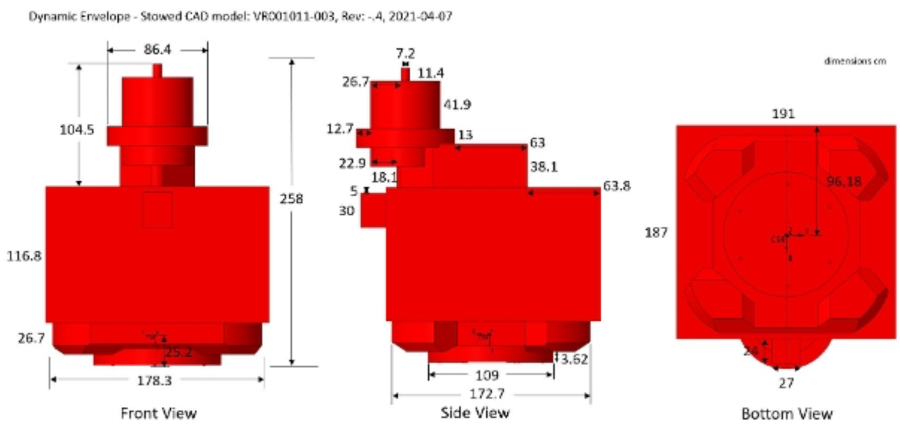


Figure 5.4-1. VIPER Dynamic Stay-In Envelope

5.4.1.4 TRANSIT COMMUNICATION ENVELOPE

[22] Lander structure and hardware shall remain outside of a 25x25 degree half-angle Keep-Out Zone on the +X side of the rover, shown in Figure 5.4-2 below, to minimize reflective losses during VIPER in-transit communication checkouts with the VIPER HGA stowed at a pan angle of 0 degrees and a tilt angle of -28 +/- 0.1 degrees below the VIPER body frame X-Y plane.

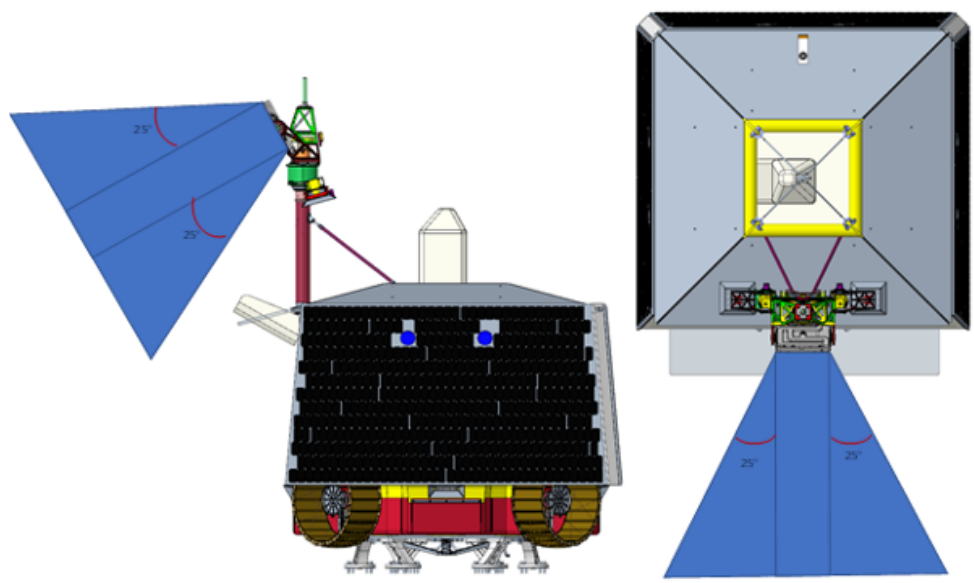


Figure 5.4-2. VIPER HGA Keep-Out Envelope

5.4.1.5 TRANSIT RADIATOR LANDER STAY-OUT ENVELOPE

[23] The Lander shall not contain any structure within the VIPER Radiator Lander Stay-Out Envelope depicted in Figure 5.4-3.

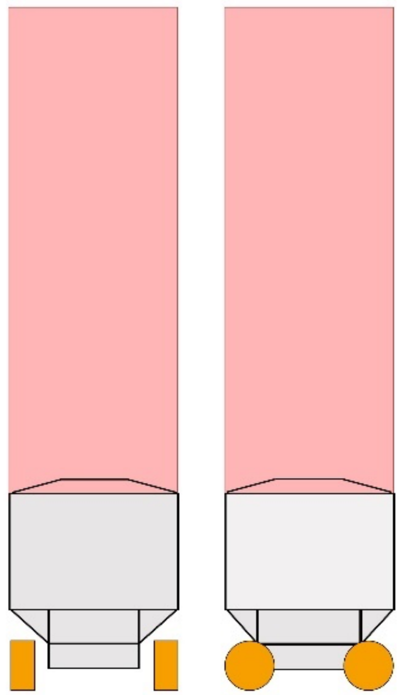


Figure 5.4-3. VIPER Radiator Lander Keep-Out Envelope

5.4.1.6 LANDER EGRESS ENVELOPE

[24] The Lander shall provide an egress path for VIPER that is free from lander structure interference, for VIPER operational activities including post-landing pre-egress kinematic checks, wheel deployment, and egress from the Lander. Contractor will need to work with VIPER to define keep out zones for VIPER suspension, chassis, dust socks to avoid snags on any lander structure features.

Interface Definition:

Table 5.4-1. VIPER Articulated and Mobile Aspects

Articulated or Mobile Aspect	Description	Operation	Stay-In Volume

Navigation Gimbal (Pan/Tilt)	Navigation cameras are located on the mast. The NavCams have Pan and Tilt capability.	Pan ROM = +180.5 / -219.5 deg Tilt ROM = +0 / -75 deg	Per VIPER CAD Model: Gimbal_Motion_Envelope.prt JEDII Version: 1.1
Communication Gimbal (Pan/Tilt)	Communications antennae are located on the mast. The HGA antenna has Pan and Tilt capability. The LGA antenna moves with the HGA Pan motion.	Pan ROM = +0.5 / -399.5 deg Tilt ROM = +25 / -28 deg	Per VIPER CAD Model: Gimbal_Motion_Envelope.prt JEDII Version: 1.1
Drive (Wheel)	The Surface Segment has 4 Wheels, all with continuous rotation.	Drive ROM = +/-360deg	Per VIPER CAD Model: WM-311_Motion_Envelope.prt JEDII Version: 1.1
Steering	The Surface Segment has independent steering control for each Wheel.	Steering ROM = +/-50deg	Per VIPER CAD Model: WM-311_Motion_Envelope.prt JEDII Version: 1.1
Suspension	The Surface Segment has independent suspension control for each Wheel.	Suspension ROM = +/-40deg	Per VIPER CAD Model: WM-311_Motion_Envelope.prt JEDII Version: 1.1
RRM Umbilical Joints (3x)	The RRM has linear slide connector umbilical joints at the three Rover hard points.	RRM Umbilical Stroke = 1.2”	The linear slides operate within the RRM volume.
Thermal Flaps (6x)	Swing close when Surface Segment stands up off the RRM.	N/A	Within the VIPER OML during post RRM release, should not affect Lander-VIPER interfaces. No drawing/model envelope is required
Sun Shade Skirt (2x)	2 skirts hang down Aft side of VIPER (see figure below). Flexible overlapping material that drapes down 20 cm (7.84 inches) from the bottom of the Rover. The design is to	N/A	Sun Shade skirt is a soft goods blanket that designed to move around and over obstacles. The VIPER OML should not affect Lander-VIPER interfaces. No

	intentionally move freely around obstacles.		drawing/model envelope is required.

VIPER mobility kinematic envelope is defined in WM-311_MOTION_ENVELOPE.PRT.

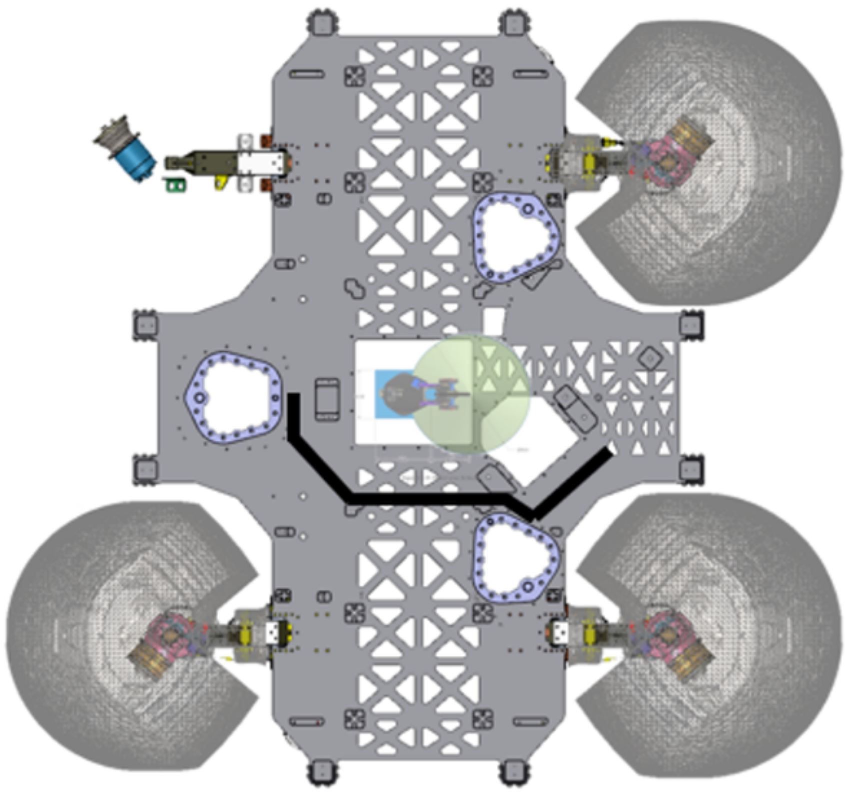


Figure 5.4-5. Sun Shade Skirt

5.4.2 COORDINATE FRAME

[25] The Contractor shall maintain reference to the VIPER Surface Segment Mechanical Coordinate Frame defined in VIPER-MSE-SPEC-002, Surface Segment Mechanical Frame.

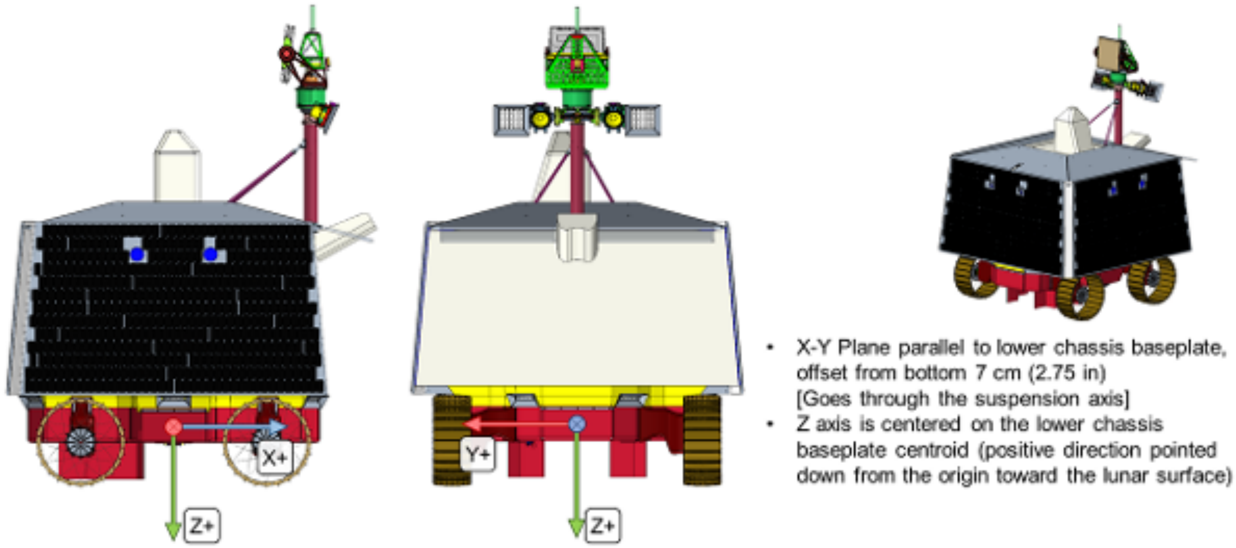


Figure 5.4-6. VIPER Surface Segment Mechanical Frame and Coordinate System

5.4.3 MASS PROPERTIES

5.4.3.1 VIPER FLIGHT ARTICLE, SURFACE SEGMENT, RRM:

[26] The Contractor shall accommodate the VIPER mass properties defined in Table 5.4-2 for all phases of the mission.

Table 5.4-2. VIPER Mass Properties

MASS PROPERTY	UNITS	NOMINAL	RANGE
VIPER Total Mass	kg	490	+/- 10
VIPER CG offset (1)	cm	X = 1.8 Y = -1.1 Z = -40.3	+/-1.5 +/-1.5 +/-1.5
VIPER MOI	kg*m^2	XX = 209.2 YY = 148.7 ZZ = 180.4	+/-4.3 +/-3.0 +/-3.7

Surface Segment (Rover + Payloads) Egress Mass	kg	455	+/- 9.0
Rover Release Mechanism Mass	kg	35	+/- 1.0

(1) Reference VIPER Coordinate Frame per VIPER-MSE-SPEC-002A Section 2.4.1

[Interface Definition] Mass information for integration hardware components:

- The mass of fasteners for the VIPER-to-Lander interface bolted connection is TBD kg.
- The mass of the VIPER-to Lander power and data umbilical cable harness (part number VR090070) is 2.14 kg.
- The mass of the VIPER-to-Lander electrical bonding straps altogether is TBD kgs.

[27] VIPER mass properties will be measured to the accuracies stated in Table 5.4-3.

Table 5.4-3. VIPER Mass Properties Measurement Accuracy

Mass Property	Measurement Accuracy
VIPER Mass	+/- 0.2%
VIPER CoG	+/- 0.635 cm
VIPER MOI	+/- 1.5%

5.4.4 STRUCTURAL / MECHANICAL

5.4.4.1 MOUNTING INTERFACE – ROVER RELEASE MECHANISM (RRM)

[28] The Lander mechanical mounting interface shall meet the VIPER mechanical interface defined in in VRL140003, release NC.

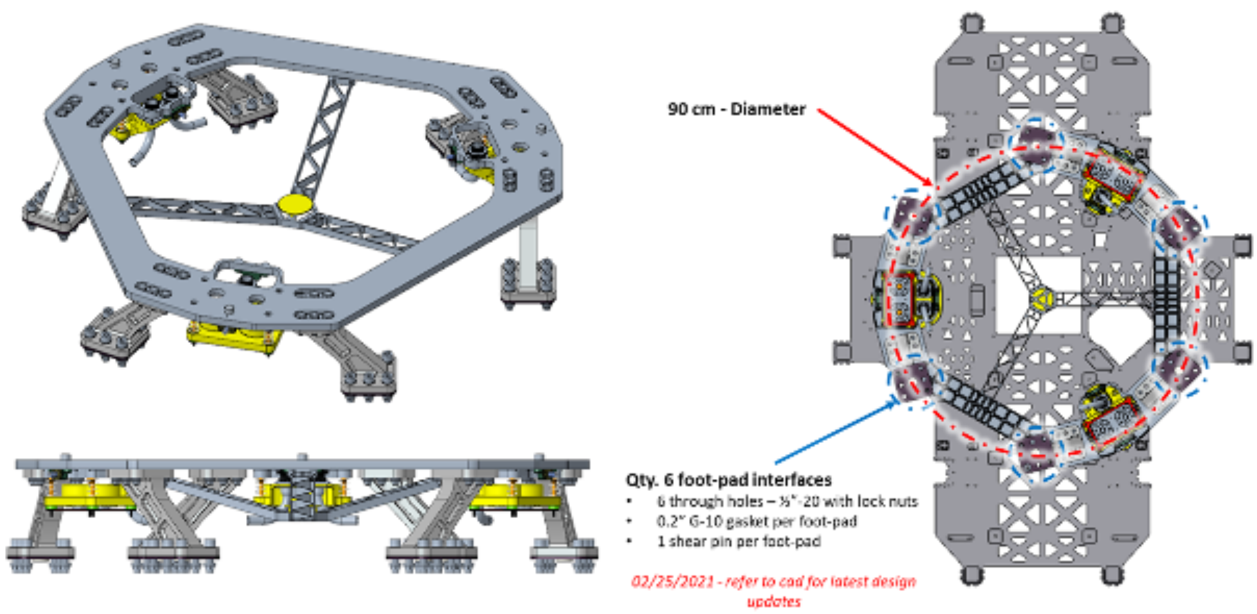


Figure 5.4-7. RRM and Attachment Point

5.4.4.2 SURFACE FLATNESS

[29] The VIPER mounting surface flatness is defined in the latest revision of the VIPER RRM Interface Drawing (VRL140003).

5.4.4.3 RRM MOUNTING FASTENERS

[30] NASA will provide to the Contractor the hardware listed in Table 5.4-4 and Figure 5.4-8 below for mounting VIPER to the Lander. The Contractor may choose to use alternative hardware which meets interface loads and have comparable material characteristics.

Table 5.4-4. RRM Mounting Hardware

Name	**Part Number**	**Quantity**
1/2"-20 Hex Head Bolt	NAS6708U21	36
Flat Washer	MS14183L-C8	36
Flat Washer	NAS1149-C0863R	36

Self-Locking Extended Washer Nut	NAS1291C8	36

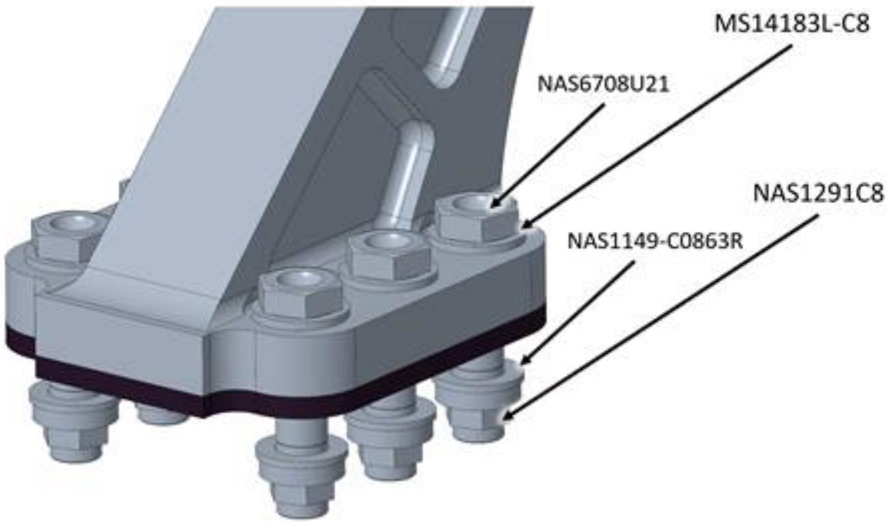


Figure 5.4-8. VIPER Mounting Hardware

5.4.4.4 LOAD PATH

[31] The Contractor shall orient VIPER on the Lander such that launch and landing loads pass through the rover in the gravity direction of the rover (+Z per the VIPER coordinate frame).

5.4.4.5 SURFACE SEGMENT HARDPOINTS

[32] The Contractor shall use the Surface Segment hardpoints for lifting the Surface Segment during integration activities.

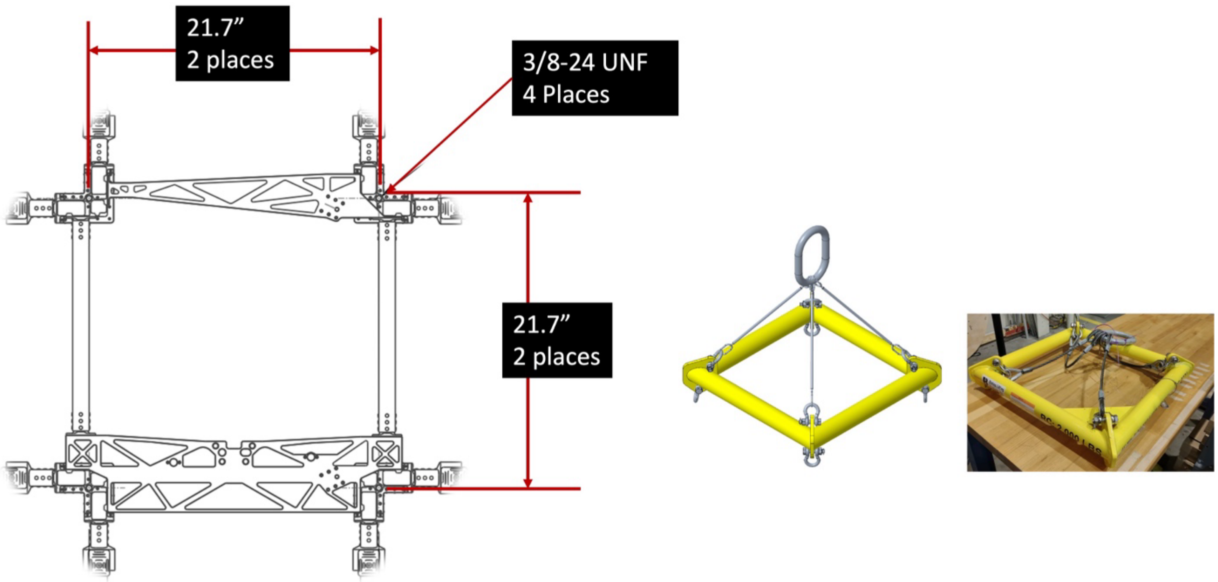


Figure 5.4-9. VIPER Four-Point Lift Fixture and attachment points on VIPER Rover (Top View)

Interface Definition: Indicated lift points are valid for lifting VIPER Surface Segment assembly up to 670 kg. Lifts shall only be performed with vehicle z-axis aligned with gravity. Load vector at the four interfaces points shall be within ± 5° of vehicle z-axis.

5.4.5 EGSE CONNECTORS

5.4.5.1 J3 GROUND POWER CONNECTOR

[33] The Contractor shall provide mechanical structure on the Lander for mounting the VIPER J3 EGSE bulkhead connector. The location of the mounted J3 connector on the Lander shall be physically accessible by personnel for use in ground testing.

Interface Definition: VIPER J3 EGSE bulkhead connector number is Glenair part number 801-009-07M13-220PA (integrated backshell), defined in VR090070, Lander Power to Rover Umbilical Cable Assembly. The available length of cable harness from the RRM-Lander mechanical interface plane to the VIPER J3 bulkhead connector is defined in VR090070. VIPER will connect EGSE to this J3 connector during ground testing.

5.4.5.2 J4 CRYPTO-KEY CONNECTOR

[34] The Contractor shall provide mechanical structure on the Lander for mounting the VIPER J4 crypto-key bulkhead connector. The location of the mounted J4 connector on the Lander shall be physically accessible by personnel in the event it is necessary for the VIPER team to access the Surface Segment crypto-key interface.

Interface Definition: VIPER J4 crypto-key bulkhead connector number is Glenair part number 280-020P4H62MEGP, defined in VR090070. The available length of cable harness from the RRM-Lander mechanical interface plane to the VIPER J4 bulkhead connector is defined in VR090070. VIPER team will connector to this J4 connector in the event that access to the Surface Segment crypto-key interface is necessary.

5.4.5.3 BONDING MECHANICAL INTERFACE

[35] The Lander shall have a mechanical interface for electrical bonding of VIPER, compatible with the VIPER bonding hardware defined in the proceeding interface definition.

Interface Definition: VIPER will provide three (3) contact points on the RRM for the internal electrical circuit common ground, structural elements, and conductive elements to ground to the Lander with specifications:

- Six (6) - NAS1351N4 -12;
- Six (6) - NAS1149C0463R; and secured using M5 fastener and one washer on each end located as shown in Figure 5.4-10.

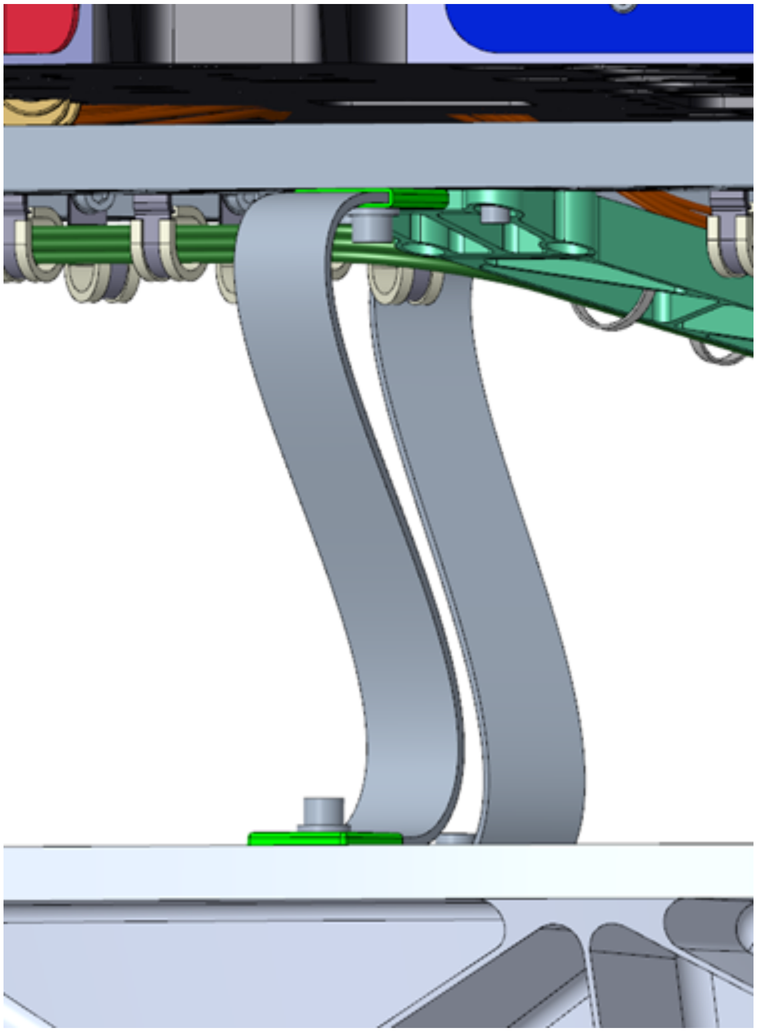


Figure 5.4-10. Grounding and Bonding Contact Points

5.4.5.4 LANDER RAMPS (IF LANDER HAS RAMP DESIGN)

[36] The Lander ramps shall have the VIPER ramp markings pattern to assist in VIPER egress. Figures 5.4-11 and 5.4-12 are exported views from Solidworks file: VIPER_STM2_ramp_markings_pattern_v5. These select views of the ramp marking patterns are an example for a specific ramp length. Final ramp markings design will be finalized between Contractor and VIPER Project.

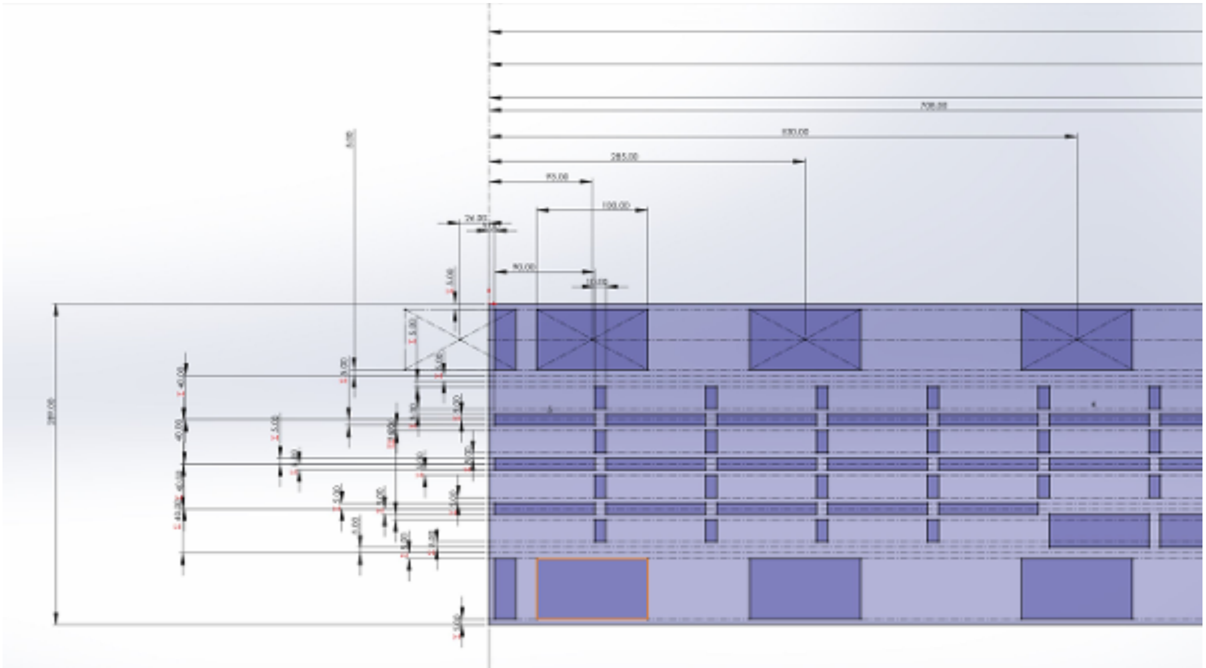


Figure 5.4-11. Rampway Markings – Micro details of markings

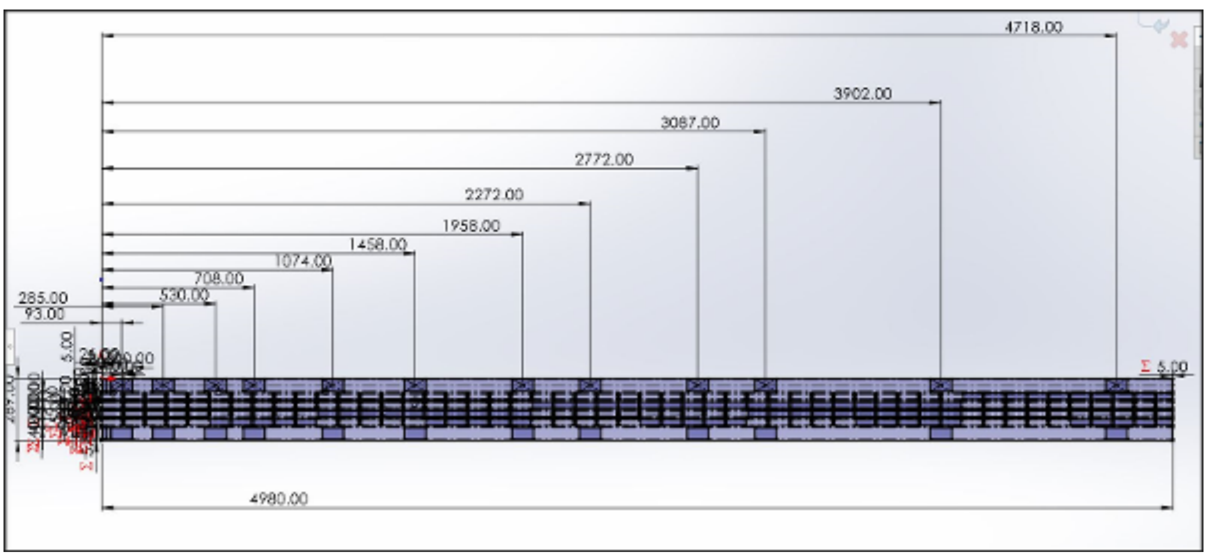


Figure 5.4-12. Rampway Markings – Macro details of markings

[37] The Lander Egress Ramps shall have positive engagement features which are compatible with the VIPER wheel and tread design.

[38] The nominal Lander y-axis distance between deployable ramp segments (parallel; no splay condition) shall be 1 cm +/-0.1 cm (tolerance).

[39] The Lander horizontal separation distance along y-axis between the inward-facing walls of adjacent left and right ramp segments shall be no less than 1.570 meters.

[40] The Lander horizontal separation distance along y-axis between the outward-facing sides of adjacent left and right ramp segments shall not exceed 1.010 meters

[41] The cross-section of a Lander ramp shall be no smaller than TBD width, with wall edges no greater than TBD height. Exceeding minimum required ramp cross-section width (i.e. width less than minimum required) will impact VIPER ability to egress from the Lander.

[42] The inside walls of Lander ramps shall be smooth and devoid of mechanical features which could interfere with VIPER egress. Ramp protrusions can impede VIPER movement and can lead to VIPER wheels climbing onto or over ramps.

[43] The top edge of Lander ramps shall be chamfered to prevent any interference with VIPER egress. Ramp protrusions can impede VIPER movement and can lead to VIPER wheels climbing onto or over ramps.

[44] The Lander deck surface on which VIPER will free-stand post-RRM release will be at a relative height of no lower than TBD cm from the base of the RRM.

5.4.6 VENT PATH

[45] The Contractor shall ensure that there are vent paths to prevent re-condensation of Non-Volatile Residue (NVR) on the vehicle during bakeout.

5.4.7 THERMAL

[46] VIPER will provide thermal isolation from the Lander with an interface conductance not to exceed 0.1 W/K at each Lander-RRM interface attachment point.

[47] The Contractor shall maintain VIPER temperatures within the operational and survival limits specified in the proceeding Interface Definition and the most current revision of the VIPER Integrated Thermal Model, from Launch through RRM Release and egress. Temperature limits for key model nodes are shown in Table 5.4-5 below for reference.

Table 5.4-5. Payload Temperature Limits

Component	Operational		Non-Operational / Survival	
	Temperature Limits (°C)		Temperature Limits (°C)	
	Allowable Flight MIN	Allowable Flight Max	Allowable Flight MIN	Allowable Flight Max
Battery	0	60	-20	80
CCU	-30	40	-30	60
Gimbal Motor – Comm Pan Acuator/Nav Pan Actuator / Comm Tilt Actuator / Nav Tilt Actuator	-45	65	N/A	140
Gimbal Motor Controller	-20	50	-45	85
Gimbal Motor Frangible Bolts	N/A	80	N/A	80
Haz Lights	-110	70	-110	137
IAU	-25	57	-40	61
IMU	-49	61	-57	75
Light Controller	-35	50	-40	95
Mobility Module – Drive Gearbox	-45	105	N/A	N/A
Mobility Module – Drive Motor	-45	105	N/A	145
Mobility Module – Frangibolts	N/A	80	N/A	80
Mobility Module – Steering Motor and Gearbox	-45	110	N/A	145
Mobility Module – Suspension Gearbox	-45	95	N/A	N/A

Mobility Module – Suspension Load Cell	-45	105	-50	140
Mobility Module – Suspension Output Bearings	-45	95	N/A	N/A
Mobility Module – Suspension Motor	-45	95	N/A	145
Mobility Motor Controller	-20	50	-45	85
MSOLO	-10	45	-40	75
Nav Lights	-105	66	-105	137
Nav/Haz/Aft Camera	-30	50	-55	60
NIRVSS Bracket Assembly (AIM RTD)	-20	50	-30	60
NIRVSS Bracket Assembly (LAMP RTD)	-20	110	-30	110
NIRVSS Fiber Optic Cable	-30	60	-30	60
NIRVSS Spectrometer	-20	40	-30	60
NIRVSS Bracket	-20	50	-30	60
NIRVSS Spectrometer	-20	40	-30	60
NSS Data Processing Module	-30	50	-40	60
NSS Sensor Module	-30	50	-40	60
RF Switch	-50	75	-50	95
RF Rotary Joint	-45	75	-100	85
Rover Kits	-45	125	-180	135

SEPIA	-35	71	-40	71
Solar Panels	-150	100	-219	144
Star Tracker	-31	43	-31	66
Transceiver	*Radio Spec*	*Radio Spec*	-35	70
Trident (Avionics Box)	-40	50	-50	70
Trident Auger	-55	125	-120	70
Trident Deploy	-55	125	-120	70
Trident Feed	-55	125	-120	70
Trident Lower Launch Locks (prior to LL actuation)	-50	80	-120	80
Trident Lower Launch Locks (after LL actuation)	-50	150	N/A	N/A
Trident Percussion	-10	125	-120	70
Vapor Lines	N/A	100	N/A	100

5.4.8 ELECTRICAL (POWER)

[48] VIPER has a single connector interface for receiving Lander power service.

5.4.8.1 SUPPLY VOLTAGE

[49] The Lander shall provide shall provide VIPER with a supply voltage of 33.6VDC ±0.5VDC as measured at a VIPER-provided voltage sense point.

[50] The Lander power interface to VIPER and its connection shall be electrically isolated from the chassis of the Lander, with a resistance greater than 1 Mohm (as measured at the interface of the Lander power supply).

5.4.8.2 VOLTAGE TRANSIENTS

[51] The Lander shall limit voltage transients to +/- 10% of the payload bus voltage with a 1% settling time of 20ms with excursions up to 50VDC with an impulse strength less than 0.1V-ms. Note: Voltage transients are stacked on top of the nominal supply voltage tolerance.

5.4.8.3 VOLTAGE RIPPLE

[52] The Lander shall limit voltage ripple to +/- 0.200Vpp.

5.4.8.4 NOMINAL CURRENT

[53] The Lander shall provide an uninterrupted current limit of 7.5A +0.3A/-0.1A while maintaining a supply voltage.

5.4.8.5 CURRENT LIMIT

[54] The Lander shall limit output current to VIPER to 7.5A +1.0A/-0.1A while maintaining bus voltage between 20VDC and 33.1VDC at the VIPER-Lander interface during an overcurrent condition.

5.4.8.6 INRUSH CURRENT

[55] The Lander shall tolerate inrush current from resistive loading of 4.5Ω or higher and capacitive loading of 240µF or lower and return to nominal bus regulation within 70ms. Note: The resistive-capacitive load assumes a resistor and capacitor that is configured in parallel.

5.4.8.7 MISSION POWER SERVICE PROFILE

[56] The Contractor shall provide VIPER Power Services during transit within Table 5.4-6 which is based on VIPER's maintaining VIPER Power generation within 90º of Sun Azimuth and 10º Sun Elevation.

Table 5.4-6: Payload Power Services

Mission phase	Average Steady state power (W)	Nominal Max power (W)	Notes
Pre-Launch	0	0	Post encapsulation
Launch	0	0	Power to be applied within 10 minutes of Lander-LV separation
Transit	100	250	Lander power services may be temporarily interrupted for attitude control, thermal, and propulsive maneuvers
Lunar Orbit	100	250	Lander power services may be temporarily interrupted for attitude control, thermal, and propulsive maneuvers
Descent	0	0	
Surface	250	250	Until VIPER-Lander Separation

5.4.8.8 P2 POWER SERVICE UMBILICAL CABLE HARNESS

5.4.8.8.1 CONNECTOR

[57] The Lander shall provide a power service connector interface which is compatible with the VIPER's umbilical cable harness P2 connector.

Interface Definition: The part number of VIPER's P2 connector is Glenair 280-088P2-3W3MEGL, which is defined in VR90070.

5.4.8.8.2 CONTACT ASSIGNMENT

[58] The Lander power interface to VIPER shall have the contact assignment defined in Table 5.4-7.

Interface Definition: The contact assignment for VIPER P2 is defined in Table 5.4-7 (source is VR090070).

Table 5.4-7. Lander Power Service Contact Assignment

Contact	Function	Comments	**Cable/Wire**
A1	V_OUT	33.6V @ 7.5A nominal	12AWG TSP
A2	DNC		
A3	V_OUT_RTN	33.6V @ 7.5A nominal	12AWG TSP

5.4.8.8.3 CABLE ROUTING SCHEME

[59] The Contractor shall route the VIPER P2 umbilical cable harness bundle from the RRM-Lander locus to the location of the Lander power interface.

Interface Definition: The locus where the VIPER P2 umbilical cable harness crosses the RRM-Lander interface plane is defined in TBD. The available length of VIPER P2 cable from this locus to the VIPER terminated P2 connector is defined in VR090070.

5.4.8.9 P301 VOLTAGE SENSE UMBILICAL CABLE

5.4.8.9.1 CONNECTOR

[60] The Contractor shall provide a Lander connector interface which is compatible with VIPER's umbilical cable harness P301 connector.

Interface Definition: The part number of VIPER's P301 connector is Glenair 801-007-26M5-3SA, which is defined in VR090070.

5.4.8.9.2 CONTACT ASSIGNMENT

[61] The Lander voltage sense interface to VIPER shall meet the contact assignment defined in Table 5.4-8.

Interface Definition: The contact assignment for VIPER P301 is defined in Table 5.4-8 (source is VR090070).

Table 5.4-8. VIPER P301 Voltage Sense

Contact	Function	Comments	**Cable/Wire**
A	Voltage Sense	36V @ 0.015A MAX	TSP
B	DNC		
C	Voltage Sense RTN	36V @ 0.015A MAX	TSP

5.4.8.9.3 CABLE ROUTING SCHEME

[62] The Contractor shall route the VIPER P301 umbilical cable harness bundle from the RRM-Lander locus, to the location of the Lander voltage sense interface for VIPER voltage.

Interface Definition: The locus where the VIPER P301 umbilical cable harness crosses the RRM-Lander interface plane is defined in TBD. The available length of VIPER P301 cable from this locus to the VIPER terminated P301 connector is defined in VR090070.

5.4.8.10 JG1, JG2, JG3, J4 CHASSIS GROUND UMBILICAL CABLES

5.4.8.10.1 CONNECTOR

[63] The Contractor shall provide a Lander chassis ground interface which is compatible with the VIPER umbilical cable harness ring terminals JG1, JG2, JG3, and JG4.

Interface Definition: The part number of VIPER's JG1, JG2, JG3, and JG4 terminals are 50832-1, defined in VR090070.

Table 5.4-9: Frame Chassis Ground Lines

Contact	Function	Comments	Cable/Wire
RING TERMINAL 1	FRAME CHASSIS GND	Ring Terminal Termination. 2 Wires to 1 Terminal	Single Conductor

RING TERMINAL 1	FRAME CHASSIS GND	Ring Terminal Termination. 2 Wires to 1 Terminal	Single Conductor
RING TERMINAL 2	FRAME CHASSIS GND	Ring Terminal Termination. 2 Wires to 1 Terminal	Single Conductor
RING TERMINAL 2	FRAME CHASSIS GND	Ring Terminal Termination. 2 Wires to 1 Terminal	Single Conductor

5.4.8.10.2 CABLE ROUTING SCHEME

[64] The Contractor shall route the VIPER umbilical chassis ground harnesses from the RRM-Lander locus, to the location of the Lander chassis ground terminal.

Interface Definition: The locus dropdown location where the VIPER JG1 through JG4 umbilical cable harnesses cross the RRM-Lander interface plane is defined in TBD. The available length of VIPER ground cable harnesses (JG1 through JG4) from the RRM-Lander interface plan to each of the VIPER ring terminals (e.g., JG1) is defined in VR090070.

5.4.8.11 GROUNDING, BONDING, AND ISOLATION

[65] Lander components shall be bonded to the spacecraft chassis in accordance with NASA-STD-4003 and MIL-STD-464C.

[66] VIPER will comply with Class R, Class H, and Class S bonding guidelines, per NASA-STD-4003.

[67] The VIPER Rover DGND will be electrically isolated from the chassis of the Lander, with a resistance greater than 100 ohms (as measured at the interface of the Lander IAU).

[68] The VIPER Rover Release Mechanism (RRM) will be isolated from the chassis of the Lander, with a resistance less than 1 ohms (as measured at the interface of the RRM).

5.4.9 ELECTRONIC (SIGNAL; COMMAND AND DATA HANDLING)

5.4.9.1 ELECTRICAL CHARACTERISTICS

[69] The Lander's electrical data interface to VIPER shall be RS-422.

5.4.9.2 P1 C&DH UMBILICAL CABLE HARNESS

5.4.9.2.1 CONNECTOR

[70] The Contractor shall provide a Lander connector interface which is compatible with VIPER's umbilical cable harness P1 connector.

Interface Definition: The part number of VIPER's P1 connector is Glenair 801-007-26M7-10PA, which is defined in VR90070.

5.4.9.2.2 CONTACT ASSIGNMENT

[71] The Lander C&DH electrical interface to VIPER shall have the contact assignment defined in Table 5.4-10.

Interface Definition: The contact assignment of VIPER P1 is defined in Table 5.4-10 (source is VR090070).

Table 5.4-10. P1 VIPER-Lander C&DH

Contact	Function	Comments	**Cable/Wire**
1	VIPER IAU TX+	VIPER TX+ & Lander RX+, RS422	100Ω Controlled Impedance TSP
2	VIPER IAU TX-	VIPER TX- & Lander RX-, RS422	100Ω Controlled Impedance TSP.
3	DNC		
4	VIPER IAU RX+	Lander TX+ & VIPER RX+, RS422	100Ω Controlled Impedance TSP.
5	VIPER IAU RX-	Lander TX- & VIPER RX-, RS-422	100Ω Controlled Impedance TSP.
6	DNC		
7	DNC		
8	DNC		
9	DNC		
10	IAU DGND	0.001A MAX	Single Conductor

5.4.9.2.3 CABLE ROUTING SCHEME

[72] The Contractor shall route the VIPER P1 umbilical cable harness bundle from the RRM-Lander locus, to the location of the Lander C&DH interface.

Interface Definition: The locus where the VIPER P1 umbilical cable harness crosses the RRM-Lander interface plane is defined in TBD. The available length of VIPER P1 cable from this locus to the VIPER terminated P1 connector is defined in VR090070.

5.4.10 SOFTWARE AND DATA

Interface Definition: All VIPER commands and telemetry are routed through the Lander MOC via YAMCS. Like the lander, the Lander MOC does not modify VIPER data, instead using transparent protocols to transmit binary data generated by the VIPER MOC to VIPER Rover and vice-versa. The VIPER MOC is responsible for generating all VIPER command binaries and decoding all VIPER telemetry to engineering units.

The Lander MOC Server should be designed to be transparent, transmitting without modification a binary command received from the VIPER MOC to the Lander where it is forwarded to VIPER. Commands are categorized into two categories:

Table 5.4-11: Command Categories

Category	Description
Independent	Execution of VIPER's Independent Telecommands has no impact to Lander functions (ex: calibration tables, data logging, etc.)
Hazardous	Execution of VIPER's Hazardous Telecommands has an impact, potentially critical, to Lander Functions. For VIPER, these commands are specifically defined as anything that is able to mechanically move or deploy an object from VIPER during flight or unexpectedly on the lunar surface.

[73] The Lander shall communicate with VIPER using the following data communication protocols:

- SLIP per RFC-1055;
- IPv4 per RFC-791 not including fragmentation;
- UDP per RFC-768, and;
- IP addresses:
    - Subnet Mask: TBD
    - Lander:
        - IP: TBD
        - UDP Port: TBD
    - VIPER

        - IP: TBD
        - UDP Port: TBD
- CCSDS Transfers:
    - For TC/Uplink
    - TC Transfer Frame per CCSDS 232.0-B-3
    - Frame size remains within Lander Maximum Transmission Unit (MTU) size limits
    - No encoding

[74] The Lander shall use RS-422 standard baud rate of 115,200 for communication with VIPER.

[75] The Lander shall use a protocol format with 8 data bits, no parity,1 stop bit, and no control flow for communication with VIPER.

[76] The Lander IPv4 MTU shall be 1006 bytes, not including overhead, for communication with VIPER.

[77] The Lander shall timestamp VIPER telemetry upon receipt.

5.4.11 RADIOFREQUENCY COMMUNICATION

[78] The Lander shall be compatible and not interfere with VIPER's radiofrequency emissions listed in Table 5.4-12.

Table 5.4-12. VIPER RF Emissions

SOURCE	FREQUENCY	BANDWIDTH	LEVELS	DESCRIPTION	OPERATION
HIGH GAIN ANTENNA	7199.7625MHz (uplink) / 8459 MHz (downlink)	150 kHz (uplink) / 8MHz (downlink)	HGA Tx EIRP: 30.3 dBWi	Tx Beamwidth (3dB): 7.5 degrees in azimuth 6.5 degrees in elevation	VIPER Comms Checkout, Nominal Surface Ops
LOW GAIN ANTENNA	7199.7625MHz (uplink) / 8459 MHz (downlink)	150 kHz (uplink) / 33 kHz (downlink) Up to 40 kHz (downlink) during COM checkouts	LGA Tx EIRP: 6.3 dBW	Tx Beamwidth (3dB): 85deg +/- 20deg in elevation, and omnidirectional in azimuth	VIPER Comms Checkout, In/Out of Hibernation, Contingency Ops

5.5 *ENVIRONMENTS*

The VIPER Surface Segment has been designed to meet the environmental conditions and loads defined in the proceeding subsections. Environment conditions are defined by mission phase.

The Contractor shall provide or manage environments which do not exceed the loads specified within these sections.

5.5.1 *PRE-LAUNCH MECHANICAL*

[79] VIPER has been designed to meet the following mechanical loads for the Pre-Launch environment for the loads induced by transportation of vehicle between facilities, and mate of the integrated spacecraft (Lander and VIPER) to the Launch Vehicle.

Table 5.5-1. Ground Transport Loads

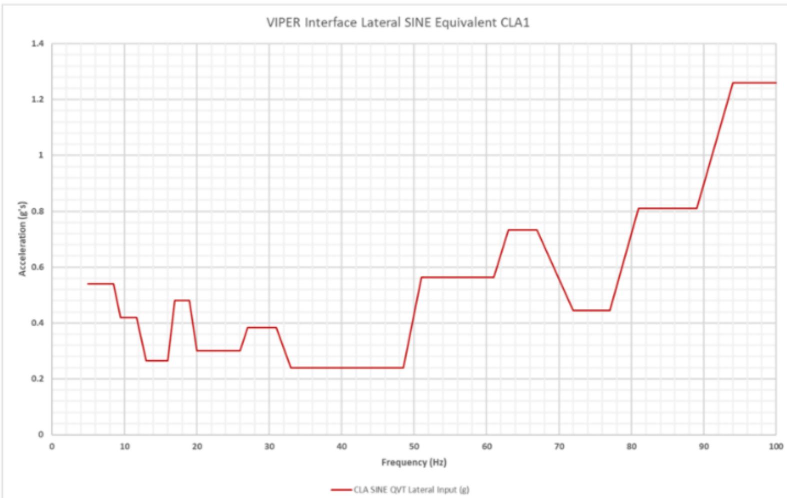
Longitudinal Load (g)	**Lateral Load (g)**	**Vertical Load (g)**
± 1.0	± 0.75	± 2.0

5.5.2 *FLIGHT MECHANICAL*

5.5.2.1 *SINE VIBRATION LOADS*

[80] VIPER has been tested to meet the sine vibration loads defined in Figures 5.5-1 and Figure 5.5-2 at the VIPER-Lander interface.

Sine CLA Input – Lateral Axes (X, Y)
Includes 1.2 Factor

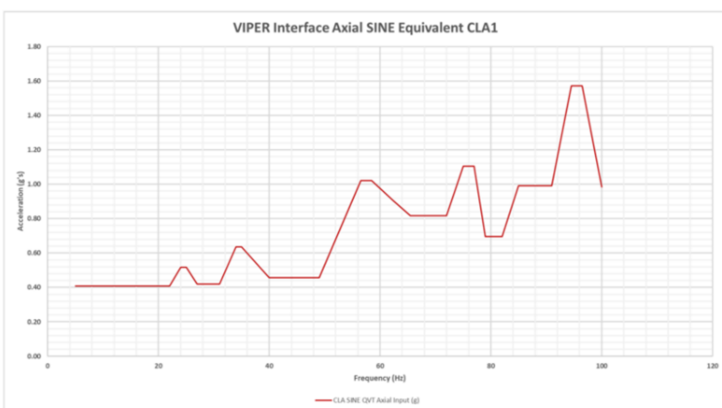


2 oct/min, 2 min 10 secs duration

CLA SINE XY-Axes QVT	
Freq (Hz)	Lateral Input (g)
5	0.54
8.5	0.54
9.5	0.42
11.7	0.42
13	0.26
16	0.26
17	0.48
19	0.48
20	0.30
26	0.30
27	0.38
31	0.38
33	0.24
48.5	0.24
51	0.56
61	0.56
63	0.73
67	0.73
72	0.44
77	0.44
81	0.81
89	0.81
94	1.26
100	1.26

Figure 5.5-1. VIPER Interface Lateral Axes (X,Y) Sine Vibration Loads Environment

Sine CLA Input – Vertical Axis (Z)
Includes 1.2 Factor



2 oct/min, 2 min 10 secs duration

CLA SINE Z–Axis QVT	
Freq (Hz)	Axial Input (g)
5	0.41
15.5	0.41
22	0.41
24	0.52
25	0.52
27	0.42
31	0.42
34	0.64
35	0.64
40	0.46
49	0.46
56.5	1.02
58.5	1.02
62.5	0.90
65.5	0.82
69	0.82
72	0.82
75	1.10
77	1.10
79	0.70
82	0.70
85	0.99
91	0.99
94.5	1.57
96.5	1.57
100	0.98

Figure 5.5-2. VIPER Interface Vertical Axis (Z) Sine Vibration Loads Environment

5.5.2.2 ACOUSTIC LOADS

[81] VIPER has been tested to meet the acoustic loads environment defined in Figure 5.5-3.

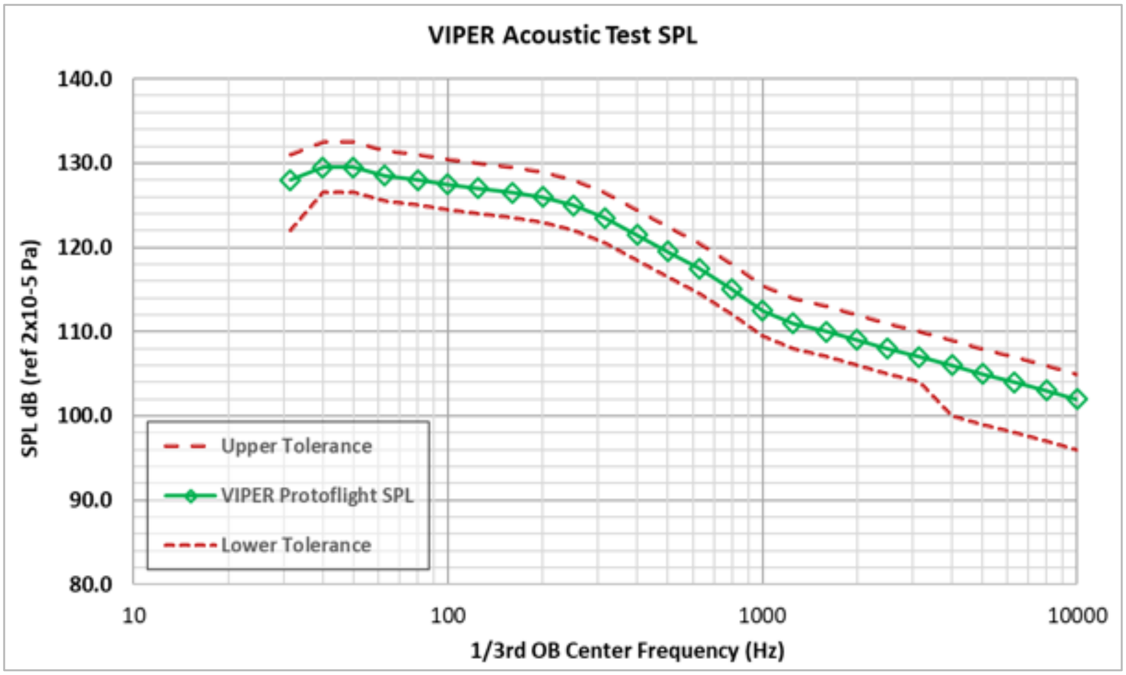


Figure 5.5-3. Acoustic Loads Environment

5.5.2.3 RANDOM VIBRATION

[82] VIPER has been tested to meet the random vibration environment defined in Figure 5.5-4.

Same profiles for X, Y , and z test configurations.

PQ Random Spectra				
Freq (Hz)	PQ -9 dB	PQ -6 dB	PQ -3 dB	PQ (g²/Hz)
20	0.001259	0.002512	0.005012	0.01
35	0.000038	0.000075	0.000150	0.0003
50	0.000038	0.000075	0.000150	0.0003
500	0.001259	0.002512	0.005012	0.01
800	0.000504	0.001005	0.002005	0.004
1000	0.001259	0.002512	0.005012	0.01
2000	0.001259	0.002512	0.005012	0.01
Grms	1.385	1.957	2.764	3.904
Duration (seconds)	30.	30.	30.	60.

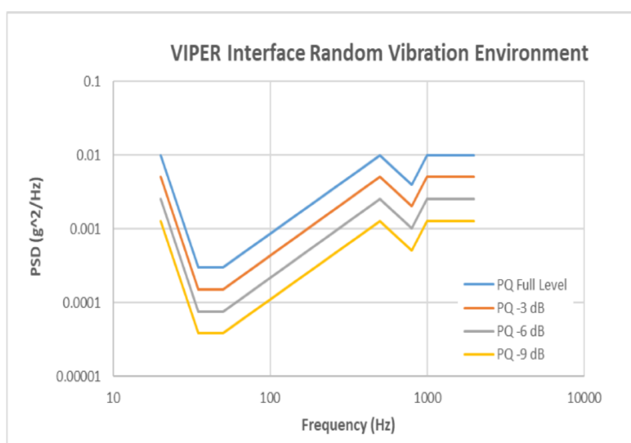


Figure 5.5-4. Random Vibration Loads

5.5.2.4 SHOCK LOADS

[83] VIPER has been tested to meet the acoustic loads environment defined in Figure 5.5-4.

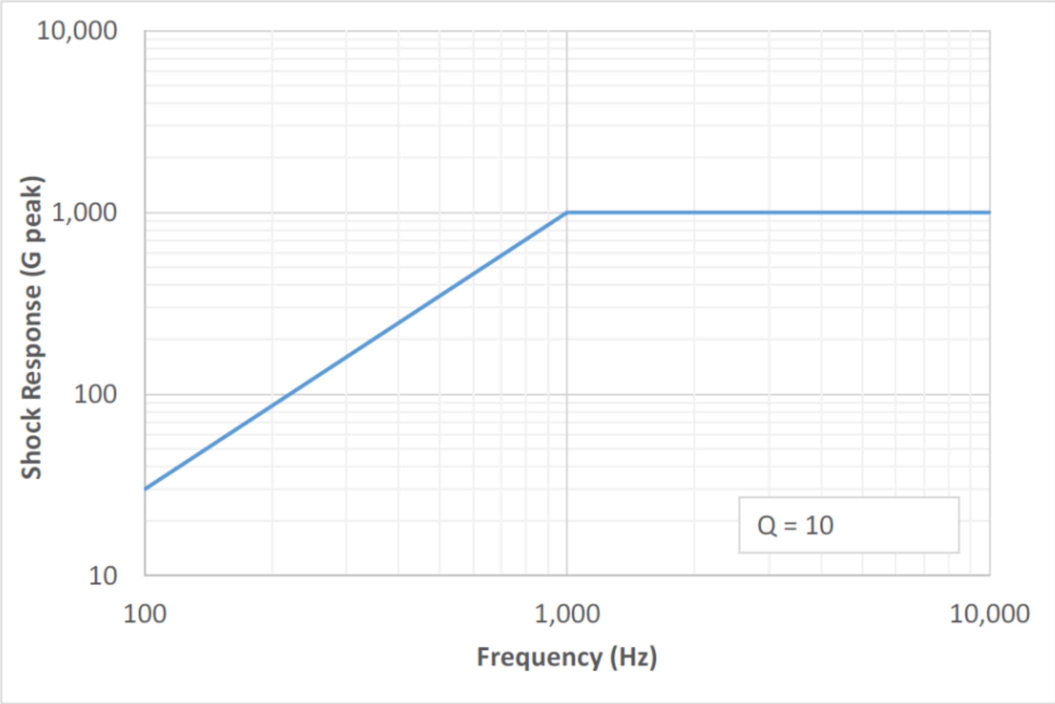


Figure 5.5.-4. Shock Loads

Table 5.5-2. Shock Loads

Frequency (Hz)	Limit (G)
100	30
1,000	1,000
10,000	1,000

5.5.2.5 FLIGHT PRESSURE

[84] During launch, the pressure drops from atmospheric to vacuum levels. The pressure drop is expected to last between 100 and 150 seconds, with a maximum rate of 0.65 psi/sec.

For the remainder of the mission, pressure levels remain at vacuum levels. These levels are predicted to be less than 3.2 x 10-5 kPa (4.64 x 10-6 PSI).

5.5.3 FLIGHT NON-IONIZING RADIATION

Note: For all EMI/EMC Tests, exceptions to levels/values may be granted by technical project authority if "Do-No-Harm" can be satisfactorily verified by other means.

5.5.3.1 MIL-STD-461G CE102

[85] VIPER components have been tested to be compliant with MIL-STD-461G requirement CE102 (Conducted Emissions, Power Leads, 10 kHz to 10 MHz).

5.5.3.2 MIL-STD-461G CS101

[86] VIPER components have been tested to be compliant with MIL-STD-461G requirement CS101 (Conducted Susceptibility, Power Leads, 30 Hz to 150 kHz).

5.5.3.3 MIL-STD-461G RE102

[87] VIPER components have been tested to be compliant with MIL-STD-461G requirement RE102 (Radiated Emissions, Electric Field, 10 kHz to 18 GHz).

5.5.3.4 MIL-STD-461G RS103

[88] VIPER components have been tested to be compliant with MIL-STD-461G requirement RS103 (Radiated Susceptibility, Electric Field, 2 MHz to 40 GHz).

5.5.4 IONIZING RADIATION ENVIRONMENT

[89] Radiation exposure from LV Separation to Landing shall be limited to less than 3 kilorads Total Ionizing Dose (through 2.54mm equivalent aluminum thickness).

5.6 PAYLOAD PROCESSING FACILITY INTERFACE REQUIREMENTS

[90] The dedicated floor space shall be controlled to an ISO Class 8 (100,000) cleanliness level (with appropriate gowning and access control) for VIPER post-shipment unpacking and checkout activities.

[91] The Contractor shall maintain ambient air temperature between 18º and 28ºC during VIPER integration and after encapsulation.

[92] The Contractor shall maintain pressure to 101.3 ± 3.4 kPa (14.69 ± 0.5 PSI) for Pre-Launch activities including storage, transport, and integration.

[93] The Contractor shall maintain Relative Humidity (RH) between 30% and 60% during VIPER integration and after encapsulation.

[94] The Contractor shall provide NASA access to facility power with at least eight 115VAC 15-Amp minimum outlets for VIPER post-shipment unpacking and checkout activities.

[95] The Contractor shall allow NASA access to facility ground for NASA equipment during VIPER post-shipment unpacking and checkout, Pre-Launch, and Launch activities.

[96] The Contractor shall provide facility wireless or hardline internet connectivity to NASA that will enable NASA Virtual Private Network access from VIPER delivery through Launch.

[97] The Contractor shall provide seating accommodations, power for laptop computers, and access to telephone, printer, and Wi-Fi networks for 15 NASA personnel with reasonable proximity to the payload integration facility.

[98] The Contractor shall provide a crane for VIPER hardware unpacking, integration, testing, and packing operations.

[99] The Contractor shall provide a secure facility location to store NASA shipping containers and Ground Support Equipment (GSE), from the time period of VIPER delivery until Launch.

5.6.1 PAYLOAD INTEGRATION PROCESS REQUIREMENTS

[100] The Contractor shall provide VIPER personnel access to VIPER immediately after physical delivery to the integration facility for unpacking and checkout activities.

[101] The Contractor shall be responsible for integrating VIPER to the Lander, and integrating the stack onto the launch vehicle.

[102] The Contractor shall ensure the Lander is connected to facility ground during integration of VIPER with the Lander, and after VIPER and Lander have been integrated.

[103] The Contractor shall notify NASA of any Contractor-developed GSE that is required to physically or electrically interface to the NASA Payload. The Contractor shall coordinate with NASA on plans for using GSE in those circumstances.

[104] Cell voltage and temperature of lithium-based batteries onboard VIPER will be monitored during charge / discharge, IAW AFSPCMAN 91-710 v3 Sections 14.1.9 and 14.2.6.

[105] VIPER and any NASA-provided Ground Support Equipment will be compliant with Range Safety User Requirements, AFSPCMAN 91-710.

5.6.2 LAUNCH VEHICLE PROCESS REQUIREMENTS

[106] The Contractor shall provide VIPER personnel access to VIPER at the launch site facility, including hardware configurations with VIPER integrated. Intent of this requirement is to allow VIPER personnel to monitor and maintain situational awareness of VIPER hardware, including activities in which VIPER is moved whilst adhering to launch site facility policies and safety protocols.

5.7 INTEGRATION / INTEGRATED TEST REQUIREMENTS

[107] The Contractor shall plan, provide input, develop procedures as needed, and perform hardware and software integrated tests with the VIPER Project Team with engineering development units and the flight units, covering the period from pre-delivery to after delivery and integration at the Payload Processing Facility, as summarized in Table 5.5-1.

Table 5.7-1. Integrated Test Activities

Test Name	Test Description	Location	Test Type	Estimated Duration
MGSE and Mechanical Integration Pathfinder	Perform mechanical integration of VIPER and Lander representative. Collaboratively, teams shall assess access during integration process and determine proper tooling/GSE needs for integration/vehicle lifts.	TBD	Engineering	TBD
Egress Test	Perform various Egress scenarios with VIPER rover and Lander representative to validate Lander interfaces during egress process. Assess interference during operations of the entire process/path of egress.	NASA ARC	Engineering	TBD
Power/Data Engineering Test	Perform initial power and data communication between VIPER power & data subsystems to Lander power & data subsystems.	TBD	Engineering	5-days

Mission Operations Centers (VIPER, Contractor) Connectivity and Data Test	Perform connectivity test between Lander Operation Center and VIPER Multi-Mission Operations Center. Ensure data and voice is communicated between each Operation Center.	TBD	Mission Operations Centers	TBD
Mission Simulations	Conduct various Mission Sims over Mission Phases with initial operational procedures.	TBD	Mission Operations Centers	TBD
Mission Operational Readiness Tests	Perform various Mission Sims with final operational procedures. Ensure operational teams are ready to conduct the mission.	TBD	Mission Operations Centers	TBD
Mission Rehearsals	Perform final readiness for launch rehearsal prior to launch. In coordination with Launch Vehicle and Lander partners	Various	Mission Operations Centers	TBD
Lander Pre-Integration Safe-to-Mate Test	Prior to first time that the Lander provides power to the VIPER during integration, the Contractor shall complete a powered on, safe-to-mate test of all connectors that will interface with VIPER. The contractor shall provide NASA with the expected results and the measured results and provide disposition rationale for any discrepancies prior to attaching any connectors to VIPER.	Launch Site - PPF	Flight Vehicle	1-day
PPF/Pre-Integration: Electrical Power and Data “Soft-mate” Test	Prior to mechanical Lander Integration, VIPER and Lander shall perform a “soft-mate” where power and data harnesses are connected to each flight vehicle while the flight vehicles are sitting side-by-side. This ensures that	Launch Site - PPF	Flight Vehicle	1-day

	proper electrically mating is achieved and reduces schedule risk of mechanical de-mating VIPER and Lander systems			
Integrated Flight Vehicles Power, Data, and EMC Test	Prior to Launch, the Contractor shall perform a power/data interface test with the flight Lander providing power to the VIPER in a flight-like configuration and the VIPER proceeding through a nominal power-up sequence.	Launch Site - PPF	Flight Vehicles	3-days
End-to-End Communication Test	Prior to launch, the Contractor shall perform an end to end, operational interface verification test that demonstrates the command and control necessary for VIPER checkout during Lunar transit via commands initiated in the VIPER Mission Control Node sent to the Lander Mission Operations, via the Lander radio frequency path and to VIPER.	Launch Site - PPF	Flight vehicles, Mission Operations Centers	5-days

[108] The Contractor shall participate in joint training/simulation exercises with the NASA Mission Ops team. The Contractor shall participate in at least two mission transit simulations. The Contractor shall also participate in at least three surface ops/egress simulations.

[109] The Contractor shall complete a successful physical demonstration of their proposed egress system, using a NASA-provided Engineering Model, prior to integrating the NASA Payload onto the Lander. The Contractor shall specify any hardware or support that NASA needs to provide to enable the physical demonstration.

5.8 MISSION PLANNING REQUIREMENTS

[110] Prior to launch, the Contractor shall work with NASA to develop a clearly outlined approach to fully egress the rover off of the lander. This approach is required to include items such as the sequence of events and go/no-go criteria. The Contractor shall obtain concurrence from NASA on the full egress approach. The Contractor shall also receive approval from NASA prior to initiating egress activities once on the surface of the moon.

[111] Prior to launch, the Contractor shall provide expected trajectory and attitude data during transit and lunar orbit to enable VIPER Mission Operations to perform power and thermal management analysis and planning.

5.9 MISSION OPERATIONS REQUIREMENTS

5.9.1.1 ALL MISSION PHASES

[112] The Contractor shall provide command and telemetry connections from the Contractor's Mission Operations Center (MOC) to the VIPER Mission Operations Center (MOC).

[113] The Contractor shall provide a dedicated network connection between the Contractor's MOC and the VIPER MOC for voice and data transfer.

[114] The Contractor shall provide a redundant network connection between the Contractor's MOC and the VIPER MOC, either via a second identical dedicated line or via a site-site VPN to be used as a backup.

[115] The Contractor shall support a minimum of two voice connections between the Contractor's MOC to the VIPER MOC. The voice connections shall be configured per Table 5.9-1 below.

Table 5.9-1. Voice Connection Assignments

Name	Description	Contractor MOC Access	VIPER MOC Access
VIPER1	Main payload operations comm loop between centers	Talk/Listen	Talk/Listen
VIPER2	Backup for VIPER1 loop	Talk/Listen	Talk/Listen

[116] Connections for real-time telemetry from both VIPER and a limited subset of Lander telemetry (likely attitude telemetry) shall be made using a YAMCS server hosted by the Contractor. Final YAMCS API version >=5.5 will be agreed upon and documented in a configuration-controlled plan document. Archived telemetry requests may also be made via this API.

[117] Connections for real-time commanding shall be made using a YAMCS server hosted by the Contractor. NASA will connect via a standard YAMCS API (either Python or HTTP/Websocket-based-both are available). Final YAMCS API version >=5.5 will be agreed upon and documented in a configuration-controlled plan document. This service will be agnostic to whether the command contents are encrypted or not from the VIPER control center.

[118] A web browser-based tool will be exposed over the dedicated connection between control centers to provide the VIPER team a schedule of mission-related events (i.e. ground station contact, joint system checkout activities, main engine maneuvers, etc.) during flight.

[119] The Contractor shall provide a Secure FTP file exchange service between the Contractor MOC and VIPER MOC for transferring file-based data (ephemeris files, Lander camera images, descent data package, etc).

[120] The YAMCS server hosted by the Contractor shall support VIPER implementing their own CFDP protocol within the command/telemetry packets sent through the YAMCS service.

5.9.2 VIPER OPERATIONS OF SPEED-MADE-GOOD

[121] The Contractor shall ensure that VIPER meets Speed-Made-Good (SMG) parameter for a verified traverse while maintaining VIPER's measurement requirements.

Interface Definition: The VIPER Mission Operations Support (MOS) team manages the overall system health of the rover against the aspect of maintaining SMG. SMG is the rover speed that incorporates all operational aspects (included but not limited to: driving, driving in science area, science activities, communication, decision-making, etc). For each traverse and to achieve Science goals, specific SMG needs to be maintained. These operational roles/teams ensure that VIPER's SMG is achievable for the VIPER Science goals.

- Mission Management Team - The MMT consists of the Flight Director, the Mission Manager, and the Science Lead. These console positions interfaces with the project MOS team to provide mission status reports, coordinate MOS support to Anomaly Review Boards, and address other topics beyond the scope of MOS decision-making authority.

- Drive Team - The Drive team operates the Rover mobility system and Rover cameras to complete all driving operations including rails driving, prospecting, and fine positioning over drill sites.

- Engineering Team - monitors overall Surface Segment system performance, integrates inputs from Rover Engineering Support Team positions, and coordinates technical support to anomaly response. This team also manages the communications link, including network connection to Contractor MOC and DSN ground stations, and command initiation enable / disable states for all MOS operators sending command requests.

- Planning Team – monitors mission execution to identify deviations from the planned mission pace (i.e. slower than expected driving and delayed performance of scheduled activities) and recommend (to the Flight Director) appropriate responses to these deviations.

- Ground System Team - monitors GDS hardware and software performance and coordinates with MOC support staff for the recovery of GDS subsystems and components as necessary.

- Rover Engineering Support Team - provides technical subject matter expertise to support the overall health assessment of the Rover System.

- Mission Science Center (MSC) - The Science Lead (Project Scientist) interfaces with other Science Investigators in the MSC to formulate science requests for tactical and strategic planning. MSC coordinates all the Science and Payloads Team, and Planning Team to incorporate science needs into the Traverse Plan.

- Lander Mission Operation Center (MOC) - The VIPER Flight Director communicates with the Lander MOC to coordinate joint operations activity execution during launch, transit, descent/landing, and post-landing operation phases.

- DSN Ground Stations – coordination between DSN station and VIPER MOS, including handovers and signal acquisition

5.9.2.1 DRIVE TEAM

Interface Definition: The Drive team consists of the Driver, Co-Driver, and Real-Time Science (RT-Sci) positions. The Driver and Co-Driver work together during all driving operations; RT-Science augments the team during prospecting operations within science stations.

The Driver holds primary responsibility for mobility system commanding (under Flight Director authority). The Co-Driver supports the Driver by assessing the Rover's surroundings and proposed driving paths. The Co-Driver also off-loads the Driver by performing other general console tasks such as console log maintenance and coordination with other console positions. The Driver and Co-Driver positions are staffed from a single pool of trained and certified drivers, and the personnel supporting these two positions will swap positions during console shifts to address driver fatigue issues.

The Drive Team is concerned with the following:

- The rover’s current position on the lunar surface and with respect to the Traverse Route
- The rover’s current orientation with respect to the Sun, for solar power generation
- The rover’s current roll and pitch with respect to gravity, and whether they are within stability and mobility system limits and margins
- The rover’s current suspension system stance
- The immediate surroundings of the rover in terms of hazards, slopes, 3D terrain
- Larger hazards or terrain features that are not within the detection limits of the ground software but may be apparent in images (e.g. far away large craters)
- Commanding the vehicle to make safe and efficient progress along the Traverse Route
- Commanding changes in rover yaw to maintain desirable power and thermal states
- Commanding suspension to maintain a desirable stance with respect to the terrain and gravity
- Commanding the NavCam gimbal orientation to maintain desirable NavCam imagery for Visual Odometry and waypoint selection

5.9.3 PRE-LAUNCH PHASE

[122] The Contractor shall provide NASA at least TBD square feet of dedicated floor space for VIPER post-shipment unpacking and checkout activities.

[123] Post-integration with the Lander but prior to fairing encapsulation, the Contractor shall enable VIPER to connect with a NASA-provided power rack for keeping VIPER's batteries charged and to monitor battery health.

[124] During pre-launch vehicle processing and while integrated with the Lander, VIPER shall be capable of surviving in an unpowered state without battery charging for the following intervals:

Table 5.9-2. Unpowered Intervals

Pre-Launch Integration Phase	**Duration**
Spacecraft Fueling	4 days
Mate to Launch Vehicle	3 days

[125] From encapsulation until post-LV separation, VIPER will remain powered off, except for mutually agreed-to contingency battery charging scenarios as defined in the Launch Site Support Plan (LSSP) or other stand-alone contingency procedures.

[126] Post-Encapsulation, all charging and battery monitoring of VIPER will occur through the Lander.

[127] Any VIPER battery charging activities will terminate no later than 12 hours prior to launch.

5.9.4 LAUNCH/TRANSIT PHASE

[128] During Lunar Transit, the Contractor shall provide VIPER required power services within 10 minutes of launch vehicle separation until start of surface operations, with the exceptions noted in Table 5.4-6, Payload Power Services.

[129] The Contractor shall provide a minimum of five (5) minutes of advance notification of any periods of time that VIPER power service will be temporarily interrupted from LV separation until Landing for planned attitude control, thermal, and propulsive maneuvers.

[130] The Contractor shall transmit real-time telemetry, from VIPER through the Lander's communications system to the VIPER MOC, within 1-minute after VIPER being powered on.

[131] From LV Separation through Surface Operations, for communications between the VIPER MOC and VIPER through the Lander, the data latency should be less than 30 seconds, round trip for real time data with a bit error rate less than 1e-5 for correctly received frames.

[132] The Contractor shall provide a maximum real time uplink and downlink rate, including all communications protocol overhead (VIPER frame overhead and Lander packet overhead of 16 bytes), as stated in Table 5.9-3 below during planned in orbit VIPER checkout and test activities.

Table 5.9-3. Data Services Uplink and Downlink Rates

Mission Phase	**Downlink Data**	**Uplink Data**
Pre-Launch	N/A	N/A
Launch	N/A	N/A
Transit	10 kbps	1 kbps
Lunar Orbit	3 kbps	1 kbps
Descent	N/A	N/A
Surface	10 kbps	1 kbps

[133] From LV Separation through Landing, during real-time contact with the Lander, the Contractor shall provide NASA coordinated access to Lander telemetry data. Telemetry data shall include at a minimum, Lander position and orientation state vector. Telemetry may also include: data from thermal sensors near the Rover, and other sensor data mutually agreed-to between NASA and the Contractor.

[134] From LV Separation until Landing, the Contractor shall provide real-time data downlink/uplink windows to enable VIPER instrument checkout and calibration activities, as summarized in Table 5.9-4.

Table 5.9-4. Instrument Checkouts

Activity
Post-Launch Configuration Check (this check shall start on initial power-up after launch vehicle separation (per RFTOP section 6.3.4.1)
Communications System Checkout (may be split into two windows)
NSS Checkout
NSS Calibration 1
NSS Calibration 2
NIRVSS Checkout
NIRVSS Bakeout (can be handled during daily 15-minute window)
MSolo Checkout
MSolo Bakeout
TRIDENT Avionics Checkout

[135] From LV Separation until Landing, in addition to planned VIPER checkout activities, the Contractor shall provide at least 15 minutes per day of real-time data download/upload to and from VIPER, at the data rates specified in Table 5.9-3, Data Services Uplink and Downlink Rates.

[136] From LV Separation until Landing, in addition to planned VIPER checkout activities, the Contractor shall provide communications services to enable NASA to download at least 25 kilobytes every 24 hours of VIPER stored data, at the data rates specified in Table 5.9-3, Data Services Uplink and Downlink Rates.

[137] During functional testing of the VIPER high-gain antenna in transit to the moon, the Contractor shall point the VIPER high gain antenna boresight to within 5.0º of the Deep Space Network (DSN) ground stations. VIPER's HGA is mechanically locked for flight.

[138] The in-transit test of VIPER's communication system shall be performed within 72 hours after launch vehicle separation, no closer than 30,000 km from Earth, and shall take up to 90 minutes. The 90 minutes of testing may be split into two 45-minute test sessions within the 72-hour window.

[139] The Contractor shall ensure at least 1.3 m^2 of VIPER solar panel area has unobstructed exposure to sunlight, from Launch Vehicle Separation through Descent Injection under nominal conditions, except during spacecraft attitude/orbit adjustment maneuvers.

5.9.5 LUNAR ORBIT/DESCENT PHASE

[140] The Contractor shall maintain TBD orientation of the lander in lunar orbit for TBD durations, in order for the VIPER NSS instrument to perform necessary background measurements prior to descent and landing.

5.9.6 LANDING / EGRESS PHASE

[141] The Contractor shall provide the most accurate landing location and Lander orientation data available to VIPER Mission Ops within 60 minutes of touchdown confirmation.

[142] The Contractor shall provide a touchdown confirmation signal to the VIPER Mission Ops within 5 minutes after touchdown.

[143] After touchdown, the Lander shall provide the required power services specified in Table 5.4-6 (Payload Power Services) to VIPER within 1 minute of touchdown confirmation through 1 hour after landing.

[144] The Contractor shall enable VIPER to communicate with the VIPER MOC via the Lander within 1 minute of touchdown confirmation through post-landing VIPER checkout.

[145] The Contractor shall enable VIPER to disembark from the Lander within 6 hours of touchdown confirmation.

[146] The Contractor shall provide Lander camera images to NASA within 60 minutes of touchdown confirmation, to support safe egress path determination.

[147] The Contractor shall provide Lander images of the VIPER egress path (or paths if the Lander has multiple egress paths) that includes at least 2 vehicle lengths of VIPER past the end of the ramp(s).

[148] The Lander shall define all Lander Camera Fields of View and provide to VIPER Operations Team.

[149] After initial post-landing image delivery and until VIPER egress is complete, the Contractor shall continually provide new lander images from cameras selected by the Contractor and VIPER operators at time of egress to the VIPER MOC at the rate those images are received from the Lander.

[150] The Contractor shall notify the VIPER MOC when the VIPER separation command may be issued.

[151] The Contractor shall provide artificial lighting to illuminate the path(s) for VIPER egress. The lighting will facilitate egress path characterization and suitability prior to egress, and enhance visibility and situational awareness during egress operations.

[152] The Contractor shall vent Lander propellant/pressurant tanks content (safing) no earlier than 24 hours after touchdown confirmation. The Contractor should vent propellant in a manner which reduces impingement of vented species onto VIPER and planned traverse path.