

4. SPACECRAFT ENVIRONMENTS

Overview This section describes the major environments to which the spacecraft is exposed from the time of its arrival at Baikonur cosmodrome until its separation from the launch vehicle during flight.

These environments and conditions include:

- Structural loads
- Random vibration
- Acoustics
- Shock
- Electromagnetic radiation
- Thermal
- Humidity
- Pressure venting
- Contamination

Unless otherwise noted, the payload environments presented in this section are common to both the three-stage Zenit-3SLB and the two-stage Zenit-2SLB.

Ground and Flight Environments Those levels associated with “ground handling and transportation” address the period from the arrival of the spacecraft at Baikonur until Stage 1 ignition and liftoff.

Those levels designated as “flight” cover the subsequent period from liftoff command through spacecraft separation.

Reference Coordinate System The coordinate system used in this section is shown in Figure 4-1. During transfer of the spacecraft in its shipping container from the airport to the Payload Processing Facility (PPF), the +X axis coincides with the direction of travel. At other times, X coincides with the longitudinal axis of the launch vehicle. The Y axis is vertical during horizontal ground operations.

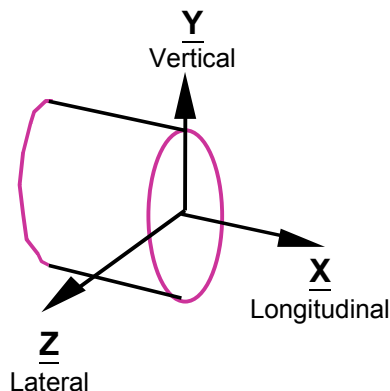


Figure 4-1. Reference Coordinate System Used for Defining Spacecraft Environments

Environmental Monitoring

Land Launch monitors and records spacecraft environments as specified in the Spacecraft-LV Interface Control Document and documents these results in the post-flight report to the customer. Typically, this includes:

- flight environments (accelerations, acoustics, shock, fairing thermal conditions during ascent, pressure decay, etc.);
- the temperature, humidity and cleanliness levels of the spacecraft processing and encapsulation areas while the spacecraft is present;
- the temperature, humidity and cleanliness levels of the conditioned air provided to the fairing with the spacecraft inside;
- accelerations experienced during all phases of ground processing, after the spacecraft has been removed from its shipping container

The responsibility normally resides with the customer to monitor the spacecraft environment (including accelerations) until it is unloaded from its shipping container at the cosmodrome.

4.1 Structural Loads

Overview

Design reference structural loading environments on spacecraft primary and secondary structures are defined here for:

- ground transportation and handling
- flight
- spacecraft sinusoidal vibration testing

Spacecraft compliance requirements related to these environments are presented in Section 7.

Quasi-Static Load Factors, Ground Handling and Transportation

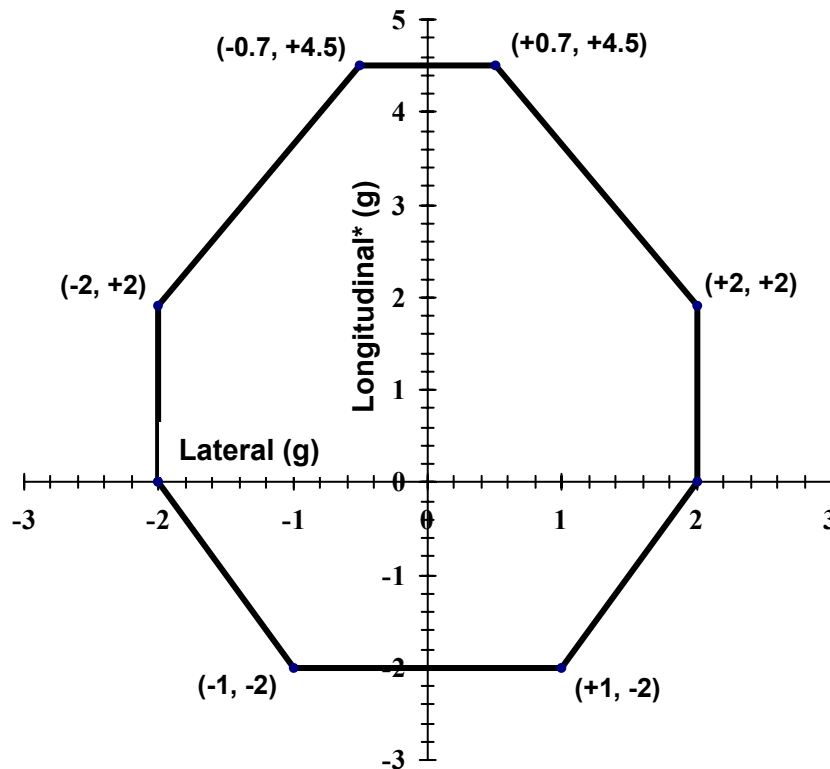
Design reference maximum acceleration levels during ground transportation, handling and processing are defined in Table 4-1. The quasi-static accelerations levels are shown for the spacecraft center of gravity while in a horizontal orientation. These accelerations can be applied simultaneously in the longitudinal, lateral and vertical directions (the axis X coincides with the velocity vector). During erection of the launch vehicle to a vertical position on the launch pad, the maximum acceleration of the spacecraft center of gravity is 1.5 g. In the course of combined operations the spacecraft briefly transitions through various vertical orientations, during which the respective axial accelerations are maintained within those limits already specified. The maximum rate of angular acceleration (about any axis) during crane lifts of the ILV is 0.055 radians per seconds squared.

Table 4-1. Maximum Quasi-Static Accelerations During Ground Operations

Spacecraft Processing Operation		Acceleration [g]			Safety Factor
		X	Y	Z	
Transfer from the airport to the PPF		± 1.0	-1 ± 1.0	± 0.4	2.0
Horizontal Combined Operations (from mating with the launcher in the PPF through completion of launcher assembly in Area 42)	Zenit-3SLB	± 0.5	-1 ± 0.5	± 0.4	1.5
	Zenit-2SLB	± 0.35	-1 ± 0.2	± 0.2	2.0
Launcher on-loading and off-loading (crane lifts in Area 42)		± 0.2	-1 ± 0.2	± 0.2	1.5
Roll out and erection on the launch pad		± 0.35	-1 ± 0.2	± 0.2	1.5

Quasi-Static Load Factors, Flight

From liftoff through spacecraft separation, the spacecraft is subjected to quasi-static steady-state and low-frequency dynamic accelerations. Figure 4-2 provides the design reference accelerations for critical loading events. These accelerations are applied at the spacecraft center of gravity and are intended for preliminary design only. Determining the ability of specific spacecraft primary and secondary structures to withstand the dynamic loading events during flight requires a coupled loads analysis (CLA), which will be performed for each mission. When generated and verified, CLA results supersede the generic quasi-static accelerations provided in Figure 4-2.



* positive longitudinal quasi-static accelerations are aligned with the direction of flight

Figure 4-2. Typical Quasi-Static Design (Maximum Expected) Loads in Flight

Sinusoidal Equivalent Vibration During Flight

The longitudinal and lateral low-frequency sinusoidal vibration environments generated at the spacecraft separation plane during liftoff and flight phases are within the limits defined in Table 4-2. The sinusoidal vibration environment for all major flight events are specifically determined for each mission during the CLA. These results determine the maximum notching in the environment spectra that can be used during spacecraft sinusoidal vibration testing.

Table 4-2. Sinusoidal Vibrations at the Spacecraft Interface

Frequency Range [Hz]	Vehicle	Amplitude [g]
5 - 100 (Longitudinal and Lateral)	Zenit-2SLB	0.6
	Zenit-3SLB	0.7

4.2 Random Vibration

Ground Random Vibration for Components Near the Spacecraft Interface

The spacecraft is subjected to low frequency random vibrations during transportation by rail at the cosmodrome. Table 4-3 envelopes this random vibration environment. The maximum duration of any rail transfer is six hours.

Table 4-3. Random Vibration During Ground Transport When the Spacecraft is Not in the Customer Container

Frequency [Hz]	Spectral Density of Power [g^2/Hz]		
	X-X Longitudinal	Y-Y Vertical	Z-Z Lateral
2	0.000075	0.00015	0.00015
4	0.000575	0.0033	0.00033
8	0.002	0.0032	0.00066
10	0.0006	0.0032	0.0008
14	0.00028	0.000833	0.00033
20	0.000275	0.00015	0.00032
25	0.000275	0.00015	0.00031
30	0.000275	0.00015	0.0003
35	0.0005	0.00015	0.000185
40	0.00018	0.00015	0.000037
45	0.000125	0.00015	0.000037
50	0.000125	0.00015	0.000037

Flight Random Vibration Environment

The random vibration environment during flight at the spacecraft interface is enveloped in Table 4-4 and Figure 4-3.

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

The environment applies to components within 0.5 m (20 inches) from the separation plane along any structural path. This environment is not to be applied to the complete spacecraft as a rigid base excitation.

Table 4-4. Random Vibration Environment During Flight

Frequency [Hz]	Spectral Density [g^2/Hz]
20 – 100	0.01 ... 0.035
100 – 700	0.035
700 – 2000	0.035 ... 0.01
Overall Level	6.8 g_{rms}

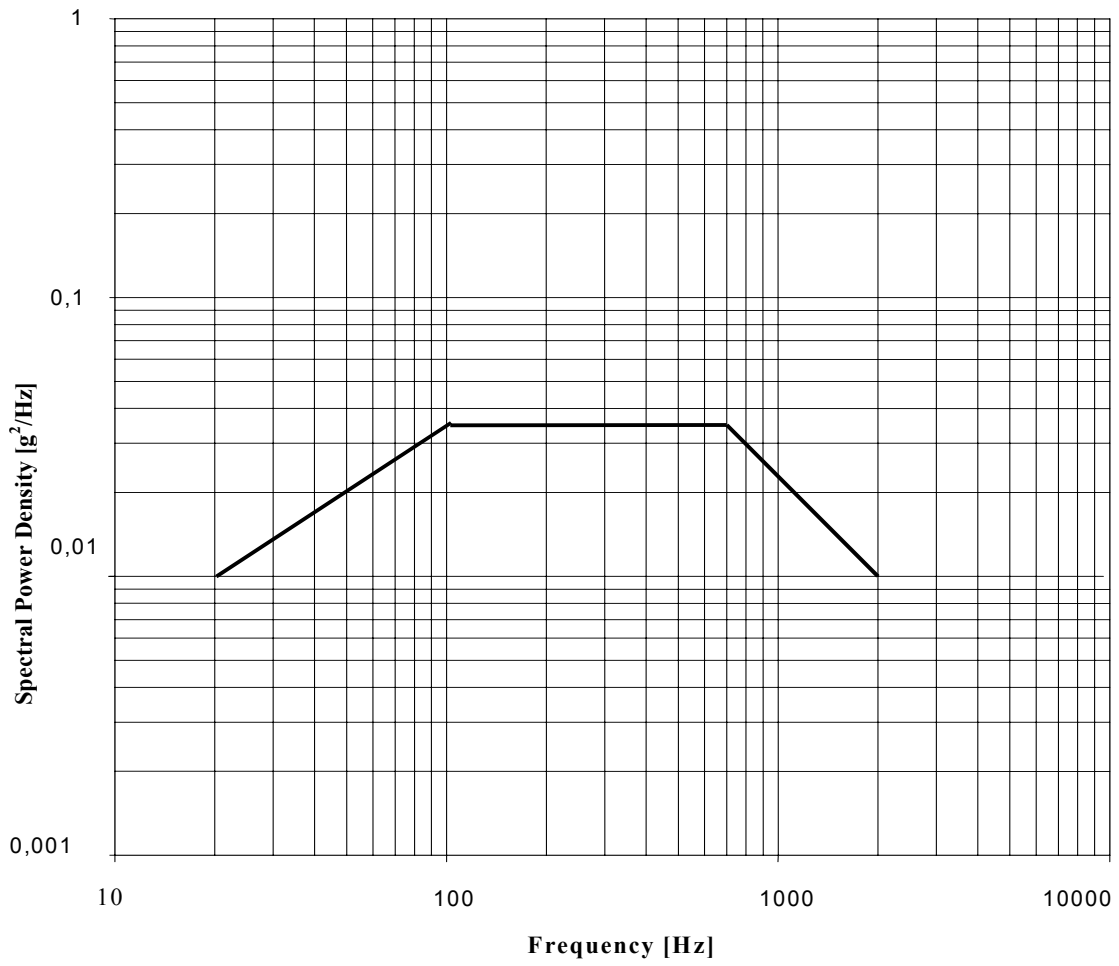


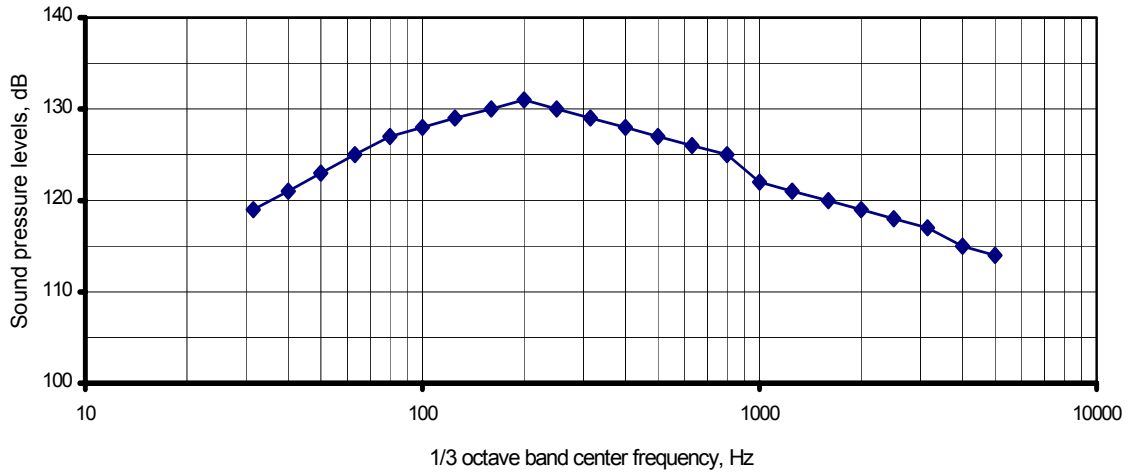
Figure 4-3. Random Vibration Environment During Flight

4.3 Acoustics

Fairing Volume Average Sound Pressure Levels Maximum acoustic pressures occur during lift off and transonic phases of flight. Acoustic characteristics inside the Land Launch fairings are enveloped in Table 4-5 and Figures 4-4 and 4-5.

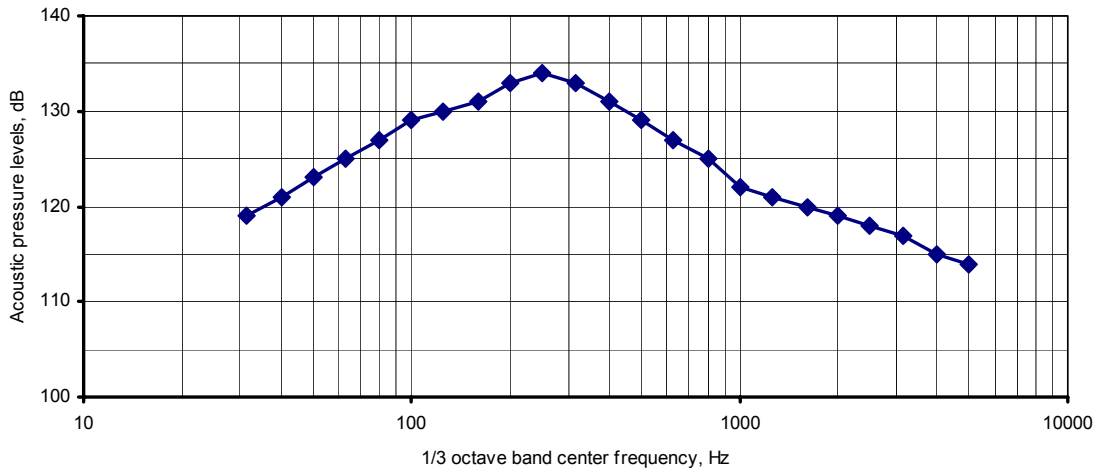
Table 4-5. Maximum Expected Acoustic Pressure Envelope Inside Land Launch Fairings

1/3 Octave Band Center Frequency [Hz]	Acoustic Pressure Level [dB]	
	Zenit-2SLB	Zenit-3SLB
31.5	119	119
40	121	121
50	123	123
63	125	125
80	127	128
100	128	129
125	129	130
160	130	131
200	131	133
250	130	134
315	129	133
400	128	131
500	127	129
630	126	127
800	125	125
1,000	122	122
1,250	121	121
1,600	120	120
2,000	119	119
2,500	118	118
3,150	117	117
4,000	115	115
5,000	114	114
6,300	113	113
8,000	111	111
OASPL	140	142
Duration	40 seconds	60 seconds
Reference: dB in respect to 2×10^{-5} Pa (2.9×10^{-9} psi)		



Note:
Overall acoustic pressure level = 140 dB

Figure 4-4. Maximum Expected Acoustic Pressure Envelope Inside the Zenit-2SLB Fairing



Note:
Overall acoustic pressure level = 142 dB

Figure 4-5. Maximum Expected Acoustic Pressure Envelope Inside the Zenit-3SLB Fairing

4.4 Shock

Overview

The maximum shock at the spacecraft interface occurs at the moment of spacecraft separation. Other shock inputs, including those associated with fairing jettison and stage separations, are within this envelope.

Zenit-3SLB

The maximum expected interface shock response spectrums for the 937-mm, 1194-mm and 1666-mm diameter interfaces are presented in Table 4-6 and Figures 4-6a through 4-6c as a function of clamp band tensioning, when using currently available Saab Ericsson Space (Saab) spacecraft adapters. Maximum SC mass and center-of-gravity corresponding to these band tensions are shown in Section 5. The shock environment may differ if other adapters are used. Customers interested in other adapters are encouraged to contact BLS for further information.

*Table 4-6. Zenit-3SLB Spacecraft Shock Response Spectra (SRS)
With Standard SAAB Adapters*

	Shock Response Spectra (g)							
Frequency (Hz)	937 Interface			1194 Interface				1666 Interface
	Band Tension (kN)			Band Tension (kN)				Band Tension
	12.5	20	30	10	20	30	40	30 kN
100				50	50	50	60	150
200	60	60	60	130	130	140	170	400
800	550	600	650	800	900	1150	1450	3,000
1300	1150	1300	1550	1500	1800	2400	3000	3,000
2000	2300	2700	3300	1850	2250	3000	3750	3,000
3000	2600	3050	3750	2300	2750	3600	4600	3,000
3500	2700	3150	3900	2500	3000	4000	5000	3,100
6000	3200	3700	4600	2500	3000	4000	5000	3,500
8000	3500	4000	5000	2500	3000	4000	5000	3,500
9000	3500	4000	5000	2500	3000	4000	5000	3,500
10000	3500	4000	5000	2500	3000	4000	5000	3,800
<ul style="list-style-type: none"> • Q factor of 10 • SRS levels are simultaneous in three mutually perpendicular directions • As measured at 50 mm (2 inches) from the separation plane on the spacecraft side of the interface 								

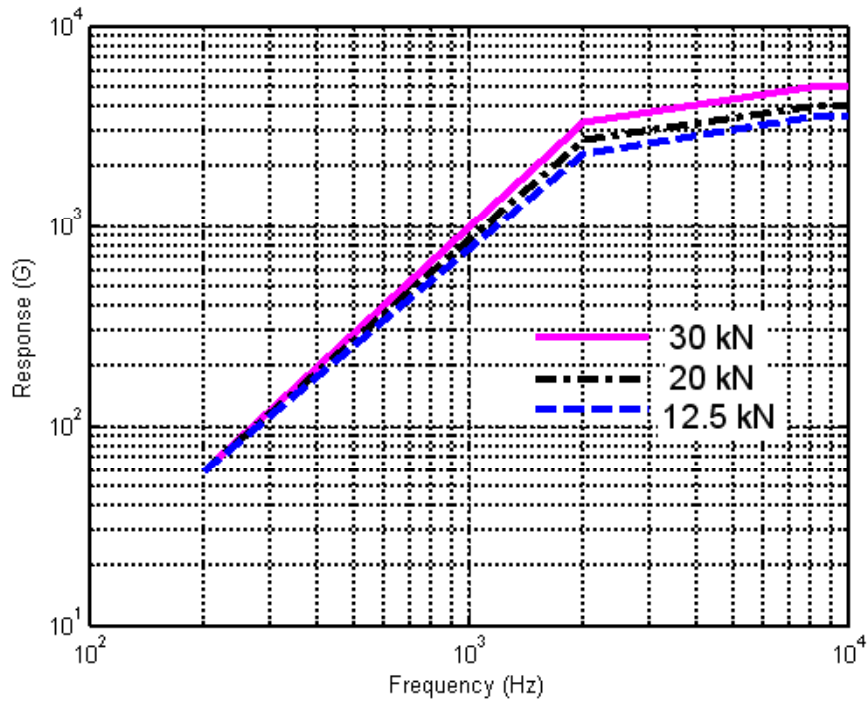


Figure 4-6a. Zenit-3SLB Spacecraft Shock Response Spectra (SRS) With Standard SAAB 937-mm Adapter, Various Band Tensions

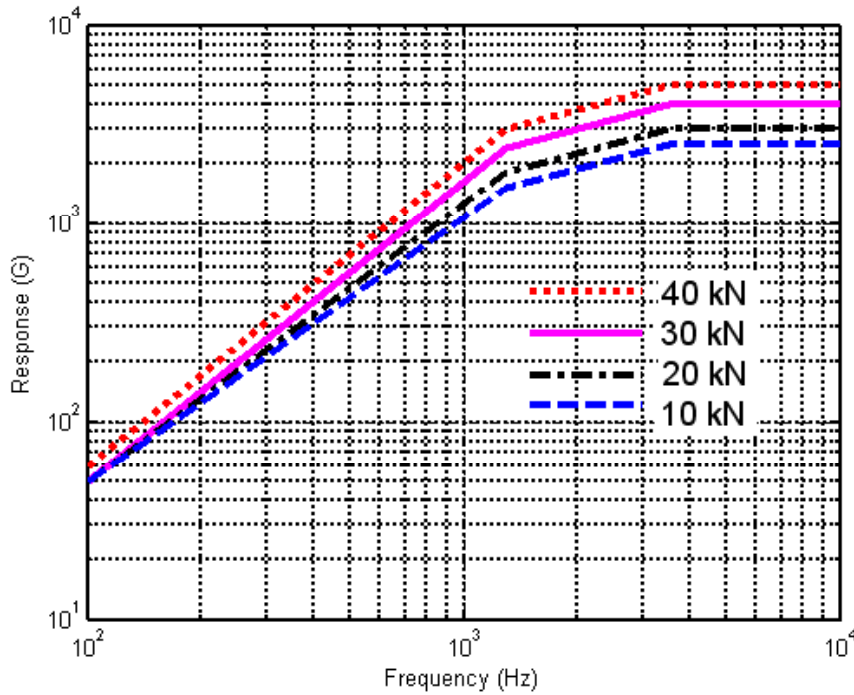
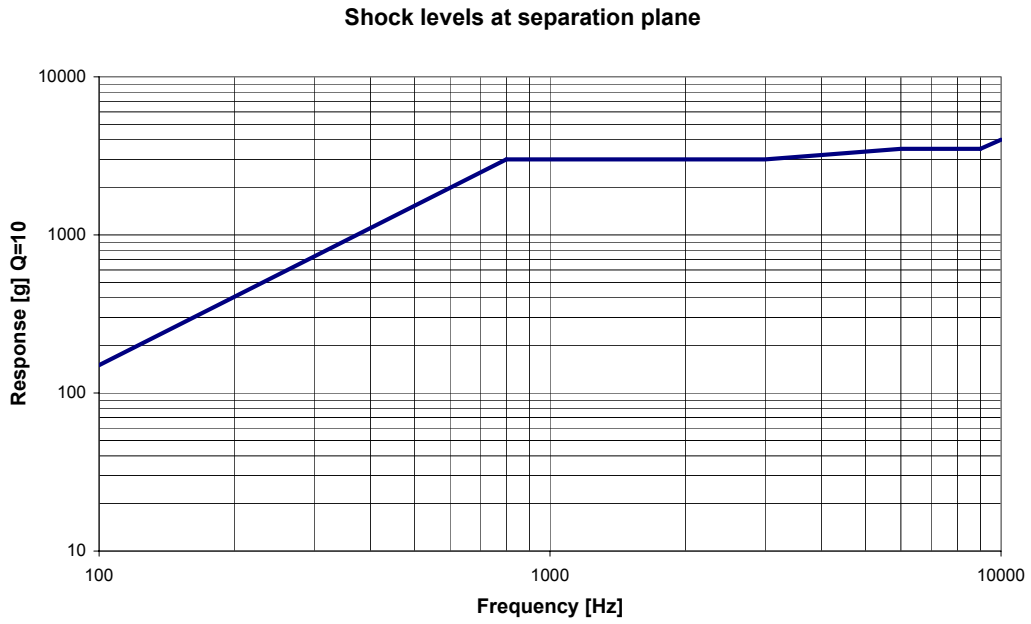


Figure 4-6b. Zenit-3SLB Spacecraft Shock Response Spectra (SRS) With Standard SAAB 1194-mm Adapter, Various Band Tensions



*Figure 4-6c. Zenit-3SLB Spacecraft Shock Response Spectra (SRS)
With Standard SAAB 1666-mm Adapter, 30 kN Band Tension*

Zenit-2SLB

The maximum expected interface shock response spectrums for a single satellite using the Zenit-2 or SAAB 2624-mm interfaces are presented in Table 4-7, with the SAAB information also pictured in Figure 4-6d. The shock environment may differ if other adapters are used, or if more than one satellite is launched at a time. Customers interested in other adapters or group launches are encouraged to contact BLS for further information.

Table 4-7. Zenit-2SLB Spacecraft Shock Response Spectra (SRS)

Shock Response Spectra (g)			
Zenit-2 Adapter (Truss)		SAAB 2624 Interface	
Frequency (Hz)	SRS	Frequency (Hz)	SRS
100-200	25-100	100-520	10-1800
200-500	100-350	520-3200	1800-5000
500-1000	350-1000	3200-10000	5000
1000-2000	1000		
2000-5000	1000-3000		

- Q factor of 10
- SRS levels are simultaneous in three mutually perpendicular directions
- As measured at 50 mm (2 inches) from the separation plane on the spacecraft side of the interface

Shock levels at separation plane

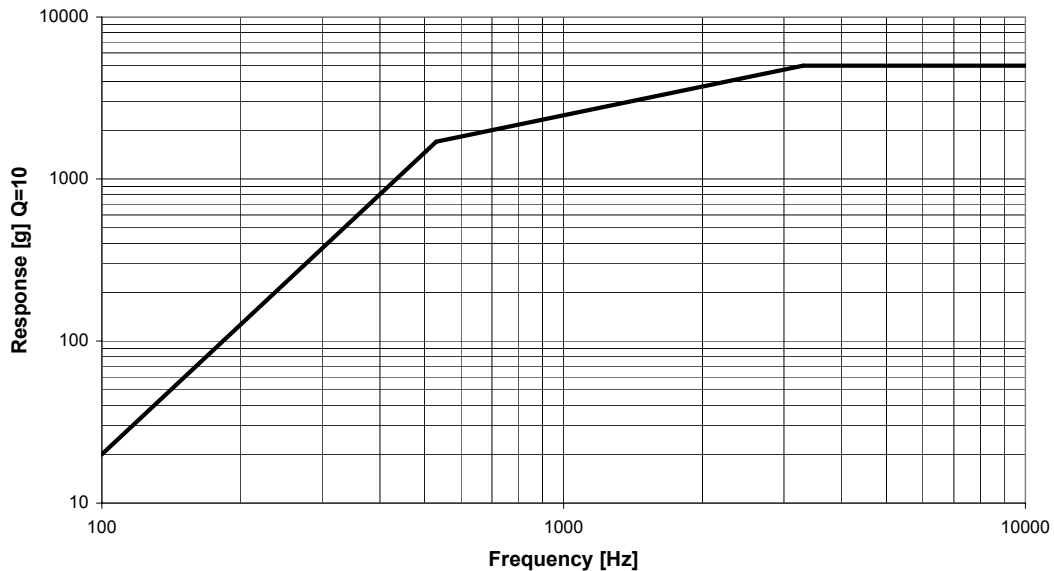


Figure 4-6d. Zenit-2SLB Spacecraft Shock Response Spectra (SRS) With Standard SAAB 2624-mm Adapter

4.5 Electromagnetic Environment

Overview The spacecraft will experience electromagnetic radiation stemming from:

- The background, or ambient, cosmodrome environment during ground processing;
- Ground emitters actively used during launch operations on the Zenit launch pad and during launch;
- The launch vehicle itself

Each of these sources is defined below.

Coordination It is necessary to coordinate the operation of spacecraft transmitters and other electronic equipment with emissions by the launch vehicle and sources at the cosmodrome. This is performed as part of the integration process. Allowable spacecraft emissions are described in Section 7.

Ambient Cosmodrome Electromagnetic Environment The ambient cosmodrome electromagnetic environment varies by location, and changes over time as new equipment is introduced and older equipment is retired. Figures 4-7, 4-8 and 4-9 therefore provide preliminary maximum values for electromagnetic fields levels in Land Launch facilities where the spacecraft will be present: respectively the two available Payload Processing Facilities, the Launcher Assembly Building and the Launch Complex. These environments will be updated during the integration process.

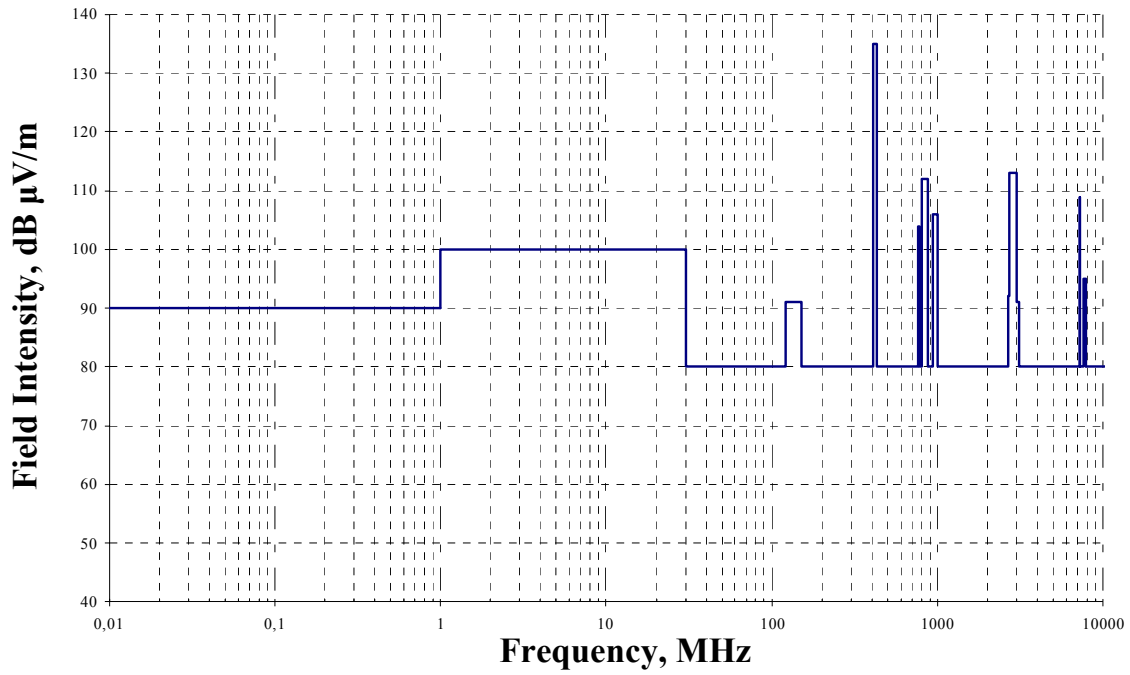


Figure 4-7a. Ambient Electromagnetic Environment within Payload Processing Facility Site 254

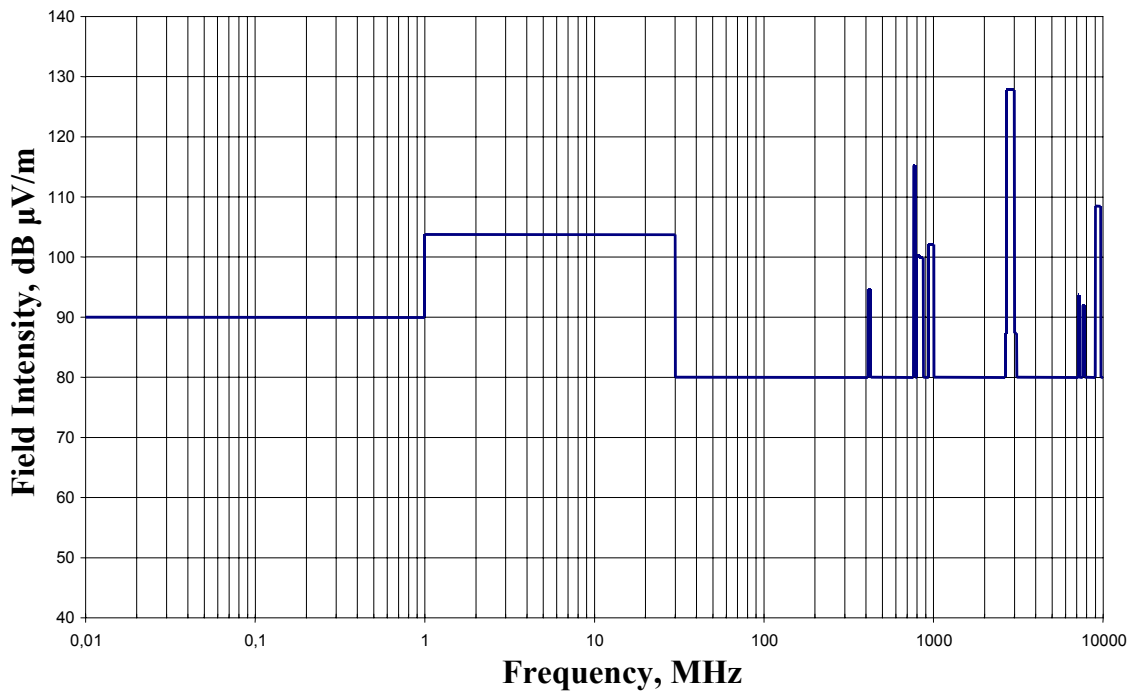


Figure 4-7b. Ambient Electromagnetic Environment within Payload Processing Facility Area 31

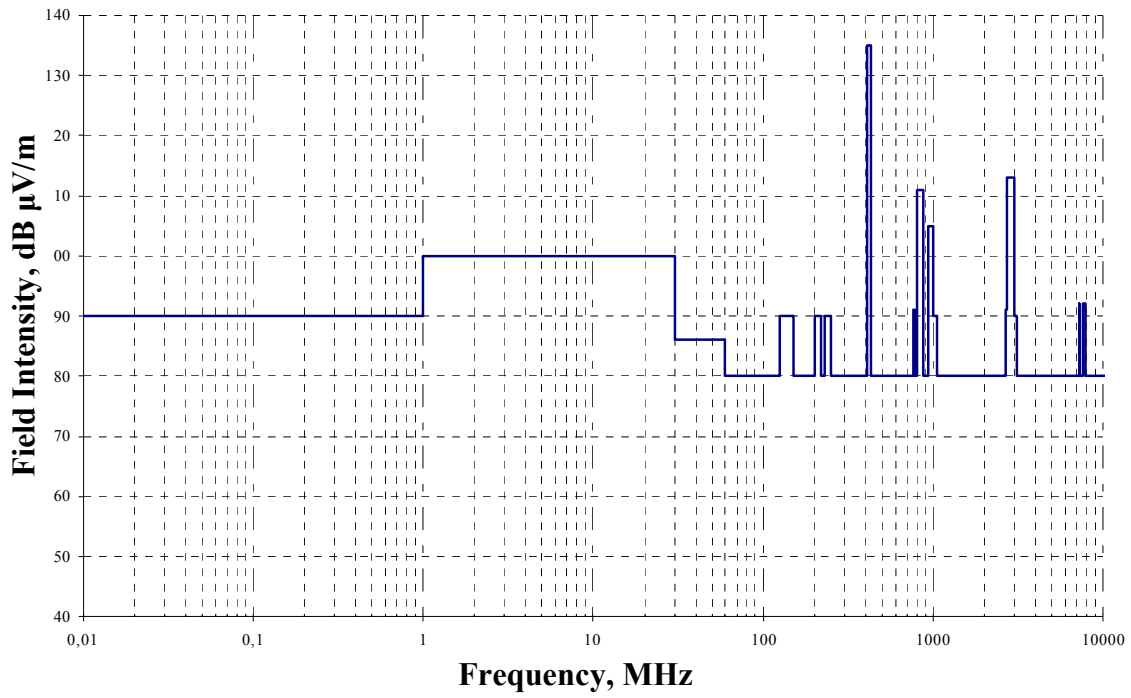


Figure 4-8. Ambient Electromagnetic Environment within the Launch Vehicle Assembly Building (Area 42)

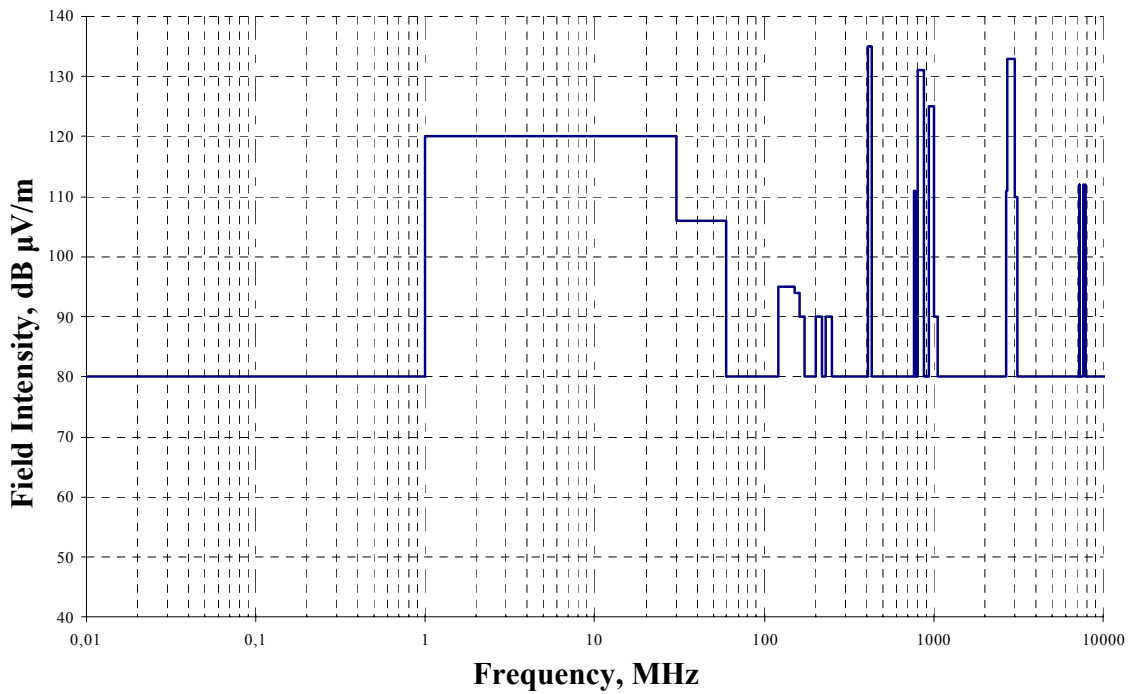


Figure 4-9. Ambient Electromagnetic Environment at the Zenit Launch Complex (Area 45)

**Launch Vehicle
Radio Equipment**

The Zenit-2SLB has three sets of Sirius telemetry systems which are located on the second stage and operate in a total of five frequencies. The Zenit-3SLB uses the same three sets of Sirius systems on its second stage operating in the same five frequencies, and also uses the BITC-B telemetry system located on the Block DM-SLB third stage that operates in two additional frequencies. Each configuration has a Glonass receiving system, located on the second stage of the Zenit-2SLB and on the third stage of the Zenit-3SLB. Characteristics of these systems are provided below in Tables 4-8, 4-9 and 4-10.

Table 4-8. Characteristics of the Sirius Transmitters (Zenit-2SLB and Zenit-3SLB)

Characteristic	Transmitter				
	Meter Band			Decimeter Band	
Nominal Frequency (MHz)	231.3	239.3	247.3	1010.5	1018
-0.5 dB Bandwidth (MHz)	± 1.3			± 1.3	
Modulation Type	PCM-FM			PCM-FM	
Max/Min Antenna Gain Coefficient (dB)	0/-7			0/-5	
Output Power	11.8 – 16 dBW (15–40 W)			10 – 14.8 dBW (10–30 W)	
Reduced level relative to main signal of spurious and harmonic emissions (dB)	40			30	

Table 4-9. Characteristics of BITC-B Telemetry Equipment (Zenit-3SLB Only)

Characteristic	Transmitter	
	Nominal Frequency (MHz)	1026.5
-0.5 dB Bandwidth (MHz)	1.25	
Modulation Type	TBD	
Max/Min Antenna Gain Coefficient (dB)	TBD	
Output Power (W)	17	
Reduced level relative to main signal of spurious and harmonic emissions (dB)	60	

Table 4-10. Characteristics of the Glonass Receiver (Zenit-2SLB and Zenit-3SLB)

Characteristic	Zenit-2SLB	Zenit-3SLB
Nominal Frequency (MHz)	1575.4 \pm 1	1575.4 \pm 1
-1 dB Bandwidth (MHz)	42	50
Receiver Sensitivity at Nominal Frequency (dBW)	-163	-145
Max/Min Antenna Gain Coefficient (dB)	7/-3	TBD

Radio Frequency Environment at the SC Separation Plane

The maximum field intensity levels generated by launcher systems at the spacecraft interface plane are provided in Table 4-11, and Figures 4-10 and 4-11. These account for such factors as the type and orientation of antennas, and the location of the antennas relative to the spacecraft, but do not account for fairing attenuation. The fairings for the Zenit-2SLB and Zenit-3SLB are both aluminum construction, and will attenuate field levels experienced by the SC during pre-launch preparations and after launch until fairing jettison. The degree of attenuation will depend on the size and location of RF windows (mission-specific) and will be analyzed for each mission.

Table 4-11. Maximum Field Intensity Levels Generated by the Launch Vehicle at the Spacecraft Separation Plane, Without Fairing Attenuation

Frequency (MHz)	Field Intensity (dB μ V/m)	
	Zenit-2SLB	Zenit-3SLB
230.0 – 232.6	150.9	128.0
238.0 – 240.6	150.9	128.0
246.0 – 248.6	150.9	128.0
1009.2 – 1011.8	149.6	124.1
1016.7 – 1019.3	149.6	124.1
1025.5 – 1027.5	110.9	140 (TBR)
1033.5 – 1035.5	110.9	140 (TBR)
All Other	110.9	70

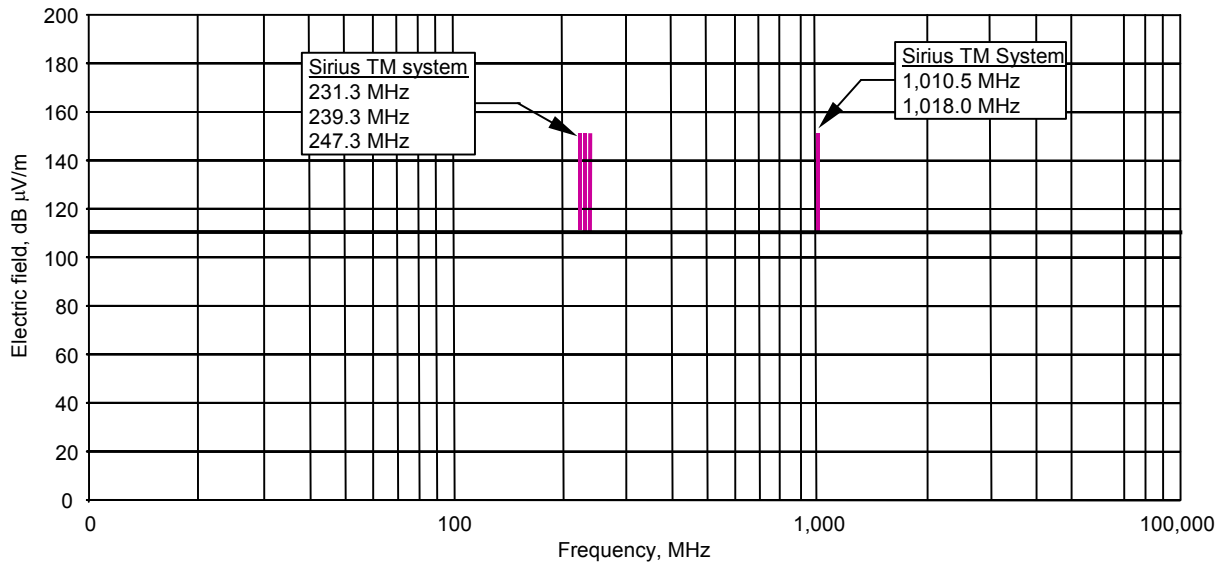


Figure 4-10. Maximum Field Intensity Levels Generated at the Spacecraft Separation Plane by the Zenit-2SLB, Without Fairing Attenuation

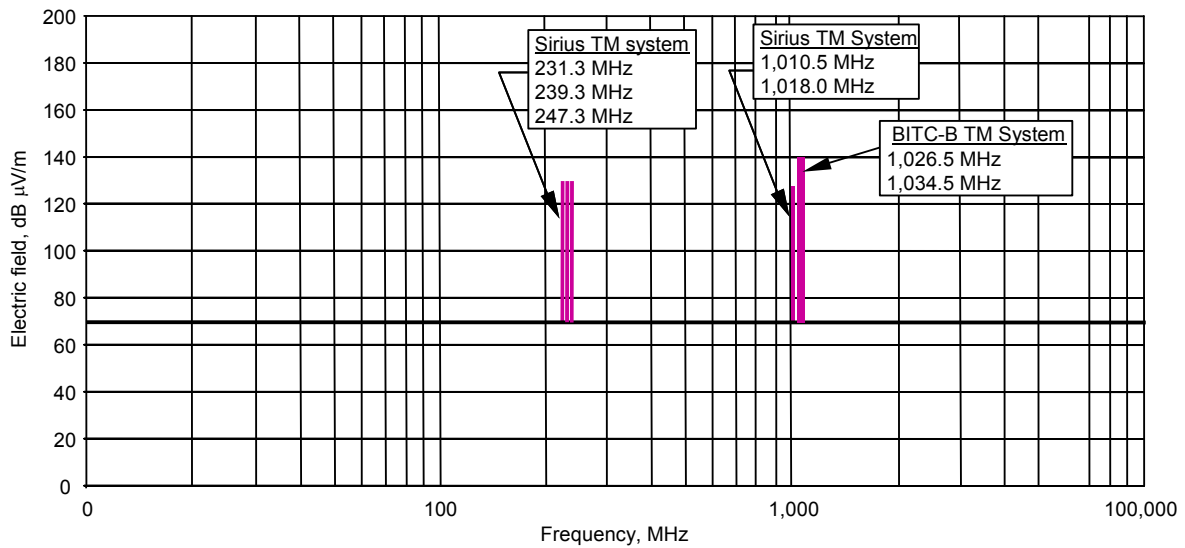


Figure 4-11. Maximum Field Intensity Levels Generated at the Spacecraft Separation Plane by the Zenit-3SLB, Without Fairing Attenuation (BITC-B field intensity levels are TBR)

4.6 Spacecraft Thermal and Humidity Environments

Introduction Described in this section are the thermal and humidity conditions to which the spacecraft will be exposed from arrival at the Baikonur airport through separation on orbit.

4.6.1 Ground Thermal and Humidity Environments

General Overview, Ground Thermal and Humidity Environments The spacecraft thermal and humidity environment is actively controlled by facility, transportation and launch pad clean air systems from the time the spacecraft container is offloaded at Baikonur airport through lift off. This supply is also maintained in the case of a launch standby or abort. Table 4-12 provides the temperature and humidity characteristics of each processing milestone or location. Figures 4-12 and 4-13 portray the air conditioning and venting schemes for the Zenit-2SLB payload unit and the Zenit-3SLB ascent unit (shown while integrated with the launch vehicle).

Facility Clean Air Systems The spacecraft is exposed to ambient facility air in the PPF from the time it is unloaded from the shipping container until it is enclosed in the fairing. Land Launch customers may use one of two PPF's (described in Section 6): Site 254 and Area 31. In both locations the temperature, humidity and cleanliness (Class 100,000 or better per FED-STD-209E) of the ambient air is actively maintained by facility clean air systems.

The Launcher Assembly Complex (Area 42) also contains a clean room with active temperature, humidity and cleanliness control that is used during mating of the Ascent Unit (or Payload Unit) to the Zenit second stage. Air supply to the fairing is shut off during this mating operation. This clean room is also available for optional customer use in case physical access to the spacecraft is desired through fairing access doors.

Transportation Clean Air Systems Clean, conditioned air is supplied to the spacecraft container by a mobile clean air system while being transported between Baikonur airport (Yubileiny) and the PPF. The mobile clean air system is also used to condition the SC enclosure during transport between the PPF and fueling area at Area 31, and to condition the fairing during all moves following payload encapsulation. There may be an interruption in the supply of conditioned air for no more than 60 minutes during loading of the fully assembled launch vehicle onto the transporter/erector inside the Launcher Assembly Complex (Area 42). Cleanliness of the encapsulated environment within the fairing is always maintained at a Class 100,000 or better level per FED-STD-209E.

**Launch Pad Clean
Air Systems**

A clean air system at the launch pad provides conditioned air to the fairing until the erector is lowered and removed at 12 minutes before launch. Conditioned air is maintained from T-12 minutes continuously through launch, and after T-0 in the event of an abort until the transporter/erector and its associated conditioned air system can be reattached to the launch vehicle, by a high pressure payload fairing purge system.

A Uninterruptible Power Supply (UPS) system ensures that backup power is available for the pad air supply unit such that conditioned air flow to the fairing can be resumed within one minute after failure of the primary power supply.

**Impingement Ve-
locity of Airflow
Upon SC Surfaces**

Airflow impingement upon the spacecraft surfaces is generally maintained at or below three meters per second.

Table 4-12. Spacecraft Ground Thermal and Humidity Environment

Operations Phase/Location		Acting System	Temperature [°C]	Relative Humidity	Nominal Flow Rate
SC Container, Airport to PPF Transfer		Mobile Unit	15 to 30*	≤ 60%	3K-6K m ³ /h
PPF Processing Areas	Area 31 Area B	Facility Air Conditioning	15 to 28	35% - 60%	N/A
	Area 31 Room 119		17 to 23	40% - 60%	
	Site 254		18 to 25	30% - 60%	
Transfer from PPF to HPF (Area 31)		Mobile Unit	15 to 30*	≤ 60%	3K-6K m ³ /h
PPF Fueling Cells	Area 31 Site 254	Facility Air Conditioning	15 to 25 TBD	30% - 60% TBD	N/A
PPF Encapsulation Halls	Area 31 Site 254	Facility Air Conditioning	15 to 28 18 to 25	35% - 60% 30% - 60%	N/A
Transfer to ILV Integration Area (Site 42)		Mobile Unit	10 to 35*	30% - 60%	3K-6K m ³ /h
ILV Integration Bay (Site 42)		Facility Air Conditioning	18 to 25	≤ 80%	N/A
Clean Room (Site 42)		Facility Air Conditioning	21 to 26.7	30% - 60%	N/A
ILV ready in Site 42 for roll-out		Mobile Unit	10 to 35*	≤ 60%	≤ 3K m ³ /h
ILV transfer to launch complex (and from launch complex after launch abort)		Mobile Unit	10 to 35*	≤ 60%	≥ 2250 kg/h
ILV erection, and while erect prior to LOX loading	Zenit-2SLB Zenit-3SLB	Pad System	10 to 35*	DP ≤ -10 ⁰ C	9500 m ³ /h
ILV de-erection if launch aborted before T-12 min			8 to 25*	DP ≤ -10 ⁰ C	5000 m ³ /h
ILV erect on launch pad, from LOX loading until T-12 min	Zenit-2SLB Zenit-3SLB	Pad System	10 to 35* 8 to 25*	DP ≤ -30 ⁰ C DP ≤ -30 ⁰ C	9500 m ³ /h 5000 m ³ /h
ILV erect on launch pad, T-12 min to T-0		High Pressure Pad System	10 to 32*	DP ≤ -55 ⁰ C	≥ 2250 kg/h
ILV erect on launch pad following launch aborted between T-12 and T-0, through ILV de-tanking and de-erection (until mobile unit is reconnected)					
Notes:					
<ul style="list-style-type: none"> • Temperatures maintained within ± 2⁰C of set point agreed with the customer • * Denotes temperatures as measured at the fairing (or SC container) inlet • The customer is responsible for monitoring the environment inside the SC container • DP = dew point, K = thousands 					

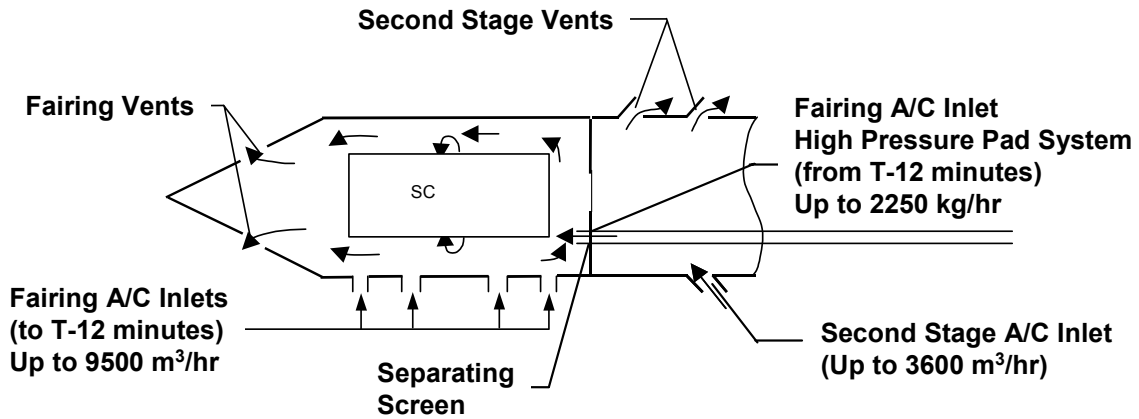


Figure 4-12. Zenit-2SLB Ascent Unit Air-Conditioning (A/C) and Venting Scheme

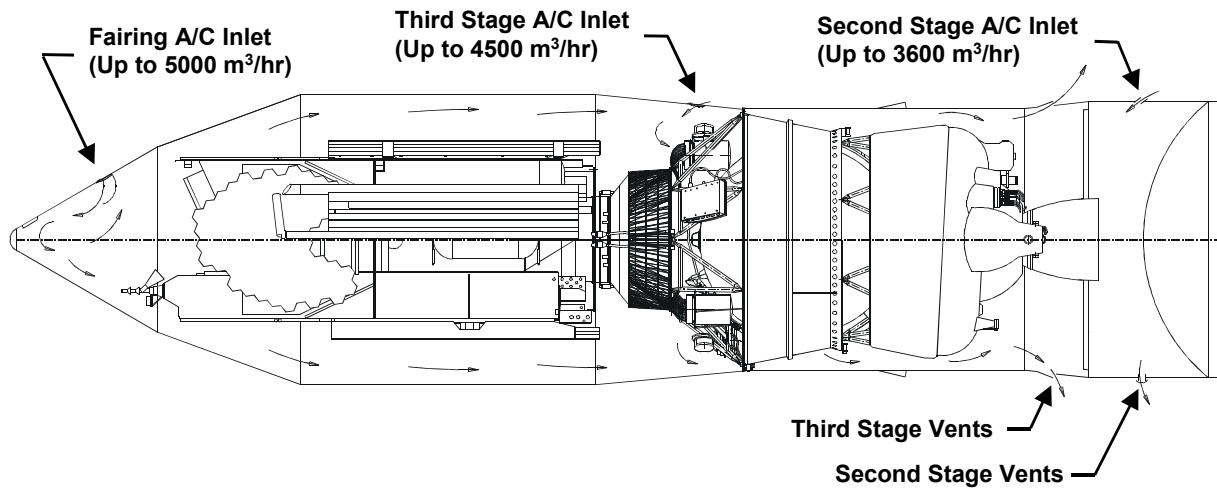


Figure 4-13. Zenit-3SLB Ascent Unit Air-Conditioning (A/C) and Venting Scheme

4.6.2 Flight Thermal Environments

**General Overview,
Flight Thermal
Environment**

After launch, the spacecraft will experience:

- Heat flux radiated from internal surfaces of the fairing, before fairing jettison. This is mitigated by insulation and ablative coatings on the fairings.
- After fairing jettison, free molecular heating and various other thermal influences. This is mitigated by the late timing of fairing jettison, by the short duration of the Zenit-2SLB mission, and on Zenit-3SLB by the thermal maneuvering capabilities of the Block DM-SLB

Thermal effects experienced by the spacecraft during flight are summarized in Table 4-13. A thermal analysis will be performed for each mission, using the spacecraft thermal model provided by the customer, to assess spacecraft temperatures during all mission phases.

Table 4-13. Flight Thermal Environments

Thermal Effect	Zenit-2SLB	Zenit-3SLB
Thermal flux radiated onto the spacecraft from fairing internal surfaces	500 W/m ² maximum	400 W/m ² maximum
Free molecular heating at fairing jettison	1135 W/m ² or less. Considerably less than 1135 W/m ² for most missions (typically around 50 W/m ²) due to drop zone requirements	
Free molecular heating after fairing jettison	Typically not significant due to short mission duration. Analyzed for each mission.	Dependent on mission profile, but may spike slightly at the time of the second Block DM-SLB burn as shown in Figure 4-14
Heat radiated onto spacecraft surfaces by the second stage solid propellant separation thrusters	9.0 Kw-s/m ² maximum	5.1 Kw-s/m ² maximum
Solar heating, planet-reflected solar heating (albedo), Earth-radiated heating, radiation to space	Typically not significant due to short mission duration. Analyzed for each mission.	Analyzed for each mission. For thermal management, the Block DM-SLB is designed to accommodate preferred attitude pointing, continuous rolls, maneuvers, and orientations during coast and pre-separation phases of flight

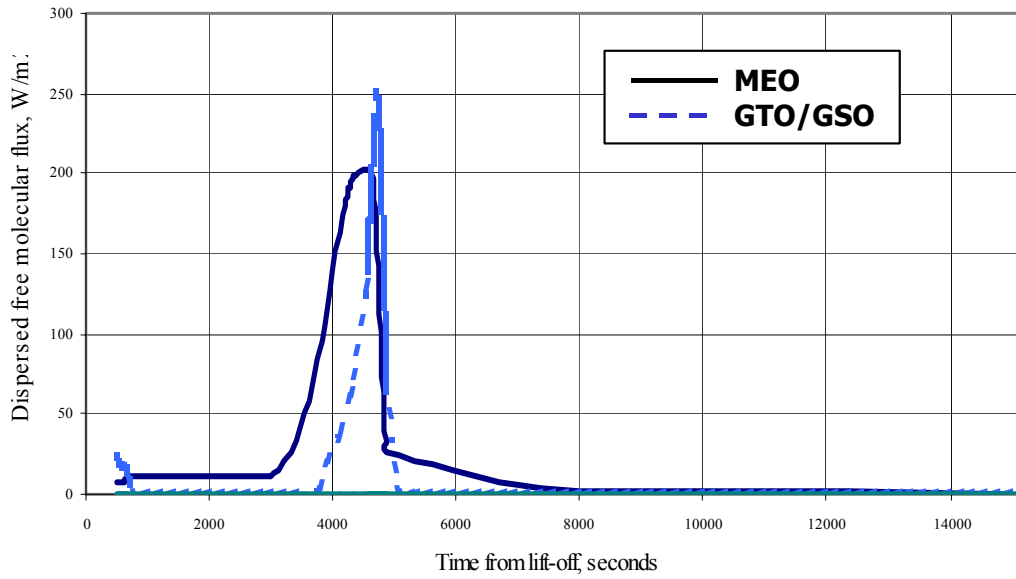


Figure 4-14. Zenit-3SLB Free Molecular Heating Environment

4.7 Pressure Venting

Overview	During ascent, the payload volume is vented through a set of orifices in the second stage equipment bay and in the third stage, as shown in Figures 4-15 and 4-16.
Pressure Decay Rate	<p>The depressurization rate, though varying somewhat by trajectory and dependent on spacecraft displaced volume, does not exceed:</p> <ul style="list-style-type: none">0.028 kgf/cm² per second for Zenit-2SLB0.032 kgf/cm² per second for Zenit-3SLB <p>A typical fairing cavity pressure curve for the Zenit-2SLB and Zenit-3SLB are provided in Figures 4-17 and 4-18, along with the associated pressure decay profiles shown in Figures 4-19 and 4-20. The specific predicted pressure venting rate for each launch is determined during the mission analysis phase.</p>
Pressure Differential at Fairing Jettison	Due to the late timing of fairing jettison due to drop zone constraints, the maximum pressure differential between the pressure inside the fairing and the external pressure at fairing jettison does not exceed a very low 0.002 kgf/cm ² for both Zenit-2SLB and Zenit-3SLB.

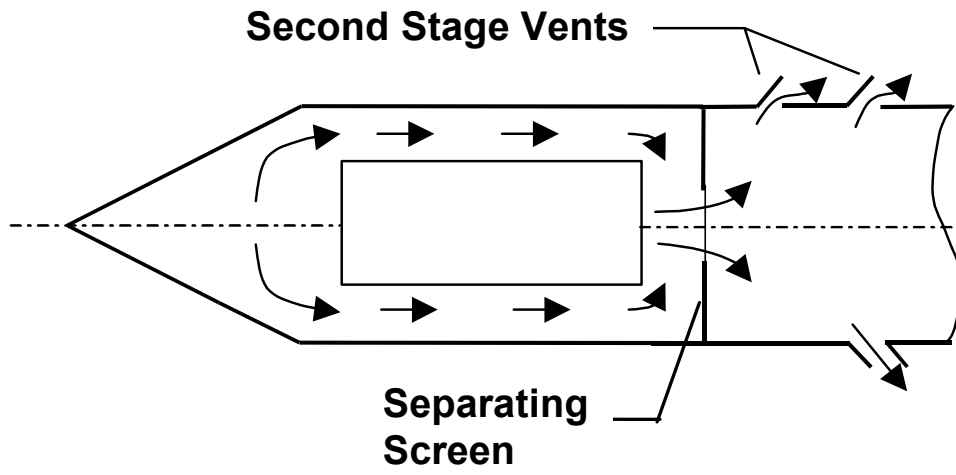


Figure 4-15. Zenit-2SLB Ascent Venting Scheme

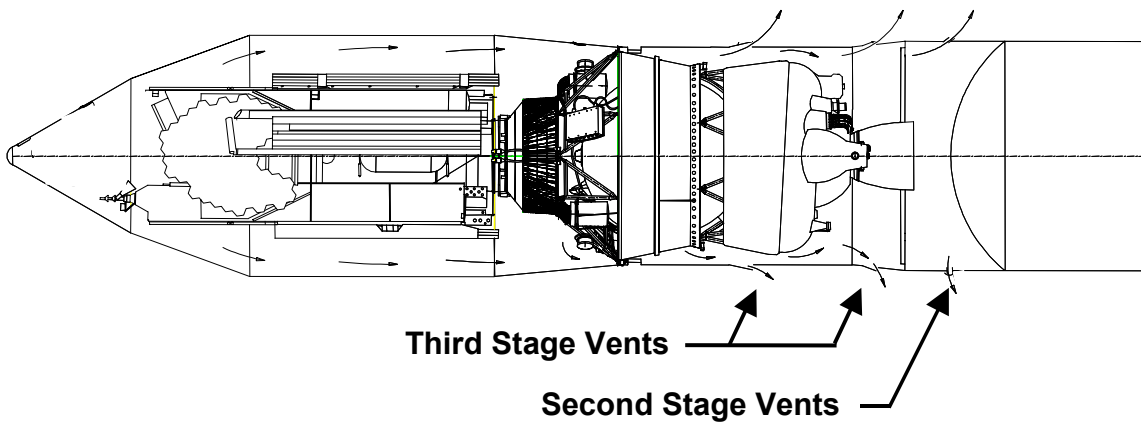


Figure 4-16. Zenit-3SLB Ascent Venting Scheme

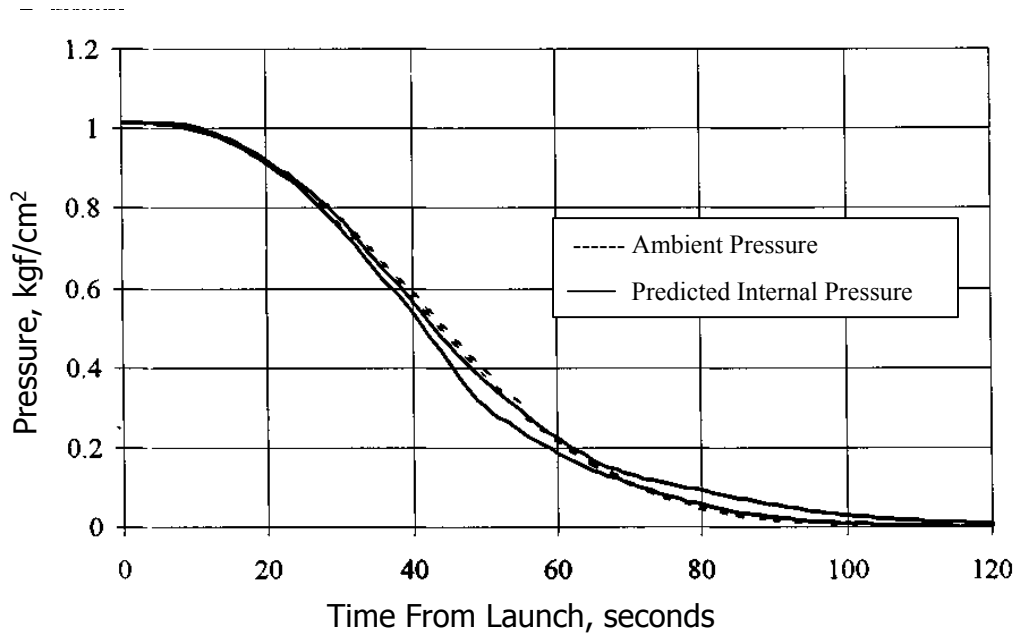


Figure 4-17. Typical Zenit-2SLB Fairing Internal Pressure Profile During Ascent

To be provided

Figure 4-18. Typical Zenit-3SLB Fairing Internal Pressure Profile During Ascent

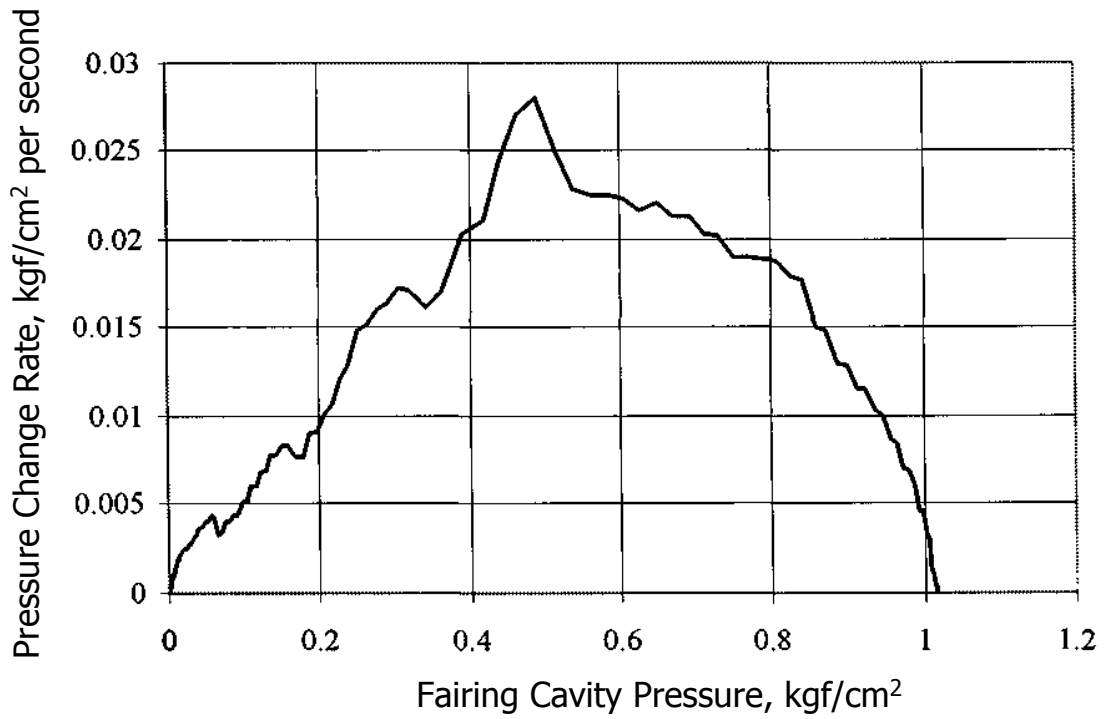


Figure 4-19. Typical Zenit-2SLB Fairing Internal Pressure Decay Profile

To be provided

Figure 4-20. Typical Zenit-3SLB Fairing Internal Pressure Decay Profile

4.8 Contamination

Contamination Control During Ground Processing

The spacecraft is protected from contamination during ground processing by:

- Supplying a continuous flow of clean, conditioned air (class 5,000 or better per FED-STD-209E) to the SC while in its container or under the LV fairings, through launch and after T-0 in the event of a launch scrub or abort. These clean air systems, both mobile and fixed pad units, are described in more detail in Section 4.6.1 and maintain a constant overpressure inside the enclosure relative to ambient to prevent outside air ingress.
- Providing Class 100,000 or better per FED-STD-209E clean room facilities for all spacecraft operations (unloading, processing, fueling, encapsulation) between removal from the SC container and encapsulation in the LV fairing.
- Precision cleaning of the launch vehicle hardware surfaces that enclose the spacecraft, prior to placing them in proximity to the spacecraft. These cleanliness levels are described in Table 4-14.

Table 4-14. Fairing Internal Surface Cleanliness Levels at Encapsulation

Particle Size	Level 500 per Mil-Std-1246C	Particles		Level 750 per Mil-Std-1246C
		Maximum Fairing Surface Levels		
		Zenit-2SLB	Zenit-3SLB	
$\geq 100 \mu\text{m}$	11,900/m ²	11,900/m ²	30,129/m ²	96,300/m ²
$\geq 250 \mu\text{m}$	281/m ²	281/m ²	753/m ²	2,310/m ²
$\geq 500 \mu\text{m}$	10.8/m ²	10.8/m ²	32/m ²	87.5/m ²

Non-Volatile Residue	
Zenit-2SLB	10 mg/m ² (Level A per Mil-Std-1246C)
Zenit-3SLB	TBD

Contamination Control During Flight

Potential sources of the SC contamination in flight are fairing materials, contaminants migrating from the launch vehicle equipment bays while venting during ascent, and plume impingement from the second stage solid propellant separation thrusters and, on Zenit-3SLB missions, from the Block DM-SLB steering engines and outgassing. All of these sources are addressed in the design of the Land Launch hardware and mission.

Fairing Design Features to Minimize Contamination

Materials exposed to the cavity shared by the spacecraft are selected to preclude crumbling, peeling, particle shedding, oxidation or corrosion, and with low outgassing properties that should not exceed the following values during testing according to GOST R 50109-92 (equivalent to ASTM E-595):

- Total mass loss (TML) less than 1%
- Collected Volatile Condensable Material (CVCM) less than 0.1%

Pyrotechnic devices used for fairing and satellite separation are sealed and do not release gasses or particles. The venting system is designed to preclude circulation from the upper stage (Zenit-3SLB) or second stage avionics bay (Zenit-2SLB) back into the payload unit.

Plume Impingement

The plume effect on the SC of the second stage solid propellant separation thrusters is negligibly small because of their location on the aft end of the stage. On three stage missions, the Block DM-SLB performs a Contamination and Collision Avoidance Maneuver (CCAM) following satellite separation to ensure a negligibly small contaminating effect on the SC from the upper stage steering engines and stage venting. CCAM features include stage attitude control for optimum orientation relative to the SC, minimum separation distance before main engine re-start, long burns for orbit separation and fuel depletion, and fuel tank venting as a final act. The Block DM family has performed CCAM hundreds of time.

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