CHAPTER 6

ENVIRONMENTAL CONDITIONS

6.1 Summary

This chapter introduces the natural environment of launch site, thermal environment during SC operation, thermal and mechanical environments (vibration, shock & noise) during LV flight and ground & on-board electromagnetic environment.

6.2 Pre-launch Environments

6.2.1 Natural Environment

The natural environmental data in XSLC such as temperature, ground wind, humidity and winds aloft are concluded by long-term statistic research as listed below.

(1) Temperature statistic result for each month at launch site.

Month	Highest (°C)	Lowest (°C)	Mean (°C)
January	7.9	***4.5***	5.9
February	10.4	5.0	8.0
March	14.5	9.7	11.7
April	17.5	13.1	15.0
May	20.2	15.6	17.7
June	21.1	17.7	19.1
July	***21.3***	19.3	20.0
August	***21.3***	18.5	19.8
September	19.3	16.2	17.2
October	16.4	13.2	14.1
November	12.3	8.4	10.0
December	8.9	4.6	6.5

(2) The ground wind statistic result for each month at launch site

Month	Mean Speed (m/s)	Days (Speed >13m/s)
January	2.2	0.5
February	2.3	1.1
March	2.3	2.5
April	2.0	1.6
May	1.5	0.6
June	1.0	0.4
July	1.1	0.2
August	1.2	0.1
September	0.9	0.2
October	1.1	0.1
November	1.4	0.0
December	1.7	0.2

(3) The relative humidity at launch site:

Maximum: 90% at rain season;

Minimum: 42% at dry season.

(4) The winds aloft used for LV design is an integrated vector profile, see **Figure 6-1**.

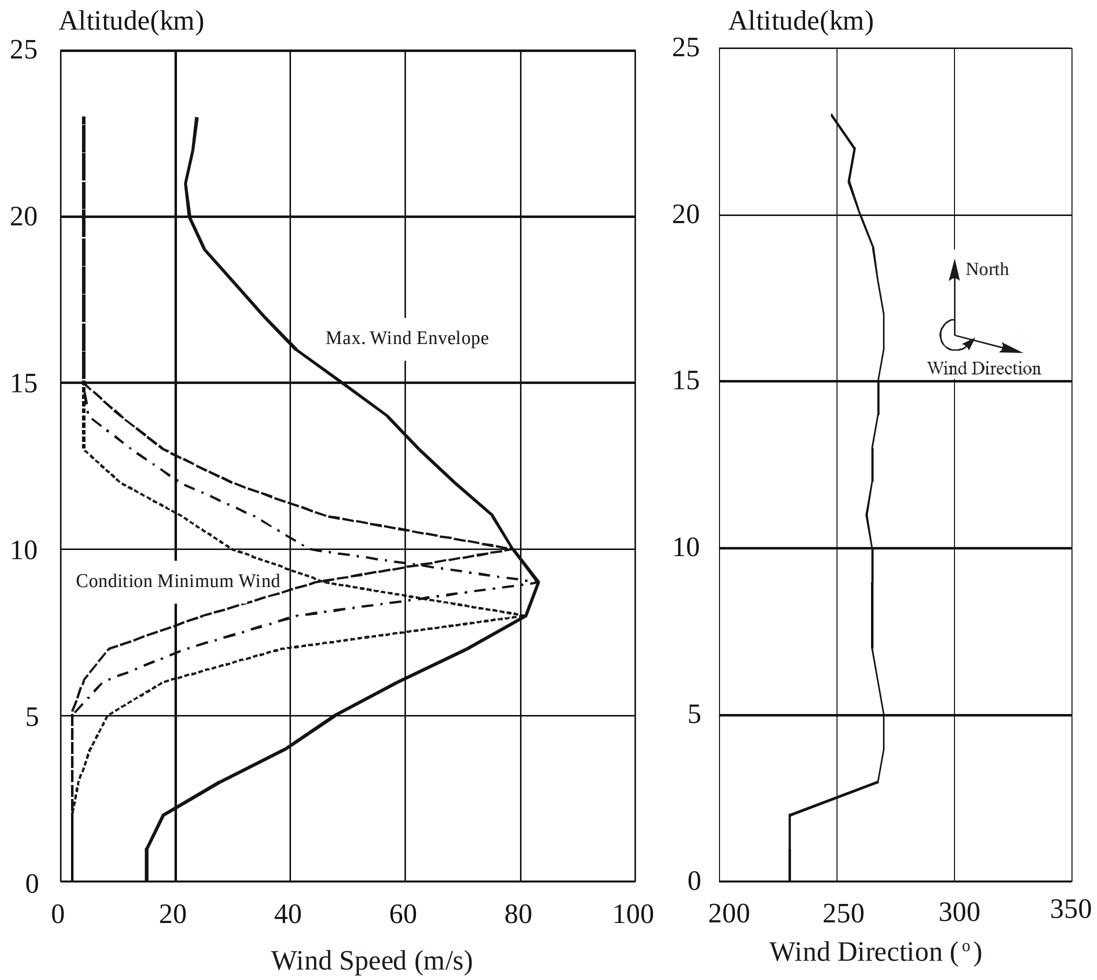


Figure 6-1 Wind Aloft Statistics Results in Xichang Area

6.2.2 SC Processing Environment

Before launch, SC will be checked, tested in SC Processing Buildings (BS2 and BS3) and then transported to the launch pad for launch. The environment impacting SC includes three phases: process in BS2 and BS3, transportation to launch pad and preparation on launch tower.

6.2.2.1 Environment of SC in BS2

The environmental parameters in BS2 and BS3 are as follows:

Temperature:	15°C~25°C
Relative humidity:	33%~55%
Cleanliness:	100,000 level

6.2.2.2 Environment of SC during Transportation to Launch Pad

It will take 30 minutes from BS3 to launch pad, during which the SC is put into a sealed container (SC Container) that can ensure the needed environment.

The SC Container is a sealed cylindrical container with an available inner space of 7450mm high and 3980mm in diameter. The thermal-insulation wall is made of Aluminum sandwich. See **Chapter 8**.

Before transportation, pure Nitrogen of 15°C~25°C will be filled into the SC Container to make pressurization protection. After the temperature of SC and container reaches 15°C~25°C, the container will be sealed and moved out of BS3. The temperature in the container is variable from 15°C to 25°C, the relative humidity is variable from 35% to 55%, the cleanliness is 100,000 level and the noise during the charging and venting process is lower than 90dB. During the transportation, because the inner pressure of container is higher than the outside air pressure, the cleanliness can be maintained at 100,000 level.

After the container is transported to the launch pad, it will be lifted to 8^{th} floor of the Service Tower, where an environmentally controlled area will be established. The detailed procedures are shown in **Chapter 8**. The environmental conditions in the clean area are listed below:

Temperature:	15°C~25°C;

Relative Humidity: 35%~55%;
Cleanliness: 100,000 level.

The container will stay in the clean area until the ambient environment meet the requirements, then the container will be opened and the SC will be moved out to mate to the Launch Vehicle.

6.2.3 Air-conditioning inside Fairing

Air-conditioning system connecting to the fairing begins to work after the fairing is encapsulated on the launch pad. The fairing air-conditioning system is shown in **Figure 6-2**.

Air-conditioning parameters inside Fairing:

Temperature:	15°C~25°C
Relative Humidity:	33%~55%
Cleanliness:	100,000 level
Air Speed inside Fairing:	≤2m/s
Noise inside Fairing:	≤90dB
Max. Air Flow Rate:	3000~4000m^3/hour

The air-conditioning is shut off at L-45 minutes and would be recovered in 40 minutes if the launch aborted. The air-conditioning inlets are shown in **Chapter 4**.

For the fairing encapsulated in BS3, the air-conditioning begins to work after the fairing and SC mating to the Launch Vehicle.

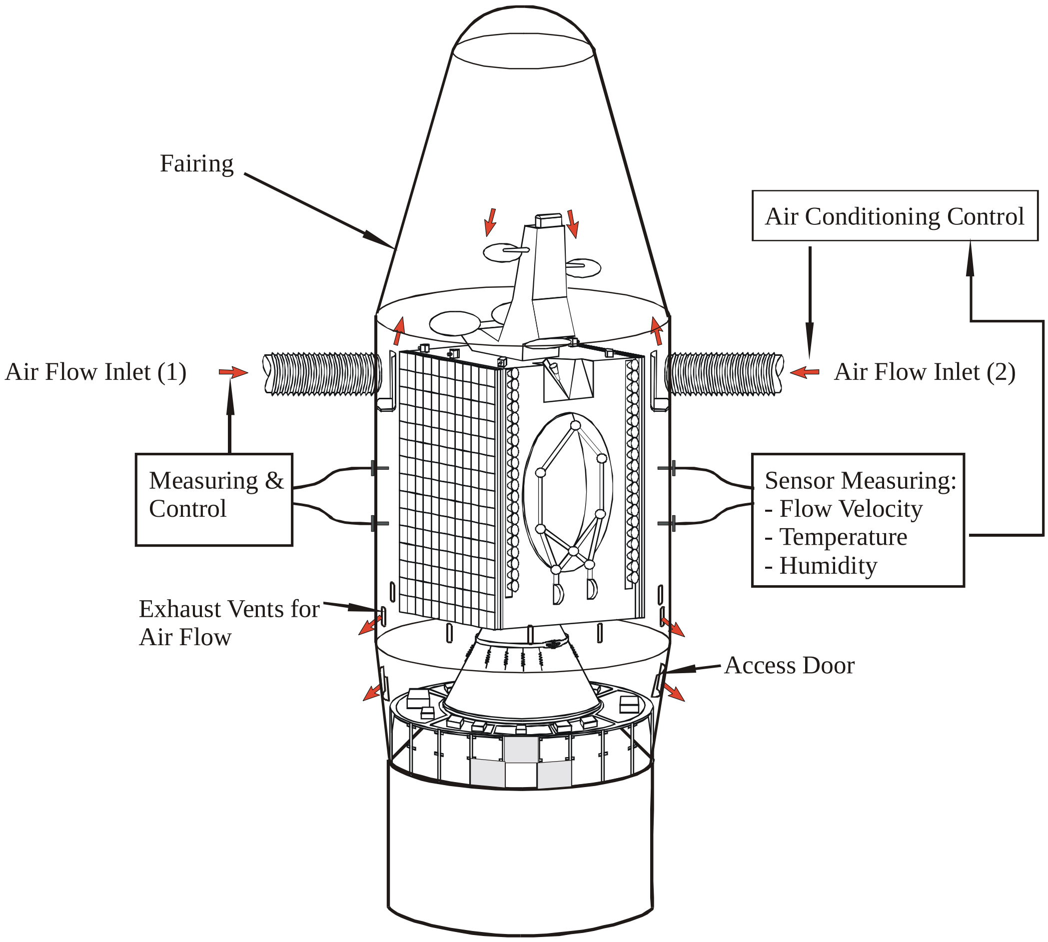


Figure 6-2 Fairing Air-conditioning on the Tower

6.2.4 Electromagnetic Environment

6.2.4.1 Radio Equipment onboard LM-3A and Ground Test Equipment

Characteristics of on-board radio equipment and ground test equipment are shown below:

	EQUIPMENT	FREQUENCY (MHz)	POWER (W)	Sensitivity	Polarization	Antenna position
LAUNCH VEHICLE	Telemetry Transmitter 3	2200~2300	10		linear	VEB
	Telemetry Transmitter 2	2200~2300	5		linear	Stage-2 Intertank
	Transponder 1	Rec.5840~5890 Tra.4200~4250	5	≤-120dBW	linear	Stage -2 Intertank
	Transponder 2	Rec.5860~5910 Tra.4210~4250	2	≤-120dBW	linear	Stage -2 Intertank
	Transponder 3	Rec. and Tra. 5580~5620	300(max) 0.8~1.0µs 800Hz P_{av}<300 mW	≤-90dBW	linear	Stage-3 Rear shell
	Beacon	2730~2770	2		linear	Stage-3 Rear shell
	Telemetry command Receiver	550~750		≤-128dBW	linear	Stage-2 Intertank
GROUND	Tester for Transponder 1	5840~5890	0.5			Tracking & safety system ground test room at launch center
	Tester for Transponder 2	5870~5910	0.5			
	Tester for Transponder 3	5570~5620	100W(peak)			
	Telemetry Command Transmitter	550~750	1W			

Onboard radio equipment mounted positions are shown in **Figure 6-3**.

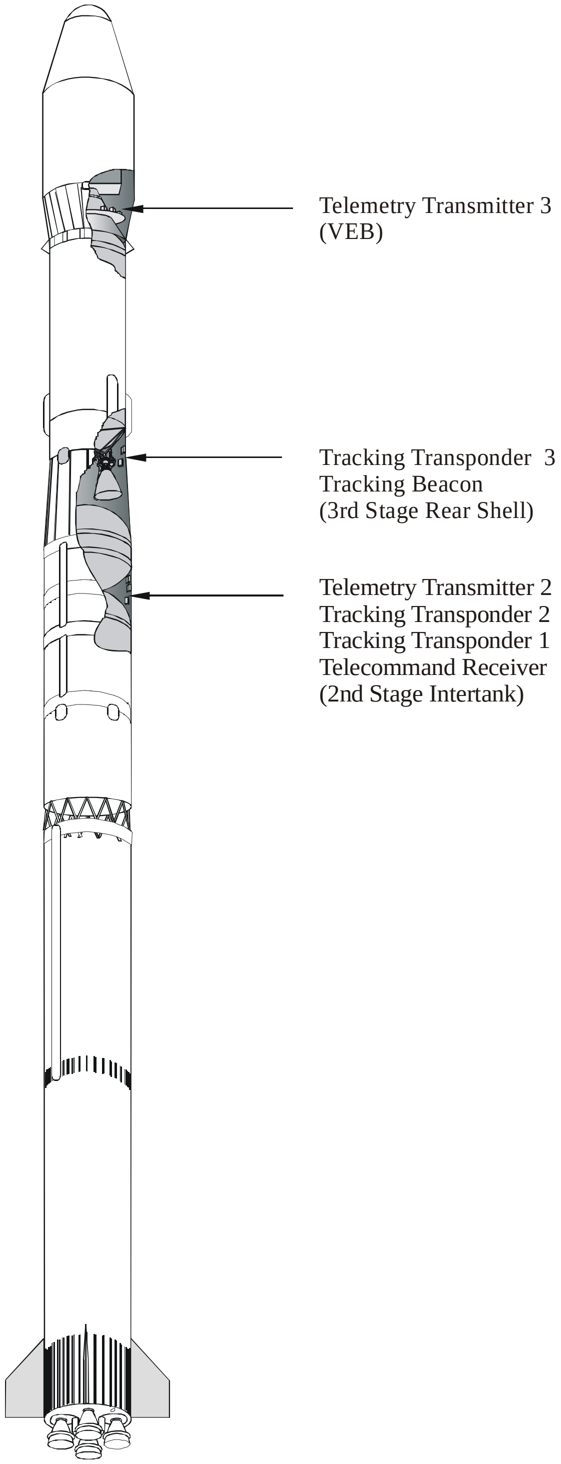


Figure 6-3 On-board Radio Equipment Mounted Positions

6.2.4.2 RF Equipment and Radiation Strength at XSLC

Working frequency:	5577~5617 MHz
Antenna diameter:	4.2m
Impulse power:	<1500 kW
Impulse width:	0.0008ms
Min. pulse duration:	1.25ms
Mean power:	<1.2kW

6.2.4.3 LV Electromagnetic Radiation and Susceptibility

The energy levels of launch vehicle electromagnetic radiation and susceptibility are measured at 1m above VEB. They are shown in **Figure 6-4** to **Figure 6-6**.

6.2.4.4 EMC Analysis among SC, LV and Launch Site

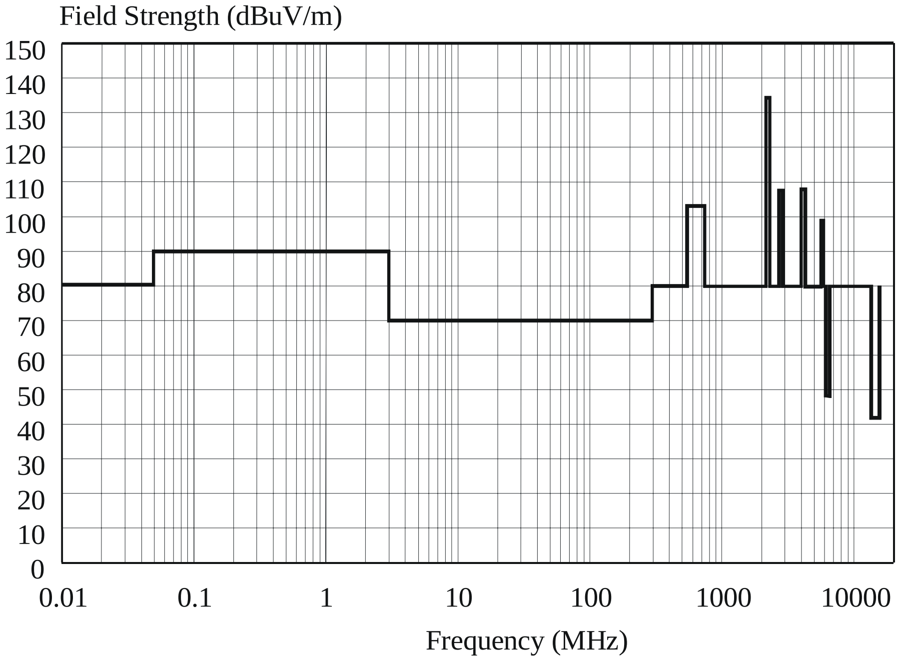
To conduct the EMC analysis among SC, LV and launch site, both SC and LV sides should provide related information to each other. The information provided by CALT are listed as **Figure 6-4** to **Figure 6-6,** while the information provided by SC side are as follows:

a. SC RF system configuration, characteristics, working time, antenna position and direction, etc.
b. Values and curves of the narrow-band electric field of intentional and parasitic radiation generated by SC RF system at SC/LV separation plane and values and curves of the electromagnetic susceptibility accepted by SC.

CALT will perform the preliminary EMC analysis based on the information provided by SC side, and both sides will determine whether it is necessary to request further information according to the analysis result.

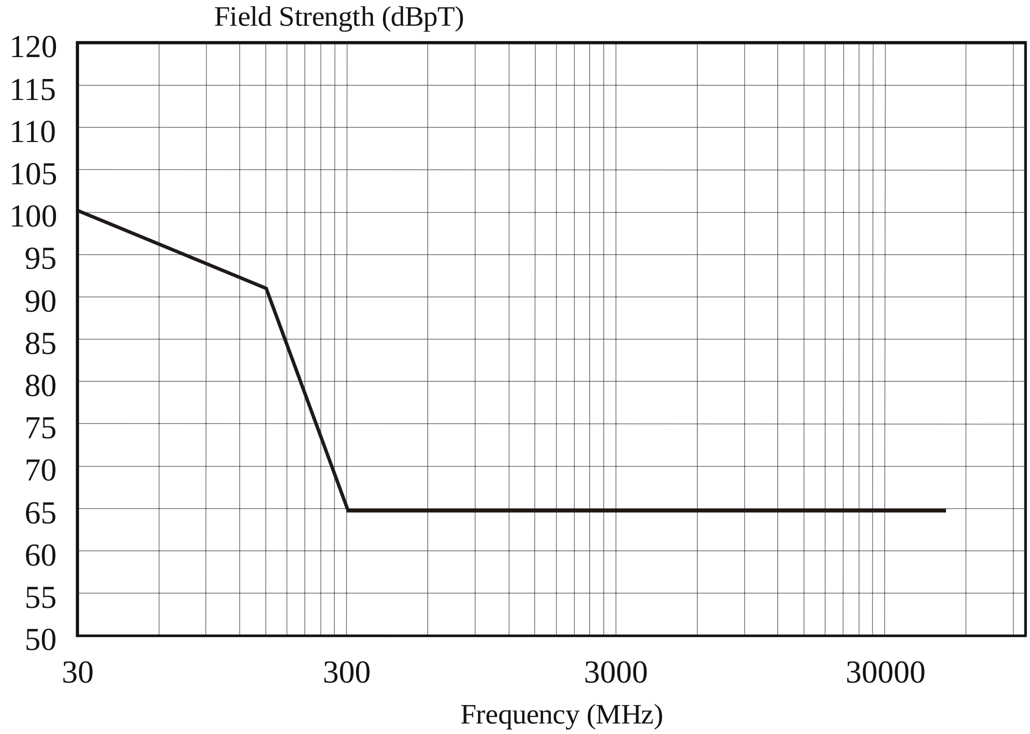
6.2.5 Contamination Control

The molecule deposition on SC surface is less than 2mg/m^2/week.



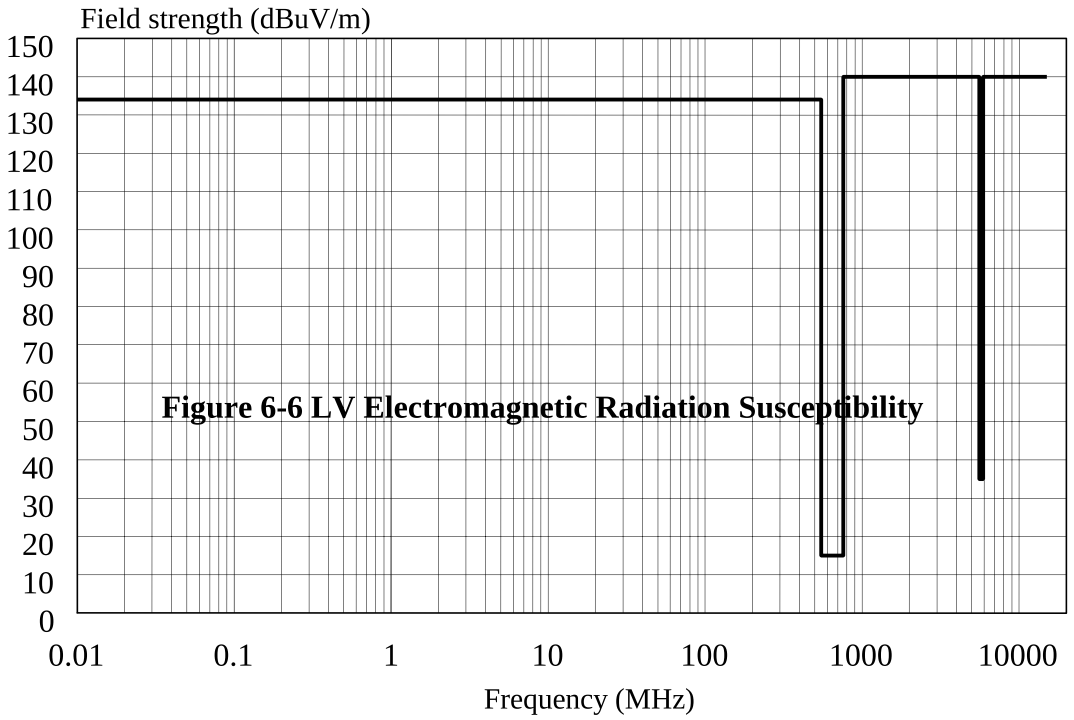
Frequency (MHz)	Field Strength (dBμV/m)
0.01-0.05	80
0.05-3	90
3-300	70
300-550	80
550-750	103
750-2200	80
2200-2300	134
2300-2730	80
2730-2770	107
2770-4200	80
4200-4250	107
4250-5580	80
5580-5620	99
5620-6000	80
6000-6500	48
6500-13500	80
13500-15000	42
15000-	80

Figure 6-4 Intentional Radiation from LV and Launch Site



Frequency (MHz)	Field Strength (dBpT)
30-150	100-91 (linear)
150-300	91-65 (linear)
300-50000	65

Figure 6-5 Magnetic Field Radiation from LV and Launch Site



Frequency (MHz)	Field Strength (dBpT)
0.01-550	134
550-760	15
5580-5910	35

Figure 6-6 LV Electro-Magnetic Radiation Susceptibility

6.3 Flight Environment

6.3.1 Pressure Environment

When LM-3A launch vehicle flights in the atmosphere, the fairing air-depressurization is provided by 12 vents (total venting area 230cm^2) opened on the lower cylindrical section. The design range of fairing internal pressure is presented in **Figure 6-7**. The maximum depressurization rate inside fairing will not exceed 6.0kPa/sec.

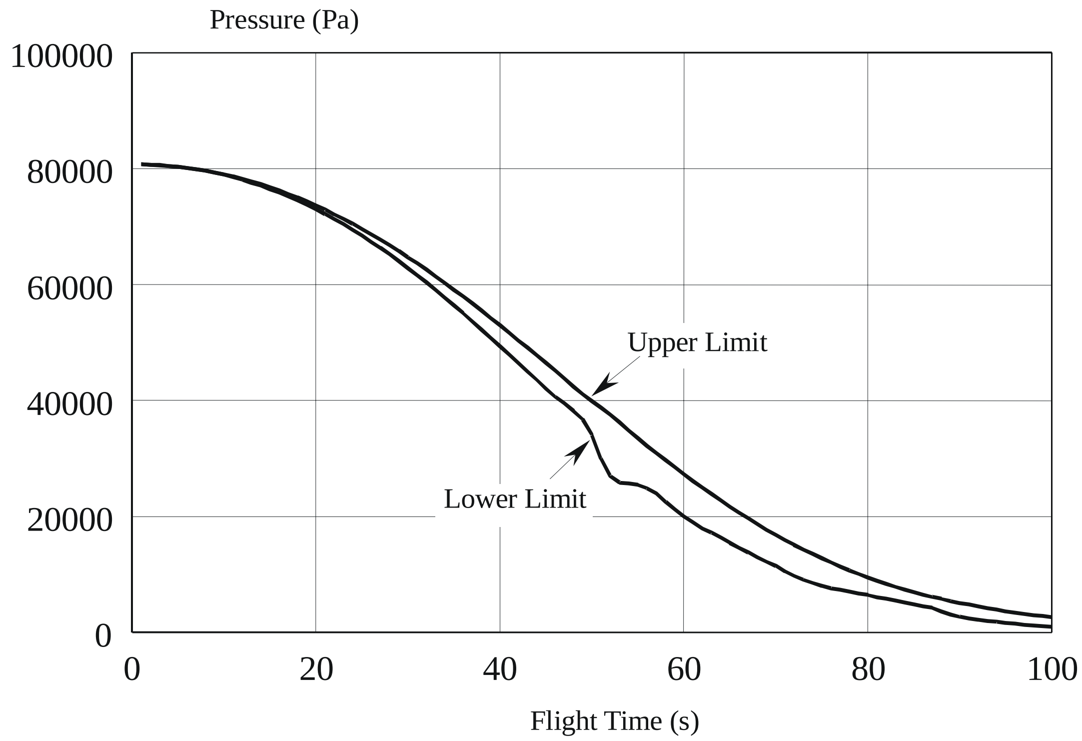


Figure 6-7 Design Range of Fairing Internal Pressure during LV Flight

6.3.2 Thermal environment

The radiation heat flux density and radiant rate from the inner surface of each section of the fairing is shown in **Figure 6-8**.

The free molecular heating flux at fairing jettisoning shall be lower than 1135W/m^2 (See **Figure 6-9**). After fairing jettisoning, the thermal effects caused by the sun radiation, Earth infrared radiation and albedo will also be considered. The specific affects will be determined through the SC/LV thermal environment analysis by CALT.

The LV retro-rockets will work 1.5 sec. and generate the heat flux of <300W/m^2 at SC/LV separation plane.

The heat flux due to third-stage engines working will not exceed 700 W/m^2 at SC/LV separation plane.

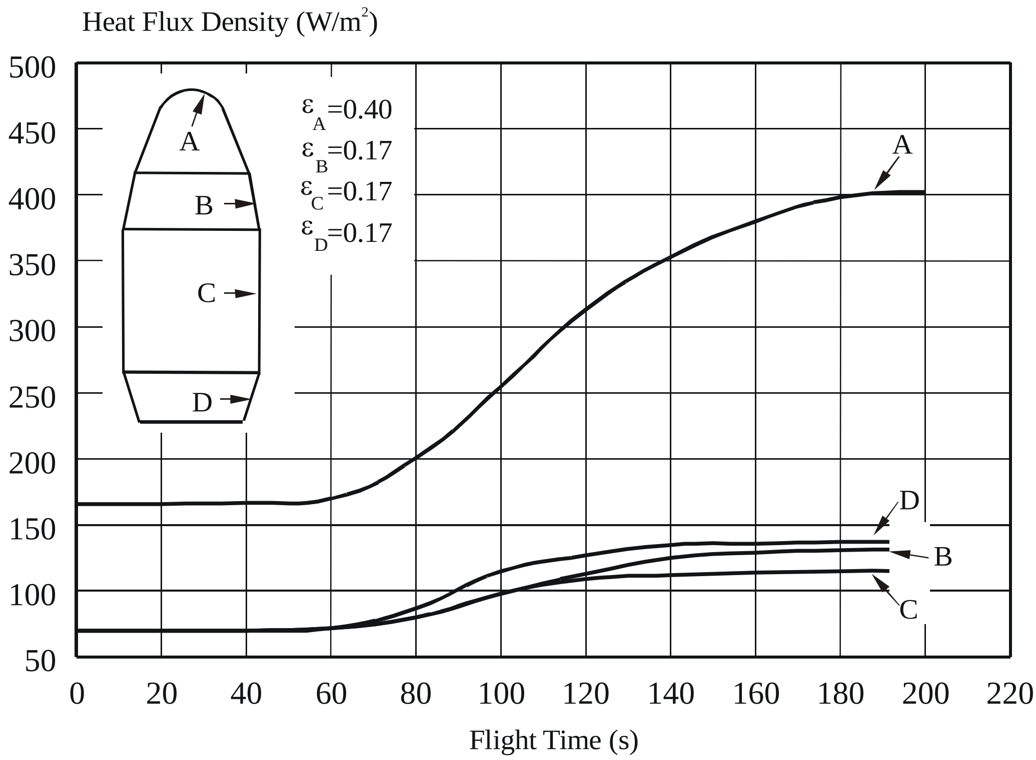


Figure 6-8 Radiation Heat Flux Density and Radiant Rate on the Inner Surface of Each Section of the Fairing

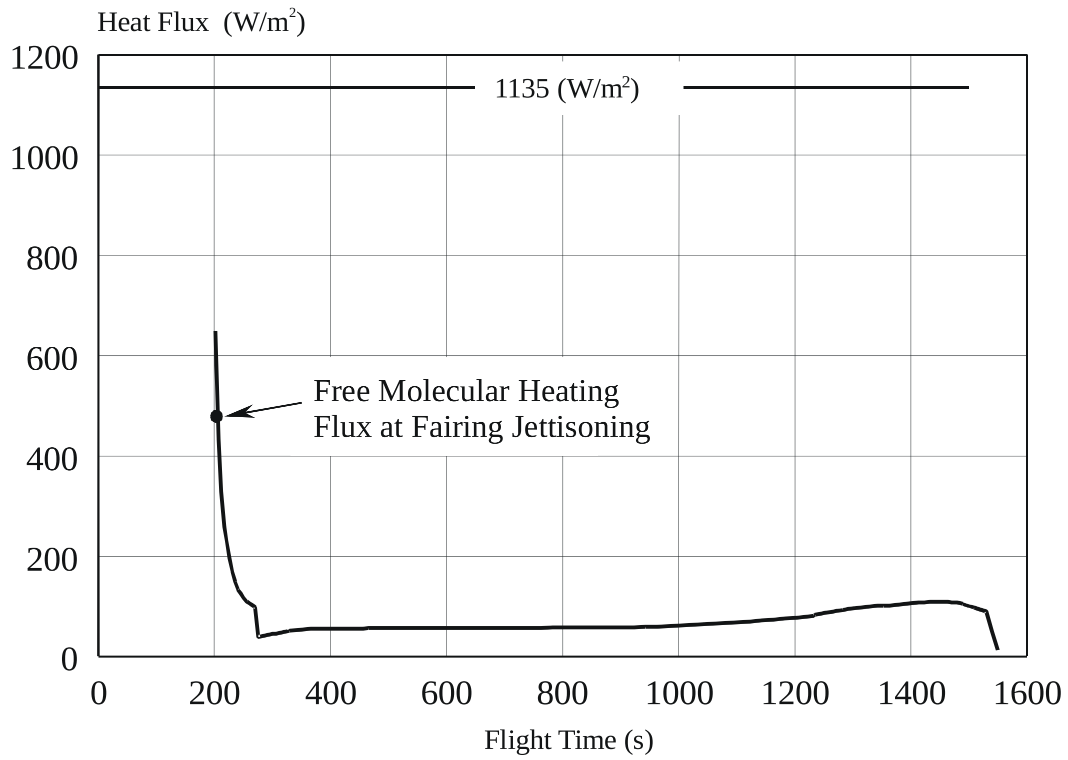


Figure 6-9 Typical Free Molecular Heating Flux

6.3.3 Static Acceleration

The launch vehicle longitudinal external forces generate the static longitudinal acceleration. They mainly include engine thrust and aerodynamic force.

The typical maximum longitudinal acceleration during LV powered flights are shown in the following table. It can be seen that the maximum static acceleration occurred just prior to booster separation. The maximum static acceleration will be slightly variable to different missions.

Events	Value
Stage I flight	+4.8g
Stage II flight	+2.9g
Stage III first power flight	+1.6g
Stage III second power flight	+2.7g

Note: Here "+" means the direction of the acceleration coincides with LV +X axis.

6.3.4 Vibration Environment

A. Sinusoidal Vibration

The SC sinusoidal vibration mainly occurs in the processes of engine ignition and shut-off, transonic flight and stage separations. The sinusoidal vibration (zero-peak value) at SC/LV interface is shown below.

Direction	Frequency Range (Hz)	Amplitude & Acceleration
Longitudinal	5 - 8 8 - 100	3.11 mm 0.8g
Lateral	5 - 8 8 - 100	2.33 mm 0.6 g

B. Random Vibration

The SC random vibration is mainly generated by noise and reaches the maximum at the lift-off and transonic flight periods.

The random vibration Power Spectral Density and the total Root-Mean-Square (RMS) value at SC/LV separation plane in three directions are given in the table below.

Frequency Range (Hz)	Power Spectral Density	Total RMS Value

20 - 200	6 dB/octave.	7.48 g
200 - 800	0.04 g^2/Hz	
800 - 2000	-3 dB/octave.	

6.3.5 Acoustic Noise

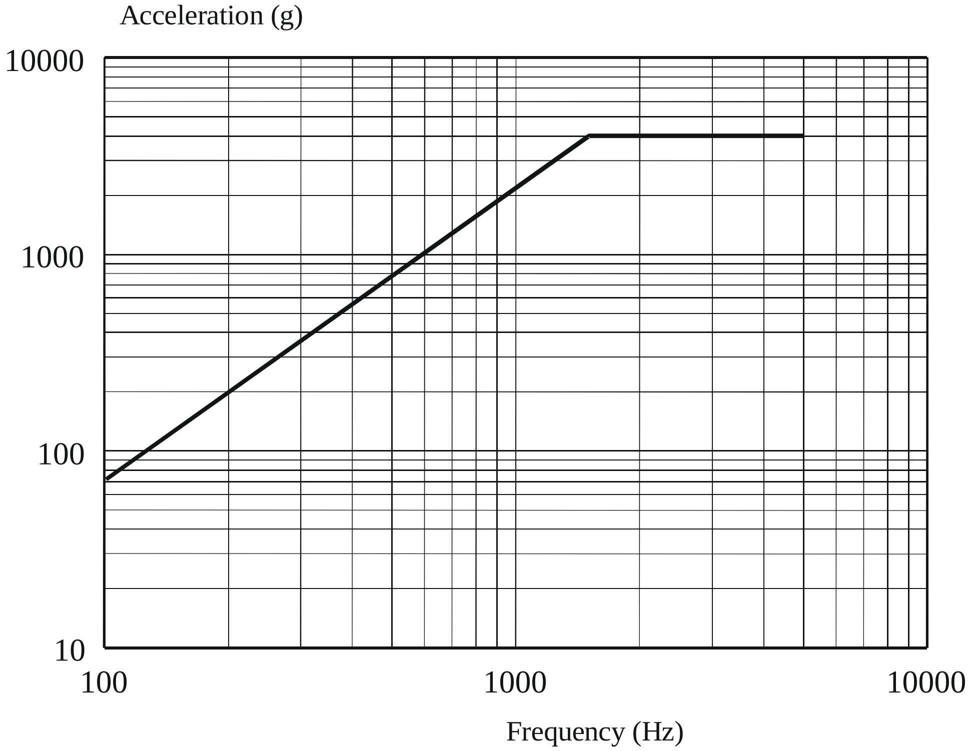
The flight noise mainly includes the engine noise and aerodynamic noise. The maximum acoustic noise suffered by SC occurs at the moment of lift-off and during the transonic flight phase. The values in the table below are the maximum noise levels in fairing.

Central Frequency of Octave Bandwidth (Hz)	Acoustic Pressure Level (dB)
31.5	120
63	126
125	132
250	136
500	135
1000	132
2000	127
4000	123
8000	116
Total Acoustic Pressure Level	141

0 dB referenced to 2×10^{-5} Pa.

6.3.6 Shock Environment

The maximum shock that SC suffered occurs at the SC/LV separation. The shock response spectrum at SC/LV separation plane is shown bellow.
See **Figure 6-10.**



Frequency Range (Hz)	Shock Response Spectrum (Q=10)
100~1500	9.0dB/octave
1500~4000	4000g

Figure 6-10 Shock Response Spectrum at SC/LV Separation Plane

6.4 Load Conditions for SC Design

6.4.1 Frequency Requirement

To avoid the SC resonance with LM-3A launch vehicle, the primary frequency of SC structure should meet the following requirement (under the condition that SC/LV separation plane is considered as rigid body):

The frequency of the lateral main mode>10Hz

The frequency of the longitudinal main mode >30Hz

6.4.2 Loads Applied for SC Structure Design

The maximum lateral load occurs at the transonic phase or Maximum Dynamic Pressure phase. The maximum axial static load occurs prior to the boosters' separation. The maximum axial dynamic load occurs after the first and second stage separation. Therefore, the following limit loads corresponding to different conditions in flight are recommended for SC design consideration.

Flight Condition		Transonic phase and MDP	First stage engines shut-down	After 1st/2nd stage separation
Longitudinal Acceleration(g)	Static	+2.0	+5.0~+0.3*	+0.8~+1.4*
	Dynamic	±0.8	±0.8	±2.6
	Combined	+2.8	+5.8 -0.5	+4.0 -1.8
Lateral Acceleration(g)		2.0	1.0	1.0

Notes:

❶ Here "*" means that the load values changes from the first figure to the second figure smoothly.

❷ Usage of the above table:

SC design loads = **Limit loads** × **Safety factor***

* The safety factor is determined by the SC designer.(CALT suggests ≥1.25)

❸ The lateral load means the load acting in any direction perpendicular to the longitudinal axis.

❹ Lateral and longitudinal loads occur simultaneously.

❺ The plus sign "+" means compression in longitudinal.

6.4.3 Coupled Load Analysis

The SC manufacturer should provide the SC mathematical model to CALT for Coupled Loads Analysis (CLA) to CALT. CALT will predict the SC maximum dynamic response by coupled load analysis. The SC manufacturer should confirm that the SC could survive from the predicted environment and has adequate safe margin. (CALT requires that the safe factor is equal to or greater than 1.25.)

6.5 SC Qualification and Acceptance Test Specifications

6.5.1 Static Test (Qualification)

The main SC structure must pass static qualification tests without damage. The test level must be not lower than SC design load required in Paragraph 6.4.2.

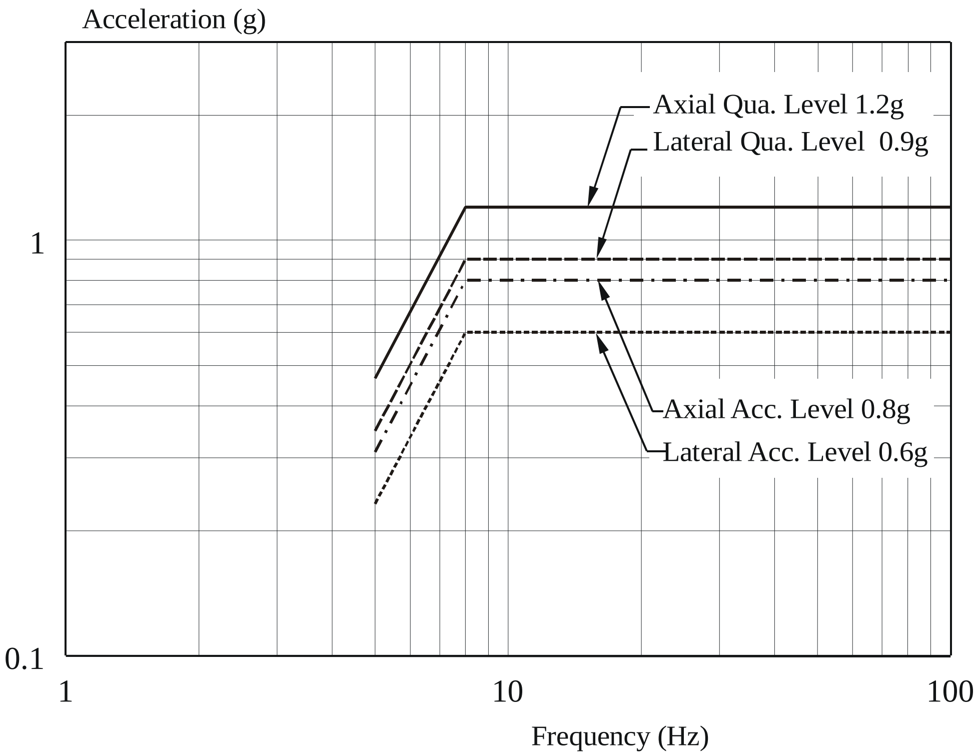
6.5.2 Vibration Test

A. Sine Vibration Test

During tests, the SC must be rigidly mounted on the shaker. The table below specifies the vibration acceleration level (0 - peak) of SC qualification and acceptance tests at SC/LV interface. (See **Figure 6-11**)

B. Random Vibration Test

During tests, the SC structure must be rigidly mounted onto the shaker. The table below specifies the SC qualification and acceptance test levels at SC/LV interface in three directions (See **Figure 6-12**).

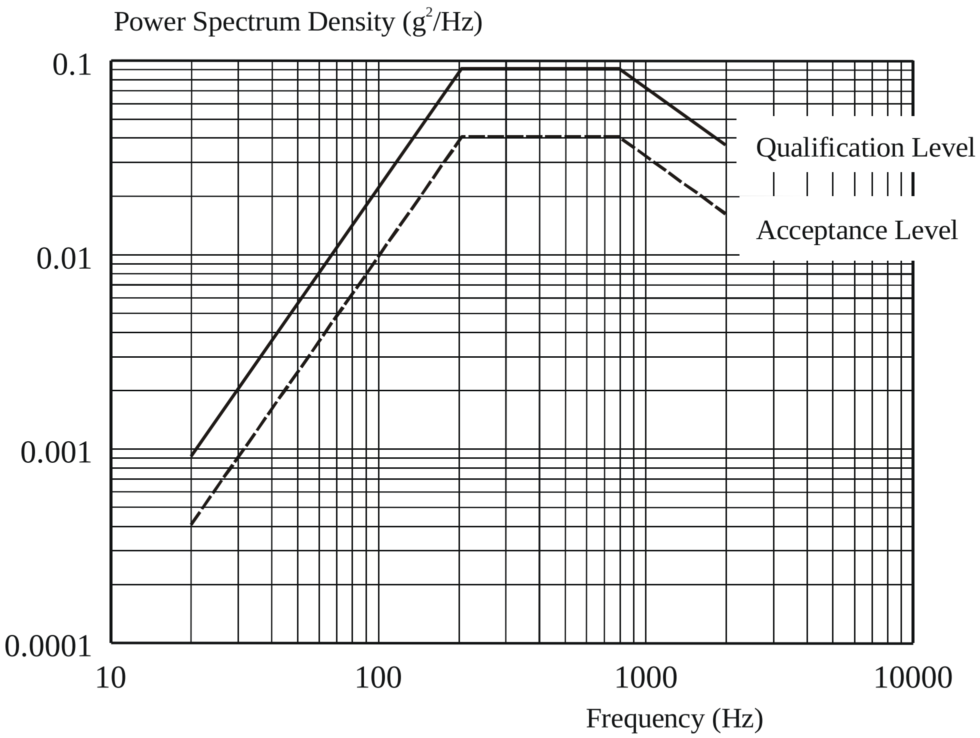


	Frequency (Hz)	Test Load	
		Acceptance	Qualification
Longitudinal	5-8 8-100	3.11 mm 0.8 g	4.66 mm 1.2 g
Lateral	5-8 8-100	2.33 mm 0.6 g	3.50 mm 0.9 g
Scan rate (Oct/min)		4	2

Notes:

- Frequency tolerance is allowed to be ±2%
- Amplitude tolerance is allowed to be -0 ~ +10%
- Acceleration notching is permitted after consultation with CALT and concurred by all parties. Anyway, the notched acceleration should not be lower than the coupled load's analysis results on the interface plane.

Figure 6-11 Sinusoidal Vibration Acceleration Level of SC Qualification and Acceptance Tests



<table>
<tr><td rowspan="2">Frequency (Hz)</td><td colspan="2">Acceptance</td><td colspan="2">Qualification</td></tr>
<tr><td>Spectrum Density</td><td>Total rms (Grms)</td><td>Spectrum Density (g^2/Hz)</td><td>Total rms (Grms)</td></tr>
<tr><td>20 - 200</td><td>6 dB/octave.</td><td rowspan="3">7.48g</td><td>6 dB/octave.</td><td rowspan="3">11.22g</td></tr>
<tr><td>200 - 800</td><td>0.04 g^2/Hz</td><td>0.09 g^2/Hz</td></tr>
<tr><td>800 - 2000</td><td>-3 dB/octave.</td><td>-3 dB/octave</td></tr>
<tr><td>Duration</td><td colspan="2">1min.</td><td colspan="2">2min.</td></tr>
</table>

Notes:
Tolerances of ±3.0 dB for power spectral density and ±1.5 dB for total rms values are allowed.

Figure 6-12 Random Vibration Acceleration Level of SC Qualification and Acceptance Tests

6.5.3 Acoustic Test

The acceptance and qualification test levels are given in the following table (also see **Figure 6-12**).

Central Octave Frequency (Hz)	Acceptance Sound Pressure Level (dB)	Qualification Sound Pressure Level (dB)	Tolerance (dB)
31.5	120	124	-2/+4
63	126	130	
125	132	136	
250	136	140	
500	135	139	
1000	132	136	
2000	127	131	
4000	123	127	-5/+4
8000	116	120	-5/+5
Total Sound Pressure Level	141	145	-1/+3

0 dB is equal to 2×10^{-5} Pa.

Test Duration:

- Acceptance test: 1.0 minute
- Qualification test: 2.0 minutes

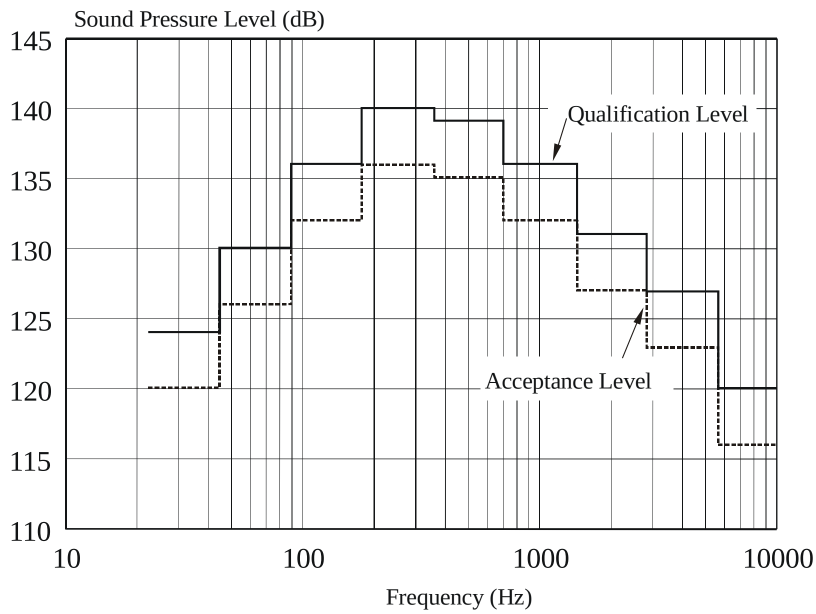


Figure 6-13 SC Acoustic Test

6.5.4 Shock Test

The shock test level is specified in **Paragraph 6.3.6**. Such test shall be performed once for acceptance, and twice for qualification. A ±6.0 dB tolerance in test specification is allowed. However, the test strength must be applied so that in the shock response spectral analysis over 1/6 octave on the test results, 30% of the response acceleration values at central frequencies shall be greater than or equal to the values of test level.

The shock test can also be performed through SC/LV separation test by using of flight SC, payload adapter, and separation system. Such test shall be performed once for acceptance, and twice for qualification.

6.5.5 Proto-flight Test

The Proto-flight test is suitable for the SC that is launched by LM-3A for the first time even though it has been launched by other launch vehicles.

The test level for the Proto-flight should be determined by satellite manufacturer and CALT and should be higher than the acceptance level but lower than the qualification level. If the same satellite has been tested in the conditions that are not lower than the qualification test level described in **Paragraph 6.5.1** to **Paragraph 6.5.4**, CALT will suggest the following test conditions:

a. Vibration and acoustic test should be performed according to the qualification level and acceptance test duration or scan rate specified in **Paragraph 6.5.2-6.5.3**.
b. Shock test should be performed once according to the level in **Paragraph 6.5.4**.

6.6 Environment Parameters Measurement

6.6.1 Measurement of environment

The inner environment of fairing is measured during each flight. The measuring parameters include temperature and pressure inside the fairing, noises inside and outside the fairing ands the vibration parameters at SC/LV interface.

6.6.2 Flight results

After the three successful flights of LM-3A, CALT made a analysis based on the telemetry data of LV vibration and inner fairing acoustics, the result shows that the telemetry data lower than the acceptance requirements.