7. SPACECRAFT DESIGN & VERIFICATION REQUIREMENTS

Overview

Most of the design considerations for spacecraft interested in flying on Land Launch are defined in other sections of this User's Guide, including:

- performance capabilities (Section 3)
- ground and flight environments (Section 4)
- spacecraft mechanical and electrical interfaces (Section 5)
- facility interfaces (Section 6)

The first part of this section provides remaining design considerations that do not fall into the above categories, including:

- constraints on spacecraft RF transmitting and receiving
- horizontal handling
- safety requirements
- ground support equipment considerations

The second part of this section outlines key methods and criteria for verifying that the spacecraft meets major design considerations.

7.1 Additional Spacecraft Design Considerations

7.1.1 Constraints on Spacecraft Transmitting and Receiving

From launch until at least 20 seconds after spacecraft separation, the spacecraft transmitters normally will not be used nor will commands be uplinked to the spacecraft. During integrated ground operations (after the spacecraft has been attached to launch vehicle) spacecraft transmitters should only be used at times and at frequencies that have been coordinated in advance. This normally consists of RF tests in the PPF and on the launch pad, during which the spacecraft transmitters should avoid intentional or unintentional radiation levels above 30 dB μV/m between 1570 MHz and 1630 MHz (the frequency range for the Glonass receivers on the launch vehicle) as measured one meter below the spacecraft separation plane. At all other frequencies between 10 KHz and 40GHz, spacecraft:

- unintentional emissions should not exceed 70 dB μV/m
- intentional emissions should not exceed 140 dB μV/m

The maximum spacecraft intentional RF impingement on the launch vehicle is shown in Figure 7-1.

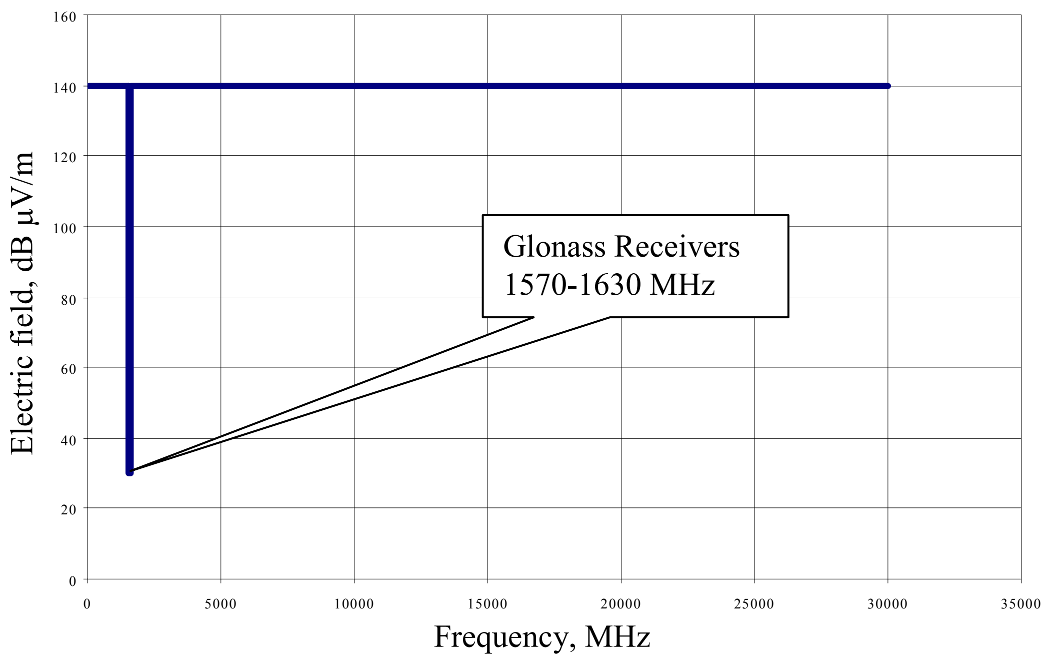

Figure 7-1. Maximum Intentional Spacecraft Electric Field Impingement on the Launch Vehicle (one meter below the separation plane)

7.1.2 Horizontal Handling

Spacecraft systems and procedures must be compatible with the spacecraft being placed in a horizontal attitude for several days (approximately seven), between encapsulation in the fairing inside the PPF and erection of the fully assembled launch vehicle at the launch pad, and again after T-0 in the unlikely event of a launch abort. While it is horizontal the spacecraft will be subjected to random vibration and accelerations during hoisting, transportation and launch vehicle assembly operations. These environments are defined in Section 4.

7.1.3 Safety Design Considerations

Pressurized systems

Design and verification of spacecraft flight hardware pressurized vessels, structures, and components of the SC pressurized systems must be in accordance with recognized aerospace industry design guidelines. These pressurized systems should also be consistent with the Land Launch system payload environment. The design of the pressurized systems must protect the launch system and personnel before launch and protect the launch system during flight from damage due to pressure system failure. Such criteria as operating pressures, stress levels, fracture control, burst factor, leak-before-burst factor, material selection, quality assurance, proof-pressure testing, and effects of processing and handling in both the horizontal and vertical orientations should be considered. Design details may be required as a portion of documentation to support regulatory agency requirements for the mission.

Ordnance systems

Ordnance systems aboard spacecraft for operation of propulsion, separation, and mechanical systems must be designed in accordance with recognized standards and regulations. These systems must preclude inadvertent firing when subjected to Land Launch specified shock, vibration, thermal, or electromagnetic environments. Ordnance devices must be classified in accordance with applicable government codes and meet applicable regulations for transportation and handling. Design for initiation of ordnance in the system must incorporate more than one action; no single failure may result in ordnance device activation. Use of a safe-and arm-device is recommended; however, other techniques may be considered with adequate justification.

System design and ordnance classification documentation may be required to support regulatory agency requirements for the mission.

7.1.4 Ground Support Equipment (GSE) Considerations

Customer GSE and checkout equipment which will be used at the Baikonur launch base should be in accordance with the recognized safety requirements, and be capable of functioning with the facility interfaces and under the conditions (temperature/ humidity mode, cleanliness class, power supply parameters, gas supply, etc.), that are defined elsewhere in this User's Guide.

Design details may be required as a portion of the documentation used to satisfy regulatory agency requirements for the mission.

7.2 Spacecraft Verification Requirements

Flexibility to meet customer needs

The design verification processes and criteria defined below are guidelines. They can be individually tailored to reflect the specific requirements of each Land Launch customers.

7.2.1 Spacecraft Structural Capability

Factors of safety

The minimum factors of safety and test levels for several test options are shown in Table 7-1.

Table 7-1. Factors of Safety and Test Options

Test option	Factors of safety		Test level	Test success criteria
	Yield	Ultimate		
Qualification test (test of dedicated article to ultimate loads)	1.0	1. 3	1.0 1.25	- No detrimental deformation at 1.0 - No failure at 1.25
Proto-qualification test (test of article used subsequently for flight or system test)	1.25	1.4	1.25	No detrimental deformation or misalignment
Qualification by analysis (test of article not required)	1.6	2.0	N/A	N/A
Acceptance test (performed on each flight article)	1.1	1.3	1.1	No detrimental deformation

Test-verified model required for final CLA

Preliminary loads for quasi-static events are calculated using the Land Launch quasi-static load factors for ground handling, transportation, and flight that are defined in Section 4. Preliminary operational loads for transient flight events are calculated by Land Launch in a coupled loads analysis (CLA) using a preliminary spacecraft model provided by the customer. The final CLA operational loads used for verification must be generated using a test-verified spacecraft model. Verification of the spacecraft model can be performed either by modal survey or sine test.

Test requirements

Land Launch requires verification of a spacecraft's structure load-carrying capability. The Land Launch qualification requirements on the spacecraft reflect standard practice, with appropriate tailoring to accommodate specific spacecraft and mission-specific characteristics. Structural testing on the spacecraft generally depends on the design heritage. Unique qualification tests can be developed by the spacecraft customer to account for design heritage. Land Launch will work with the spacecraft customer by evaluating customer-proposed testing to support the spacecraft integration process.

The following tests are accepted by Land Launch for demonstrating structural compliance:

- modal survey test;
- static loads test;
- sine vibration testing;
- acoustic testing;
- shock qualification.

If a candidate qualification approach is not addressed here, Land Launch is open to proposed alternatives for ensuring spacecraft compatibility.

Modal survey test

The objective of a modal survey test is to determine the dynamic characteristics of the spacecraft structure. Following the test, the spacecraft mathematical model is adjusted. The adjusted model is categorized as "test verified."

Static loads test

Spacecraft static load testing is one option for validating the spacecraft structural strength. The extent of testing depends on the heritage of the spacecraft structure, but compliance with Table 7-1 is the objective.

Sine vibration testing

The sine vibration test levels for qualification, proto-qualification and acceptance are shown in Table 7-2, and are derived from the operational levels defined in Table 4-2.

Qualification testing is for a dedicated test article. For proto qualification testing, the test article will be the first flight unit of a spacecraft series. Acceptance testing is generally performed to demonstrate workmanship and is an option available to the spacecraft customer for minor spacecraft design changes on proven spacecraft designs that have not previously flown on Land Launch. The extent of the testing depends on the heritage of the spacecraft structure. Spacecraft compliance must be demonstrated as described above.

Test envelope "notching" (decrease of sine environment amplitudes) may be employed to prevent excessive loading of the spacecraft structure. However, the resulting sine vibration environment with notching should not be less than a test amplification factor level times the equivalent sine vibration level determined by CLA and provided by Land Launch. The test amplification factor levels depend on the test options chosen and are described above.

Table 7-2. Sine Vibration Amplitudes and Sweep Rates

Frequencies	Vehicle	Test		
		Qualification	Proto-qualification	Acceptance
5 – 100 (Longitudinal and Lateral)	Zenit-2SLB	0.75 g	0.75 g	0.6 g
	Zenit-3SLB	0.88 g	0.88 g	0.7 g
Test frequency sweep rate (octaves/min)		2	4	4

Acoustic testing

Land Launch requires that each new spacecraft design undergo acoustic qualification or proto-qualification testing. The maximum expected flight acoustic levels are provided in Section 4. Acoustic levels and durations for qualification, proto-qualification and acceptance testing are shown in Table 7-3.

Table 7-3. Spacecraft Acoustic Margins and Test Durations

Test	Levels	Duration [sec]
Qualification	+ 3 dB over levels of maximum expected acoustic environment	120
Proto-qualification	+ 3 dB over levels of maximum expected acoustic environment	60
Acceptance	Maximum expected acoustic environment	60

Shock qualification

The spacecraft should be compatible with the shock environment in Section 4 with a 3-dB margin. The shock environment in Section 4 represents the maximum expected environment (operational levels) with no added margin. Analysis, similarity, and/or test can demonstrate qualification. A shock test using the spacecraft flight article, spacecraft adapter and flight equivalent separation system can be performed to qualify the spacecraft.

7.2.2 Matchmate Test

Land Launch generally uses off-the-shelf spacecraft adapters with a flight history on other launchers. For spacecraft types lacking prior flight experience with the adapter/separation system to be used, Land Launch requires a matchmate test between the spacecraft and the adapter flight hardware (see Figure 7-2). This test is usually performed at the spacecraft manufacturer's production facility. It includes mechanical and electrical mate and checkout. It can also include the firing of the spacecraft separation ordnance to define the shock environment at the SC interface. Repeat missions of a spacecraft type typically do not require a matchmate. Instead, an adapter fit-check will typically be performed in the PPF at Baikonur at the start of the processing flow.

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Figure 7-2. Electrical and Mechanical Matchmate Test