Chapter 6 Spacecraft Design and Verification Requirements

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6 Spacecraft Design and Verification Requirements

This chapter defines the spacecraft design and verification requirements that have to be taken into account in preparation of a launch on *Rockot/Breeze-KM*. Any deviation from these requirements has to be mutually agreed.

6.1 Safety Requirements

The Customer is required to design and operate the spacecraft in accordance with the launch site safety regulations described in chapter 9. It must be assured by appropriate means (mechanical ground support equipment design, operational procedures) that constraints related to ground operations do not become design drivers for the flight hardware.

6.1.1 Selection of Payload Materials

Properties as well as types of materials and components used for the spacecraft design must be based on recognised standards agreed by the launcher authority.

6.2 Design Characteristics

6.2.1 Mass Properties

The spacecraft mass properties shall be defined according to the following accuracies to enable dynamic analyses to be undertaken as part of the overall spacecraft to commence vehicle preliminary mission analyses. The mass shall be specified with an accuracy of better than ±2.5 %, the mass moment of inertia better than ±10 %. The CoM shall be specified with an accuracy of 50 mm along the launch vehicle longitudinal axis and within a circle of 30 mm radius around the launch vehicle longitudinal axis.

For spacecraft using liquid propellant the dynamics of the liquid shall be specified by means of a proper sloshing model at different acceleration levels.

6.2.2 Centre of Mass Constraints

The *Rockot* launch vehicle is capable of supporting a large variation of the CoM position along its *X*-axis. However, the dependency of the lateral accelerations on the CoM position may limit its position on the *X*-axis.

The total displacement of the composite CoM of the spacecraft or a combination of multiple spacecraft and the *Breeze-KM* must stay within a radius of 30 mm around the launch vehicle longitudinal axis. This imbalance directly affects the controllability of the upper stage and thus the spacecraft angular velocities at separation

6.2.3 Structural Integrity

6.2.3.1 Factors of Safety

The minimum factors of safety to be taken into account for structural dimensioning are:

- Yield load: $j \geq 1.1$
- Ultimate load: $j \geq 1.25$

The factors of safety apply to combinations of simultaneously acting mechanical and thermal limit loads.

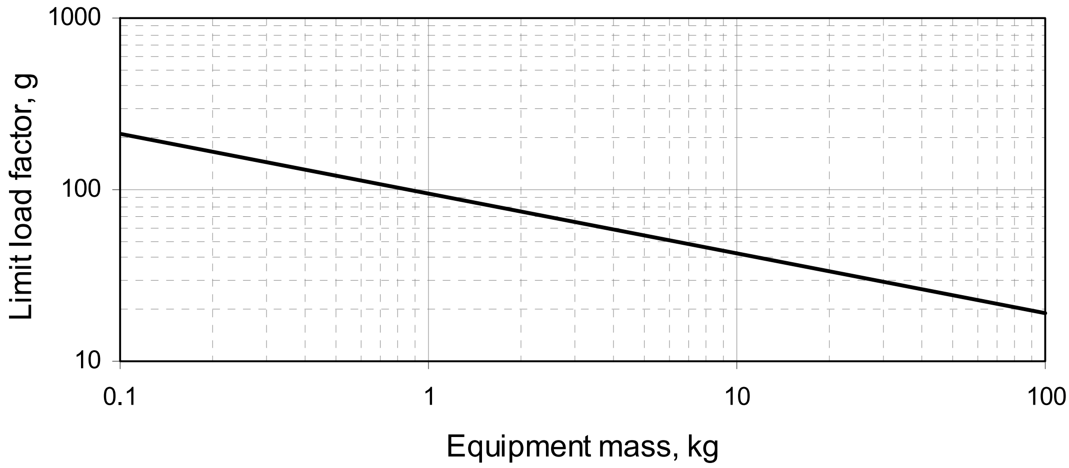

Figure 6-1 Typical limit load factors for initial dimensioning of secondary structures and equipment brackets.

6.2.3.2 Dimensioning Loads

Structural dimensioning must take into account critical combinations of simultaneously acting load types.

Generic design accelerations for spacecraft primary structure dimensioning are compiled in chapter 5.1.2.

Secondary structures and equipment brackets must be dimensioned taking into account local responses to the combined effect of simultaneously acting low frequency transient and high frequency random vibrations. Typical mass-dependent combined load factors n are presented in Figure 6-1 as a design guideline. For dimensioning, limit load factors have to be applied

- at equipment / unit CoM,
- in the worst case spatial direction with respect to resulting stresses and reactions.

Limit load factors cover equipment / unit responses due to quasi-static and low-frequency transient and random accelerations encountered during lift-off and ascent.

6.2.4 Stiffness

To avoid dynamic coupling between the low-frequency launch vehicle and payload modes, the payload minimum natural frequency f_0 is required to be:

- Lateral (Y-Z plane): $f_0 \geq 15$ Hz
- Axial (X): $f_0 \geq 33$ Hz

Note: Resonance requirements are related to spacecraft modes with significant effective mass of $m_{eff} \geq 70\%$. The minimum natural frequency values are targets for design, if existing spacecraft are not compliant, the given requirement can be relaxed based on CLA results. For heavy spacecraft, additional coordination with EUROCKOT is required to ensure that the structural modes of the integrated spacecraft/ adapter stack do not decrease below critical limits.

6.2.5 Overflux

Overflux refers to disturbances of the axial line load at the interface of the adjacent mating structures. These local disturbances are caused by structural discontinuities such as stringers, cut-outs, etc.

Overflux requirements apply to clamp adapters only and will be specified on a case-by-case basis.

6.3 Spacecraft Mechanical Qualification and Acceptance Tests

The Customer shall demonstrate that the spacecraft structure complies with the required design characteristics as defined in Chapter 6.3, taking into account the environmental conditions stated in chapter 5.

Additionally, spacecraft mathematical models submitted to the launcher authority for performance of final coupled analyses and flight mechanics analyses must be verified by tests.

A typical qualification/acceptance test matrix is shown in Table 6-2. The spacecraft verification plan finally selected needs to be approved by the launcher authority.

6.3.1 Static Load Test

On the basis of dimensioning loads given in chapter 6.2.3.2, EUROCKOT defines critical load cases to which the spacecraft structure will be subjected. The structure must successfully pass static load tests up to:

- Qualification model: ultimate load (1.25 times limit loads)
- Protoflight model: yield load (1.1 times limit load)

For a realistic simulation of the load introduction, the spacecraft must be attached to a flight representative adapter or separation system during the static test.

6.3.2 Sinusoidal Vibration Test

The inputs at the spacecraft adapter interface are shown in Table 5-2, and the test factors in Table 6-1.

A permission for notching of sine test levels at critical resonances may be requested from EUROCKOT in order not to exceed the spacecraft flight responses predicted by coupled load analysis.

	Acceptance	Qualification
Test factors	1	1.25
Sweep rates (one sweep per axis)	4 oct/min	2 oct/min

Table 6-1 Sinusoidal vibration loads.

6.3.3 Random Vibration Test

Random vibration test is recommended only for small satellites of 100 kg mass or less and for satellites with small dimensions. The vibration loads for this purpose will be specified on a case-by-case basis, see chapter 5.1.5.

For larger spacecraft, EUROCKOT recommends to perform an acoustic test to accurately reflect the in-flight random environments experienced. Since the vibration level depends on the dynamic properties of the payload adapter structure, this test should be performed with the spacecraft attached to a flight-like payload adapter (not hard mounted) to accurately represent the flight configuration.

A permission for notching of random vibration test levels at critical resonances may be requested from the launcher authority in order not to exceed local responses measured during an acoustic noise test or determined by an acoustic response analysis.

Test Hardware	Required Tests									
	Static Chap. 6.3.1		Sinusoidal Chap. 6.3.2		Random Chap. 6.3.3		Acoustic Chap. 6.3.4		Shock Chap. 6.3.5	
	Q	A	Q	A	Q	A	Q	A	Q	A
Prototype Philosophy: Qualification Model Flight Model	X		X	X	X1)	X1)	X	X	X	X2)
Protoflight Philosophy: Protoflight Model	X		X		X1)		X		X2)	

1) alternatively for small satellites
2) optionally

Table 6-2 Typical mechanical verification test matrix for qualification (Q) and acceptance (A) of the spacecraft.

6.3.4 Acoustic Noise Test

The acoustic noise spectrum as defined in chapter 5.1.4 must be used as the test input with the factors and durations of Table 6-3 applied.

	Acceptance	Qualification	Protoflight Qualification
Test factor for acoustic pressure	Per SC designer's national standard		
Exposure duration, s	60	120	60

Table 6-3 Acoustic noise spectrum.

The requested test duration takes into account a scatter factor significantly greater than four.

6.3.5 Shock Test

Shock tests of complete spacecraft must be conducted by firing of the planned separation system. For predicted shock response spectra, see Chapter 5.1.6.

6.4 Interface Tests

Depending on the specific mission the following set of compatibility tests may have to be performed:

- The Matchmate test, also referred to as Fit-check test for verification of electrical and mechanical interfaces of the spacecraft to the adapter and separation system. This test is performed preferably with flight units and can be combined with a functional test of the separation system. This test is mandatory for each mission.

- If necessary, volume compatibility test with fairing and adapter. A satellite dummy simulating the spacecraft static envelope will be used for this purpose

Additionally, the following test have to be performed in case of necessity:

- Thermal tests
- EMC tests
- Dedicated electrical interface tests when non-standard interfaces are used