6 Spacecraft Design and Verification Requirements

This chapter defines the spacecraft design and verification requirements that have to be taken into account by any Customer intending to be compatible.

6.1 Safety Requirements

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

6.2 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.

6.3 Design Characteristics

6.3.1 Center of Gravity Constraints

To comply with the launcher's structural constraints, the axial location of the payload centre of gravity (CoG) along the X-axis is restricted as shown in Figure 6-1 and Figure 6-2. For large and heavy satellites, exceptions to this requirement can be considered on a case-by-case basis upon detailed discussion with EUROCKOT. Along the Y- and Z- axes the payload CoG must be within a 30 mm radius of the vehicle centreline. If the spacecraft has its CoG significantly displaced with respect to given limitations along X-, Y- and Z-axes, the Customer is requested to discuss structural dynamic verification with EUROCKOT.

6.3.2 Spacecraft Balancing

6.3.2.1 Static Imbalance

For non-spin-stabilised spacecraft, the only static imbalance constraint derives from the controllability of the upper stage and corresponds to the CoG lateral displacement in the Y-Z plane. The total displacement of the composite CoG of the payload and the *Breeze* must stay within a radius of less than or equal to 30 mm.

Note: Static imbalances directly affect the spacecraft angular velocities on separation.

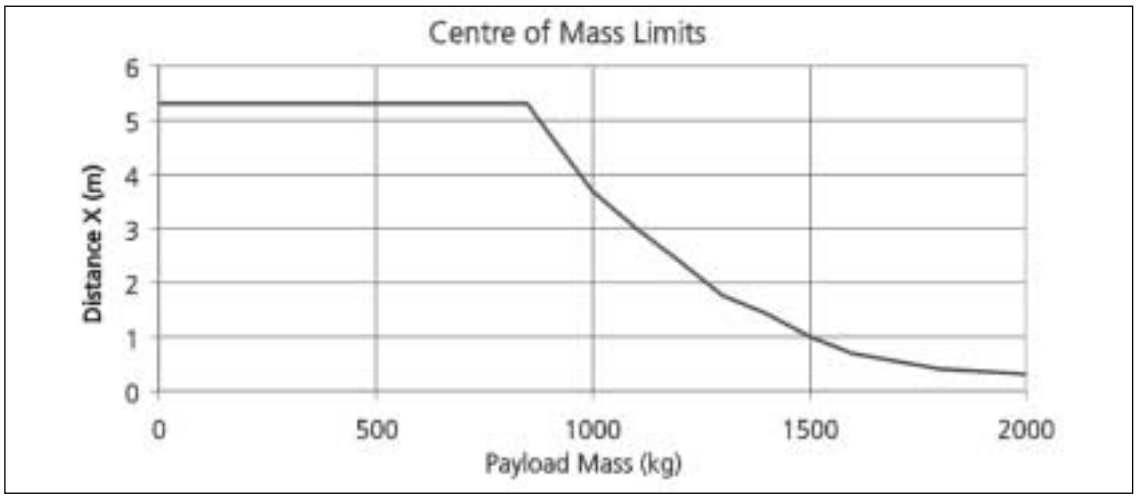

Figure 6-1: Spacecraft CoG Constraints

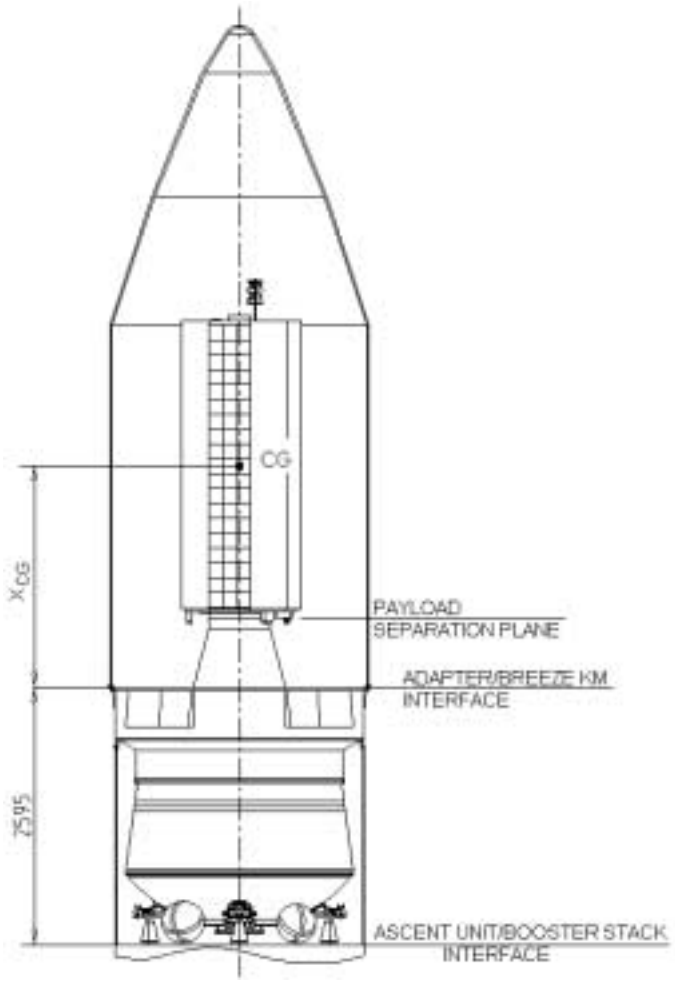

Figure 6-2: Definition of Upper Composite CoG

6.3.2.2 *Dynamic Imbalance*

For spin-stabilised spacecraft, the combined CoG of the spacecraft and adapter must remain within a distance of 1.5 mm from the *Breeze* centreline and have a principal axis misalignment of less than 0.25° with respect to the spacecraft centreline. The spacecraft centreline is defined as a line perpendicular to the separation plane and passing through the combined CoG of the spacecraft/adapter.

The *Breeze* centreline is defined as a line perpendicular to the separation plane and pasing through the *Breeze* geometric centre (as per launch vehicle X-axis defined in Figure 2-1).

6.3.3 *Structural Integrity*

6.3.3.1 *Factors of Safety*

Minimum factors of safety to be taken into account for structural dimensioning are

- j (yield) ≥ 1.1
- j (ultimate) ≥ 1.25

Factors of safety (FS) apply to combinations of simultaneously acting mechanical and thermal limit loads.

6.3.3.2 *Dimensioning Loads*

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

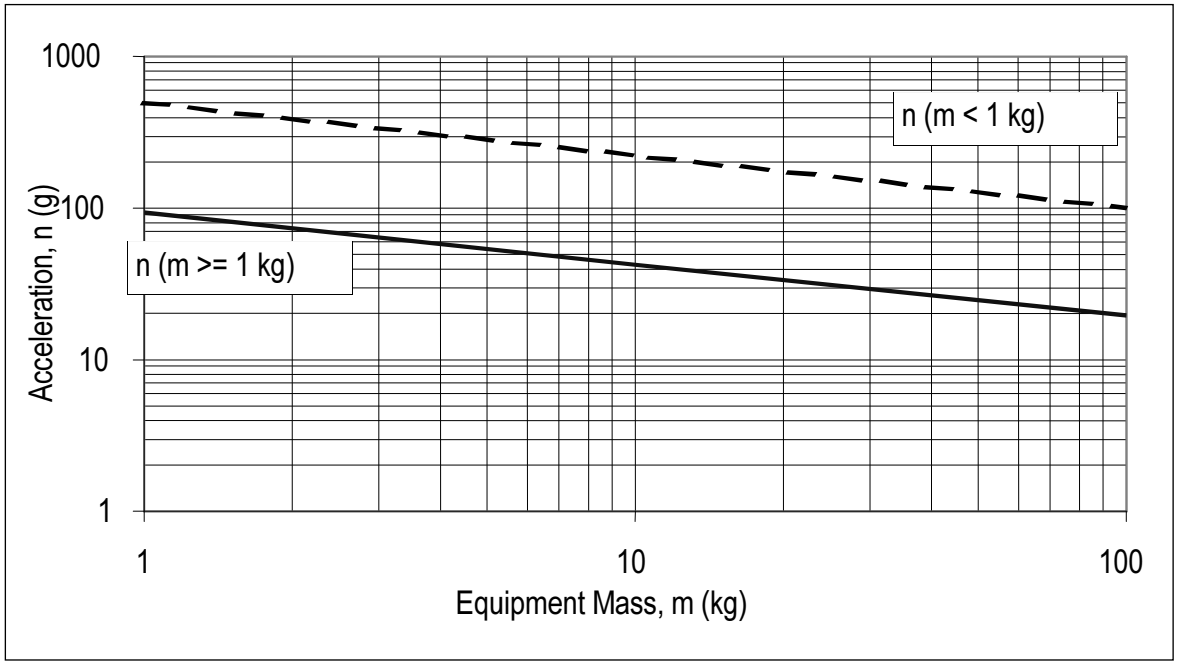

Figure 6-3: Typical Limit Load Factors for Initial Dimensioning of Secondary Structures and Equipment Brackets

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 are presented in Figure 6-3 as a design guideline.

For dimensioning, limit load factors "n" have to be applied

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

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

6.3.4 *Stiffness*

To avoid dynamic coupling between the low-frequency launch vehicle and payload modes, the payload fundamental frequency f_0 must meet the following stiffness requirements:

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

Note: Resonance requirements are related to spacecraft modes with significant effective mass ($m_e \geq 70\%$). The stiffness values are targets for design, if existing spacecraft are not compliant, figures can be relaxed based on CLA results.

6.3.5 *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.

6.4 *Spacecraft Compatibility Tests*

6.4.1 *Spacecraft Mechanical Qualification and Acceptance Tests*

The Customer must 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 launche 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 6.4.1-1. The spacecraft verification plan finally selected needs to be approved by the launcher authority.

6.4.1.1 *Static Load Test*

On the basis of dimensioning loads, Chapter 6.3.3.2, 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 realistic simulation of load introduction, the spacecraft must be attached to a flight representative adapter or separation system during the static test.

6.4.1.2 *Sinusoidal Vibration Test*

The inputs at the spacecraft adapter interface are shown in Table 5.1.3-1, and the loads in Table 6.4.1.2-1.

Permission for notching of critical input-resonances may be requested from EUROCKOT in order not to exceed the spacecraft flight responses predicted by coupled load analysis.

	Acceptance	**Qualification**
Test factors	1.25	1.5
Sweep rates (one sweep per axis)	4 oct/min	2 oct/min

Table 6.4.1.2-1: Vibration loads, sinusoidal

6.4.1.3 *Random Vibration Test*

The inputs at the spacecraft-to-adapter interface will be specified on a case-by-case basis, see chapter 5.1.5.

The random vibration test can be omitted. EUROCKOT recommends the performing of an acoustic test.

Permission for notching of input-critical resonances may be requested from the launcher authority in order not to exceed local responses measured during acoustic noise test or acoustic response analysis.

Test Hardware	**Required Tests**									
	Q: Qualification				**A: Acceptance**					
	Static Chap. 6.4.1.1		Sinusoidal Chap. 6.4.1.2		Random Chap. 6.4.1.3		Acoustic Chap. 6.4.1.4		Shock Chap. 6.4.1.5	
	Q	A	Q	A	Q	A	Q	A	Q	A
Prototype Philosophy:										
Qualification Model	X		X		X[1]		X[1]		X	
Flight Model				X		X[1]		X[1]		X[2]
Protoflight Philosophy:										
Protoflight Model	X		X		X[1]		X[1]		X[2]	
1) alternatively 2) optionally										

Table 6.4.1-1: Typical Mechanical Test Matrix

	Accep-tance	Qualifi-cation	Protoflight Model Qualification
Test factor for PSD level	1.56	2.25	2.25
Exposure duration per axis	60s	120s	60s

Table 6.4.1.3-1: Vibration loads, random

6.4.1.4 *Acoustic Noise Test*

The lift-off acoustic noise spectrum as defined in Chapter 5.1.4 must be used as the test input with the factors and durations of Table 6.4.1.4-1 applied.

	Accep-tance	Qualifi-cation	Protoflight Qualification
Test factor for acoustic pressure (dB)	2.0 dB	3.5 dB	3.5 dB
Exposure duration	60s	120s	60s

Table 6.4.1.4-1: Acoustic Noise Spectrum

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

6.4.1.5 *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.

6.4.2 *Interface Tests*

The following tests will generally be performed:

- Compatibility tests
  - Matchmate (verification of electrical and mechanical interface to the adapter)
  - Volume compatibility test with fairing and adapter
- Thermal tests
- EMC tests