GK LAUNCH SERVICES

APPENDIX #1

1. MECHANICAL LOAD ENVIRONMENTS FOR SECONDARY PAYLOADS

1.1. General provisions

This section provides mechanical loads that secondary payloads (small SC) experience during Soyuz-2 / Fregat ground operations and launch.
Quasi-static accelerations as well as shock levels and number of shocks during the ascent phase are highly sensitive to a SC location on the payload frame and its mounting method.
Thus, quasi-static accelerations and shock levels given below may be adjusted during preliminary works on adaptation of the specific SC.
It is allowed to perform test in each axis one after another.

1.2. Stiffness requirements

The SC rigidly mounted at the base shall not have resonance frequencies below 40 Hz.

Resonance frequencies below 40 Hz are allowed in some specific cases upon additional consultations with NPOL.

1.3. Requirements for a dynamic model (finite element model) of the secondary payload

If the SC has no resonance frequencies below 40 Hz and SC manufacturer doesn't insist on providing its own payload dynamic model, this SC will be described within the common dynamic model of the Upper Composite as a rigid element with corresponding mass and moments of inertia. In this case CLA will provide SC accelerations (at the CoG) in six degrees of freedom for specified load cases.

If the SC manufacturer plans to use its own dynamic model it can be provided in ".opt4NASTRAN" format with an appropriate description. If the SC manufacturer wants to provide its model it should communicate this intention at the beginning of joined works on SC adaptation. After that, deadlines for model provision will be defined and additional issues associated with its integration into the integrated dynamic model of the Upper Composite will be discussed and agreed.

1.4. Safety factors

The values of flight loads are defined by dividing qualification loads by a safety factor corresponding to a specific loading event.
Safety factors:

Quasi-static accelerations	1.3
Vibration accelerations	1.5
Acceleration spectral density	2.0
Loads duration	2.0
Shock spectrum due to separation systems	1.5
Sound pressure	+3 dB

Customer shall perform qualification tests and provide the report. Customer shall perform Acceptance tests and provide the report upon request of LSP. The Volume and levels of the Acceptance tests are defined by the Customer based on the flight levels.

1.5. Quasi-static accelerations

Below are preliminary (conservative) levels for qualification quasi-static loads to be considered for the purpose of SC strength analysis and qualification.

Final levels of quasi-static accelerations are confirmed via coupled (along with LV) load analysis.
Qualification values for linear quasi-static accelerations are to be taken equal to 10g in the flight axis and to 5g…9g in each of lateral directions; exposure time is 10 minutes in each axis.
The specific value of lateral accelerations will be defined for the SC depending on its mass and inertia properties and the way of its mounting on the adapter of the Upper stage.
Note 1: The values of max accelerations in lateral axes should be specifically defined for loading environment of a particular SC depending on its mass and inertia properties and the way of its mounting on the adapter of the Upper Stage.
Note 2: It is allowed to replace quasi-static tests by sine vibration at a frequency of 0,25…0,3·F1, where F1 is the first natural frequency.
These tests can be performed in the mode of usual sine vibration with constant amplitude at the frequency chosen from the abovementioned range, or in the "Sine Burst" mode. In this case, it is required to perform first the test at flight loads during:

- 180 sec in the flight axis (T_{FULL}=180 sec);
- 30 sec in each lateral axis (T_{SIDE}=30 sec),

To demonstrate strength margin these modes shall be followed by qualification loads applied during 2-3 sec (proof strength).

1.6. Vibration loads

Qualification levels of vibrations at SC attachment points to the adapter in each of three orthogonal directions are given:
- in Table 1 for sine vibration within the frequency range up to 20 Hz (vibration acceleration varies linearly within each frequency sub-range);
- in Table 2 for random vibrations within frequencies from 20 Hz to 2000 Hz (changes of Spectral Density vs Frequency within each frequency band is linear when a logarithmic scale is used for both frequency and PSD).

Table 1: Sine vibration qualification levels

Flight events (operational phase)	Duration, sec	Frequency band, Hz			
		1 – 2	2 – 5	5 - 10	10 - 20
		Amplitude of vibration accelerations, g (g = 9,81 m/s²)			
Operation of LV stages	600	0,3-0,5	0,5	0,5-1,0	1,0
Operation of Fregat upper stage engines	875	0,2-0,3	0,3-0,4	0,4-0,5	0,5

Notes:
1. If natural frequencies of a spacecraft are above 40 Hz and quasi-static qualification tests were performed, it is allowed to omit vibe tests at frequencies up to 20 Hz.
2. If SC is turn-off during the "Upper Stage Operation", it is allowed to omit tests for this flight event.

Table 2: Random vibration qualification levels

Flight events (operational phase)	Phase Duration, sec	Frequency sub-range, Hz						Acceleration RMS, g
		20-50	50-100	100-200	200-500	500-1000	1000-2000	
		Acceleration spectral density (ASD), g^2/Hz						
Operation of LV stages	120	0.02	0.02	0.02-0.05	0.05	0.05-0.025	0.025-0.013	7.42
	480	0,02	0,02	0,02	0,02-0,008	0,008-0,004	0,004-0,002	3.58
Operation of Fregat upper stage engines	875	0,004	0,004	0,004	0,004	0,004	0,004-0,002	2.59

Notes:

1. If SC is turn-off during the "Upper Stage Operation", it is allowed to omit tests for this flight event.
2. During vibration tests, notching is allowed at resonance frequencies. To agree particular notches with NPOL the SC manufacturer must send a request providing reasons for required notches. If the issue is related to qualification of specific equipment it is necessary to provide qualification levels of this equipment.

1.7. Shocks

During flight operations, secondary payloads are exposed to shock loads generated by separation systems of LV stages and by the separation system of a specific SC.

4.7.1 Shock qualification levels in all axes produced by LV separations systems are given in table 3. The shock levels are given for Q = 10. Number of shocks is equal to 5.

Table 3: Shock qualification levels in all axes produced by LV separation systems

Frequency, Hz	100-200	200-500	500-1000	1000-2000	2000-5000
Shock response spectrum A_s, g	30-60	60-255	255-750	750	750-1500

4.7.2. When using a secondary payload customer provided separation system, the shock spectrum is specified by the manufacturer of the separation system. It is to be agreed with NPOL.

4.7.3 For a separation system provided by NPOL, the shock qualification levels in all axes are given in Table 4. The shock spectrum corresponds to Q=10. Number of shocks is equal to 1.

Table 4: Shock qualification levels generated by NPOL-provided separation system

Frequency, Hz	100-200	200-500	500-1000	1000-2000	2000-5000
Shock response spectrum, A_s, g	150-300	300-750	750-1500	1500-4500	4500-15000

Note:

Shock Levels at the SC interface given in Table 4 demonstrate the levels at the points of pyros operation. Shock levels that are transferred at the same time to the body of the SC highly depend on its structure. According to tests results, the actual loads on the SC usually do not exceed 1000g at frequencies of about 1000Hz and 2000g at frequencies of 2000Hz and higher.

1.8. Acoustic loads

During the launch small spacecraft are exposed to sound pressure. Acoustic levels under the fairing (peak flight acoustic loads and duration) are given in Table 5.

Table 5

The center frequency within the octave band Hz	Sound pressure level, dB (datum point 2×10^{-5} Pa)	Duration, s
31.5	132	
63	137	
125	140	
250	141	
500	140	
1000	133	
2000	128	
4000	123	
RMS, dB	146,2	120

Note: The necessity, extent and methods of acoustic tests for secondary payloads are defined by a spacecraft manufacturer.

1.9. Maximum QSL during on-ground transfers

Load Case	QSL (g)					
Transport	Lateral			Longitudinal		
	Static	Dynamic	Total	Static	Dynamic	Total
	0.0	±1	±1	-1	±1	0/-2

The “minus” sign indicates compression along the longitudinal axis and the “plus” sign indicates tension.