Small Satellite Environmental Testing

Mechanical Testing

Soyuz-2/Fregat Rideshare
1. Test Specification

The following sections specify load requirements, test sequence and success criteria for testing of cubesats to acceptance, qualification and protoflight level for the Soyuz-2/Fregat launch vehicle. Qualification testing shall be performed with a qualification model of the satellite to demonstrate design quality. Acceptance tests shall be conducted with the flight model satellite to verify quality of workmanship and readiness for launch. If the project does not foresee production of a qualification model, a protoflight testing approach can be chosen which is performed with the flight model satellite.

1.1 Test Axes

The small satellite rideshare cluster on Soyuz-2/Fregat is integrated on the Rideshare Payload Frame. Flight and lateral axes are determined by the mounting location and clocking of the EXOpod deployer or CarboNIX microsatellite separation ring. The balconies shown in Figure 1 are inclined by 13 deg. This angle may be neglected for testing purposes. For most missions, the following can be assumed for cubesat payloads if not specified otherwise: Y is the flight axis. X and Z are the lateral axes.

Figure 1: Examples of Rideshare cluster configurations on the Fregat Upper Stage Payload Frame.

Figure 2: Coordinate system of the Exolaunch EXOpod.
## 1.2 Test Margins

<table>
<thead>
<tr>
<th>All axes</th>
<th>Acceptance</th>
<th>Protolflight (Cubesats)</th>
<th>Qualification</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Load Margin</td>
<td>Duration Margin</td>
<td>Load Margin</td>
</tr>
<tr>
<td>Quasi Static</td>
<td>1.0</td>
<td>10 cycles</td>
<td>1.0</td>
</tr>
<tr>
<td>Sine Vibe</td>
<td>1.0</td>
<td>300+438 sec</td>
<td>1.5</td>
</tr>
<tr>
<td>Random Vibration</td>
<td>1.0</td>
<td>1+4 min/axis</td>
<td>1.0</td>
</tr>
<tr>
<td>Shock</td>
<td>N/A</td>
<td>N/A</td>
<td>100 g</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

## 1.3 Quasi-static Loads (Sine-Burst)

Quasi-static loads may be tested with a Sine-Burst(Sine-Dwell) approach to replace static testing. If the mounting orientation of the satellite is not clear at the time of testing, then flight axis loads should be used on all potential flight axes.

Test requirements for microsatellites are higher, requiring an additional Sine Dwell at Qualification level. In this case Sine-Dwell and Sine-Burst are performed in succession without a Resonance Sweep in between.

**Table 1: Sine-Burst loads for CUBESATS.**

<table>
<thead>
<tr>
<th>Test Levels</th>
<th>Parameters</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Load, g</td>
</tr>
<tr>
<td>Acceptance Level</td>
<td>Flight axis</td>
</tr>
<tr>
<td>Protolflight Level</td>
<td>Lateral axes</td>
</tr>
<tr>
<td>Qualification</td>
<td>Flight axis</td>
</tr>
<tr>
<td></td>
<td>Lateral axes</td>
</tr>
</tbody>
</table>

**Table 2: Sine-Burst/Sine-Dwell loads for MICRO SATELLITES.**

<table>
<thead>
<tr>
<th>Acceptance Level</th>
<th>Parameters</th>
</tr>
</thead>
<tbody>
<tr>
<td>Flight Axis</td>
<td>Load, g</td>
</tr>
<tr>
<td>7.7</td>
<td>10 cycles</td>
</tr>
<tr>
<td>Lateral Axes</td>
<td>3.85</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Qualification Level</th>
<th>Parameters</th>
</tr>
</thead>
<tbody>
<tr>
<td>Flight Axis</td>
<td>Load, g</td>
</tr>
<tr>
<td>7.7</td>
<td>180</td>
</tr>
<tr>
<td>7</td>
<td>2-3</td>
</tr>
<tr>
<td>Lateral Axes</td>
<td>Load, g</td>
</tr>
<tr>
<td>5.38</td>
<td>30</td>
</tr>
<tr>
<td>7</td>
<td>2-3</td>
</tr>
</tbody>
</table>

*Frequency can be changed to avoid an odd-numbered harmonic of the test article, e.g. test frequency should not be 20 Hz if test article’s fundamental frequency is 60 Hz or 100 Hz.*
1.4 Sine Vibe

Sine Vibe testing may be omitted for Soyuz-2/Fregat if the first resonance frequency of the spacecraft determined in the preceding resonance survey is above 40 Hz and a Quasi-static load test has been performed. If any of these criteria are not met or in doubt, the Sine Vibe is to be performed as indicated below. Note that the range up to 5 Hz may be omitted if the test device (shaker table) is not capable of operating in that range.

<table>
<thead>
<tr>
<th>Test Levels</th>
<th>Duration, sec</th>
<th>Frequency, Hz</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>1</td>
<td>2</td>
</tr>
<tr>
<td>Acceptance LV</td>
<td>300</td>
<td>0.2</td>
</tr>
<tr>
<td>Fregat operation</td>
<td>438</td>
<td>0.13</td>
</tr>
<tr>
<td>Protolight LV</td>
<td>600</td>
<td>0.3</td>
</tr>
<tr>
<td>Qualification</td>
<td>875</td>
<td>0.2</td>
</tr>
</tbody>
</table>

1.5 Random Vibration

The Soyuz-2 Launch Vehicle requires testing Random Vibration with two different load profiles, which are tested in sequence, without a Resonance Survey in between.

<table>
<thead>
<tr>
<th>Test Levels</th>
<th>Phase Duration, sec</th>
<th>Frequency sub-range, Hz</th>
<th>Acceleration Spectral Density (ASD), g²/Hz</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>20</td>
<td>100</td>
</tr>
<tr>
<td>Acceptance All axes</td>
<td>Profile A</td>
<td>60</td>
<td>0.01</td>
</tr>
<tr>
<td></td>
<td>Profile B</td>
<td>240</td>
<td>0.01</td>
</tr>
<tr>
<td>Qualification All axes</td>
<td>Profile A</td>
<td>120</td>
<td>0.02</td>
</tr>
<tr>
<td></td>
<td>Profile B</td>
<td>480</td>
<td>0.02</td>
</tr>
<tr>
<td>Protolight All axes</td>
<td>Profile A</td>
<td>120</td>
<td>0.01</td>
</tr>
<tr>
<td></td>
<td>Profile B</td>
<td>480</td>
<td>0.01</td>
</tr>
</tbody>
</table>

1.6 Shocks

Shock testing is not performed at Acceptance level. Cubesats may perform a low level shaker-based Shock at Protolight or Qualification level as indicated below.

<table>
<thead>
<tr>
<th>Qualification, Protolight</th>
<th>Parameters</th>
<th>Type</th>
<th>Duration</th>
<th>Acceleration</th>
<th>Number of Shocks</th>
</tr>
</thead>
<tbody>
<tr>
<td>All axes</td>
<td></td>
<td>Half sine</td>
<td>2 ms</td>
<td>100 g</td>
<td>5</td>
</tr>
</tbody>
</table>
Microsatellites have to undergo a full Shock campaign using the SRS given below. In some cases, the highest Shock loads experienced by a microsatellite are generated by its separations system. If a third party separation system is used, its proprietary shock levels may exceed those provided by the launch provider and may change the requirements for the qualification campaign. In this case, the test profile shall be discussed and agreed upon in advance.

<table>
<thead>
<tr>
<th>Qualification Level</th>
<th>Frequency, Hz</th>
</tr>
</thead>
<tbody>
<tr>
<td>All Axes</td>
<td>100</td>
</tr>
<tr>
<td>SRS, g</td>
<td>30</td>
</tr>
</tbody>
</table>

Table 6: Shock loads for MICROSA TELLITES.

1.7 Resonance Survey

Tests are accompanied by Resonance Surveys (sine sweep test) before, in between and after the individual tests to observe changes in the system’s resonance frequencies. The first resonance survey performed before subjecting the satellite to higher loads serves as reference.

<table>
<thead>
<tr>
<th>Resonance Survey</th>
<th>Frequency range</th>
<th>Amplitude</th>
</tr>
</thead>
<tbody>
<tr>
<td>Scanning speed</td>
<td>5 Hz … 2000 Hz</td>
<td>0.2 g</td>
</tr>
</tbody>
</table>

Table 7: Specification of the Resonance Survey.

1.8 Test Sequence

The nominal test sequence is shown below. Note that the Sine Vibe test may be omitted for the Soyuz-2/Fregat test under conditions outlined in Section 1.4. Shock testing is not performed at acceptance level.

Figure 3: Typical test sequence of a mechanical testing campaign. Tests with dashed borders are only performed in certain cases.

1.9 Test Success Criteria

Pre- and post-test resonance survey data shall be overlaid. If the first natural frequency changes by more than 10%, or the response peak drops by more than 50%, then the test shall be stopped, and the anomaly investigated. All resonant peaks shall be within 10% of each other in each axis to be considered passing. Ultimate pass/fail evaluation shall be made by the responsible test engineer.