Phase D

Mechanical tests at qualification level for EQM

Test Report

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RECORD OF REVISIONS

ISS/REV	Date	Modifications	Created/modified by
1/0	16/10/08	Initial Issue	Guillaume Roethlisberger
1/1	23/10/08	Inserted M. Noca's comments	Guillaume Roethlisberger

1 REFERENCES

1.1 Normative references

[N1] ECSS-E-10-02A Verification (17 November 1998)

[N2] ECSS-E-10-03A Testing (15 February 2002)

1.2 Informative references

[R1] ISIS.ISILaunch.EL.PSLV, Issue 1.2

[R2] PSLV User's manual, Issue 5

[R3] S3-D-2-2-Sine_vib_EQM

[R4] S3-D-2-2-Random_vib_EQM

[R5] S3-D-3-2-Shock_EQM.doc

[R6] 08-0841_DLR-MDT-096-08_RUAG_SwissCube_EQM_Testreport_komplett

[R7] S3-D-1-2-PL_Alignment_Report

[R8] S3-D-SET-1-6_REDV Test Procedure Report

2 TERMS, DEFINITIONS AND ABBREVIATED TERMS

2.1 Abbreviated terms

ADS Antenna Deployment System

EPS Electrical Power System

EQM Engineering Qualification Model

PCB Printed Circuit Board

PMB Power Management Board

S/C Spacecraft

2.2 Definitions

PSD The power spectral density describes the frequency content of the vibration and is equal to the mean square acceleration (g^2) in a selected frequency band divided by the width of that band.

3 TEST OBJECTIVES

The purpose of the mechanical vibration testing is to demonstrate the ability of the satellite to withstand excitations of the PSLV launch vehicle increased by a qualification factor. The qualification levels are provided for the PSLV launch vehicle as described in [R1]. However the pyroshock test levels were performed at higher levels than for PSLV as this test shall serve for other launch vehicles as well.

The requirements 3_SSR_52_03, 3_SSR_52_04 and 3_SSR_52_06 as stated below shall be verified.

3.1 Sinusoidal vibration

3_SSR_52_03 **Sinusoidal vibration**

The Space System shall be able to sustain the sine vibration qualification test along each axis and for the frequency range specified in Figure 1 and Table 1.

Environment levels PSLV [R1]

2_PR_14_02

Table 1 Sinusoidal vibration tests at qualification level.

Frequency [Hz]	5	8	100
Amplitude [g]	1	4.5	4.5
Sweep rate	2 oct/mn		

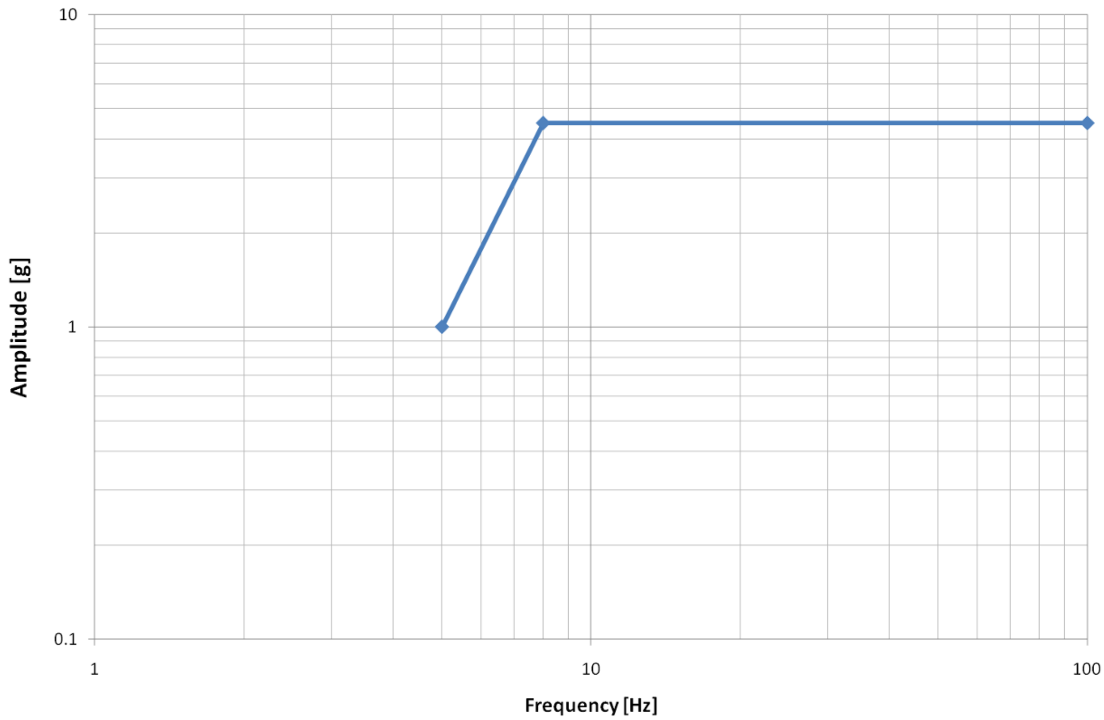

Figure 1- Amplitude of sinusoidal vibrations at qualification level.

3.2 Random vibration

3_SSR_52_04

Random vibration

The Space System shall be able to sustain the random vibration qualification tests along each axis and for the frequency range specified in Figure 2 and Table 2.

Environment levels PSLV [R1]

2_PR_14_02

Table 2 Random vibration tests at qualification level.

Frequency [Hz]	20	110	250	1000	2000	Overall G_{rms}
PSD [10^{-3} g^2/Hz]	2	2	34	34	9	6.71
Duration	2mn per axis					

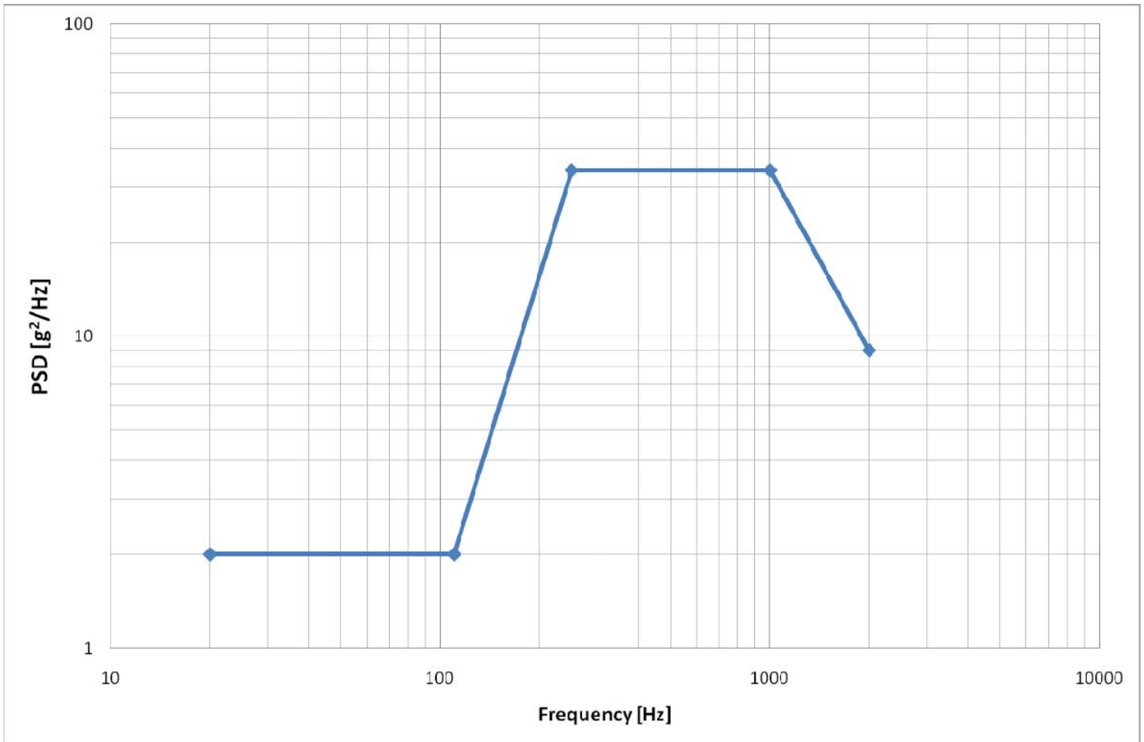

Figure 2 PSD for qualification test.

3.3 Pyroshock

3_SSR_52_06

Pyroshock

The Space System shall be able to sustain the pyroshock qualification test for the frequency range specified in Figure 3 and Table 3.

Worst case between Vega, Soyuz, Dnepr and Ariane 5 LVs

2_PR_14_02

Table 3 Shock vibration tests at qualification level.

Frequency [Hz]	30	100	600	1000	2000	5000	10000
Acceleration [g]	8	60	1400	2200	3500	4500	4500
Shocks per axis	3						

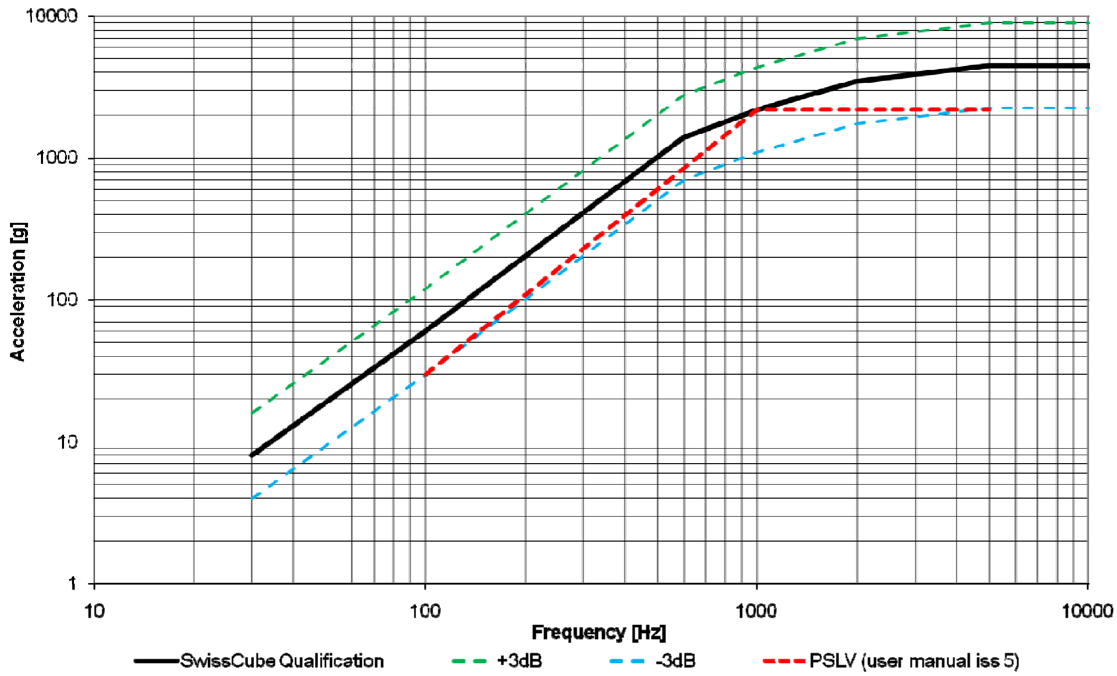

Figure 3 Amplitude of the qualification shock test.

The pyroshock levels provided in Figure 3 accommodates a large number of launch vehicles. As this type of test facility is not readily available in Switzerland, the project decided to qualify the satellite for higher levels than required by PSLV. However, and as stated in [R6], for facility technical reasons, the Y and Z axes could not be performed at these levels. The levels they were performed at do satisfy the PSLV requirements (as specified in [R2]) though.

4 TEST FLOW

Figure 4 details the planned sequence for the mechanical qualification test campaign.

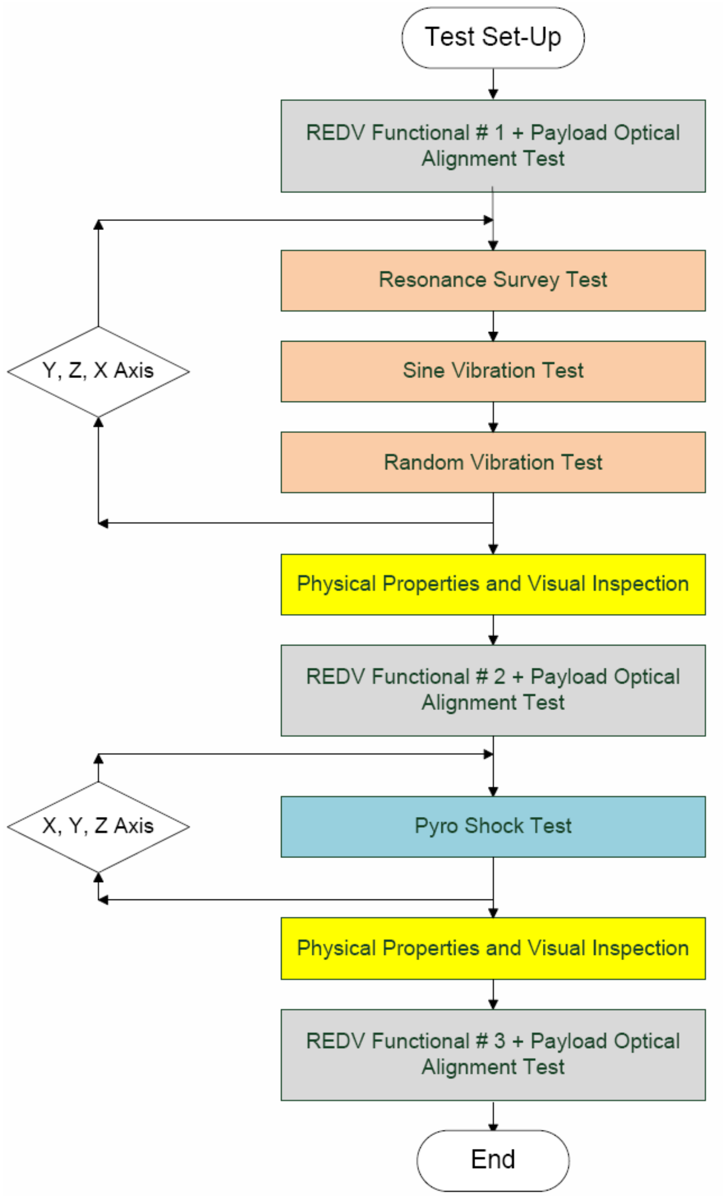

Figure 4 EQM mechanical test flow.

First the EQM will undergo the sine and random vibrations at qualification level as described above and a list of detailed specifications given in Chapter 7 has to be verified. The vibration profile will be applied only on one axis at a time.

A resonance survey test before and after running each test at full level will be run to compare the results for any possible damage to the S/C during the full-level tests. For this reason three accelerometers (one per axis) will be placed onto the Test-POD. The resonance survey test parameters are:

- Frequency 5 – 2000 Hz
- Amplitude 0.5 g
- Sweep rate 2 oct/min (one upsweep)

Second, the EQM will undergo pyroshocks at qualification level as described above and a list of detailed specifications given in Chapter 7 has to be verified.

The test procedures are given in [R3], [R4] and [R5].

The sine and random tests were performed on the 8th of October in Astro Berlin. The pyroshock test was performed on the 9th of October in *Astro- und Feinwerktechnik Adlershof GmbH* (Berlin). All results and graphs are provided in [R6].

For the SwissCube part, Muriel Noca, Nicolas Steiner and Guillaume Roethlisberger performed the test. Martin Rose from *Astro- und Feinwerktechnik Adlershof GmbH* was responsible for the test facility.

5 TEST SET-UP

Detailed lists of all used sensors can be found in [R6]. The following figures show the configuration of the Test-POD onto the shaker or pyroshock test facility, respectively.

5.1 Sine and random tests

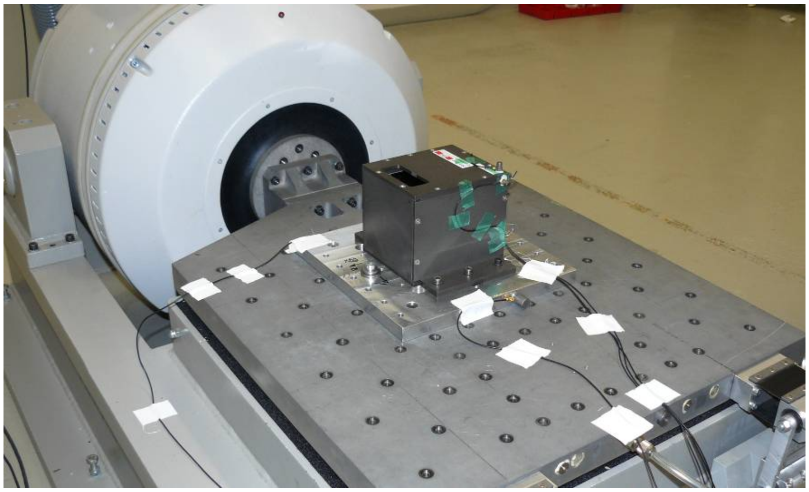

Figure 5 Test set-up for Y-axis.

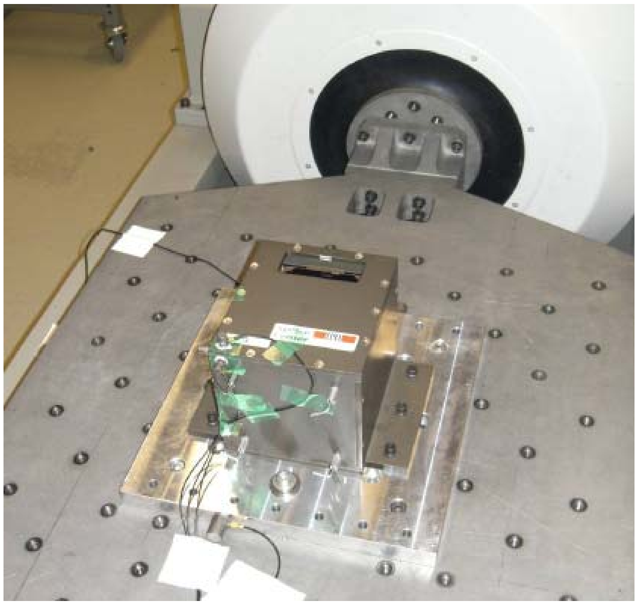

Figure 6 Test set-up for Z-axis.

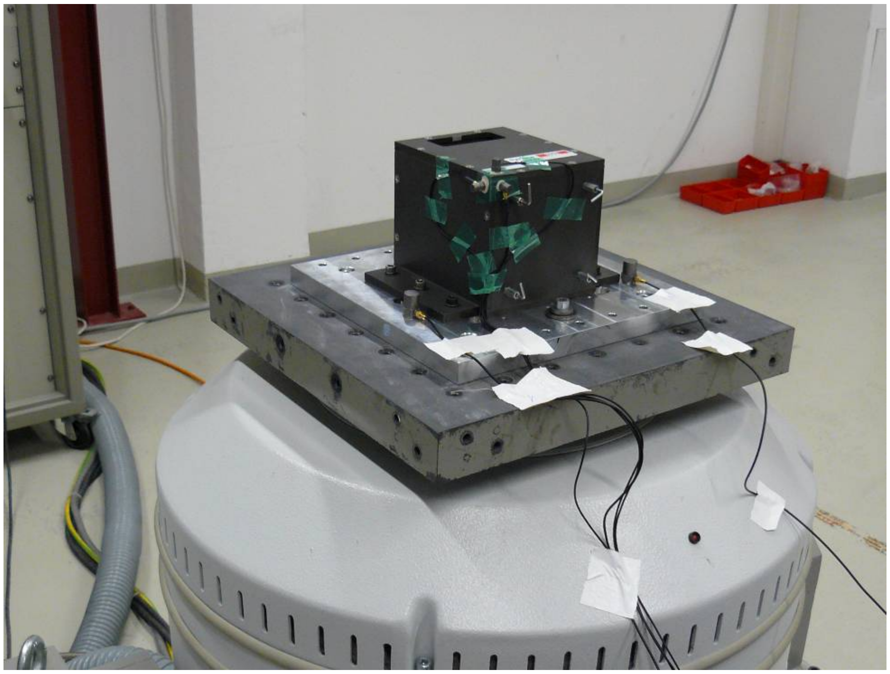

Figure 7 Test set-up for X-axis.

5.2 Pyroshock tests

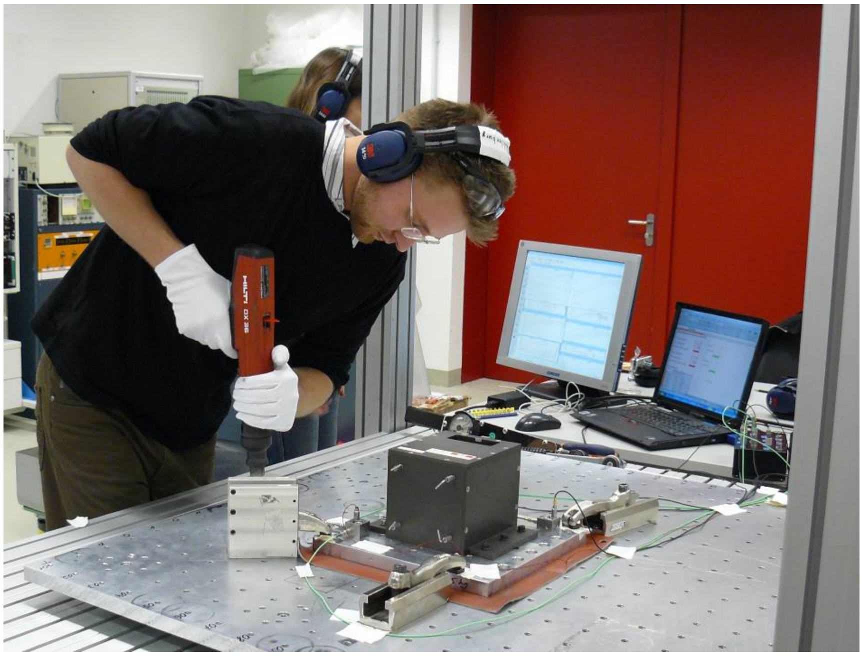

Figure 8 Test set-up for X-axis.

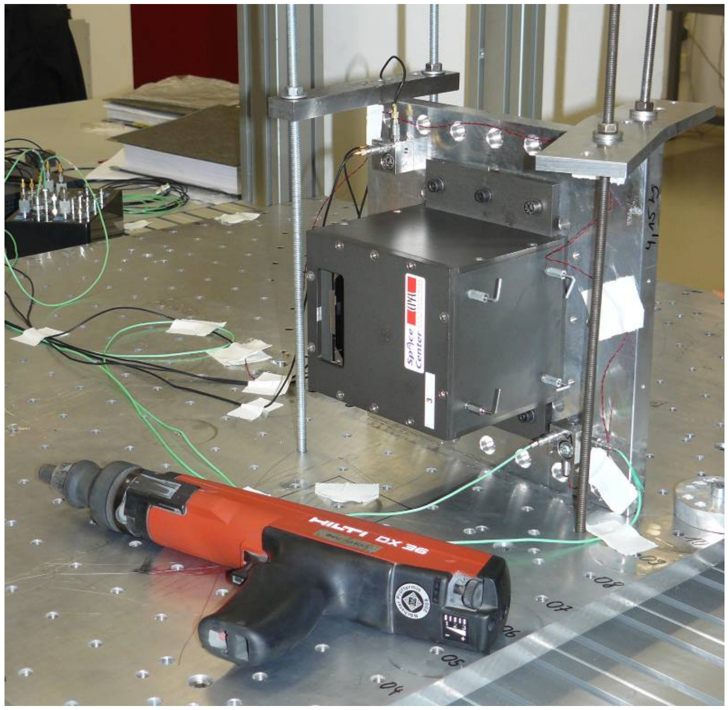

Figure 9 Test set-up for Y-axis.

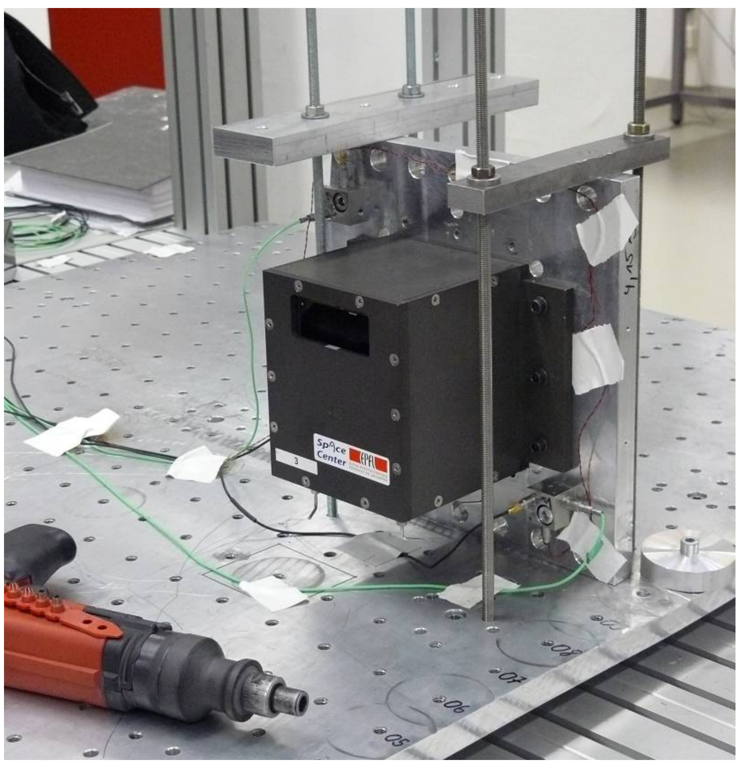

Figure 10 Test set-up for Z-axis.

6 STEP BY STEP INSTRUCTION FOR OPERATION

6.1 Test preparation

Visual inspection, REDV test and Payload Alignment test shall be performed before vibration test, as described below. Especially the checklist (see Chapter 7) shall be filled before the test. -> done

Rails and solar cells shall be identified via a number. -> done

6.2 Test performances

The mechanical qualification test campaign is as follow:

Task n°	Task description	Operator	QA
1	Visual inspection, REDV test (#1) and Payload Alignment test	Done	Ok
2	Mount the three accelerometers onto the Test-POD	Done	Ok
3	Insert satellite into the Test-POD. Add the top panel from the test pod assembly	Done	Ok
4	Setup Test Pod so that the Y axis is the test axis of the shake table.	Done	Ok
5	Be sure to check all fasteners and data lines between tests to ensure a safe operating environment and accurate results	Done	Ok
6	Run the resonance survey test for Y-axis, then the sine vibration test at qualification level and finally again the resonance survey test. Then run the random test at qualification level and finally again the resonance survey test.	Done	Ok
7	Setup Test Pod so that the Z axis is the test axis of the shake table.	Done	Ok
8	Be sure to check all fasteners and data lines between tests to ensure a safe operating environment and accurate results	Done	Ok
9	Input sine vibration parameters for Z-axis into controller	Done	Ok
10	Run the resonance survey test for Z-axis, then the sine vibration test at qualification level and finally again the resonance survey test. Then run the random test at qualification level and finally again the resonance survey test.	Done	Ok

11	Reorient the shaker in order that the shaker excitation is in the vertical direction and setup Test Pod so that the X-axis is the test axis of the shake table.	Done	Ok
12	Be sure to check all fasteners and data lines between tests to ensure a safe operating environment and accurate results	Done	Ok
13	Input sine vibration parameters for X-axis into controller	Done	Ok
14	Run the resonance survey test for X-axis, then the sine vibration test at qualification level and finally again the resonance survey test. Then run the random test at qualification level and finally again the resonance survey test.	Done	Ok
15	Unscrew the Test-POD from the shaker. Open the Test-POD and remove the satellite.	Done	Ok
16	Visual inspection, REDV test (#2) and Payload Alignment test	Done	Ok
17	Mount the feedback accelerometers onto the adaptor plate	Done	Ok
18	Insert satellite into the Test-POD. Add the top panel from the test pod assembly	Done	Ok
19	Setup Test Pod so that X axis is the test axis of the pyroshock facility.	Done	Ok
20	Be sure to check all fasteners and data lines between tests to ensure a safe operating environment and accurate results	Done	Ok
21	Perform three times the shock test for X-axis.	Done	Ok
22	Setup Test Pod so that Y axis is the test axis of the pyroshock facility.	Done	Ok
23	Be sure to check all fasteners and data lines between tests to ensure a safe operating environment and accurate results	Done	Ok
24	Perform three times the shock test for Y-axis.	Done	Ok
25	Setup Test Pod so that Z axis is the test axis of the pyroshock facility.	Done	Ok
26	Be sure to check all fasteners and data lines between tests to ensure a safe operating environment and accurate results	Done	Ok
27	Perform three times the shock test for Z-axis.	Done	Ok
28	Unscrew the Test-POD from the shaker. Open the Test-POD and remove the satellite.	Done	Ok
29	Visual inspection, REDV test (#3) and Payload Alignment test	Done	Ok

6.3 Pass-fail criteria

The success criteria are:

- No point of failure after visual inspection
- All housekeeping data after electrical check-up

7 CHECKLIST – TEST RESULTS

7.1 CubeSat Acceptance Checklist

First the SwissCube shall be removed from the Test POD and the table below shall be filled.

List item	Required	Measured before test	Measured after sine & random tests on three axes	Measured after pyroshock test on three axes
Rails	Cold welding marks	Some marks	Some marks	Some marks
Deployment Switches	Functional	Functional	Functional	Functional

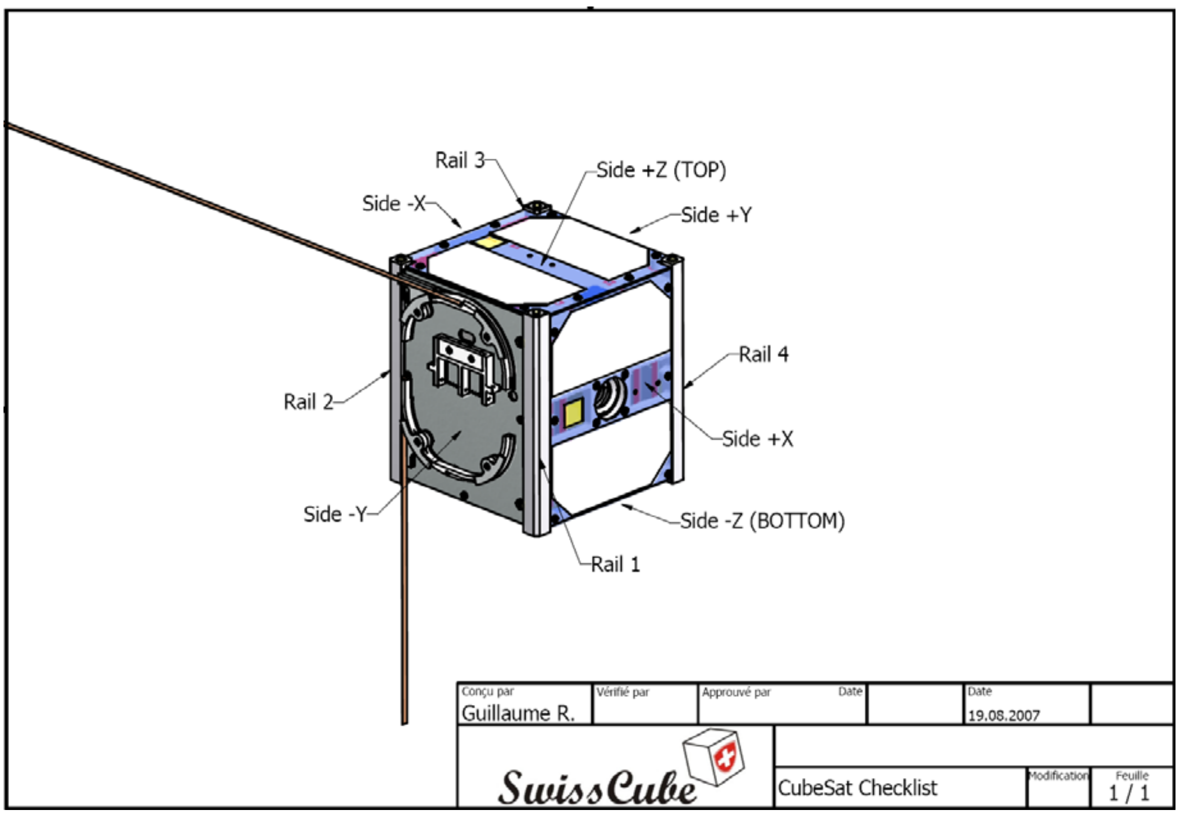

Figure 11 Rails and sides denomination.

7.2 Screws and torques

Once the step above is performed, the torque of the external screws shall be checked. A dynamometric screwdriver is used to know if the screws are a little bit loose and can be screwed again. The screws that shall be controlled are those that attach the side panel, the +X, +Y, -Y and +Z panels and the Payload assembly (see Figure 12).

Screw number	Screw torques [Nm]	Screw torque before test	Screw torques after three axes sine & random tests	Screw torques after three axes pyroshock tests
PL, 1	0.3	Ok	Ok	Ok
PL, 2	0.3	Ok	Ok	Ok
+X, 1	0.3	Ok	Ok	Ok
+X, 2	0.3	Ok	Ok	Ok
+X, 3	0.3	Ok	Ok	Ok
+X, 4	0.3	Ok	Ok	Ok
+Y, 1	0.3	Ok	Slightly loose (1/4 turn)	Slightly loose (1/8 turn)
+Y, 2	0.3	Ok	Ok	Ok
+Y, 3	0.3	Ok	Ok	Ok
+Y, 4	0.3	Ok	Ok	Ok
-Y, 1	0.3	Ok	Ok	Ok
-Y, 2	0.3	Ok	Slightly loose (1/4 turn)	Slightly loose (1/8 turn)
-Y, 3	0.3	Ok	Slightly loose (1/4 turn)	Slightly loose (1/8 turn)
-Y, 4	0.3	Ok	Ok	Ok
+Z, 1	0.3	Ok	Ok	Ok
+Z, 2	0.3	Ok	Ok	Ok
+Z, 3	0.3	Ok	Ok	Ok
+Z, 4	0.3	Ok	Ok	Ok

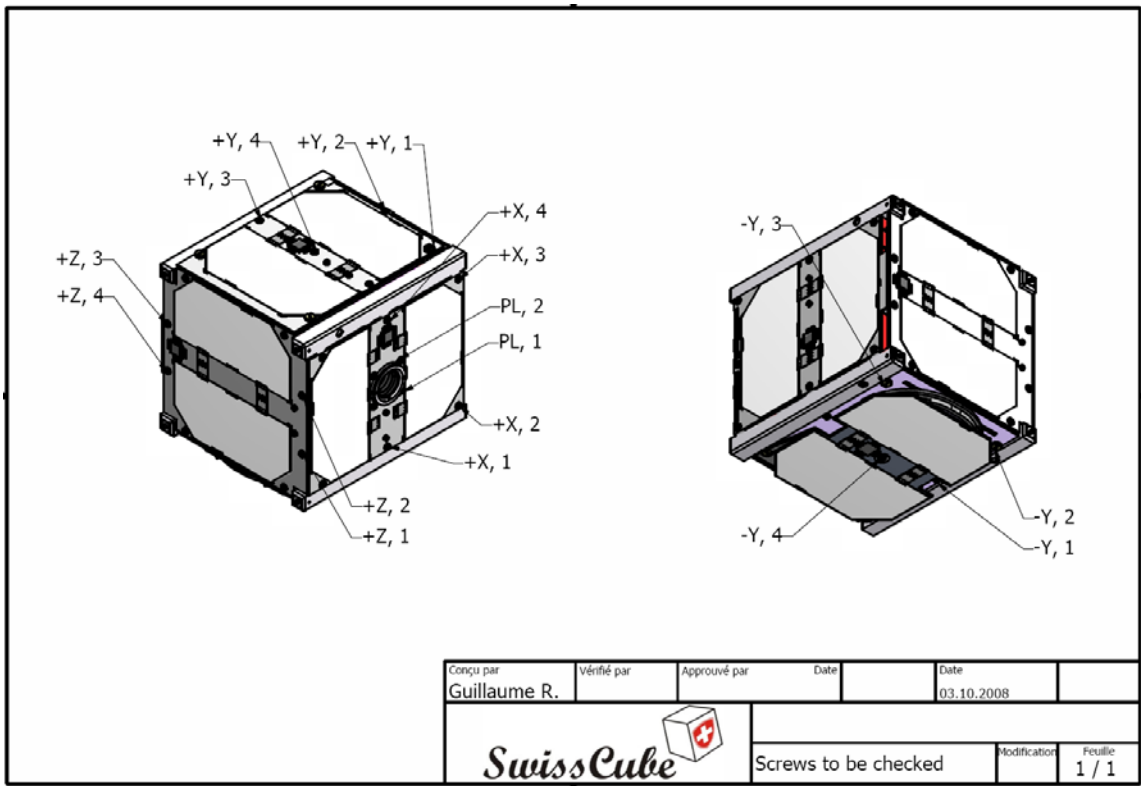

Figure 12 Screws that shall be checked

7.3 Solar Cells

7.3.1 Visual inspection

Once the step below is performed, the solar cells shall be visually inspected to the naked eye.

This visual inspection aims at verifying that there is no crack on the surface of the solar cells. For the denomination of the solar cells, see Figure 13.

Solar cells	Crack before test	Crack after three axes sine & random tests	Crack after three axes pyroshock
+X,1	None	None	None
+X,2	None	None	None
-X,1	None	None	None
-X,2	None	None	None
+Y,1	None	None	None
+Y,2	None	None	None

-Y,1	None	None	None
-Y,2	None	None	None
+Z,1	None	None	None
+Z,2	None	None	None
-Z,1	None	None	None
-Z,2	None	None	None

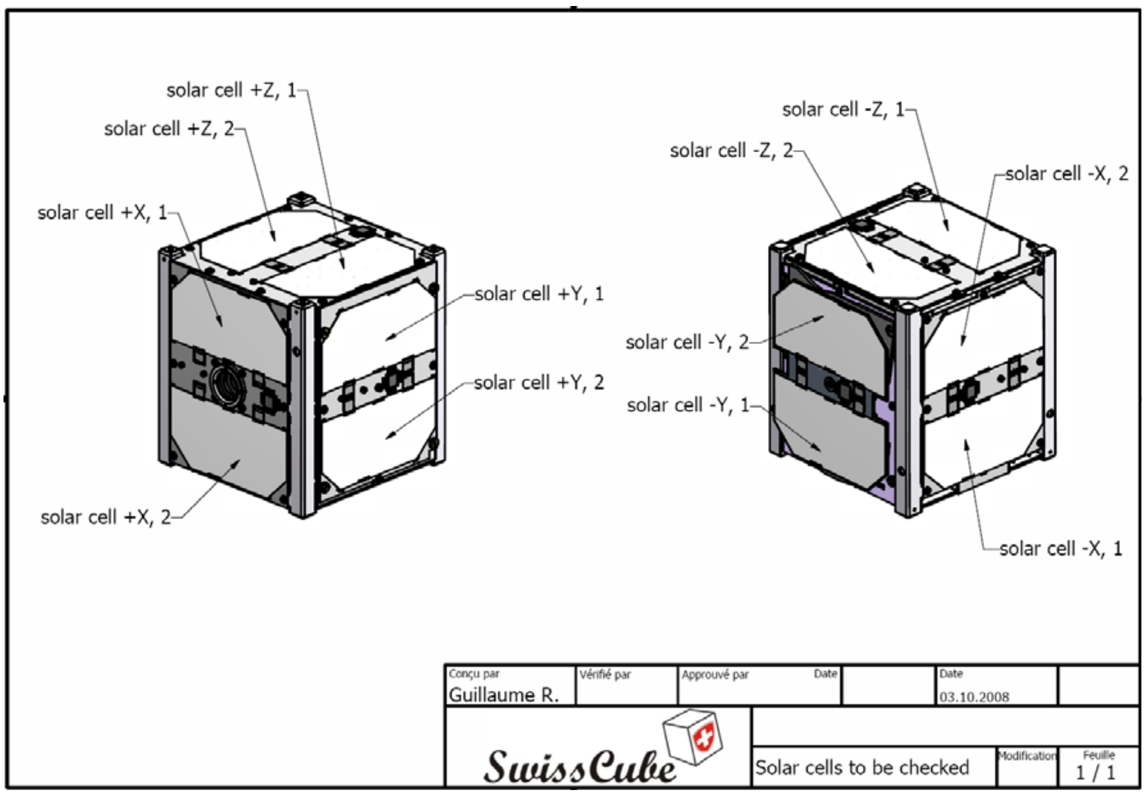

Figure 13- Location of the solar cells

7.4 Antennas Deployment System (ADS)

Attention should be paid to the Antenna Deployment System. The dyneema shall be visually inspected after each axis test to verify that it is still properly attached and that it still maintains the antennas in bended position.

	Attachment before test	Attachment after three axes sine & vibe tests	Attachment after three axes pyroshock tests
ADS Dyneema Wire	Ok	Ok	Ok

7.5 Payload Alignment test

The results of the Payload Alignment test can be found in [R7].

7.6 Remote Electrical and Data Verification (REDV)

The results of the REDV test can be found in [R8].

8 CONCLUSION AND RECOMMENDATIONS

8.1 CubeSat checklist

No problems appeared. No changes in dimensions were recorded.

8.2 Screws and torques

Only the PCB screws were a little bit unscrewed. For the future a threadlocker like Loctite should be used to avoid this potential problem.

8.3 Solar cells

8.3.1 Visual inspection

No cracks or marks.

8.4 ADS

The antennas remained stowed all a long the tests.

8.5 Payload Alignment test

According to the corresponding test report [R7] there is no major problem.

8.6 REDV

According to the corresponding test report [R8] there is no major problem.

8.7 Conclusion

The SwissCube Qualification Model is qualified for sine, random and pyroshock at the PSLV qualification levels.