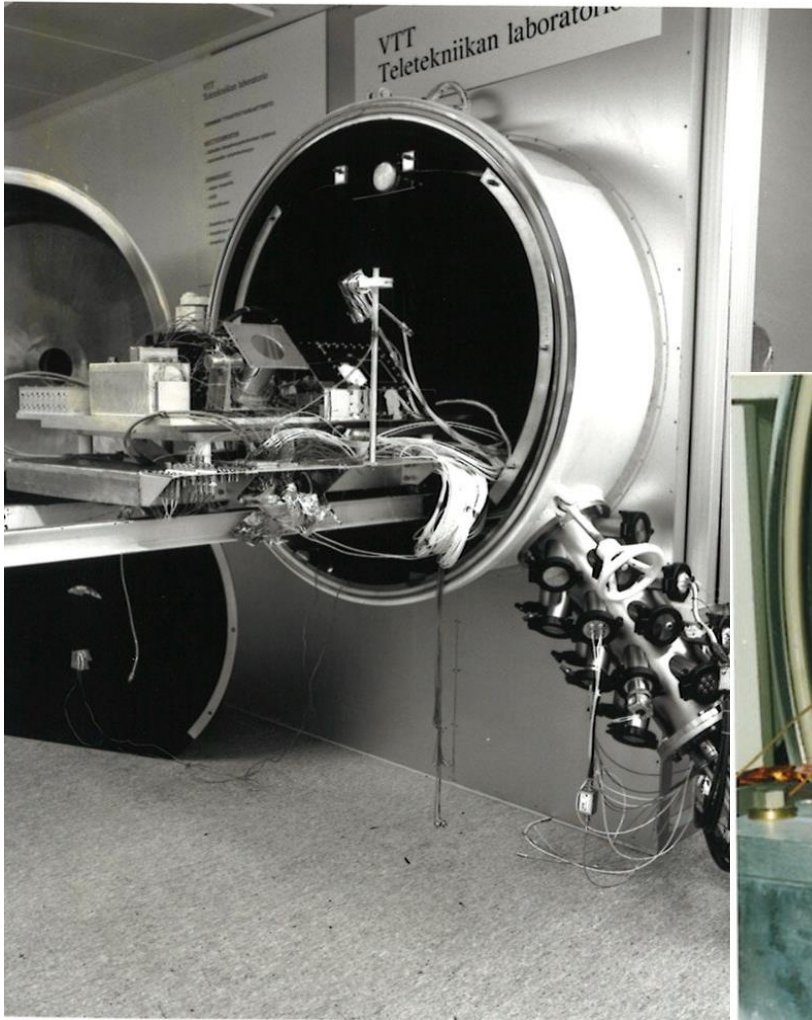


Mechanical testing of space instruments

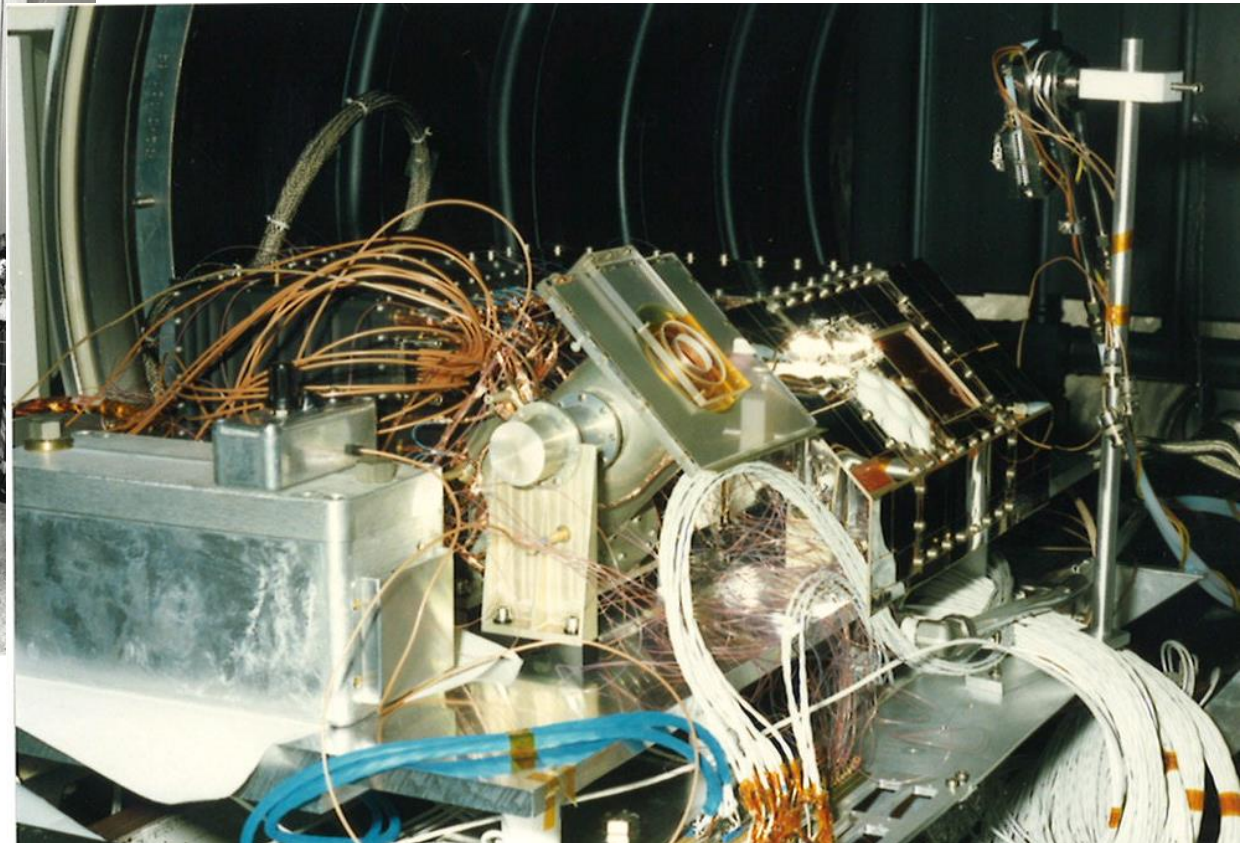
Olavi Nevalainen
VTT Expert Services Ltd

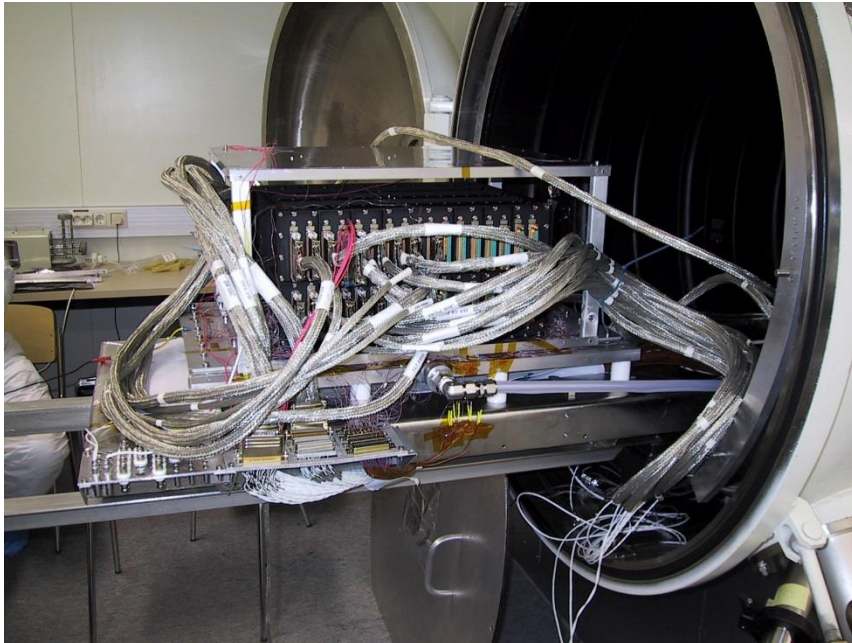
Environmental tests for space instruments from beginning of 1990 to this day

- Few projects:
 - SOHO
 - Huygens
 - Cluster
 - Gassini
 - Rosetta, PL-PDU
 - Herchel
 - GOME, GPDU
 - X-ray Solar Monitor (XSM)
 - Planck, Radiometers
- GMES, Sentinel-1, SAR Electronics Subsystems
- Aalto-1 ja Aalto 2
- Suomi 100 CubeSat
- ICEY
- Hello World CubeSat

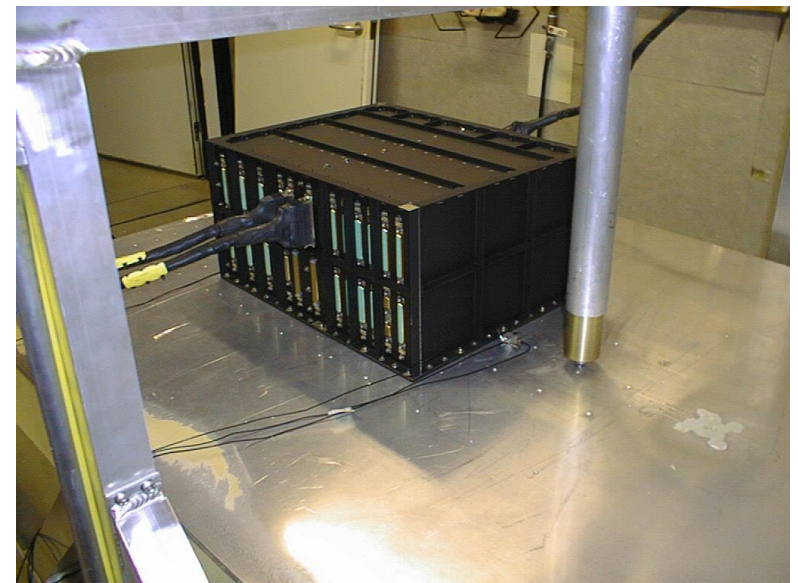
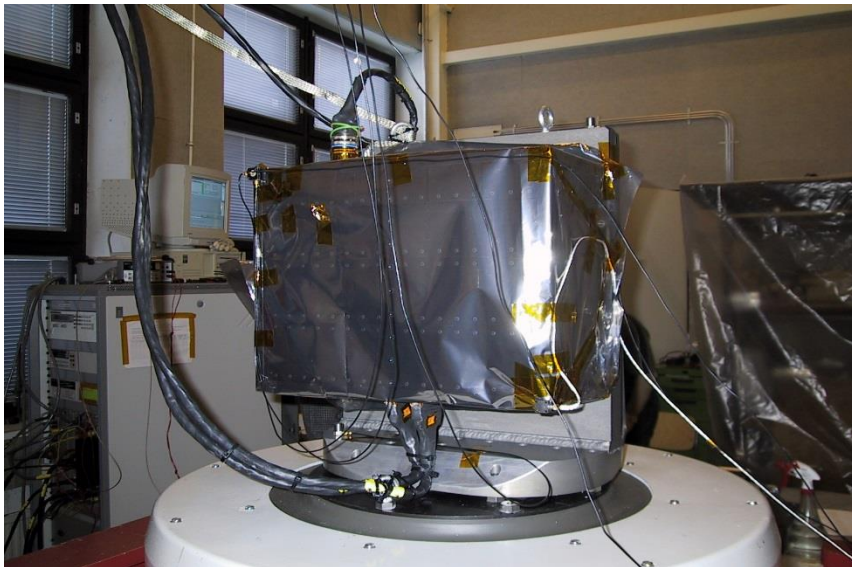


Thermal vacuum test for SOHO project





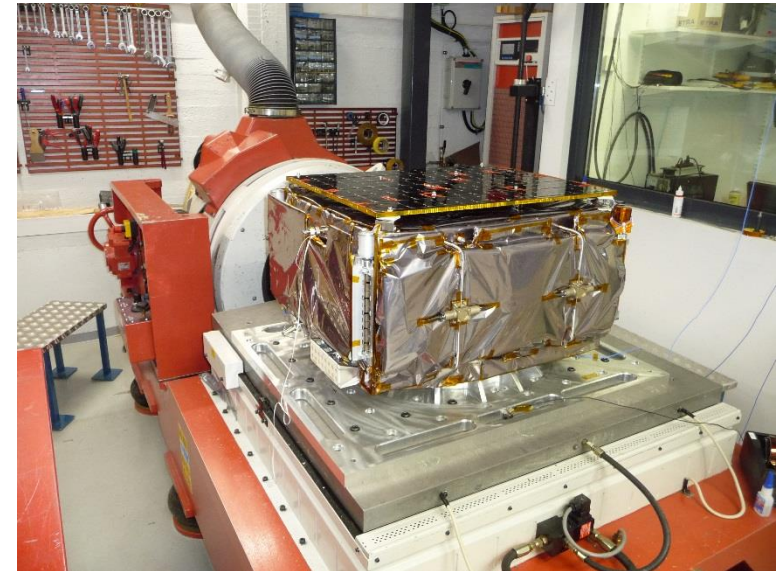
Rosetta (PL-PDU),
thermal test, vibration
tests and shock test



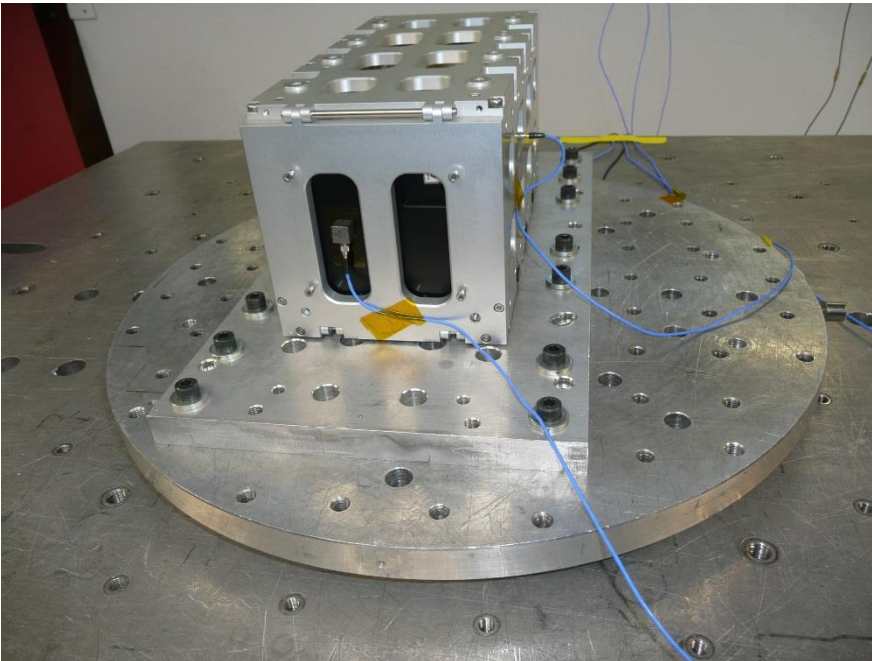
Aalto-1, FM



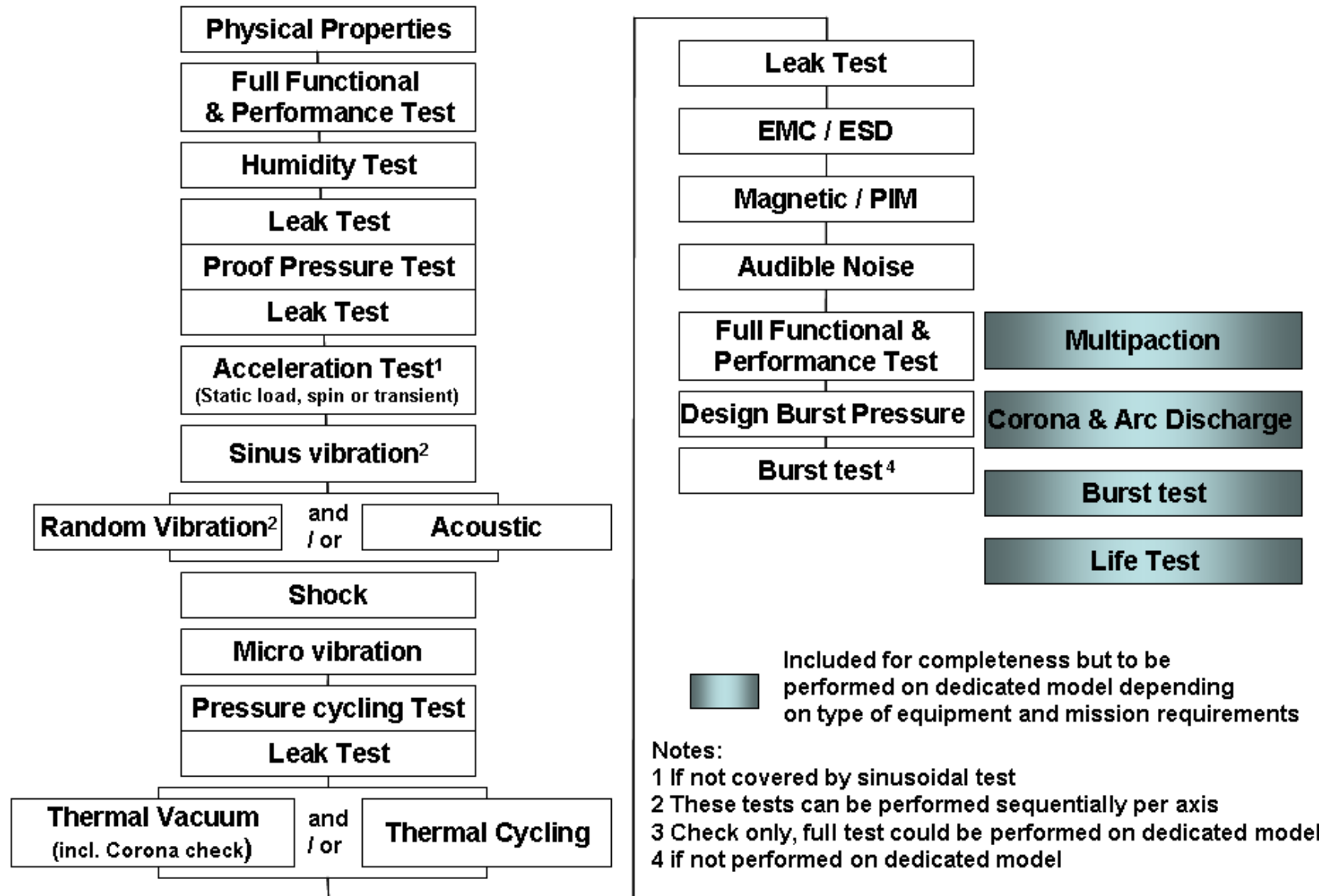
ICEY



Hello World, CubeSat



Space equipment test sequence,



VTT Expert Services Ltd, Mechanical Testing

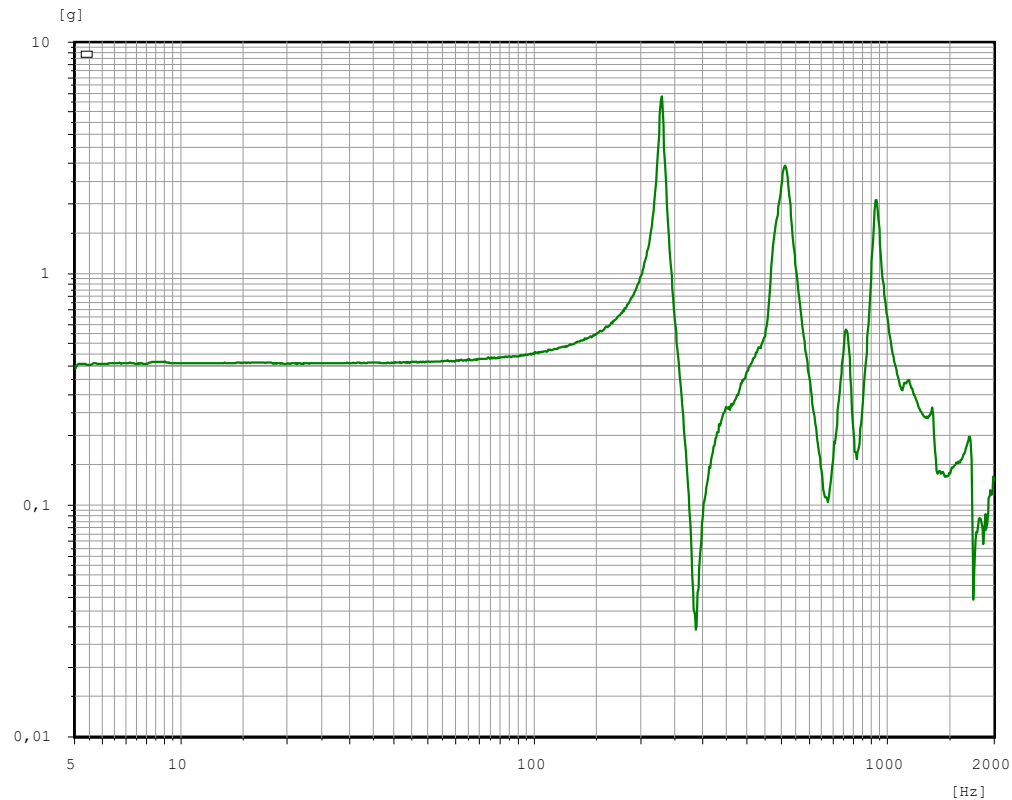
- General requirements for mechanical tests
 - The equipment is mounted to a test fixture through its normal mounting points
 - The stiffness of the test fixture
 - Tests will be carried out three perpendicular axes (x, y , z)
 - Cleanliness requirements
 - Operational equipment if powered during launch
- Acceleration test
 - Static load
 - Test is used to verify uniform force distribution on the space equipment
 - Test is normally carried out with centrifuge, but can be covered by sine test on the shaker
 - High velocity and large displacement

Low level sinusoidal sweep test

- The test is used to evaluate the space equipment integrity, a resonance search shall be performed before and after the random vibration test and sinusoidal vibration test
- Criterias for the resonance search:
 - Less than 5 % shift in frequency
 - Less than 10 % shift in amplitude
- Normally one sweep from 5 Hz to 2000 Hz with an acceleration 5 m/s²

Sine

Akku Zaxis



Chan.no: 5
 Chan.type: M Filtered
 Sweep type: logarithmic
 Sweeps done: 1
 Sweeps req.: 1
 Sweep direct.: up
 Sweep rate: 2,00 Oct/min
 Contr.strat.: Average
 Unit: g
 Peak (act.): 5,865 g
 Peak (req.): 0,4
 Contr.strat.: Closed loop

-- Testing time --

elapsed: 000:04:18
 remaining: 000:00:00

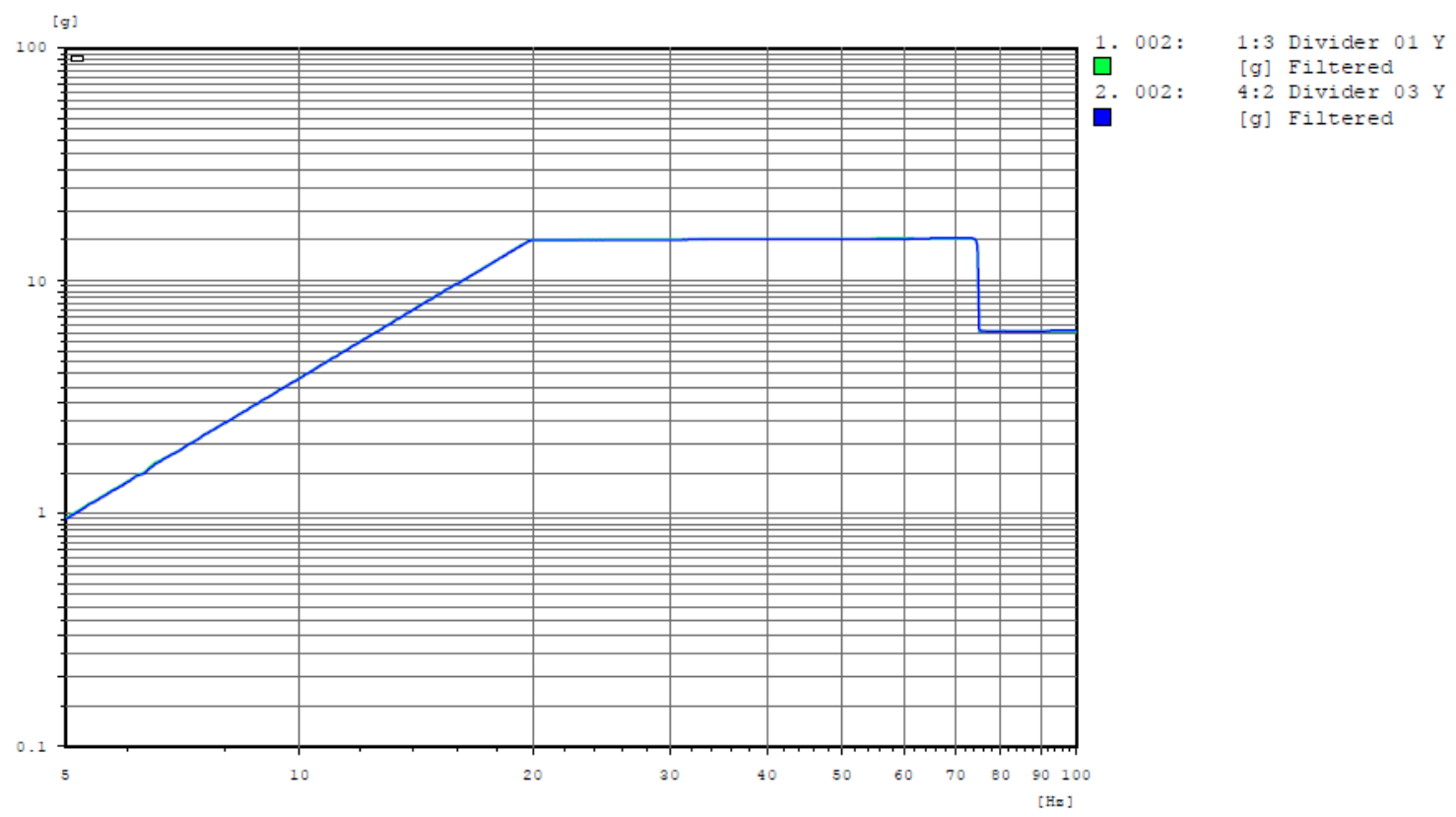
Date: 02-26-16
 Time: 12:30:05

Sinusoidal vibration

- Continuous sinusoidal sweep cycle (up and down)
- Example of test requirements:
 - Frequency range 5...100 Hz
 - Amplitude $\pm 9,3\text{mm}$, 5...20 Hz
 - Constant peak acceleration 15 g_n , 20...75 Hz
 - Constant peak acceleration 6 g_n , 75...100 Hz
 - One sweep up and one sweep down
 - Sweep rate 2 oct/min (Qualification level)
 - Sweep rate 4 oct/min (Acceptance level for flight model)

Sine

m+p



Random vibration test

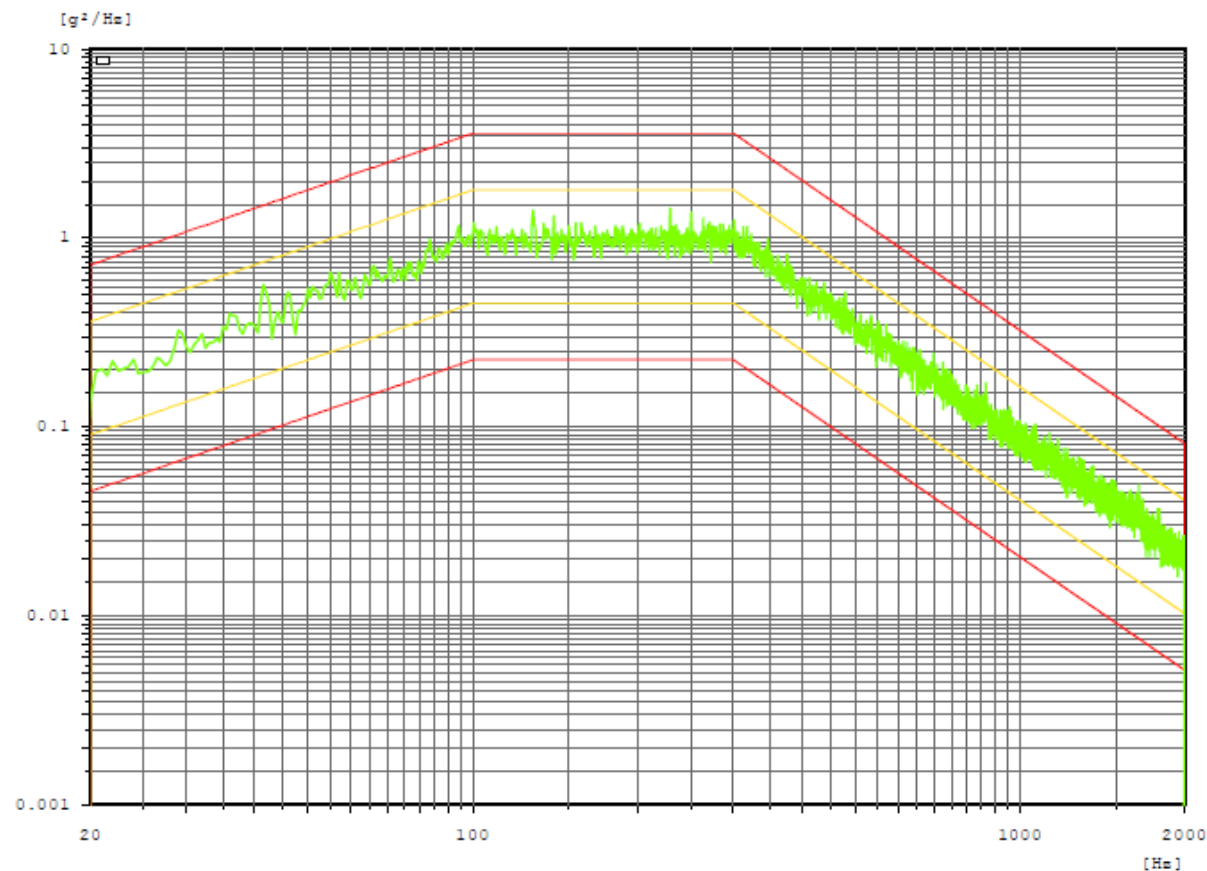
- Random vibration is simulating very strong vibration stress affecting during the launch of space craft
- Normally in the qualification level the test duration is 2 min and for the flight models the test duration is 1 min
- One example of test parameters:

Axis	Frequency (Hz)	PSD	Total spectral acceleration
Out of plane (Z)	20 - 100	+3 dB / Oct	31,76 g _{rms}
	100 - 300	2 g ² /Hz	
	300 - 2000	-6 dB / Oct	
In plane (X, Y)	20 - 100	+3 dB / Oct	21,3 g _{rms}
	100 - 300	0,9 g ² /Hz	
	300 - 2000	-6 dB / Oct	

Random

Control channel

mp



Chan. type: X
 DOF: 240
 Level: 0,0 dB
 Resolution: 0,5 Hz
 Contr. strat.: Average
 Unit: g²/Hz
 RMS (curr.): 22,19 g
 RMS (ref.): 21,3 g
 Contr. strat.: Closed loop

-- Time on curr. level --
 elapsed: 000:02:00
 remaining: 000:00:00

-- Time total --
 elapsed: 000:02:20
 remaining: 000:00:00

Date: 12-07-16
 Time: 12:03:02

Shock test

- The shock tests demonstrate the ability of the space equipment to withstand the shocks encountered during the lifetime, e.g.: fairing separation, space equipment separation, booster burn out, apogee boost motor ignition, solar arrays and antennas deployment, shocks from landing of reusable elements
- The test requirements are normally based on the measured or analyzed shock levels on the mounting structure of the equipment
- The shock level is specified in shock response curve

Characteristic		Qualification	Acceptance	Proto-flight
Test		Not required	Analysis required	Analysis required
Directions	{BRF}		X, Y, Z	X, Y, Z
Profile	Frequency [Hz]		Amplitude [g]	Amplitude [g]
	20		30	30
	2000		1000	1000
	10000		1000	1000
# of shocks			- [/axis]	- [/axis]

Shock test carried out
with ringing plate

gn
490.00000

Jigietureuna(t): 0.1000, -0.3358

Time pulse

Shock response
(SRS)

gn
3000.00

Jigietureuna_MaxSRS(f): 594.6394, 343.4002

Other mechanical tests

- Acoustic test
 - Acoustic tests are often but not always conducted on space equipment with large surfaces, which are likely to be susceptible to acoustic noise excitations, e.g. solar arrays, antennas
 - In that case random vibration testing is not performed
- Micro vibration tests
 - The equipment will be in its nominal operational configuration similar to the on-orbit operational conditions

Mechanical testing services in VTT Expert services Ltd.

Electrodynamic shakers

	LDS V875	LDS V964
Max. force, sine/random	40 kN/40 kN	80 kN/80 kN
Frequency range	5...2000 Hz	5...2000 Hz
Max.acceleration, sine	1000 m/s ²	1000 m/s ²
Max. velocity	1,8 m/s	2,0 m/s
Max. displacement	50 mm	25 mm
Test tables	Max. load 600 kg	Max. load 4000 kg
- Vertical direction	Expanders Ø 810 mm and Ø 500 mm Table 910 mm x 910 mm	Expander Ø 810 mm Tables 1370 mm x 760 mm and 1685 mm x 1125 mm
- Horizontal direction	Slip table 1050 mm x 1050 mm	Slip tables; 1000 mm x 1000 mm and 1000 mm x 3000 mm
Control systems	m+p International Vib Control	m+p International Vib Control
	12 input channels	16 input channels
	Sinusoidal vibration	Sinusoidal vibration
	Sine dwell	Sine dwell
	Random vibration	Random vibration
	Shock impulses	Shock impulses
	Shock responses	Shock responses
	RoR-testaus	RoR-testaus
	Time history measurements and analysis	Time history measurements and analysis

Shock table Ringing plate

- Max. load 20 kg
- Falling hammer and pendulum hammer
- Shock response measurements with Dactron Laser USB

Bibliography

- ECSS-E-ST-10-03C, Space engineering, Testing, 2012.
- Environment levels, ISILaunch09, Auxiliary payloads
- VTT Tiedotteita 1781, Ympäristötestaus, Space 2000, 1996



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