Space structures

8. Verification by test and quality assurance

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GROUND TESTING

Verification Logic

The spacecraft authority shall demonstrate that the spacecraft structure and equipments are capable of withstanding the maximum expected launch vehicle ground and flight environments.

S/C development approach	Model	Static	Sine vibration	Acoustic	Shock
With Structural Test Model (STM)	STM	Qual test	Qual test	Qual test	Shock test characterization and analysis
	FM1	By heritage from STM *	Protoflight test	Protoflight test	Shock test characterization and analysis or by heritage*
	Subsequent FM's	By heritage from STM *	Acceptance test (optional)	Acceptance test	By heritage* and analysis
With ProtoFlight Model	PFM = FM1	Qual test or by heritage *	Protoflight test	Protofligt test	Shock test characterization and analysis or by heritage*
	Subsequent FM's	By heritage *	Acceptance test (optional)	Acceptance test	By heritage* and analysis

* If qualification is claimed "by heritage" , the representativeness of the structural test model (STM) with respect to the actual flight unit must be demonstrated.

Table 4.3.1.a – Spacecraft verification logic for structural tests

The spacecraft compatibility must be proven by means of adequate tests.

The verification logic with respect to the satellite development program approach is shown in table 4.3.1.a.

Ground testing is supposed to envelop mission environment, with margins.

From ARIANE 5 user manual

GROUND TESTING (2)

S/C tests	Qualification		Protoflight		Acceptance	
	Factors	Duration/Rate	Factors	Duration/Rate	Factors	Duration/Rate
Static (QSL)	1,25 ultimate 1,1 yield	N/A	1,25 ultimate 1,1 yield	N/A	N/A	N/A
Sine vibrations	1,25	2 oct/min	1,25	4 oct/min	1.0	4 oct/min
Acoustics	1.41 (or +3 dB)	120 s	1.41 (or +3 dB)	60 s	1.0	60 s
Shock	1.41 (or +3 dB)	N/A	1.41 (or +3 dB)	N/A	N/A	N/A

Table 4.3.2.a - Test factors, rate and duration

From ARIANE 5 user manual

SINUSOIDAL VIBRATION TEST

The objective of the sine vibration tests is to verify the spacecraft structure dimensioning under the flight limit loads multiplied by the appropriate safety factors. The spacecraft qualification test consists of one sweep through the specified frequency range and along each axis.

Flight limit amplitudes are specified by the launcher user manual and are applied successively on each axis. The tolerance on sine amplitude applied during the test is usually ± 10%.

A notching procedure may be agreed - on the basis of previous analyses conducted the coupled dynamic behaviour of the launcher and its satellite(s) - to prevent excessive loading of the spacecraft structure or equipment. However, it must not jeopardize the tests objective to demonstrate positive margins of safety with respect to the flight loads.

Sweep rates may be increased on a case-by-case basis depending on the actual damping of the spacecraft structure. This is done while maintaining the objective of the sine vibration tests.

SINUSOIDAL VIBRATION TEST

Sine	Frequency range (Hz)	Qualification levels (0-peak)	Acceptance levels (0-peak)
Longitudinal	4-5 5-100	12.4 mm 1.25 g	9.9 mm 1 g
Lateral	2-5 5-25 25-100	9.9 mm 1 g 0.8 g	8.0 mm 0.8 g 0.6 g
Sweep rate		2 oct./min	4 oct./min

Table 4.3.3.a – Sinusoidal vibration tests levels

From ARIANE 5 user manual

ACOUSTIC VIBRATION TEST

Acoustic testing is accomplished in a reverberant chamber applying the flight limit spectrum provided in chapter 3 and increased by the appropriate safety factors. The volume of the chamber with respect to that of the spacecraft shall be sufficient so that the applied acoustic field is diffuse. The test measurements shall be performed at a minimum distance of 1 m from spacecraft.

Octave band centre frequency (Hz)	Qualification Level	Acceptance level (flight)	Test tolerance
	ref: 0 dB = 2×10^{-5} pascal		
31.5	131	128	-2, +4
63	134	131	-1, +3
125	139	136	-1, +3
250	138	135	-1, +3
500	135	132	-1, +3
1000	129	126	-1, +3
2000	123	120	-1, +3
Overall level	143.5	140.5	-1, +3
Test duration	2 minutes	1 minute	

Table 4.3.3.3.a – Acoustic vibration test levels

From ARIANE 5 user manual

SHOCK QUALIFICATION (1)

The demonstration of the spacecraft ability to withstand this shock shall be made through a test and analytic demonstration performed in two steps:

• A shock test characterization (generating a shock at the interface), during which interface levels and equipments base levels are measured. This test can be performed on the STM, PFM or on the first flight model, provided that the spacecraft configuration is representative of the flight model (structure, load paths, equipment presence and location,…). This test can be performed once, and the verification performed covers the spacecraft platform as far as no structural modification alters the validity of the analysis.

From ARIANE 5 user manual

SHOCK QUALIFICATION

• An analytic demonstration of the qualification of the equipment. This is obtained by comparing the component unit qualification levels to the equipment base levels experienced applying the interface shock specified in chapter 3 for the L/V shock events and in the annexes for the S/C separation itself, with the addition of a qualification margin of 3 dB, and with the transfer functions defined during the shock characterization test. This demonstration could be made by using equivalent rules on other environment qualification test (i.e. random or sine).

On top of standard clampband release tests, a SHOck Generation UNit (SHOGUN), generating a shock more representative to the one that occurs in flight, can be provided by Arianespace. This system allows to reduce the uncertainties margins taken into consideration for the shock compatibility analytic demonstration.

From ARIANE 5 user manual

PRODUCT ASSURANCE (ECSS 4.11)

General

Product assurance shall be based on the creation and implementation of an effective programme of quality control, inspection and surveillance.

Model traceability

Traceability of CAD, CAE, CAM and finite element models, and the relationship between each other shall be ensured.

CONCLUDING REMARKS

Interaction with analysis and design

Typical qualification and acceptance test

Product assurance