



National Aeronautics and Space
Administration
Jet Propulsion Laboratory
California Institute of Technology

2nd International Workshop on Verification and Testing of Space Systems



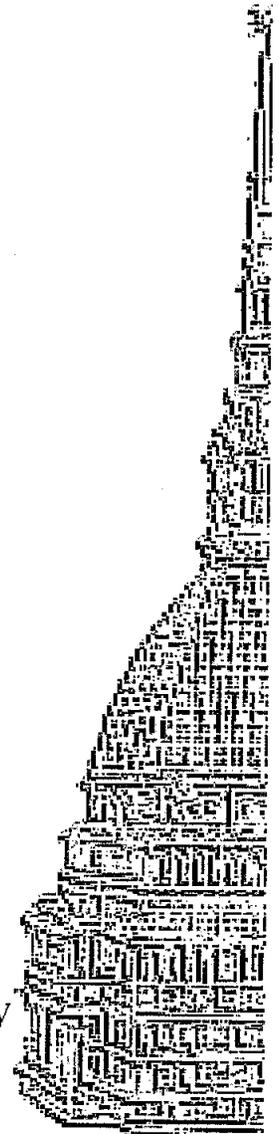
Session 1/3 Verification and Testing Standards

Title Comparison of JPL and European Environmental Testing Standards

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Agenda

- **JPL Environmental Testing Documents**
- **European Environmental Testing Document**
- **Comparison of JPL and European Environmental Testing Standards**
 - **Test Policy**
 - **Documentation**
 - **Programmatics**
 - **Functional Testing**
 - **Reporting**
 - **Test Levels, Durations, and Margins (Dynamics, Thermal, EMC)**
- **Summary and Conclusions**



JPL Environmental Testing Documents

1. **Flight Project Practices Rev. 5**
 - Captures the approaches and methods for a standardized execution of flight projects.
2. **Design Principles, Rev. 2**
 - Captures the institutional standards for designing, verifying, and operating flight systems.
3. **Spacecraft System Dynamic and Static Testing, Rev. 0**
 - Specifies the standards and parameters for spacecraft-level dynamic and static testing.
4. **Spacecraft System Thermal Testing, Rev. 1**
 - Specifies the standards and parameters for spacecraft-level thermal testing.
5. **Assembly and Subsystem Level Environmental Verification, Rev. 0**
 - Specifies the standards and parameters for assembly and subsystem level environmental testing and verification.



European Environmental Testing Document

CEN TC

prEN CST02073

CEN TC

Secretariat:

Space engineering — Testing

Einführendes Element — Haupt-Element
Élément introductif — Élément central

ICS:

Descriptors:

Document type: European Standard
Document subtype:
Document stage: Unique Acceptance Procedure
Document language: E

EN 14824:2003 (E)

- **Space Engineering - Testing (EN 14824:2003)**
 - Specifies the standard environmental and performance test requirements for a space system and its constituents.
 - Document reviewed and approved by ECSS (European Cooperation for Space Standardization), which is a cooperative effort of the European Space Agency, National Space Agencies, and European industry associations for the purpose of developing and maintaining common standards.



Focus of the Comparison

- **Compare environmental testing standards in these 2 documents:**
 1. **Assembly and Subsystem Level Environmental Verification, Rev. 0**
 2. **Space Engineering - Testing (EN 14824:2003)**
- **Compare environmental testing for flight hardware**
 - **Functional testing is also addressed**
- **Compare assembly (or equipment) level testing**
 - **Environmental testing of spacecraft tends to be more mission specific**
- **Compare Qual and FA**
 - **Protoflight is a subset of Qual/FA (in general Qual levels and FA durations)**
- **Highlight significant similarities and differences between JPL and European standards**



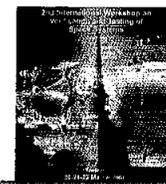
Test Policy

Paragraph #	Assembly and Subsystem Level Environmental Verification (JPL)	Paragraph #	Space Engineering - Testing (European)
4	Testing in lieu of analysis shall be used	4.1.1 g	Testing is the preferred verification method
4	Environmental verification requirements shall be approved before environmental verification is performed	4.11.1	Test standard documentation shall consist of the test specification, test procedure; and test report to be generated as part of the verification documentation.
4.1	Appropriate margin shall be applied during environmental testing.	4.8.1.1a	Margins to both test levels and duration should be applied to the environmental tests.



Documentation

Paragraph #	Assembly and Subsystem Level Environmental Verification (JPL)	Paragraph #	Space Engineering - Testing (European)
4.2	The Environmental Program for a project shall be documented in project-approved and released documents.	4.1.2a	All equipment product specifications shall indicate their intended verification method for each stated requirement.....
4.2	The Environmental Program documentation shall specify the environmental Test and Analysis Matrix (TAM) that apply to each assembly.	4.1.2b	A dedicated test matrix shall be prepared defining the detailed types of tests to be implemented.
4.4.4	Environmental tests of flight hardware shall be performed in accordance with approved environmental test plans and procedures.	4.11.2.2	The test specification shall be prepared for each major test activity described in the test plan
		4.11.3	The test procedure shall be written in conformance with the test specification.



Programmatics (1)

Paragraph #	Assembly and Subsystem Level Environmental Verification (JPL)	Paragraph #	Space Engineering - Testing (European)
4.4.1	<p>Assembly design and performance shall be verified by test using the following verification programs:</p> <p>a) Protoflight; or</p> <p>b) Qualification/Flight Acceptance (FA)</p>	4.2	<p>The test baseline definition shall be based on the project model philosophy:</p> <p>a) Prototype approach</p> <p>b) Protoflight approach</p> <p>c) Hybrid approach</p>
4.4.5	<p>The Qual test for an assembly design shall be completed before FA tests.</p>	4.1.5	<p>Qualification testing should be completed prior to the initiation of the flight item manufacturing.</p>
4.4.5	<p>It is preferable to perform EMC testing prior to dynamics or thermal testing.</p> <p>It is preferable to perform dynamics testing before thermal testing.</p>	4.1.2e	<p>The determination of test sequences should be based on two main considerations:</p> <ol style="list-style-type: none"> 1. preserve the order in which environments are encountered during the operational life; and 2. detect potential failures and defects as early in the test sequence as possible.



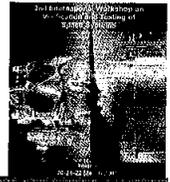
Programmatics (2)

Paragraph #	Assembly and Subsystem Level Environmental Verification (JPL)	Paragraph #	Space Engineering - Testing (European)
4.4.3	Test articles shall be tested in flight configuration, including electrical cabling, connectors, and other flight fittings associated with the test article.	4.4.6	The complete flight element (i.e. flight vehicle) should be used during environmental testing
4.4.4	All tests shall be performed in an approved test facility using properly calibrated instrumentation and trained test personnel	4.1.2 d3	The test plan shall specify the test facilities.
		4.8.2.2a	The accuracy of instruments used to control or monitor the test parameters shall be verified periodically
		4.8.2.2b	The accuracy of the instruments shall be consistent with the tolerance for the variable to be measured
		4.8.2.2c	All instrumentation to be used for testing shall be subjected to approved calibration procedures and shall be within the normal calibration period at the time of the test.



Programmatics (3)

Paragraph #	Assembly and Subsystem Level Environmental Verification (JPL)	Paragraph #	Space Engineering - Testing (European)
4.4.7	When a failure or malfunction occurs during environmental testing, a P/FR (Problem/Failure Report) shall be generated	4.7.2a	The failure or anomalies occurred during the testing activities, shall be recorded on a non-conformance report (NCR)
4.4.10	Environmental retests are performed: 1) To complete the testing of h/w that has failed during environmental test. 2) To re-qualify flight hardware design where design changes, modifications, or configuration changes occur after completion of initial qual testing. 3) To verify the flight worthiness of refurbished units as flight spares. 4) To verify the flight acceptability of workmanship performed as part of the rework not covered by (1), (2), or (3) above.	4.7.1b	There are five situations, which can result in a retest: 1) Failure or anomaly during qualification, acceptance or protoflight testing 2) Implementation of a design modification after completion of qualification testing 3) Long duration storage of flight hardware after acceptance testing 4) Hardware to be re-flown 5) Flight use of qualification hardware



Functional Testing

Paragraph #	Assembly and Subsystem Level Environmental Verification (JPL)	Paragraph #	Space Engineering - Testing (European)
4.4.6	Required functional testing shall be defined in a functional test procedure.	4.11.3e	The test procedure shall be written in conformance with the test specification and specify the Step-by-step instructions for operation.
4.4.6	Functional testing shall be performed before, during, and after each environmental test	5.1.3.1f	Functional and performance tests shall be performed prior and following environmental tests.
		5.1.3.1h	Equipment functional tests shall be performed while the environment is being imposed, if the equipment is expected to be (fully) operational under that environment.
4.4.6	The test article shall perform within its functional tolerances and identifiable limits without any adjustments that are not possible during flight.	4.4.3	The qualification test levels shall exceed the maximum predicted levels by a factor of safety which assures that, even with the worst combination of test tolerances, the flight levels shall not exceed the qualification test levels.



Reporting

Paragraph #	Assembly and Subsystem Level Environmental Verification (JPL)	Paragraph #	Space Engineering - Testing (European)
4.4.11	Upon completion of each environmental test, the test reporting section of the ETAS is updated This is irrespective of whether or not the test has been satisfactorily completed.	4.10a	For an evaluation of the product performance under the various specified test conditions, test measurements and the environmental conditions on the products shall be recorded.
		4.11.1a3	Test standard documentation shall consist of the test report.

ETAS = Environmental Test Authorization & Summary



Dynamics Test Levels, Durations, & Margins

Dynamics Test	JPL		European (EN 14824:2003)	
	Qualification (Qual)	Flight Acceptance (FA)	Qualification (Qual)	Flight Acceptance (FA)
Acoustics: Level Duration	MEFL + 3 dB 2 min	MEFL 1 min	MEFL + 4 dB 2 min	MEFL 2 min
Random Vibration: Level Duration	MEFL + 3 dB 2 min/axis	MEFL 1 min/axis	MEFL + 4 dB 2.5 min/axis	MEFL 2 min/axis
Sine Vibration: Level Duration	Mission-specific	---	MEFL + 4 dB 2 Octave/min 1 sweep up & down (5-100Hz)	---
Pyro Shock: Level Duration	MEFL + 3 dB 2 shocks/axis	---	MEFL + 6 dB 3 shocks/axis	MEFL 1 shock/axis

MEFL = Maximum Expected Flight Level

--- = Test not required



Thermal Test Levels, Durations, & Margins

Thermal Test	JPL		European (EN 14824:2003)	
	Qualification (Qual)	Flight Acceptance (FA)	Qualification (Qual)	Flight Acceptance (FA)
Temperature: Margin Level	The more severe of: AFT -15 C to AFT+20 C or -35 to +75 C (Electronics)	The more severe of: AFT -5 C to AFT+5 C or -25 to +55 C (Electronics)	Max Predicted +10 C, Min Predicted -10 C Hardware dependent	Max Predicted +5 C, Min Predicted -5 C Hardware dependent
Thermal Cycles:	2-10 (max)	2-10 (max)	8	4
Operational Dwell: Electronics Non-electronics	24 hr cold/ 144 hr hot 24 hr cold/ 24 hr hot	8 hr cold/ 60 hr hot 24 hr cold/ 24 hr hot	16 hr cold/ 16 hr hot (2 hr /cycle)	8 hr cold / 8 hr hot (2 hr /cycle)
Non-Op. Dwell: (Electronics and non-electronics)	8 hr cold/ 8 hr hot	8 hr cold/ 8 hr hot	2 hr cold/ 2 hr hot (1cycle only)	2 hr cold/ 2 hr hot (1cycle only)
Temp Ramp Rate (dT/dt):	≤ 5 C/min	≤ 5 C/min	< 20 C/min	< 20 C/min

AFT = Allowable Flight Temperature



EMC Test Levels, Durations, & Margins

EMC Test	JPL		European (EN 14824:2003)	
	Qualification (Qual)	Flight Acceptance (FA)	Qualification (Qual)	Flight Acceptance (FA)
Susceptibility: (Radiated and Conducted)	MEFL + 6 dB	--- (grounding/isolation)	+ 6 dB	---
Emission: (Radiated and Conducted)	MinEFL - 6 dB	--- (grounding/isolation)	- 6 dB	---
Durations:	Operate sufficiently to exercise all operational modes	Operate sufficiently to exercise all operational modes	Depending on operating modes	Depending on operating modes

MEFL = Maximum Expected Flight Level
MinEFL = Minimum Expected Flight Level



Summary and Conclusions

- **Compared the JPL and European Environmental testing standards**
- **Similarities in all categories**
- **Main Differences:**
 - **Dynamic test levels, durations, and margins (European higher)**
 - **Sine test (required for European, mission-specific for JPL)**
 - **Thermal test margins, cycles, and durations (JPL requires more dwell time and fewer cycles)**
- **Would be advantageous to develop a US-European Environmental Testing Standard for Space Systems**
- **And eventually develop an environmental standard involving other space organizations (Japan, China, Russia, & others)**