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Essais;
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Nationales Vorwort

Die *European Cooperation for Space Standardization (ECSS)*, eine Einrichtung zur Erstellung eines kohärenten, einheitlichen Normenwerkes zur Anwendung in allen europäischen Raumfahrtprojekten, hat am 1996-11-13 vom *Europäischen Komitee für Normung (CEN)* das Mandat (M/237) erhalten, für den CEN-Subsector T02 „Aerospace“ Europäische Normen (EN) auszuarbeiten.

Aufgrund der zwischen ISO/TC 20/SC 14 „Raumfahrt“ und ECSS vereinbarten A-Liaison werden die Normungsprogramme dieser Partner abgestimmt und die Abstimmungsregeln gemäß Abschnitt 5.2 der Wiener-Vereinbarung angewendet.

Die vorliegende Norm EN 14824:2003 wurde von CEN/CS T02 auf Basis der ECSS-E-10-03 erarbeitet.

English version

Space engineering - Testing

Ingénierie spatiale - Essais

Raumfahrttechnik - Tests

This European Standard was approved by CEN on 1 October 2003.

CEN members are bound to comply with the CEN/CENELEC Internal Regulations which stipulate the conditions for giving this European Standard the status of a national standard without any alteration. Up-to-date lists and bibliographical references concerning such national standards may be obtained on application to the Management Centre or to any CEN member.

This European Standard exists in three official versions (English, French, German). A version in any other language made by translation under the responsibility of a CEN member into its own language and notified to the Management Centre has the same status as the official versions.

CEN members are the national standards bodies of Austria, Belgium, Czech Republic, Denmark, Finland, France, Germany, Greece, Hungary, Iceland, Ireland, Italy, Luxembourg, Malta, Netherlands, Norway, Portugal, Slovakia, Spain, Sweden, Switzerland and United Kingdom.



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Foreword

This document (EN 14824:2003) has been prepared by CMC.

This European Standard shall be given the status of a national standard, either by publication of an identical text or by endorsement, at the latest by June 2004, and conflicting national standards shall be withdrawn at the latest by June 2004.

In this European Standard the annexes A and B are informative and the annex C is normative.

It is based on a previous version¹⁾ originally prepared by the ECSS Space engineering testing Working Group, reviewed by the ECSS Technical Panel and approved by the ECSS Steering Board. The European Cooperation for Space Standardization (ECSS) 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.

This standard is one of the series of space standards intended to be applied together for the management, engineering and product assurance in space projects and applications.

Requirements in this standard are defined in terms of what shall be accomplished, rather than in terms of how to organize and perform the necessary work. This allows existing organizational structures and methods to be applied where they are effective, and for the structures and methods to evolve as necessary without rewriting the standards.

According to the CEN/CENELEC Internal Regulations, the national standards organizations of the following countries are bound to implement this European Standard: Austria, Belgium, Czech Republic, Denmark, Finland, France, Germany, Greece, Hungary, Iceland, Ireland, Italy, Luxembourg, Malta, Netherlands, Norway, Portugal, Slovakia, Spain, Sweden, Switzerland and the United Kingdom.

¹⁾ ECSS-E-10-03A

1 Scope

This European Standard;

- a) specifies standard environmental and performance test requirements for a space system and its constituents;
- b) specifies the test requirements for products and systems that are generally applicable to all projects;
- c) specifies the documentation associated with testing activities;
- d) is applicable to all types and combinations of project, organization and product;
- e) is applicable to space systems and its constituents; and
- f) covers each stage of verification by testing, for a space system from development to post-landing.

This European Standard does not specify acceptance criteria, specifications or procedures for any particular project or class of projects. In addition this standard does not apply to software testing, hardware below equipment levels, nor covers the following:

- sounding rockets;
- launch facilities;
- test facilities;
- training facilities and ground refurbishment;
- logistic facilities; and
- engine testing.

The requirements specified in this European Standard should be tailored to match the requirements of the particular profile and circumstances of a project.

NOTE Tailoring is a process by which individual requirements or specifications, standards and related documents are evaluated and made applicable to a specific project by selection, and in some exceptional cases, modification of existing or addition of new requirements.

2 Normative references

This European Standard incorporates by dated or undated reference, provisions from other publications. These normative references are cited at the appropriate places in the text, and the publications are listed hereafter. For dated references, subsequent amendments to or revisions of any of these publications apply to this European Standard only when incorporated in it by amendment or revision. For undated references the latest edition of the publication referred to applies (including amendments).

EN 13701:2001, *Space systems — Glossary of terms*.

3 Terms, definitions and abbreviated terms

3.1 Terms and definitions

For the purposes of this European Standard, the terms and definitions given in EN 13701:2001 and the following apply.

3.1.1 acceptance stage

verification stage with the objective of demonstrating that the product is free of workmanship defects and integration errors and ready for its intended use

3.1.2 airborne support equipment (ASE)

equipment installed in a recoverable launch vehicle to provide support functions and interfaces for the spacecraft during launch and orbital operations of the recoverable launch vehicle

NOTE ASE includes the hardware and software that provides the structural, electrical, electronic and mechanical interfaces with the launch vehicle. ASE is recovered with the launch vehicle.

3.1.3 burst pressure

maximum test pressure that pressurized equipment withstands without rupture to demonstrate the adequacy of the design in a qualification test

NOTE 1 Burst pressure is equal to the product of the maximum expected operating pressure, a burst pressure design factor, and a factor corresponding to the differences in material properties between test and design temperatures.

NOTE 2 An item subjected to a burst pressure test is not used for other purposes.

3.1.4 design environments

composite of the various environmental loads, to which the hardware is designed

NOTE Each of the design environments is based upon:

- maximum and minimum predicted environments during the operational life of the item;
- qualification margin that increases the environmental range to provide an acceptable level of confidence that a failure does not occur during the service life of the item;
- uncertainties and tolerances related to the analytical prediction.

3.1.5 environmental design margin

increase of the environmental extremes for the purpose of design and qualification above the levels expected during the life cycle

NOTE Environmental design margin includes levels such as mechanical, thermal, radiation as well as the time of exposure of them.

3.1.6 environmental test

simulation of the various constraints (together or separately) to which an item is subjected during its operational life cycle

NOTE Environmental tests cover natural and induced environments.

3.1.7**fundamental resonance (for structural modes)**

first major significant resonance's as observed during one-axis vibration test for each of the three test axes

NOTE 1 The term fundamental resonance is used in conjunction with notching of sinusoidal vibration input spectrum for item qualification.

NOTE 2 Significant resonances are modes that have an effective mass greater than 10 % of the total mass of the item.

3.1.8**in-orbit stage**

verification stage valid for projects whose characteristics (e.g. mission and in-orbit operations) require in-orbit verification

3.1.9**integrated system check**

sub-set of the integrated system test, able to involve all major functions, at the maximum extent automatically performed and with the scope to provide the criteria for judging successful survival of the element in a given test environment, with a high degree of confidence, in a relatively short time

NOTE Integrated system check is also known as "abbreviated functional test".

3.1.10**integrated system test**

test that has the scope to verify that the performance of the element meets the specification requirements, in terms of correct operation in all operational modes, including back-up modes and all foreseen transients

NOTE Integrated system test is also known as "system functional test".

3.1.11**limit load**

maximum anticipated load, or combination of loads, which a structure is expected to experience during the performance of specified missions in specified environments

NOTE Since the actual loads that are experienced in service are in part random in nature, statistical methods for predicting limit loads are generally employed.

3.1.12**low level sinusoidal vibration**

exposing an item to a frequency sweep of low level sinusoidal vibrations to show possible deficiencies in workmanship, as a consequence of another environment

NOTE Low level sinusoidal vibration test is also known as "signature test".

3.1.13**maximum and minimum predicted equipment temperatures**

highest and lowest temperatures that are expected to occur in flight on each equipment of the spacecraft during all operational and non-operational modes which include uncertainties

3.1.14**maximum predicted acceleration**

acceleration value determined from the combined effects of the quasi steady acceleration and the transient response of the vehicle to engine ignition, engine burnout and stage separation

NOTE Where the natural frequency of the equipment mount or mounting structure can couple with engine initiated transients, the maximum predicted acceleration level accounts for the possible dynamic amplification.

3.1.15**maximum predicted acoustic environment**

maximum value of the time average root-mean-square (r.m.s.) SPL (sound pressure level) in each frequency band occurring below payload fairing or within STS (space transportation system) orbiter cargo bay, which occurs during lift-off, powered flight or re-entry

NOTE The maximum predicted acoustic environment test spectrum is specified in octave or 1/3 octave bands over a frequency range of 31,5 Hz to 10 000 Hz. The duration of the maximum environment is the total period when the overall amplitude is within 6 dB of the maximum overall amplitude.

3.1.16

maximum predicted operating pressure

working pressure applied to equipment by the pressurizing system with the pressure regulators and relief valves at their upper operating limit, including the effects of temperature, transient peaks and vehicle acceleration

3.1.17

maximum predicted pyro shock environment

maximum absolute shock response spectrum determined by the response of a number of single degree of freedom systems using an acceleration amplification factor at the resonant frequency of lightly damped system ($Q = 10$)

NOTE 1 The shock response spectrum is determined at frequency intervals of one-sixth octave or less over a frequency range of 100 Hz to 4 000 Hz or more.

NOTE 2 The pyro shock environment imposed on the spacecraft equipment is due to structural response when the space or launch vehicle electro-explosive devices are activated. Resultant structural response accelerations have the form of superimposed complex decaying sinusoids that decay to a few percent of their maximum acceleration in 5 m/s to 15 m/s.

3.1.18

maximum predicted random vibration environment

random vibration environment imposed on the spacecraft, subsystems and equipment due to the lift-off acoustic field, aerodynamic excitations, and transmitted structure-borne vibration

NOTE 1 A different spectrum can exist for different equipment zones or for different axis. The equipment vibration levels are based on vibration response measurements made at the equipment attachment points during ground acoustic tests or during flight. The duration of the maximum environment is the total period during flight when the overall level is within 6 dB of the maximum overall level.

NOTE 2 The power spectral density is based on a frequency resolution of 1/6 octave (or narrower) bandwidth analysis, over a frequency range of 20 Hz to 2 000 Hz.

3.1.19

maximum predicted sinusoidal vibration environment

predicted environment imposed on the spacecraft, subsystems and equipment due to sinusoidal and narrow band random forcing functions within the launch vehicle or spacecraft during flight or from ground transportation and handling

NOTE 1 In flight, sinusoidal excitations are caused by unstable combustion, by coupling of structural resonant frequencies (POGO), or by imbalances in rotating equipment in the launch vehicle or spacecraft. Sinusoidal excitations occur also during ground transportation and handling due to resonant responses of tires and suspension systems of the transporter.

NOTE 2 The maximum predicted sinusoidal vibration environment is specified over a frequency range of 5 Hz to 100 Hz for flight excitation.

3.1.20

model philosophy

definition of the optimum number and characteristics of physical models to achieve a high confidence in the product verification with the shortest planning and a suitable weighing of costs and risks

3.1.21

moving mechanical assemblies

mechanical or electromechanical devices that control the movement of one mechanical part of a spacecraft relative to another part

NOTE Moving mechanical assemblies include:

deployment mechanisms, pointing mechanisms, drive mechanisms, design mechanisms and the actuators, motors, linkages, latches, clutches, springs, cams, dampers, booms, gimbals, gears, bearings and instrumentation that are an integral part of these mechanical assemblies (e.g. recorders).

3.1.22

multipacting

resonant back and forth flow of secondary electrons in a vacuum between two surfaces separated by a distance such that the electron transit time is an odd integral multiple of one half the period of the alternating voltage impressed on the surface

NOTE 1 Multipacting does not occur unless an electron impacts one surface to initiate the action, and a secondary emission of one or more electrons at each surface to sustain the action takes place.

NOTE 2 Multipacting is an unstable self-extinguishing action which occurs at pressures less than $6,65 \times 10^{-2}$ hPa, however, it becomes stable at a pressure less than $1,33 \times 10^{-3}$ hPa.

NOTE 3 The pitting action resulting from the secondary emission of electrons degrades the impacted surfaces. The secondary electron emission can also increase the pressure in the vicinity of the surfaces causing ionization (corona) breakdown to occur.

NOTE 4 These effects can cause degradation of performance or permanent failure of the radio frequency cavities, wave guides or other devices involved.

3.1.23

notching of sinusoidal vibration input spectrum

notching of the shaker input spectrum to limit structural responses at resonant frequencies according to qualification or acceptance loads

NOTE Notching of sinusoidal vibration input spectrum is a general accepted practise in vibration testing.

3.1.24

operational modes

combination of operational configurations or conditions that can occur during the service life for equipment or spacecraft

EXAMPLE Power-on or power-off, command modes, readout modes, attitude control modes, antenna stowed or deployed, and spinning or de-spun.

3.1.25

post-landing stage

verification stage valid for projects where characteristics for post-landing verification is performed (e.g. multimission projects)

3.1.26

pre-launch stage

verification stage with the objective to verify that the flight article is properly configured for launch and capable to function as planned for launch

3.1.27

proof pressure

test pressure for pressurized equipment to sustain without detrimental deformation

NOTE 1 The proof pressure is used to give evidence of satisfactory workmanship and material quality, or to establish maximum possible flaw size.

NOTE 2 The proof pressure is equal to the product of maximum predicted operating pressure (see 3.1.16), proof pressure design factor, and a factor accounting for the difference in material properties between test and design temperature.

3.1.28

qualification stage

verification stage with the objective to demonstrate that the design conforms to the requirements including margins

3.1.29

service life

total life expectancy of an item, equipment or space vehicle

NOTE The service life starts at the completion of assembly of the item and continues through all acceptance testing, handling, storage, transportation, launch operations, orbital operations, refurbishment, retesting, re-entry or recovery from orbit, and reuse if applicable.

3.1.30

space element

product or set of products intended to be operated in outer space

NOTE 1 In order to avoid repetition in the level of decomposition of the space product, the term element is used to define "systems within the system". The term element is used to identify any system within the space system.

NOTE 2 Elements that operate entirely in space or on the ground are referred to as "Space segment" and "Ground Segment" respectively.

3.1.31

space vehicle

integrated set of subsystems and equipment capable of supporting an operational role in space

NOTE A space vehicle can be an orbiting vehicle, a major portion of an orbiting vehicle, or a payload that performs its mission while attached to a launch or upper-stage vehicle. The ground support equipment is considered to be a part of the space vehicle.

3.1.32

stabilized test temperature

specified temperature for equipment and subsystem tests that has been achieved and has not changed by more than 1 °C during the previous one-hour period

NOTE During system level tests, performance verification testing can be started when the rate of change is below 1 °C within a time period equal or near the time constant of the spacecraft.

3.1.33

temperature reference, reference point

physical point located on the equipment providing a simplified representation of the equipment thermal status

NOTE 1 Depending upon the equipment dimensions, more than one temperature reference can be defined.

NOTE 2 The temperature of the reference point is measured by temperature sensors during test. The temperature distribution within the equipment and hot spots on the external casing due to point heat sources are not used as reference points.

3.1.34

ultimate load

maximum static load to which a structure is designed

NOTE Ultimate load is obtained by multiplying the limit load by the ultimate factor of safety.

3.2 Abbreviated terms

For the purposes of this European Standard the following abbreviated terms apply.

Abbreviation	Meaning
ABCL	as-built configuration list
ABM	apogee boost motor
AFT	abbreviated functional test
AOCS	attitude and orbit control system

APTC	ambient pressure temperature cycling
ASE	airborne support equipment
ATC	accelerate thermal cycling
AVM	anti vibration mounts
AVT	acceptance vibration test
BAPTA	bearing and power transfer assembly
CCB	configuration control board
CIDL	configuration item data list
CoG	centre of gravity
DRD	document requirements definition
ECLS	environmental control and life support
EGSE	electrical ground support equipment
EMC	electromagnetic compatibility
EQM	engineering qualification model
ESD	electrostatic discharge
ESSEH	environmental stress screening of electronic hardware
FM	flight model
FOP	flight operations plan
GSE	ground support equipment
HFE	human factors engineering
hi-rel	high reliability
ISC	integrated system check
ISST	integrated subsystem test
IST	integrated system test
LCDA	launcher coupled dynamic analysis
LEO	low Earth orbit
LEOP	launch and early orbit phase
LV	launch vehicle
M	mass
MEC	microgravity environmental compatibility
MIL (spec)	specification of the US Department of Defence

MLI	multi-layer insulation
Mol	moment of inertia
NCR	nonconformance report
NDIU	network data interface unit
NRB	nonconformance review board
PFM	protoflight model
PSD	power spectral density
PTC	passive thermal control
POGO	propulsion generated oscillations
QAVT	qualification vibration test
QM	qualification model
r.m.s.	root-mean-square
RSS	root-sum-square
RF	radio frequency
SADM	solar array drive mechanism
SFT	system functional test
SPL	sound pressure level
STM	structural-thermal model
STS	space transportation system
TC	telecommand
TCL	test configuration list
TCS	thermal control subsystem
TM	telemetry
TMM	thermal mathematical model
TT&C	telemetry, tracking and command
TWT	travelling wave tube
TWTA	travelling wave tube amplifier
VTC	vacuum temperature cycling

4 General requirements

4.1 Testing philosophy

4.1.1 Test programmes are an essential part of the overall verification to ensure that the product achieves all the design, performance and quality requirements.

4.1.2 Test planning, test requirements, and test criteria shall be derived from the design requirements.

NOTE The design requirements indicate the expected performance of the test item as well as the conditions under which it operates.

- a) To facilitate this process, all system, element, subsystem, and equipment product specifications shall indicate their intended verification method (test, analysis, review of design, or inspection) and level for each stated requirement (verification matrix);
- b) Starting from the verification matrix, a dedicated test matrix shall be prepared defining the detailed types of tests to be implemented;
- c) Based on the test requirements as above documented, a test plan shall be established as part of the overall verification plan;
- d) The test plan shall:
 - 1) describe and sequence all the tests;
 - 2) state the objectives and the scope of the tests;
 - 3) specify the test facilities; and
 - 4) govern the execution of all tests.
- e) The determination of test sequences should be based on two main considerations:
 - 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.
- f) When defining a test baseline, the specific item characteristics (e.g. design maturity and margins, qualification status, and model philosophy) and the programmatic characteristics (e.g. cost and acceptable risks) shall be considered for each project;
- g) Testing is the preferred verification method with the lowest risk, but, because it represents a large expense, the tailoring of the test programme should also assure that a cost effective programme is achieved.

4.1.3 The overall test programme shall encompass different stages at different project levels and in different phases in accordance with the verification process definition.

EXAMPLE Development, qualification, acceptance testing, both on-ground and in-orbit.

4.1.4 The test programme should satisfy the specific objectives of each stage prior to the accomplishment of next stage, using a sequential bottom-up product approach.

4.1.5 Design suitability should be demonstrated in the development phase prior to the start of the formal qualification testing.

Qualification testing should be completed and consequential design improvements incorporated, prior to the initiation of the flight item manufacturing.

4.1.6 The environmental tests should be imposed sequentially, rather than in combination.

NOTE Features of the hardware design or of the service environments can justify the necessity of combined environments in some tests.

Where it is not feasible to test a product as a single entity, major assemblies, modules or stages of the product may be tested, with the support of analyses, simulations or simulators.

EXAMPLE The service and payload module in the case of a space vehicle and first, or second stage in the case of a launcher, which can be integrated and tested separately.

NOTE Launch vehicle testing is very intensive during development and qualification stages and more limited for production models. Apart from functional tests, very few tests are done on complete launch vehicles. Most of the tests are conducted at equipment and subsystem level. Element level testing takes place only at the launch range or in qualification flights.

4.2 Model philosophy

4.2.1 The test baseline definition shall be based on the project model philosophy.

NOTE Referring to the model philosophies, and related activity identification, it can be seen how the qualification, acceptance and protoflight test activities are shared among the different models. This sharing depends on model philosophy, project characteristics and model representativeness.

4.2.2 The following project model philosophy situations can exist:

a) Prototype approach:

- 1) The qualification testing can be conducted on one or more qualification model (QM), according to the project requirements and objectives, always with qualification levels and duration;
- 2) For tests on more than one QM, the tests shall be performed on the different models according to their representativeness (e.g. functional qualification is performed on EQM) and the test sequences for each model shall be adapted accordingly;
- 3) The FM shall be subjected to complete acceptance testing.

b) Protoflight approach:

- 1) All the qualification tests shall be performed on the same model to be flown, normally with qualification levels and reduced duration;
- 2) The protoflight model (PFM) should be subjected to a test programme defined on a case-by-case basis.

NOTE The test programme combines both qualification and acceptance tests to satisfy the qualification and the acceptance objectives, see 4.4 and 4.5.

c) Hybrid approach:

- 1) A combination of the prototype and protoflight rules shall be applied;
- 2) Specific qualification testing in the critical areas may be conducted on dedicated models (e.g. STM, QM, EQM or others);
- 3) In critical areas acceptance testing shall be performed only on the PFM.

4.3 Development testing

4.3.1 The objective of development testing is to support the design feasibility and to assist in the evolution of the design.

Development tests are used to validate new design concepts and the application of proven concepts and techniques to a new configuration.

4.3.2 Development tests shall be used to confirm;

- 1) performance margins,
- 2) manufacturability,
- 3) testability,
- 4) maintainability,
- 5) reliability,
- 6) life expectancy,
- 7) failure modes and
- 8) compatibility with safety requirements.

NOTE 1 Development tests need not be subjected to the same levels and controls associated with the qualification, acceptance, pre-launch, in-orbit and post-landing test campaigns.

NOTE 2 Development testing cannot be reduced to a standardized set of procedures.

NOTE 3 Development testing requirements are dependent upon the maturity of design and upon the operational requirements of the specific project.

Where practicable, development tests should be conducted over a range of operating conditions that exceed the design limits to identify marginal design features.

Development tests can be conducted on mock-ups, development (breadboards) and integration models.

Adequate records of test configuration, test results and other pertinent data shall be maintained so that this information is available to supplement other portions of the verification programme as required, or when failure occurs during the functioning of qualification and flight models.

4.4 Qualification testing

4.4.1 The objective of qualification testing is the formal demonstration that the design implementation and manufacturing methods have resulted in hardware and software conforming to the specification requirements.

4.4.2 The purpose of qualification testing shall be to demonstrate that the items perform satisfactorily in the intended environments with sufficient margins.

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.

4.4.4 The qualification testing shall be conducted on dedicated qualification models (QM) that are produced from the same drawings, using the same materials, tooling and methods as the flight item.

NOTE The standard of the QM can be slightly relaxed with respect to flight standard, e.g. by using lower quality parts instead of the space qualified hi-rel ones, without affecting the test validity (EQM).

4.4.5 Minor changes with respect to the flight models may be made to the QM used for qualification testing, providing they do not affect the qualification objectives.

EXAMPLE Adding items such as thermocouples, strain gauges and monitoring leads, necessary to conduct the test.

4.4.6 The complete flight element (i.e. flight vehicle) should be used during environmental testing for qualification.

NOTE Environmental testing of a complete element is not always feasible (e.g. due to its size it can exceed the capacity of a test facility). In this case, qualification of an element can be achieved by a combination of tests on various assembly levels, supported by analysis and similarity assessment, review of design, and inspection.

The requirements for tests on levels below the element shall be derived from the system qualification requirements.

The effects of constituents, which are interacting on the element level, but which are not present during these tests, shall be taken into consideration.

4.4.7 The environments used during qualification tests shall be the design levels which are usually more severe than those predicted to occur during flight in order to account for variability in subsequent production articles and other uncertainties (see 4.8.1).

4.5 Acceptance testing

4.5.1 The purpose of acceptance testing is to demonstrate conformance to specification and to act as quality control screens to detect manufacturing defects, workmanship errors, the start of failures and other performance anomalies, which are not readily detectable by normal inspection techniques.

4.5.2 The acceptance tests shall be formal tests conducted to demonstrate the adequacy and readiness of an item for delivery and subsequent usage.

4.5.3 Acceptance testing shall not create conditions that exceed safety margins or cause unrealistic modes of failure.

4.5.4 Acceptance tests shall be conducted on flight models under environmental conditions no more severe than those expected during the mission.

4.5.5 The acceptance tests shall be conducted on all the flight products (including spares) according to the model philosophy of 4.2, and ground elements.

4.5.6 Systems and elements that cannot be flight acceptance tested as a whole due to size limitations of available test facilities shall undergo a controlled acceptance process corresponding to the qualification process described in 4.1.

All tests below the system level shall be traceable to the system acceptance requirements.

Effects of constituents, which are interacting on system level, but which are not present during these tests, shall be taken into account.

4.6 Protoflight testing

4.6.1 In a minimum risk programme, as in the prototype approach, the products that were subjected to qualification tests are not eligible for flight, since there was no demonstration of remaining life of the product.

The protoflight approach can present a higher risk than the prototype approach in which design margins are demonstrated by testing of a dedicated qualification product.

A strategy to minimize the risk can be applied by enhancing development testing, by increasing the design factors of safety and by implementing an adequate spare policy.

The protoflight approach can be applied at each level of decomposition of space system



Documents

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4.6.2 The protoflight test levels and durations shall be as follows:

- a) protoflight test levels: as qualification margins (see 4.8.1.2);
- b) protoflight test durations: as acceptance durations (see 4.8.1.3).

4.7 Retesting

4.7.1 General

- a) Since the scope and the nature of retesting differs so much, standard test requirements or test guidelines shall be decided on a case-by-case basis.
- b) There are five situations, which can result in a retest described in 4.7.2 to 4.7.6 below.

4.7.2 Failure or anomaly during qualification, acceptance or protoflight testing

- a) The failure or anomalies occurred during the testing activities, shall be recorded on a non-conformance report (NCR) and the non-conformance review board (NRB) shall convene to decide on the course of actions to take;
- b) After the implementation of the NRB disposition and the elimination of the failure cause, a retest should be performed;
- c) The NRB shall decide on the necessity and the extent of the retest in order to demonstrate the correctness of the disposition made.

4.7.3 Implementation of a design modification after completion of qualification testing

The configuration control board (CCB) shall evaluate and decide the extent of the qualification test sequence to be repeated if:

- a) a design modification is implemented after the completion of qualification testing; or
- b) modification (after being qualified) is retrofitted to an already accepted piece of hardware (or software), in which case the complete or part of the acceptance test sequence (as defined in clause 6) shall be repeated to demonstrate the absence of poor quality or bad workmanship.

4.7.4 Long duration storage of flight hardware after acceptance testing

4.7.4.1 If flight hardware is stored for an extended time (six months or longer) between acceptance and shipment to the launch site, periodic checks on its health status shall be performed.

Periodic maintenance shall be performed on items such as travelling wave tubes (TWTs), tape recorders, batteries (conditioning) and special lubricated mechanisms and motors.

Age sensitive items shall be assessed for their life expectancy and replaced if they do not achieve the operating requirements prior to shipment.

4.7.4.2 Upon removal of flight hardware from storage for shipment it shall be determined, if a full or partial set of mechanical and functional tests (as defined in clause 6) shall be repeated.

NOTE The determination depends on storage time, the complexity of the subject hardware and whether any items were temporarily removed (e.g. batteries, sensors and propellant) or disconnected.

4.7.5 Hardware to be re-flown

Hardware that is re-flown shall be thoroughly inspected for any hidden damage.

NOTE The type and extent of retests (acceptance) depends on the following:

- the time between the first acceptance test and the intended second usage;
- whether the hardware is used in the same application;
- the residual fatigue life.

If the conditions and the configurations are different from the previous usage, then a delta qualification should be performed.

4.7.6 Flight use of qualification hardware

4.7.6.1 Introduction

Often former qualification hardware is refurbished to be used as;

- flight hardware (typically when there is more than one item of the same hardware needed); or
- flight spare.

This approach usually comes from programme costs and schedule constraints.

4.7.6.2 Assessment

A detailed assessment shall be established by the design engineer and the quality engineer to determine the refurbishment required to make the hardware acceptable, e.g. replacement of items, which are over-stressed or have the potential to be over-stressed due to qualification testing.

4.7.6.3 Acceptance tests

After the refurbishment the hardware should be subjected to a full or partial acceptance test depending on the extent of the refurbishment and disintegration.

4.8 Test conditions and tolerances

4.8.1 Test levels and duration

4.8.1.1 General

- a) Margins to both test levels and duration should be applied to the environmental tests;

NOTE Functional and performance test requirements do not present margins.

- b) Each test environment should be based on actual flight data, often scaled for differences in parameters, or if more reliable, by analytical prediction or a combination of analysis and flight data;
- c) A margin can include an increase in level or range, an increase in duration or cycles of exposure, as well as any other appropriate increase in severity.

4.8.1.2 Qualification test levels and duration

- a) The qualification environmental conditions shall stress the hardware to more severe conditions than those expected to occur during the service life. Therefore, the qualification test levels and duration shall be the predicted flight maximum increased by a qualification margin.

NOTE The qualification margin is intended to:

- avoid qualification test levels and duration that are less severe than those expected in flight;

- provide test levels which cover minor differences among qualification and flight units due to variations in parts, materials, processes, manufacturing and degradation during usage;
- provide appropriate test duration against fatigue failures due to repeated testing and operational use (e.g. acceptance plus flight(s) and re-testing);
- meet requirements under extreme conditions of flight, which when expressed statistically are the P99/90 estimates (i.e. an environment not expected to be exceeded on 99 % of flights, estimated with 90 % confidence).

Table 1 — Qualification test levels and durations

Test	Levels		Duration	
	Equipment	Space element	Equipment	Space element
Shock	+6 dB ^a	N/A	3 shocks in both directions of 3 axes	3 activations of explosive firing
Acoustic	+4 dB ^a	+3 dB	2 min ^b	2 min ^b
Vibration	Random/Sine: +4 dB	Random/Sine: +3 dB	Random: 2,5 min per axis ^b Sine: 2 octave/min 1 sweep up and down (5 Hz-100 Hz)	Random: 2 min per axis ^b Sine: 2 octave/min (5 Hz-100 Hz) (notching, if necessary)
Thermal cycling	10 °C extension of maximum and minimum predicted temperatures ^a	10 °C extension of maximum and minimum predicted temperatures ^c	8 cycles	8 cycles
Thermal vacuum	10 °C extension of maximum and minimum predicted temperatures ^a	10 °C extension of maximum and minimum predicted temperatures ^c	8 cycles if combined with thermal cycling, 1 cycle if thermal cycling is performed	8 cycles if combined with thermal cycling, 1 cycle if thermal cycling is performed
EMC	+6 dB EMC safety margin		Depending on operating modes	
Static/ Acceleration	1,25	1,25	100 s + 50 s per mission	Sufficient to record test data
Pressure	1,5 (proof), 2 (burst)	1,5	5 min (3 cycles for valves) only for proof	5 min (3 cycles)
Life	N/A (margins only for accelerated tests)		4 times operating life	
^a If the equipment qualification is carried out for multi-project utilization standard spectra or temperature limits can be used. ^b Duration is dependent on the number of missions. ^c A suitable distribution of the flight delta temperature for equipment is used, i.e. temperature limit is reached as soon as one unit in a selected area is at the hot and cold temperature reached during the unit qualification thermal testing.				

- b) Qualification testing shall not create conditions that exceed applicable design safety margins or cause unrealistic modes of failure;
- c) The qualification test margin for levels and duration specified in Table 1, with the indication, of the applicability to equipment or space element levels, shall be applied.

NOTE The table does not include tests for some ambient conditions such as humidity and toxic-off gassing because they are performed exposing the hardware to the environment without margin.

4.8.1.3 Acceptance test levels and duration

- a) The acceptance test levels shall cover the maximum flight levels encountered during the service life (except for equipment thermal tests where a margin shall be used to cover uncertainties of mathematical model) according to table 2.
- b) The test duration shall not degrade the item and be taken into account in the lifetime of the item itself.
- c) The acceptance test levels and durations to be applied are summarized in Table 2, with the indication, where necessary, of the applicability to equipment or space element levels.

NOTE Table 2 does not include tests for some ambient conditions such as humidity and toxic-off gassing because they are performed exposing the hardware to the environment without margin.

- d) For vibration, the random acceptance test spectrum shall not be lower than the minimum spectrum (see Table 2).

Table 2 — Acceptance test levels and durations

Test	Levels		Duration	
	Equipment	Space element	Equipment	Space element
Shock	Maximum expected shock spectrum	N/A	1 shock in both directions of 3 axes + dwell and burst tests	1 activation of explosive firing
Acoustic	Envelope of maximum expected acoustic spectrum		2 min	1 min
Vibration	Random: Envelope of maximum and minimum expected spectrum ^a	Random: Envelope of maximum and minimum expected spectrum ^a	Random: 2 min per axis	Random: 1 min per axis
Thermal Cycling	5 °C extension of maximum and minimum predicted temperatures ^b	Flight temperature ^c	4 cycles	4 cycles
Thermal vacuum	5 °C extension of maximum and minimum predicted temperatures ^b	Flight temperature ^c	4 cycles if combined with thermal cycling, 1 cycle if thermal cycling is performed	4 cycles if combined with thermal cycling, 1 cycle if thermal cycling is performed
Pressure	1,5	1	5 min (only one cycle)	Sufficient to establish leakage
^a For random acceptance test spectrum see 4.8.1.3 For the equipment, the minimum spectrum is the acceptance vibration test (AVT) spectrum having no relation with the expected mission and derived from experience on several projects. ^b If the equipment acceptance is carried out for multi-project utilization standard spectra or temperature limits can be used. ^c A suitable distribution of the flight delta temperature for equipment is used, i.e. temperature limit is reached as soon as one unit in a selected area is at the hot and cold temperature reached during the unit acceptance thermal testing.				

4.8.1.4 Protoflight test levels and duration

- a) The protoflight approach as defined in 4.6 combines the qualification and acceptance tests into protoflight tests with modified test levels and durations.
- b) The protoflight qualification test levels and durations shall be as follows:
 - 1) protoflight test levels: as qualification levels (see Table 1);
 - 2) protoflight test durations: as acceptance durations (see Table 2).

4.8.2 Test measurements

4.8.2.1 Test tolerances

The test level tolerances specified in Table 3 shall be applied to the nominal test value specified.

NOTE The tolerances specified in Table 3 are the maximum range within which the test level can vary. They are exclusive of instrument accuracy from test parameter 1 to 11. From test parameters 12. to 15. they are coincident with the maximum measurement instrument accuracy.

4.8.2.2 Accuracy of test instrumentation

- The accuracy of instruments used to control or monitor the test parameters shall be verified periodically and shall be compatible with the test objectives.
- The accuracy of the instruments shall be consistent with the tolerance for the variable to be measured, as specified in Table 3, and should be at least one third of the tolerance itself.
- 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.

Table 3 — Maximum allowable test tolerances

Test parameters	Tolerances	
1. Temperature from -50 °C to +100 °C	High	Low
	$T_{\max}^{+3}_{-0}$	$T_{\max}^{+0}_{-3}$
below -50 °C or above +100 °C	$T_{\max}^{+4}_{-0}$	$T_{\max}^{+0}_{-4}$
2. Relative humidity	±5 %	
3. Pressure (in vacuum chamber) > 1,3 hPa 1,3 10 ⁻³ hPa to 1.3 hPa < 1,3 10 ⁻³ hPa	±15 %	
	±30 %	
	±80 %	
4. Acceleration	0 / +10 %	
5. Sinusoidal vibration Frequency Amplitude Sweep rate	±2 % from 10 Hz to 2 000 Hz	
	±10 %	
	±5 %	
6. Random vibration Frequency PSD from 20 Hz to 500 Hz (filter bandwidth 25 Hz or less) PSD from 500 Hz to 2 000 Hz (filter bandwidth 50 Hz or less) Random overall g r.m.s.	±5 % (or 1 Hz whichever is greater)	
	-1/ +3 dB for Qualification and -3/+1,5 dB for Acceptance	
	±10 %	
7. Acoustic noise Sound pressure level 1/3 octave band (centre frequency) Overall	±3,0 dB	
	±1,5 dB	

Table 4 — Maximum allowable test tolerances (continued)

Test parameters	Tolerances
8. Test time	0/+10 %
9. Shock	
Response spectrum amplitude (1/6 octave centre frequency)	±6 dB (with 30 % of the response spectrum centre frequency amplitudes greater than nominal test specification)
Shock duration	
≤ 20 ms	0/+20 %
> 20 ms	0/+10 %
Shock level	0/+20 %
10. Solar flux	
Mean value	±3 % on reference plane(s)
Test volume	±1 %
11. Infrared flux	
Mean value	±3 % on reference plane(s)
12. Mass	
Equipment	±2 × 10 ⁻² kg or ± 0,1 % (whichever is greater)
Space vehicle, element or module	±0,3 kg
13. Centre of gravity (CoG)	
Equipment	Within a 1 mm radius sphere
Space vehicle, element or module	±2,5 mm along Z-axis
14. Moment of inertia (Mol)	
Equipment	±3 %
Space vehicle, element or module	±1 % each axis
15. Leak rate	±10 ⁻⁵ Pa m ³ s ⁻¹ of Helium at 1 013 hPa pressure differential
16. Microgravity	
Quasi-static force or torque	±10 %
Dynamic forces	±20 %
Sound-power:	
1/3 octave band centre frequencies	
32,5 Hz - 160 Hz	±3 dB
160 Hz - 500 Hz	±2 dB
17. Audible noise	
32,5 Hz to 160 Hz	±3 dB
160 Hz to 15 kHz	±2 dB
18. Flow rate	±5 %
19. Strain	±10 %

4.9 Operations validation testing

4.9.1 Introduction

4.9.1.1 This subclause addresses the specific test philosophy applicable to the ground segment implementation and mission operations testing. The “ground segment” or “operational entity” consists of:

- a) organizational elements operating the space mission and consisting of staff, manuals, plans, mission rules, and procedures;
- b) functional elements which form the ground segment (software or hardware) facilities used in the operations of the mission.

4.9.1.2 The objective of the ground segment and operations validation testing covers both of the element categories distinguished above and can be formulated as follows:

To obtain assurance prior to launch that the integrated hardware and software facilities perform as intended and that the ground segment can accomplish all operational mission requirements within the constraints imposed by the operational environment.

4.9.1.3 The testing philosophy as outlined in 4.1 should be applied to the ground segment.

Due to the specific characteristics of the ground segment rigid applicability of the space vehicle test principles should not be imposed. In particular, the ground segment equipment need not to be subjected to precisely the same qualification and test requirements as “flight” hardware since post-launch maintenance and replacement is possible. Furthermore, many essential space vehicle test requirements are not relevant for ground hardware (e.g. model philosophy and environmental testing).

4.9.1.4 Specific acceptance and validation testing requirements for ground segment elements shall be performed for the in-orbit elements when adequate availability and performance of the ground segment constitutes a critical condition for the fulfilment of the mission objectives.

4.9.2 Overview of ground segment facilities

The following list provides a high-level overview of the different kinds of ground segment support facilities to consider.

- a) Mission control system, consisting of:
 - operations control system;
 - payload control system; and
 - mission exploitation system (often under responsibility of a “user” organization);

NOTE The mission control system comprises all monitoring, control and data processing software and hardware, the mission operations rules, plans and procedures, as well as the control centre control facilities and the relevant operations and maintenance support staff.

- b) Ground station system;

NOTE The ground station system includes telemetry and telecommand subsystems as well as antenna, ranging, timing, and station monitor and control subsystems.

- c) Communications network system.

NOTE The communications network system covers the data and voice communications lines and their connections to the ground stations and mission control system as well as data communications facilities with the users.

4.9.3 Ground segment subsystem acceptance tests

4.9.3.1 The objective of acceptance tests on ground segment subsystems is to confirm or to establish confidence in the performance of a particular individual subsystem (with its specific hardware or software function) at the conclusion of its development stage. This refers specifically to the “integrity” of the equipment with respect to its conformance to the applicable functional, performance, and interface requirements.

4.9.3.2 Test objectives and test procedures shall be documented and approved before the start of the tests.

Test results shall be documented in corresponding test reports immediately following the completion of the test.

4.9.3.3 Through acceptance testing of a subsystem, it shall be demonstrated and documented that the subsystem fulfils all specified functional and performance requirements.

Acceptance tests should include the confirmation of specific user requirements relating to the performance of the equipment within the intended operational environment.

4.9.3.4 Specific dedicated test facility (hardware or software) should be developed or procured along with the subsystem itself for verifying functional performances and interface requirements.

4.9.3.5 All new or modified hardware and software subsystems shall be subjected to rigorous acceptance testing before delivery.

Software functions associated with the hardware should be considered as an integral part of its overall functional capabilities.

4.9.3.6 Software acceptance tests shall be conducted by running and evaluating a number of specific software tasks as specified before and in cooperation with the software user.

4.9.4 Ground segment integration tests

4.9.4.1 The objective of ground segment integration test is to establish confidence that two or more assembled subsystems are capable of functioning together, i.e. satisfying all relevant interface requirements.

4.9.4.2 Integration testing shall be performed in a progressive step-by-step manner, building up the complete ground system out of elements which by themselves were previously integrated and validated in terms of their functional and interface performances.

4.9.4.3 The relevant interface characteristics with other parts of the ground segment should be tested with the help of software simulators before exercising the actual hardware interfaces.

4.9.5 Operations validation tests

4.9.5.1 Overview and background

4.9.5.1.1 Operations validation tests refer to the system-level ground segment validation.

The objective of operations validation tests is to establish the correct functioning of a substantial portion of the (partly or wholly) integrated ground segment and is summarized as follows:

- a) to validate the correctness of the operations control and monitoring software in relation to the space vehicle design and performance requirements;
- b) to validate the interface integrity and robustness of the integrated hardware and software subsystems within realistic nominal and back-up operations scenarios;
- c) to validate the procedural contents of the flight operation plan (FOP) at system level. Therefore, it is important that these tests are conducted as far as practical in accordance with the control procedures and timelines outlined in the FOP;
- d) to confirm the functional and performance integrity of the relevant ground stations within the relevant operational context;
- e) to validate the integrity of the data communications interfaces between the control centre and the ground stations (i.e. by means of data flow tests coupled with functional and performance tests).

NOTE Table 4 provides examples of ground segment and operations validation test activities.

Table 5 — Examples of ground segment validation tests

Mission control system	Monitoring and control system validation
	Validation of deliverable data products and services
	Validation of operations plans and procedures
	Validation of timeline and mission rules
	Validation of flight dynamics capabilities
Ground station facilities	RF compatibility tests
	TM and TC data interface tests
	Station computer functional tests
	Ranging and antenna pointing data interface tests
Communications network	TM and TC data flow tests
	Ground station system operations tests
	Ranging and antenna pointing operations tests
NOTE Additional tests are given in 4.9.5.2 to 4.9.5.4.	

4.9.5.1.2 Operations validation tests shall be conducted within a realistic operational environment in order to demonstrate the ability to meet specific operational conditions, for instance imposed by time critical operations sequences.

NOTE When new subsystem facilities are involved, these tests can often require a number of iterations or “restarts”.

4.9.5.1.3 To achieve the system-level test objectives the categories of tests distinguished in 4.9.3 and 4.9.4 shall be conducted in a sequential order.

4.9.5.1.4 Subsystem acceptance tests shall be completed satisfactorily before initiating their successive integration; similarly, operations validation tests shall be started only after successful integration testing of significant parts of the ground segment.

4.9.5.2 RF compatibility tests

4.9.5.2.1 The objective of the RF compatibility test is to establish confidence that the uplink and downlink characteristics of the space vehicle and of the ground stations, to be used during the launch and early orbit phase (LEOP) and operational phase of the mission, are compatible in terms of their RF characteristics.

4.9.5.2.2 A series of standard tests should be performed using the ground station (or a representative model) and a satellite “suitcase” model consisting of the space vehicle telecommunications and data handling subsystems.

NOTE Sometimes, the actual space vehicle is used.

4.9.5.3 Space vehicle to ground segment compatibility tests

4.9.5.3.1 The objective of the space vehicle to ground segment compatibility tests is to validate the monitor and control system with regard to its TM and TC interactions with the space vehicle.

4.9.5.3.2 Space vehicle to ground segment compatibility tests shall be performed directly with the actual satellite linked to the control centre via a data communications network for TM, TC and voice.

A network data interface unit (NDIU) shall be attached to the space vehicle for performing the ground station TM and TC data processing functions.

NOTE “Space vehicle compatibility tests” (which aim at validating the “compatibility” between the actual satellite and the mission control system) is sometimes referred to as “system validation tests”. The use of this term is discouraged since these tests cover only one specific (although extremely important) interface verification and not a complete ground segment system-level validation.

4.9.5.3.3 Prior to the compatibility tests with the space vehicle, the control system should be validated with the aid of a dedicated software simulator.

Actual telemetry tapes generated during satellite check-out tests can be used.

4.9.5.3.4 Two compatibility tests should be performed with the satellite typically at about 6 and 3 months before launch and each with a duration of one to two weeks as follows:

- a) during these tests, all space vehicle operating modes and their reconfigurations should be exercised in realistic operations sequences;
- b) the first compatibility test shall focus on software and database validation activities that includes all monitor and control software facilities;
- c) the second compatibility test shall:
 - 1) (re)validate outstanding software capabilities; and
 - 2) exercise and validate critical FOP (flight operation plan) operations sequences with the actual space vehicle.

4.9.5.4 Simulations programme

4.9.5.4.1 The objectives of simulation activities is to ultimately validate the mission rules, the timelines, and operations procedures contained in the flight operation plan.

4.9.5.4.2 Simulations shall be performed within the actual operations environment containing the integrated mission control system, the ground stations and communications network as well as the relevant control and support teams.

A software simulator shall be used for generating the telemetry data and for handling telecommand.

4.9.5.4.3 Simulations shall be designed to familiarize the flight control teams and support personnel in the control centre and at the ground stations with the relevant mission operations activities as defined in the operations plan.

The monitor and control activities for the relevant flight sequences shall be exercised and validated under realistic conditions as imposed by the actual timeline and actual organizational characteristics.

Both nominal and contingency operations procedures shall be exercised in the simulations programme.

4.9.5.4.4 The flight dynamics team and the space vehicle engineering support team should be considered as an integral part of the mission control team.

NOTE The number of teams involved in simulations gradually increases as the simulation programme progresses.

The specific interfaces between the various teams should be exercised in realistic conditions during a number of individual simulations sessions in order that problems are minimized during the actual operations.

4.9.6 Ground segment mission readiness test

4.9.6.1 The objective of the ground segment mission readiness test is to confirm the operational readiness status of the ground segment, in particular the control system and the communications network in the relevant nominal and back-up modes.

4.9.6.2 Ground segment mission readiness should cover extended data flow tests with additional processing, display requirements or specific on-station performance checks.

4.10 Test data

- a) 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;
- b) These records shall be used for post-test analysis to supplement the real-time monitoring and to facilitate the accumulation of trend data for the critical test parameters;
- c) The test data should be compared across major test sequences for trends or evidence of anomalous behaviour;
- d) Test data shall be examined for possible anomalies;
- e) Test data can be used as inputs to analysis (to mathematical models) for verification closure.

4.11 Test documentation

4.11.1 Introduction

- a) Test standard documentation shall consist of the following DRDs:
 - 1) test specification;
 - 2) test procedure; and
 - 3) test report.
- b) The documentation should be generated at all product levels as part of the verification documentation.

4.11.2 Test specification

4.11.2.1 The objectives of the test specification are to define the test requirements to be implemented to demonstrate the item performance. Test specification may be combined with AIV plan and test procedure.

4.11.2.2 The test specification shall be prepared for each major test activity described in the test plan activity sheets with the objective to detail test requirements.

The test specifications shall contain as minimum, the

- 1) activity objectives;
 - 2) selected approach;
 - 3) article configuration;
 - 4) set-up description;
 - 5) GSE to use;
 - 6) equipment and instrumentation;
- 30

- 7) conditions for the activity;
- 8) facilities to use;
- 9) sequence of activities with the detailed requirements;
- 10) pass-fail criteria;
- 11) organization and responsibilities;
- 12) involved documentation;
- 13) relationship with product assurance activities; and
- 14) schedule.

NOTE Parts of the test specification can be contained in separate documents (e.g. test configuration and measurement plan).

4.11.3 Test procedure

The test procedure shall be written in conformance with the test specification and specify the following information, as a minimum:

- a) Objective of the test including identification of the requirements to be verified;
- b) Identification and configuration of the test article, including:
 - 1) applicable documentation (e.g. CIDL, ABCL and TCL);
 - 2) deviation from specified requirement baseline; and
 - 3) equipment reference axes.
- c) Test set-up identification, including:
 - 1) test facility and data handling;
 - 2) ground support equipment and manuals;
 - 3) instrumentation (including accuracy and calibration data); and
 - 4) adapters and interfaces.
- d) Test conditions (reference to test specification), including:
 - 1) test levels and duration;
 - 2) tolerances; and
 - 3) data acquisition and reduction.
- e) Step-by- step instructions for operation, including:
 - 1) test preparation;
 - 2) test performance (step-by-step procedure);
 - 3) pass-fail criteria; and
 - 4) post-test activities (relationships).

- f) Safety and security instructions;
- g) Personnel required and responsibilities;
- h) Criteria and rules for deviations.

4.11.4 Test report

The test reports shall describe the execution and the results of the test activity and contain:

- a) the as-run test procedure including any deviations and failures (NCR);
- b) facility data including environmental data and conditions;
- c) test article data including measurements made on the item under test;
- d) evaluation of the test data; and
- e) summary of the test evaluation and conclusion.

5 Qualification testing

5.1 Equipment test requirements

5.1.1 Introduction

The requirements provided in this clause are of two types:

- a) General:
 - 1) The general qualification philosophy provides requirements for multi-project utilization (i.e. different launchers and different missions);
 - 2) With this philosophy the equipment is qualified independently from the specific project, assuring the compatibility with the requirements of a specified set of launchers (ARIANE 4 and 5, and STS) and with a wide range of mission types.

The general philosophy makes use of standard spectra for structural tests and of standard temperature limits for each category of equipment.

- b) Specific:

The specific qualification philosophy provides requirements tailored for each specific project.

With this approach the equipment qualification is limited to the requirements of a particular project (e.g. launcher mission).

The philosophy specifies the criteria for determination of test levels in terms of margins to be applied. In principle, the test durations shall be the same as specified in the general approach.

5.1.2 Equipment classification

5.1.2.1

Equipment shall be classified according to the following categories:

- a) Category A:
Off-the-shelf equipment with no modifications and subjected to a qualification test programme for static

applications at least as severe as that imposed by the actual project specifications.
Further qualification testing need not be performed.

- b) Category B:
Off-the-shelf equipment with no modifications that was already tested and qualified but subjected to a different qualification programme or to a different environment.
Delta qualification test programme shall be decided and performed on a case-by-case basis.
- c) Category C:
Off-the-shelf equipment with minor design modifications.
Delta or full qualification test programme shall be decided case-by-case depending on the impact of the modification.
- d) Category D:
Completely new equipment designed and developed or existing equipment with major redesign.
A full qualification test programme shall be performed.

Table 6 — Equipment qualification test baseline

Test	Reference subclause	Recommended sequence	Category/type of equipment											
			a	b	c	d	e	f	g	h	i	j	k	l
Physical properties	0	1	R	R	R	R	R	R	R	R	R	R	R	R
Functional and performance	5.1.5	2 ^a	R	R	R	R	R	R	R	R	R	-	R	R
Humidity	5.1.6	3	O	O	O	O	O	O	O	O	O	O	O	O
Leak	5.1.7	4,6,11,14 ^g	R ^b	-	R ^b	R	R	R	O	O	-	-	-	-
Pressure	5.1.8	5 ^g	R ^b	-	R ^b	R	R	R	R	-	-	-	-	-
Acceleration	5.1.9	7	O	R ^j	O	O	-	O	-	-	R ^j	-	-	O
Sinusoidal vibration	5.1.10	8	R	R	R	R	R	R	R	R	R	R	R	-
Random vibration	5.1.11	9	R	R ^c	R	R	R	R	R	R	R	R	R	-
Acoustic	5.1.12	9	-	R ^c	-	O	-	-	-	-	-	O	O	R
Shock	5.1.13	10	R ^j	O	O	O	O	-	O	O	O	-	-	O
Corona and arcing	5.1.14	12	R ^e	R ^e	O	O	O	-	-	-	-	-	-	-
Thermal vacuum ⁱ	5.1.15	13 ^f	R	R	R	R	R	O	R	R	R	O	R	R
Thermal cycling ^k	5.1.16	13 ^f	R	R	R	R	R	O	R	R	R	O	R	O
EMC/ESD	5.1.17	15	R	O	-	R	O	-	O	-	-	-	-	-
Life	5.1.18	16	O	O	O	O	O	O	O	O	O	O	O	O
Microgravity ^d	5.1.19	17	R	R	-	R	R	-	R	-	R	R	R	-
Audible noise ^h	5.1.20	18	R	R	-	R	R	-	R	-	-	R	R	-
Categories / Types of Equipment														
a	Electronic and electrical equipment			g	Thrusters									
b	Antennas			h	Thermal equipment									
c	Batteries			i	Optical equipment									
d	Valves			j	Mechanical equipment									
e	Fluid or propulsion equipment			k	Mechanical moving assemblies									
f	Pressure vessels			l	Solar arrays									
Key														
R	Required		O	Optional		-	Not required							
a	See 5.12.2 f													
b	Required only on sealed or pressurized equipment.													
c	Either random vibration or acoustic test required with other optional.													
d	Mission dedicated for in-orbit active mechanical assemblies.													
e	To be performed for equipment which is switched on during ascent phase only.													
f	Can be combined in thermal vacuum cycling test.													
g	Can be combined.													
h	Required for equipment for manned space vehicle.													
i	Required for equipment exposed to vacuum and sensitive to it.													
j	Required for equipment sensitive to the environment and located in zones where the environment is critical.													
k	Including temperature test.													

5.1.2.2 The type and the extent of the test programmes to be performed for each category depend also on the project model philosophy. The hardware matrix shall identify, for each equipment, the related qualification status and models.

The equipment qualification test baseline shall consist of the tests specified in Table 5.

NOTE The categorization of tests into “required”, “optional” and “not required” is guided by the sensitivity of the type of equipment to the specific environment and by the applicability of the environment.

Where equipment falls into two or more types of Table 5 the required tests specified for each type shall be applied.

EXAMPLE A star sensor can be considered to fit both “electronic equipment” and “optical equipment” types, therefore, an EMC test is conducted since it is applicable for electronic equipment, even though there is no requirement for optical equipment.

5.1.3 Rules for test programme

5.1.3.1 The following rules shall be taken into account in establishing the test programme:

- a) Equipment qualification tests should be accomplished entirely at the equipment level;

NOTE In some circumstances equipment qualification can be conducted partially or entirely at a higher level (e.g. interconnecting tubes, radio frequency circuits and wiring harness)

- b) Leak tests shall be performed only on sealed or pressurized equipment, where equipment is sensitive to loss of pressure or vacuum;

- c) If the equipment is not fully environmentally protected on the ground and in flight, then a humidity qualification test shall be performed;

NOTE For equipment which is environmentally protected, the humidity qualification test is optional.

- d) A humidity qualification test should be performed for tests such as fungus, sand, dust, salt spray, and radiation;

- e) Equipment qualification life tests shall be optional unless a reliability analysis has shown that such tests are essential to demonstrate that the equipment can withstand the maximum duration or cycles of operation without fatigue or wear-out failures;

- f) Functional and performance tests shall be performed prior and following environmental tests;

- g) Equipment functional and performance tests shall be performed at the beginning, the end and at specific times during the test sequence to check that equipment has survived a certain test environment;

- h) Equipment functional tests shall be performed while the environment is being imposed, if the equipment is expected to be (fully) operational under that environment;

NOTE Many defects, which otherwise escape detection by pre-test and post-test functional checks, reveal themselves during environmental tests.

- i) The performance and functional tests should be designed so that a database of critical parameters can be established for trend analysis;

- j) The database of critical parameters shall be established by measuring the same critical parameters in all the functional tests conducted before, during and after each of the baseline environmental tests;

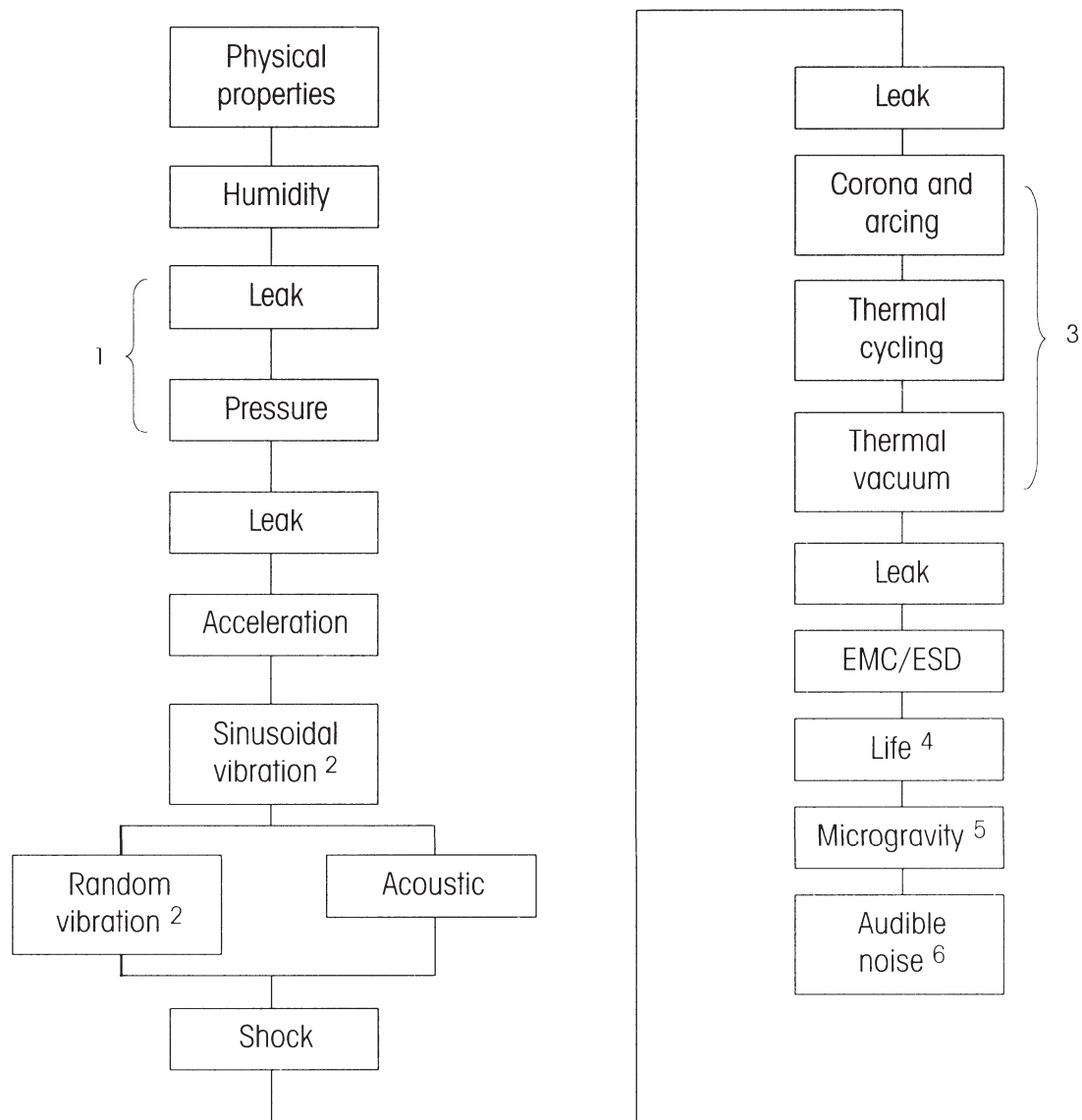
- k) Any unusual or unexpected trends shall be evaluated to determine the existence of any trends towards an out of limit value or of an incipient failure;

- l) The EGSE or other support systems of the test article shall:

- 1) not influence the results of EMC tests;
- 2) be designed for low emissions; and
- 3) be hardened against susceptibility testing.

5.1.3.2 The qualification test sequence is given in figure 1 should be followed.

NOTE The sequencing in Figure 1 is based on a combination of the order in which the environments are encountered during flight and the purpose to perceive defects as early in the test sequence as possible.



Key

- ¹ These tests may be combined.
- ² See 5.1.3.2.
- ³ These tests may be combined.
- ⁴ Performed for completeness. It can be performed on separate equipment.
- ⁵ Equipment for microgravity utilization space vehicle.
- ⁶ To be performed for manned space vehicle.

Figure 1 — Equipment qualification test sequence

The sinusoidal and random vibration should be performed at the same time per axis.

5.1.4 Physical properties measurements, equipment qualification

5.1.4.1 Purpose

The purpose of physical properties measurements is to determine the equipment physical characteristics, i.e. dimensions, mass, centre of gravity and momentum of inertia.

5.1.4.2 Test description

a) Dimensions:

- 1) The characteristic dimensions of the equipment (height, width, and length) shall be measured.
- 2) The interface dimensions shall be measured.

b) Mass:

The mass of the equipment shall be measured.

c) Centre of gravity:

- 1) The position of the centre of gravity shall be determined with respect to a given co-ordinate system for three mutually perpendicular axes.
- 2) This measurement should be performed by means of standard laboratory instrumentation.

d) Momentum of inertia:

- 1) The momentum of inertia shall be measured with respect to the given co-ordinate system.
- 2) A torsional pendulum and standard laboratory instrumentation should be used.

5.1.4.3 Supplementary requirements

- a) Alternative methods can be used, provided that they assure the required accuracy for the measurements.
- b) The test article shall be in flight configuration. Any non-flight items, which cannot be removed, shall be subtracted by calculation.
- c) For equipment with simple shapes, the centre of gravity location and momenta of inertia can be determined by calculation.

5.1.5 Functional and performance test, equipment qualification

5.1.5.1 Purpose

The purpose of the functional and performance test is to verify that the electrical and mechanical functions and the performance of the equipment conform to the equipment specification.

5.1.5.2 Functional and performance test basic requirements

- a) Electrical tests shall include application of expected voltages, impedance, frequencies, pulses, and wave forms at the electrical interface of the equipment, including all redundant circuits.
- b) Mechanical tests:
 - 1) Mechanical tests shall include application of torque, load and motion as appropriate;
 - 2) Test parameters shall be varied throughout their specification ranges and the sequences of operations during operation;

- 3) The equipment output shall be measured to verify the equipment performance to specification requirements.
- c) Functional performance shall include electrical continuity, stability, response time, alignment, pressure, leakage or other special functional tests related to a particular equipment configuration.
- d) Functional and performance tests shall be executed during test exposures if the equipment is operational during its mission.

5.1.5.3 Functional and performance test supplementary requirements

- a) Complete functional and performance tests shall be performed at the beginning and at the end of the test sequence.
- b) Reduced functional and performance tests shall be conducted before and after each environmental exposure as follows:
 - 1) the test shall be designed in order to provide reliable criteria for judging successful survival of the equipment to the test environment;
 - 2) a database of critical parameters shall be established for trend analysis;
 - 3) unusual or unexpected trends should be evaluated to determine the existence of any drift towards an out of limit value or the start of a failure.
- c) Functional tests shall be performed while the environment is being imposed, if the equipment is expected to be fully operating under that environment (exceptions solar panels and antenna feeds during thermal vacuum tests).
- d) The benefit to equipment (functionally operated and monitored during the environmental tests, regardless of the functional mode of the equipment during launch and ascent), shall be evaluated to increase the overall test effectiveness, without jeopardizing equipment integrity.

NOTE Many defects, which otherwise escape detection by pre- and post-test functional checks, reveal themselves during environmental tests e.g. intermittence can be caused by inadequate clearances, cracks, debonds and damaged connectors that can only be revealed during environmental tests (e.g. relay change over during vibration).

5.1.6 Humidity test, equipment qualification

5.1.6.1 Purpose

The purpose of this test is to demonstrate the ability of the equipment to withstand the humid environment that can be imposed upon the equipment during its life on ground.

5.1.6.2 General

- a) In cases where exposure is controlled during the life cycle to standard ambient conditions, verification by test shall not be performed.
- b) Since some items can experience higher levels of humidity in manned flights, the humidity test shall be performed if the equipment is sensitive to humidity.

5.1.6.3 Humidity test description and levels

- a) Pre-test conditions:
 - 1) The equipment shall be installed in the humidity chamber;
 - 2) Chamber temperature shall be at room-ambient conditions.

b) Cycle 1:

- 1) The temperature shall be increased to +35 °C over a 1 h -period;
- 2) The relative humidity shall be increased to not less than 95 % over 1 h-period with the temperature maintained at +35 °C;
- 3) The conditions specified above shall be maintained for 2 h;
- 4) The temperature shall be reduced to 2 °C over a 2 h-period with the relative humidity stabilized at not less than 95 %;
- 5) The conditions specified above shall be maintained for 2 h.

c) Cycle 2:

- 1) Cycle 1 shall be repeated with the exception that the temperature shall be increased from +2 °C to +35 °C over a 2 h-period;
- 2) Moisture shall be not added to the chamber until +35 °C is reached.

d) Cycle 3:

- 1) The chamber temperature shall be increased to +35 °C over a 2 h-period without adding any moisture to the chamber;
- 2) The test equipment shall be dried with air at room temperature and 50 % maximum relative humidity by blowing air through the chamber for 6 h;
- 3) The volume of air used per minute shall be between one and three times the volume of the test chamber;
- 4) A suitable container can be used in place of the test chamber for drying the test equipment.

e) Cycle 4:

- 1) The equipment shall be placed in the test chamber and the temperature increased to +35 °C and the relative humidity increased to 90 % over a 1 h-period;
- 2) The conditions above shall be maintained for at least 1 h;
- 3) The temperature shall be reduced to +2 °C over a 1 h-period with the relative humidity stabilized at 90 %;
- 4) The conditions above shall be maintained for at least 1 h;
- 5) A drying cycle should follow (see Cycle 3).

5.1.6.4 Humidity test supplementary requirements

- a) The equipment shall be checked prior to the test and at the end of Cycle 3 (within 2 h after the drying) and visually inspected for deterioration or damage.
- b) The equipment shall be tested during the Cycle 4 period of stability (i.e. following the 1 h-period after reaching +35 °C and 90 % relative humidity conditions).
- c) The equipment shall be visually inspected for deterioration or damage after removal from the chamber.

5.1.7 Leakage test, equipment qualification

5.1.7.1 Purpose

The purpose of leakage test is to demonstrate the ability of pressurized equipment to meet the design leakage rate constraints specified in the equipment specification.

5.1.7.2 Leakage test description

5.1.7.2.1 General

- a) Equipment leak checks shall be made prior to initiation of, and following the completion of equipment qualification thermal and structural tests.
- b) Proof pressure tests defined in 5.1.8.2 shall be successfully completed before conducting leakage tests.
- c) The test method employed shall have sensitivity and accuracy consistent with the specified maximum allowable leak rate.

5.1.7.2.2 Method

One of the following methods shall be used:

a) Method I (gross leak test):

- 1) The equipment shall be completely immersed in a friendly and non-corrosive liquid, so that the uppermost part of the test item is 5 cm $\pm$ 2,5 cm below the surface of the liquid;

NOTE Any observed leakage during immersion as evidenced by a continuous stream of bubbles emanating from the equipment indicates a failure of seals.

- 2) The critical side or side of interest of the component shall be in a horizontal plane facing up;
- 3) The liquid, pressurizing gas, and the test items shall be 23 °C $\pm$ 10 °C;
- 4) The gas used for pressurizing shall be clean and dry with a dew-point of at least -32 °C;

b) Method II (fine leak test):

- 1) This method shall be applied to fluid loop components and similar equipment;
- 2) The equipment shall be purged with nitrogen and then charged with helium to the pressure specified in the equipment specification before being sealed;
- 3) The equipment shall be placed in a suitable vacuum chamber or bag or container and tested for helium leakage with a helium leak detector;
- 4) The leakage rate shall be used to determine seal integrity and shall not exceed the amount specified in the equipment specification.

c) Method III (for battery cases or pressurized equipment):

- 1) The equipment shall be pressurized with dry nitrogen or other appropriate gas to the specified value;
- 2) The pressure shall be monitored by a gauge (or pressure transducer) for the required time;
- 3) The drop in pressure shall not exceed the permitted amount as specified in the equipment specification;

d) Method IV (for hermetically sealed alkaline storage batteries):

- 1) The battery shall be cleaned with alcohol while in the discharged state;
- 2) A suitable indicator (e.g. dilute solution of phenolphthalein or other suitable colour change indicator) shall be applied to all seals, terminals and pinch tubes subject to leakage of electrolyte;

NOTE A change in the colour of the indicator is an indication of a leak.

- 3) After testing, the test solution shall be removed (e.g. with distilled water).

e) Method V (for equipment of pressurized fluid systems):

- 1) The equipment shall be pressurized to their maximum design pressure in each of the functional modes;
- 2) Leakage shall be detected using the standard method as described in Method II;
- 3) All pressurized fluid equipment shall be evacuated to the internal pressure normally used for propellant loading and the internal pressure monitored for indications of leaking.

f) Method VI (for pressurized modules or compartments):

- 1) Full scale pressurized modules or compartments shall be subjected to pressure decay tests for verification of total leak rate requirements under limit pressure;
- 2) This leak test shall verify the integrity of the pressure shell and all seals and measure the total leak rate of the assembled module over a sufficient time to confirm the long duration "keep pressure" capability.

5.1.7.3 Leakage test levels and duration**5.1.7.3.1 General**

- a) The leak tests shall be performed with the equipment pressurized at the maximum operating pressure and then at the minimum operating pressure if the seals are dependent upon pressure for proper sealing.
- b) The test duration shall be sufficient to detect any significant leakage.

5.1.7.3.2 Test levels and durations for specific methods

The test levels and duration for the typical methods of 5.1.7.2 are as follows.

a) Method I:

The duration of immersion shall be 60 min at each pressure.

b) Method II:

The external test pressure shall be 10^{-3} hPa or less and the duration of the test shall be at least 2 h (for equipment that is operational in orbit for more than one day).

c) Method III:

- 1) The test pressure should be less than 3 430 hPa;
- 2) The pressure drop shall not exceed the specified amount (typically about 69 hPa in a 6 h-period at room temperature).

d) Method IV:

The test results should be visible within seconds.

e) Method V:

The duration of the evacuated propulsion system equipment leak test shall not exceed the time that this condition is normally experienced during propellant loading.

f) Method VI:

The duration shall be 10 h minimum.

5.1.8 Pressure test, equipment qualification

5.1.8.1 Purpose

The purpose of the pressure test is to demonstrate that the design and structural integrity of such items as pressure vessels, pressure lines, fittings and valves provide an adequate margin such that structural failure or excessive deformations do not occur at the maximum expected operating pressure.

5.1.8.2 Pressure test description

The following test shall be performed as part of a fracture control programme.

a) Proof pressure:

- 1) For pressure vessels, pressure lines and fittings, the temperature of the equipment shall be consistent with the operational temperature and subjected to a minimum of one cycle of proof pressure.
- 2) A proof pressure cycle shall consist of raising the internal pressure (hydrostatically or pneumatically, as applicable) to the proof pressure, maintaining it for 5 minutes and then decreasing the pressure to initial condition.

NOTE Any evidence of permanent deformation, distortion or failure of any kind indicates a failure to pass the test.

b) Proof pressure for valves:

- 1) With the valve in open and closed position, the proof pressure shall be applied for a minimum of three cycles to the inlet port for 5 minutes (hydrostatically or pneumatically).
- 2) Following the 5 minutes pressurization period, the inlet pressure shall be reduced to ambient conditions.
- 3) The exterior of the unit shall be visually examined.
- 4) Evidence of deformation or any failure shall indicate a failure to pass the test.
- 5) The test may be conducted at room ambient temperature.

c) Burst pressure for pressure vessels, pressure lines and fittings:

- 1) The temperature of the equipment shall be consistent with the operational temperature.
- 2) The equipment shall be pressurized (hydrostatically or pneumatically) to design burst pressure.
- 3) The internal pressure shall be applied at a uniform rate such that stresses are not imposed due to shock loading.

NOTE Any evidence of rupture when tested at design burst pressure indicates a failure to pass the test.

d) Burst pressure for valves:

- 1) With the valve in the open and closed position, the design burst pressure shall be applied to the inlet port for 5 min (hydrostatically or pneumatically).