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Space systems — General test methods for spacecraft, subsystems and units

Systèmes spatiaux — Méthodes d'essai générales pour véhicules spatiaux, sous-systèmes et équipements

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Contents

Page

Foreword

ISO (the International Organization for Standardization) is a worldwide federation of national standards bodies (ISO member bodies). The work of preparing International Standards is normally carried out through ISO technical committees. Each member body interested in a subject for which a technical committee has been established has the right to be represented on that committee. International organizations, governmental and non-governmental, in liaison with ISO, also take part in the work. ISO collaborates closely with the International Electrotechnical Commission (IEC) on all matters of electrotechnical standardization.

The procedures used to develop this document and those intended for its further maintenance are described in the ISO/IEC Directives, Part 1. In particular, the different approval criteria needed for the different types of ISO documents should be noted. This document was drafted in accordance with the editorial rules of the ISO/IEC Directives, Part 2 (see www.iso.org/directives).

Attention is drawn to the possibility that some of the elements of this document may be the subject of patent rights. ISO shall not be held responsible for identifying any or all such patent rights. Details of any patent rights identified during the development of the document will be in the Introduction and/or on the ISO list of patent declarations received (see www.iso.org/patents).

Any trade name used in this document is information given for the convenience of users and does not constitute an endorsement.

For an explanation of the voluntary nature of standards, the meaning of ISO specific terms and expressions related to conformity assessment, as well as information about ISO's adherence to the World Trade Organization (WTO) principles in the Technical Barriers to Trade (TBT), see www.iso.org/iso/foreword.html.

This document was prepared by Technical Committee ISO/TC 20, *Aircraft and space vehicles*, Subcommittee SC 14, *Space systems and operations*.

This second edition cancels and replaces the first edition (ISO 15864:2004), which has been technically revised.

The main changes compared to the previous edition are as follows:

— harmonized expressions throughout this document, including terminologies;

— added necessary but minimum modifications to requirements such as traceability in 4.9.6 and magnetic test in 7.4;

— added the most current published documents as normative references: ISO 19924 and ISO 21494.

Any feedback or questions on this document should be directed to the user's national standards body. A complete listing of these bodies can be found at www.iso.org/members.html.

Introduction

Throughout this document, the minimum essential criteria are identified by the use of the keyword "shall". Recommended criteria are identified by the use of the keyword "should" and, while not mandatory, are considered to be of primary importance in providing serviceable, economical and practical designs. Deviations from the recommended criteria should occur only after careful consideration, extensive testing and thorough service evaluation have shown alternative methods to be satisfactory. The acceptance criteria, specifications or procedures, and other detail test requirements applicable to a particular programme are defined in the applicable technical specifications and statement of work. When requirements have to be verified by measuring product performance and function under various simulated environments, the method is referred to as "Test". The requirements of this document may be tailored for each specific space programme application.

Space systems — General test methods for spacecraft, subsystems and units

1 Scope

This document provides the baseline standard on the subject of testing at the system, subsystem and unit levels for applicable unmanned spacecraft programmes. It also provides the requirements for documentation associated with testing activities.

This document contains provisions for qualification and acceptance testing, or proto-flight testing (PFT). It assumes that hardware development is complete.

2 Normative references

The following documents are referred to in the text in such a way that some or all of their content constitutes requirements of this document. For dated references, only the edition cited applies. For undated references, the latest edition of the referenced document (including any amendments) applies.

ISO 14302, *Space systems — Electromagnetic compatibility requirements*

ISO 14303, *Space systems — Launch-vehicle-to-spacecraft interfaces*

ISO 14623, *Space systems - Pressure vessels and pressurized structures — Design and operation*

ISO/IEC 17025, *General requirements for the competence of testing and calibration laboratories*

ISO 19924, *Space systems — Acoustic testing*

ISO 21494, *Space systems — Magnetic testing*

ISO 23461, *Space systems — Programme management — Non-conformance control system*

3 Terms, definitions and abbreviated terms

3.1 Terms and definitions

For the purposes of this document, the following terms and definitions apply.

ISO and IEC maintain terminology databases for use in standardization at the following addresses:

— ISO Online browsing platform: available at https://www.iso.org/obp

— IEC Electropedia: available at http://www.electropedia.org/

3.1.1
development model
representative of *spacecraft* (3.1.10), *subsystem* (3.1.11) or *unit* (3.1.14) dedicated to increasing confidence in design and subjected to development tests

3.1.2
flight model
spacecraft (3.1.10), *subsystem* (3.1.11) or *unit* (3.1.14) model dedicated to being launched and operated in orbit and subjected to acceptance testing

3.1.3
maximum predicted level
highest level that can be expected during a structure's service life in association with the applicable operating environments

Note 1 to entry: See 4.4.

3.1.4
maximum predicted temperature
highest temperature that can be expected to occur during the entire life cycle of the *subsystem* (3.1.11)/ *unit* (3.1.14) in all *operational modes* (3.1.6) plus an uncertainty factor

3.1.5
minimum predicted temperature
lowest temperature that can be expected to occur during the entire life cycle of the *subsystem* (3.1.11)/ *unit* (3.1.14) in all *operational modes* (3.1.6) plus an uncertainty factor

3.1.6
operational modes
modes for *spacecraft* (3.1.10), *subsystems* (3.1.11) and *units* (3.1.14) that include all combinations of operational configurations that can occur during service life

EXAMPLE Power on or power off, the main or redundant system is selected.

3.1.7
proto-flight model
model that is intended for both qualification and flight and is subjected to the qualification levels and acceptance duration during testing

3.1.8
qualification model
spacecraft (3.1.10), *subsystem* (3.1.11), or *unit* (3.1.14) dedicated to qualifying the design of *flight model* (3.1.2) and subjected to qualification testing

3.1.9
quasi-static load
load with magnitude and direction that are independent of time; includes that varies slowly and in which dynamic response of the structure is insignificant

Note 1 to entry: This load can be induced by steady wind, aerodynamic forces and thrust (constant or wind slow variations), manoeuvres and spin stabilization.

3.1.10
spacecraft
integrated set of *subsystems* (3.1.11) and *units* (3.1.14) designed to perform specific tasks or functions in space

3.1.11
subsystem
assembly of functionally related *units* (3.1.14), which is dedicated to specific functions of a system

3.1.12
test article
spacecraft (3.1.10), *subsystem* (3.1.11) or *unit* (3.1.14) on which a test is conducted

3.1.13
test facility
technical plant or location (including equipment, fixtures, instrumentation and all associated infrastructure) capable of performing a test

3.1.14
unit
lowest level of hardware assembly that works with specified complex electrical, thermal and/or mechanical functions

3.2 Abbreviated terms

AT	acceptance test
CG	centre of gravity
EED	electro-explosive devices
EMC	electromagnetic compatibility
LBB	leak-before-burst
MEOP	maximum expected operating pressure
MMA	moving mechanical assembly
PFT	proto-flight test
QT	qualification test
RF	radio frequency

4 General requirements

4.1 Testing philosophy

In principle, testing is one verification method that ensures that the spacecraft meets all design, performance and product assurance requirements.

Performance requirements contained in the contract documentation are compared to performance achieved during testing and provide the basis for judging the capability of the spacecraft to operate as intended. Besides verifying performance, test programmes provide the following items:

a) training for personnel in the operation of the spacecraft;

b) incorporation of corrective actions taken for non-conformances;

c) validation of data processing;

d) opportunity to perform calibrations under simulated space conditions;

e) verification of ground hardware compatibility with the spacecraft for operations.

Factors that contribute to the provisions of test specifications include experience with similar spacecraft, subsystem and unit; cost considerations; and reliability requirements and risk tolerance. This document contains range conditions to which the items under test shall be operated and test conditions that shall be used to demonstrate capability.

4.2 Tailoring of requirements

The test requirements may be tailored to fulfil the objectives of individual tests. Tailoring parameters shall be determined by negotiations among the customer, spacecraft manufacturer and launch service provider.

4.3 Development tests

Development tests support design feasibility and assist in evolution of design. Development tests are necessary to validate new design concepts and the application of proven concepts and techniques to a new configuration. Development tests are used to confirm structural and performance margins, manufacturability, test simplification, maintainability, reliability, lifetime prediction and compatibility with safety. Therefore, requirements for development testing depend on the maturity of the design used and the operational requirements of the specific project. By its nature, development testing cannot be reduced to a standardized set of procedures.

Where practicable, development tests shall be conducted over a range of operating conditions that exceed design limits to identify marginal design features. Development tests may be conducted on mock-ups, breadboards, development models or integration models.

4.4 Qualification tests

Qualification tests demonstrate that items meet design requirements and include proper margin. The qualification test level shall exceed the maximum predicted levels by a factor of safety or qualification margin; unless otherwise specified, the qualification test duration shall be longer than the maximum environment duration with an appropriate qualification margin. In addition, qualification tests shall validate methods, procedures, facility conditions and ground support test equipment that will be reused for acceptance.

4.5 Acceptance tests

Acceptance tests shall demonstrate that the item is free of workmanship defects and integration errors and that its function and performance can meet stipulated mission requirements. Acceptance tests detect latent material or workmanship defects introduced during the manufacturing and assembly process by measuring function and performance parameters. Such parameters shall be measured through sequential tests to identify function and performance degradation that is likely to damage mission purposes and to establish a baseline to ensure that no degradation is found in the data history.

4.6 Proto-flight tests

Proto-flight approach presents a higher risk than the approach in which design margins are demonstrated by the testing of a dedicated non-flight qualification item. Moreover, programmatic realities of limited production, tight schedules, and budgetary limits do not always allow the use of dedicated non-flight qualification items. In response, several strategies have evolved to minimize the risk created by this situation. The higher risk of the proto-flight approach is an example. In principle, the proto-flight approach may be applied at each level of decomposition of the space system.

Proto-flight tests shall qualify the design and manufacturing methods of hardware for the purpose of acceptance for flight operations. Qualification of design and manufacturing methods is accomplished by imposing environmental levels more severe than environments expected during ground and orbital operations. Hardware fatigue is prevented by limiting exposure so as not to expend a significant portion of the useful life of the hardware. This means in general PFT is performed with qualification loads and acceptance durations. These tests also detect latent material and manufacturing defects and provide experience with each test item's performance under conditions similar to the mission environment.

4.7 Prelaunch validation tests

Prelaunch validation tests for spacecraft shall be conducted at the launch site, if they are necessary. These tests demonstrate that transportation to and handling at the launch site cause no spacecraft parameter changes and verify that spacecraft and launch vehicle interface and compatibility testing with the tracking and control system stay within the stipulated limits as part of launch site operations. The tests shall exercise every operation mode of spacecraft within practical limits in order to ensure that all mission requirements can be satisfied.

4.8 Retest

4.8.1 General

In principle, there are four situations that may require retest.

4.8.2 Retest due to design modification after completion of qualification

Whenever hardware design is modified, the hardware involved shall be retested, and all documentation pertinent to the design modification shall be revised. Depending on the type and extent of the implemented modification, the issue of whether to partially or completely repeat the qualification test sequence shall be evaluated. The acceptance test sequence shall be either partially or completely repeated to demonstrate that no new problems have been introduced.

4.8.3 Retest due to non-conformance

If non-conformance occurs during testing activities, a necessary action shall be taken in accordance with the test procedure, and the causes of non-conformance shall be identified. If non-conformance is caused by the test set-up, test software or failures in test equipment, the test being conducted at the time of the failure may be continued after repair is completed, as long as the non-conformance does not overstress the test items. If non-conformance caused in the test items is disposed, an initial failure analysis and an appropriate corrective action shall be completed before retesting. If a failure occurs during the environmental test, the test may be continued as long as the non-conformance does not affect continuity of the test. The non-conformance process shall be consistent with ISO 23461.

The details of retesting shall be determined in consideration of the nature of each failure. If the units must be substantially redesigned, all previous qualification tests shall be repeated. After the redesign of the unit is qualified, all acceptance test programmes shall be repeated.

4.8.4 Retest after refurbishment

Former qualification hardware is often refurbished to be used as flight hardware (typically when more than one item of the same hardware is needed) or as a flight spare. This approach may be dictated by programme costs and schedule constraint. A detailed assessment shall be established by the design and quality engineers to determine the necessary refurbishment to make this hardware flight worthy (e.g. replacement of items overstressed or potentially overstressed by qualification testing). After refurbishment, the hardware should be subjected to a partial or complete acceptance test, depending on the extent of refurbishment and disintegration.

4.8.5 Retest during and after long-term storage

Tests performed during and after long-term storage depend on the failure modes likely to occur during storage. At a minimum, these tests are necessary to validate moving mechanical assemblies, check preloads, ensure lubrication, and validate interfaces and required functional operations.

4.9 Test documentation

4.9.1 General

The contract between the customer and manufacturer shall call out required test documentation. The following documents are among those most frequently used in the contract to establish detail requirements for the test.

4.9.2 Test plans

Test plans shall provide a general description of each planned test and its conditions. Test plans shall be based on a function-by-function mission analysis and all specified testing requirements. Test objectives

shall be planned to verify compliance with the design and specified requirements of the items involved, including interfaces. Test plans shall incorporate or provide references for the following:

a) a brief background of the applicable project and descriptions of the test items;

b) an overall test philosophy, testing approach, and test objective for each item, including any special tailoring or interpretation of design and testing requirements.

4.9.3 Test specifications

Test specifications are documents that define test requirements and associated conditions to be implemented to properly demonstrate an item's performance. For some tests (e.g. sinusoidal vibration), test requirements shall be based on test predictions. These documents shall be prepared for each major test activity described in the test plan activity sheets, with the objective to detail test requirements.

4.9.4 Test procedures

Tests shall be conducted using documented test procedures prepared for performing all required tests in accordance with approved test plans and specifications. Test objectives, testing criteria, and pass-fail criteria shall be stated clearly in the test procedures. Test procedures shall cover all operations in enough detail to eliminate doubt as to the execution of any step. Test objectives and criteria shall be stated clearly to relate to design or operations specifications. Where appropriate, minimum requirements for valid data and pass-fail criteria shall be provided at the procedure step level based on analysis using an appropriate mathematical model. Traceability shall be provided from the specifications or requirements to the test procedures. Where practicable, the individual procedure step that satisfies the requirement shall be identified. The test procedure for each item shall include, at a minimum, descriptions of the following:

a) identification of test items;

b) criteria, objectives, assumptions and constraints;

c) test set-up;

d) initialization parameters;

e) input data;

f) test instrumentation;

g) expected intermediate test results;

h) output data format;

i) expected output data (by supporting analysis and predictions);

j) minimum requirements for valid data to consider the test successful;

k) pass-fail criteria for evaluating results;

l) safety considerations and hazardous conditions;

m) procedural steps required for successful test and verification signature;

n) personnel involved and relevant responsibility.

4.9.5 Test data

Pertinent test data shall be maintained in a quantitative form to permit evaluation of performance under the various specified test conditions; pass or fail statements alone may be insufficient. The test data shall also be compared across major test sequences for trends or evidence of anomalous behaviour. To the extent practicable, all relevant test measurements and environmental conditions imposed on the

units shall be recorded on computer-compatible electronic media, such as disks, magnetic tapes or other suitable means to facilitate automated accumulation and sorting of data for critical test parameters. These records are intended to be an accumulation of trend data and critical test parameters that shall be examined for out-of-tolerance values and characteristic signatures during transient and mode switching.

4.9.6 Test reports

A summary of the test results shall be documented in test reports. Test reports shall detail the degree of success in meeting the test objectives of the approved test plans and specifications, and shall document test results, deficiencies, problems encountered, and problem resolutions. The test reports shall be provided to the customer and the launch vehicle side to prove compliance with all requirements. Test specifications shall ensure traceability between the test requirement and the requirement to be tested to allow evaluation of completeness and correctness.

4.9.7 Test log

Formal test conduct shall be documented in a test log. The test log shall identify personnel involved and be time-tagged to permit reconstruction of test events such as start time, stop time, anomalies and any periods of interruption.

4.10 Tests facilities and other requirements

4.10.1 General

The spacecraft, subsystem, and unit tests shall be performed using facilities that simulate the environmental exposure within the specified test tolerance and measure the required operational performance. All test facilities shall have current and valid calibration; controls to avoid over- or under-testing; proven software operational programmes; and controlled temperature, humidity and cleanliness.

4.10.2 Test condition tolerances

Test condition tolerances and measuring precision shall be determined on the basis of the performance of test facilities, and others shall be determined by the design standard. Test levels and duration for the design standard should be consistent with the launch environment determined by the launch service providers according to ISO 14303.

4.10.3 Instrumentation

The instruments to be used for tests shall be calibrated periodically to remain accurate, and each instrument shall have an expiration date. The calibration shall be carried out in accordance with ISO/IEC 17025.

5 Spacecraft system tests

5.1 Test items and sequence

Test items and their sequence shall be defined in a verification/test plan and established early in the programme or campaign. Table 1 shows all possible tests from which the set of qualification tests (QTs), acceptance tests (ATs), and proto-flight tests (PFTs) is selected. A minimum test series shall include all items marked as R.

5.2 Test levels and duration

Test levels and duration shall be determined on the basis of the environments to which the system will be exposed, and others shall be determined by the design standard. The launch environment shall be determined by the launch service providers.

6 Subsystem/unit tests

6.1 Test items and sequence

The test items and their sequence shall be defined in a verification plan and established early in the programme or campaign. The set of QTs may include some or all tests described in Table 2. The set of ATs may include some or all tests described in Table 3. The set of PFTs may include some or all tests described in Table 4.

6.2 Test levels and duration

Test levels and duration shall be determined on the basis of the environments to which the subsystem/unit will be exposed during the service life of the system. The system supplier shall derive the maximum predicted values, as maximum load (AT levels and duration) for each subsystem/unit test.

Table 1 — Spacecraft QT, AT, and PFT items and sequence

Test	Reference sub-clause	Suggested sequence [a]	Minimum test series		
			QT	AT	PFT
Functional	7.2	1, 15	R	R	R
EMC	7.3	2	R	O	R
Magnetic field	7.4	19	O	O	O
Antenna pattern [d]	7.5	—	—	—	—
Optical alignment	7.6	4, 10, 16	R	R	R
Physical properties	7.7	5	R	R	R
Dynamic balance	7.8	20	O	O	O
Launcher/spacecraft interface	7.9	—	R	R	R
Static load [d]	7.10	—	—	—	—
Acceleration [d]	7.11	—	—	—	—
Modal survey [b]	7.12	6	R	O	R
Sinusoidal vibration	7.13	7	R	R	R
Random vibration [c]	7.14	8	R	R	R

Key

R required

O optional, shall be evaluated

— not required

[a] The test sequence suggested may be modified according to the efficiency of the operation, schedule of test facilities and effects to detect malfunctions. However, the following principles shall not be changed:

1) Functional tests shall be conducted at the beginning and end of each environmental test, at a minimum.

2) The leakage test and alignment check shall be conducted at the beginning and end of the environmental tests, at a minimum.

[b] Some cases can be replaced by a combination of analysis and/or modal survey.

[c] Either vibration or acoustic test is recommended, whichever is more appropriate, with the other discretionary.

[d] These tests are mainly applied to subsystem and unit level.

Table 1 *(continued)*

Test	Reference sub-clause	Suggested sequence [a]	Minimum test series		
			QT	AT	PFT
Acoustic [c]	7.15	8	R	R	R
Shock	7.16	9	R	O	R
Thermal balance	7.17	13	R	O	R
Thermal vacuum	7.18	14	R	R	R
Thermal cycle	7.19	12	O	O	O
Pressure	7.20	17	R	R	R
Leakage	7.21	3, 11, 18	R	R	R
Burn in and wear in [d]	7.22	—	—	—	—
Tracking and control system/spacecraft compatibility	7.23	—	R	R	R

Key

R required

O optional, shall be evaluated

— not required

[a] The test sequence suggested may be modified according to the efficiency of the operation, schedule of test facilities and effects to detect malfunctions. However, the following principles shall not be changed:

1) Functional tests shall be conducted at the beginning and end of each environmental test, at a minimum.

2) The leakage test and alignment check shall be conducted at the beginning and end of the environmental tests, at a minimum.

[b] Some cases can be replaced by a combination of analysis and/or modal survey.

[c] Either vibration or acoustic test is recommended, whichever is more appropriate, with the other discretionary.

[d] These tests are mainly applied to subsystem and unit level.

Table 2 — Subsystem/unit QT items and sequence

Test	Reference subclause	Suggested sequence [a]	Minimum test series											
			Electrical and electronic	Antenna	MMA	Solar array	Battery	Valve	Propulsion	Pressure vessel	Thruster	Thermal	Optical	Structural
Functional	7.2	4, 13, 20	R	R [c]	R	R	R	R	R	R	R	R	R	—
EMC	7.3	21	R	O	O	—	—	—	—	—	—	—	—	—
Magnetic field	7.4	22	O	—	O	—	O	R	O	O	O	—	O	—
Antenna pattern	7.5	—	—	R [c]	—	—	—	—	—	—	—	—	—	—
Optical alignment	7.6	5, 12, 18	—	O	—	—	—	—	—	—	O	—	O	O
Physical property	7.7	2, 24	R	R	R	R	R	R	R	R	R	R	R	R
Dynamic balance	7.8	—	—	—	—	—	—	—	—	—	—	—	—	—
Launcher/spacecraft interface	7.9	—	—	—	—	—	—	—	—	—	—	—	—	—
Static load	7.10	1	O[d]	O[d]	O[d]	O[d]	O[d]	—	—	O[d]	—	—	O[d]	R[d]
Acceleration	7.11	3	O[d]	O[d]	O[d]	O[d]	O[d]	—	—	O[d]	—	—	O[d]	R[d]
Modal survey	7.12	7	O	R	O	R	O	—	O	O	O	O	O	R
Sinusoidal vibration	7.13	8	O	O	R	O	R	O	O	R	R	O	O	R
Random vibration	7.14	9	R	R [b]	R	R [b]	R	R	R	R	R	R	R [b]	R [b]

Key

R required

O optional, shall be evaluated

— not required

[a] The test sequence suggested may be modified according to the efficiency of the operation, schedule of test facilities and effects to detect malfunctions. However, the following principles shall not be changed:

1) Functional tests shall be conducted at the beginning and end of each environmental test, at a minimum.

2) The leakage test and alignment check shall be conducted at the beginning and end of the environmental tests, at a minimum.

[b] Either random vibration or acoustic test is recommended, whichever is more appropriate, with the other discretionary.

[c] Usually, antenna pattern test is performed as part of functional test.

[d] Either static load or acceleration is recommended, as appropriate, with the other discretionary.

[e] Either thermal vacuum or thermal cycle is recommended, whichever is more appropriate, with those that vacuum is not perspective to potential failure, thermal cycle may replace thermal vacuum in case of thermal temperature is equivalent.

Table 2 *(continued)*

Test	Reference subclause	Suggested sequence [a]	Minimum test series											
			Electrical and electronic	Antenna	MMA	Solar array	Battery	Valve	Propulsion	Pressure vessel	Thruster	Thermal	Optical	Structural
Acoustic	7.15	9	O	R [b]	—	R [b]	—	—	—	—	—	R	R [b]	R [b]
Shock	7.16	10	R	O	O	O	O	O	O	—	O	O	O	R
Thermal balance	7.17	15	O	O	O	O	O	—	O	—	—	O	O	—
Thermal vacuum	7.18	16	R [e]	R	R	R	R	R	R	O	R	R	R	—
Thermal cycle	7.19	14	R [e]	O	O	O	O	O	O	O	O	O	O	O
Pressure	7.20	17	—	—	O	—	R	R	R	R	R	—	—	—
Leakage	7.21	6, 11, 19	O	—	O	—	R	R	R	R	O	R	—	—
Burn in and wear in	7.22	23	—	—	O	—	—	—	—	—	—	—	—	—

Key

R required

O optional, shall be evaluated

— not required

[a] The test sequence suggested may be modified according to the efficiency of the operation, schedule of test facilities and effects to detect malfunctions. However, the following principles shall not be changed:

1) Functional tests shall be conducted at the beginning and end of each environmental test, at a minimum.

2) The leakage test and alignment check shall be conducted at the beginning and end of the environmental tests, at a minimum.

[b] Either random vibration or acoustic test is recommended, whichever is more appropriate, with the other discretionary.

[c] Usually, antenna pattern test is performed as part of functional test.

[d] Either static load or acceleration is recommended, as appropriate, with the other discretionary.

[e] Either thermal vacuum or thermal cycle is recommended, whichever is more appropriate, with those that vacuum is not perspective to potential failure, thermal cycle may replace thermal vacuum in case of thermal temperature is equivalent.

Table 3 — Subsystem/units AT items and sequence

Test	Reference sub-clause	Suggested sequence [a]	Minimum test series											
			Electrical and electronic	Antenna	MMA	Solar array	Battery	Valve	Propulsion	Pressure vessel	Thruster	Thermal	Optical	Structural
Functional	7.2	2, 14	R	R [c]	R	R	R	R	R	R	R	R	R	—
EMC	7.3	15	O	—	—	—	—	—	—	—	—	—	—	—
Magnetic field	7.4		—	—	—	—	—	—	—	—	—	—	—	—
Antenna pattern	7.5	—	—	R [c]	—	—	—	—	—	—	—	—	—	—
Optical alignment	7.6	3, 12	—	O	—	—	—	—	—	—	—	—	O	—
Physical property	7.7	1, 17	R	R	R	R	R	R	R	R	R	R	R	R
Dynamic balance	7.8	—	—	—	—	—	—	—	—	—	—	—	—	—
Launcher/spacecraft interface	7.9	—	—	—	—	—	—	—	—	—	—	—	—	—
Static load	7.10	—	—	—	—	—	—	—	—	—	—	—	—	—
Acceleration	7.11	—	—	—	—	—	—	—	—	—	—	—	—	—
Modal survey	7.12	5	O	O	O	O	O	—	O	O	—	—	O	O
Sinusoidal vibration	7.13	6	O	O	O	O	—	—	O	O	—	—	O	R
Random vibration	7.14	7	R	R [b]	R	R [b]	R	R	R	R	R	R [b]	R	R [b]
Acoustic	7.15	7	O	R [b]	—	R [b]	—	—	—	—	—	R [b]	O	R [b]
Shock	7.16	8	O	—	—	—	—	—	—	—	—	—	—	—

Key

R required

O optional

— not required

[a] The test sequence suggested may be modified according to the efficiency of the operation, schedule of test facilities and effects to detect malfunctions. However, the following principles shall not be changed:

1) Functional tests shall be conducted at the beginning and end of each environmental test, at a minimum.

2) The leakage test and alignment check shall be conducted at the beginning and end of the environmental tests, at a minimum.

[b] Either random vibration or acoustic test is recommended, whichever is more appropriate, with the other discretionary.

[c] Usually, antenna pattern test is performed as part of functional test.

[d] Either thermal vacuum or thermal cycle is recommended, whichever is more appropriate, with those that vacuum is not perspective to potential failure, thermal cycle may replace thermal vacuum.

Table 3 *(continued)*

Test	Reference sub-clause	Suggested sequence [a]	Minimum test series											
			Electrical and electronic	Antenna	MMA	Solar array	Battery	Valve	Propulsion	Pressure vessel	Thruster	Thermal	Optical	Structural
Thermal balance	7.17		—	—	—	—	—	—	—	—	—	—	—	—
Thermal vacuum	7.18	10	R[d]	O	R	O	R	R	O	O	R	R	R	—
Thermal cycle	7.19	9	R[d]	O	O	O	O	O	O	—	—	—	—	—
Pressure	7.20	11	—	—	O	—	R	R	R	R	O	—	—	—
Leakage	7.21	4, 13	O	—	O	—	R	R	R	R	O	R	—	—
Burn in and wear in	7.22	16	R	—	O	—	—	R	—	—	R	—	—	—

Key

R required

O optional

— not required

[a] The test sequence suggested may be modified according to the efficiency of the operation, schedule of test facilities and effects to detect malfunctions. However, the following principles shall not be changed:

1) Functional tests shall be conducted at the beginning and end of each environmental test, at a minimum.

2) The leakage test and alignment check shall be conducted at the beginning and end of the environmental tests, at a minimum.

[b] Either random vibration or acoustic test is recommended, whichever is more appropriate, with the other discretionary.

[c] Usually, antenna pattern test is performed as part of functional test.

[d] Either thermal vacuum or thermal cycle is recommended, whichever is more appropriate, with those that vacuum is not perspective to potential failure, thermal cycle may replace thermal vacuum.

Table 4 — Subsystem/units PFT items and sequence

Test	Reference subclause	Suggested sequence [a]	Minimum test series											
			Electrical and electronic	Antenna	MMA	Solar array	Battery	Valve	Propulsion	Pressure vessel	Thruster	Thermal	Optical	Structural
Functional	7.2	4, 13, 20	R	R [c]	R	R	R	R	R	R	R	R	R	—
EMC	7.3	21	R	O	O	—	—	—	—	—	—	—	—	—
Magnetic field	7.4	22	O	—	O	—	O	O	O	O	O	—	O	—
Antenna pattern	7.5	—	—	R [c]	—	—	—	—	—	—	—	—	—	—
Optical alignment	7.6	5, 12, 18	—	O	—	—	—	—	—	—	O	—	O	O
Physical property	7.7	2, 24	R	R	—	R	R	R	R	R	R	R	R	R
Dynamic balance	7.8	—	—	—	—	—	—	—	—	—	—	—	—	—
Launcher/spacecraft interface	7.9	—	—	—	—	—	—	—	—	—	—	—	—	—
Static load	7.10	1	O [d]	O [d]	O [d]	O [d]	O [d]	—	—	O [d]	—	—	O [d]	O [d]
Acceleration	7.11	3	O [d]	O [d]	O [d]	O [d]	O [d]	—	—	O [d]	—	—-	O [d]	O [d]
Modal survey	7.12	7	O	R	O	R	O	—	O	O	O	O	O	R
Sinusoidal vibration	7.13	8	O	O	R	O	R	O	O	R	R	O	O	R
Random vibration	7.14	9	R	R [b]	R	R [b]	R	R	R	R	R	R	R [b]	R [b]
Acoustic	7.15	9	O	R [b]	—	R [b]	—	—	—	—	—	R	R [b]	R [b]

Key

R required

O optional

— not required

[a] The test sequence suggested may be modified according to the efficiency of the operation, schedule of test facilities and effects to detect malfunctions. However, the following principles shall not be changed:

1) Functional tests shall be conducted at the beginning and end of each environmental test, at a minimum.

2) The leakage test and alignment check shall be conducted at the beginning and end of the environmental tests, at a minimum.

[b] Either random vibration or acoustic test is recommended, whichever is more appropriate, with the other discretionary.

[c] Usually, antenna pattern test is performed as part of functional test.

[d] Either static load or acceleration is recommended, as appropriate, with the other discretionary.

[e] Either thermal vacuum or thermal cycle is recommended, whichever is more appropriate, with those that vacuum is not perspective to potential failure, thermal cycle may replace thermal vacuum in case of thermal temperature is equivalent.

Table 4 *(continued)*

Test	Reference sub-clause	Suggested sequence [a]	Minimum test series											
			Electrical and electronic	Antenna	MMA	Solar array	Battery	Valve	Propulsion	Pressure vessel	Thruster	Thermal	Optical	Structural
Shock	7.16	10	O	O	O	O	O	O	O	—	O	O	O	R
Thermal balance	7.17	15	O	O	O	O	O	—	O	—	—	O	O	—
Thermal vacuum	7.18	16	R[e]	R	R	R	R	O	O	O	R	R	R	—
Thermal cycle	7.19	14	R[e]	O	O	O	O	O	O	—	—	—	—	—
Pressure	7.20	17	—	—	O	—	R	R	R	R	R	—	—	—
Leakage	7.21	6, 11, 19	O	—	O	—	R	R	R	R	O	R	—	—
Burn in and wear in	7.22	23	R	—	O	—	—	R	—	—	R	—	—	—

Key

R required

O optional

— not required

[a] The test sequence suggested may be modified according to the efficiency of the operation, schedule of test facilities and effects to detect malfunctions. However, the following principles shall not be changed:

1) Functional tests shall be conducted at the beginning and end of each environmental test, at a minimum.

2) The leakage test and alignment check shall be conducted at the beginning and end of the environmental tests, at a minimum.

[b] Either random vibration or acoustic test is recommended, whichever is more appropriate, with the other discretionary.

[c] Usually, antenna pattern test is performed as part of functional test.

[d] Either static load or acceleration is recommended, as appropriate, with the other discretionary.

[e] Either thermal vacuum or thermal cycle is recommended, whichever is more appropriate, with those that vacuum is not perspective to potential failure, thermal cycle may replace thermal vacuum in case of thermal temperature is equivalent.

7 Test requirements

7.1 General

Test requirements specified in this section shall apply to all levels of test articles, including spacecraft, subsystems and units, as appropriate. Test specifications are different in imposed levels and duration among models (qualification, flight and proto-flight). Since such quantitative requirements are not specified in the subclauses identified by test levels and duration, it is presupposed that requirements for each model are specified by test specifications accepted by procurement and launch service providers as appropriate.

7.2 Functional test

7.2.1 Purpose of test

The functional test verifies that the electrical and mechanical performance of the test article meet specification requirements.

7.2.2 Test facilities and set-up as basic requirements

Electrical tests shall include application of expected voltages, impedance, frequencies, pulses and wave forms at the electrical interface of the test article, including all redundant circuits.

Mechanical tests shall include application of torques, loads, and motion of mechanisms as appropriate. These parameters shall be varied throughout their specification range and the sequence of operation expected in flight. Test results shall be used to verify the test article performance with respect to specifications.

Functional test shall also include electrical continuity, stability, response time, or other special functional tests related to a particular configuration.

7.2.3 Test article configuration

Functional tests shall also be performed while the environment is being imposed, if the test article is expected to be fully operational in that environment (except for solar panels, antennae, propellant, etc. during thermal vacuum test). Simulated thruster valves and batteries shall also be adopted to verify overall compatibility.

7.2.4 Monitoring during test

A database of critical parameters shall be established for trend analysis. Any unusual or unexpected trends shall be evaluated to determine the existence of drift toward out-of-limit value or incipient failure.

7.2.5 Test levels and duration

There are no mandatory requirements.

7.2.6 Test condition and guidelines

The hardware configuration for system and subsystem/unit functional testing shall consist of all flight hardware and applicable flight software. Through the test article environmental tests, sequential functional tests shall confirm that no degradation has occurred. Satisfactory electrical performance shall be demonstrated in all applicable operational modes before, during and after specified environmental exposures. During the test, the spacecraft electrical and mechanical subsystems/units shall be in various operational modes appropriate for launch and orbital configurations. At that time, all subsystems/units shall be powered, if possible. Test requirements for functional tests shall be defined

not only for those tests performed before and after environmental tests, but also for functional and performance verification of the items under test.

7.2.7 Tailoring guide

Complete functional tests shall be performed at the beginning and end of the test sequence. Partial functional test shall be conducted before and after each environmental exposure.

7.3 Electromagnetic compatibility (EMC) test

7.3.1 Purpose of test

The EMC test demonstrates the test article compatibility with the induced environment and ensures that adequate margins exist in a simulated electromagnetic environment during the service life and in all possible operational modes, as applicable.

7.3.2 Test facilities and set-up as basic requirements

Test facilities and set-up shall be prepared for far-field environment and radio frequency (RF) environment, which simulate the actual space environment. External RF signals shall be shielded. Spurious RF reflected signals shall be minimized. Discrimination between spurious and intentional emissions shall be performed for EMC test data evaluation. Telemetry/telecommand and RF communication signals shall be tested using airlink configuration.

7.3.3 Test article configuration

Two configurations shall be tested — the on-orbit configuration, and the pre-launch through plus-count and separation configuration. Electro-explosive devices (EEDs) used to initiate spacecraft functions (such as appendages deployment and separation) shall be replaced by inert EEDs except for bridgewires.

7.3.4 Monitoring during test

During EMC tests, power ripple and peak transients shall be measured. Selected critical parameters shall be monitored.

7.3.5 Test levels and duration

The test program (emission and susceptibility) shall comply with ISO 14302. Supplementary requirements as necessary to achieve EMC compliance are provided by the product provider's specifications and interface documents (launch manual, etc.).

7.3.6 Test condition and guidelines

The operation of spacecraft and selection of instrumentation shall be suitable for determining the margin against malfunctions and unacceptable or undesired responses resulting from electromagnetic incompatibilities. The test shall demonstrate satisfactory electrical and electronic equipment operation in conjunction with the expected electromagnetic radiation and conduction from other subsystems or units, such as from other spacecraft elements and the launcher. The electromagnetic radiation and conduction from the spacecraft shall not disturb the launcher. An electrostatic arc discharge susceptibility test shall be conducted if the spacecraft has the possibility of disturbance that may arise from electrostatic discharge on orbit. Inert EEDs shall be installed and monitored during all tests. EMC between system and subsystem shall be demonstrated functionally with required margins.

7.3.7 Tailoring guide

EMC test shall be performed only once in the test flow for each test article.

7.4 Magnetic test

7.4.1 Purpose of test

The magnetic test determines the magnetic field (e.g. remnant magnetic field, stray magnetic field and induced magnetic field) magnetic moment (e.g. remnant moment, stray magnetic moment, and induced magnetic moment) of the test article and demonstrates compliance with magnetic cleanliness requirements.

7.4.2 Test facilities and set-up as basic requirements

There are no mandatory requirements.

7.4.3 Test article configuration

The on-orbit configuration shall be represented as much as possible.

7.4.4 Monitoring during test

There are no mandatory requirements.

7.4.5 Test levels and duration

The test program shall comply with ISO 21494. Supplementary requirements as necessary to achieve magnetic compliance are provided by the product provider's specifications.

7.4.6 Test condition and guidelines

When a precise estimation of the system-level magnetic moments is required (in which magnetic torque is one major disturbance factor) or a spacecraft carries a magnetic sensitive payload, a magnetic field test shall be conducted on the spacecraft. If necessary, in order to estimate or control spacecraft-level magnetic moments, a subsystem- or unit-level magnetic field test shall be performed.

7.4.7 Tailoring guide

If there are no stringent magnetic cleanliness requirements related to the test article, this test may be replaced by analysis.

7.5 Antenna pattern test

7.5.1 Purpose of test

The antenna pattern test verifies the characteristics of the antenna for spacecraft configuration during launch and orbit operational phases.

7.5.2 Test facilities and set-up as basic requirements

The spacecraft shall be subjected to a comprehensive test programme at an appropriate antenna test facility to accurately determine the radiation pattern and phase (if appropriate) of each spacecraft antenna.

7.5.3 Test article configuration

The test shall be conducted for each spacecraft configuration in which the antennae will be operated. The test article configuration shall be representative of external spacecraft shape, including deployable appendages.

7.5.4 Monitoring during test

There are no mandatory requirements.

7.5.5 Test levels and duration

There are no mandatory requirements.

7.5.6 Test condition and guidelines

There are no mandatory requirements.

7.5.7 Tailoring guide

If it is not possible to perform the antenna pattern test for spacecraft configuration, mock-ups or scale models simulating the spacecraft may be used.

7.6 Optical alignment measurement

7.6.1 Purpose of test

The optical alignment measurement determines if the optical alignments of the test article are within specified tolerances for the spacecraft.

7.6.2 Test facilities and set-up as basic requirements

Test facilities and set-up shall be prepared so the necessary angle may be measured within specified tolerances. Test articles shall be subjected to measurement of the mounted locations and the angles subtended between the spacecraft axes and optical sensors, antennae, nozzles and thrusters.

7.6.3 Test article configuration

The test article shall be equipped with all necessary optical gauging and references so appropriate angles may be measured.

7.6.4 Monitoring during test

There are no mandatory requirements.

7.6.5 Test levels and duration

There are no mandatory requirements.

7.6.6 Test condition and guidelines

In addition to initial baseline alignment measurements, the test shall be performed before and after environment tests (such as vibration and thermal environment) and after major transportation that may affect alignment of test articles.

7.6.7 Tailoring guide

Alignment measurements to be performed before and after thermal environment tests may be omitted if the alignment predicted values demonstrate large margins with respect to specification requirements.

7.7 Physical property measurement

7.7.1 Purpose of test

The physical property measurement determines the physical characteristics of the test article (i.e. dimensions, mass, centre of gravity (CG), and moment of inertia). Dynamic balance tests are described in 7.8.

7.7.2 Test facilities and set-up as basic requirements

The test article shall be installed in facilities capable of measuring physical characteristics.

7.7.3 Test article configuration

The test article shall be in launch configuration. Any flight items that cannot be installed and any non-flight items (such as testing fixtures) that cannot be removed shall be compensated for by analysis.

7.7.4 Monitoring during test

There are no mandatory requirements.

7.7.5 Test levels and duration

There are no mandatory requirements.

7.7.6 Test condition and guidelines

The test conditions and guidelines shall measure parameters of dimensions, mass, centre of gravity and moment of inertia that are required in predicting vehicle performance during boost and spacecraft orientation during injection and orbit. If measurements are performed with an empty tank, a correlation with the analytical model (tank full) shall be done.

7.7.7 Tailoring guide

If the analysis of physical properties has large margins, this test may be omitted, except for mass measurement.

7.8 Dynamic balance

7.8.1 Purpose of test

The dynamic balance test compensates unbalances such as centre of gravity offset and product of inertia around the defined coordinate axes (normally the geometric spin axis). This test shall be performed for sensors, spacecraft or upper stages that have balance requirements that cannot be verified by analysis.

7.8.2 Test facilities and set-up as basic requirements

The test article shall be installed on the appropriate dynamic balance machine.

7.8.3 Test article configuration

The test article shall be as closely representative as possible of the configuration of critical balance for the mission. If dynamic balance testing is done with empty tanks, a correlation with the analytical model (tank full) shall be done. Any flight items that cannot be installed and any non-flight items (such as testing fixtures) that cannot be removed shall be compensated for by analysis.

7.8.4 Monitoring during test

There are no mandatory requirements.

7.8.5 Test levels and duration

Test accuracy and duration depend on mission profile and spin rates.

7.8.6 Test condition and guidelines

The initial balance if required shall verify the feasibility of attaining the stipulated final balance and evaluate the method of attaching the balance mass and its effect on the operation of the test article during environmental tests. The final balance is performed to properly adjust for all changes to mass distribution made during the test programme, such as unit replacement or redesign. It is recommended that changes to the system that may affect weight distribution be minimized after completion of the final balance test.

7.8.7 Tailoring guide

When the required accuracy can be met, small mass items that may not be assembled during test shall be accounted for by analysis.

7.9 Launcher/spacecraft interface test

7.9.1 Purpose of test

The launcher/spacecraft interface test shall be performed to verify the interfaces between launcher and spacecraft, which are defined in ISO 14303.

7.9.2 Test facilities and set-up as basic requirements

The test article shall be tested in facilities capable of handling the spacecraft.

7.9.3 Test article configuration

The physical/electrical interface of the test article shall be in launch configuration.

7.9.4 Monitoring during test

Requirements concerning monitoring during test are derived from the respective launch vehicle user manual and spacecraft design standard.

7.9.5 Test levels and duration

Test levels and duration are derived from the respective launch vehicle user manual and spacecraft design standard.

7.9.6 Test condition and guidelines

A team composed of both the launcher and spacecraft side shall perform this test. The location and time of each test shall be determined by launcher and spacecraft coordination. The verification of electrical interface shall be performed before launch site test except for clean interface. The measurement of interface dimensions, or fit checks, shall be performed with master gauges to verify the mechanical interface. The optional umbilical connector pull-out test checks separation.

7.9.7 Tailoring guide

There are no mandatory requirements.

7.10 Static load test

7.10.1 Purpose of test

The static load test demonstrates the ability of the primary structure of a spacecraft or a large structural subsystem (for example, antenna, solar panel, observation instrument) to sustain the quasi-static loads induced by the launch vehicle, apogee boost motor and spin motion.

7.10.2 Test facilities and set-up as basic requirements

The support and load fixture shall duplicate the boundary conditions and the load levels of the flight environment. Primary structure shall be mounted on a test fixture that has the same structural characteristics as the spacecraft adapter. Large structural subsystem shall be mounted on a support fixture that duplicates spacecraft interface.

7.10.3 Test article configuration

The model to which the static load test is applied shall have the same configuration, material and production process as those of the flight model.

7.10.4 Monitoring during test

Strain and deformation shall be recorded during test and after removal of the test load; and, if required, the loads shall be increased until structural failure occurs in order to evaluate the design margin.

7.10.5 Test levels and duration

The loads shall be increased step by step until the stipulated test load is applied. At each load level, strain and deformation shall be recorded. Considering the critical flight temperature and load combinations, load levels shall be determined so the expected worst-case stress may be applied. Dwell time at each load level shall be the minimum time required to complete recording of stress, strain, deformation and temperature.

7.10.6 Test condition and guidelines

The test conditions shall encompass the extreme predicted combined effects of acceleration, vibration, pressure and temperature. These effects may be simulated in the test conditions as long as the combined effects are covered by the design margins.

7.10.7 Tailoring guide

A large centrifuge acceleration test facility or shaker excitation may be used in place of the stationary test method.

7.11 Acceleration test

7.11.1 Purpose of test

The acceleration test is intended for a unit sensitive to static acceleration. It shall be performed to determine the ability of a unit to maintain structural integrity and operate correctly when it is subjected to constant acceleration generated during the launch.

7.11.2 Test facilities and set-up as basic requirements

The test article shall be attached, as it is during the launch, to a test fixture, and subjected to acceleration in the appropriate directions.

7.11.3 Test article configuration

The test article shall be mounted to a test fixture through its normal mounting points. If necessary, the test article shall be protected by a shroud. The test article shall be tested in each of three mutually perpendicular axes, if other conditions are not determined by the test programme.

7.11.4 Monitoring during test

Before and after each acceleration test, electrical performance and mechanical functioning tests of the test article shall be performed.

7.11.5 Test levels and duration

Test levels and duration are specified in the respective launch vehicle user manual.

7.11.6 Test condition and guidelines

The specified acceleration shall be applied to the centre of gravity of the test item. If a centrifuge is used, the arm (measured to the geometric centre of the test item) shall be longer than the dimension of the test item measured along the arm. The acceleration gradient across the test item shall not result in acceleration that falls below the qualification level on any critical member of the test item. Inertial units (such as gyroscopes and platforms) may require counter-rotating fixtures on the centrifuge arm.

7.11.7 Tailoring guide

There are no mandatory requirements.

7.12 Modal survey

7.12.1 Purpose of test

The modal survey test determines experimentally the natural frequency, mode shapes and damping factors of the test article throughout the dynamically relevant range. Results of a modal survey determine whether or not any natural frequencies fall into an undesirable range and/or adjust the natural frequencies and modes determined analytically with the help of a finite element mathematical model of the structural system. Once the latter is in good agreement with the physical system, it may be used to predict structural responses.

7.12.2 Test facilities and set-up as basic requirements

There are three typical methods: base excitation, single-point excitation, and multiple-point excitation. In each case, the boundary condition shall be carefully considered in order not to affect its natural frequencies and mode shapes.

7.12.3 Test article configuration

The test article shall be the flight or qualification model to the maximum extent practicable. If simulators are used as subsystems/units, they shall be representative of the omitted subsystems/units in mass, and the centre of gravity shall be designed not to stiffen the test article.

7.12.4 Monitoring during test

Instrumentation shall be adequate to verify the analytical model for main structural modes in the range of interest.

7.12.5 Test levels and duration

There are no mandatory requirements.

7.12.6 Test condition and guidelines

In general, support of the test article during test shall duplicate the boundary conditions expected during launch. When that is not feasible, other boundary conditions shall be employed and the frequency of the test shall be adjusted accordingly. Interface flexibility shall be considered when other-than-normal boundary conditions are used. Any test method capable of meeting the test objectives with necessary accuracy may be used to perform the modal survey. The input-forcing function may be transient, fixed frequency, sweep sine wave or random nature.

7.12.7 Tailoring guide

After an acceptable modal survey as defined by programme requirement has been conducted on a representative structural model, a modal survey of the flight and the proto-flight models may be unnecessary. A representative structural model is defined as one that duplicates the structure in materials, configuration, fabrication and assembly methods. It is also one that satisfactorily simulates other items mounted on the structure in location, method of attachment and physical properties.

7.13 Sinusoidal vibration test

7.13.1 Purpose of test

The sinusoidal vibration test demonstrates that the test article can withstand low-frequency excitations of the launch vehicle or other self-induced sinusoidal vibration environments.

7.13.2 Test facilities and set-up as basic requirements

The test article shall be placed in a vibration test facility capable of generating sufficient vibration for the test requirement. The test article shall be mounted to a fixture at the normal mounting points. Vibrations shall be applied in three mutually orthogonal directions, one being parallel to the thrust axis.

7.13.3 Test article configuration

The test article shall be in launch configuration. Propellant tanks may be empty during spacecraft testing, provided the filled-tank configuration has been test-validated. Antennae and other devices that extend or change position after orbital injection shall be in launch configuration during the test article response.

7.13.4 Monitoring during test

During system vibration test, the test article shall be operated in a duty cycle typical of that to be employed at the launch phase and monitored for malfunctions in telemetry and all other systems that operate during boost. Subsystem and unit tests shall be performed with the article powered. Exact requirements for such monitoring shall be specified in the test plan for a particular test article.

7.13.5 Test levels and duration

Test levels and duration are derived from the respective launch vehicle user manual and spacecraft design standard. The final requirements shall be specified in the test specification reflecting the strategy defined in the verification plan considering other factors.

7.13.6 Test condition and guidelines

The required conditions of the sinusoidal vibration test are as follows:

a) accelerometer and shaker control:

For sinusoidal vibration test, at least one control accelerometer shall be attached rigidly on the test fixture near the fixture-spacecraft adapter interface and aligned with the axis of applied vibration. Sinusoidal excitations shall be applied at the base of the mounting adapter.

b) requirements for pressurized vessels:

Normally, sealed units shall be pressurized to their prelaunch pressure. In cases of significant changes in strength, stiffness or applied loads resulting from variations in internal or external pressure during launch phase, a special vibration test shall be performed to evaluate those effects.

If the filling material is toxic or explosive, a fluid or gas having equivalent physical properties of no toxicity and no adverse effect on the test article shall be used.

7.13.7 Tailoring guide

Notching shall be used to prevent the overstress and shall be based on the coupled load analysis. These cases concern items having fundamental frequencies below 100 Hz. Notching procedures may be acceptable during vibration testing by agreement with the contracting authority.

7.14 Random vibration test

7.14.1 Purpose of test

The random vibration test demonstrates that the test article can withstand the random vibration environment imposed during its service life.

7.14.2 Test facilities and set-up as basic requirements

The test article shall be placed in a vibration test facility capable of generating sufficient vibration for the test requirement environment. The test article shall be mounted to a fixture at the normal mounting points. Random excitations shall be applied in three mutually orthogonal directions, one being parallel to the thrust axis.

7.14.3 Test article configuration

The test article shall be in launch configuration. Propellant tanks may be empty during spacecraft testing, provided that the filled-tank configuration has been test-validated. Antennae and other devices that extend or change position after orbital injection shall be in launch configuration during the test article response.

7.14.4 Monitoring during test

During system vibration test, the test article shall be operated in a duty cycle typical of that to be employed at the launch phase and monitored for malfunctions in telemetry and all other systems that operate during boost. Subsystem and unit tests shall be performed with the article powered. Exact requirements for such monitoring shall be specified in the test plan for a particular test article.

7.14.5 Test levels and duration

Test levels and duration are specified in the respective launch vehicle user manual and spacecraft design standard; however, the final requirements shall be specified in the test specification reflecting the strategy defined in the verification plan.

7.14.6 Test condition and guidelines

The required conditions of the random vibration test are as follows:

a) accelerometer and shaker control:

For random vibration test, at least one control accelerometer shall be attached rigidly on the test fixture near the fixture-spacecraft adapter interface and aligned with the axis of applied vibration. Random excitations shall be applied at the base of the mounting adapter.

b) requirements for pressurized vessels:

Normally, sealed units shall be pressurized to their prelaunch pressure. In cases of significant changes in strength, stiffness or applied loads resulting from variations in internal or external pressure during launch phase, a special vibration test shall be performed to evaluate those effects.

If the filling material is toxic or explosive, a fluid or gas having equivalent physical properties of no toxicity and no adverse effect on the test article shall be used.

7.14.7 Tailoring guide

Random vibration tests may be waived if acoustic tests are to be performed, provided that the acoustic input envelops the structure-borne input at the article mounting location. The selection of either of these tests is specified in the test specification of a particular test article.

7.15 Acoustic test

7.15.1 Purpose of test

The acoustic test demonstrates the ability of the test article to endure acoustic levels imposed by the launch vehicle and validates unit random test levels. The test program shall comply with ISO 19924.

7.15.2 Test facilities and set-up as basic requirements

The test article shall be installed in an acoustic test facility capable of generating sound fields at or above the levels imposed by the launch vehicle.

7.15.3 Test article configuration

The test article shall be in launch configuration. Propellant tanks may be empty during spacecraft testing, provided that the filled-tank configuration has been test-validated. Significant fluid and pressure conditions shall be replicated to the extent practicable. Appropriate dynamic instrumentation shall be installed to validate test article responses.

7.15.4 Monitoring during test

During the tests, the test article shall be operated in a duty cycle typical of that to be employed at launch and during boost and monitored to verify that interface and interoperability requirements are met.

7.15.5 Test levels and duration

Test levels and duration are specified in the respective launch vehicle user manual and design standard.

7.15.6 Test condition and guidelines

Normally, sealed units shall be pressurized to their prelaunch pressure. If the filling material is toxic or explosive, a fluid or gas having equivalent physical properties of no toxicity and no adverse effect on the test article shall be used. In the test, the chamber sound pressure level and test article structure response acceleration shall be measured.

7.15.7 Tailoring guide

The random vibration test may be conducted instead of an acoustic test for small, compact test articles that can be exited more effectively via interface vibration than by an acoustic field.

If strength, stiffness, and applied loads resulting from changes of internal and external pressure are not changed significantly or can be estimated with enough accuracy, the pressurized units may not need to be pressurized.

7.16 Shock test

7.16.1 Purpose of test

The shock test demonstrates the capability of the test article to meet requirements during and after exposure to the shock environment during its service life.

7.16.2 Test facilities and set-up as basic requirements

The test article in a flight configuration shall be installed in a shock test facility capable of generating shock transient time histories and shock response spectra simulating the environment. Where feasible, flight structure and flight duplicate shock-producing hardware may be employed.

7.16.3 Test article configuration

The test article shall be supported and configured to allow flight-like dynamic response of the article with respect to amplitude, frequency content, and paths of transmission.

7.16.4 Monitoring during test

During the tests, the test article shall be operated and monitored for malfunctions.

7.16.5 Test levels and duration

Test levels and duration are specified in the respective launch vehicle user manual and spacecraft design standard.

7.16.6 Test condition and guidelines

Test conditions shall be determined by the type of shock and shock phase.

7.16.7 Tailoring guide

If the specified shock spectrum is enveloped by the random vibration spectrum and propagation path and damping characteristics are well known, the shock test may be eliminated.