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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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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