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Space systems — General test methods for space craft, subsystems and units

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

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ISO copyright office
Case postale 56 • CH-1211 Geneva 20
Tel. + 41 22 749 01 11
Fax + 41 22 749 09 47
E-mail copyright@iso.org
Web www.iso.org

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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.

International Standards are drafted in accordance with the rules given in the ISO/IEC Directives, Part 2.

The main task of technical committees is to prepare International Standards. Draft International Standards adopted by the technical committees are circulated to the member bodies for voting. Publication as an International Standard requires approval by at least 75 % of the member bodies casting a vote.

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.

ISO 15864 was prepared by Technical Committee ISO/TC 20, *Aircraft and space vehicles*, Subcommittee SC 14, *Space systems and operations*.

Introduction

Throughout this International Standard, the minimum essential criteria are identified by the use of the key word “shall”. Recommended criteria are identified by the use of the key word “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.

Space systems — General test methods for space craft, subsystems and units

1 Scope

This International Standard 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.

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 International Standard may be tailored for each specific space programme application.

2 Normative references

The following referenced documents are indispensable for the application 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*

3 Terms, definitions and abbreviated terms

3.1 Terms and definitions

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

3.1.1
development model
representative of spacecraft, subsystem or unit dedicated to increase confidence in design and subjected to development tests

3.1.2
flight model
spacecraft, subsystem or unit model dedicated to be launched and operated in orbit and subjected to acceptance testing

3.1.3
limit load
maximum predicted load or combination of loads that a structure may experience during its service life in association with the applicable operating environments

3.1.4
maximum and minimum predicted temperatures
highest and lowest temperatures that can be expected to occur during the entire life cycle of the subsystem/unit in all operational modes plus an uncertainty factor

3.1.5
operational modes
modes for spacecraft, subsystems and units 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.

3.1.6
proto-flight model
model that is subjected to the qualification levels and acceptance duration

3.1.7
qualification model
spacecraft, subsystem, or unit dedicated to qualifying the design of flight model and subjected to qualification testing

3.1.8
quasi-static load
load with magnitude and direction that are independent of time; or load that varies slowly and in which dynamic response of the structure is insignificant

NOTE This load can be induced by steady wind, aerodynamic forces, thrust (constant or wind slow variations), maneuvers and spin stabilization.

3.1.9
spacecraft
vehicle of an integrated set of subsystems and units capable of supporting an operational role in space

3.1.10
subsystem
assembly of functionally related units

3.1.11
test article
spacecraft, subsystem or unit on which a test is conducted

3.1.12
test facility
location (including equipment, fixture and instrumentation) capable of performing a test

3.1.13
unit
lowest level of hardware assembly for which acceptance and qualification tests are required

3.2 Abbreviated terms

AT acceptance test

CG center of gravity

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

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 nonconformances;

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. This International Standard 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 fulfill 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 maximum environment duration with 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 to the extent practicable 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

It shall be recognized that the proto-flight approach presents a higher risk than the approach in which design margins are demonstrated by the testing of a dedicated nonflight qualification item. Moreover, programmatic realities of limited production, tight schedules, and budgetary limits do not always allow the use of dedicated nonflight 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 not to expend a significant portion of the useful life of the hardware. 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 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 as necessary, 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 nonconformance

If nonconformance occurs during testing activities, necessary action shall be taken in accordance with the test procedure, and the causes of nonconformance shall be identified. If nonconformance 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 nonconformance did not overstress the test items. If nonconformance caused in the test items is disposed, initial failure analysis and 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 nonconformance does not affect continuity of the test.

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 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 test objectives in 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 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 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 tape 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.