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Space systems — Ground test for the separation between a launch vehicle and a spacecraft — Requirements for combined separation tests, horizontal separation tests and individual falling separation tests

Systèmes spatiaux — Essais au sol pour la séparation entre un lanceur et un engin spatial — Exigences relatives aux essais de séparation combinée, aux essais de séparation horizontale et aux essais de séparation par chute individuelle

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Foreword

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

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

The separation between the launch vehicle and the spacecraft on orbit is a critical activity for a successful orbit injection. Any failure during the separation can cause serious consequences. A separation test on ground between the spacecraft and the launch vehicle is an effective way to simulate and test the characteristics of the separation, to reveal the risk of failure of the separation system between the launch vehicle and the spacecraft, and to improve the separation function during the separation on orbit. This document provides three typical separation test methods, which are the combined separation test, the horizontal separation test and the individual falling separation test, for different application scenarios.

The overview and interdependencies of test methods are illustrated in Annex A. For the testing of separation movements and separation dynamics between launch vehicle and spacecraft with zero-gravity effect or no acceleration conditions at the time of separation, the separation test may take the form of combined separation test or horizontal separation test as illustrated in Annex B and Annex D respectively. For the testing of separation with purposes of fit-check and shock-response-level confirmation, the test may take the form of individual falling separation test as illustrated in Annex C.

Apart from these three separation test methods, there are many other methods of verifying separation systems and processes, such as modelling the systems or processes, comparing similarity with existing systems or processes, which may apply to different scenarios with consistency. This document does not deny the use of these useful methods in the simulating and testing of the characteristics of the separation.

The technical requirements in this document may be tailored to meet the objectives of tests as the separation objectives can be different for different projects or for different development stages.

Space systems — Ground test for the separation between a launch vehicle and a spacecraft — Requirements for combined separation tests, horizontal separation tests and individual falling separation tests

1 Scope

This document provides the test requirements of three typical separation test methods, which are the combined separation test, the horizontal separation test, the individual falling separation test, for the separation between the launch vehicle (LV) and the spacecraft (or between stages of a prototype LV model). It also provides the requirements for the separation test unit, test data, test timing and sequence, pre-test simulation, test environment, exception handling, test results assessment, test documentation, test facilities, test installation, preliminary adjustment of the test setup, measurement and data acquisition.

This document is applicable to test providers and interested parties to implement the separation test between the launch vehicle and the spacecraft.

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 14620-1:2018, *Space systems — Safety requirements — Part 1: System safety*

ISO 15864:2021, *Space systems — General test methods for spacecraft, subsystems and units*

ISO 22137, *Space systems — Program management — Test reviews*

3 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 https://www.electropedia.org/

3.1
combined separation test
test in which a combination of spacecraft parts and launch vehicle parts drops simultaneously from the hanging point

Note 1 to entry: The test articles finish the separation movements before being captured during the separation test.

3.2
fit check
check to verity the matching consistencies of the electrical interface and the mechanical interface between the spacecraft and the launch vehicle to some degree

Note 1 to entry: This check usually consists of an electrical interface check and a mechanical interface check between the spacecraft and the launch vehicle before the separation test.

3.3
horizontal separation test
test in which a combination of spacecraft parts and launch vehicle parts is separated horizontally

3.4
individual falling separation test
test in which a combination of spacecraft parts and launch vehicle parts is separated vertically and either spacecraft parts or launch vehicle parts fall down from the combination

3.5
launch vehicle stages separation system
assembly of functionally related subsystems and/or units for the separation between launch vehicle stages

3.6
mating and unlocking device
device that connects the spacecraft and the launch vehicle together before separation and disconnects the linkage between the spacecraft and the launch vehicle at the time of separation

3.7
separation impulse device
device that provides the energy to separate the spacecraft from the launch vehicle

3.8
separation system between launch vehicle and spacecraft
assembly of functionally related subsystems and/or units for the separation between launch vehicle and spacecraft

3.9
test article
spacecraft, subsystem or unit on which a test is conducted

Note 1 to entry: For this document the definition is extended to address also launch vehicle system, subsystem or unit.

3.10
separation test unit
assembly of test articles which undergoes separation test

4 Symbols and abbreviated terms

CoG	centre of gravity
LV	launch vehicle
SC	spacecraft
SDOF	single degree of freedom
SRS	shock response spectrum
ζ	damping ratio

5 General requirements

5.1 Purposes of separation testing

5.1.1 General

The separation testing is conducted for two types of purposes, which are verification purposes and diagnostic purposes. A verification purpose is to verify conformity of characteristics of a separation system between the LV and the SC (or between stages of a prototype LV model) with the specified requirements. A diagnostic purpose is testing for physical system or operational design analysis.

5.1.2 Verification purposes

Verification purposes typically include:

a) to verify the functionality and characteristics of the separation system design and compatibility of interfaces, including mechanical and electrical interfaces (e.g. fit check), between the LV and the SC, as specified in ISO 14303:2002, Clauses 4 and 5;

b) to measure the parameters of separation relative movement, such as separation velocity, acceleration, angular motion, separation displacement;

c) to measure the separation clearances between the separating hardware;

d) to measure the separation characteristic action timing during the separation process, such as time to commence, time to clear.

5.1.3 Diagnostic purposes

Diagnostic purposes typically include:

a) to check and revise the separation analysis computational model and basic assumptions used in the separation analysis;

b) to measure the shock levels on the points that are relevant to the launch vehicle side or to the spacecraft side, and to check if the spacecraft is able to withstand the shock environment;

c) to test the separation function of the device (e.g. mating and unlocking device) designed for separation of structural elements;

d) to test the distancing function provided by the separation impulse device;

e) to test purposes demanded by the test requirements, such as flexible-body distortion loads, which are relevant to the launch vehicle side or to the spacecraft side during the separation process.

5.1.4 Tailoring guide

The purposes of separation testing in 5.1.2 and 5.1.3 may be tailored as the separation purposes can be different for different projects or for different development stages.

5.2 General separation test process

5.2.1 General

The general separation test process flow is shown in Figure 1. The test process typically includes:

a) test documentation preparation and pre-test simulation;

b) test implementation;

c) test result data collection;

d) development and issuing of a test results assessment report.

5.2.2 Test documentation preparation and pre-test simulation

The test documents, which include documents of test plan, test specification, test procedure as defined in ISO 15864:2021, 4.9, shall be prepared.

The test requirements for test articles, test facilities, test installation, preliminary adjustment of test setup, measurement and data acquisition, as required in a separation test, shall be defined in the test specification documents.

The documents of test specification and test procedure should be reviewed by the relevant sides to make sure the documents conform to the test requirements. The test documentation review in the test process flow shall be in line with the requirements of ISO 22137.

Pre-test simulation, which is specified in 5.6, shall meet the requirements of the test specification documents and support the making of the test procedure documentation.

5.2.3 Test implementation

Test implementation typically includes the following procedures: test preparation, test execution, follow-up activities after test, as illustrated in Annex E for a separation test.

5.2.4 Test results data collection

The test results data collection shall meet both the test data requirements, which are specified in 5.4, and the measurement and data acquisition requirements, which are specified in Clause 9.

5.2.5 Test results evaluation

The test results shall be evaluated to assess whether the test results meet the test objectives as specified in 5.9.

If the test results meet the test objectives, the test process may step into "Issue the test report documentation" and end of the test process as shown in Figure 1.

If the test results do not meet the test objectives, a selection can be made between three ways to react corresponding to the failures as shown in Figure 1.

a) If the failure is due to systems or interfaces design problems, the test should move to the step of “redesign of the relevant systems or interfaces between the LV and SC”, then move to the step of “test plan”, and proceed with the whole test process.

b) If the failure is due to test procedure problems, the test should move to the step of “test procedure documentation review” to figure out whether the test procedure documentation meet the test requirements given in the test specification documentation, then move to next step as shown in Figure 1.

c) If the failure is due to test specification problems, the test should move to the step of “test specification review” to figure out whether the test specification documentation meet the test requirements given in the test plan documentation, then move to next step as shown in Figure 1.

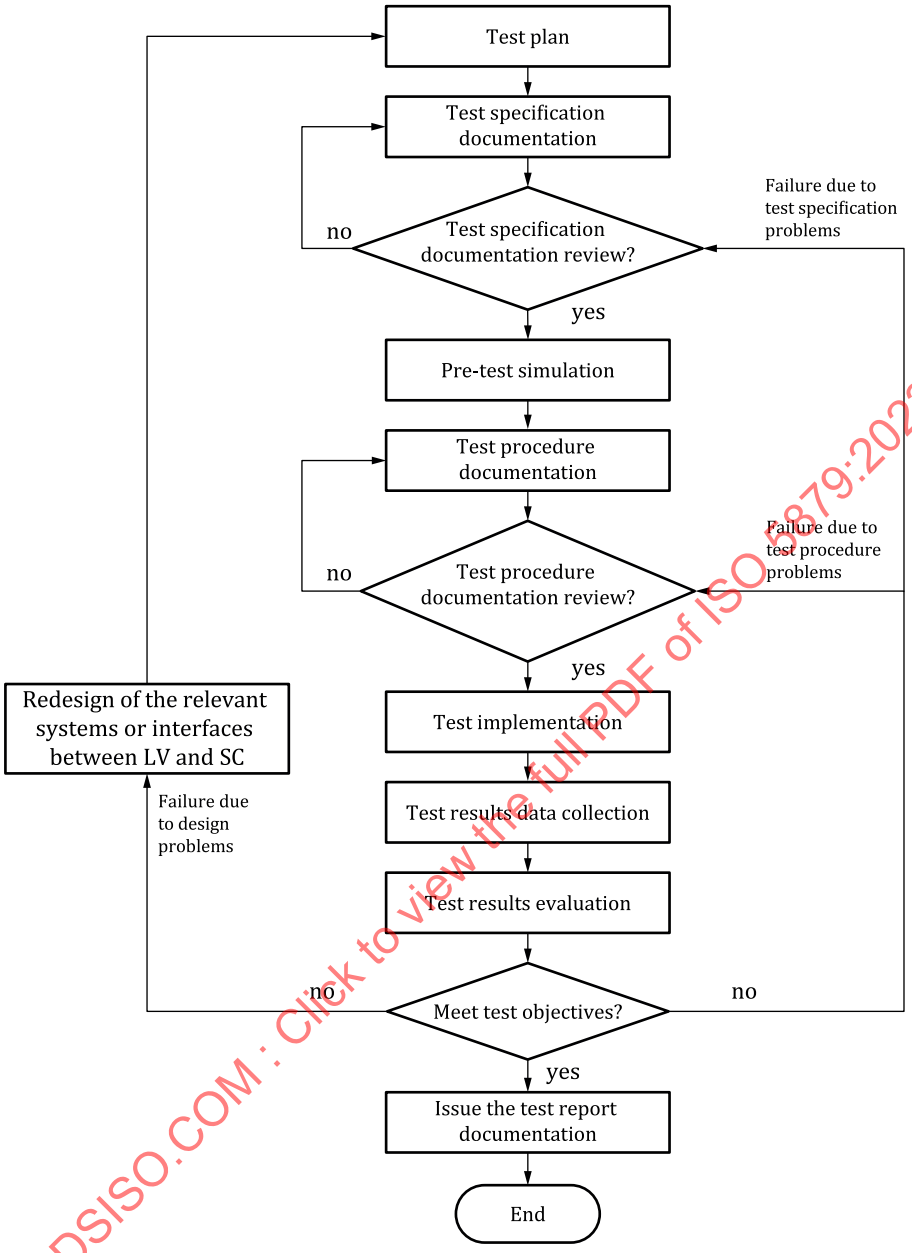


Figure 1 — General separation test process

5.3 Test articles under separation test

5.3.1 Specification of separation test unit

5.3.1.1 Acceptance test

The separation test unit for an acceptance test comprises the following test articles: a flight model or proto-flight model of a separation system between launch vehicle and spacecraft, a flight model or proto-flight model of a certain part of a spacecraft and a flight model or proto-flight model of a certain part of a launch vehicle.

5.3.1.2 Development test

In a development test between the SC and the LV, the separation test unit comprises the following test articles: a prototype model of a separation system between launch vehicle and spacecraft, a mock-up of a certain part of spacecraft and a mock-up of a certain part of a launch vehicle.

In a development test between stages of a prototype LV model, the separation test unit comprises the following test articles: the mock-ups of two connecting launch vehicle stages and a prototype model of the corresponding launch vehicle stages separation system.

5.3.2 Requirements for test articles

5.3.2.1 Technical characteristics

Technical characteristics of the test articles shall conform to the test specification documentation.

5.3.2.2 Interfaces

The mechanical and electrical interfaces at the separation surfaces of the test articles shall be identical to those of the prototype model or the flight model, depending on different test purposes as defined in 5.3.1.

5.3.2.3 Substitutes

Some parts of test articles may be substituted by the mock-up parts when these mock-up parts do not interfere with the purposes of the separation test.

5.3.2.4 Mass and stiffness

The mass and stiffness characteristics of the separation parts of test articles shall be identical to those of the prototype model or the flight model, depending on different test purposes, when measuring the separation motion parameters of the test.

5.3.2.5 Specification of difference between the SC/LV mock-up model and the flight model

The SC/LV mock-up model should be the structurally and/or physically similar items presenting a simplified reproduction of a test object of SC/LV or its part intended for test.

The SC/LV flight model or proto-flight model is dedicated to be launched and operated in orbit and should be subjected to acceptance testing.

While it is not always feasible to conduct full-scale mock-up tests, a reduced mock-up may be used in the separation test where relevant technical characteristics of the reduced mock-up model should be designed to be identical to those of the prototype model or the flight model.

5.3.2.6 Markings

There shall be obvious marks on the test articles for the high-speed video shooting.

5.3.3 Technical safety requirements for test articles

5.3.3.1 Confirmation

The test article's technical safety status shall be confirmed before test.

5.3.3.2 Handling

The operators shall follow the relevant technical safety rules under the consideration of the requirements of ISO 14620-1:2018, 8.3 in planning and executing the handling of the test articles, such as hoisting, placement, transporting, installation.

5.3.3.3 Grounding

The test articles shall be electrically grounded. IEC 62305-3 provides information on the ground resistance.

5.3.3.4 Safety protection

There shall be safety protection measures to protect the test articles from damaging both during and after the process of the test.

5.4 Data requirements

5.4.1 Test data

Depending on the purpose of the test campaign, separation movement data and/or separation shock response data, and/or the dedicated data by test requirements, shall be acquired.

5.4.2 Separation movement data

Separation movement data shall include translational acceleration, separation velocity, separation displacement, angular velocity, attitude angle of the LV test articles and the SC test articles.

Separation movement data may be measured directly or obtained by processing the measured data.

5.4.3 Separation shock response data

Separation shock response data shall include shock acceleration time history data and shock response spectrum data.

5.4.4 The dedicated data by test requirements

The dedicated data to be acquired, such as flexible-body distortion loads, shall be specified by the test requirements, as the data can be different for different types of separation test.

5.5 Test timing and sequence

Timing and sequence shall be synchronized for every system involved in the test. Synchronization accuracy shall be suitable to meet the test requirements.

5.6 Requirements for pre-test simulation

5.6.1 Purposes of pre-test simulation

Pre-test simulation shall:

a) evaluate kinematics of the test articles before the separation test;

b) determine the parameters of separation movement sensors, such as the measurements ranges, accuracy. and the placement of the separation movement sensors;

c) determine the installation positions of high-speed cameras to get the most appropriate shooting angle of field of view;

d) determine the placement of test articles capture systems to secure the safe recovery of the test articles;

e) validate the analytical method and basic assumptions used in the separation by cross checking the results between ground tests and simulation; the validated method is then used to verify that requirements are met under worst-case flight conditions.

5.6.2 Requirements for the simulation modelling

5.6.2.1 Computational model

The computational model shall allow effective and reasonable simulation of the whole separation process under consideration of the test requirements.

5.6.2.2 Coordinate systems

The coordinate systems for separation pre-test simulation shall be defined to be advantageous to express the separation motion model in the simulation.

5.6.2.3 Sloshing/flexibility effect

The sloshing effect or the flexibility effect of the test articles during the separation process shall be evaluated before the modelling of the test articles to decide if the sloshing effect or the flexibility effect shall be included in the modelling.

5.6.2.4 Timing and sequence

The separation timing and sequence shall be set to duplicate the separation timing and sequence of the separation test.

5.6.2.5 Initial conditions

The initial conditions shall be set to duplicate the initial conditions of the separation test.

5.6.2.6 Boundary conditions

As far as possible, the main boundary conditions modelling (e.g. constraint, contact) shall duplicate the separation test boundary conditions.

5.6.2.7 Mass characteristics

The main mass characteristics (e.g. mass, CoG location, moment of inertia) of the test articles models shall be set to duplicate the main mass characteristics of the physical test articles as far as possible.

5.6.2.8 Geometrical characteristics

The main geometry characteristics of the models shall conform to the main geometry characteristics of the real test articles in the scenario of measuring the separation clearances between the separating models or in other proper scenarios.

5.6.2.9 Separation impulse

As far as possible, the modelling of separation impulses shall duplicate the separation impulses in the separation test.

5.6.3 Requirements for the simulation solver

The settings of optional parameters for the simulation solver, such as integrator type, simulation time length, integral step size, integral accuracy, shall meet the simulation requirements.

5.6.4 Requirements for the simulation results

The simulation results shall include:

a) attitude angle of separation articles over time during the separation process;

b) attitude angular velocity of separation articles over time during the separation process;

c) critical clearance between separation articles over time during the separation process;

d) relative distance between separation articles over time during the separation process;

e) relative velocity between separation articles over time during the separation process.

The requirements for the simulation results may be tailored as the separation test purposes can be different for different projects or for different development stages.

5.6.5 Validation of the simulation results

The validation of the simulation results shall include:

a) comparison of the results between separation test and the simulation method;

b) comparison of the results between different simulation methods.

5.7 Requirements for test environment

The test environment shall be specified in line with requirements of the test, usually including temperature, atmosphere pressure, relative humidity, cleanliness and other requirements.

5.8 Exception handling

5.8.1 Test interruption

If any of the following situations appears, the test shall be interrupted:

a) test equipment failure;

b) the technical requirements are not met;

c) test articles failure.

5.8.2 Interruption handling

The requirements for retest in ISO 15864:2021, 4.8 shall be considered for the interruption handling.

5.9 Test results assessment

There shall be an assessment for the completeness, validity and correctness of test execution, test results and data measured during the separation test with respect to the test objectives.

5.10 Test documentation

As defined in ISO 15864:2021, 4.9, the test documentation shall include a test plan, a test specification, test procedures, test data, a test report and test logs

The test documentation may be tailored to fulfil the objectives of test.

6 Test facilities

6.1 General

Test facilities typically include control instrumentation, measurement instrumentation and equipment and testing fixture.

6.2 Calibration requirements

Control and measurement instrumentation as specified in 6.3 and 6.4 shall be calibrated periodically under consideration of ISO 15864:2021, 4.10.3.

6.3 Control instrumentation requirements

The main function of control instrumentation and equipment is, in line with the test timing, to send release instructions (e.g. pyrotechnic devices ignition instructions) to the hold-down/release mechanism controller to start the separation movement. Control instrumentation and equipment typically include: electrical power source, hold-down/release mechanism controller (e.g. pyrotechnic devices ignition controller) and connection cables.

6.3.1 Requirements for electrical power source

The output power, electric current and voltage of the electrical source shall conform to the test requirements.

6.3.2 Requirements for hold-down/release mechanism controller and connection cables

6.3.2.1 Function

The hold-down/release mechanism controller shall allow hold-down/release mechanism timing controlling.

6.3.2.2 Resolution

The timing resolution for the hold-down/release mechanism controller shall meet the test requirements and shall be indicated.

6.3.2.3 Timing set

The timing set shall conform to the test requirements.

6.3.2.4 Self-locking

The controller shall be capable of self-locking to prevent incorrect operation.

6.3.2.5 Control channels and electrical properties

The amount of control channels and their electrical properties shall meet the test requirements.

6.3.2.6 Interfaces

The connectors and pin assignment of the connection cables and the length of the cables shall meet the test requirements.

6.4 Measurement instrumentation and equipment requirements

6.4.1 General

Measurement instrumentation and equipment typically includes:

a) accelerometer for translational motion measurement;

b) high-speed video camera, which is used for separation movement recording and kinematics evaluation;

c) rate gyroscope, which is used for rotation motion measurement;

d) timing measurement system, which is used to measure the separation action timing during the separation process, such as pyrotechnic devices ignition time, separation time to commence;

e) optical displacement measurement system, which is usually used for the displacement measurement during the separation test;

f) shock measurement system, which is used for the shock response measurement.

As far as possible, a commonality should be found between ground tests sensors and flight test sensors, to allow:

— complementary qualification of flight tests sensors with ground tests;

— low bias transposition between ground and flight conditions.

6.4.2 Requirements for accelerometer for translational motion measurement

6.4.2.1 Measurement accuracy

The translational acceleration measurement error of the accelerometer shall meet the test requirements and shall be indicated.

6.4.2.2 Measurement range

The measurement range of the accelerometer shall conform to the test requirements.

6.4.2.3 Sensitivity

The sensitivity of the accelerometer shall conform to the test requirements.

6.4.2.4 Adaptability

The adaptability of the test environment shall conform to the test requirements.

6.4.3 Requirements for high-speed video camera

6.4.3.1 Frame rate

The frame rate of the high-speed video camera shall conform to the test requirements and shall be indicated.

6.4.3.2 Resolution

The resolution of the high-speed video camera shall conform to the test requirements.

6.4.3.3 Image processing

The capability of the image processing shall conform to the test requirements.

6.4.3.4 Storage space

The cache memory for the high-speed video camera shall have enough storage space to record the whole separation test process time with suitable margin.

6.4.4 Requirements for rate gyroscope

6.4.4.1 Measurement accuracy

The angular velocity measurement error of the rate gyroscope shall conform to the test requirements and shall be indicated.

6.4.4.2 Measurement range

The measurement range of the rate gyroscope shall conform to the test requirements.

6.4.4.3 Resonance frequency

The resonance frequency of the rate gyroscope shall conform to the test requirements.

6.4.4.4 Adaptability

The adaptability of the test environment shall conform to the test requirements.

6.4.5 Requirements for timing measurement system

6.4.5.1 Functional constraints

The time measurement system shall not affect the separation movement during the separation process.

6.4.5.2 Anti-interference

The capacity of anti-interference of the time measurement system shall conform to the test requirements.

6.4.5.3 Measurement accuracy

The measurement precision shall conform to the test requirement.

6.4.6 Requirements for optical displacement measurement system

6.4.6.1 Measurement resolution

The optical displacement measurement system shall have sufficient measurement resolution to meet the test requirements, and then, based on the results, to estimate the following:

a) real-time drift of the control unit mounting locations;

b) final drift of the control unit mounting locations, as well as drift of optical axes of electric optical payload (star trackers, electric optical special-purpose equipment).

6.4.6.2 Field of view

The angle of field of view of the optical displacement measurement system shall conform to the test requirements.

6.4.6.3 Measurement frequency

The measurement frequency of the optical displacement measurement system shall conform to the test requirements.

6.4.7 Requirements for shock measurement system

6.4.7.1 General

The equipment for shock measurement typically includes accelerometers for shock measurement, a signal conditioner and a data acquisition and processing system.

The signal conditioner is the signal processing device between sensors and the data acquisition and processing system.

The data acquisition and processing system acquires the real-time test data, and processes the test data in real time or after the test.

6.4.7.2 Requirements for shock accelerometer

6.4.7.2.1 Selection requirements

The shock accelerometer shall be selected in accordance with the requirements of the test.

6.4.7.2.2 Function

The shock accelerometer shall be capable of meeting the test requirements with sufficient measurement resolution, measurement range, frequency range and lighter weight to mitigate influence of addition mass.

6.4.7.2.3 Sensitivity

The shock accelerometer shall:

a) be capable of meeting the test requirements with sufficient sensitivity and lower background noise;

b) be capable of meeting the test requirements with minute transverse sensitivity; the lateral sensitivity and the transverse sensitivity shall be indicated.

6.4.7.2.4 Linearity of amplitude

The linearity of amplitude shall conform to the test requirements.

6.4.7.2.5 Flatness of frequency response

The flatness of frequency response shall conform to the test requirements.

6.4.7.3 Requirements for signal conditioner

The measurement range and frequency range shall meet measurement requirements. The following main technical characteristics shall be indicated:

a) frequency range;

b) amplification gain;

c) flatness of frequency response.

6.4.7.4 Requirements for data acquisition and processing system

6.4.7.4.1 Analogue signal processing

To avoid signals frequency aliasing, the analogue signals shall be processed by the low-pass filter before the analogue-to-digital conversion. The low-pass cut-off frequency of the low-pass filter shall be the upper-limit analysed frequency.

6.4.7.4.2 Attenuation

The attenuation outside of the low-pass cut-off frequency shall conform to the test requirements and shall be indicated.

6.4.7.4.3 Linear phase shift

To avoid signals distortion, the low-pass filter shall have the function of linear phase shift in the analysed frequency band.

6.4.7.4.4 Accuracy

The phase difference error and the band-pass flatness error shall conform to the test requirements and shall be indicated.

6.4.7.4.5 Sampling rate

To ensure the signals analysis accuracy, the sampling rate shall conform to the test requirements and shall be indicated.

6.4.7.4.6 Coding

To ensure the enough effective digital bits after the analogue-to-digital conversion, the number of coding for the analogue-to-digital conversion shall meet the test requirements and shall be indicated.

6.5 Testing fixture requirements

6.5.1 General

The testing fixture is used to lift, hang, release and recover test articles. The testing fixture typically includes a test scaffolding, an angular rotation mechanism, a release mechanism between test fixture and test articles, and test articles captive systems.

6.5.2 Requirements for the test scaffolding

6.5.2.1 Dimensions

The size of the test scaffolding shall conform to the requirements of the test article assembly, lifting and hanging, and the separation movement space.

6.5.2.2 Strength and stiffness

The test scaffolding shall have sufficient strength and stiffness to support test articles and to withstand the static and dynamic load triggered by the separation of test articles.

6.5.3 Requirements for the angular rotation mechanism

The angular rotation mechanism, which typically includes a spin mechanism and a swing mechanism, is used to produce the angular rotation movement of the test articles at the beginning of the separation test.

The angular rotation mechanism shall conform to the test requirements for establishing the specified initial conditions of the separation.

6.5.4 Requirements for the release mechanism between test fixture and test articles

6.5.4.1 General

The release mechanism is intended to hold and release the test articles.

6.5.4.2 Load capability

The maximum load capability shall conform to the test requirements and shall be indicated.

6.5.4.3 Function

The function of lifting and releasing shall be reliable and have as less interference as possible on the separation movement.

6.5.5 Test article capture system requirements

6.5.5.1 General

The test article capture system is intended to ensure the safe recovery of test articles in order to prevent the separated parts from collision during the separation test and to protect the test articles from being damaged if unexpected detriments occur during the test.

The test article capture system typically includes an upper recovery system and a lower recovery system.

6.5.5.2 Upper recovery system

The upper recovery system is intended to safely recover the upper separation part of the separation test unit. The upper recovery system shall:

a) have enough buffer capability for the safe recovery of the upper separation part of the separation test unit;

b) keep the whole separation movement undisturbed and unconstrained.

6.5.5.3 Lower recovery system

The lower recovery system is intended to safely recover the lower separation part of the separation test unit. The lower recovery system shall:

a) have enough buffer capability for the safe recovery of the lower separation part of the separation test unit;

b) keep the whole separation movement undisturbed and unconstrained.

6.6 Technical safety requirements for test facilities

6.6.1 Consolidation and support of test scaffolding

The test scaffolding shall be fixed up securely and reliably to prevent waggling or collapsing.

6.6.2 Confirmation of safety status of test facilities

a) The testing fixture's technical safety status, such as load capability, grounding connection, status of fastening between units of the testing fixture, shall be confirmed before the test.

b) The technical safety status of control and measurement instrumentation as specified in 6.3 and 6.4, such as electrical power load, cable, grounding connection, shall be confirmed before the test.

6.6.3 Test area

The test area shall be equipped with related safety devices, such as caution sign, safety fence and electrostatic discharger.

7 Test installation

7.1 General

The test installation usually includes the test articles installation, the sensors installation and the high-speed video camera installation.

7.2 Test articles installation requirements

7.2.1 Installation process

The test articles installation shall be in line with the related test documents.

7.2.2 Functional constraints

The cables and any other attachments connecting to the test articles shall not generate additional restriction or noise and shall not affect the separation movement of the test article.

7.3 Sensors installation requirements

7.3.1 Accelerometers for translational motion measurement installation requirements

7.3.1.1 Installation location

The accelerometers for translational motion measurement shall be installed in places where the movement of the mass centre of the test article can be best represented.

7.3.1.2 Installation orientation

The sensitive axes of the accelerometers shall be placed according to the directions in line with the test requirements.

7.3.1.3 Electrical insulation

In the case accelerometers are used that are not electrically insulated, electrical insulation measures shall be taken to provide adequate insulation between the accelerometers and the test structure when mounting the accelerometers to the test structure.

7.3.1.4 Functional constrains

The installation of the sensors and attached cables routing of the sensors shall neither impose additional restrictions on the separation test unit, nor modify the response characteristics of the test articles.

7.3.2 Rate gyroscopes installation requirements

7.3.2.1 Installation orientation

Sensitive axes of the rate gyroscope shall be placed according to the directions in line with the test requirements.

7.3.2.2 Electrical insulation

In the case rate gyroscopes are used that are not electrically insulated, electrical insulation measures shall be taken to provide adequate insulation between the rate gyroscopes and the test structure when mounting the rate gyroscopes to the test structure.

7.3.2.3 Functional constraints

The installation of the sensors and attached cables routing of the sensors shall neither impose additional restrictions on the separation test unit, nor modify the response characteristics of the test articles.

7.3.3 shock accelerometers installation requirements

7.3.3.1 Installation orientation

The shock accelerometers shall be placed in line with the test requirements; and the sensitive axes of the shock accelerometers shall be placed according to the directions in line with the test requirements.

7.3.3.2 Installation location

The minimum distance between the shock source and the shock accelerometers shall be in line with the test requirements.

7.3.3.3 Mounting type

The mounting type of the shock accelerometers shall meet the frequency range requirements.

7.3.3.4 Electrical insulation

In the case shock accelerometers are used that are not electrically insulated, electrical insulation measures shall be taken to provide adequate insulation between the shock accelerometers and the test structure when mounting the accelerometers to the test structure.

7.3.3.5 Functional constraints

The installation of the sensors and attached cables routing of the sensors shall neither impose additional restrictions on the separation test unit, nor modify the response characteristics of the test articles.

7.4 High-speed video camera installation requirements

7.4.1 Camera arrangement

The number and placement of the high-speed video cameras shall meet the test requirements of test articles movement measurement.

7.4.2 Installation location

The high-speed video cameras shall be installed in a safe place and put into places where the details of the separation movements can be shot.

7.4.3 Purpose

The cameras installed on the test articles shall shoot the special separation movements of the test articles.

7.4.4 Luminance

The luminance for the high-speed video cameras shall meet the test requirements.

7.5 Technical safety requirements for test installation

7.5.1 Training and qualification

The personnel responsible for the test installation shall be technically trained and qualified under the consideration of ISO 14620-1:2018, 4.8 before the test installation.

7.5.2 Working high above the ground

When working high above the ground, the related safety equipment such as ladder, working platform and safety belt, shall be used.

8 Requirements for the preliminary adjustment of the test setup

The purpose of the preliminary adjustment of the test setup is to coordinate and check the systems involved in the test setup to work properly to meet the test requirements prior to the actual separation test. Mass dummy units which feature the same mass and inertia characteristics as those of the test articles may be used in the preliminary adjustment of the test setup.

The preliminary adjustment should be performed in order to:

a) identify any inconsistencies in the systems involved in the test setup, for example, if there are problems in the lifting, rotating and separation of the test articles;

b) test and coordinate the separation timing;

c) adjust the buffer capability of the test articles captive systems to secure the safe recovery of the test articles;

d) test and check the safe measures of the separation test to meet the test requirements.

9 Measurement and data acquisition requirements

9.1 General

The purpose of test measurement and test data acquisition is to measure, record and process the test data produced during the separation test.

9.2 Acquisition and processing requirements for the dedicated data by test requirements

The following aspects shall be specified:

a) measurement and/or processing methods;

b) measurement quality or measurement uncertainty range;

c) data format.

9.3 Acquisition and processing requirements for separation movement data

9.3.1 Noise reduction

All measurement data shall be processed through noise reduction processing, typically through low pass processing.

9.3.2 Data format

Separation movement data should be provided both in tabular form and in plots.

9.4 Acquisition and processing requirements for shock response data

9.4.1 Shock response data

The data sampled and processed by the data acquisition and processing systems shall include the whole shock process.

9.4.2 Detection of anomalies

The shock signal shall be evaluated (e.g. visual inspection for errors in the data sampled or integration from sampled acceleration signal to velocity signal for further check) to detect and invalidate the anomalous data.

9.4.3 Processing requirements

As far as possible, the shock data shall be forced to yield a net velocity change of zero from the beginning to the end of the transient before the SRS calculation is performed. The trend term in the data shall be eliminated.

9.4.4 SRS values

As the absolute acceleration is the most commonly used response parameter for calculating the SRS, the SRS values shall be the maximum acceleration responses of the oscillators at any time in either direction (maximum SRS) with a specific value of damping, usually defined in terms of a damping ratio, ζ, or a quality factor, $Q = 1/(2\zeta)$, typically $\zeta = 0{,}05$ or $Q = 10$. The damping ratio, ζ, is the same damping ratio assumed in a series of single-degree-of-freedom (SDOF) systems, each of which has a different resonance frequency, for the SRS calculation.

9.4.5 Time data format

As a minimum, shock acceleration time data shall be provided in tabular form indicating the maximum levels.

9.4.6 Shock response spectrum

9.4.6.1 Data format

The shock response spectrum shall be processed in plots and in tabular form if requested.

9.4.6.2 Plot format

The plot should be displayed in logarithmic scale with:

a) the abscissa showing frequency in hertz;

b) the ordinate showing SRS in g or meter per second squared for different scenarios;

c) the frequency interval no greater than 1/6 octave.

There should be no need to apply window function for the shock signal processing.

Annex A
(informative)

Overview and interdependencies of test methods

A.1 Overview of test methods

For different separation test objectives, there exist different separation test methods. Usually there are three common separation test methods:

a) combined separation test;

b) individual-falling separation test;

c) horizontal separation test.

The test methods are described in Annex B, Annex C and Annex D respectively; the test implementation is described in Annex E.

A.2 Scenarios for the application of combined separation test

The combined separation test method can be performed for development testing primarily for the prototype SC model and/or the prototype LV model separation verification and/or diagnostic.

The test approximates the boundary condition of interfaces to be the unconstrained 'free-free' boundary condition with zero-gravity effect or no acceleration conditions at the time of separation. The combined separation test method is able to simulate the separation situation on orbit. A combined separation test can be performed for all the purposes in 5.1.

A.3 Scenarios for the application of individual falling separation test

The individual falling separation test method can be performed for development testing, or for acceptance testing of the prototype model or the flight model.

The test method features that test articles are hanged vertically at the beginning of the test and that effects of the gravity on the movement of separation exist during the test.

The individual falling separation test method can be performed for the separation verification and/or diagnostic with main purposes of fit-check and shock-response-level confirmation.

By using suitable theoretical separation analysis computational model, individual falling separation tests can also be performed for the kinematics evaluation.

A.4 Scenarios for the application of horizontal separation test

The horizontal separation test method can be performed for development testing primarily for the purpose of separation verification and/or diagnostic for the prototype SC model and/or the prototype LV model, and is a basic way of doing separation test, which requires relatively less sophisticated facilities than those for the combined separation test.

The test method features that test articles are held horizontally at the beginning of the test and that minute effects of the gravity on the movement of separation exist during the test. On condition of tiny effects on the test articles separation movement with the constraints of suspension slings, the test can

be performed to measure the parameters of the separation movement between test articles, such as the separation velocity, acceleration, and angular motion, as well as for the other purposes in 5.1.

A.5 Kinematics evaluation by individual falling separation test

When combined separation tests and horizontal separation tests are not possible to be performed (e.g. if they need a too large test facility), individual falling separation tests can be performed with the secondary objective of kinematics evaluation.

In that case, individual falling ground tests can be performed using instrumentation associated to kinematics, such as tachometers.

To cross check theoretical kinematics model with ground test results, the following two types of parameters can be compared:

a) pseudo-measurements (e.g. falling body angular rates) coming from the theoretical model tuned with 1 g acceleration communicated to the falling body;

b) measurements coming from ground test sensors (e.g. angular rates coming from tachometers positioned on the falling body); measurements are limited by their measurement range.

A.6 Respective effect of unlocking device and separation impulse device

To evaluate the respective effect of unlocking device and separation impulse device, individual falling separation tests can be undertaken in the following two configurations:

a) with unlocking device and without separation impulse device;

b) with unlocking device and with separation impulse device.

Annex B
(informative)

Combined separation test

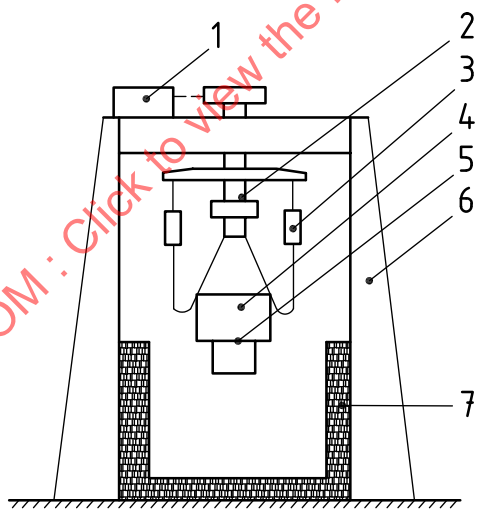
B.1 Test purposes

The test purposes are defined in 5.1.

The test procedures may be tailored to conform to the test purposes, as the test purposes can be different for different projects or for different development stages.

B.2 Test set-up

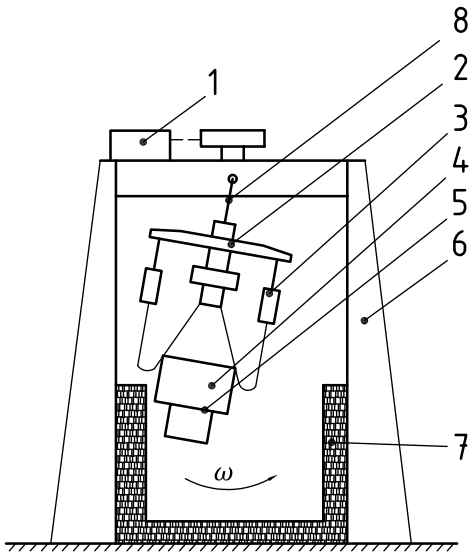
The test set-up typically consists of a spin mechanism for spin movement (optional), the releasing mechanism for the dropping of the test articles, the upper recovery system for the safe recovery of the test articles, the separation test unit, a test scaffold, the lower recovery system for the safe recovery of the test articles and a swing mechanism for the angular rotation movement (optional), as illustrated in Figure B.1 and Figure B.2.



Key

1 spin mechanism for spin movement
2 releasing device for the dropping of the test articles
3 upper recovery system for the safe recovery of the test articles
4 separation test unit
5 separation plane
6 test scaffold
7 lower recovery system for the safe recovery of the test articles

Figure B.1 — Test configuration (with rotation mechanism)



Key

1 spin mechanism for spin movement
2 releasing device for the dropping of the test articles
3 upper recovery system for the safe recovery of the test articles
4 separation test unit
5 separation plane
6 test scaffold
7 lower recovery system for the safe recovery of the test articles
8 swing mechanism for the swing angular rotation movement
ω angular rate of the separation test unit

Figure B.2 — Test configuration (with swing mechanism)

B.3 Test method

The test can be used to check the separation process between the spacecraft and the launch vehicle. The separation test unit subject to separation can be coupled before it is hung. Before the test articles are coupled to the separation test unit, each test article, subject to separation, must be weighed and balanced out; and its actual moments of inertia can be defined.

The spin movement (optional) and swing angular rotation movement (optional) of the separation test unit can be produced by the spin mechanism and swing mechanism respectively.

When the spin speed (optional) and/or the swing angular rotation motion speed (optional) of the separation test unit meet the test requirements, the separation test unit is released from a proper height. Then the combination is in the state of zero gravity. During the state of zero gravity, the separation system acts in timing and test articles are separated from each other by the action of the separation impulse device.

The measurement system can acquire the test data meeting the requirements of 5.4 and Clause 9.

Annex C
(informative)

Individual falling separation test

C.1 Test purposes

The test purposes typically include:

a) to verify the functionality and characteristics of the separation system design and compatibility of interfaces, including mechanical and electrical interfaces;

b) to measure the explosive-ordnance shock levels on the points that are relevant to launch side or to spacecraft side, and to check if the spacecraft can withstand the explosive-ordnance shock environment;

c) to test the separation function of the device designed for separation of structural elements;

d) to test the distancing function provided by the separation impulse device;

e) to measure the separation characteristic action timing during the separation process, such as time to commence, time to clear;

f) to check and revise the separation analysis computational model and basic assumptions used in the separation analysis;

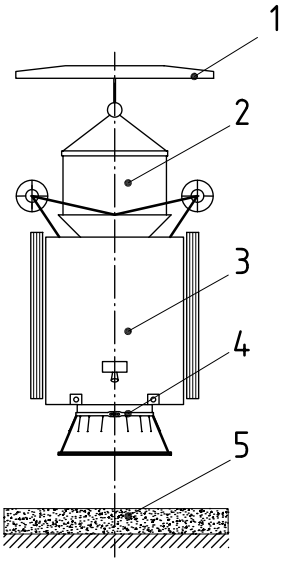
g) to measure the other dedicated data demanded by the test requirements, such as flexible-body distortion loads, which are relevant to launch vehicle side or to spacecraft side during the separation process.

By using theoretical separation analysis computational model, individual falling separation tests can also be used for the kinematics evaluation.

The test procedures may be tailored to conform to the test purposes, as the test purposes can be different for different projects or for different development stages.

C.2 Test set-up

The test set-up typically includes a crane which is used to hang the test articles, a lifting sling which is used to lift the test articles, the separation test unit, and the lower recovery system for the safe recovery of the falling test article, as illustrated in Figure C.1.



Key

1 crane which is used to hang test articles
2 lifting sling which is used to lift the test articles
3 separation test unit
4 separation plane
5 lower recovery system for the safe recovery of the falling test article

Figure C.1 — Test configuration

C.3 Test method

The test can be used to check that either SC parts or LV parts drop from the combination during the separation test in line with the test requirements using the flight/prototype model interfaces between the SC and the LV.

The separation test unit subject to separation can be coupled before it is lifted. Before the test articles are coupled to the separation test unit, each test article, subject to separation, must be weighed and balanced out, and its actual moments of inertia can be defined.

When the test begins, the separation system acts in timing and the falling test article is separated from the combination either by the combined action of the separation impulse device and the gravity of the falling test article or by the only action of the gravity of the falling test article, depending on the requirements of the test.

The typical form of the test is the separation of the adapter of the LV from the SC. Before the test, the mating and unlocking device, such as a clamp-band typically, is used to combine the spacecraft and the adapter together. The combination of the spacecraft and the adapter is lifted up to a proper height and right place. When the test commences, the hold-down/release mechanism releases the mating and unlocking device (e.g. the separation pyrotechnic devices are fired), the adapter then is separated from the spacecraft.

The measurement system can acquire the test data meeting the requirements of 5.4 and Clause 9.