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# Space systems — Micro-vibration testing

*Systèmes spatiaux — Essais de microvibration*



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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

Spacecraft on-orbit experience a micro-vibration environment which can induce severe disturbances to sensitive payload with high pointing stability and/or position stability. It can affect mission success of payload equipment, e.g. earth observation, space telescopes, optical experiments, telecommunication.

For such applications, it is necessary to verify their resistance to the micro-vibration environment on-orbit. This verification may be supported by spacecraft level micro-vibration tests on ground. In that case:

— the vibration transmissibility from the disturbance sources to the sensitive payloads should be investigated;

— the performance of these payloads under the influence of the relevant disturbance sources should be identified by response measurements;

— the modal parameters of the spacecraft should be extracted to update the analysis model.

This document specifies contents to meet test requirements. It includes test purpose, general test information, test equipment, test requirements and recommendations, test flow and procedure, test interruption and handling, test data and result evaluation, and test reports for spacecraft level micro-vibration tests.

# Space systems — Micro-vibration testing

## 1 Scope

This document specifies requirements for the implementation of spacecraft level micro-vibration tests on space systems to be considered by test providers, including test designers and test engineers. It also gives guidance for spacecraft designers and interested parties.

The spacecraft level micro-vibration test is applicable to space systems which contain payload equipment sensitive to the micro-vibration environment which only induced by the internal disturbance sources on-orbit, e.g. for the purpose of earth observation, space telescopes, optical experiments, telecommunication.

## 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, *Space systems — Safety requirements — Part 1: System safety*

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

ISO 17566:2011, *Space systems — General test documentation*



## 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**
**micro-vibration environment**
dynamic environment on-orbit which is characterized by very low acceleration level compared with the usual dynamic environment during launch

Note 1 to entry: Micro-vibration environment affects the normal performance or function of sensitive payload equipment of the spacecraft on-orbit.

Note 2 to entry: Generally, the micro-vibration environment of the sensitive payload equipment on-orbit is in the range of micro-g's to milli-g's, and the frequency range is from a few hertz up to a few hundred hertz[1].

**3.2**
**background noise**
noise coming from sources other than the test signal

[SOURCE: ISO 13472-1:2022, 3.8]

**3.3**
**signal-to-noise ratio**
*S/N*
difference between the level of the nominal useful signal and the level of the *background noise* (3.2) at the moment of detection of the useful event

Note 1 to entry: The signal-to-noise ratio is given in decibels.

[SOURCE: ISO 13472-1:2022, 3.9]

**3.4**
**design safety factor**
factor by which limit loads are multiplied in order to account for uncertainties and variations that cannot be analysed or accounted for explicitly in a rational manner

Note 1 to entry: Design safety factor is sometimes referred to as design factor of safety, factor of safety or just safety factor.

[SOURCE: ISO 10786:2011, 3.15]

## 4 Symbols and abbreviated terms

| | |
|---|---|
| FFT | fast Fourier transform |
| FM | flight model |
| LoS | line-of-sight |
| RMS | root mean square |
| *S/N* | signal-to-noise ratio |
| SADA | solar array drive assembly |
| SM | structural model |
| STM | structural/thermal model |



## 5 Test purpose

The main purpose of the spacecraft level micro-vibration test is to verify the dynamic characteristics in micro-vibration environment. This is achieved by:

— obtaining transfer characteristics from disturbance source to the sensitive payload to verify the transfer path design through transfer function measurements;

— obtaining modal parameters of the spacecraft through a modal survey test, in order to update the analysis model;

— obtaining the micro-vibration response of sensitive payload equipment through response measurements.

Usually, the verification of the dynamic characteristics in a micro-vibration environment is based on a combination of analytical prediction and test.

# 6 General test information

## 6.1 Tailoring

Requirements of this document may be tailored to fulfil the objectives of the test.

## 6.2 Disturbance sources

Disturbance sources can be classified as external sources and internal sources. External sources can be found in the space environment, e.g. eclipse entry and exit. Internal sources can be found from within the spacecraft.

Annex A presents typical internal disturbance sources and their characteristics.

## 6.3 Preliminary analysis

A preliminary micro-vibration analysis shall be conducted before the spacecraft level micro-vibration test. The objectives of the preliminary analysis are:

a) to identify the payloads sensitive to micro-vibration;

b) to identify the main disturbance sources on-orbit;

c) to decide whether a spacecraft level micro-vibration test for a specified spacecraft is necessary.

Annex B may be considered to decide whether spacecraft level micro-vibration tests are necessary or not for the spacecraft with pointing stability as the sensitive index, depending on the nature and characteristics of the mission.

In cases where spacecraft level micro-vibration testing is decided to be necessary, modelling and analysis of spacecraft dynamics should be done before test for test planning and the following tasks shall be executed:



— Obtain the prediction results to be used for test planning and specification.

— Define the configuration of the test article under the consideration that the test configuration can differ from the flight configuration.

— Determine the dynamic characteristics of the disturbance sources to be replaced by analogue exciters in the test configuration.

— Define the test frequency range according to the sensitive frequency range of the sensitive payloads.

— Evaluate the influence of boundary simulation equipment.

# 7 Test equipment

## 7.1 Test configuration for transfer function measurement and modal survey test

The test configuration for the transfer function measurement and modal survey test shall:

a) provide approximated "free-free" boundary conditions for the test article;

b) apply the excitation force to the pre-defined excitation points in the test article;

c) measure, acquire and process response signals;

d) obtain transfer functions from the response signals with the excitation signal as the reference;

e) obtain modal parameters based on the transfer functions, so as to update the analysis model if needed or requested.

NOTE The "free-free" boundary conditions can be chosen and justified so that it remains representative of the dynamic characteristics of the test article on orbit flight conditions.

An example of test configuration is shown in Figure 1.

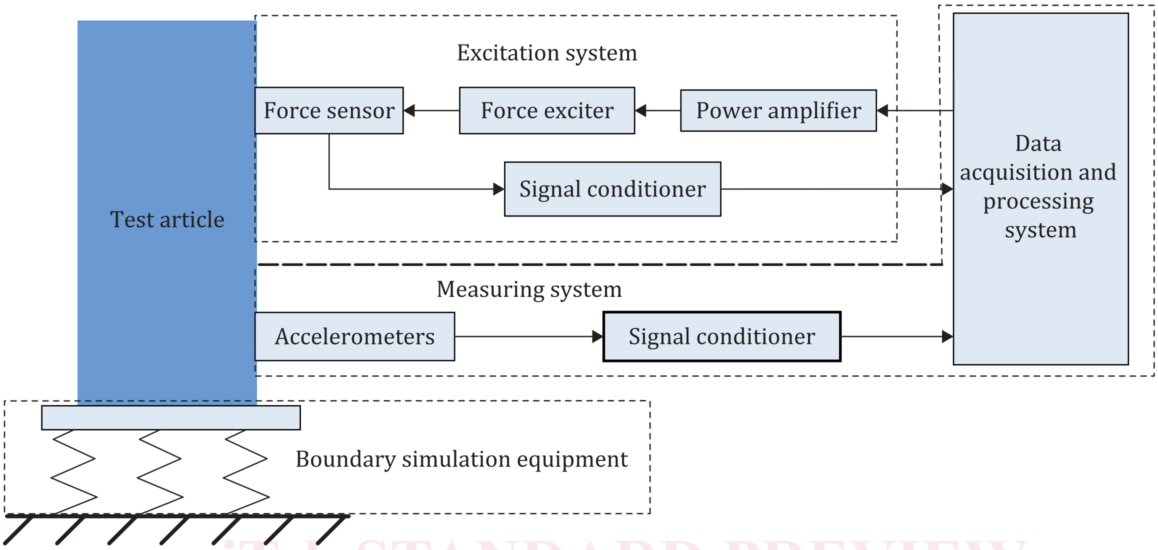



**Figure 1 — Test configuration for transfer function measurements and modal survey test**



## 7.2 Test configuration for response measurement



The test configuration for response measurement shall:

a) provide approximated "free-free" boundary conditions for the test article;

b) excite the test article by disturbance sources or analogue exciters;

c) measure, acquire and process response signals (typical sensors are accelerometers, displacement sensors, force sensors, angular sensors).

NOTE The "free-free" boundary conditions can be chosen and justified so that it remains representative of the dynamic characteristics of the test article on orbit flight conditions.

An example of test configuration is shown in Figure 2.

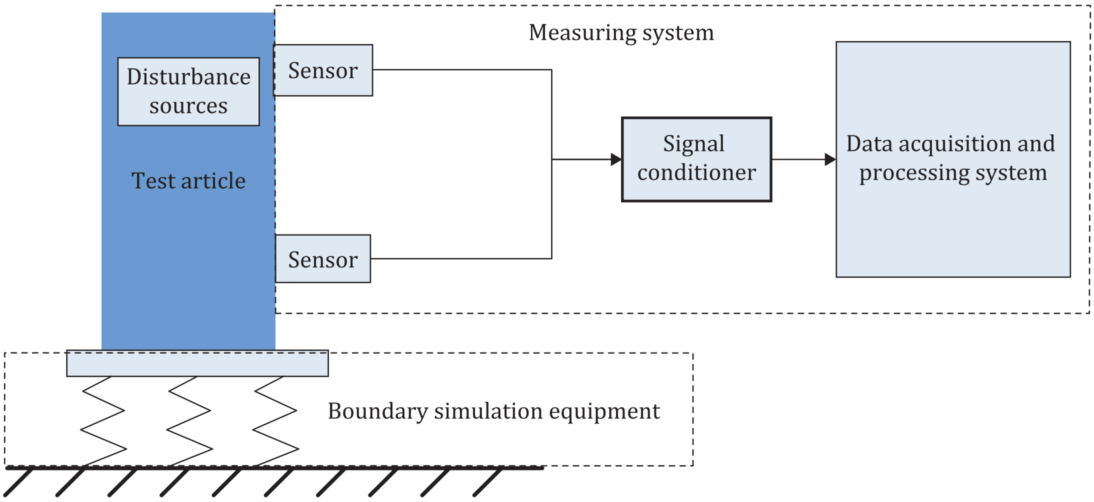



**Figure 2 — Test configuration for response measurement of micro-vibration**

## 7.3 Test equipment functional requirements and recommendations

### 7.3.1 Boundary simulation



The test configuration shall simulate the on-orbit dynamic conditions as close as possible in order to get reliable estimates for the expected on-orbit performances. In particular, the test article shall be in a quasi "free-free" boundary condition and the gravity forces acting on the structure and surrounding air effects shall be minimized.

The requirements and recommendations for the boundary simulation equipment are as follows:



a) The boundary simulation equipment shall provide the function of suspension and safety protection for the test article.

b) Suspension frequencies, which are the first six rigid body frequencies of the system composed of boundary simulation equipment and the test article, should be lower than 25 % of the first elastic modal frequency of the test article under the free-free boundary condition.

c) The attached mass moving synchronously with the test article should be sufficiently less than the mass of the test article (e.g. less than 5 % of the mass of the test article) to ensure that its dynamic characteristics are unchanged as far as possible.

d) The influence of the boundary simulation equipment on the dynamic characteristics of the test article shall be analysed.

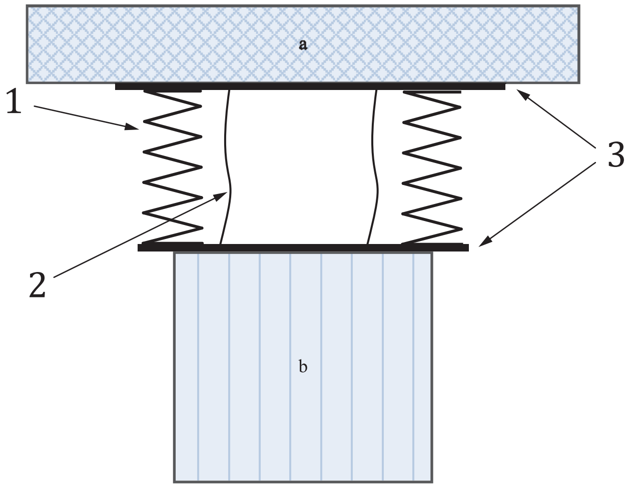
e) The design safety factor of boundary simulation equipment under static load induced by the gravity force of the test article shall meet the requirements of the customers.

f) One end of the boundary simulation equipment shall match the interface of the test article, and the other end shall match the ground base or coping of the laboratory.

NOTE The "free-free" boundary conditions can be chosen and justified so that it remains representative of the dynamic characteristics of the test article on orbit flight conditions.

Examples for typical boundary simulation equipment are shown in Figures 3 and 4.




**Key**

1 flexible suspension component

2 safety protection component

3 mechanical interface component

a Coping of the testing laboratory or structural frame.

b Test article.

**Figure 3 — Suspending-fashion boundary simulation equipment**

