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Space systems — Mass properties control

Systèmes spatiaux — Contrôle des propriétés de masse

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Foreword

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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 22010:2007), which has been technically revised.

The main changes are as follows:

— the reference to ANSI/AIAA S-120-2015 has been changed to ANSI/AIAA S-120-2015 (2019);

— the reference to "SAWE Recommended Practice Number A-3 (RP-A-3), Mass Properties Control for Space Systems" has been added.

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

This document establishes the minimum requirements for providing adequate control of the mass properties of space systems to meet mission requirements. In addition, many recommended practices that add value to the mass properties monitoring tasks are presented. Throughout this document, 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 timely and accurate mass properties support for contracts. It is advisable that deviations from the recommended criteria only occur after careful consideration and thorough evaluation have shown alternative methods to be satisfactory.

The requirements can be tailored for each specific space programme application.

Space systems — Mass properties control

1 Scope

This document describes a process for managing, controlling and monitoring the mass properties of space systems. The relationship between this management plan and the performance parameters for mass properties to be met throughout the mission is described. Ground handling, dynamics analysis and test set-ups that rely on accurate mass properties inputs are identified. This document covers all programme phases from pre-proposal through to end of life.

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 22108, *Space systems — Non-flight items in flight hardware — Identification and control*

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
basic mass
best engineering estimate based on an assessment of the most recent baseline design, excluding *mass growth allowance* (3.8)

3.2
calculated properties
mass properties (3.9) determined from released drawings or controlled computer models

3.3
contractor limit
predicted mass (3.13) plus a *contractor margin* (3.4) to allow for uncertainties during the design cycle

3.4
contractor margin
system margin
difference between the *contractor limit* (3.3) and the *predicted mass* (3.13)

3.5
customer reserve
allowance defined by the customer according to the agreements of the contract

3.6
estimated properties
mass properties (3.9) determined from preliminary data, such as sketches or calculations from layout drawings

3.7
mass control parameters
factors used as an indicator of the *basic mass* (3.1), *predicted mass* (3.13) and margins/limits for a *space system* (3.14)

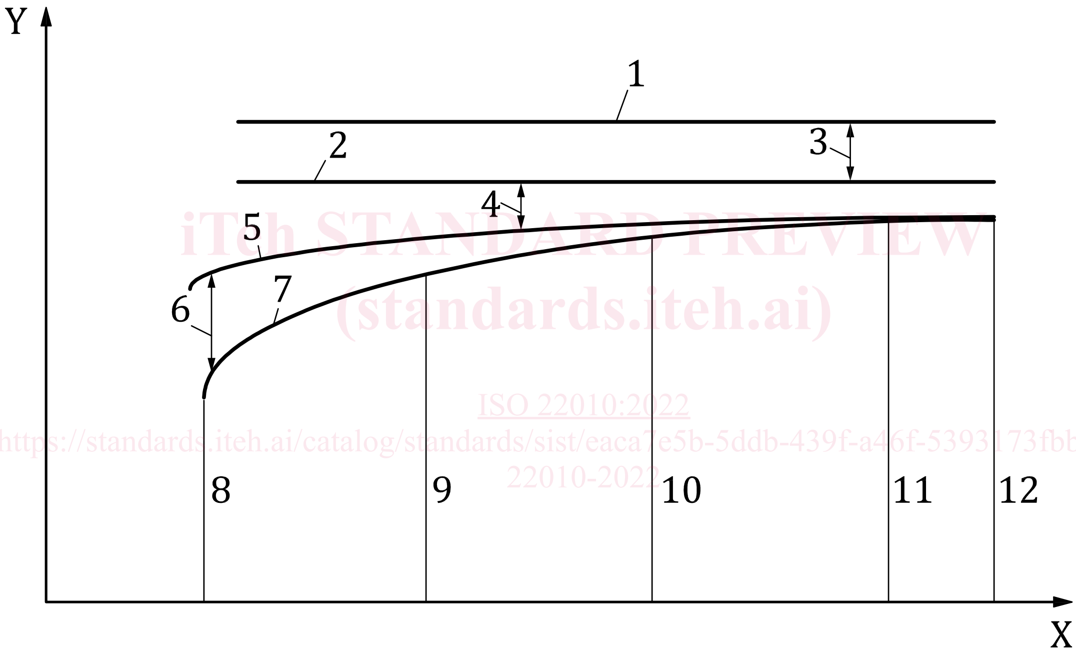
Note 1 to entry: See Figure 1.

3.8
mass growth allowance
predicted change to the *basic mass* (3.1) of an item, based on an assessment of the design and fabrication status of the item and an estimate of the in-scope design changes that may still occur

Note 1 to entry: See Annex A.

Note 2 to entry: This mass growth allowance is not intended to be a tolerance.

Note 3 to entry: Figure 1 is an illustration of related terms commonly used in reporting *mass properties* (3.9) during the development of *space systems* (3.14) hardware.



Key

X	time
Y	mass
1	mission limit
2	contractor limit
3	customer reserve
4	contractor margin/system margin
5	predicted mass
6	mass growth allowance
7	basic mass
8	authorization to proceed
9	preliminary design review
10	critical design review
11	actual mass
12	system delivery

Figure 1 — Mass control parameters

3.9
mass properties
mass, centre of gravity, moments of inertia, and products of inertia

3.10
mass properties categories
criteria used to indicate the confidence in or maturity of the design

3.11
measured properties
mass properties (3.9) determined by measurement or by comparison of nearly identical components, for which measured mass properties are available

3.12
mission limit
maximum mass that can satisfy all of the mission performance requirements

3.13
predicted mass
sum of the *basic mass* (3.1) and the *mass growth allowance* (3.8), intended to estimate the final mass at system delivery

3.14
space system
system that contains at least a space, a ground or a launch segment

Note 1 to entry: This document addresses only flight systems: launch vehicles, satellites, space vehicles, or components thereof.

4 Abbreviated terms

ACS	attitude control system
ANSI	American National Standards Institute
ATP	authorization to proceed
GSE	ground support equipment
MPCB	mass properties control board
NTE	not to exceed
TPM	technical performance measurement

5 Mass properties control plan

5.1 General

A mass properties control plan shall be documented.

A mass properties control plan shall be based on the critical parameters that need to be controlled. In some cases, that may only be mass. In the extreme, a spin-stabilized space system may have a set of requirements that warrants control of all the mass properties, including final measurements of mass, centre of mass, and moments and products of inertia. The depth and detail of analysis, reporting and testing shall reflect the critical parameters.

5.2 Control process

5.2.1 Basis of the process

The mass properties control process shall be started in the pre-proposal or conceptual design phases, where an initial mass budget is established. A proposal team may be established so as to guide subsystem and component mass allocations and the launch vehicle selection process, if applicable. This team should be supported by other members who have experience in the allocation process.

NOTE Space system mass is a prime concern. Without early mass properties control, there is a significant risk of performance, schedule, and/or cost problems later in the programme.

The control process after authorization to proceed (ATP) may include one or more of the following elements:

a) understanding of the flow-down of requirements that affect mass properties analysis and test plans;

b) a mass reduction plan;

c) implementation of a mass properties control board (MPCB);

d) mass allocation and trend analysis;

e) mass properties monitoring;

f) subcontractor mass control.

Application of some of the more stringent elements listed above is contingent on available mass and stability margins, cost considerations and the planned verification (measurement versus analysis) schema. The various elements and their applicability are discussed in 5.2.2 to 5.2.7.

5.2.2 Requirements definition

There shall be a review of all requirements that affect mass properties including, but not limited to, the contractual, attitude control, mission and ground handling requirements. Different space system designs have different mass properties requirements.

EXAMPLE A space system that is spin-stabilized throughout its mission requires a finer balance than one that is three-axis-stabilized.

5.2.3 Mass reduction plan

After establishing a credible mass summary during the proposal phase, a database shall be used with the tools necessary to develop a predicted mass for the space system at delivery. A contractor or system mass margin against the contractor limit shall be determined. If the mass margin is not sufficient, a rigorous mass reduction programme should be initiated. In this case, the programme office should fully support the effort.

Mass reduction is generally a costly undertaking, therefore it is advisable that programme offices allocate a sufficient budget to accomplish the goal. A historical database of previous weight reduction ideas is advisable.

5.2.4 Mass properties control board (MPCB)

In conjunction with a mass reduction plan, an MPCB may be convened to audit the mass properties database, critically review designs for optimum mass, and perform cost/mass trades as well as review margins. The MPCB should have a programme office and systems engineering representation. Some of the MPCB members should also have experience with this process. The MPCB should have the authority to direct design changes that reduce mass, within the considerations of cost, schedule and technical performance. MPCB members should attend all design reviews to ensure that mass optimisation is considered.

5.2.5 Mass allocation and trend analysis

One of the most effective ways of controlling mass is to set maximum, “not to exceed” (NTE), allocations at the subsystem or unit level. With reference to Figure 1, if the contractor margin at the beginning of the programme is small or negative, it may be necessary to challenge each subsystem so as to ensure that the contractor limit is exceeded. The same idealized chart can be used to represent each subsystem's mass NTE allocation. These technical performance measurement (TPM) charts should be used to monitor the progress of each subsystem. If the predicted mass exceeds the NTE allocation, mass reduction is necessary; in some cases, a re-allocation among subsystems may solve the problem. This trend analysis is particularly critical prior to preliminary design review, when designs are still evolving and mass reduction efforts are less costly.

5.2.6 Mass properties monitoring

For programmes with adequate margins in all mass properties parameters, a simple mass history chart and a table showing the predicted mass properties versus the requirements suffice. The chart and table should be included in periodic reports to the customer (see 5.3.6).

5.2.7 Subcontractor mass properties control

The prime contractor shall be involved in the development of NTE masses in the procurement specification that is issued to subcontractors. If additional controls, such as centre of mass or inertia, are required, those NTE values shall also be added to the specification and contract. The status of the critical values shall be reported by the subcontractor in periodic reports as specified by the contractor. If mass reduction is needed to bring the deliverable items within specification, the programme office may want to set up regular meetings with the subcontractor (including a mass review board) until the problem is mitigated, or until all avenues for meeting the specification have been exhausted. Incentives and penalties against specification values written into the contract may be of use.

5.3 Documentation

5.3.1 General

Mass properties documentation consists of plans and reports. Plans define the programme management methods for controlling, reporting and measuring mass properties. Reports provide visibility into the hardware configuration and design maturity through the development process.

5.3.2 Control plan

The overall control plan described in 5.1 and 5.2 shall be documented so as to provide an organized process that can be implemented early in the development phase and carried through to hardware delivery. The control plan should contain the applicable elements of the control process outlined in 5.2, as applicable, as well as a reporting plan and a verification plan.

5.3.3 Report plan

Report format and frequency of delivery may be specified in the contract. An initial report may be expected one month after ATP. Formal monthly reports should be provided through critical design review, with quarterly reports thereafter. For mass critical programmes, a weekly mass update may be required. A final test report provides the customer with the space system's measured mass properties, from which mission predictions are made.

5.3.4 Analysis plan

In some cases, full space systems analysis using computer-aided design (CAD) systems may not be possible, because of resource limitations. In other cases, parametric data from other programmes may prove to be accurate enough until programme-specific hardware measurements are taken. In those cases, an analysis plan should be documented, informing the customer of the uncertainties related to the mathematical model.