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Space systems — Unmanned spacecraft transportation — General requirements

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National foreword

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The UK participation in its preparation was entrusted to Technical Committee ACE/68, Space systems and operations, which has the responsibility to:

— aid enquirers to understand the text;

— present to the responsible international/European committee any enquiries on the interpretation, or proposals for change, and keep the UK interests informed;

— monitor related international and European developments and promulgate them in the UK.

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Space systems — Unmanned spacecraft transportation — General requirements

Systèmes spatiaux — Transport des véhicules spatiaux non habités — Exigences générales

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Foreword

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ISO 16458 was prepared by Technical Committee ISO/TC 20, *Aircraft and space vehicles*, Subcommittee SC 14, *Space systems and operations*.

Introduction

International cooperation in space system design and operation determines how a spacecraft (SC) and its hardware are transported, such as

— transportation of special hardware for setup and operation of the SC from other countries;

— transportation of the SC with hardware for integration with the launch vehicles.

To ensure that the problems of ground transportation of the SC and its hardware will not hinder the development of international cooperation

— transportation should not require excessive or unusual preparation of the SC and its hardware, and

— transportation should be based on the available civilian or military transport facilities.

It would be ideal to develop international transportation requirements for all SC and all types of transportation modes. However, development of such requirements for all areas and all SC of other countries is difficult; so the following general requirements should be established initially:

— the environment for the SC transportation;

— the loads from all transportation modes;

— the rules for the SC loading, transportation, and unloading.

This International Standard contains a list of requirements for different types of transport (rail, road, air, and water).

Space systems — Unmanned spacecraft transportation — General requirements

1 Scope

This International Standard is applicable to unmanned spacecraft and their supporting hardware including science instrument and payloads. It establishes the requirements for transportation by rail, road, air, and water and as a part of a launch vehicle and establishes the requirements for special containers and loading/unloading operations meant to safeguard unmanned spacecraft and their supporting hardware during transportation.

This International Standard is intended to be applied in international transportation. It may also be used in national transportation.

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 14303, *Space systems — Launch-vehicle-to-spacecraft interfaces*

ISO 15863, *Space systems — Spacecraft-to-launch-vehicle interface control document*

ISO 17401, *Space systems — Documents for space craft interface requirements for launch vehicle services*

3 Symbols and abbreviated terms

LC launch complex

OD operational documentation

RF radio frequency

SC spacecraft

TS technical specification

4 Transportation requirements

4.1 General provisions

4.1.1 SC shipping containers or railway cars

When transporting an SC to an LC or to a maintenance structure, the spacecraft shipping container and other special devices shall provide for the safe transportation of the spacecraft. The shipping container shall safely provide for various transportation conditions, such as temperature, humidity, and shock. These conditions shall be specified in the operational documentation (OD).

4.1.2 Mechanical loads

During transportation and loading/unloading operations, structural loads act on the SC. These loads depend on SC securing methods, the stiffness of the transport device, the loading/unloading facilities used, and the environment faced by transport. The limiting values and duration of the loads shall be specified in documentation of the SC developer.

4.1.3 Types of transport

The types of transport, as well as the requirements for transportation, shall be specified in the OD for the SC.

4.1.4 Major components, support equipment and spare parts

Major components or subsystems shall be transported under the same conditions as the SC. Accessories, tools, and spare parts shall be transported in accordance with the supplier's specifications.

4.1.5 Safety requirements

The SC shall be completely secured during transportation (except when transported as part of the launch device). Containers with active fluid or active electrical systems shall not jeopardize transportation safety. International transportation of SC shall comply with the international transportation regulations and the international safety constraints that exist under the authority of the United Nations.

Transportation within a country shall conform to the national transportation safety regulations. Transportation within a LC shall conform to the LC safety regulations.

4.1.6 Moisture and contamination

The components of SC or the entire SC that are sensitive to moisture and/or contamination that adversely affect function or performance shall have a system to avoid or reduce the moisture and/or contamination during transportation in accordance with the specific requirements defined in the OD for the SC.

4.1.7 Electrical grounding

The SC and container shall be electrically grounded during transportation in accordance with the OD for the SC.

4.1.8 Pyrotechnic safety

Pyrotechnic components shall be in a safe inactive condition.

4.2 Requirements for the SC shipping containers and control over transportation conditions

4.2.1 Containers

A container shall protect the SC from damage during transportation, loading/unloading operations, or storage, as well as ensure protection against the natural environment.

4.2.2 Lifting devices and tie-down points

Lifting devices (yokes, shackles, etc.) and pick-up/tie-down points shall be provided for lifting and securing containers on a transportation device. The location of the lifting points shall provide a stable lift during any lifting operations. Intermediate elements for securing the container by lifting devices (yokes, shackles) on the transportation device shall be in accordance with the requirements of the OD. Requirements for proof loading of lift points, frames, and slings prior to use shall be specified in the OD.

4.2.3 Container dimensions

Dimensions of containers should be in accordance with the dimensional outlines of rolling stock adopted in international and/or national practice. The container dimensions shall provide a safe clearance between the SC and internal face of the container.

4.2.4 Design requirements

The design of the container shall ensure that

a) dust and moisture tightness is provided, protection against water penetration is provided, and environmental parameters inside the container are maintained within the established limits;

b) air pressure inside the container is equal to the environment at air pressure or higher air pressure in accordance with that specified in the OD;

c) relative air humidity inside the container is not more than 60 %, and the absolute humidity is not more than 0,019 kg/m^3 or in accordance with the OD for the SC;

d) temperature inside a container is from −50 °C to +50 °C or in accordance with the OD for the SC;

e) protection against penetration of rodents and insects is provided;

f) dust-generating materials are controlled;

g) container provides protection against static electricity build-up and/or a capability of discharge;

h) design load margins are in accordance with the OD for the SC;

i) transportation pressure is equalized, which adds a design requirement regarding the pressure equalization capability of the shipping containers;

j) products and amounts of out-gassing materials in proximity of the SC are specified in the OD for the SC;

k) materials are compatible with SC propellants if an SC is transported filled with fuel; a propellant leak and/or spillage cannot cause a spontaneous combustion and/or fire;

l) design and materials used for the SC shipping container are compatible for entry/operation inside a clean room;

m) RF (radio frequency) shielding is required when the spacecraft being transported is sensitive to external RF energy;

n) containers are constructed of corrosive-resistant materials or coatings, if likely to be subjected to corrosive environments.

4.2.5 Thermal containers

Thermal containers shall ensure the following transportation conditions:

a) temperature is in accordance with the OD for the SC;

b) pressure is from 93 kPa to 113 kPa or in accordance with the OD for the SC;

c) relative humidity is a maximum of 60 % or in accordance with the OD for the SC;

d) air cleanliness is in accordance with the OD.

4.2.6 Shock absorption system

In order to reduce structural loads acting on SC during transportation down to acceptable values, the container shall be equipped with a shock-absorption system or other load-reduction systems when required to meet the TS.

4.2.7 Monitoring and recording

For transportation of an SC in a container, the monitoring and recording of transportation conditions shall be performed when required by the OD for the SC. In order to ensure monitoring of SC parameters without opening the container, the container design shall provide for remote monitoring. Shock monitor/recording sensors shall be made a part of the shipping container internally and externally when required by the OD for the SC. Volumes and permissible ranges of values of monitored parameters of transportation conditions shall be stipulated in the OD for the SC.

4.3 Transportation by commercial rail

4.3.1 Requirements for transportation

SC transportation by rail shall be carried out in accordance with rules adopted in international or national practice.

4.3.2 Loads

The location and orientation of the SC (vertical, horizontal, etc.), securing of the SC in a container and the shock-absorption system shall be designed to accommodate the loads imposed by the OD for the SC.

4.3.3 Approval of deviations

Railway authorities shall approve overall container dimensions when they deviate from the overall dimensions of the rolling stock.

4.3.4 Precautions

During SC transportation, abrupt jolts, jerks, and disconnection of inter-car joints of the braking system are not allowed. Railway cars and platforms carrying SC shall not be subject to descending from sorting gravity yards and shall require higher caution measures during manoeuvres.

Speed with which a locomotive (with railway cars or without them) approaches immobile railway cars with SC shall not be more than 0,8 m/s. Speed with which detached or separate railway cars approach a hump yard as well as during manoeuvres shall not be more than 1,4 m/s. Do not hump rail cars carrying SC.

NOTE A hump yard is a rail yard permitting the switching of a group of rail cars where they are pushed onto a hump (high point), detached and moved by gravity toward another rail yard.

Railway cars carrying SC shall not be included in a train containing explosion hazards or chemically aggressive cargoes.

Railway cars carrying SC shall have signs and inscriptions on them that indicate precautions necessary for the descending from rail yards, abrupt jolts during manoeuvres, or detaching escort and protection railway cars.

4.3.5 External inspection during stops

During stops en route, external inspection of a transportation device, container, and container-securing assemblies shall be performed. The procedure and frequency of the inspection shall be specified in the OD for the SC.

4.4 Transportation by road

4.4.1 Working condition

Prior to loading/unloading operations, the working condition of the transportation device shall be inspected. Prior to first movement, the security of the container carrying the SC shall be inspected.

4.4.2 Loads

The location and orientation of SC (vertical, horizontal, etc.), securing of the SC in a container, and the shock-absorption system shall be designed to accommodate the loads imposed by the OD for the SC.

4.4.3 Driving regulations

During SC transportation by road, traffic and driving regulations shall be strictly enforced. Under harsh driving conditions (rain, snow, fog, dust storm, etc.), as well as in bad road conditions (mud, ice, roughness), the speed shall be reduced to a minimum, and sudden braking and sudden starting shall not be allowed.

4.4.4 Periodic checks and inspections

At a distance of 1 km to 1,5 km from the start of movement, then every 150 km of the journey, or in accordance with the OD for the SC, the security of the container carrying the SC shall be inspected, as well as an inspection of the motor vehicle shall be performed. Special attention shall be given to

a) the securing of the container carrying the SC on the transportation device;

b) the condition of the steering system and brakes of pull rod coupling of transportation device, as well as devices and equipment ensuring safety of movement (signalling, lighting devices, etc.);

c) the connections of pneumatic brakes and electrical equipment of tractor-drawn devices;

d) the security of the wheels, and the condition and securing of springs, shock absorbers, and torsion bars.

If specified by the OD for the SC, a security escort shall be provided.

4.5 Transportation by air

4.5.1 Limitations

Transportation of the SC by air shall be carried out without limitation of speed and distance. Limitations, if any, on the number of takeoffs and landings and the total flight times shall be determined by the OD for the SC.

4.5.2 Loads

The location and orientation of the SC (vertical, horizontal, etc.), securing of the SC in a container, and the shock-absorption system shall be designed to accommodate the loads imposed by the OD for the SC.

4.5.3 Inspection

Prior to each takeoff and after each landing, external inspection of the container and its tie-down assemblies in the aircraft shall be performed. The inspection procedure shall be specified in the OD for the SC.

4.5.4 Static and vibration accelerations

In order to ensure SC transportation by aircraft transport, the aircraft shall be capable of withstanding the maximum static and vibration accelerations, as well as the atmospheric pressure differentials arising during the normal and emergency flying regime and descent of the transport aircraft.

4.5.5 Loads on assemblies

Assemblies securing the SC in a container and the container itself shall be designed to withstand the structural loads acting on them during an emergency landing of the transport aircraft.

4.5.6 Setting values

For each type of aircraft, values of loads, flight altitude, and descent speed, as well as requirements to the SC and its securing, shall be set in accordance with specifications for the equipment and cargoes meant for transportation by transport aircraft.

4.6 Transportation by water

4.6.1 Limitations

SC transportation by water shall be carried out without limitation of speed and distance in accordance with regulations on cargo transportation in force for sea and river transport. Sea and river vessels that meet the requirements given in 4.6.2 to 4.6.5 for an SC should be used.

4.6.2 Loads

The location and orientation of the SC (vertical, horizontal, etc.), securing of the SC in a container and the shock-absorption system shall be designed to accommodate the loads imposed by the OD for the SC.

4.6.3 Tying down containers

Containers carrying an SC shall be safely tied down in accordance with the OD for the SC using additional devices (braces, ropes, wire, yokes, wooden pads, beams, etc.) specified by the OD for the SC.

4.6.4 Protection from water

Containers carrying SC placed on an upper deck of a ship shall be protected from atmospheric precipitation, seawater and river water.

4.6.5 Inspection of containers

The tie-down condition of containers carrying SC shall be checked not less than 4 times every 24 h (the first inspection shall be 0,5 h to 1 h from the start of movement) or in accordance with the OD for the SC.

4.7 Transportation of SC as a part of a launch vehicle

4.7.1 Distance and speed

When transporting a fully assembled SC from an assembly area to a launch pad, the distance shall be specified in the OD for the SC. The speed shall be in accordance with the OD for the SC.

4.7.2 Transportation conditions

During transportation of an SC as part of a launch vehicle, transportation conditions specified in the OD for the SC shall be in accordance with ISO 14303, in accordance with the interface requirements document specified in ISO 17401 and in accordance with the interface control document specified in ISO 15863.

4.8 Requirements for conducting and maintaining control over loading/unloading operations

4.8.1 Crossbars and cranes

During loading of an SC into a transportation container and onto a transportation device, proof loaded slings, shackles, cables, crossbars and cranes, etc., suitable for the job, having slow, lifting speeds and transferring

mechanisms, and equipped with two brakes acting independently from each other, shall be used. Only trained and certified operators shall perform lifting or handling operations.

4.8.2 Loading/unloading equipment certification

Prior to the beginning of loading/unloading operations, documents (passports or record books) on the cranes, crossbars, and containers, certifying their fitness for the lift, shall be checked to ensure that the proposed handling equipment was verified as satisfactory for the intended application.

4.8.3 Rigging devices

During loading/unloading operations, rigging devices shall be attached to all the points meant for the container lifting. All rigging devices shall be satisfactorily load-tested prior to use.

4.8.4 Tag lines

For turning, as well as preventing the container carrying the SC from spontaneous turning, lifting, or transfer, ropes (tag lines) shall be used (no less than two per container).

4.8.5 Lifting/loading equipment

Lifting/loading equipment shall be removed from a container or a crane hook only after the container has been set up safely on its base.

4.8.6 Flammable substances

Flammable substances that are not part of the SC and transportation system shall not be present in a loading/unloading area during the SC loading/unloading operations.

4.8.7 Cleaning the site

The loading/unloading site shall be cleaned of dirt, sand, mud, water, snow, ice, and other debris that might cause a safety issue to the personnel or the flight hardware.

4.8.8 Freezing conditions

Spacecraft containers exposed to freezing conditions can become frozen to the floor or supporting structure. The SC container shall not be lifted under these conditions until such time as an unrestrained lift can be ensured.

4.8.9 Signs and inscriptions

During loading/unloading and transfer of crates with assembly parts of SC, requirements for methods of handling cargoes (including manipulation signs and caution inscriptions) shall be met.

4.8.10 Prevention of electrostatic build-up

Proper grounding of the container and the people loading/unloading the container shall be performed in order to reduce or eliminate static electricity build-up.

4.8.11 Mechanical load control

During loading/unloading operations, control over mechanical loads acting on SC shall be maintained, in cases specified in the OD for the SC.

4.8.12 Environmental conditioning outside a climate-controlled building

If an SC requires continuous environmental conditioning outside of a climate-controlled facility, the OD for the SC shall specify the allowable time the SC can be without the conditioning during handling operations.

4.8.13 Nonthermal conditioning container

After SC transportation in a container without thermal conditioning at temperatures below 0 °C, the container shall be opened only after it has been kept at an indoor temperature for a time interval specified in the OD for the SC.

4.9 Verification of transportation and loading/unloading conditions

SC transportation and loading/unloading conditions shall be verified. The following parameters shall be subject to verification:

a) mechanical loads acting on the container in the fixation points;

b) pressure, temperature, and humidity inside of the container.

Each case of exceeding the set values of the previous parameters or exceeding the set allowable range shall be recorded together with the time when this event occurred. On the basis of the results of these recordings, a transportation package shall be prepared, containing a record of all violations of the set conditions as well as analysis of the reasons and seriousness of such violations.

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