



International Standard

ISO 14620-4

Space systems — Safety requirements —

Part 4: Spacecraft assembly, integration and test

Systèmes spatiaux — Exigences de sécurité —

Partie 4: Assemblage, intégration et test d'engins spatiaux

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Foreword

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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.

Space systems — Safety requirements —

Part 4: Spacecraft assembly, integration and test

1 Scope

This document provides requirements for the safety management and operation of assembly, integration and test (AIT) activities related to spacecraft projects and applications including the responsibilities of the organization involved in the AIT operations for spacecraft products.

This document provides a method to identify hazards, control and reduce safety risk to acceptable levels in the activities of spacecraft assembly, integration, testing, hoisting, logistics and handling.

This document is applicable to space test centres and entities providing operating infrastructure and facilities for spacecraft AIT. It can serve as a reference for the AIT of the spacecraft system, its subsystems and equipment.

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 10795, *Space systems — Programme management and quality — Vocabulary*

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

ISO 14620-2, *Space systems — Safety requirements — Part 2: Launch site operations*

ISO 14625, *Space systems — Ground support equipment for use at launch, landing or retrieval sites — General requirements*

ISO 17666, *Space systems — Risk management*

ISO 18322, *Space systems — General management requirements for space test centres*

3 Terms and definitions

For the purposes of this document, the terms and definitions given in ISO 10795 and the following 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 logistics

science and practice of interconnecting, and finding the best way of goal attainment, for bringing material objects or living beings in sufficient quantity to the right place in the right time.

[SOURCE: ISO 5127:2017, 3.1.2.26]

3.2

operator

governmental or non-governmental entities, international organization, or natural person carrying out a space operation independently and under its responsibility.

[SOURCE: ISO 14620-2:2019, 3.15]

3.3

risk

undesirable situation or circumstance that has both a likelihood of occurring and a potential negative consequence on a project

Note 1 to entry: Risks arise from uncertainty due to lack of predictability or control of events. Risks are inherent to any project and can arise at any time during the project life cycle; reducing these uncertainties reduces the risks.

[SOURCE: ISO 17666:2016, 3.1.12]

3.4

space test centre

complete entity including the organization which provides, maintains, develops and operates test facilities for space project and applications including accompanied services

[SOURCE: ISO 18322:2017, 3.7]

3.5

safety risk

measure of the potential consequences of a hazard considering the probability of the associated mishap, the harm caused to people and the damage caused to public and private property and the environment

Note 1 to entry: The safety risk is defined to be differentiated from political, financial, industrial, project, and other risks (3.3).

Note 2 to entry: An example of a safety risk is the expected number of casualties.

[SOURCE: ISO 14620-2:2019, 3.19]

3.6

safety representative

representative from the *space test centre* (3.4) management with designated responsibility for safety

[SOURCE: ISO 18322:2017, 3.5, modified — Note 1 to entry has been removed.]

4 Abbreviated terms

AIT assembly, integration and test

GSE ground support equipment

5 Safety organization

5.1 General

The safety organization shall be established to organize, inspect and implement safety activities in the AIT process.

5.2 Requirements for the safety organization

The following requirements apply to the safety organization.

- a) The safety organization shall be established in accordance with ISO 14620-1.

- b) Operations at the launch site shall conform to the safety requirements specified in ISO 14620-2.
- c) Ground support equipment used for launch, landing or retrieval operations shall meet the general requirements specified in ISO 14625.
- d) Space test centres shall meet the general management requirements specified in ISO 18322.
- e) The safety organization shall ensure that safety requirements and related AIT tasks are appropriately integrated into all project plans and procedures.
- f) The implementation of safety requirements shall be verified at defined intervals.

5.3 Safety representative

The following requirements apply to the safety representative.

- a) The safety representatives shall coordinate with all relevant bodies, including the safety launcher authority, medical boards, radiation protection committees, industrial safety organizations and environmental protection agencies.
- b) The safety representative:
 - 1) shall have the right to obtain all safety-related information;
 - 2) shall report to the project manager;
 - 3) shall have access to top management;
 - 4) shall have the authority to report safety issues independently;
 - 5) shall not be restricted by any organization in any aspect of safety.

5.4 Personnel

The following requirements apply to operating personnel involved in spacecraft AIT.

- a) Personnel shall be qualified in fundamental safety skills related to inspection, testing, maintenance and operation in the AIT process.
- b) Personnel performing or controlling hazardous operations, or handling, using or transporting hazardous materials, shall be trained and qualified with the necessary knowledge, skills and, if specified in the job description, abilities to perform the job safely.

NOTE This rule applies to tasks that pose an immediate danger to the operator (death or injury) if not performed correctly, or that can endanger others nearby (death or injury) or cause damage to surrounding equipment or facilities.

- c) Personnel shall have successfully completed safety and technical training and shall be familiar with the safety measures, safety plans and responsibilities associated with the operations they perform.
- d) All contractor personnel engaged in potentially hazardous operations or the handling of hazardous materials shall be qualified through similar training as described in item c).
- e) Operators shall wear dust resistant and anti-static work clothes, safety helmets and safety belts.
- f) During spacecraft integration, operators shall wear:
 - 1) split suit anti-static work clothes with tight cuffs and without pockets and buttons;
 - 2) anti-static wristbands according to the needs of work.
- g) When handling thermal control materials or other sensitive spacecraft products, operators shall wear masks and anti-static gloves or finger covers.

- h) Operators shall wear protective equipment in the work area.
- i) Unauthorized personnel shall not enter the work area.

6 Safety programme

6.1 General

- a) The safety programme:
 - 1) shall be established in accordance with ISO 14620-1:2018, Clause 4, to ensure that during AIT activities, the safety of spacecraft products, personnel (including customers and visitors), ground support equipment, facilities and the environment is fully addressed, taking full responsibility for safety performance during products testing;
 - 2) shall take into account the applicable safety requirements of either the spacecraft or the project, or both;

NOTE The objective of the safety programme is to ensure that all safety risks associated with the AIT, handling and logistics of spacecraft products are adequately identified, assessed, minimized, controlled and finally accepted. The safety programme includes the identification of hazards, assessment of safety risks, implementation of control measures for unacceptable risks, reassessment of risks following control measures and the reduction of risks to an acceptable level.
 - 3) shall ensure that all hazards related to spacecraft AIT are systematically identified, risks are assessed, and where risks are unacceptable, control measures are recommended to eliminate or mitigate the hazards.
- b) Information, data and analysis results obtained during hazard analysis and safety risk assessment shall be communicated to design, operations and management teams in a timely manner to implement early measures for effectively ensuring safety.
- c) Interfaces shall be established between the safety programme and other plans and programmes (e.g. AIT, handling, reliability, quality assurance) to integrate relevant data and information into hazard analysis and safety risk assessment.

6.2 Hazard analysis

The purpose of the hazard analysis is to identify, at an early stage, hazards related to spacecraft AIT that can pose a threat to the safety of personnel, spacecraft products and facilities.

The AIT phase hazard analysis shall cover at least the following aspects:

- a) hazardous materials (e.g. propellants, gunpowder, explosive devices, toxic substances, power supplies, radioactive materials, and high-pressure gas sources);
- b) the environment in which the system operates, including the natural environment and induced environments (e.g. vibration, shock, extreme temperatures, vacuum, electromagnetic interference);
- c) system functional faults or abnormal operating conditions;
- d) defects in safety-critical instructions and control software;
- e) risks that may arise or be introduced during AIT, handling or logistics;
- f) incorrect operation;
- g) the storage, handling and transportation of hazardous materials;
- h) safety-related equipment, safety protection devices and other safety assurance measures;
- i) analysis of safety requirements and lessons learned from similar previous operations.

6.3 Safety risk assessment

The purpose of the safety risk assessment is to analyse the identified hazards related to spacecraft AIT by evaluating the risk level based on severity and occurrence probability and to determine the need for risk reduction measures.

The following requirements apply for safety risk assessment.

- a) The safety risk assessment shall be performed for each identified hazard in accordance with ISO 17666.
- b) The safety risk assessment shall determine the risk level for each identified hazard based on severity and occurrence probability.
- c) Hazard severity shall be classified as catastrophic, critical, marginal and negligible in accordance with the definitions in ISO 14620-1.
- d) The safety risk assessment shall determine the acceptability of each risk based on the safety policy and accordingly, identify the need for control measures.
- e) A safety risk assessment report shall be prepared; and the results of the assessment shall be considered a key element in the special safety review to ensure that any remaining risks are acceptable.

6.4 Safety risk control

6.4.1 Purpose of safety risk control

The purpose of safety risk control is to reduce unacceptable safety risks or safety-critical items to an acceptable level.

6.4.2 Safety risk control measures

For the selection and implementation of safety risk control measures the following order applies.

- a) Elimination of hazards: hazards should be eliminated from the operational scheme by aligning task objectives with the selection of assembly and test operations.
- b) Minimum risk design: for hazards that cannot be eliminated, sufficient safety margins shall be ensured to control the risk to a minimum acceptable level.
- c) Safety measures: automatic or other operational measures may be implemented to reduce risks to an acceptable level.
- d) Warning design: warning devices should be established to alert personnel if safety measures cannot fully eliminate the hazard or reduce its associate risk to an acceptable level.
- e) Safety operation procedures and training: specific safety operation procedures should be developed and necessary trainings provided for risks that cannot be eliminated through design, safety measures or warning devices.

6.4.3 Safety critical items

The following requirements apply to the definition of control measures for safety-critical items.

- a) The production and test documents of safety-critical parts shall be appropriately identified (e.g. safety-critical characteristics, critical processes, critical parts).
- b) The AIT and handling of items with potential hazards to personnel or hardware shall be optimized for operational safety; and traceability shall be maintained.
- c) Safety-critical items (including safety-critical operation procedures), control methods and test requirements of safety-critical items shall be tracked.

6.5 Verification of safety risk control measures

The following requirements apply to the verification of safety risk control measures.

- a) The implementation of process control measures and safety improvement measures for safety-critical items shall be verified.
- b) When safety control measures require verification at a mandatory inspection point, the safety inspection shall be conducted during the AIT phase accordingly.
- c) After verification of implementation, the safety risk assessment shall be repeated to update the product AIT and process operation risks, and to re-evaluate whether the control measures effectively meet the safety requirements.
- d) The documentation shall be updated to consider system configuration modifications, and updates to safety-critical items and corresponding control requirements.
- e) Unresolved residual risks shall be comprehensively documented and prepared for management review to support decisions regarding their acceptance.

6.6 Safety documentation

6.6.1 General

The following requirements apply to the safety documentation.

- a) Contingency plans for the spacecraft, its subsystems, test equipment and infrastructure shall be documented.
- b) Safety-related documents or forms shall be developed to ensure the traceability of safety activities.
- c) Hazardous materials and risk factors involved in the spacecraft AIT process shall be identified; and the related documentation shall be approved by the safety representative.
- d) Clear signboards for hazardous materials, protective measures and the emergency response plan shall be established and maintained at all times.

6.6.2 Safety summary records

The following requirements apply to safety summary records.

- a) The safety status shall be reported and documented at the end of each test phase.
- b) If an emergency occurs during AIT, the outcome of the emergency response shall be recorded.
- c) If a safety incident occurs during AIT, the treatment process, rescue efforts, accident losses and post-incident actions shall be investigated and clarified.
- d) Lessons learned from safety events shall be made public and used to continuously improve the safety management system, safety programme and safety requirements.

6.6.3 Safety inspection records

The following requirements apply to safety inspection records.

- a) All safety reviews, inspections and checks shall be recorded.
- b) Records shall be stored for at least the lifetime of the corresponding spacecraft to ensure traceability of the AIT process.
- c) Records shall be available for review at any time.

- d) Relevant information from the records shall be shared with other project teams when necessary.

7 Safety requirements for AIT facilities and equipment

7.1 Ground support equipment

The following requirements and recommendations apply to GSE for AIT.

- a) GSE with human-machine interfaces should be designed to minimize the potential for hazardous events caused by human errors.
- b) GSE hazard analysis should be available for reference, so that AIT personnel are aware of the hazards associated with each operation.
- c) The GSE user's manual should contain sufficient information regarding hazards to alert personnel and prevent accidents.
- d) GSE design should fully consider the operating conditions and include safety margins.
- e) The design of GSE key functions and components should incorporate redundancy to ensure normal operation is not affected by a system or component failure.
- f) The electrical system of GSE should ensure the accuracy and reliability of power transmission, signal transmission and control performance to prevent hazards caused by mechanical damage.
- g) The power supply system of GSE shall be painted with safety colours and include warning signs at locations with electric shock hazards.
- h) GSE with electrical systems should be equipped with indicators for general power supply on/off status, fault signals, and alarm signals, where necessary.
- i) Signals (indications, faults and alarms) should be clearly either visible or audible, or both, to operators.
- j) The execution of safety-critical functions should be confirmed or initiated by the operator; procedures for controlling power-on or start-up shall be established.
- k) Safety signs should be designed for hazardous operations or locations and shall be clearly visible.

7.2 Environmental conditions

The following requirements apply to the AIT environment.

- a) The temperature, humidity, cleanliness, power supply, grounding and anti-static facilities of the test centre shall meet the requirements of either the product or its components, or both.
- b) Clear warning and alarm signs shall be posted; and corresponding protective measures shall be taken before operations where risks such as electric shock, falling from heights or radiation can occur.
- c) Safety precautions shall be taken for any trenches and pits at the operation site.

7.3 Processes

The following requirements and recommendations apply to the AIT processes.

- a) Space test centres shall be supported by a safety management system, safety procedures and contingency plans, including emergency measures.
- b) Hazardous areas of the pressure vessels and pressure pipelines shall be identified and regularly inspected.
- c) A safety analysis should be systematically conducted for AIT operations as described in [Clause 6](#).

- d) Hazardous operations shall be performed in accordance with approved documentation.
- e) Equipment shall be used strictly in line with the operating documentation.
- f) When selecting materials, it should be ensured that hazards related to material characteristics (e.g. toxicity, flammability) are eliminated or controlled. If this is not possible, the system design should incorporate necessary measures to control hazardous events associated with material characteristics, in accordance with the requirements of this standard.
- g) Hazardous goods, such as flammable, explosive, and radioactive materials used during AIT activities, shall be stored in a safe location and clearly marked with visible warning signs.
- h) After hazardous materials handling is completed, any remaining hazardous materials shall be safely stored.
- i) Depending on the toxicity of the hazardous materials, the area shall not be released until chemical analysis confirms that air is safe for breathing.

8 Safety requirements for integration and mechanical performance testing

8.1 Hazards to be considered

The following hazards shall be considered as integration risk factors based on the safety requirements of the project:

- a) dangerous articles, such as explosive device, power supplies, radiofrequency sources, radioactive substances, propellants and high-pressure gas sources;
- b) dangerous operations such as work at height;
- c) safety-related equipment, safety protection devices and other safety assurance measures.

8.2 Measures to reduce safety risks

8.2.1 General

The following recommendations support the reduction of safety risks during integration.

- a) Safety control measures should be implemented to prevent tools from falling.
- b) Safety control measures should be implemented for live battery-related operations to prevent battery short circuits.
- c) Inflammable and explosive items, if present, should be stored in the designated and suitably protected storage area.
- d) Safety control measures should be implemented to prevent bright light from directly flashing into optically sensitive lenses when taking pictures of sensitive areas, unless explicitly permitted.

8.2.2 Integration of pyrotechnic devices

The following requirements and recommendations support the reduction of safety risks during integration of pyrotechnic devices.

- a) Pyrotechnic devices shall be fitted with short-circuit protection plugs during storage, transportation, installation and inspection.
- b) After pyrotechnic devices are removed from the dedicated storage area, they should be installed immediately or, in case of delay, immediately returned to the dedicated storage area.

- c) When pyrotechnic devices are being installed:
 - 1) operators shall wear anti-electrostatic wristbands;
 - 2) the anti-electrostatic wristbands shall be reliably grounded.
- d) When pyrotechnic devices are being installed:
 - 1) all systems on the spacecraft shall be unpowered;
 - 2) the spacecraft shall be reliably grounded.
- e) Pyrotechnic shall be protected from impact as much as possible.
- f) Striking, bumping and other dangerous actions shall be avoided during installation.
- g) After installation, operations such as cutting and punching on product shall be avoided.

8.2.3 Integration of radioactive products

The following requirements support the reduction of safety risks during the integration of radioactive products.

- a) Radioactive products shall be stored in lead-shielded containers and dedicated storage areas.
- b) All radiation sources shall be managed under specialized supervision with accounts established, maintained and regularly checked.
- c) Safety isolation areas shall be established at the operation site, with appropriate warning and monitoring measures implemented for radiation hazard areas.
- d) An operational walkthrough shall be conducted before the assembly of radioactive source products.
- e) Operators assembling radioactive products shall wear protective equipment, such as lead-shielded clothing, and use pen radiation dosimeters.
- f) If radioactive products are involved in AIT, radioactivity levels at the operation site shall be continuously monitored to conform to applicable standards and requirements.
- g) During work with radioactive materials or devices, operators' health and received radiation doses shall be recorded on a permanent basis.

8.2.4 Mechanical performance testing

The following requirements and recommendations support the reduction of safety risks during integration testing.

- a) When laser test equipment is used:
 - 1) the laser light source shall be prevented from directly irradiating human eyes;
 - 2) warning marks should be pasted if necessary.
- b) When operating near the spacecraft, the test equipment support shall be locked to ensure stability and prevent overturning.
- c) The target, markings and protective covers for measurement on the spacecraft should be removed before launch; measures shall be taken to prevent interference with the normal operation of the spacecraft if they cannot be removed under special circumstances.
- d) Maximum load and eccentric torque shall remain below the maximum allowable limits of the equipment.
- e) The product shall be connected to GSE.

- f) No obstacles shall be present within the spacecraft's work envelope that could affect the test.
- g) For pressurization tests:
 - 1) isolation measures for the test area shall be implemented and enforced;
 - 2) test equipment used for pressurization shall be equipped with over-pressure protection to ensure that rated allowable pressure limits are not exceeded.
- h) Measures to prevent either tipping or uncontrolled gas release, or both, shall be implemented during the use of gas source containers.
- i) A safety operation procedure shall be documented and implemented for the use of high-pressure systems.
- j) All activities not related to the test shall be suspended in the affected area during high-pressure pressurization and leak detection tests.

8.2.5 Hoisting

The following requirements support the reduction of safety risks during hoisting.

- a) Safety operation procedures for hoisting shall be established.
- b) Crane operators shall hold the appropriate qualification.
 - 1) The safety representative shall verify the validity of the operators' training certificates.
 - 2) If a certificate is out of date, the operation shall be immediately interrupted.
- c) Hoisting equipment shall have a valid inspection certificate or other documentation confirming it is safe for operation.
- d) The safety status of crane lifting appliances shall be regularly checked, especially the brake function and the safety of the hook's anti-fall mechanism, with records and documentation maintained accordingly.
- e) Unless a reliable tightening device is used:
 - 1) the load shall not be suspended without control;
 - 2) the load movement shall not be allowed to pass over the personnel.
- f) Outdoor hoisting shall be stopped if wind speed is too high.
- g) The total lifting load shall not exceed the rated load of the lifting equipment.
- h) When two pieces of lifting equipment are used jointly:
 - 1) the load on each lifting equipment shall be estimated in proportion to ensure that the slings remain vertical during lifting;
 - 2) the load shall not exceed the rated capacity of either piece of equipment when lifted separately.
- i) When the spacecraft is turned over, operators shall ensure that the horizontal projection of the spacecraft's centre of mass remains within the horizontal projection range of the lifting point's envelope at all times.

8.2.6 Logistics

The following recommendations apply to internal logistics.

- a) The ground handling safety requirements should be specified and documented in the transportation plan.
- b) During transport, the product should be securely attached to the means of transport.

- c) During transport, an effective electrostatic discharge path should be maintained between the spacecraft and the ground.
- d) The transportation speed should not exceed the value defined in safety regulations.
- e) Once the product logistics transportation route and plan are determined, they should generally not be changed temporarily.

9 Safety requirements for electrical performance testing

9.1 Hazards to be considered

The following hazards should be considered for electrical performance test hazard analysis and safety risk assessment:

- a) the environment, including both the ambient environment and the induced environment (e.g. electromagnetic effects);
- b) safety-critical instructions;
- c) product and test facility control software failures;
- d) safety related equipment, safety protection devices and other safety assurance measures.

9.2 Measures to reduce safety risks

The following requirements and recommendations support the reduction of safety risks during electrical performance testing.

- a) A technical safety management team should be established for space testing, responsible formulating technical safety control and management requirements, implementation safety measures and conducting inspections.
- b) Before each test phase, the technical safety management team shall perform a technical safety inspection on power supply and distribution facilities, as well as grounding of spacecraft and ground facilities at the test site.
- c) When testing high-power radiation devices, a secure enclosed area shall be set up and marked with clearly visible warning signs.
- d) Operators working in ultra-high frequency and microwave radiation areas shall wear anti-microwave clothing and anti-microwave glasses.
- e) For control commands involving dangerous or restricted conditions, locking and enabling mechanisms shall be established (e.g. by means of software control, condition discrimination, hardware locking).
- f) The activation of pyrotechnic devices shall be protected by a locking and enabling function, ensuring that:
 - 1) locking is only released prior to planned activation;
 - 2) the activation command can only be sent after enabling;
 - 3) the locking is re-established after the activation commands are sent.
- g) During the test, the safety state parameters of the spacecraft shall be determined and monitored in real time (e.g. pressure and temperature of high-pressure gas cylinders, on-off state of the ignition power source of the pyrotechnic devices, and the voltage and current of power supply bus).
- h) Operators shall not stand at the hazardous direction of pyrotechnic devices during their installation.

10 Safety requirements for environmental testing

10.1 Hazards to be considered

The following hazards should be considered for environment test hazard analysis and safety risk assessment:

- a) dangerous articles, such as explosive devices, toxic substances, radiofrequency sources, power supplies, propellants and high-pressure gas sources;
- b) the environment, including both the ambient environment and the induced environment (e.g. vibration, shock, temperature, vacuum, electromagnetic effects);
- c) product and test facility functional faults or abnormal operating conditions;
- d) risks that can arise or be introduced during the assembly and integration of the test setup, testing, handling of the product and test facility, and product logistics;
- e) operator error;
- f) safety-related equipment, safety protection devices and other safety assurance measures.

10.2 Measures to reduce safety risks

10.2.1 General

The following requirements and recommendations apply to environmental testing in general.

- a) The test site:
 - 1) shall be equipped with devices to reduce or eliminate hazardous and harmful factors;
 - 2) shall be actively monitored, with an over-limit warning function.
- b) Operators shall regularly inspect the equipment under test and the test facilities during the test.
- c) If any safety problem occurs, it shall be immediately handled and reported.
- d) For environment testing, any toxic substances shall be replaced by substances or simulation parts with the same test performance but as little toxicity as possible.
- e) In outdoor areas where nitrogen is emitted, signs shall set up to prevent personnel from suffocation.
- f) Indoor areas at risk of breathable air contamination shall be equipped with oxygen detection and warning devices.
- g) Work shall not be performed in environments where oxygen content is below the specified limit, unless oxygen-supply protective masks are worn and appropriate supervision is ensured.
- h) When operating in a narrow or specialized equipment (e.g. nitrogen outlet), in areas where oxygen concentration is below 19 % no personnel activity shall take place without protective equipment.
- i) Evacuation training should be performed at least once a year and include rescue simulations.
- j) In the event of operator fainting:
 - 1) an emergency rescue plan shall be executed immediately;
 - 2) rescue personnel shall be properly equipped during the rescue.
- k) Work at height shall have appropriate safety measures in place.