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Space systems — Flight-to-ground umbilicals

Systèmes spatiaux — Ombilicaux bord-sol

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ISO copyright office
CP 401 • Ch. de Blandonnet 8
CH-1214 Vernier, Geneva
Phone: +41 22 749 01 11
Email: copyright@iso.org
Website: www.iso.org

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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 document 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).

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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*.

This second edition cancels and replaces the first edition (ISO 15389:2001), which has been technically revised. It also incorporates the Amendment ISO 15389:2001/Amd 1:2005 and the Technical Corrigendum ISO 15389:2001/Cor 1:2006.

The main changes are as follows:

— addition of 4.9 on the prevention of accidental cross-connection.

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 general requirements and criteria for flight-to-ground umbilical systems used by space systems. The purpose of this document is to establish uniform engineering practices and methods and to ensure the inclusion of essential requirements in the design of reusable flight-to-ground umbilical systems that support the launch of space systems. This document is not intended to define how to design umbilicals but to define the minimum requirements for umbilicals.

Prevention of accidental cross-connection of umbilical system connectors and couplings is extremely important. Launch vehicle and spacecraft assemblies and features are often unique, requiring many connectors and couplings to be in close proximity to each other. The accidental cross-connection of service lines can result in very serious and even tragic consequences. For example:

— supplying other gas or fluids;

— supplying gas or fluid under other pressure;

— supplying the electric power with other parameters;

— supplying an error signal (command).

Therefore, differences in design of connectors and couplings that are located close to each other should be significant. Such differences can be both in design and in marking for identification.

International cooperation in space engineering assumes international cooperation in design, manufacture, and operation. The application of uniform methods increases the reliability of space systems by minimizing the accidental cross-connection of connectors and couplings. The application of unified symbols promotes mutual understanding and personnel training.

Space systems — Flight-to-ground umbilicals

1 Scope

This document defines the general criteria for the development of flight-to-ground umbilical systems used by a space system. These criteria apply to the service arms or equivalent mechanisms, umbilical carriers and plates, couplings, connectors, withdrawal and retract devices, handling mechanisms and control systems for mechanisms, as well as the prevention of accidental cross-connection.

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

IEC 60364-5-54, *Electrical installations of buildings — Part 5: Selection and erection of electrical equipment — Chapter 54: Earthing arrangements and protective conductors*

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
carrier
device that groups *coupling* (3.3) and *connector* (3.2) halves together to provide a common means for their positioning, retention, unlocking, and separation

Note 1 to entry: The term is commonly used in relation to the facility ground-side of umbilical *interfaces* (3.8).

3.2
connector
device, consisting of two halves, that permits engagement and disengagement of electrical circuits at an *interface* (3.8)

3.3
coupling
device, consisting of two halves, that permits transfer of fluid across and disconnection at an *interface* (3.8)

3.4
flanged connection
connection at which halves of *connectors* (3.2) or *couplings* (3.3) are mated by means of flanges

3.5
ground control
equipment, fluids, or signals, provided for command or control purposes, which are neither on board nor originate on board the launch vehicle

3.6
handling mechanism
device used to provide positioning, manipulation, and physical dead-weight support of an object

3.7
inflight
term that denotes an occurrence or function after vehicle *lift-off* (3.10)

3.8
interface
mechanical, thermal, electrical, or operational common boundary between two elements of a system

EXAMPLE Ground-to-vehicle interface, physical interface, or responsibility interface.

3.9
launch processing system
operating consoles, data handling and display equipment, and the associated transmission system configured to issue commands and analyse and display response data required in checkout and operation of ground support equipment (GSE) and flight hardware

3.10
lift-off
instant of flight at which the vehicle's contact is terminated with all areas of hold-down and/or support devices

Note 1 to entry: Lift-off is commonly called "first motion" of the vehicle.

3.11
nipple
half of a hydraulic or gas *coupling* (3.3) with an external sealing surface

3.12
plate
device that groups coupling and *connector* (3.2) halves together to provide a common means for retention

Note 1 to entry: The plate is a passive device, containing cooperating but usually immobile portions of positioning, locking, and separation machinery.

Note 2 to entry: The term is commonly used in relation to the vehicle side of umbilical *interfaces* (3.8) or with the *carrier* (3.1).

EXAMPLE Carrier plate.

3.13
pre-flight
<occurrence or function> occurring before vehicle *lift-off* (3.10)

3.14
rise-off
<device> actuated solely by a vehicle's vertical motion

3.15
service arm
retractable structure, usually attached to a tower used to provide either umbilical requirements, personnel access, or both to the flight vehicle

Note 1 to entry: A service arm is commonly called access arm, umbilical arm, or swing arm, depending upon whether it provides services for access only, *umbilicals* (3.19) only, or both, respectively.

Note 2 to entry: The service-arm retracting motion may be along an arc or in a vertical or horizontal plane.

3.16
T–0
time minus zero
last moment in the launch countdown, measured in seconds, at which time the launch vehicle lifts off the ground

3.17
tail service mast
retractable structure used to provide umbilical requirements to the aft portion (tail) of a space vehicle

Note 1 to entry: Movement is usually a rotation about a pivot point away from the vehicle.

3.18
threaded connection
connection at which halves of *connectors* (3.2) or *couplings* (3.3) are mated by means of a thread on each of the halves

3.19
umbilical
device that provides fluid (supply/return and purge) and electrical requirements at physical *interfaces* (3.8) between ground facilities and various areas of a space vehicle

3.20
umbilical assembly
mated *carrier* (3.1) and *plate* (3.12) containing all *couplings* (3.3) and *connectors* (3.2) for a specified umbilical region of the vehicle

3.21
umbilical service line
fluid line or electrical cable routed through an *umbilical* (3.19) such as a *service arm* (3.15) or equivalent mechanism that is to be disconnected prior to engine ignition or at *T–0* (3.16) or in flight

3.22
umbilical supply device
movable structure used to connect and/or disconnect the umbilical *plates* (3.12) at various locations on a space vehicle

3.23
umbilical system
functional assembly of all items required for providing fluid and electrical servicing to a launch vehicle and/or a payload

Note 1 to entry: This system usually includes the following:

— *service arms* (3.15) or equivalent *umbilical supply device* (3.22) mechanisms;

— umbilical *carriers* (3.1) and *plates* (3.12);

— *couplings* (3.3) and *connectors* (3.2), all separation, withdrawal, and retraction devices;

— control equipment;

— control fluids and electrical signals;

— all interconnecting lines across the service arms or the equivalent mechanism on the ground side.

Note 2 to entry: The mating-half *interface* (3.8) for the couplings/connectors and umbilical carrier should be located on the exterior surface of the launch vehicle at an orientation compatible with the launch structure.

3.24
union
half of a hydraulic or gas *coupling* (3.3) with an internal sealing surface

4 General requirements

4.1 Umbilical system principles

The umbilical design shall not require reconnection of disconnected umbilical service lines to abort safely on the launch pad. Passive umbilical systems disconnected at lift-off by gravity is the preferred system as opposed to active systems to minimize failure modes and potential damage to the flight hardware. Adequate safety margins and/or system redundancy shall be included in the design to preclude premature umbilical disconnect that can jeopardize the flight hardware environment or vehicle and/or personnel safety. System design shall be a balance between ensuring umbilicals remain engaged and sealed under all static and dynamic pre-launch environments and safely disconnecting at lift-off.

Disconnect after lift-off should have at least secondary and, if possible, tertiary modes to ensure vehicle safety as the primary feature and protection of the ground systems under the launch environment as a secondary feature. Umbilical failures shall not propagate into the flight vehicle system. Flight-to-ground umbilical systems shall conform to the general requirements specified in ISO 14625.

4.2 Mating

4.2.1 Time

The time required to connect and verify an umbilical assembly shall be minimized. Factors that should be considered include:

a) the number of steps required;

b) the number of component parts to be installed or manipulated in the connection process;

c) availability of, and accessibility with, mechanical handling aids;

d) available working space;

e) requirements for operating personnel;

f) safety requirements;

g) alignment requirements;

h) the adaptability to automated verification.

The goal for the time required to perform the mating operation is one work shift or less.

4.2.2 Handling and engagement

Rapid handling and engagement are necessary in order to minimize impact on the ground turnaround and crew size for launch support. To provide ease with which an umbilical assembly is mated and connected to a vehicle, consideration shall be given to mass, torque requirements, manual force required for connection, and rigidity of electrical cables, flex lines, propellant flex lines, ducts for environmental control systems, etc.

4.2.3 Alignment

The umbilical assembly shall be self-aligning. The design shall not require critical manual horizontal, vertical, or parallel alignment for mating.

4.2.4 Verification

Mated umbilical assemblies shall allow quick and reliable verification of integrity.

4.2.5 Materials

Umbilical materials shall be compatible with service line media, shall be corrosion-resistant, and shall meet flammability, odour, and off-gassing, or vacuum-stability requirements that may be required by the flight hardware system.

4.3 Mass

Umbilical parts shall be as lightweight as feasible to minimize launch-induced loads and ground-handling requirements.

4.4 Loads

4.4.1 General

Umbilical design shall accommodate all static and dynamic pre-launch loads, such as dead loads, fluid pressure loads, and catenary loads imposed on all lines running from the flight vehicle to the supporting structure coupled with wind loads. Connections shall be located on or within the carrier so as to evenly distribute the forces required for disconnect or retain the vehicle about the locking, release, and ejection mechanisms. The same consideration shall also be given to the design of the handling systems. Loads during lift-off (such as retractable, acoustical, vibrational, and heat- or blast-pressure loads, as applicable) shall also be accounted for during umbilical development.

4.4.2 Side loads

Carriers and plates shall be designed and used in a manner that prevents connectors or couplings and latching and/or carrier mechanisms from having side loads.

4.4.3 Tracking loads

The vehicle shall bear all loads associated with the tracking of vehicle motion by the umbilical assembly and the attached hardware and the loads shall be as low as possible, consistent with practical GSE design and reasonable vehicle interface structural requirements. Other than vehicle requirements, determining factors for loads shall include overall costs for the life of the program.

4.5 Contamination prevention

Both halves of all fluid couplings shall incorporate internal devices for the protection of the system from debris during the launch, flight, and recovery operations. The devices shall be normally in the closed position and shall be opened automatically by the engagement of the two coupling halves. The device shall close automatically as the two coupling halves are separated. The device may also be capable of being opened or closed upon command from the ground control system or launch processing system.

4.6 Purges

Electrical umbilical connectors shall be provided with an inert environment, to the extent required to ensure safety. Cryogenic connections should be purged as required to prevent moisture condensation as well as resulting ice build-up or liquefaction of air. Systems for hypergolic or other corrosive or

hazardous fluids shall have a purge, scrubbers, etc., as required for safe connect and disconnect operations. There shall be only one purge in a cavity between the carrier and the plate.

4.7 Leak detection

When hazardous fluids are present, such as hypergols or nitrogen, umbilical couplings shall utilize primary and secondary seals and shall have sensors to detect primary and secondary seal leakage to the extent possible. Redundant seals and integrity monitoring are desirable to achieve this goal in most instances.

4.8 Leakage disposal

Disposal of hazardous media leakage from couplings shall be provided during vehicle servicing.

4.9 Prevention of accidental cross-connection of fluid couplings

4.9.1 General

The design of couplings for liquid or gas service lines to the umbilical shall ensure that it is impossible to mate a coupling improperly.

4.9.2 Requirements for umbilical connectors and couplings located on the same plate

The cross-coupling requirements and recommendations in 4.9.3 to 4.9.12 apply to umbilical assemblies connected to pipelines and equipment cables at a launch complex or to the launch vehicle or spacecraft. These requirements can be used by those participating in the development, renovation, modernization, and operation of launch complexes and address umbilical connectors and couplings located on the same plate to prevent an accidental service-line cross-connection. There are two types of requirements: design and symbolic. The design requirements provide the distinctive characteristics of elements for attaching connectors (threaded connections, flanges, etc.). The symbolic requirements provide for the presence of distinctive marking of connectors and couplings (pipelines, cables) by symbols or colour.

4.9.3 Design and symbolic requirements to prevent cross-coupling

Electrical and fluid connectors and couplings located on a single umbilical carrier plate (or carrier) shall be designed to prevent the accidental cross-connection of incorrect coupling halves.

This requirement may be implemented in one of the following ways:

a) use of a different design (use of different threading, flange design, or both);

b) application of distinctive marking.

The simultaneous use of both prevention methods is recommended.

4.9.4 Recommended fastener elements

These fastening elements are recommended:

a) removable bolts or screws;

b) folding bolts;

c) locks with different attachment methods.

4.9.5 Design requirements for threaded connections

Where different threading is intended, it shall be distinguished by one or more of the following:

a) diameter - not less than by 4 mm;

b) arrangement - external, internal;

c) step - not less than by 1,5 mm;

d) number of threads per unit of measure;

e) direction – right-hand or left-hand threads.

Other features include the following:

— guide elements;

— fixing elements;

— arrangement of nipples and unions, etc.

4.9.6 Design requirements for flanged connections

Where a different flange pattern is intended, it shall be distinguished by one or more of the following:

a) geometrical configuration (circle, oval, square, triangle, irregular polygon, etc.);

b) flange thickness;

c) attachment (perpendicular or parallel to plate) orientation;

d) quantity of attachment features;

e) arrangement of attachment features;

f) type of fastening elements (bolt with a nut, screw, pin, lock);

g) diameter of threaded elements;

h) quantity of connectors (couplings) located on a flange;

i) location of flanges [flanges on both halves of connectors (couplings) or only on a part of the pipeline (cable)].

4.9.7 Design recommendations for electrical connections

Electrical connectors (except the requirements previously specified) should differ in the following:

a) pin quantity;

b) geometrical configuration of pin combination;

c) pin diameter;

d) arrangement of “pin–socket” couple.

4.9.8 Distinctive marking requirements

Marking by figures, letters, or symbols and colour is recommended. See 4.9.9 through 4.9.11.

Both halves of connectors and couplings, as well as their respective pipelines and cables attached to them, shall have identical marking.

Marking shall be put directly on both halves of connectors and couplings and on the pipelines and cables attached to them.

Marking may be by a mechanical method or by painting.

When it is impossible to mark both halves of connectors and couplings or pipelines and the cables directly, one half should have a label marker. In this case, places for label attachment shall be provided on halves of connectors and coupling (pipelines and cables).

On vacuum pipelines, an inscription “vacuum” is made besides marking.

4.9.9 Marking figures and letters

The marking content and location shall be indicated on the schematics, diagrams, and drawings. The size of figures and letters should be not less than 5 mm. The marking shall be clear and precise to preclude an error in reading and understanding.

4.9.10 Marking by symbols

The marking symbols shall indicate danger if it can arise with cable (pipeline) damage (e.g. high voltage/ pressure and poisonous substances).

The halves of the marking symbols should be as specified on the schematics, diagrams, and drawings. In all cases, the symbols shall be explained in the operation and maintenance documentation.

The symbol size should be not less than 15 mm.

The symbol colour should be black or white depending on the background. Symbols should be placed inside an equilateral triangle with the size of the side not less than 24 mm. The colour of the triangle background should be yellow.

Symbol tracing should be clear and precise to avoid an error in understanding.

The concrete parameters can be utilized as marking, for example, voltage 25 V.

4.9.11 Marking by colour

Colour marking should indicate the following:

a) the function (application) of a connection (unit A power supply, bottles, charging control, tank fill and drain, tank pressurization, fire suppression, etc.);

b) the value of dangerous characteristics (more than 250 V, more than 4 MPa, etc.);

c) the fluid and gas type [combustible gases (including liquefied); non-combustible gases; inert gases; air; combustible fluids; water; fire-suppression products; mixes, etc.];

d) the particular fluid or gas (oxygen, hydrogen, kerosene, helium, nitrogen, compressed air, etc.).

In the case where the use of a colour symbol is required for marking bands (loops), the following will apply:

— symbol size should be not less than 15 mm;

— line thickness should be not less than 5 mm;

— colour should correspond to a function, characteristic, type, etc.;

— width of a band should be not less than 5 mm.

If it is necessary to identify several characteristics, add one or more bands. The first band should be the function, followed by additional bands with a description.

Additional bands corresponding to other characteristics may be added to the basic colour bands.

The distance between additional bands and also from an edge of a basic band is not less than 5 mm.

When using cables with colour isolation, the colour of the isolation shall correspond to a function colour.

When using painted pipes, their colour shall correspond with the function colour.

When applying additional bands, black or white lines that are 1-mm thick should be applied to the edges of colours that are similar (e.g. red/orange) or the same.

Marking colour shall be established to meet national, customer, or launch vehicle supplier requirements. The convention used shall be identified in the appropriate operations manual.

4.9.12 Connector and coupling service requirement

During assembly, test, and operation, connectors and couplings should not be in a zone of simultaneous service. All connectors and couplings in this zone shall have a very different design and be marked to prevent an incorrect connection.

4.10 Electrical connectors

Electrical connectors shall be dead-faced and self-aligning. Data bus, power, and command functions shall be in separate connectors to the extent possible. Connectors contained in the carrier shall not be self-locking. The design of electrical connectors shall prevent incorrect mating of the connector.

4.11 Grounding

Umbilicals shall be grounded in accordance with the requirements of IEC 60364-5-54.

4.12 Electromagnetic compatibility (EMC)

Umbilical electrical and electronic systems shall be designed to minimize the generation of and susceptibility to electromagnetic interference in order to eliminate any possible deterioration of the performance of the system and surrounding systems. EMC requirements shall be in accordance with the requirements established by the flight hardware system.

4.13 Lightning current paths

Umbilical connections above the base area of a space vehicle shall be eliminated or minimized to reduce the number of electrical paths through the vehicle from a lightning strike on the facility structure.

4.14 Environmental conditions

4.14.1 General

A flight-to-ground umbilical shall meet natural and induced environments to which it is to be subjected during its life cycle. The natural and induced environmental conditions shall be defined and taken into consideration during the umbilical development.

4.14.2 Natural environment

Flight-to-ground umbilicals shall function properly at their respective geographical locations after exposure to the natural environment and shall be tailored to reflect program-defined risks and exposure times.

4.14.3 Launch-induced environment

Flight-to-ground umbilicals shall function properly when subjected to the launch-induced environment such as launch-induced acoustics, vibration, plume impingement, heat, and blast pressures, as applicable.

4.14.4 Fire- and/or explosion-hazard environment

Umbilicals operated in locations where fire or explosion hazards may exist due to flammable gases, vapours, and/or flammable liquids shall be hazard-proofed to prevent such hazardous conditions.

4.15 Component selection

Components used in the design of umbilical systems for a space vehicle shall be qualification tested for the intended application.

4.16 Corrosion control

The natural atmosphere and the induced environment contain residue that is readily deposited on exposed surfaces. This, combined with substantial moisture and generally high temperatures, results in an environment conducive to extensive corrosion of metals. The designer shall provide for corrosion control due to these environmental conditions by selecting materials and coatings and designing equipment for the prevention of crevice, stress, and galvanic corrosion.

4.17 Maintainability

Flight-to-ground umbilicals shall minimize the complexity and frequency of maintenance, the maintenance resources required to keep the system operational, and maintenance downtime. High-failure-rate items should be identified for accessibility concerns. Fault detection and isolation should be considered based on criticality and cost of failures.

4.18 Accessibility

The umbilical shall provide ready access for operating, testing, fault detecting, repairing, and replacing components. The design shall allow these functions to be performed without interfering with other components or assemblies.

4.19 Component position feedback

All remotely operated components used for an umbilical's ground controls shall have position feedback signalling to the extent possible. Command and feedback signals shall not usually be combined in the same connector or cable, regardless of source.

4.20 Connection inspection

The umbilical system shall provide for inspection of the proper mating of all connections between the flight and ground portions of the umbilical.

5 Design guidelines

5.1 Pre-flight disconnect

The design of the umbilical system should have all pre-flight disconnects. Inflight disconnects are not recommended. In some situations, inflight disconnects are unavoidable. Acceptable alternatives are described in 5.2.

5.2 Inflight umbilical assembly

5.2.1 Inflight preferences

When the vehicle requirement cannot be met by a pre-flight umbilical assembly only, the preferred design alternative for all inflight disconnects is the rise-off type. The second alternative is to have only those services that are to remain connected to achieve a safe abort routed through the rise-off umbilical assembly. The third preference should be to use a transverse disconnected umbilical activated at T–0, such as a tail service mast.

5.2.2 Rise-off umbilical assembly

5.2.2.1 General

The rise-off umbilical is characterized by the inflight umbilical plate being disconnected as a direct result of a vehicle's vertical motion. The ground carrier remains at a fixed elevation after mating and tracks the vehicle's motion during pre-launch and launch conditions. The ground carrier may be removed by a device that provides for the unrestrained lift-off of the launch vehicle and protection from plume impingement.

The vehicle plate is subjected to relative motion with respect to the launcher due to the various induced forces (wind, temperature changes, fuel-loading operations, firing effects from the engine, etc.) between the time of umbilical mating and launch. The ground carrier shall be capable of tracking the vehicle to allow for these motions after mating without inducing premature disconnect. The couplings and connectors shall be designed to allow for these motions relative to the carrier plate and ground system.

The ground carrier shall use an alignment device to engage with mating receptacles such as an alignment pin. The device shall ensure the ground carrier is aligned with the vehicle's plate before any of the couplings and connectors start to engage. The carrier shall be elevated for connections by self-locking mechanisms, such as worm screw actuators. Provisions shall be made to limit loads transferred to the vehicle by such systems. Each of the couplings and connectors shall be self-aligning to ensure proper final engagement. Horizontal movement shall be inhibited by appropriate devices.

Disconnection lanyards or mechanisms should include redundant backup in case of failure of the primary mode.

5.2.2.2 Umbilical couplings and connectors

Umbilical couplings and connectors shall be of the non-latching type. For the fluid couplings, partial motion of the vehicle shall be accommodated by a sliding seal between the coupling halves or by flexible elements of the system (e.g. hose or cable). The electrical connector halves on the ground carrier shall accommodate the vehicle's vertical motion and lateral motion, if applicable. This design shall overcome the dynamic loading due to noise and vibration generated by the engine.

5.2.2.3 Cryogenic coupling

The preferred cryogenic coupling can be of the slip type with dual self-forming lip seals. A tertiary seal may be used to contain a gaseous purge adjacent to the dual seals. The gaseous purge prevents cryo-pumping and ice build-up on the sliding seal surface.

The cryogenic coupling shall not require the application of additional insulation after mating. The volume between the dual lip seals of the cryogenic coupling should preferably be vented through a tubing connection on the ground carrier side. This vent tubing shall then be monitored for leaks during verification of the connection phase when the coupling is pressure tested with gaseous helium. The couplings shall also provide for the mounting of leak detection devices.

The mounting provisions for the ground-carrier-half of the coupling and the attached flexible duct shall allow lateral and angular motion with respect to the ground carrier to ensure the coupling halves align