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Revision A

DESIGN CRITERIA FOR REUSABLE SPACE VEHICLE UMBILICAL SYSTEMS

MAY 1993

ENGINEERING DEVELOPMENT DIRECTORATE

GP-986
Revision A

DESIGN CRITERIA FOR REUSABLE SPACE VEHICLE UMBILICAL SYSTEMS

Approved:

Garland Reichle, Chief
Launch Accessories Branch

This Revision Supersedes All Previous Editions of This Document

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JOHN F. KENNEDY SPACE CENTER, NASA

RECORD OF REVISION/CHANGES

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NOTE
The portion of the text affected by a technical change is indicated by a vertical line in the outer margin of page

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FOREWORD

This document establishes the general criteria and design goals for design, development, test, evaluation, and verification of reusable space vehicle umbilical systems.

The purpose of this document is to organize, for use in the design of reusable umbilical systems, the experience and knowledge accumulated in space programs at KSC. This document reflects KSC technical experience, lessons learned, and information to induce greater consistency, reliability, and efficiency in the design of reusable umbilical systems. It also reflects the desired methods/design concepts for systems to enhance safety and the cost of operations.

Requests for information or for making corrections or additions to this document should be directed to the Engineering Development Directorate, Mail Code: DM-MED-3, Kennedy Space Center, Florida 32899. Requests for additional copies of this document should be sent to the Engineering Documentation Center (EDC), Kennedy Space Center, Florida 32899.

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1. SCOPE

This document establishes the general design criteria for reusable space vehicle umbilical systems. The criteria specified herein is limited to the service arms or equivalent mechanisms, umbilical carriers and plates, couplings, connectors, withdrawal and retract devices, handling mechanisms, and mechanism control systems.

2. APPLICABLE DOCUMENTS

The following documents form a part of this document to the extent specified herein. When this document is used for procurement, including solicitations, or is added to an existing contract, the specific revision levels, amendments, and approval dates of said documents shall be specified in an attachment to the Solicitation/Statement of Work/Contract.

2.1 GOVERNMENTAL.

2.1.1 STANDARDS.

John F. Kennedy Space Center (KSC)

KSC-STD-132	Potting and Molding Electrical Cable Assembly Terminations, Standard for
KSC-STD-E-0004	Pneumatic and Hydraulic Mechanical Components, Electrical Design, Standard for
KSC-STD-E-0011	Standard for Electrical Power Receptacles
KSC-STD-E-0012	Bonding and Grounding, Standard for
KSC-STD-E-0013	Lightning Protection for Facilities, Standard for
KSC-STD-G-0003	Qualification of Launch Support and Facility Components, Standard for

2.1.2 PUBLICATIONS.

KSC-DE-512-SM	Guide for Design Engineering of Ground Support Equipment and Facilities for Use at Kennedy Space Center

(Copies of Government specifications, standards, documents, drawings, and publications required by contractors in connection with specific procurement functions should be obtained from the procuring activity or as directed by the contracting officer.)

3. REQUIREMENTS

3.1 UMBILICAL SYSTEM DEFINITION

The umbilical system is the functional assemblage of all items required for providing vehicle fluid and electrical servicing. It usually includes service arms or equivalent mechanisms; umbilical carriers and plates; couplings and connectors; all separation, withdrawal, and retraction devices; control equipment; the control fluids and electrical signals; and all interconnecting lines across the service arms or the equivalent mechanism on the ground side. The mating half/interface for the coupling/connectors and umbilical carrier should be located on the moldline of the launch vehicle at an orientation compatible with the launch structure.

3.2 GENERAL DESIGN REQUIREMENTS

Reusable space vehicle umbilical systems shall conform to the general requirements specified in KSC-DE-512-SM.

3.2.1 UMBILICAL SERVICES. Any fluid or electrical service routed through an umbilical service arm or equivalent mechanism that is to be disconnected prior to engine ignition shall not require reconnection to abort safely on the pad; otherwise, they must remain connected until launch commit and through abort. They shall be T-0/launch commit or inflight disconnected umbilicals. Rise-off-type umbilicals disconnected with vehicle motion at launch shall be the preferable design for these critical service connections.

3.2.2 MATING. The time required to achieve umbilical assembly connection and verification shall be minimized. Factors that should be considered include the number of steps required; the number of component parts to be installed or manipulated in the connection process; availability of, and accessibility with, mechanical handling aids; available working space; operating personnel requirements; overall safety requirements; alignment requirements; and the adaptability to automated verification. As a goal, the time required for the mating operation shall be one shift or less.

3.2.2.1 Handling and Engagement. Rapid handling and engagement is necessary in order to minimize impact on the ground turnaround and launch support crew

size. To provide ease with which an umbilical assembly is mated and connected to a vehicle, consideration shall be given to weight, torque requirements, manual force required for connection, and rigidity of electrical cables, flex lines, propellant flex lines, Environmental Control System (ECS) ducts, etc.

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

3.2.2.3 Verification. Mated umbilical assemblies shall be designed to allow quick and reliable verification of integrity.

3.2.2.4 Materials. Umbilical assemblies shall be compatible with service media and corrosion resistant.

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

3.2.4 LOAD BALANCE. Connections shall be located on or within the carrier so forces required for disconnect or retention to the vehicle are evenly distributed about the locking, release, and ejection mechanisms. The same consideration shall also be given in the design of the handling systems.

3.2.5 CONTAMINATION PREVENTION. Both halves of all couplings shall incorporate internal devices for protection of the system from debris during the launch, flight, and recovery operations. The devices shall be normally in the closed position and opened automatically by the engagement of the two coupling halves. The device shall close automatically as the two coupling halves are separated.

3.2.6 PURGES. Electrical umbilical connectors shall be provided with an inert environment. Cryogenic connections shall be purged as required to prevent moisture condensation and resulting ice buildup or liquefaction of air. Hypergolic or other corrosive or hazardous fluids shall have purge, scrubbers, etc., required for safe connect and disconnect operations. There shall be one purge in a cavity between the carrier and the plate.

3.2.7 SIDELOADS. Design and use of carriers and plates shall be in a manner that prevents side loads on the connectors or couplings and latching/carrier mechanisms.

3.2.8 TRACKING LOADS. All loads associated with tracking of vehicle motion by the umbilical assembly and attached hardware shall be borne by the vehicle and be as low as possible consistent with practical GSE design and reasonable vehicle

interface structural requirements. Vehicle requirements alone shall not be the determining factor. The determination shall include overall cost for the life of the program.

3.2.9 LEAK DETECTION. When hazardous fluids are present such as hypergols, umbilical couplings shall utilize primary and secondary seals and have sensors to detect primary and secondary seal leakage. As a goal, redundant seals and integrity monitoring are desirable in most instances.

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

3.2.11 ELECTRICAL CONNECTORS. Electrical connectors shall be dead faced and self-aligning. Data bus, power, and command functions shall be in separate connectors. Connectors contained in the carrier shall not be self-locking. Electrical ground power receptacles and plugs shall be in accordance with KSC-STD-E-0011.

3.2.12 GROUNDING. Umbilicals shall be grounded in accordance with the requirements of KSC-STD-E-0012 and KSC-STD-E-0013.

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

3.2.14 LAUNCH-INDUCED ENVIRONMENT. Umbilical carriers, plates, couplings, connectors, service lines, cables, etc., shall be protected from launch-induced acoustics, vibration, plume impingement, heat, and blast pressures.

3.2.15 COMPONENT SELECTION. Components used in the design of space vehicle umbilical systems shall be qualified in accordance with KSC-STD-G-0003.

3.2.16 CORROSION CONTROL. The natural atmosphere at KSC contains a high salt content; and the induced environment contains solid rocket booster 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. Refer to TM-584 for detailed requirements.

3.2.17 MAINTAINABILITY. Material and its installation shall be designed to achieve the required launch vehicle turnaround objectives.

3.2.18 ACCESSIBILITY. The designer shall provide for 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.

3.2.19 COMPONENT POSITION FEEDBACK. All remotely operated components used for umbilical ground controls shall have position feedback signaling. Command and feedback signals shall not be combined in the same connector or cable, regardless of source. Electrical design for these electromechanical components shall be in accordance with KSC-STD-E-0004.

3.3 DESIGN GOAL

It is preferred that the umbilical system design have all preflight disconnects. Inflight disconnects are not recommended. In some situations, inflight disconnects are unavoidable. Acceptable alternatives are described in 3.3.1.

3.3.1 INFLIGHT UMBILICAL ASSEMBLY. When the vehicle requirement cannot be met by a preflight umbilical assembly only, the preferred design alternative for all inflight disconnects shall be the rise-off type. The second alternative is to have only those services that must remain connected to achieve a safe abort routed through the rise-off type umbilical assembly. The third preference shall be to use a transverse disconnected umbilical activated at T-0 launch commit, such as a tail service mast.

3.3.1.1 Rise-Off-Type Umbilical Assembly.

a. The rise-off-type umbilical is characterized by the inflight umbilical plate being disconnected as a direct result of vehicle vertical motion. The ground carrier remains at a fixed elevation after mating and tracks vehicle motion during prelaunch and launch conditions.

b. 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, engine firing effects, 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. The coupling and connectors shall be designed to allow for these motions relative to the carrier plate and ground system.

c. The ground carrier shall use initial alignment pins to engage with mating receptacles. The design of the pins shall ensure the ground carrier is aligned with the vehicle 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.

3.3.1.1.1 Umbilical Couplings and Connectors. Umbilical couplings and connectors shall be of the nonlatching type. For the fluid couplings, partial vehicle motion shall be accommodated by a sliding seal between the coupling halves. The electrical connector halves on the ground carrier shall accommodate vehicle vertical motion. This design shall overcome the dynamic loading due to engine-generated noise and vibration.

3.3.1.1.2 Cryogenic Coupling.

a. The preferred cryogenic coupling shall be of the slip type with dual self-forming lip seals. A tertiary seal shall be used to contain a gaseous purge adjacent to the dual seals. The gaseous purge would prevent cryo-pumping and ice buildup on the sliding seal surface.

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

c. 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 will align during engagement and disengagement. The vehicle half of the coupling shall be rigidly attached to the vehicle plate.

3.3.1.1.3 Electrical Connectors.

a. The data bus electrical connector as well as the command circuits connector shall be separate from the electrical ground power connector. All connectors shall incorporate carrier-mounting alignment provisions and gaseous nitrogen purge provisions. Electrical ground power receptacles and plugs shall be in accordance with KSC-STD-E-0011.

b. The connector design shall incorporate the necessary devices to ensure proper connection while accommodating vertical relative motion. All connectors shall be dead-face type.

c. The faceplate shall be purged with gaseous nitrogen. The back-shell shall be potted and molded in accordance with KSC-STD-132 or purged with gaseous nitrogen. Strain relief devices shall be incorporated in the back-shell design of all connectors to prevent stress loading of wire terminations.

3.3.1.1.4 Protective Blast Cover (Ground). This device shall be actuated after the vehicle has risen to an altitude that provides sufficient clearance for movement. The outer surface shall have structural and thermal integrity to withstand the direct impingement of the engine exhaust during the launch. The device shall close completely before the vehicle rises to an altitude that allows for direct exhaust impingement on the umbilical couplings. A breakaway lanyard attached to the vehicle is the preferred source of door actuation energy.

3.3.1.2 Tail Service Mast. The tail service mast is characterized by the horizontal (i.e., perpendicular to the direction of flight) release of the couplings. All couplings and connectors shall be contained in a single assembly. This umbilical assembly shall enclose the electrical connectors sufficiently to maintain an inert gas purge. Purging of cryogenic couplings shall be utilized to provide hazardproofing and the retention of ice buildup.

3.3.1.2.1 Umbilical Couplings. Because there is no appreciable relative motion between the ground carrier and vehicle plate, the choice of couplings is not restricted. However, it is preferred that ball-and-cone couplings (with the ball half located in the ground carrier and the cone half located in the vehicle plate) be used. These couplings shall use springs for low pressure, bellows for medium pressure, and pressure-balanced slip couplings for pressures over 3450 kilopascals (kPa) gage [500 pounds per square inch gage (psig)]. Dual seals shall be utilized and the volume between the seals vented through the ground side to provide for leakage verification. The coupling shall have provisions for mounting leak detection devices.

3.3.1.2.2 Electrical Connectors. The data bus electrical connector as well as the command circuits connector shall be separate from the electrical ground power connector. All connectors shall incorporate carrier-mounting alignment provisions. All connectors shall be of the dead-face type. The back-shell and faceplate shall be purged with gaseous nitrogen. Strain relief devices shall be incorporated in the back-shell design of all connectors to prevent stress loading of wire terminations. Electrical ground power receptacles and plugs shall be in accordance with KSC-STD-E-0011.

3.3.1.2.3 Locking Devices. The vehicle plate and ground carrier shall be secured by a breakaway bolt. Individual locking devices shall not be incorporated into the design of couplings or connectors. Guide pins shall be utilized to align the vehicle plate and ground carrier. These guide pins shall engage before the locking device or couplings and shall be removed after mating. Side loads/motion shall be taken by a nonbinding-type connection to the vehicle plate.

3.3.1.2.4 Handling and Control Systems. For launch vehicle erection, provisions shall be incorporated for the necessary mechanisms and controls to retract the mast. Provisions shall also be made for local manual control of the mechanisms to allow rapid engagement of the ground carrier to the vehicle plate. The retraction of the mast shall also provide protection of the ground system from the vehicle engine exhaust blast.

3.3.2 PREFLIGHT UMBILICAL ASSEMBLY. As in the inflight umbilical assembly, all couplings and connectors shall be contained in a single assembly. The vehicle plate and ground carrier shall be secured by a single locking device. Individual locking devices shall not be incorporated into the design of couplings and connectors. Guide pins shall be utilized to align the vertical plate and the ground carrier. These guide pins shall engage before the locking device or couplings. Separation of the ground carrier shall be accomplished by release of the locking device (a mechanical backup shall be provided). The umbilical assembly shall enclose the electrical connectors sufficiently to maintain an inert gas purge. Purging of cryogenic couplings shall be utilized to provide hazard-proofing and the prevention of ice buildup.

3.3.2.1 Umbilical Couplings.

a. Dual seals shall be utilized and the volume between the seals shall be vented through the ground side to provide for leakage verification. The couplings shall have provisions for mounting a leak detection device.

b. Fluid couplings conveying high pressure 3450 kPa gage (500 psig) and over media shall utilize balanced pressure design features to minimize thrust loads. Low pressure [1050 kPa gage (150 psi) or less] couplings shall utilize springs for the sealing force; and medium pressure [1050 to 3450 kPa gage (150 to 500 psi)] couplings shall utilize bellows for the sealing force.

3.3.2.2 Electrical Connectors. Carrier mounting alignment and gaseous nitrogen purge provisions shall be incorporated into the design of the data bus electrical connection and the command connection. All connectors shall be of the dead-face type. The back-shell and faceplate shall be purged with gaseous nitrogen. To

prevent stress loading of wire terminations, back-shell design of all connectors shall utilize strain relief devices. Electrical ground power receptacles and plugs shall be in accordance with KSC-STD-E-0011.

3.3.2.3 Locking Devices. The locking device may be a collet, four ball-lock, or other mechanical design and shall have the capability to engage the ground carrier to the vehicle plate at a distance far enough away to allow guide pin alignment before the couplings and connectors halves mate. A manually operated system shall translate the locking device and guide pins to maintain the ground carrier in alignment with the vehicle plate while the assembly and all couplings and connectors are engaged simultaneously. Positive locking shall be verified visually.

3.3.2.4 Handling System. If required, a counterbalanced system shall provide support of the dead weight of the ground carrier, cables, and hoses during manual engagement of the guide pins and locking device. The counterbalance system shall also provide powered forces to withdraw the ground carrier away from the vehicle after release and carrier ejection.

3.3.2.5 Control System.

a. The ground control system shall utilize redundant valving, power supply, and fluid stored energy supply. Design of the system shall be for the normal operation in the following sequence: (1) unlock of the locking device, (2) ejection of the ground carrier and separation from the vehicle plate, (3) withdrawal of the ground carrier and service lines to permit a clearance envelope between the vehicle, and (4) subsequent retraction. The redundancy shall provide for a backup mode to accomplish the normal sequence. Should normal carrier unlock or ejection fail, a secondary device shall accomplish the unlock or ejection in normal sequence.

b. The ground control system shall incorporate both local manual control and remote control and monitoring for operation in the final prelaunch sequence. The system shall be able to provide data inputs to the Launch Processing System (LPS).

4. QUALITY ASSURANCE PROVISIONS

All umbilical systems designed and fabricated for use at KSC will be tested in the Launch Equipment Test Facility. Testing will simulate the conditions the umbilical system could be subjected to during use with the exceptions of launch blast, launch acoustic environment, corrosive launch atmosphere, etc. The quality assurance testing shall include, but is not limited to, the following three tests.

4.1 STATIC TEST

Static tests include verifying fit and form of the umbilical system with other mating systems. Static tests also ensure mating of the umbilical system in the manner intended.

4.2 DYNAMIC TEST

Dynamic testing shall subject the umbilical system to dynamic conditions by tracking the umbilical through all of its excursions that could be encountered while the umbilical is mated to the vehicle. This testing shall also include provisions to ensure no loads greater than allowed are transmitted to the vehicle. Dynamic testing shall also include disconnection if it is T-0 or rise-off-type umbilical design.

4.3 CRYOGENIC TEST

Cryogenic testing shall subject the umbilical system to the flow of cryogenic liquids that are the same as the actual liquid or a liquid that simulates the actual liquid [liquid nitrogen to simulate liquid oxygen and liquid hydrogen for liquid hydrogen testing in the Launch Equipment Test Facility (LETF)]. Cryogenic testing shall ensure that the umbilical system can transmit cryogenics in a safe manner as intended in the design.

5. PREPARATION FOR DELIVERY

This section is not applicable.

6. NOTES

6.1 INTENDED USE

This document is intended to be used in the establishment of uniform engineering practices and methods and to ensure the inclusion of essential requirements in the design of reusable space vehicle umbilical systems used to support the launch of space vehicles at KSC.

6.2 DEFINITIONS

For the purpose of uniformity of nomenclature, the following terms and their definitions shall apply.

a. **Carrier: A device that groups coupling and connector halves together to provide a common means for their positioning, retention, unlocking, and**

separation. The term is commonly used in relation to the facility ground side of umbilical interfaces.

b. Connector: A device, consisting of two halves, that permits engagement and disengagement of electrical circuits at an interface.

c. Coupling: A device, consisting of two halves, that permits transfer of fluid across and disconnection at an interface.

d. Ground Control: The equipment, fluids, or signals, provided for command or control purposes, which are neither onboard nor originate onboard the launch vehicle.

e. Handling Mechanism: A device used to provide positioning, manipulation, and dead-weight support of an object.

f. Inflight: A modifier, applied to denote an occurrence or function after vehicle lift-off.

g. Interface: A region of mating, or boundary, between separating or cooperating elements, established by a governing characteristic (such as ground-to-vehicle interface, physical interface, or responsibility interface).

h. Launch Processing System: Consists of those operating consoles, data handling and display equipment, and the associated transmission system, configured to issue commands and analyze and display response data required in checkout and operation of ground support equipment (GSE) and flight hardware.

i. Lift-Off: A term designating the instant of vehicle flight at which vehicle contact is terminated with all areas of holddown and/or support devices. Commonly called "first motion" of the vehicle.

j. Plate: A device that groups coupling and connector halves together to provide a common means for retention. The plate is a passive device, containing cooperating but usually immobile portions of positioning, locking, and separation machinery. The term is commonly used in relation to the vehicle side of umbilical interfaces or with the carrier (i.e., carrier plate).

k. Preflight: A modifier, applied to designate an occurrence or function before vehicle lift-off.

l. Rise-Off: An adjective, applied to a device to denote that its actuation is solely caused by vehicle vertical motion.

m. Service Arm: A retractable structure, usually moving in a horizontal path, used to provide either umbilical requirements, or access, or both to the vehicle. Commonly called access arm, umbilical arm, or swing arm, depending upon whether it provides services for access only, umbilicals only, or both, respectively, to the vehicle.

n. Tail Service Mast: A retractable structure used to provide umbilical requirements to the aft portion (tail) of a space vehicle. Movement is usually a rotation about a pivot point away from the vehicle in a horizontal plane.

o. Umbilical: A device that provides fluid and electrical requirements at the interfaces between ground facilities and a space flight vehicle.

p. Umbilical Assembly: The mated carrier and plate, containing all couplings and connectors for a specified umbilical region of the vehicle.