

Guide

Guide for Utility Connector Interfaces for Serviceable Spacecraft

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Guide for Utility Connector Interfaces for Serviceable Spacecraft

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Abstract

This Guide provides technical information for the development of spacecraft utility connectors. The perspective on utility connectors has been obtained from aerospace historical applications on commercial and military aircraft, rocket launch vehicles, and NASA Programs. Designers and project managers of future spacecraft can benefit from this document. A utility connector contains a multiple of utilities, which may include electrical power, data, microwave, fiber optic, and fluids. This document classifies utility connectors as follows: Class I - Manual or EVA, Class II - Robotic System, and Class III - Automatic System. The use of standard utility connectors will contribute to cost effective on-ground and on-orbit servicing functions.

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Contents

Paragraph		Page
	Foreword	iii
1.0	INTRODUCTION	1
1.1	Scope	1
1.2	Purpose	1
1.3	Application	1
1.4	Intended Use	1
1.5	Applicable Documents	1
2.0	DEFINITIONS	1
3.0	GENERAL REQUIREMENTS	2
3.1	Standard Units of Measure	2
3.2	Coordinate System	2
3.3	Design Considerations	3
3.4	Interface Considerations	2
3.5	Pin and Port Shape	3
3.6	Definition of Mate/Demate Sequence	3
3.7	Application of Requirements	3
3.8	Materials	3
3.9	Interchangeability	3
3.10	Protective Covers	4
3.11	Launch Vehicle Safety	4
3.12	Failure Tolerance	4
3.13	Failure Deterrent	4
3.14	Position Indicators	4
3.15	Indexing (Keying)	4
3.16	Maintainability	4
3.17	ORU Utility Connectors	5
3.18	Non-Brazed or Non-Welded Fluid Lines	5
3.19	Accessibility	5
4.0	DETAILED REQUIREMENTS	5
4.1	Mechanical Design	5
4.2	Electrical Design	6
4.3	Fluid Design	7
4.4	Thermal Design	7
4.5	Optical Design	7

APPENDIX A

A.1	EXAMPLES OF AIRCRAFT UTILITY CONNECTORS	11
A.1.1	F-111 Pylon Blind Mate Disconnect	11
A.2	EXAMPLES OF MISSILE UTILITY CONNECTORS.....	13
A.2.1	High Endoatmospheric Defense Interceptor (HEDI) Missile Umbilical Connector	13
A.2.2	SRAM Missile Umbilical Connector.....	15
A.2.3	Peacekeeper Missile Umbilical Connector	17
A.2.4	ICBM Umbilical Connector	19
A.2.5	Minuteman Missile Umbilical Plug.....	21
A.3	EXAMPLES OF SPACECRAFT CLASS I MANUAL OR EVA OPERATED	
A.3.1	SKYLAB Utility Connector.....	23
A.3.2	Columbus Utility Connector.....	24
A.5	EXAMPLES OF SPACECRAFT CLASS III AUTOMATIC UTILITY CONNECTORS	
A.5.1	Orbiting Maneuvering Vehicle (OMV) Fluid Interface System	25
A.5.2	Automated Umbilical Connector.....	27
A.5.3	Resupply Interface Mechanism.....	29
A.5.4	Explorer Platform Payload Equipment Deck.....	31
A.5.5	Multimission Modular Spacecraft Module Structure Assembly.....	33

Foreword

This Guide for Utility Connector Interfaces for Serviceable Spacecraft has been sponsored by the American Institute of Aeronautics and Astronautics as part of its Standards Program.

This Guide provides technical information for the development of spacecraft utility connectors. The perspective on utility connectors has been obtained from aerospace historical applications on commercial and military aircraft, rocket launch vehicles, and NASA programs. Designers and project managers of future spacecraft can benefit from this document. A utility connector contains a multiple of utilities, which may include electrical power, data, microwave, fiber optic, and fluids. This document classifies utility connectors as follows: Class I - Manual or EVA, Class II - Robotic System, and Class III - Automatic System. The use of standard utility connectors will contribute to cost effective on-ground and on-orbit servicing functions.

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1.0 INTRODUCTION

This document addresses the design guidelines for utility connectors, which are also called utility couplings, plugs, and quick-disconnects. As serviceable spacecraft systems become more complex, ease of utilization, weight and volume restrictions are becoming critical, new ground and on-orbit servicing issues arise, and, multiple utilities in a single connector becomes a favored design solution. Utility options include electrical power, datum, microwave, fiberoptics, and fluids. Generally, as the size of the connector and number of contacts and fluid ports increase, so does the alignment and engagement forces. Based on application, there are three classes of utility connectors: Class I - Manual or EVA, Class II - Robotic, and Class III - Automation. An internationally approved set of metric standards for utility connectors is recommended for the design of international spacecraft, both manned and unmanned.

1.1 Scope

This guide provides historical information for three classes of utility connectors, manual, robotic, and automated for use on aircraft and space vehicles. Applications include ground and on-orbit servicing of spacecraft, satellites, platforms, and space stations. The document may also be useful for non-serviceable spacecraft, especially during design, test, and pre-launch checkout stages.

1.2 Purpose

The purpose of this document is to provide design guidelines for the selection and specification of spacecraft utility connectors.

1.3 Application

This document encompasses the mechanical aspects of interfaces for spacecraft utility connectors, which include, but are not limited to the following utilities - electric power, data, microwave, fiberoptic, and fluids.

1.4 Intended Use

This guide should be used by spacecraft contractors, project managers, interface designers, system engineers, and space operations personnel.

It is recommended that the interface designs set forth in this guide be used by all agencies, domestic and international, when specifying and developing spacecraft utility connectors.

1.5 Applicable Documents

The following documents form a part of this Guide to the extent specified herein.

DoD-Std-1476a Metric System Application in New Design
 Fed-Std-376a Preferred Metric Units for General Use by the Federal Government
 NASA-Std-3000 Man-Systems Integration Standards (MSIS)
 NASA SSP 30550 Robotic Systems Integration Standard (RSIS)
 NSTS 07700 NASA Shuttle Orbiter/Cargo Standard Interfaces
 AIAA G-042-1991 AIAA Guide for the Design for On-Orbit Spacecraft Servicing
 JSC 23925 Interface Design Considerations for Serviceable Satellites
 JSC 23920 Interface Design Considerations for Robotic Satellite Servicers
 MSFC-Hdbk-527 Materials Selection List for Space Hardware

2.0 DEFINITIONS

Anti-bind Roll-off - Feature that prevents shell binding caused by side loads during mate and demate of a utility connector.

Automatic Mate/Demate - Automatic utility connector engagement and disengagement by a mechanical device which does not have a man in the control loop.

Backshell - A connector accessory for use with electrical connectors which provides strain relief cable support and suppression of radio frequency and electromagnetic interference.

Blind-mate - The mechanical coupling / uncoupling of two structures automatically accommodates the mating and demating of electrical connector(s) without the need to view the connector operation. Allows both connector halves to be joined in a normal engaging mode when either one or both connectors are concealed.

Electromagnetic Interference Electronic Documents
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Interference from sources outside the system.

EVA - Extravehicular Activity - Typically the activity of an astronaut on-orbit while wearing a space suit outside of the spacecraft.

Force, Disengagement - Force required to demate the connectors.

Force, Engagement - Force required to mate the connectors to permit fluid flow.

Misalignment, Angular - The maximum included angle between the two axes of the connector halves.

Misalignment, Lateral Offset - The maximum distance between the two centerlines of the connector halves.

Plug - The connector half, with mounting flange or side latch, which enters the receptacle housing; contains socket contacts.

Receptacle - Connector half, with mounting flange typically hard-mounted to a panel, which receives the plug housing; contains pin contacts.

Robotic Mate/Demate - Utility connector operation with the aid of a robotic system manipulation with or without a man in the control loop.

Scoop Proof - Scoop proof refers to the impossibility of a mating plug connector being inadvertently cocked into a mating receptacle and damaging or electrically shorting the contacts.

Self-aligning - Allows engagement to be accomplished with angular/lateral/rotational misalignment, within specified limits.

Serviceable Spacecraft - Spacecraft specifically designed for ease of on-orbit servicing, including replacement of modular parts and refueling, reloading.

Servicee - The spacecraft side of the utility connector.

Servicer - The supply side of the utility connector.

TBD - To be determined

Utility Connector - Also called a coupling or quick disconnect connector, consisting of a Servicer half and Servicee half, which when mated permits the safe transfer of utilities, including electric power, data, microwave signal, fiberoptic communication, and fluid flow across the interface.

3.0 GENERAL REQUIREMENTS

3.1 Standard Units of Measure

Units designed to the requirements of this guideline should incorporate the International System of units (SI) as the basic measurement system. These units are defined in DoD-Std-1376a. For measurement values not covered in DoD-Std-1476a, the document Fed-Std-376a may be used as a supplement. Linear dimensions should be in whole millimeters.

3.2 Coordinate System

An X, Y, Z three axis orthogonal coordinate system is defined for utility connectors, with the X coordinate is parallel to the connector interface. The Y and Z axes are, by definition, perpendicular to the X axis with the Z axis vertical toward a designated 'up' index point around the X axis. The Y axis is perpendicular to the Z axis and is oriented lateral to the designated 'up' index of the Z axis.

3.3 Design Considerations

The design and mechanical interfaces should be kept as simple as possible.

3.4 Interface Considerations

Considerations for the design of utility connector interface hardware must compensate for the worst case uncertainties to assure a successive mate and demate without damage to the internal connections. An example of a typical interface footprint with power, data, fiberoptic and fluid connections is illustrated in Figure 1.

Conditions which must be considered in the interface design are: mate/demate engagement tolerance, activation force limits, engagement over-center force limits, mounting structure integrity requirements, impact momentum tolerance, tip-off dynamics limits, emergency disconnect provisions, thermal distortions, shell, electrical, and

microwave, fiberoptic and fluid interfaces alignment, electrostatic differences at contact, sizing, mass (lightest design for required strength), and reliability.

3.5 Pin and Port Shape

Electrical pins, fiberoptic fiber ends, and fluid ports should be clearly identified and physically incompatible when they differ in content (e.g., different voltages, fluids, etc.). (NASA-30550)

3.6 Definition of Mate / Demate Sequence

3.6.1 Initial Condition Capture / Centering

Guide with suitable alignment the utility connector plug and receptacle shells into coincidence on the path required to complete a soft docking action. Fluid ports require added provision for a two phase engagement: first, latching to resist pressure separation, and second, opening to permit fluid flow.

3.6.2 Mate

Complete the attachment sequence contacting and completing the connection of utilities and locking the connector shells.

3.6.3 Demate

With a minimized change in dynamics, the above sequence is reversed.

3.7 Application of Requirements

Detailed requirements described in this Guide can to be applied as appropriate to all spacecraft utility connectors.

3.7.1 Ground-based and On-orbit Operations

Each operation requires different operating practices. Where crew or robotic interfaces are involved, both NASA-Std-3000, Man-System Integration Standard and NASA SSP 30550, Robotic Systems Integration Standard, applies.

3.7.2 Utility Connector Mate/Demate Classifications

When the engagement force exceeds the capacity for manual or EVA operation, it is necessary to use mechanical assistance for mate/demate. The mechanisms include special hand tools, and robotic and automatic systems.

3.7.2.1 Class I - Manual or Extravehicular Activity

Manual or EVA utility connector activation may be performed when the z axis engagement or disengagement force does not exceed 8 Newton's (20 pounds).

3.7.2.2 Class II - Robotic System

EVA and robotically compatible operations may be performed when z axis engagement or disengagement force are less than 8 newtons (20 pounds), or 40 newtons (100 pounds) when autonomous robotic systems are used.

3.7.2.3 Class III - Automatic System

Automatic operations may be performed when the z axis engagement or disengagement force exceeds the capacity of EVA and Robotic Systems, and when automatic operations are feasible.

3.8 Materials

The connector should be constructed of materials that will not be affected by fluid media, space environment, or service life cycle specified.

3.9 Interchangeability

3.9.1 Connectors

Connectors of the same part number should be interchangeable. This includes like assemblies, subassemblies, and replaceable parts. (NASA-30550)

3.9.2 Resupply and docking/berthing System

Where practical, have resupply transfer system and docking and berthing system commonality (JSC 23920).

3.10 Protective Covers

If required by the part standard drawing, covers are generally required for each demated connector half as a means of protecting all exposed critical surfaces, seals, etc. from damage and to minimize the entry of contaminants. Each cover should be tethered to its respective half.

3.11 Launch Vehicle Safety

The connector should comply with the applicable safety requirement of launch and transportation vehicles in both the mated and demated positions, and during all operational phases associated with its use.

3.12 Failure Tolerance.

3.12.1 Critical Hazards

Critical hazards should be controlled such that no single failure or operator error can result in damage to launch equipment, a disabling personnel injury, or the use of unscheduled safety procedures that affect operations. A utility connector hazard is exemplified by the case of incompatible connector mating caused arcing in an explosive environment.

3.12.2 Catastrophic Hazards

Catastrophic hazards should be controlled such that no single or combination of two failures or operator errors can result in the potential for a disabling or fatal personnel injury or loss of the launch vehicle, ground facilities, or equipment.

3.13 Failure Deterrent

The connector should be designed such that:

3.13.1 Liquid Traps

Built-in liquid traps, which would cause malfunction or failure, should be eliminated. (NASA-30550)

3.13.2 Blind Pockets

Hidden corrosion could develop in blind pockets and should therefore be prohibited. (NASA-30550)

3.13.3 Multiple Failures

Failure propagation protection should be provided such that transient out-of-tolerance conditions or component failures should not cause other component or subsystem failures. (NASA-30550)

3.13.4 Threaded Fasteners

Positive locking on threaded parts and fasteners should be incorporated to prevent loosening during service. The use of safety wire should be prohibited.

3.13.5 Installation

Backward or improper installation of unidirectional components or piece parts should be prevented by use of non-symmetry of configuration, different connecting sizes, or other comparable means.

3.13.6 Sliding Fits

Sliding fits should be designed to preclude frictional failures and/or binding. (NASA-30550)

3.13.7 Induced Environment

Fatigue failure resulting from flow-induced vibration in flexible sections should be prevented by proper design practices, engagement approach, and materials selection.

3.14 Position Indicators

The connector should be designed with appropriate indicators to provide indication that the connector has been fully mated or demated.

3.15 Indexing (Keying)

The connector should incorporate an indexing feature to prevent mating with other connector part numbers and/or with the same connector part number. (NASA-30550)

3.16 Maintainability

When practical, the connector should be designed so that maintenance, overhaul, or adjustment during its operating life can be accomplished on the service half.

3.17 ORU Utility Connectors

ORU's requiring electrical power and data transfer should be designed with an integrated utility connector. (NASA-30550)

3.18 Non-Brazed or Non-Welded Fluid Lines

All non-brazed or non-welded liquid lines should be provided with a convenient to use, permanently installed connectors that permit in-orbit maintenance. (NASA-Std-3000).

3.19 Accessibility

3.19.1 Interference

It shall be possible to mate/demate or replace utility connectors without having to remove or replace other connectors (NASA -Std-3000).

3.19.2 Hand Access

Connectors should be spaced far enough apart so that they can be grasped firmly for mate/demate (NASA -Std-3000).

3.19.3 Transfer Line Length

Minimize transfer line length to reduce the number of bends in the line, reduce line tethering / retention problems, lessen collateral damage potential of line contact, and minimize servicing time (JSC 23920).

4.0. DETAILED REQUIREMENTS

Performance requirements are to be presented in the specification or standard to establish the characteristics necessary for the connector to completely satisfy system operating conditions. Examples of wording for each paragraph are given below:

4.1 Mechanical Design

The following mechanical design features should be considered for all utility connector interfaces.

4.1.1 Emergency Disconnect

All designs should have emergency disconnect provisions that will have minimum impact on the

spacecraft structure, and should be capable of abort/disengagement by manual, manually commanded, or autonomous means. Following emergency disconnection the design should be resetable to its pre-emergency disconnect operational status. There should be no degradation in capability as a result of emergency disconnect.

4.1.2 EVA Handholds

Where applicable, the designs should include EVA handholds for emergency use.

4.1.3 Grasping Interface

EVA and robotic grasping interfaces should, as near as practical, be in-line with the centers of masses of the two shells being joined.

4.1.4 Alignment

Where practical, the design should include provision for automatic alignment of the two interface halves.

4.1.5 Locking

4.1.5.1 Indicator

All mate/demate mechanisms should allow for visual and vibratory feedback or indication that the operation of the connection is complete.

4.1.5.2 Self Locking

Connector plugs should provide a self-locking safety catch. (NASA -Std-3000)

4.1.6 Latch Mounting Structure

Design should be for deflection and stress levels with a safety factor of two above the levels that would result in mate/demate malfunction.

4.1.7 Robotic Mate/Demate

All robotically operated utility connectors should be designed to be mate/demate with one manipulator.

4.1.8 Mated Load Capacity

After mating, the load carrying capacity (force and moment) of the joint should be a minimum of 1.5

times the maximum load imposed during demate by manual or automatic means.

4.1.9 Visual Cues

Visual cues should be provided to assist the robotic system with grasping and positioning the utility connector before mate/demate.

4.1.10 Alignment Cues

Utility connector shells should be provided with alignment guides for both course and fine alignment for mate/demate.

4.1.11 Installation

Utility connector shells should be designed so that it will be physically impossible to install them incorrectly.

4.1.12 Labeling

Each type of utility connector will have an identification label in a format compatible with manual, EVA, robotic system, and automatic operations. (NASA-Std-3000)

4.1.13 Translation Direction

Utility connectors should be designed for mate/demate in a straight line motion.

4.1.14 Misalignment Tolerances

Engagement of the utility connector should be accomplished with misalignment of up to angular + or - 10 degrees; lateral 3.0 mm (0.12 inch); and rotational + or - 1 degree when used with an appropriate user supplied floating compliant mounting device on one end of the connector halves.

4.1.15 Scoop Proof Shell

A scoop proof design should prevent inadvertent damage to contacts or ports.

4.1.16 Anti-bind Rolloff

An anti-bind rolloff design should be incorporated to prevent shell binding caused by side loads during demate.

4.1.17 Manual Torque Limit

If manual mate/demating is required during nominal or emergency operations, the manual torque required should not exceed 15 newton-meters. (NASA-Std-3000)

4.1.18 Emergency Demate

Methods for emergency demate should not cause damage to the system.

4.1.19 Design Margin

For over-center latches the margin of safety during the latch operation should not be less than 1.0 based on tensile strength and 0.5 based on yield strength..

4.1.20 Tip-off Load Limit

Upon demate the tip-off dynamics (6 degrees-of-freedom) should not exceed the capability of the alignment system to stabilize.

4.1.21 Working Envelope

The separation envelope should be of sufficient size and shape so that no damage results to either of the two connector halves.

4.2 Electrical Design

The following electrical design features should be considered for all utility connector interfaces.

4.2.1 Cabling

Electrical connectors and cable installations should be designed with sufficient flexibility, length, and protection to permit mate/demate without damage to wiring or connectors. (NASA -Std-3000)

4.2.2 Arcing

Electrical contacts should be designed to confine/isolate any electrical arcs or sparks during mate/demate. (NASA -Std-3000)

4.2.3 Static Discharge

Design should have means for discharge of static potential between the plug and receptacle shell.