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FLIGHT CABLE/ELECTRICAL CONNECTOR MATING AND DEMATING

MEASUREMENT SYSTEM IDENTIFICATION: US Customary Units

Prepared By:

Eric Borrero
Digitally signed by Eric Borrero
Date: 2025.12.08 15:30:04 -05'00'

Eric Borrero
GSFC Workmanship Program Manager
Code 373
NASA Goddard Space Flight Center

Approved By:

Matthew Ritsko
Digitally signed by Matthew Ritsko
Date: 2025.12.17 20:39:12 -05'00'

Matthew W. Ritsko
Deputy Director, Engineering and Technology Directorate
NASA Goddard Space Flight Center

David Reth
Digitally signed by David Reth
Date: 2025.12.18 08:49:33 -05'00'

David A. Reth
Director, Safety and Mission Assurance
NASA Goddard Space Flight Center

NASA GODDARD SPACE FLIGHT CENTER
Greenbelt, Maryland 20771

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FOREWORD

This standard is published by NASA's Goddard Space Flight Center (GSFC) to provide uniform engineering and technical requirements for processes, procedures, practices, and methods that have been endorsed as standard for NASA programs and projects, including requirements for selection, application, and design criteria of an item.

This standard establishes the set of requirements and guidelines for the safe connection and disconnection (e.g., mating and demating) of flight electrical connectors. This standard is relevant to flight electrical connectors on cables and harnesses as well as sub-assemblies or boxes. This standard may be levied on suppliers at the discretion of the project. This document is not intended to infer any design rules for flight hardware.

Requests for information, corrections, or additions to this standard should be submitted via "Contact GTSP" to the Executive Secretary for the GSFC Technical Standards Program on the GSFC Technical Standards website at http://standards.gsfc.nasa.gov.

Robert Sticka
Digitally signed by Robert Sticka
Date: 2025.12.01 17:11:11 -05'00'

Robert Sticka
Technical Standard Program Manager
NASA Goddard Space Flight Center

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1. SCOPE

This standard identifies the minimum set of control mechanisms for the safe and proper mating and de-mating of electrical connectors on flight electrical cable/harnesses and sub-assemblies at NASA GSFC.

1.1 Purpose

This standard prescribes the minimum requirements for the training, records, tool handling, and procedural requirements for the control of electrical connector mating and de-mating operations. This document supplements the workmanship standards referenced in NASA-STD-8739.6 by incorporating training information and identification of personnel authorized to perform mate and de-mate operations.

This is not to be used as a standalone quality document for cable/harness fabrication and testing. It is intended to provide a supplemental, common, safe procedure for the handling of flight electrical connectors in integration and test (I&T). In the event of a conflict between this standard and approved engineering procedures/instructions, the approved engineering procedures/instructions take precedence. In the event of a conflict between this standard and any document referenced in NASA-STD-8739.6, this standard takes precedence.

1.2 Applicability

This document is applicable to personnel who perform, inspect, or witness cable/harness mates and de-mates to flight connectors and deliverable test equipment in the I&T campaign for programs and projects governed by NPR 7120.5 (e.g., test conductors, integration personnel, electrical engineers).

In this standard, all mandatory actions (i.e., requirements) are denoted by statements containing the term "**shall**." The terms "may" or "can" denote discretionary privilege or permission; "should" denotes a good practice and is recommended but not required; "will" denotes expected outcome; and "are/is" denotes descriptive material.

Note: The safety of all cable/harness hardware processed and handled is dependent on the proper inspection, cleaning of tools and materials, safe operation of test equipment (e.g., in the presence of high voltage potential), and following connector manufacturer instructions. The methods prescribed herein are designed for the protection of hardware from improper integration and are not intended to guarantee the safety of the technician from all possible electrical hazards. This is particularly true when employing conductive work surfaces or floors. Additional human safety precautions are contained in GPR 1700.7, Electrical Safety.

This standard does not apply to the integration, mating, or de-mating of optical fibers, fiber optic cables, or hybrid (opto-electrical) cables. For hybrid optical-electrical devices and assemblies, this standard **shall** be used for mating/demating to the electrical interface, while the appropriate optical or fiber optic standard should be used for the optical interface.

2. APPLICABLE DOCUMENTS

2.1 General

The documents listed in this section contain provisions that constitute requirements of this standard. The latest issuances of cited documents **shall** be used unless otherwise approved by the assigned TA. The applicable documents are accessible via the NASA Technical Standards System at https://standards.nasa.gov/, directly from the Standards Developing Organizations, or from other document distributors.

2.2 Government Documents

GPR 1700.7	Electrical Safety
GPR 8730.1	Metrology: Control of Measuring and Test Equipment
GPR 8730.9	GSFC Workmanship Program Requirements
MIL-DTL-17	General Specification for Cables, Radio Frequency, Flexible and Semi Rigid
MIL-DTL-38999	Connectors, Electrical, Circular, Miniature, High Density, Quick Disconnect (Bayonet, Threaded or Breech Coupling), Environment Resistant with Crimp Removable Contacts or Hermetically Sealed with Fixed, Solderable Contacts, General Specification For
MIL-PRF-39012	Military Specification Sheet, Connectors, Plug, Electrical, Coaxial, Radio Frequency
MIL-STD-889	Dissimilar Metal (Military Standard)
NASA-STD-8709.22	Safety and Mission Assurance Acronyms, Abbreviations, and Definitions
NASA-STD-8739.4	Workmanship Standard for Crimping, Interconnecting Cables, Harnesses, and Wiring
NASA-STD 8739.6	Implementation Requirements for NASA Workmanship Standards

2.3 Non-Government Documents

EIA-364-37	Contact Engagement and Separation Test Procedure for Electrical Connectors
IPC/WHMA-A-620	Requirements and Acceptance for Cable and Wire Harness Assemblies
IPC/WHMA-A-620xS	Space and Military Applications Electronic Hardware Addendum to IPC/WHMA-A-620
SAE AS39029	Contacts, Electrical Connector, General Specification for

2.4 Order of Precedence

When this standard is applied as a requirement or imposed by contract on a program or project, the technical requirements of this standard take precedence, in the case of conflict, over the technical requirements cited in applicable documents or referenced guidance documents.

3. ACRONYMS AND DEFINITIONS

3.1 Acronyms and Abbreviations

BOB	Breakout Box
CSO	Chief Safety and Mission Assurance Office
EMI	Electromagnetic Interference
ESD	Electrostatic Discharge
FOD	Foreign Object Debris
GSFC	Goddard Space Flight Center
GTSP	Goddard Technical Standards Program
I&T	Integration and Test
ID	Identification
MRB	Material Review Board
NMTTC	NASA Manufacturing Technology Transfer Center
QA	Quality Assurance
TA	Technical Authority
WOA	Work Order Authorization

3.2 Definitions

Accessories, connector	Removable mechanical hardware, such as cable clamps, backshells, and screws, that are parts of the connector assembly in a harness.
Backshell	A connector accessory that is installed onto the rear connector accessory threads of plug or receptacle connectors to provide mechanical protection to the individual harness wires entering the back of the connector.
Borescope	A miniature optical inspection apparatus designed to articulate and enter constrained spaces.
Breakout Box	Electrical equipment which includes connectors that serves as a single location for a test technician to operate test equipment and/or mission hardware during system integration.
Cable	A shielded single conductor, or a combination of conductors insulated from one another (multiple conductor).
Conductor	A lead or wire, solid, stranded, or printed wiring path serving as an electrical connection.
Connector Body	The main portion of a connector to which contacts and other accessories are attached.
Connector Grommet	An elastomeric seal used on the cable side of a connector body to seal the connector against contamination and to provide stress relief.
Connector Insert	The part of a connector that holds the contacts in position and electrically insulates them from each other and the connector body.
Connector Saver	Short jumper harness or connector which is temporarily installed to a mission hardware connector during the test phase of manufacturing to mitigate the physical wear of repeated connector mating cycles.
Contact	The conductive element in a connector or other terminal device that mates with a corresponding element for the purpose of transferring electrical energy.
Contaminant	An impurity or foreign substance present in a material that affects one or more properties of the material.
Demate	The disconnection of two elements intended to be physically coupled and decoupled.

Electromagnetic interference	The unwanted intrusion of electromagnetic radiation energy whose frequency spectrum extends from subsonic frequency to X-rays.
EMI Spring	A spring-shaped connector feature installed between the flanges of two mated connectors that maintains electrical continuity between the connector bodies, aiding in electromagnetic interference mitigation.
Electrostatic Discharge	A rapid transfer of electrostatic charge between bodies at different electrostatic potentials caused by direct contact or indirect contact if transferred by a high electrostatic field.
Grommet	An insulator that covers sharp edges of holes through panels and partitions to protect wire insulation from cut-through damage.
Harness	One or more insulated wires or cables, with or without helical twist; with or without common covering, jacket, or braid; with or without breakouts; assembled with two or more electrical termination devices; and arranged that as a unit it can be assembled and handled as one assembly.
Interfacial seal	A sealing of mated connectors over the whole area of the interface to provide sealing around each contact.
Jackpost	A threaded nut or standoff attached to one half of a two-piece, multiple-contact connector and used to draw both halves together and to separate them.
Jackscrew	A screw attached to one half of a two-piece, multiple-contact connector and used to draw both halves together and to separate them.
Locking Ring	A connector feature which provides physical securement of the two elements being mated.
Locking Indicator	A connector feature which provides positive indication to the user that the interfaces are completely engaged by the connector manufacturer’s design.
Mate	The connection of two elements intended to be physically coupled and decoupled.
Pin	An electrically conductive element designed to engage with a socket within a connector housing. See A.11, Contact.
Quality Assurance	A planned and systematic pattern of all actions necessary to provide adequate confidence that adequate technical requirements are

	established; products and services conform to established technical requirements; and satisfactory performance is achieved.
Reagent Grade	Describing a grade of high purity chemistry. Suitable for high cleanliness laboratory and manufacturing environments.
Socket	An electrically conductive element designed to engage with a pin within a connector housing. See A.11, Contact.
Stripping (threads)	Physical malformation of threads caused by out of axial engagement, or over-torquing of threaded fasteners.
Threads	The helical shape of a hardware fastener which provides coupling action under rotational force to its mating fastener.
Torque	The measure of a force which can cause rotational force about an axis. The torque required to tighten a connector or fastener depends on the size and type of fastener, the materials being engaged, and the desired tightness.
Verification	The act of performing the tests and/or inspections to periodically confirm performance.
Witness	A person who is present (virtually or physically) during the execution of a task for the purpose of observation and verification of the task being performed. Witnesses to electrical flight connector mating activity have been trained to the contents of this GPR. The witness may be required to affirm and record the results of the task performed.
Work Order	A document that authorizes the performance of work. It specifies the work to be done, the materials and resources required, and may include the schedule for completion and/or cost.

4. REQUIREMENTS

4.1 Training

4.1.1 Personnel who perform or witness cable/harness mates and de-mates to flight connectors in the I&T campaign, including system checkout and qualification testing, **shall** be trained to the content of this standard every two years.

4.1.2 Training may be conducted by the GSFC-approved workmanship training facility or through a supplier-developed course which is subject to review and approval by the GSFC Workmanship Program upon request.

4.1.3 Personnel who complete retraining within a 90-day window prior to the expiration of the existing training period **shall** be granted a new expiration date that is exactly two years following the existing expiration date.

4.1.4 Personnel who take and pass the training course **shall** be awarded evidence of successful completion of training (e.g., certificate, wallet-sized card, electronic record) by the instructor which includes the training expiration date, trainer's name, and training organization.

4.2 Records and Logs

4.2.1 The retention period of connector mate/demate records should be the project lifecycle + 10 years, per NASA Records Retention Schedules 1441.1.

Record Title	Record Custodian	Retention
GSFC Flight Connector Mate/Demate Log	Project CSO, Quality Assurance (QA) Lead, or assigned delegate	*NRRS

**NRRS 1441.1 – NASA Records Retention Schedules*

Note: Some projects may need the record custodian to be a delegated electrical engineer or I&T specialist, depending on available personnel and scheduling.

4.2.2 A record/log of connector mate/demate cycles **shall** be maintained for each flight connector, including mates of flight connectors to test equipment and connector savers. The mate/demate log should include the following criteria:

a. Part number, serial number, or reference designator of the connector
b. Date and time of the mate
c. Authorization/Work Order Authorization (WOA)/Event requiring the mate/demate procedure.
d. ID of the technician performing the mate/demate
e. ID of the third-party witness of the mate/demate
f. Number of mate/demate cycles until cleaning

Note: An example connector mate/demate log is contained in Appendix A herein and meets this requirement. This example may be used and modified as needed by production teams.

Note: Connector mates which do not include flight connectors are not required to be logged in a mate/demate log.

4.3 Tools

4.3.1 Wrenches

a. Wrenches, sockets, and other tools used for the installation of connectors should be non-adjustable.

Note: Adjustable tools have the propensity to lose the setting over time and can lead to stripped or damaged fasteners or connector accessories.

4.3.2 Drivers

a. Screw and nut drivers should be of the correct design and size for the hardware being manipulated.

b. Drivers **shall** be hand operated (e.g., not electrically or pneumatically operated).

c. Drivers should be held straight along the axis of the fastener being manipulated.

Note: Insufficient physical space to access a fastener may require the use of a tool such as a ball driver for off-axis access to the fastener.

d. Ball drivers may be used, but also should be the correct size for the hardware manipulation, and the angle of engagement should not exceed ~30 deg, where the ball driver becomes ineffective.

4.3.3 Torque Values

a. The torque value used for torque-controlled fasteners (e.g., coupling nuts, jackscrews, jackposts, etc.) should be defined in the engineering documentation (or torque spec for the connector, or defined in the WOA, or as provided by the manufacturer).

Note: The connector datasheet or manufacturer's application notes are the recommended primary source for this torque value. Including the torque value to work instruction or work order document is sufficient.

4.3.4 Soft Jaw Pliers

a. Soft jaw pliers (e.g., nonmetallic) should be used where possible for the disengagement of locking rings, unless easily turned by hand.

Note: Soft jaw pliers come in many shapes and sizes. It is best to use the design which matches the connector being disengaged. Tools should be evaluated for compliance to local contamination and Electrostatic Discharge (ESD) requirements.

4.3.5 De-Mate Tool

a. De-mate tools specific for the disengagement of matching connector designs should be used where applicable.

Note: Tools should be evaluated for compliance to local contamination and ESD

policies. Preferably a non-metallic ESD compliant prying tool. If a prying stick is used, ensure force is equally applied to both sides (even by alternating sides, if needed) in order to minimize the likelihood of bending contacts.

4.3.6 Borescope

a. When there is insufficient space to inspect for the cleanliness, placement, identification, or condition of connectors by human eyesight alone, a borescope or similar inspection aid capable of rendering accurate colors and sufficient resolution may be used.

4.3.7 Calibration

a. Tools requiring calibration (e.g., torque tools) **shall** be calibrated to GPR 8730.1, Metrology: Control of Measuring and Test Equipment.

4.4 Connector Cleanliness and Inspection

4.4.1 Cleaning Interval

a. Flight connectors, connector savers, test harnesses, including flight cable/harness test equipment (e.g., panels, breakout boxes) should be cleaned as specified by the project. Discovery of visible contaminants during an inspection should constitute a cleaning action.

Note: A common interval to require cleaning is every 5 cycles and as needed. This is due to the propensity for connector components to generate particulates when the materials rub against one another during the mate/demate process. This interval may be extended or contracted as needed for project needs and noted on the mate/demate record.

b. Cleaned and dried connectors **shall** be covered with a clean dust cap. See 4.5.

Note: Complex connector designs may warrant a low temperature bake out to ensure the cleaning solvent has completely outgassed prior to covering with a protective cap. Flight hardware which is highly sensitive may require an air dry prior to covering with a clean dust cap.

4.4.2 Materials for Cleaning

a. De-ionized water or other water-based solvents **shall** not be used to clean cable/harness assemblies.

Note: Many wires used in fabrication are copper with a silver-plated finish. If the interface of the silver to copper is exposed to water, a corrosive side effect known as Red Plague can occur. Because I&T personnel often are working with finished products, the composition of the wire can be unknown. Use an approved solvent that meets project and workmanship requirements.

b. Application of solvent to areas being cleaned **shall** be controlled by a lint-free swab, shop wipe, or similar tool which minimizes the amount of liquid applied to the connector being cleaned, and readily absorbs contaminated liquid.

Note: The application of the solvent to the connector needs to be controlled to prevent intrusion of contaminated liquid into the connector or other regions which can't be readily cleaned. The orientation of the connector relative to gravity should be considered.

4.4.3 Tools for Cleaning

a. Swabs, cloths, and shop wipes used in the cleaning of connector elements should be of a lint free composition that does not deposit foreign material onto the connector.

b. Particulates should be removed from external areas of harnesses and connectors using vacuum removal methods.

Note: Specially designed vacuum cleaners with ESD-safe nozzles exist for the purpose of removing particulates from ESD sensitive electronic equipment. If ESD sensitive hardware is in the vicinity, ensure compliance to the local ESD control plan. Compressed air is not recommended due to the high likelihood of uncontrolled deposition of contaminants or particulates to other areas of the assembly. Ensure the tool that is used meets the cleanliness requirements of the local environment.

c. Handling of flight hardware **shall** be performed with protective gloves worn by the handling technician.

Note: Some cables incorporate small diameter thread-like wires which must be handled carefully compared to common cables. Units may be classified as "handling-sensitive" and may be identified on the packaging as such.

4.5 Protection

4.5.1 Protective Covers

Connector caps (i.e., dust covers) used for the matching connector at time of original assembly should be saved for future assembly phases as a means of preventing debris intrusion and physical damage. While having an original dust cover designed for a given connector is ideal, protective measures such as employing shorting plugs, connector savers, clean ESD shielded bagging, or sealing with polyimide tape may be necessary to meet the following requirements.

a. Protective covers **shall** be used on all un-mated connectors.

b. Protective covers **shall** be of a material which is approved for flight use.

c. All replaceable covers **shall** be inspected for cleanliness prior to installation.

d. Caps should be of the correct size and design for the connector being protected.

e. When using tapes as a protective measure, the adhesive side should not come in contact with pins or sockets.

Note: If hardware is received that does not have protective covers or aren't made of a compliant material (e.g., for ESD control), the caps should be replaced with ones that fit the connector properly and are made of the appropriate material. If protection from ESD is required, but dissipative caps aren't available, the use of an ionizing air stream on the exposed connector should be employed at time of mate/demate. For more guidance on ESD control, review the local ESD control plan.

4.5.2 Connector Savers

a. Connector savers should be visibly marked with a brightly colored indicator that can be located from outside the immediate work area.

b. Interface surfaces for connector savers **shall** be inspected for cleanliness, and if necessary, cleaned, at the time of mate to a flight connector.

4.6 Connector Features

4.6.1 Threads

a. Threaded connector nuts and fastener hardware should be carefully aligned prior to engagement to their mating hardware.

Note: Cross-threading or stripping of threads can occur if the connector is not held parallel to the mating connector during engagement. Technician practice with a matching non-flight or heritage connector should be carried out prior to handling of flight connectors to have a better understanding of the mechanical resistance of the engaging hardware.

b. Thread locking material, when present, should be cleaned from threads after demating using a solvent, and re-applied at the time of next mate.

Note: Ensure that the solvent is approved by the project for use prior to application.

4.6.2 Fasteners and Hardware

a. Connectors with jackscrews should only have the jackscrews engaged after the connector pins and sockets are fully seated.

b. When torquing jackscrews to jackposts, the torque applied to the jackscrews **shall** be less than the jackposts' torque to the connector or bulkhead.

Note: Jackposts may become loose when excessive force is applied. This can happen even if staking material has been applied between the jackpost and the chassis wall. It is important to hold the jackposts in place with an appropriate wrench, hex driver, or other tool when applying any force to the jackscrews.

c. If a jackscrew has hit the internal bottom cavity of a jackpost, or significantly increases resistance unexpectedly, the technician **shall** not continue to force the jackscrew to rotate.

d. Jackscrews, when present, **shall** be threaded completely (fully engaged) to the jackpost.

e. Retaining clips used as a means to capture disengaged jackscrews should be installed to the connector in an orientation which properly retains the disengaged screw.

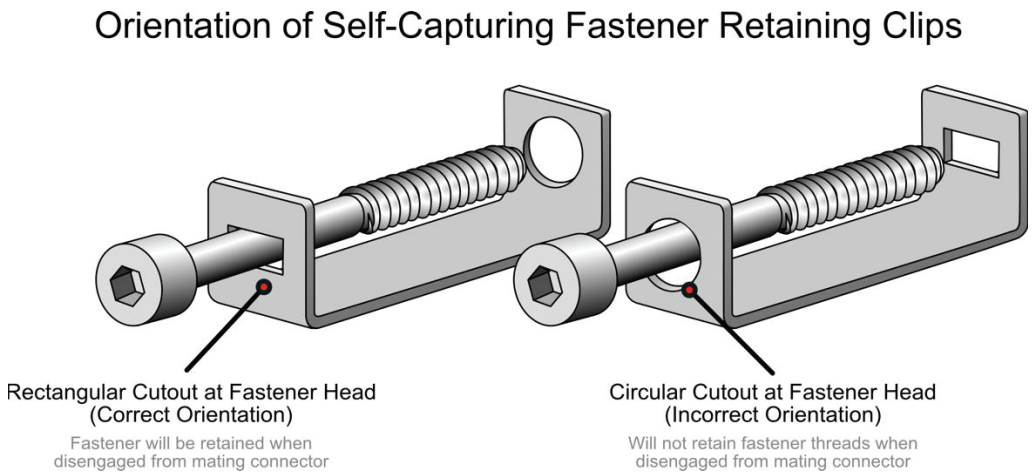

Figure 1 - Orientation of Self-Capturing Fastener Retaining Clips

4.6.3 Locking Indicators

a. Locking indicator features, (e.g., blue mark on locking tab), **shall** be visible in the inspection window after mate, if included as part of a connector design.

4.6.4 Interfacial Seals

a. Interfacial seals should be replaced if the existing interfacial seal is contaminated or damaged, or at a periodicity determined by either the connector manufacturer or project.

4.6.5 EMI Springs

a. Damaged EMI springs should be replaced using a documented procedure which is approved by the project prior to replacement.

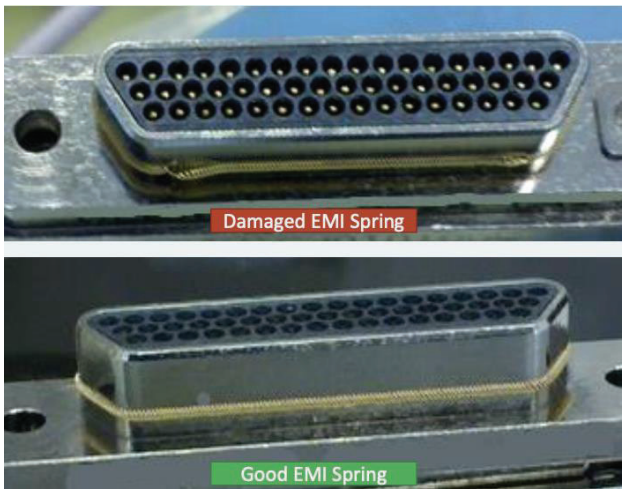

Figure 2 - Damaged EMI Spring (above) and Intact EMI Spring (below)

Note: Connector manufacturers may provide guidance or procedures specifically for the removal and replacement of delicate EMI springs.

4.7 Mating/Demating Requirements

This section contains generic procedures for electrical connector mating and demating. The order of operations may not suffice and may need to be omitted or modified for a particular cable/harness design. Therefore, the procedures herein are included to provide a common baseline for cable/harness assembly installation, and for WOA development.

4.7.1 Time of Mate

4.7.1.1 Inspection

a. All flight connectors, connector savers, test harnesses, including flight. cable/harness test equipment (e.g., panels, breakout boxes) **shall** be visually inspected at the time of mate to verify:

i. The Part Number and Serial Number of plug and socket connectors match the drawing or WOA.

ii. Supplemental hardware and fasteners used are of the appropriate size, material, surface finish, and design.

iii. The pin and socket pattern (“pinout”) of mating connectors match one another.

iv. There is no damage to the connector body, insert, grommet, pins, sockets, interface elements, threads, mounting hardware, etc.

v. There are no chips or cracks in the surface finish coating.

vi. There are no bent or deformed interface elements (e.g., pins, sockets, threads, interfacial seals).

vii. There are no present contaminants such as Foreign Object Debris (FOD), or flux residue.

b. Inspection **shall** be performed at 10X magnification ±15%, or higher. magnification permissible for Micro-D and similar connectors.

Note: Other small connector styles besides Micro-D may constitute higher magnification levels (e.g., 20X, 40X), but should be documented at the time of inspection.

c. Supplementary lighting should be used as necessary to aid inspection.

4.7.2 Connector Engagement/Disengagement

a. Cable and connector bodies should be physically supported at the time of mate.

Note: Weight of the cable can cause strain at the interface. Supporting the cable and connectors helps ensure cables do not become deformed or unnecessarily strained.

b. Connector keys and keyways **shall** be aligned to the mating configuration prior to engagement.

Note: Pushing the connector face against a mating connector where the key is misaligned with the keyway can generate FOD or damage to keys, keyways, threads, plating, or contacts. Do not "grind and find"!

c. Free rotation of the cable's axis relative to the connector body **shall** be avoided:

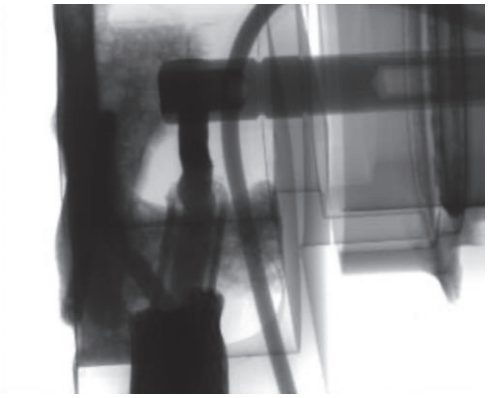

Figure 3 - X-Ray Image of Internal Kinked Conductor

Note: When the cable is excessively rotated along its axis relative to the connector, the internal conductor may deform and kink, changing the electrical characteristics, or leading to an open circuit. Only the coupling nut should move when engaging a threaded

connector.

d. Connectors **shall** be mated or demated one at a time under the supervision of the designated QA witness.

e. The QA witness and the technician performing mate/demate action should have simultaneous access to view the mate or demate activity as it is carried out, when possible. Accordingly, sometimes a blind mate is necessary for the electrical connections but should be avoided during the design phase.

Note: In constrained spaces, the use of additional camera systems or borescopes can aid significantly to ensure that the hardware is engaging properly. The use of a tool such as a digital borescope may be necessary in some cases to see the mate. Additionally, the use of audio cues (i.e., 'click') and/or the 'feel' of the engagement are all the technicians can use, depending on accessibility.

f. The QA witness and the technician performing mate/demate action **shall** ensure cable is properly supported and is perpendicular to the mating (or demating) connector.

Note: If the cable is not supported and aligned with the mating connector, proceeding with engagement can result in damage to the connector threads, pins, sockets, or other features due to axial torque.

g. If at any point during time of mate, unexpected mechanical resistance is experienced, the technician **shall** carefully disengage the connector and inspect both the jack and the plug for damage/cross-threading/stripping.

h. The technician and the witness to connector mate/demate activity **shall** record the result of the mate or demate in the corresponding mate/demate record.

i. Check for full pin/socket engagement; there should be some mating resistance felt with mating pins and sockets (Defined in MIL-DTL-38999, EIA-364-37, and SAE AS39029). If no resistance is felt, consult the QA for appropriate action.

j. If jackpost are used with the type of connector used, verify connector fully engages and is not restricted by the height of the Jackpost. Too high a jackpost will inhibit full engagement of the connector.

5. PROCEDURES

The content in this section may be used for writing work orders or work instructions. The procedures herein contain embedded notes to engineering for tailoring this content to a specific cable/harness design. The procedures herein do not constitute requirements, unless included to project engineering documentation (e.g., work orders, work instructions).

5.1 General Safe-to-Mate Procedure

a. Ensure technician and third-party QA witness (e.g., quality assurance, quality engineer, test engineer) are trained to perform safe to mate activities in accordance with Mission Assurance Requirements (MAR) if so directed or specific safe to mate procedural and accountable executable instructions.

b. If unfamiliar with a particular connector design, technicians should practice using non-flight hardware of the same design before mating flight connectors.

c. Verify that all systems are de-energized and do not present a hazard to technicians.

Note: Circuits containing batteries may not be possible to completely de-energize. In configurations such as this, system check out and safety reviews may be necessary to understand when and how to handle the system in a safe manner.

Note: The safety of all cable/harness hardware processed and handled is dependent on the proper inspection, cleaning of tools and materials, safe operation of test equipment (e.g., in the presence of high voltage potential), and following connector manufacturer instructions. The methods prescribed herein are designed for the protection of hardware from improper integration and are not intended to guarantee the safety of the technician from all possible electrical hazards. This is particularly true when employing conductive work surfaces or floors. Additional human safety precautions may be required in accordance with GPR 1700.7, Electrical Safety.

d. Follow the WOA/Procedure defined for the given system during system checkout.

5.2 General Connector Mating Procedure

Table 1 - Example Connector Mating Procedure

WOA Step	Instruction	Technician	QA Witness
PREPARATION FOR FLIGHT CONNECTOR MATE			
10	*[Note for Engineering: The following is an example general connector mating procedure. The order of events may not suffice for all WOAs. Consider the order of operations when developing your WOA. If events can worked out of sequence, it should be noted in the first sequence/event of the WOA.]* For practice, technicians should use non-flight hardware of the same design before mating flight connectors. Notify QA witness work is ready to begin. Ensure training is current.		

WOA Step	Instruction	Technician	QA Witness
20	Verify all tools to be used are clean, undamaged, and within valid calibration.		
30	Prepare to perform photo documentation. (Technicians notify the photographer, or use the lab camera to take pictures, as specified by the project.) *Note: ESD monitor should provide direction for ESD mitigation with cameras, such as ionized air stream, conductive camera body, or other.*		
40	*[Note for Engineering: Project temperature and RH ranges may be included to remind technicians to not proceed with work if outside range. ESD controls described in this step should meet minimum controls for the hardware level per local ESD control plan.]* ESD caution applies to proceeding any events in the WOA. If this WOA is interrupted, ESD cautions should be revisited at time of resuming work. QA or Electrical Engineer will provide ESD overview to all personnel involved with proceeding operation: - ESD precautions and controls in accordance with the local ESD control plan. - All personnel working on the hardware must have current ESD certification, Handling controls: - Wear ESD wrist ground straps and ESD garments at all times inside the ESD protective area (EPA) - Complete ground strap check as needed when entering the EPA - Only perform work within the EPA - Turn off ionized air sources when not in the EPA - Hold insulative tools and tapes to be applied to the ESD sensitive hardware in front of an ionized air stream for 5 seconds before application. As applicable record: Temperature Reading _____ Humidity Reading _____ Hygrometer Model_____ Hygrometer SN_____ Hygrometer Cal Due Date_____		
50	*[Note for Engineering: Optional item, may be covered in safe-to-mate or other project procedure. Documentation of equipment*		

WOA Step	Instruction	Technician	QA Witness
	should be captured for traceability, but may not be in mate WOA] Document the following tool information at the start of work. Tools and equipment should remain consistent throughout the process for test accuracy. Record equipment information: Digital Multimeter (DMM) Model: _____ DMM SN: _____ DMM Cal-Due: _____ ESD Field Meter: Model: _____ ESD Field Meter SN: _____ ESD Field Meeting Cal-Due: _____ Torque Wrench Model: _____ Torque Wrench SN: _____ Torque Wrench Cal-Due: _____ Torque Driver Model: _____ Torque Driver SN: _____ Torque Driver Cal-Due: _____ *[Any other expected equipment, as necessary]*		
60	Verify all hardware and equipment to be mated are powered off and fully de-energized. If batteries are part of the circuit, they should be sufficiently discharged or disconnected. *Note: Circuits containing batteries may not be possible to completely de-energize. In configurations such as this, system check out and safety reviews may be necessary to understand when and how to handle the system in a safe manner.* *Note: The safety of all cable/harness hardware processed and handled is dependent on the proper inspection, cleaning of tools and materials, safe operation of test equipment (e.g., in the presence of high voltage potential), and following connector manufacturer instructions. The methods prescribed herein are designed for the protection of hardware from improper integration and are not intended to guarantee the safety of the technician from all possible electrical hazards. This is particularly true when employing conductive work surfaces or floors. Additional human safety*		

WOA Step	Instruction	Technician	QA Witness
	precautions may be required in accordance with GPR 1700.7, Electrical Safety.		
70	Verify all connectors on the box/panel are correctly installed, and acknowledge if protective covers are used (or not). Capture photo documentation of connector configuration. Document box/panel connectors without protective covers: _____ _____ _____		
80	One at a time, remove box/panel connector protection covers, and inspect all connectors and/or connector savers for contamination and damage. Reinstall protective cover after verification, or clean as necessary (see next step). Capture photo documentation as necessary. When damage is found, photograph, and discuss with the cognizant engineer and QA for the appropriate action, and/or generate a problem report (PR). If a PR is drafted, it should be dispositioned through a review board (e.g., ARB, MRB, FRB).		
90	For box/panel connectors which are identified to be cleaned, carry out cleaning procedure. If cleaning with a solvent, sufficient drying of the connector is necessary before any power is applied. If extreme cleaning is required; defer the cleaning to the contamination control group. Connector(s) cleaned:_____ Cleaning method (dry swab, or approved solvent with bake-out): _____ _____ Solvent Lot Number (if applicable): _____ Solvent Expiration Date (if applicable): _____ *Note: Dry cleaning of connectors is recommended to be used before wet cleaning applications. Wet cleaning often requires a bake-out step to fully dry the connector. However, some sensitive flight*		

WOA Step	Instruction	Technician	QA Witness
	hardware may require ambient temperature air dry.		
100	Test grounding of box/panel connector backshell. Use a digital multi-meter (DMM) with reference (black) to common ground reference. Measure and verify resistance is <1.0Ω at the backshells of the box/panel connectors. Ground and discharge DMM and breakout box (if present) first, before measuring. Record the resistance to reference ground: Jack A Backshell to Ref Ground: _____Ω Jack B Backshell to Ref Ground: _____Ω Jack C Backshell to Ref Ground: _____Ω *[Additional connectors as necessary]* In leu of a DMM, a milliohm-meter can be used to take the resistance measurements from ground to the backshell; IAW design drawing/safe-to-mate procedure. In addition, capture the ID and calibration due date of the meter used: ID: _____ ; Cal Due Date: _____		
110	Verify harness ID. Remove the harness from its storage container and verify all connectors' labels match the mating diagram. *Note: If the storage container is not an ESD bag, ensure a charge mitigation strategy is used during removal and handling. See Step 40.*		
120	Document harness connectors without protective covers: _____ _____ _____		
130	Test grounding of harness connector backshell. Use a digital multi-meter (DMM) with reference (black) to common ground reference. Measure and verify resistance is <1.0Ω at the backshells of the harness connectors. Ground and discharge DMM and breakout box (if present) first, before measuring.		

WOA Step	Instruction	Technician	QA Witness
	Record the resistance to reference ground: Plug A Backshell to Ref Ground: _____Ω Plug B Backshell to Ref Ground: _____Ω Plug C Backshell to Ref Ground: _____Ω *[Additional connectors as necessary]*		
140	One at a time, remove harness connector protective covers, and inspect all connectors and/or connector savers for contamination, damage, and verify pinout matches mating connector. Reinstall protective cover after verification, or clean as necessary (see next step). Capture photo documentation as necessary. When damage is found, photograph and disposition through a review board (e.g., ARB, MRB, FRB).		
150	For harness connectors which are identified to be cleaned, carry out cleaning procedure. Connector(s) cleaned:_____ Cleaning method (dry swab, or approved solvent with bake-out): _____ _____ Capture photo documentation as necessary. Solvent Lot Number (if applicable): _____ Solvent Expiration Date (if applicable): _____ *Note: Dry cleaning of connectors is recommended to be used before wet cleaning applications. Wet cleaning often requires a bake-out step to fully dry the connector. However, some sensitive flight hardware may require ambient temperature air dry.*		
FLIGHT CONNECTOR SAFE-TO-MATE			
160	If connector savers are used for the process, validate that they are available for use: PN:_____ SN:_____		

WOA Step	Instruction	Technician	QA Witness
	PN:_____ SN:_____ PN:_____ SN:_____ *[Additional connector savers as necessary]* *[Engineering Note: Connector savers are not required but are encouraged for test applications where multiple mates to a given connector will take place. Connector savers may have ID numbers or serial numbers for further identification. Engineering should include any connector savers for flight connectors in this list for the given harness.]*		
170	If harness is to be tested for functionality with a safe-to-mate procedure, ensure the safe-to-mate procedure is approved. A breakout box will be used for testing. Verify the following breakout box (BOB) is available, and is discharged: ID: _____ SN: _____ Cal Due Date: _____		
180	Some connectors may be identified for connector saver installation during test. Carefully install the connector saver(s) to the relevant connector(s) as described below. **For circular connectors:** If keys are present: Visually verify the key and keyways of the plug and jack align and will mate. Align the center key to the mating keyway. Minimize rotation during alignment. Align the connectors parallel, and carefully push the plug into the jack. Bayonet style connectors will have a coupling nut which rotates along the axis until a locking mechanism engages. Verify the locking mechanism engages and the indicator is present. Threaded connectors will be torqued. Carefully engage the threads of the plug to the threads of the jack, ensuring the coupling nuts remain parallel, and tighten using a torque wrench to the specified torque per 540-PG-8072.1.2. Coupling Nut Torque: *[x]* (in. lbs., N)		

WOA Step	Instruction	Technician	QA Witness
	For rectangular connectors: Visually verify the connector pinouts will mate, and if present, the master key is aligned with the master keyway. Ensure supplemental hardware (e.g., EMI springs, retaining clips) are present, clean, and installed to the correct orientation. Align the connectors parallel, and carefully push the plug into the jack. If a locking mechanism is present, ensure it has engaged. If jackscrews are present, drive them using a hand-operated driver while keeping the connector flange parallel. Tighten using a torque driver to the specified torque. Jackscrew Torque: *[x]* (in. lbs., N) *[Engineering Note: The jackscrew torque must be less than the torque of the mating jackpost.]* Connector Saver PN: _____ Connector ID: _____ Torque Tool ID: _____ Torqued to (if necessary): _____ (in. lbs., N) *[Additional connectors as necessary]* Record the mate to Mate/Demate Log.		
190	Follow the safe-to-mate procedure. Procedure Number: _____ Capture photo documentation as necessary.		
FINAL FLIGHT CONNECTOR MATE PROCESS			
200	Route harness connector to the approximate location where the first connector mate will happen. Connector pair *[Pxx – Jxx]*. Support the cable as necessary to prevent unnecessary flexure.		
210	If "state of health" test will be carried out on the spacecraft, determine the phase of testing and whether or not the connector savers need to be removed before testing. If the removal of the connector savers is necessary, demate accordingly and log in the		

<table>
<tr><th>WOA Step</th><th>Instruction</th><th>Technician</th><th>QA Witness</th></tr>
<tr><td></td><td>appropriate mate/demate log and proceed with testing. keep connector savers on the flight harness whenever possible to minimize the potential of flight connector damage.

If this testing is not to be carried out, connector savers will be removed.

Remove protective cover for the first connector to be mated.

If connector savers removed, record the demate in the Mate/Demate Log.

Capture photo documentation as necessary.</td><td></td><td></td></tr>
<tr><td>220</td><td>Carry out the final mate for the listed connectors one at a time.

<table><tr><th>Connector Pair</th><th>Technician</th><th>QA Witness</th></tr><tr><td>Pxx – Jxx</td><td></td><td></td></tr><tr><td>Pxy – Jxy</td><td></td><td></td></tr><tr><td>Pxz – Jxz</td><td></td><td></td></tr><tr><td colspan="3">[Additional connector pairs as necessary]</td></tr></table>
For circular connectors:
If keys are present: Visually verify the key and keyways of the plug and jack align and will mate. Align the master key to the mating keyway. Minimize rotation during alignment.

Align the connectors parallel, and carefully push the plug into the jack.

Bayonet style connectors will have a coupling nut which rotates along the axis until a locking mechanism engages. Verify the locking indicator if present.

Threaded connectors will be torqued. Carefully engage the threads of the plug to the threads of the jack, ensuring the coupling nuts remain parallel, and tighten using a torque wrench to the specified torque.

Coupling Nut Torque: [x] (in. lbs., N)

For rectangular connectors:</td><td></td><td></td></tr>
</table>

WOA Step	Instruction	Technician	QA Witness
	Visually verify the connector pinouts will mate, and if present, the master key is aligned with the master keyway. Ensure supplemental hardware (e.g., EMI springs, retaining clips) are present, clean, and installed to the correct orientation. Align the connectors parallel, and carefully push the plug into the jack. If a locking mechanism is present, ensure it has engaged. If jackscrews are present, drive them using a hand-operated driver while keeping the connector flange parallel. Tighten using a torque driver to the specified torque. Jackscrew Torque: *[x]* (in. lbs., N) *[Engineering Note: The jackscrew torque must be less than the torque of the mating jackpost.]* Connector Saver PN: _____ Connector ID: _____ Torque Tool ID: _____ Torqued to (if necessary): _____ (in. lbs., N) *[Additional connectors as necessary]* Record each mate to the Mate/Demate Log. Capture photo documentation as necessary.		

5.2.1 General Connector De-mating procedure

WOA Step	Instruction	Technician	QA Witness
	PREPARATION FOR FLIGHT CONNECTOR DE-MATE		
10	For practice, technicians should use non-flight hardware of the same design before de-mating flight connectors. Notify QA witness work is ready to begin. Ensure training is current.		
20	Verify all tools to be used are clean, undamaged, and within valid calibration.		

WOA Step	Instruction	Technician	QA Witness
30	Prepare to perform photo documentation. (Technicians notify the photographer, or use the lab camera to take pictures, as specified by the project.) *Note: ESD monitor should provide direction for ESD mitigation with cameras, such as ionized air stream, conductive camera body, or other.*		
40	*[Note for Engineering: Project temperature and RH ranges may be included to remind technicians to not proceed with work if outside range. ESD controls described in this step should meet minimum controls for the hardware level per local ESD control plan.]* ESD caution applies to proceeding any events in the WOA. If this WOA is interrupted, ESD cautions should be revisited at time of resuming work. QA or Electrical Engineer will provide ESD overview to all personnel involved with proceeding operation: - ESD precautions and controls in accordance with the local ESD control plan. - All personnel working on the hardware must have current ESD certification, Handling controls: - Wear ESD wrist ground straps and ESD garments at all times inside the ESD protective area (EPA) - Complete ground strap check as needed when entering the EPA - Only perform work within the EPA - Turn off ionized air sources when not in the EPA - Hold insulative tools and tapes to be applied to the ESD sensitive hardware in front of an ionized air stream for 5 seconds before application. As applicable record: Temperature Reading _____ Humidity Reading _____ Hygrometer Model_____ Hygrometer SN_____ Hygrometer Cal Due Date_____		
50	Verify that all systems are de-energized and do not present a hazard to technicians. *Note: Circuits containing batteries may not be possible to completely de-energize. In configurations such as this, system check out and*		

WOA Step	Instruction	Technician	QA Witness
	safety reviews may be necessary to understand when and how to handle the system in a safe manner. *Note: The safety of all cable/harness hardware processed and handled is dependent on the proper inspection, cleaning of tools and materials, safe operation of test equipment (e.g., in the presence of high voltage potential), and following connector manufacturer instructions. The methods prescribed herein are designed for the protection of hardware from improper handling and are not intended to guarantee the safety of the technician from all possible electrical hazards. This is particularly true when employing conductive work surfaces or floors. Additional human safety precautions may be required in accordance with GPR 1700.7, Electrical Safety.*		
60	Disengage any threaded hardware used for mating with a hand-operated driver while keeping the connector flange parallel to the mated surface. If jackposts are present, support with an appropriately sized wrench. If captive hardware clips are used, verify that hardware is retained after disengagement. Torque Stripe Present: ☐Yes ☐No Capture photo documentation.		
70	Ensure protective covers are present and ready to be installed after disengagement.		
80	Some connectors may be identified for connector saver installation during test. Carefully install the connector saver(s) to the relevant connector(s) as described below. **For circular connectors:** Bayonet style connectors will have a coupling nut which rotates along the axis. The locking mechanism must be overcome for free rotation to begin. For threaded/torqued connectors, both the plug and the bulkhead (jack) must be supported during the disengagement process. Ensure an appropriate tool is used that will not incur damage to the hardware.		

WOA Step	Instruction	Technician	QA Witness
	Note: Remember that locking compounds (e.g., arathane), if present, will make the disengagement more difficult. As the connectors de-mate, ensure the harness connector is pulled perpendicular to the mated connector until it is completely disengaged. Capture photo documentation. **For rectangular connectors:** If locking mechanism is present, ensure it is completely disengaged. If jackscrews are present, ensure they are disengaged from the jackposts. (Ensure jackposts are always supported). Gently pull on the flange of the connector. If it is able to be removed by hand force only, ensure that the connector remains parallel to the mated connector through the entire removal process. Some connectors may require a prying technique to disengage. For these connectors, ensure the lifting motion does not lead to contact bending (keep connectors as parallel as possible, lift from both sides of the connector). *Note: Never pull on the cable, wire, or harness for disengagement. Operate the connector only by the connector body.* **For all connectors:** After disengagement, ensure supplemental hardware (e.g., EMI springs, retaining clips) are present, clean, and undamaged. Inspect the de-mated connectors for damage, debris, or other non-conformances. Ensure all pins and sockets are able to be viewed from all angles during this step. Capture photo documentation. Connector Saver PN (if applicable): _____ Connector ID 1: _____ Tool ID: _____ Connector ID 2: _____ *[Additional connectors as necessary]* Record the mate to Mate/Demate Log.		

WOA Step	Instruction	Technician	QA Witness
90	If debris, FOD, or torque stripe residue is present, clean with an appropriate solvent in a controlled manner to prevent accumulation of solvent on the assembly. As applicable: Solvent: _____ Connector ID: _____ Connector ID: _____ Photographic evidence taken.		
100	Safe the exposed connectors with protective covers.		
110	Connector de-mate complete.		

APPENDIX A – Example Connector Mate/Demate Log

The following is an example Mate/Demate Log which satisfies the record keeping requirements of this Standard. Instructions are provided on the usage of the spreadsheet.

NASA Box Link to Mate/Demate Log

	A	B	C	D	E	F	G	H	I	J
1	Return									
2	**CYCLE**	**DATE**	**TECH**	**QE**	**Authorization WOA Event**	**CYCLE**	**DATE**	**TECH**	**QE**	**Authorization WOA Event**
3	MATE					DEMATE				
4	MATE					DEMATE				
5	MATE					DEMATE				
6	MATE					DEMATE				
7	MATE					DEMATE				
8	INSPECT				CLEAN (Y or N):	Comments:				
9	MATE					DEMATE				
10	MATE					DEMATE				
11	MATE					DEMATE				
12	MATE					DEMATE				
13	MATE					DEMATE				
14	INSPECT				CLEAN (Y or N):	Comments:				
15	MATE					DEMATE				
16	MATE					DEMATE				
17	MATE					DEMATE				
18	MATE					DEMATE				
19	MATE					DEMATE				
20	INSPECT				CLEAN (Y or N):	Comments:				
21	MATE					DEMATE				
22	MATE					DEMATE				
23	MATE					DEMATE				
24	MATE					DEMATE				
25	MATE					DEMATE				
26	INSPECT				CLEAN (Y or N):	Comments:				
27	MATE					DEMATE				
28	MATE					DEMATE				
29	MATE					DEMATE				
30	MATE					DEMATE				
31	MATE					DEMATE				
32	INSPECT				CLEAN (Y or N):	Comments:				
33	MATE					DEMATE				
34	MATE					DEMATE				
35	MATE					DEMATE				
36	MATE					DEMATE				
37	MATE					DEMATE				
38	INSPECT				CLEAN (Y or N):	Comments:				

Figure 4 - Example Connector Mate/Demate Log