Space Station Electrical Bonding Requirements

International Space Station

Revision E

15 October 1999

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National Space Development Agency of Japan

esa
european space agency

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(Italian Space Agency)

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National Aeronautics and Space Administration
Space Station Program Office
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INTERNATIONAL SPACE STATION PROGRAM

SPACE STATION ELECTRICAL BONDING REQUIREMENTS

15 OCTOBER 1999

PREFACE

This document defines the Space Station electrical bonding requirements. The contents of this document are intended to be consistent with SSP 30243, Space Station Program Requirements for Electromagnetic Compatibility. The Space Station Electrical Bonding Requirements shall be implemented on all SSP contractual and internal activities and shall be included in any existing contracts. This document is under the control of the Space Station Control Board.

INTERNATIONAL SPACE STATION PROGRAM OFFICE

SPACE STATION ELECTRICAL BONDING REQUIREMENTS

15 OCTOBER 1999

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SPACE STATION ELECTRICAL BONDING REQUIREMENTS

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ESA Concurrence:
Reference SSP 50019 Joint Management Plan and
JESA 30000, Section 3, Appendix B

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LIST OF CHANGES

15 OCTOBER 1999

All changes to paragraphs, tables, and figures in this document are shown below:

SSCBD	ENTRY DATE	CHANGE	PARAGRAPH(S)
000008 R1	6–3–94	Revision B	ALL
	5–31–96	Revision C	ALL
	6–4–98	Revision D	ALL
	10-15-99	Revision E	ALL

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1.0 GENERAL

1.1 SCOPE

This requirements document defines the Space Station electrical bonding requirements in accordance with SSP 30243, Space Station Systems Requirements for Electromagnetic Compatibility (EMC), and SSP 30240, Space Station Grounding Requirements. These requirements address the characteristics, application, and testing of electrical bonding. Joining of surfaces, objects, equipment, and structures shall satisfy the requirements of this document, regardless of application or conductivity.

1.2 PURPOSE

These bonding requirements and tests are intended to ensure that the Space Station is free from such hazards as electrical shock and static discharge. In addition, these requirements provide for reliable fault clearing paths and the suppression of electromagnetic interference.

1.3 CLASSIFICATION

The electrical bonding classifications for the joining of all surfaces, objects, equipment and structures as defined in this document delineate a uniform methodology and performance that will result in a safe, reliable spacecraft with a uniform bonding design.

1.4 INTENDED USE

This requirements document is intended to define the requirements for bonding and joining of materials, equipment, flight elements and structural components provided by program participants.

1.5 PRECEDENCE

SSP 41000, defines the EMC design and performance requirements for the Space Station Program (SSP) by invoking SSP 30243. In the event of any conflict between SSP 30243 and this document, SSP 30243 shall take precedence.

2.0 DOCUMENTS

The documents in this paragraph, of the exact issue shown in the current issue of SSP 50258, are applicable to the extent specified herein. Inclusion of applicable documents herein does not in any way supersede the order of precedence identified in 1.5. The references show where each applicable document is cited in this document.

2.1 APPLICABLE DOCUMENTS

The documents in this paragraph are applicable to the extent specified herein.

DOCUMENT NO.	TITLE
MIL–M–3171	Magnesium Alloys, Processes for Pretreatment and Prevention of Corrosion Reference paragraph 3.3.6.3.1.
MIL–C–5541	Chemical Conversion Coating on Aluminum and Aluminum Alloys Reference paragraph 3.3.6.3.2.
SSP 30233	Space Station Requirements for Materials and Processes Reference paragraphs 3.3.1, 3.3.2.3, 3.3.4.3, 3.3.6, 3.3.6.3.1, and 3.3.6.3.2.
SSP 30242	Space Station Cable/Wire Design and Control Requirements for Electromagnetic Compatibility Reference paragraph 3.3.2.2.
SSP 30243	Space Station Requirements for Electromagnetic Compatibility Reference paragraph 3.1.
SSP 41173	Space Station Quality Assurance Requirements Reference paragraph 4.0.

3.0 REQUIREMENTS

3.1 DEFINITION OF SPACE STATION ELECTRICAL BONDING REQUIREMENTS

The chassis or structure of all equipment which is operating from a common power source shall be bonded such that maximum electrical fault currents can be conducted without creating a thermal or electrical hazard. Electrical bonds between all equipment shall be made to minimize differences in potential. The criteria for bonding design shall be included in the Electromagnetic Effects (EME) Control Plan as specified in SSP 30243 and the actual design included in the EME Design Analysis Report.

3.2 CHARACTERISTICS

3.2.1 CLASSES OF APPLICATION

Where a single bond is used to serve two or more classes of application, the design shall conform to the more stringent requirement of bonding. Hardware providers shall analyze the application of the bond under evaluation and shall apply the class of bond that meets the functional requirements of the device, equipment, structure or interface in question.

3.2.1.1 CLASS H BONDING (SHOCK HAZARD)

Class H bonds shall be applied to electrical and electronic equipment, assembled elements or structure and between mated, docked or berthed spacecraft. Class H bonding applies to nonpermanent interfaces such as mobile interfaces, direct current (dc) power sources or during docking or berthing. See appendix C for exception (Electromagnetic Effects Control Board (EMECB) Tailoring/Interpretation Agreement (TIA)–0067, EMECB TIA–0099, and EMECB TIA–0179) to this paragraph.

3.2.1.1.1 RESISTANCE

Conductive conduit carrying electrical wiring shall have a low resistance bond of less than 0.1 ohm to conducting structure at each termination and breakpoint. The bonding path may be through the equipment at which the conduit terminates.

3.2.1.1.2 GROUNDING

Exposed conducting frames or parts of electrical or electronic equipment shall have a low resistance bond of less than 0.1 ohm to conducting structure. If the equipment design includes a ground terminal or pin which is internally connected to exposed parts, a ground connection to the terminal or pin shall be provided.

3.2.1.2 CLASS R BONDING (HIGH FREQUENCY POTENTIALS, ANTENNA'S)

A Class R bond shall be applied where electronic devices require a low noise, near equipotential environment, a minimum potential drop or where the bond is part of a safety mandated, high frequency (minimum delay time) function such as fault clearing in the presence of an Intervehicular Activity (IVA) or Extravehicular Activity (EVA). See appendix C for exception (EMECB TIA–0038 and EMECB TIA–106) to this paragraph.

3.2.1.2.1 IMPEDANCE

All electrical and electronic units or components which use or produce electromagnetic energy shall be installed to provide a continuous low impedance path from the equipment enclosure to the conductive structure. The supplier shall demonstrate by test or analysis that the proposed bonding method results in a dc resistance of less than 2.5 milliohms across each faying surface in the bond path from enclosure to structure and an impedance of less than 100 milliohms up to a frequency of 1 megahertz. The bond from the equipment enclosure to the mounting plate furnished with the equipment shall also comply with these requirements, except that a suitable ground strap may be used across any necessary vibration isolators or other environment isolators. The impedance of the ground strap (length to width ratio no greater than 5 to 1) is not included in this measurement but the impedance of the faying surface to mating surface of the strap is. See appendix C for exception (EMECB TIA–0166) to this paragraph.

Bonds shall be noted on equipment and structure drawings that show bond surface preparation locations. All Orbital Replaceable Unit (ORU) to mounting surface and structural Class R bonds shall be tested for impedance during acceptance testing, or use processes that have been proven by coupon test to meet this bonding requirement, or have been specifically accepted by the EME Control Board. DC resistance measurements of bonds may be replaced by other in process measurements within a certified process.

The accepted process should address: Materials control, including types of acceptable materials for cleaning, surface prep, sealing, etc.; cleaning methods, including methods for cleaning faying surfaces prior to bonding, coating, etc.; surface preparation, including removal of paints and other nonconductive coatings, machining of surfaces to meet smoothness specifications, etc.; coatings and corrosion control, including definition of acceptable corrosion control coatings, methods for controlling corrosion, acceptable methods for controlling galvanic corrosion, etc,; quality assurance; and process control. The process should have supporting test data to verify repeatability and alternating current (ac) impedance. The list of EME accepted processes shall be maintained in D684–10263–01.

3.2.1.2.2 NEARBY CONDUCTORS

All conducting items having any linear dimension of 30 centimeters (cm) or more installed within one–fourth of the wavelength of the highest operating frequency of wiring carrying signals with frequencies that exceed 10 MHz, such as transmitting or receiving antenna lead–ins, shall have a bond to structure at least every interval that is one–fourth the wavelength of the highest operating frequency. Direct metal–to–metal contact is preferred. If a jumper/strap is used, the jumper/strap shall comply with the requirements of Class R bonds.

3.2.1.2.3 SPACE STATION STRUCTURE

Space Station structure shall be so designed that the conducting members provide a uniform low impedance path through inherent bonding during construction. Structure bond design shall include accommodation of the effects of operational vibration and resultant breakdown of insulating finishes or intermittent electrical contact.

3.2.1.3 CLASS S BONDING (STATIC CHARGE)

3.2.1.3.1 CONDUCTING STRUCTURAL ITEMS

All isolated structural conducting items having an area greater than 100 square centimeters which carry fluids in motion, or otherwise are subject to frictional charging or plasma–induced current flow or charging, shall have a mechanically secure conducting connection to conductive structure. The resistance of the connection shall be less than 1 ohm. See appendix C for exception (EMECB TIA–0012, EMECB TIA–0015, EMECB TIA–0017, EMECB TIA–0018, EMECB TIA–0032, EMECB TIA–0076, EMECB TIA–0078, and EMECB TIA–0099) to this paragraph.

3.2.1.3.2 COMPOSITE MATERIALS

All composite structural materials which are subject to frictional charging or plasma–induced current flow or charging shall have a mechanically secure conductive connection to adjacent conductive structural items. The dc resistance between the composite material connection and the structure shall not exceed 1000 ohms.

3.2.1.3.3 CONDUCTIVE MECHANICAL SUBASSEMBLIES/PARTS

All moving parts having a surface area greater than 100 square centimeters and which are subject to frictional charging (charging mechanism required), e.g., gears, cams, rotary joints, etc., shall be equipped with a charge bleed–off mechanism. This mechanism may take the form of bleed wire, wiper strap, conductive lubricant, etc. The bleed–off path shall not exceed 1000 ohms to conductive structure. See appendix C for exception (EMECB TIA–0006, EMECB TIA–0029, EMECB TIA–0047, and EMECB TIA–0099) to this paragraph.

3.2.1.3.4 PIPE AND HOSE BONDING

All conductive pipes, tubes, and hoses that carry fluids shall have a mechanically secure conductive connection to conductive structure that shall measure 1 ohm or less. The pipe, tube, or hose installation shall not be the primary path for electrical power under normal or fault conditions. Nonconductive plumbing installations shall be designed so that the static voltage generated by fluid flow will not exceed 350 volts at any point outside the pipes, tubes, or hoses.

3.2.1.3.5 TRADITIONALLY HOMOGENEOUS STRUCTURAL MATERIALS

The traditionally homogeneous class of structural materials includes glass, quartz, surface coatings, polymers, plastics, etc. These materials cover a wide range of conductivities. In each case where Class S applies (in all cases where none of the other classifications applies), the bond methodology shall assure that no conductive surface area greater than 200 square cm is without a bond path from conductive layer to conductive structure. The bond resistance from the connection point to conductive structure shall be less than 1 ohm. For example, a metalized thermal blanket may have the dielectric surface exposed to the plasma as long as the metalized layers are grounded to conductive structure. See appendix C for exception (EMECB TIA–0136) to this paragraph.

3.2.1.3.6 MULTILAYER INSULATION

Conductive layers shall be bonded together in at least two locations. The bonding resistance from those locations to structure shall be less than one ohm. See appendix C for exception (EMECB TIA–0120) to this paragraph.

3.3 PROCESSES, METHODS, AND PROCEDURES

3.3.1 SELECTION OF MATERIALS

Materials and parts for electrical bonding shall be as specified herein. Materials specified in this document shall also be selected in accordance with SSP 30233.

3.3.2 STANDARD PARTS

Standard parts (Military Standard (MS), Army Navy (AN), or Joint Army Navy (JAN)) that comply with the requirements of this document shall be used for electrical bonding wherever suitable for the purpose intended and shall be identified on drawings by part numbers. Commercial standard parts such as screws, bolts, washers, nuts, and cotter pins that comply with the requirements of this document shall be permitted for electrical bonding in place of standard parts (MS, AN, or JAN).

3.3.2.1 JUMPERS/STRAPS

Bonding jumpers/straps shall be avoided whenever possible. Bonding jumpers/straps across movable vibration or thermal isolation joints shall meet the applicable bond class resistance/impedance requirements. Bonding jumpers/straps shall be kept short and direct and have a length–to–width ratio that does not exceed 5 to 1. Bonding designs that require more than two (2) standard bonding jumpers/straps in parallel shall require approval. Bonding designs that require more than one bonding jumpers/straps in series to provide the required overall length, shall not be permitted. See appendix C for exception (EMECB TIA–0009, EMECB TIA–0058, and EMECB TIA–0107) to this paragraph.

3.3.2.2 CABLE AND WIRE

The requirements for cable and wiring shall be as specified in SSP 30242

3.3.2.3 HARDWARE USAGE

The hardware used shall permit the bond to meet performance requirements over the mission life in the specified environments. Hardware shall comply with the material requirements of the applicable specification and SSP 30233. Any coatings requiring refurbishment or maintenance on orbit shall not be used on removable joints. Where the fasteners are used to join two conductive materials that have their surfaces passivated, the fasteners shall provide a penetration of the passivating coatings to meet Class S bonding requirements.

3.3.3 DESIGN

3.3.4 METHODS OF BONDING

CRES and titanium are acceptable material for metal–to–metal bonding. A jumper (fault current)/ground strap (Class R), which meets the requirements in 3.3.2.1, across a bond is acceptable as a redundant fault current path. When parallel fault current paths exist for Class R and Class H bonds, at least one path shall meet all requirements in 3.3.6.3.2 using CRES or titanium.

3.3.4.1 BONDING INSTALLATIONS

Bonding installations are considered to be permanent and inherently bonded when using metal–to–metal joints by welding, bolting, brazing, sweating, or swaging.

3.3.4.1.1 SEMI–PERMANENT BONDING APPLICATIONS

Examples of semi–permanent installations are the following:

- Bare metal–to–metal joints of machined surfaces held together by threaded locking devices and sealed
- Sealed metal–to–metal joints held together by a minimum of three threaded locking devices that penetrate insulating surface coatings
- Sealed riveted joints with a minimum of three rivets that penetrate insulating surface coatings. The use of this bond methodology requires analysis of metal relaxation effects on bond viability over the Station lifetime (Class S or H Bond Application only)
- Tie rods (Class S Bond Application Only)
- Structural wires under tension (Class S Bond Application Only)
- Bare metal–to–metal pinned fittings driven tight and sealed (Class S or H Bond Application only)
- Normally permanent and immovable clamp fittings which have been assembled after insulating finishes have been removed from the contact area and sealed after assembly (Class S or H Bond Application only)

3.3.4.2 BONDING CONNECTIONS

Bonding connections shall be installed so that vibration, expansion, contraction, or relative movement incident to normal service use will not break or loosen the connection to such an extent that the resistance will vary during the movement. Bonding connections shall be located in a protected area, insofar as practical, and whenever possible near a hand hole, inspection door, or other accessible locations to permit rapid inspection or replacement The following conditions shall also apply:

- Equipment shall be bonded directly to the basic conducting structure or through permanently bonded parts. Bonding of overall shields to the connector backshell is the preferred method.
- Bonding jumpers shall be avoided whenever possible, but if they are utilized, they shall be installed so that movable components are not impeded in their operation by the jumper
- Bonding connections shall not be compression fastened through nonmetallic materials

See appendix C for exception (EMECB TIA–0081) to this paragraph.

3.3.4.3 CONDUCTIVE EPOXY RESINS

The use of conductive epoxy resins on equipment impractical to bond with preferred methods is permitted provided it conforms to the performance requirements of this document and SSP 30233.

3.3.4.4 TUBULAR STRUCTURAL MEMBERS

3.3.4.4.1 CONDUCTING MATERIAL

Bonding of cylindrical or tubular conducting members not inherently bonded shall be accomplished by a plain clamp with a jumper or approved equivalents. The bond resistance should not be allowed to fluctuate as a result of thermal or mechanical stress and movement. Bonding clamps, when required on flexible metallic conduit or hose, shall be installed so as not to crimp or damage the conduit or hose.

3.3.4.4.2 LOW–CONDUCTIVITY MATERIAL

Low–conductivity materials shall be bonded to provide for static electrical discharges. The bonding resistance shall meet the Class S bond requirements.

3.3.4.5 DISSIMILAR METALS

When the joining of dissimilar metals cannot be avoided, the jumpers and other hardware used in the bonding connection shall be selected to minimize the possibility of corrosion. Washers shall not be surface treated or coated in any manner that will impair electrical conductivity. Unprotected, nonstainless steel shall not be used as a washer.

3.3.4.6 REFINISHING

When it is necessary to remove any protective coating on metallic surfaces to conform with this requirements document, the completed assembly shall be refinished after inspection. Inspection shall be conducted after refinishing.

3.3.4.7 INTERMITTENT ELECTRICAL CONTACT

Intermittent electrical contact between conducting surfaces shall be prevented either by bonding or by insulation if bonding is not necessary to conform to this requirements document.

3.3.4.8 UNAPPROVED BONDING METHODS

Antifriction bearings, wire–mesh vibration cushion mounts, or lubricated bushings shall not be used as a bonding path. Piano hinges shall not be used as a bonding path. Chemical conversion coatings shall not be used on internal removable bonding surfaces.

3.3.5 BONDING FAYING SURFACE PREPARATION

3.3.5.1 METAL–TO–METAL

Surface preparation for an electrical bond shall be accomplished by removing all anodic film, grease, paint, lacquer, or other high–resistance properties from the faying surfaces of the bond to ensure negligible impedance between adjacent metal parts. Abrasives which cause corrosion if embedded in the metal shall not be used. Abrasives or scrapers used to remove any protective finish shall produce a smooth surface without removing excessive material under the protective finish. Chemical cleaning and surface preparation shall be in accordance with the requirements of this document.

3.3.5.2 NONMETAL–TO–NONMETAL

Surface preparation for an electrical bond shall be accomplished by removing protective films, grease, paint, lacquer, or other high–resistance properties from the immediate area to ensure a surface and contact resistance sufficient to meet the requirements of the applicable lower class of bonding. Abrasives or scrapers used to remove any protective finish shall produce a smooth surface without removing excessive material under the protective finish. Chemical cleaning and surface preparation shall be in accordance with the requirements of this document.

3.3.5.3 METAL–TO–NONMETAL

Surface preparation for the metal member shall be as specified in 3.3.5.1 for metal–to–metal surfaces. Surface preparation for the nonmetal member shall be as specified in 3.3.5.2 for nonmetal–to–nonmetal surfaces.

3.3.6 PREPARATION OF ELECTRICAL MATING SURFACES

The following procedures shall be used in the preparation of metals for electrical mating surfaces. Alternative, equivalent processes shall be approved by the EME Control Board, and Materials and Processes. Materials and processes shall be in accordance with SSP 30233.

3.3.6.1 NONCONDUCTIVE FILMS

Grease, oil, or other nonconductive films shall be removed with a cleaning agent which will remove the film without damaging the underlying metal or adjacent surfaces, including protective coatings.

3.3.6.2 NONSOLUBLE FILMS

Nonsoluble films shall be removed by sanding and polishing, using caution so as not to remove excessive metal. The area shall be cleaned.

3.3.6.3 SURFACE TREATMENT

After cleaning, the following substrate specific surface treatments shall be used:

3.3.6.3.1 MAGNESIUM ALLOYS

Magnesium alloys, when used in accordance with the limitations specified in SSP 30233, shall be treated as follows:

A. Wash the bare metal areas with a corrosion protection solution conforming to Type 1 of MIL–M–3171 for one minute and then thoroughly rinse with clean water within 5 seconds.

B. Dry thoroughly prior to organic finish repair, sealing, or assembly, as required to meet the performance requirements of 3.2.1.1, 3.2.1.2, or 3.2.1.3, and SSP 30233.

3.3.6.3.2 ALUMINUM ALLOY

For nonremovable bonding surfaces, aluminum alloys shall be treated as follows:

A. After polishing mating surfaces, apply a chemical conversion coating conforming to Class 3 of MIL–C–5541.

B. Dry thoroughly prior to organic finish repair, sealing, or assembly, as required to meet the performance requirements of 3.2.1.1, 3.2.1.2, or 3.2.1.3, and SSP 30233.

C. For internal removable bonding surfaces, plated metallic finishes are required. Selective or capsule plating of nickel is preferred, with adequate corrosion protection provided to counteract the dissimilar metal couple created as specified by SSP 30233.

Nickle plated aluminum is an acceptable substitute for meeting requirement.

See appendix C for exception (EMECB TIA–0071) to this paragraph.

3.3.7 USE OF SEALANT

For Class S bonds, the use of sealant which meets the requirements of SSP 30233 in its usage environment, such as BMS 10–79 and RTV–142, is acceptable for meeting the requirements in 3.3.6.3.2 (assuming the DC resistance value meets the requirement in 3.2.1.3.1).

4.0 QUALITY ASSURANCE PROVISIONS

All quality assurance provisions shall be in accordance with the Space Station Program Quality Assurance Program Requirements as specified in SSP 41173 or equivalent document for International Partner (IP) Agencies.

4.1 RESPONSIBILITY FOR INSPECTION

Unless otherwise specified, the supplier is responsible for the performance of all inspection requirements as specified herein. Except as otherwise specified, the supplier may use his own facilities or any other commercial laboratory acceptable to NASA or responsible IP agencies. NASA or IP agencies reserve the right to perform any of the inspections set forth in the requirements document where such inspections are deemed necessary to assure supplies and/or services conform with prescribed requirements.

4.2 BONDING VERIFICATION

Visual inspection, analysis, and limited resistance/impedance measurements shall be performed as partial proof of satisfactory bonding.

4.3 REFINISHING

Any part which has its finish damaged during the bonding tests shall be suitably refinished or replaced as applicable.

APPENDIX A ABBREVIATIONS AND ACRONYMS

ac	alternating current
AN	Army Navy
CI	Configuration Item
CFRP	Carbon Fiber Reinforced Plastic
cm	centimeter
dB	decibel
dc	direct current
ECOMM	Early Communication
EMC	Electromagnetic Compatibility
EME	Electromagnetic Effects
EVA	Extravehicular Activity
IP	International Partner
ISS	International Space Station
IVA	Intravehicular Activity
JAN	Joint Army Navy
kV	kilovolt
m	meter
μF	microfarad
MHz	megahertz
MLI	Multi–layered Insulation
MPLM	Mini–Pressurized Logistics Module
MS	military standard
No.	Number
NPRV	Negative Pressure Relief Valve

ORU	Orbital Replaceable Unit
OTCM	ORU/Tool Change out Mechanism
pF	picofarad
PN	Part Number
psid	pounds per square inch differential
PV	Photovoltaic
RF	radio frequency
SGANT	Space to Ground Antenna
SPDM	Special Purpose Dexterous Manipulator
SSP	Space Station Program
TIA	Tailoring/Interpretation Agreement
torr	unit of pressure
Vdc	Volt direct current

APPENDIX B GLOSSARY

BOND (NOUN)

Any fixed union existing between two objects that results in electrical conductivity between the objects. Such union occurs either from physical contact between conductive surfaces of the objects, or from the addition of a firm electrical connection between the objects.

BONDING JUMPERS

A braided wire or metal strap that provides the necessary electrical conductivity between the unit and vehicle structure which would otherwise not be in sufficient electrical contact.

BONDING OR TO BOND

The act of connecting objects to obtain electrical conductivity between them.

CONDUCTIVE STRUCTURE

A structural element with resistivity less than 100 microhm–centimeter grounded to a Space Station single point ground.

CONDUCTIVE SURFACES OR OBJECTS

All surfaces or objects having a resistivity of less than 100 microhm–centimeter.

EQUIPMENT

Any electrical, electronic, or electromechanical device or collection of devices intended to operate as a single unit and to perform a single function. As used herein, equipment includes, but is not limited to the following: receivers, transmitters, transponders, power supplies, hand tools, processors, test apparatus, and test instruments.

APPENDIX C APPROVED TAILORING/INTERPRETATION AGREEMENTS

EMECB TIA–0006

C.3.2.1.3.3 CONDUCTIVE MECHANICAL SUBASSEMBLIES/PARTS

Exception: The Common Berthing Mechanism (Configuration Item (CI) Number (No.) 683D27A) Capture Latch Arm and Link and the Ready to Latch Mechanism are not required to meet the Class S bond requirements of SSP 30245.

Rationale: The hazard potential and the charging mechanism of these parts is very small.

EMECB TIA–0009

C.3.3.2.1 JUMPERS/STRAPS

Exception: The radiator cinch mechanisms, Figure C.3.3.2.1–1, (Part Number (PN)s 83–39422 and 83–39421) are allowed to use two parallel Class S ground wires in place of Class R bond strap. The copper ground wires will have a least as great a copper cross section as a Beryllium copper bond strap and will carry full fault currents.

Rationale: The cinch mechanisms are used immediately after the Photovoltaic (PV) Module S1/PV Module P1 segments are powered on orbit. They are only used once in the life of the program and have an EVA override if the electrically driven pyrotechnic device fails. The time between the decision to deploy the array and the firing of the pyrotechnics is expected to be very short (tens of seconds). Figure C.3.3.2.1–2 shows a conceptual diagram of the Electrical Bonding for the Squibs. The Squib circuit is referenced to chassis inside the Squib Fire Unit, Figure C.3.3.2.1–3. The Squib itself is electrically isolated from its chassis by design. For the short time that this device is used, the multiple bond paths that exist, and that the Squib itself is to be isolated from the structure, then not having a true Class R bond path is not significant.

EMECB TIA–0012

C.3.2.1.3.1 CONDUCTING STRUCTURAL ITEMS

Exception: The Space Vision System Targets are not required to meet the Class S bonding requirements of SSP 30245 on all 35 elements.

Rationale: The hazard potential and the charging mechanism of these parts is very small.

EMECB TIA–0015

C.3.2.1.3.1 CONDUCTING STRUCTURAL ITEMS

Exception: These Hatch (CI No. 683A01A) bolted–down structural components are electrically bonded to the Hatch Plate by “incidental contact” through threaded fasteners:

– 683–13010, Latch Assembly

– 683–13020, Drive Mech Assembly

– 683–13051, Handle

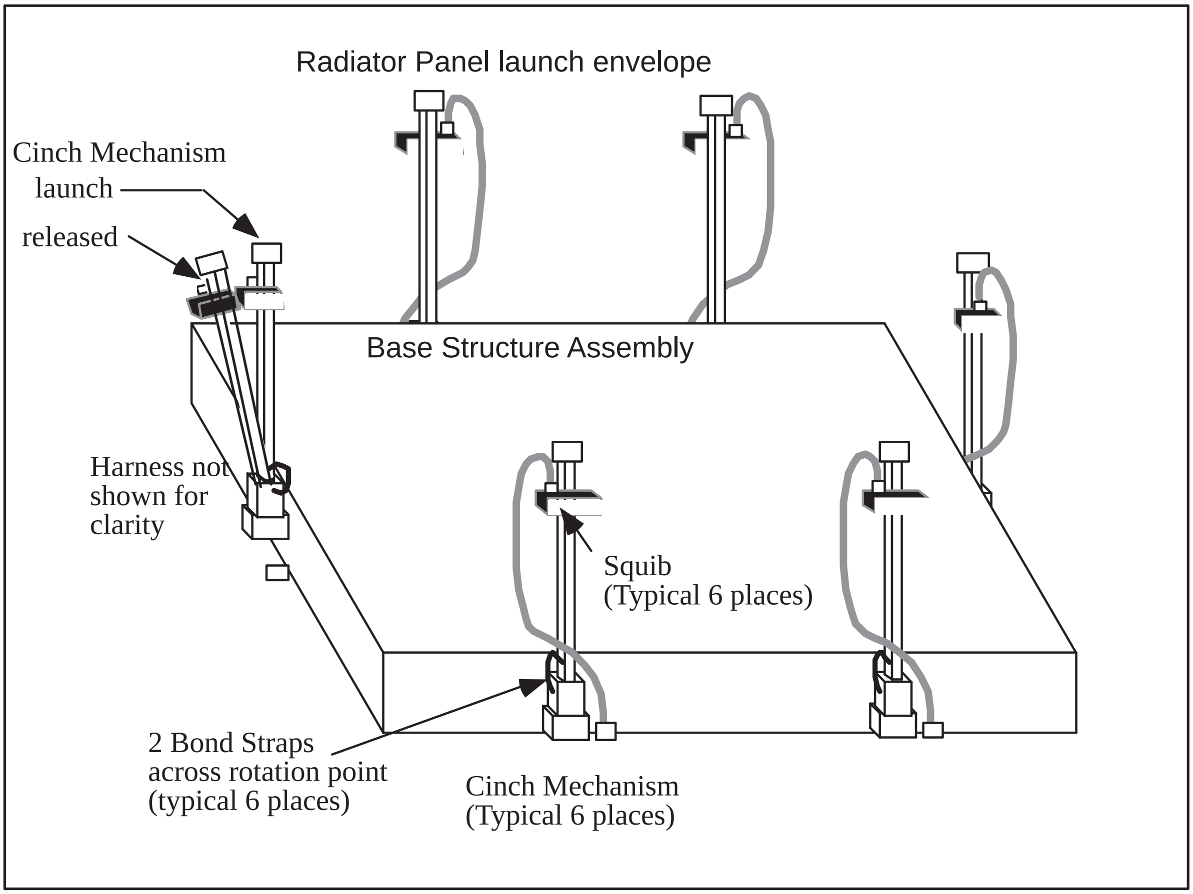

FIGURE C.3.3.2.1–1. CINCH MECHANISM IN THE LAUNCH CONFIGURATION

– 683–13052, Stowage Latch Assembly

– 683–13054, Stowage Handle Assembly

– 683–13030, Window Assemblies

– 683–13070, Alignment Guide Assembly

These listed components are not required to meet the Class S bonding requirements in SSP 30245. Resistance between these components and the Hatch Plate must be less than 0.5 ohm to ensure that resistance between these components and primary structure is less than 1 ohm. One hundred percent acceptance testing is required.

Rationale:

A. Testing has shown that the resistance of these components is very small (microohms) despite no specific bonding provisions designed in.

B. Hazard potential is very small.

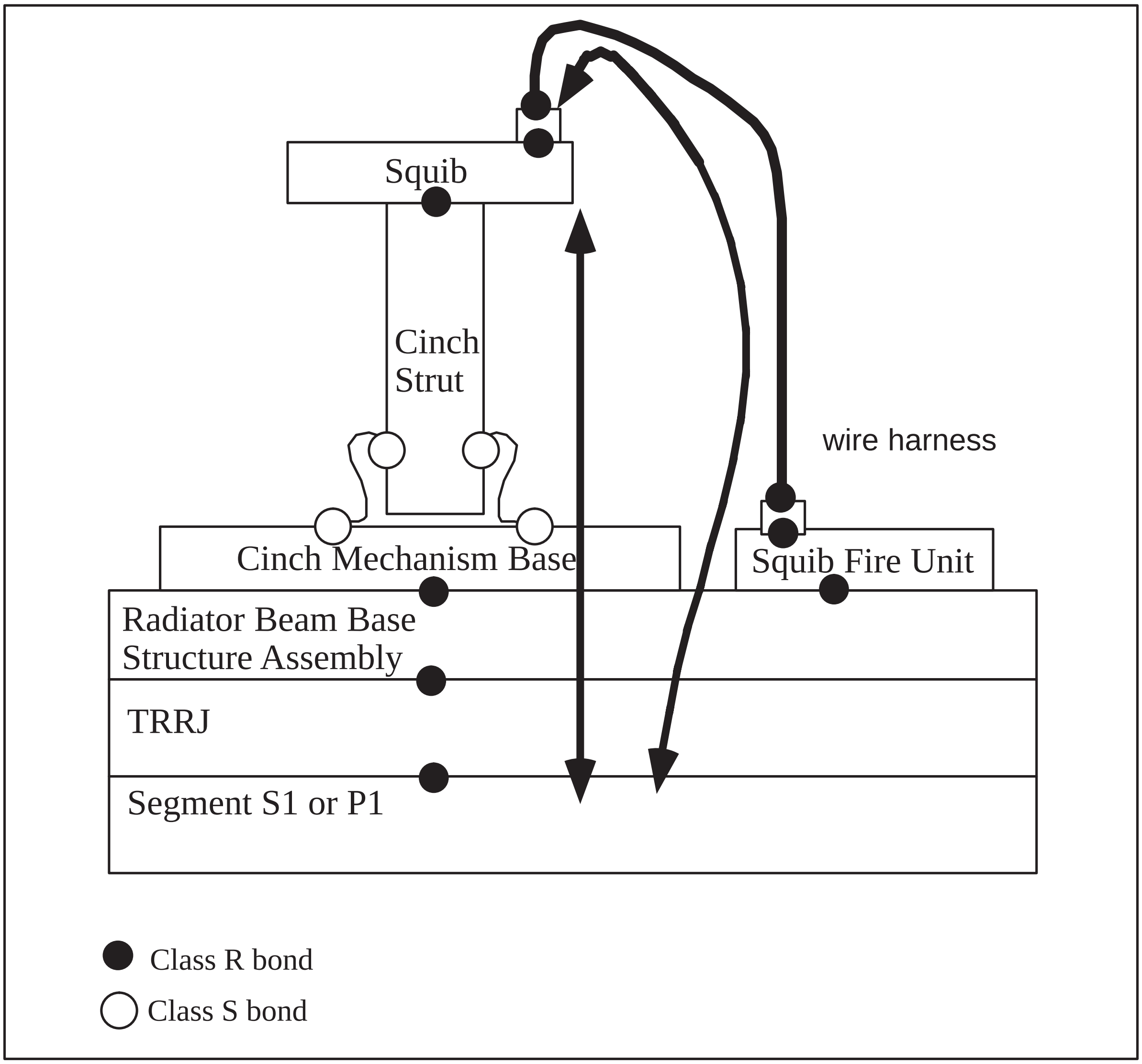

FIGURE C.3.3.2.1–2 ELECTRICAL BONDPATHS FOR THE SQUIBS

C. Charging mechanism is small.

D. One hundred percent acceptance testing will ensure that resistance meets requirements on each and every component.

E. Class S.

EMECB TIA–0017

C.3.2.1.3.1 CONDUCTING STRUCTURAL ITEMS

Exception: The Drive Ring (PN 683–13019) to Hatch Plate SSP 30245 requirement for a Class S bond is allowed to be made through threaded fasteners.

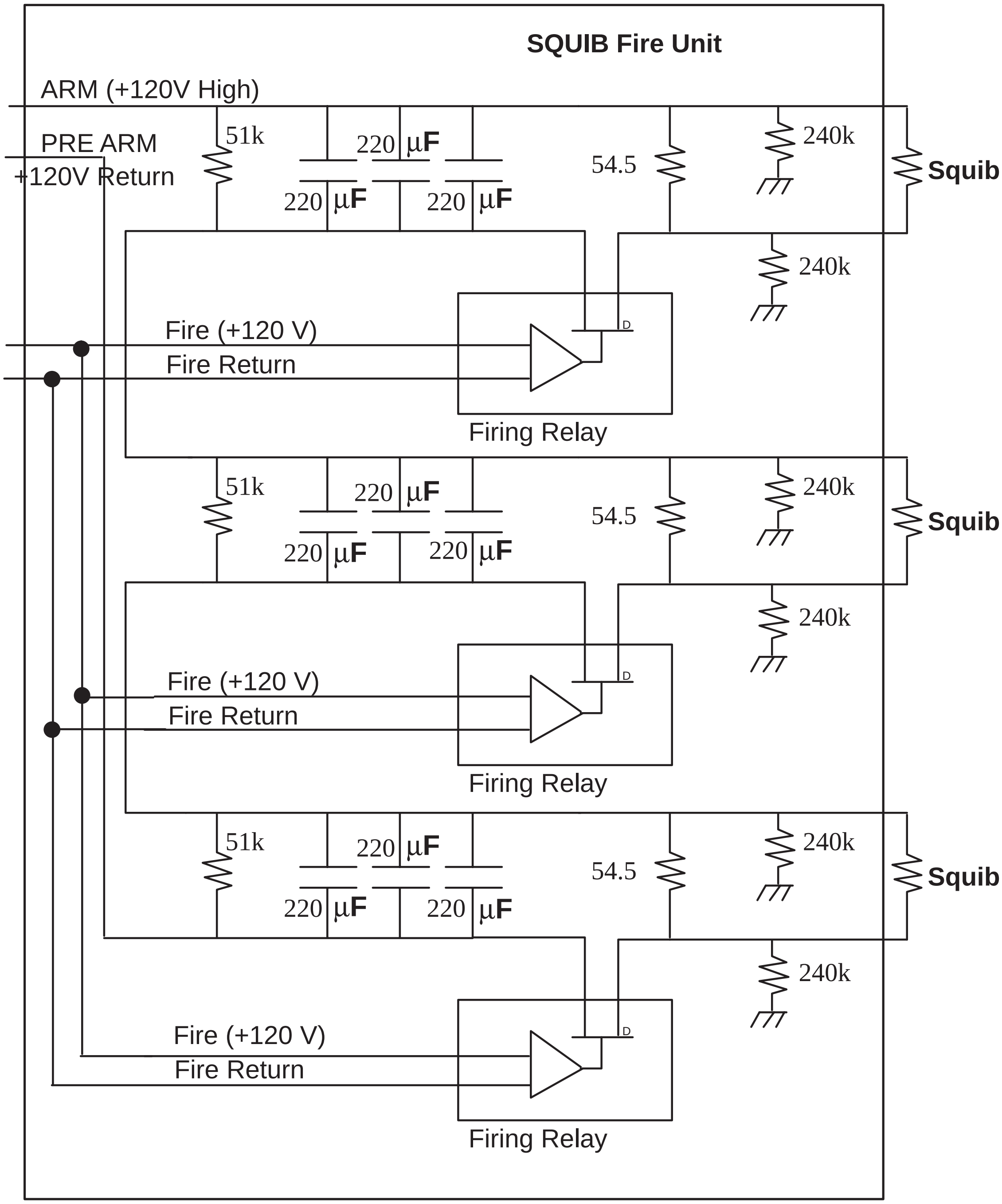

FIGURE C.3.3.2.1–3 SQUIB FIRE UNIT

Rationale:

A. Bonding provisions are designed in except for areas where bonding is through threaded fasteners.

B. One hundred percent acceptance testing.

C. Small hazard.

D. Small charging mechanism.

E. Minimum redesign.

F. Moving mechanism.

EMECB TIA–0018

C.3.2.1.3.1 CONDUCTING STRUCTURAL ITEMS

Exception: The Hatch (CI No. 683A01A) Tension Rod Assembly and Crank Handle are not required to meet the Class S bonding requirements of SSP 30245.

Rationale:

A. Small hazard.

B. Insufficient charging mechanism.

C. Insufficient surface area exposed to charging mechanism.

D. Bonding provisions would interfere with operation of mechanism.

E. The largest of these parts has a surface area of approximately 45 square inches. This equates to a spherical radius of: SQRT(45/4/π) = 1.9 in or 0.048 m. Therefore the capacitance is 4 x π x 8.854E–12 x 0.048 = 5.3E–12. At this capacitance, the stored voltage required to produce a charge build–up of 0.7E–6 Joules is: SQRT(2 x 0.7E–6/5.3E–12) = 514 volts. There is no credible charging mechanism which could cause this high a voltage in any of these parts.

EMECB TIA–0029

C.3.2.1.3.3 CONDUCTIVE MECHANICAL SUBASSEMBLIES/PARTS

Exception: The small EVA connector Multi–layered Insulation (MLI) covers of about one square foot at selected locations on the S1 and P1 truss segments are not required to meet the bonding requirements of SSP 30245. These covers are described in drawing 1F71063 Revision A.

Rationale: No significant amount of change can be developed on this size of MLI material in the International Space Station (ISS) environment. The EME Control Board agrees that these small MLI covers will not develop sufficient charge to arc in the ISS external environment.

EMECB TIA–0032

C.3.2.1.3.1 CONDUCTING STRUCTURAL ITEMS

Exception: The Aisle Stowage Container (CI No. 683K87A) Instruction Markers are not required to meet the SSP 30245 Class S bonding requirements.

Rationale: At 249 square centimeters of area, unit will not collect sufficient charge to pose a threat during launch on shuttle.

EMECB TIA–0038

C.3.2.1.2 CLASS R BONDING (HIGH FREQUENCY POTENTIALS, ANTENNA'S)

Exception: The Utility Rails (CI Nos. 222050A through D) installed in the Node 1 assembly are not required to meet the Class R bonding requirements contained in SSP 30245.

Rationale: At 249 square centimeters of area, unit will not collect sufficient charge to pose a threat during launch on shuttle.

EMECB TIA–0047

C.3.2.1.3.3 CONDUCTIVE MECHANICAL SUBASSEMBLIES/PARTS

Exception: The Node 1 Tension Rod Assembly and Crank Handle Meteroids and Orbital Debris cover (PN 683–14575) turnbuckle bonding does not have to meet the Class S electrical bonding requirements of SSP 30245.

Rationale:

A. Small hazard.

B. Insufficient charging mechanism.

C. Insufficient surface area exposed to charging mechanism.

D. Bonding provisions would interfere with operation of mechanism.

E. The Turnbuckle has a surface area of approximately 24 sq. in. This equates to a spherical radius of: SQRT (24/4/π) = 1.38 in. or 0.035 m. Therefore the capacitance is 4 x π x 8.854E–12 x 0.035 = 3.91E–12 farads. At this capacitance, the stored voltage required to produce a charge build–up of 0.7E–6 Joules is: SQRT (2 x .7E–6/3.91E–12) = 598 volts. There is no credible charging mechanism which could cause this high a voltage in any of these turnbuckles.

EMECB TIA–0058

C.3.3.2.1 JUMPERS/STRAPS

Exception: The Node 1 Port and Starboard hatch ground wires for the Early Communication (ECOMM) are permitted to have breakaway splices from the hatch plates to the Node 1 structure as shown in Figure C.3.3.2.1–4.

Rationale:

A. This will preclude a violation of safety requirements to be able to open/close the hatches in an emergency.

B. These wires are contingency grounding wires in the event of a power short within the ECOMM hatch plate cabling.

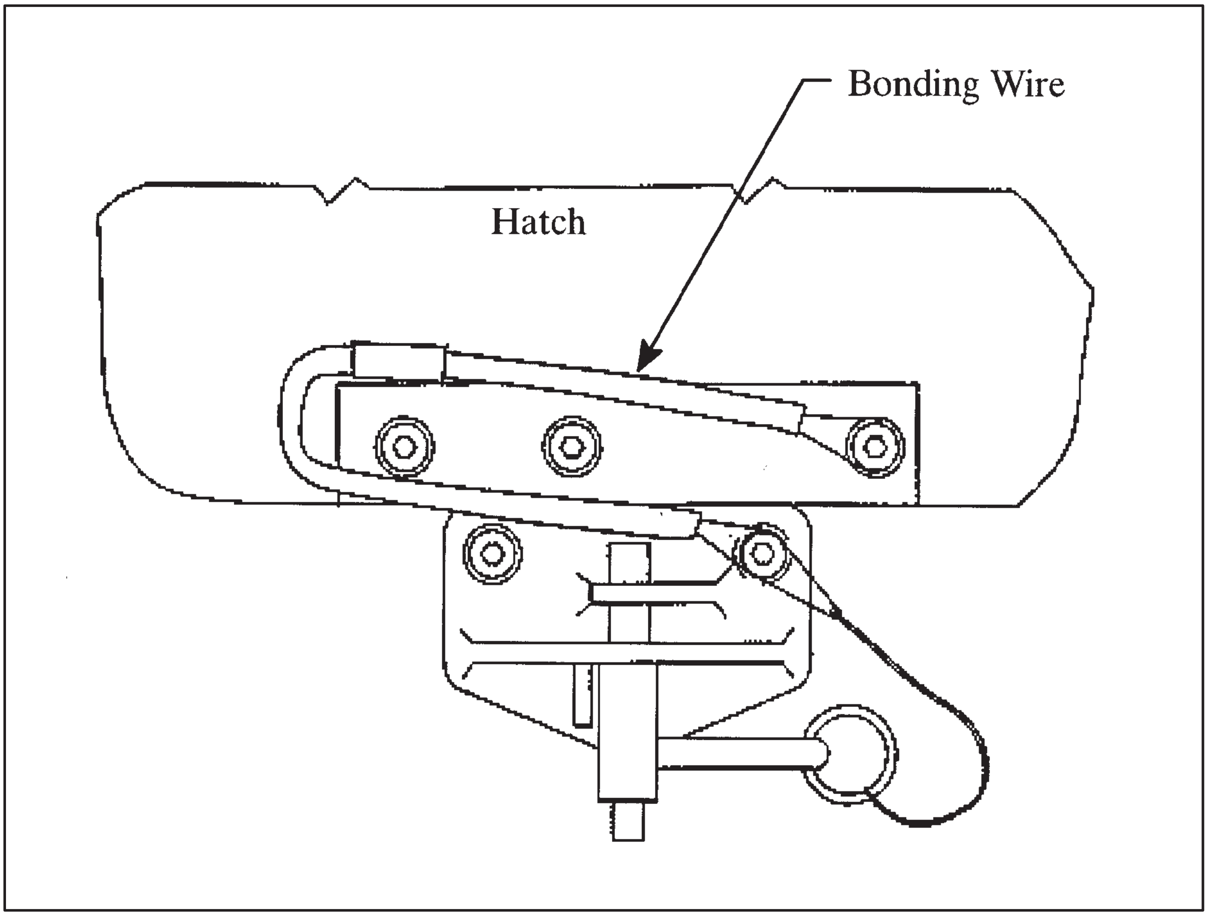

FIGURE C.3.3.2.1–4 ECOMM GROUND WIRES

EMECB TIA–0067

C.3.2.1.1 CLASS H BONDING (SHOCK HAZARD)

Exception: The Special Purpose Dexterous Manipulator (SPDM) ORU/Tool Changeout Mechanism (OTCM) (PN51602–4000–1) and tools is exempted from meeting the requirements of SSP 30245, paragraph 3.2.1.1 (Class H bonding) and the requirements of 3.2.1.3.1 and 3.2.1.3.3 (conducing structural items and moving parts subject to frictional or plasma induced charging).

Note: ORUs requiring power during transfer shall be provided with a Class H grounding path via the power connector.

Rationale: It is a known that the plasma contactor holds all parts of the station structure within 40 V of the plasma potential. Thus, although the ORU will rapidly attain the plasma potential, the maximum potential difference between the ORU and station structure will be 40 V or less. The maximum capacitance between the ORU and structure can be estimated by considering a large metal sphere in proximity to an infinite conductive ground plane. A representative value is approximately 100–200 pF. The energy stored is far too little to be of concern from the surface finish point of view. (Fine orbital–debris and micro–meteoroids will be a greater concern.)

Since all electronic equipment has to be able to withstand at least 4 kV on any pin from a 100 pF source in series with 15 kOhm, there is no chance of equipment damage. The voltage and discharge current is too low to be of any consequence to an astronaut during EVA.

Background supportive information rationale:

A. The plasma contactor keeps station hardware down to within 40 V of the plasma potential.

B. The ungrounded gripper jaws do not present a problem all the time the plasma contactor is working within specification, because a potential difference of 40 V and the corresponding low currents are insufficient to damage equipment surface finishes or electronics.

C. Two contactors are fitted to the station. The xenon gas supply is predicted to run out in two years and the secondary unit is scheduled to be phased in before the expiry of the prime unit. In the unlikely event of a random contactor failure or damage, unscheduled commissioning of the secondary contactor can take up to 200 hours, i.e. about eight days, which is the time taken to heat up the xenon gas supply.

D. Plasma contactor performance is monitored by looking at the contactor ”leakage” current. An operational constraint is being placed on the OTCM gripper jaws so that they should not be used to pick up or transfer an ORU in the event of a contactor failure until the secondary contactor unit is in operation and working within specification.

E. The SPDM is not required to make the secondary contactor operational. It can be used to replace a defective contactor once the secondary unit is fully operational.

F. The first plasma contactor is to be launched on 3A and scheduled to be activated before the 160 V solar arrays arriving on 4A.

G. Given that the OCTM gripper jaws can be nonconductive, then it makes no difference whether the OTCM tools are conductive or not. Similar logic applies, and the use of ungrounded tools is equally acceptable.

H. The provision of a Class ”H” bond through the power connector on ORUs that require ”keep–alive” power during transfer, ensure that safety requirements are met and eliminates any charge build–up or dishcarge concerns.

EMECB TIA–0071

C.3.3.6.3.2 ALUMINUM ALLOY

Exception: The Mini–Pressurized Logistics Module (MPLM) is allowed not to follow the requirements of 3.3.6.3.2 and to use alodine finishes as prescribed in MIL–C–5541. The use of alodine will not apply to the bonding of the International Standard Payload Racks.

Rationale: Since the operation of restoring bond interfaces is not planned for MPLM while in Orbit, the preclusion of finishes indicated in MIL–C–5541 (alodine) will not be applied to the MPLM. Any refurbishing of bond interfaces will be performed on the ground, utilizing the normal appropriate procedure. The Rack ground straps will meet the requirements of SSP 41002 and SSP 41155.

EMECB TIA–0076

C.3.1.2.3.1 CONDUCTING STRUCTURAL ITEMS

Exception: The Water Modulating Valve/Water On–Off Valve (CI M51110F and PN 60121.AA) is exempted from meeting the bonding requirements of 3.2.1.3.1.

Rationale: This design has already flown in National Space Transportation System flights. The manual override is accessible ONLY when requested by contingency operations; otherwise accessibility is physically precluded by cover panels. The area of the valve is not large enough to allow sufficient charge build–up for a discharge to occur, nor is it in contact with any charging mechanism. See Figure C3.1.2.3.1–1.

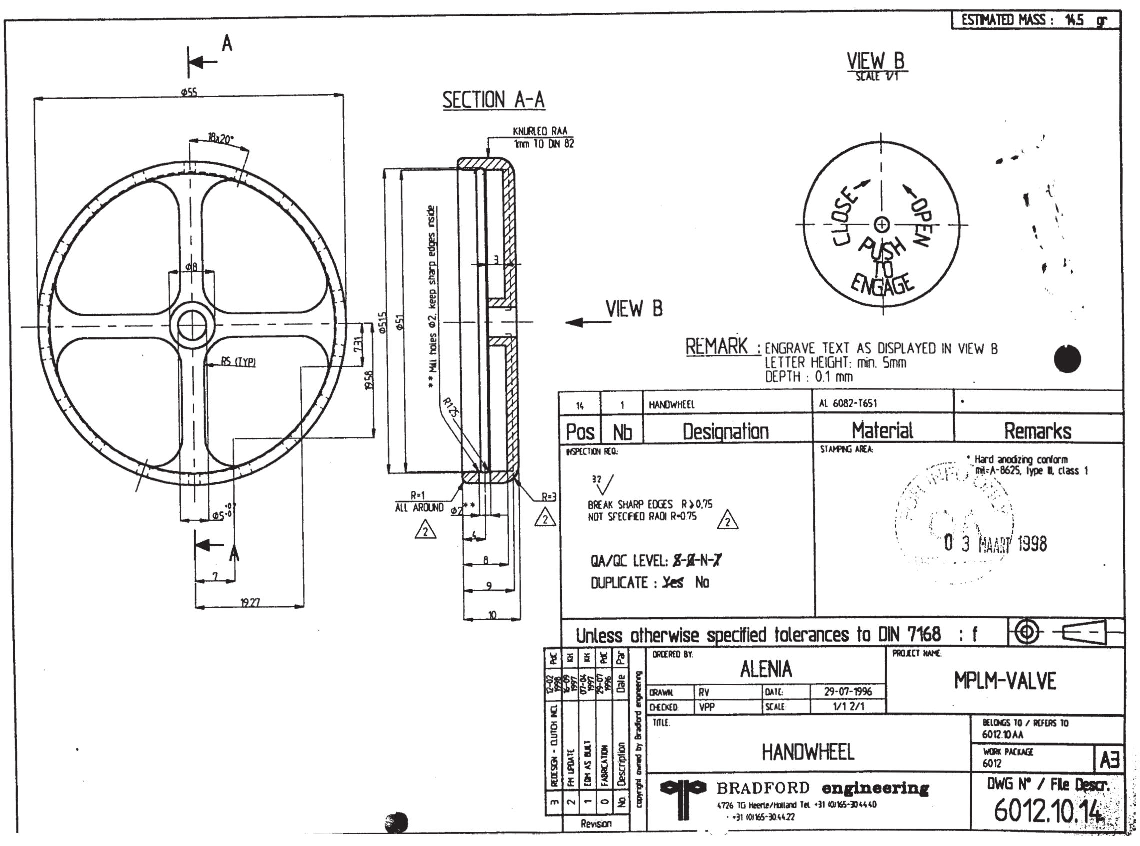

FIGURE C.3.1.2.3.1–1 HANDWHEEL DRAWING.

EMECB TIA–0078

C.3.2.1.3.1 CONDUCTING STRUCTURAL ITEMS

Exception: The Negative Pressure Relief Valve (NPRV) (CI 683K16A, PN 683–14719) cover is exempted from meeting 3.2.1.3.1, static grounding criteria.

Rationale: The static grounding analysis of the NPRV cover shows that no static discharging mechanism is needed during operation.

Analysis results are provided below:

ASSUMPTIONS

A. This analysis will assume a worst case condition for pressure difference across the valve. The module interior will be at a pressure of approximately one atmosphere and the outside pressure will be 0.2 psid higher. The negative pressure will burp the valve and a fixed mass of air will inflow into the module to equalize the pressure. Because a module represents a fixed volume and the valve only has inflow capability, the total worst case inflow is limited.

B. Shuttle recovery, for the purposes of this analysis, will cause the shuttle to fly through visibly contaminated atmosphere. It is well known that clean air does not charge objects but contaminated air will charge objects if the velocity and the contamination density are sufficiently large.

C. This analysis uses one million 5 micron, or larger, particles per cubic foot of atmosphere for the shuttle recovery. This represents a severe condition with reduced visibility.

D. Particle velocity (air velocity) is not used in this analysis because maximum charge transfer and 100 percent transfer efficiency will be assumed. Each particle entering the valve will be assumed to transfer 10 electron charges to the cover due to triboelectric charging. Not all particles will actually hit the cover surface so this assumption is worst case. A 10 electron charge transfer is also worst case since this is an upper limit at which a 5 micron particle can carry a charge.

A complete list of assumed parameter values are listed in Table C.3.2.1.3.1–1.

TABLE C.3.2.1.3.1–1 ASSUMED PARAMETER VALUES (PAGE 1 OF 1)

Parameter	Assumed Value
Outside Air Particle Density	1E6 per cubic foot
Particle Charge Transfer	10 electron charges (1.6E–18 Coulomb)
Delta Pressure	0.2 psid
Module Volume	117 cubic meter
Temperature	273 degree absolute
Pressure	760 torr
Impinging Area of Cover	0.12 square meter

CALCULATIONS

A. Mass and volume inflow calculation:

(1) The mass inflow can be calculated from the density change inside the module and the fixed volume of a module. Change in density is calculated as shown below.

$D_1 * T_1 / P_1 = D_0 * T_0 / P_0$, where

P_0, P_1, P_2 Pressure – inside pressure before and after valve operation and outside pressure respectively

:P_0 = 760 torr

:P_1 = 770.34 torr

:P_2 = 770.34 torr

D_0, D_1, D_2 Density – inside density before and after valve operation and outside density, respectively

:D_0 = 1.2047 gram per litre

:D_1 = 1.2211 gram per litre

:D_2 = 1.2211 gram per litre

T_0,T_1,T_2 Temperature – unchanged at 273 degree absolute

(2) Air density and module volume are multiplied to show that an estimated 4.22 pound mass of outside air will enter module.

(3) By using the density of the outside air and the total inflow mass, an estimated 56 cubic feet of outside air will pass into the module. This quantity will raise the pressure of a 117 cubic meter volume at standard temperature and pressure by about 0.2 psid.

B. Self–capacitance calculation:

To estimate the self capacitance of the cover, we use the below formula which is derived from the capacitance of a sphere.

$C = \varepsilon * (4 * \pi * AREA)^{0.5}$ farad, where

ε permittivity of free space, $1 / 36 * \pi * 10^{-9}$, Farad per meter

AREA area of electrically isolated metal = 0.12 square meter

This represents a capacitance of 11 picofarad for an 0.12 square meter area. This self capacitance is typical of small parts. A small hand tool case has 10 to 20 picofarad self–capacitance. A human has an excepted nominal 200 picofarad self–capacitance.

C. Total charge calculation:

The total possible charge transferred to the isolated metal cover is given by the following equation.

Q = N*F* q , coulomb, where

N	density of particle contamination in the outside air, particles per cubic foot
F	inflow volume air of, cubic foot
q	charge transfer per particle, coulomb per particle.

Assuming 1E6 contamination particles per cubic foot and 10 electron charges per particle transferring to the cover represent a worst case total charge, Q, of 90 picocoulomb.

D. Voltage potential calculation:

The voltage potential of a capacitor is given by:

V = Q / C volt , where

Q	total charge transfer, coulomb
C	self–capacitance of the cover, farad

The estimated worst case voltage, using the above parameters is 8.2 volts.

CONCLUSION

Since the worst case static voltage potential on the NPRV is more than an order of magnitude less than a conservative design limit of 100 volt, no grounding provisions need to be incorporated.

SSP 30245 requires parts having a surface area greater than 100 square centimeters and which are subject to frictional charging (charging mechanism required) to be equipped with a charge bleed–off mechanism. The valve meets SSP 30245 static bonding and grounding specifications since, as shown by this analysis, a creditable charging condition does exist.

EMECB TIA–0081

C.3.3.4.2 BONDING CONNECTIONS

Exception: MPLM Air Duct (CI 3024S5) acceptable bonding connection can be compression fastened through nonmetallic materials with a bonding DC resistance between strap and MPLM structure not higher than 1 Ohm over service life.

Rationale: Air ducting pieces are bonded with the methodology given in TIA–0011. The duct bonding design can not always be accommodate a dedicated housing so the bonding strap is compression fasted through nonmetallic materials via the supporting clamps. The conduit is not a path for fault current neither is it part of the MPLM ground plane. One kOhm exceeds possible compression degradation (because of lifetime and environment) and it is accepted by SSP 30245 for Carbon Fiber Reinforced Plastic (CFRP) Bonding.

The slight exceeding of a beginning of life (value of 1.2 Ohms, rather than 1 Ohm) is considered negligible.

EMECB TIA–0099

C.3.2.1.1 CLASS H BONDING (SHOCK HAZARD)
C.3.2.1.3.1 CONDUCTING STRUCTURAL ITEMS
C.3.2.1.3.3 CONDUCTIVE MECHANICAL SUBASSEMBLIES/PARTS

Exception: The Orbital Attachment Interface–Active (OAI–A) and OAI–P (CI 136628A, PN 9008100) are not bonded together and are not required to meet the requirements of SSP 30245, paragraph 3.2.1.1 (Class H) or the requirements of 3.2.1.3.1 & 3.2.1.3.3 (Class S conducting structural items and moving parts subject to frictional or plasma induced charging).

Rationale: The plasma contactor holds all parts of the station structure within 40 V of the plasma potential. Thus, during EVA/Extravehicular Robotics transporting of the OAI–A with the ORU attached and during OAI–A and OAI–Passive (P) mate, the OAI–A will rapidly attain the plasma potential. The maximum potential difference between the OAI–A and the station structure will be 40 V or less. The energy stored in ORU/OAI–A system with this potential is small and would cause no damage to the structure finishes if a discharge occurs. Electronic equipment damage is of no concern since all electronic equipment is required to withstand much larger energy sources without damage. The voltage and potential discharge current is too low to be of any consequence to an astronaut during EVA.

Background supportive information and rationale:

A. The plasma contactor keeps station hardware down to within 40 V of the plasma potential.

B. The ORU/OAI system does not present a problem all the time the plasma contactor is working within specification, because a potential difference of 40 V and the corresponding low currents are insufficient to damage equipment surface finishes, electronics, or crew.

C. Two contactors are fitted to the station. The xenon gas supply is predicted to run out in two years and the secondary unit is scheduled to be phased in before the expiration of the prime unit. In the unlikely event of a random contactor failure or damage, unscheduled commissioning of the secondary contactor can take up to 200 hours, i.e. about eight days, which is the time taken to heat up the xenon gas supply.

D. Plasma contactor performance is monitored by looking at the contactor ”leakage” current. It is recommended that an operational constraint be placed on transfer of any ORU/OAI–A in the event of a contactor failure until the secondary contactor unit is in operation and working within specification.

E. The first plasma contactor is to be launched on 3A, and scheduled to be activated before the 160 V solar arrays arriving on 4A. The OAI will not be used until the UF–1 mission.

F. This TIA applies to the interface between the OAI–A and OAI–P. Each half of the OAI hardware is bonded in accordance with SSP 30245 to other interfaces (OAI–A to ORU flight support equipment, OAI–P to SPDM).

EMECB TIA–0106

C.3.2.1.2 CLASS R BONDING (HIGH FREQUENCY POTENTIALS, ANTENNAS)

Exception: Accept unit bonding to MPLM ground plane, as follows:

A. Sampling Line Shut Off Valve (SLSOV) (CI M36020F, PN C–11948) < 10 m. (SLSOV is a motorized valve of Environmental Control and Life Support Systeem, randomly operated)

B. Remote Control Assembly (RCA) (CI M42040F, PN 219103) < 100 m. (RCA is a switch for the General Luminaire Assembly)

Rationale: The electromagnetic activity of the involved units is not such to require absolutely bonding Class R bonding, which is used as default for unit to ground plane bonding. After analysis by the EMECB it has been determined that Class H bonding is the only type of bonding required in this installation. There are no radio frequency (RF) generating circuits in these components and the bonds do not conduct high voltage fault currents, therefore, a Class H bond is all that is required.

EMECB TIA–0107

C.3.3.2.1 JUMPERS/STRAPS

Exception: MPLM Bonding requirement is modified as follows:

A. End cone panels will use two bond straps of 12:1 length/width ratio each.

B. Standoffs will use five bond straps for each standoff of 6:1 length/width ratio each.

Rationale: Self–compatibility of the MPLM module has been tested and proven with actual bond straps installed. Bond straps do not affect MPLM electromagnetic compatibility and will safely clear fault currents.

EMECB TIA–0120

C.3.2.1.3.6 MULTILAYER INSULATION

Exception: The Impedance Matching Unit MLI blanket (PN 1F00504) is not required to meet 3.2.1.3.6 bonding requirements to use two bond paths. It is allowed to use just one electrical bond strap to connect to the Impedance Matching Units conductive structure.

Rationale: The blanket is small enough that there will be insignificant charge built up on the MLI blanket to allow the blanket to discharge with no bond strap therefore the use of one bond strap is sufficient. The use of one electrical bond strap will not compromise the function of the thermal blanket. The blanket surface area is 195.9 square inches. Due to overlapping flaps the exposed surface area is 154.4 square inches.

EMECB TIA–0136

C.3.2.1.3.5 TRADITIONALLY HOMOGENEOUS STRUCTURAL MATERIALS

Exception: The Brackets - Emergency Light Strips (PNs 683–56422–5–001003, 683–56422–5–001004, 683–56422–5–001005, 683–56422–5–001006) are not required to meet the bonding requirements of SSP 30245, paragraph 3.2.1.3.5.

Rationale: This bracket doesn't need to be bonded because of its small size (even if the requirement is being exceeded).

In addition, the actual exposed surface is very low (it is the area not covered by the Emergency Egress Light) and it is not conductive. Thus, the possible little quantity of charge can not be discharged.

EMECB TIA–0166

C.3.2.1.2.1 IMPEDANCE

Exception: The Space to Ground Antenna (SGANT) (CI 222016A, PN 10033190–1) is allowed to exceed the SSP 30237, paragraph 3.2.3.1.2, RE02 requirements by 28 dB from 1 MHz to 7 MHz. The SGANT is permitted to not follow the SSP 30240, paragraph 3.2.2.7, requirement by not terminating the harness shield at both ends. The SGANT is allowed to not meet the SSP 30245, paragraph 3.2.1.2.1, Class R Bonding requirement at the titanium interfaces.

Rationale:

A. Currently there are no intended receiver systems in the noted frequency band, hence low level signals would impose no impact on RF systems

B. An emission level of 80 dBμV is 54 dB below the radiated susceptibility RS03 test level of 5 V/m in that frequency band. This level of incident field would not impose any threat to ORUs qualified to that RS03 level.

C. The data busses and power busses near to the SGANT that would be illuminated by the out–of–specification field have been thoroughly tested in both laboratory and installed vehicle environments. Neither have shown any susceptibility in the frequency range noted at fields much greater than those noted.

D. Assuming the SGANT emissions to be a plane wave, the field intensity would decrease as 1/r, hence a 25 meter sphere would be considered as potentially illuminated by this field. The systems and ORUs within this sphere comprise the P6 assembly, all of which have been successfully tested at field strengths significantly higher than those noted.

E. The SGANT passed the RS03 tests.

EMECB TIA–0179

C.3.2.1.1 CLASS H BONDING (SHOCK HAZARD)

Exception: The IMAX audio recorder, battery charger, battery, ballast, and photoflood (PNs ACC0033, ACC0035–7, ACC0051–1, ACC0028–4, ACC0023–1) are allowed to exceed the SSP 57000, paragraph 3.2.4.2 bonding requirements called for in the SSP 30245, paragraph 3.2.1.1 requirement of 100 milliOhms resistance by a maximum of 150 milliOhms based upon analysis that shows that the IMAX3D equipment exceedance is not hazardous to the ISS crew or ISS hardware.

Rationale: The battery charger and the ballast both contain isolated DC–to–DC converters which isolate the power output to the battery, recorder, and photoflood from the power which is provided by the ISS to the battery charger and ballast. Therefore, the analysis for resistance should end at the battery charger and ballast rather than extending to the downstream equipment. There are a primary fault ground path (cable pin to cable socket via green safety wire) and a secondary fault ground path (cable connector backshell to cable connector backshell via shield) for the battery charger and the ballast with the following resistances:

Battery Charger Primary Path Worst Case =	144 milliOhms
Battery Charger Secondary Path Worst Case =	409 milliOhms
Ballast Primary Path Worst Case =	241 milliOhms
Ballast Secondary Path Worst Case =	481 milliOhms

The IMAX3D is powered by the Utility Outlet Panel which has 12 Ampere circuit protection. With 1 Ohm of resistance in the grounding circuit only 12 Vdc could be generated at the equipment with a direct short from the power source. Since the exceedances are less than 150 milliOhms above the 100 milliOhm limit for the primary fault bond path and the secondary fault bond path resistances are less than 500 milliOhms, the IMAX3D will not pose a hazard to either the ISS crew or ISS equipment. Hazardous voltages to personnel start at 30 Vdc. Approval of this TIA would still maintain 16 dB of margin with respect to developing a hazardous condition.