Space Station Cable/Wire Design and Control Requirements for Electromagnetic Compatibility

International Space Station

Revision F

31 July 2002

NASDA

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european space agency

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(Italian Space Agency)

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National Aeronautics and Space Administration
Space Station Program Office
Johnson Space Center
Houston, Texas

REVISION AND HISTORY PAGE

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INTERNATIONAL SPACE STATION PROGRAM

SPACE STATION CABLE/WIRE DESIGN AND CONTROL REQUIREMENTS FOR ELECTROMAGNETIC COMPATIBILITY

31 JULY 2002

PREFACE

This document contains wiring and cabling requirements for electromagnetic compatibility. The contents of this document are intended to be consistent with requirements as defined in the SSP 41000 and SSP 30243. Space Station Cable/Wire Design and Control Requirements for Electromagnetic Compatibility shall be implemented on all SSP contractual and internal activities. This document is under control of the Space Station Control Board.

INTERNATIONAL SPACE STATION PROGRAM OFFICE

SPACE STATION CABLE/WIRE DESIGN AND CONTROL REQUIREMENTS FOR ELECTROMAGNETIC COMPATIBILITY

31 JULY 2002

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INTERNATIONAL SPACE STATION PROGRAM

SPACE STATION ELECTROMAGNETIC CABLE/WIRE DESIGN AND CONTROL REQUIREMENTS FOR ELECTROMAGNETIC COMPATIBILITY

31 JULY 2002

For NASA	DATE
For ASI	DATE

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INTERNATIONAL SPACE STATION PROGRAM

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INTERNATIONAL SPACE STATION PROGRAM

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ESA Concurrence:
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INTERNATIONAL SPACE STATION PROGRAM

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INTERNATIONAL SPACE STATION PROGRAM

SPACE STATION CABLE/WIRE DESIGN AND CONTROL REQUIREMENTS FOR ELECTROMAGNETIC COMPATIBILITY

LIST OF CHANGES

31 JULY 2002

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

SSCBD	ENTRY DATE	CHANGE	PARAGRAPH(S)
6568	7/31/02	3.2.1	Circuit Classification
3282		3.2.2.1.3	Shield Grounding Requirements
			TABLE(S)
3282	07/31/02	3.2.1.1–1	EMC Classification, Wire Type, and Shield Grounding
			FIGURE(S)
	07/31/02		None
			APPENDIX
6568	7/31/02	A	Abbreviations and Acronyms
		C.3.2.1	Circuit Classification

TABLE OF CONTENTS

TABLE OF CONTENTS – Continued

TABLES

1.0 GENERAL

1.1 INTRODUCTION

Wiring and cabling carrying electrical signals will couple those signals to other wires and cables. Wire and cable separation and shielding treatment can be used to reduce the coupling effects and the resulting undesirable circuit effects. Design analysis, maintenance and correction of problems cannot be implemented without identification of wire and cable bundles and routing. This document identifies requirements for wire and cable signal classification, signal separation, and identification.

1.2 SCOPE

This document defines wiring and cabling requirements for Electromagnetic Compatibility (EMC) in accordance with the specifications of SSP 30243. The requirements of this document are applicable to all flight elements of the Space Station Program (SSP) and to all equipment at the interface with flight elements.

1.3 PURPOSE

The purpose of this document is to provide a uniform specification and methodology for cabling and wiring requirements for EMC. These requirements will minimize the effect of magnetic and/or electric field coupling between the wiring and circuits associated with the wiring.

1.4 PRECEDENCE

SSP 30243 invokes this document for cable/wire design and control requirements for EMC. In the event of any conflict between this document and any other document, SSP 30243 shall take precedence.

2.0 APPLICABLE DOCUMENTS

The following applicable documents of the exact issue shown in the current issue of SSP 50257 form a part of this specification to the extent specified in the referenced paragraphs. Inclusions of applicable documents does not supersede the order of precedence identified in 1.4.

DOCUMENT NO.	TITLE
SSP 30240	Space Station Grounding Requirements Reference paragraphs 3.1 and 3.2.2.1.3
SSP 30243	Space Station Requirements for Electromagnetic Compatibility Reference paragraphs 1.2, 1.4, 3.1, 3.2.2, and 3.2.2.3.2
SSP 41173	Space Station Quality Assurance Requirements Reference paragraph 4.0

2.1 REFERENCE DOCUMENTS

DOCUMENT NO. **TITLE**

The following documents are referenced in this specification as a guide for context and user convenience. The references to these documents are not listed in SSP 50257.

DOCUMENT NO.	TITLE
SSP 30245	Space Station Electrical Bonding Requirements Reference paragraph 3.1
SSQ 21654	Cable, Single Filter, Multimode, Space Quality, General Specification Reference paragraph 3.1

3.0 REQUIREMENTS

3.1 CABLE/WIRE DESIGN DEFINITION FOR ELECTROMAGNETIC COMPATIBILITY

The use of fiber–optic cables for signal transmission is recommended to reduce electromagnetic noise coupling problems. The requirements for fiber–optic cables are contained in SSQ 21654. The reduction of electromagnetic effects in the wiring will be accomplished by isolating incompatible circuits via wire cable bundling, routing, shielding, separation, and wire treatment requirements presented herein. All external interface circuits and electrical or electronic equipment will be evaluated and will receive an Electromagnetic Environment Effects Control (EMEEC) classification based upon the following circuit parameters. The approach to cable design including wiring/cable classifications, shielding, and routing will be included in the Electromagnetic Effects (EME) Control Plan as specified in SSP 30243. The classification designations, i.e., ML, EO, HO, and MO, are arbitrary and have no implied meanings. Bonding and grounding will be in accordance with SSP 30245 and SSP 30240.

3.2 CHARACTERISTICS

3.2.1 CIRCUIT CLASSIFICATION

The following criteria shall be applied to determine the appropriate EMEEC circuit classification for each circuit. See appendix C for the exceptions (EMECB TIA–0066, EMECB TIA–0122, EMECB TIA–0125, EMECB TIA–0126, EMEP TIA–0221, EMEP TIA–0341, and EMEP TIA–0404) to this paragraph.

3.2.1.1 FREQUENCY OR RISE/FALL TIME

For Table 3.2.1.1–1 classification purposes, the fundamental component of steady state operation shall determine the frequency of the circuit unless the rise/fall time (pulsed wave forms) is less than 10 microseconds. If the rise/fall time is less than 10 microseconds and the voltage is less than 6 volts, the circuit shall be classified as Radio Frequency (RF) regardless of the fundamental frequency. Power circuits which are switched on and off shall be classified as HO or EO even if their rise/fall times are less than 10 microseconds. See appendix C for exception (EMECB TIA–0087) to this paragraph.

TABLE 3.2.1.1–1 EMC CLASSIFICATION, WIRE TYPE, AND SHIELD GROUNDING

Frequency f: Rise, Fall Time (ms) t_r, t_f	Voltage or Sensitivity	Load Impedance (ohms)	Circuit Class	Minimum Wire Type	Shield Ground[1]
Analog	≤ 100 mV	<600 k	ML	TWS	MPG
(ac, dc)	≤ 100 mV	≥600 k	ML	TWDS	MPG
f ≤ 50 kHz	< 6 V	All	ML	TWS	MPG
t_r, t_f ≥ 10µs	6 – 40 V	All	HO	TW	None
	> 40 V	All	EO	TW	None
50 kHz >f	< 100 mV	All	RF	TWDS	MPG
≤4 MHz t_r, t_f ≤ 10 µs	> 100 mV	All	RF	TWS	MPG
f > 4 MHz[1]	All	All	RF	TWS, Coax or Twin–ax	MPG
BWAD Fiber Optics	All	All	MO FO	TWS Fiber Optics	MPG

Acronyms and Abbreviations:

ML, HO, EO, MO, FO	Arbitrary Nomenclature to define circuit Classification
MPG	Multiple Point Ground
RF	Radio Frequency
TW	Twisted
TWDS	Twisted Double Shielded
TWS	Twisted Shielded

Notes:

(1) Shield grounding shall be compatible with the circuit application.

(2) The length of termination–to–ground lead for all circuits shall be the minimum length practical.

(3) The preferred method is to connect the shield peripherally to the back shell of the connector with a continuous impedance electrical bond path through both halves of the connector shell and the connector to mounting surface interface.

(4) Digital signals shall be classified as RF (and routed as wire type called out in this table).

3.2.1.2 IMPEDANCE

The actual impedance of the interconnecting circuit, i.e., the complex “Z” that includes resistance, inductance and capacitance, shall be used to classify the source and load impedances using Table 3.2.1.1–1. These source and load impedances determine the magnetic and electric field coupling mode category. The equivalent circuit pickup resistance, i.e., the sum of the load and equivalent reactive/resistive components, shall be used to identify potential areas for magnetic or electric field coupling.

3.2.1.3 VOLTAGE

The maximum peak–to–peak voltage appearing at the source of each circuit shall be used to determine the circuit classification using Table 3.2.1.1–1.

3.2.1.4 SENSITIVITY

If the interface circuit is susceptible to magnetic or electric field coupling that can cause induced noise with amplitudes less than the source voltage that will affect measurement and/or conversion accuracy, circuit classification shall be based upon circuit sensitivity considerations rather than upon frequency, rise/fall time, impedance, or voltage. Circuits assigned a classification based on sensitivity rather than on source voltage shall be identified on all wiring diagrams containing such circuits.

3.2.1.5 SIGNAL TYPE AND WIRE TYPE

Table 3.2.1.1–1 describes the classification of signal types and required wire type to control cable coupled interference. Cable and wire treatment shall be based on Table 3.2.1.1–1 and the wire/cable and isolation requirements.

3.2.2 CLASSIFICATION/WIRING PROCEDURE

The following requirements shall be applied to determine the classification of wiring treatment and installation of all interface circuit types:

<u>STEP 1. Circuit Classification</u>

To determine the appropriate EMEEC classification, the parameters of each subsystem equipment interface circuit shall be considered in the following order: (1) frequency or rise/fall times, (2) impedance, (3) voltage, and (4) sensitivity. Classification criteria are specified in Table 3.2.1.1–1. This classification shall appear on all wiring diagrams in which the circuit appears.

<u>STEP 2. Determination of Interface Wiring Requirements</u>

The appropriate wiring treatment shall be assigned to each circuit as required by the classification considerations applied in STEP 1. The wire type, twisting, shielding, and shield grounding requirements shall be reflected on all schematics, wiring diagrams, and interface control documents in which the circuit appears.

STEP 3. Bundling of All Coded Circuits

Circuits having different circuit classifications or redundancy codes and routed in the same area shall not be commonly bundled but may be routed in a common connector if a 20 dB coupling margin is maintained. Each bundle shall be coded with a bundle code which is the same as the circuit classification of the circuits which it contains. Each bundle classification shall be designated on drawings in which the bundle appears.

STEP 4. Redundancy Requirements

In cases where wiring redundancy is a requirement, separate cable bundles shall be formed. Such bundles shall be coded with the circuit classification code, plus a numeric designator code to identify the redundancy classification: ML–1, ML–2, EO–1, EO–2, etc.

STEP 5. Installation of Bundles

Cable bundles and wire bundles installed in the Space Station Program flight elements shall use the 20 dB separation attenuation requirements of SSP 30243. Minimum edge–to–edge bundle separation requirements (in inches) for parallel runs of length L (in feet) shall be calculated. Separation requirements shall be determined by redundancy requirements or calculations based on analysis of signal and power parameters, circuit sensitivities, wire/cable design, etc., whichever is greater. Cable separation requirements and supporting analyses shall be documented in the EME Design Analysis Report.

3.2.2.1 DETERMINATION OF INTERFACE WIRING REQUIREMENTS

The following criteria shall be used to determine the wiring requirements for each circuit.

3.2.2.1.1 WIRE TYPE

The categorization of each circuit in terms of frequency, impedance, voltage or sensitivity to assure proper EMEEC classification shall permit the selection of wire type as specified in Table 3.2.1.1–1. The wire types given in Table 3.2.1.1–1 are general in nature and do not alleviate the responsible design groups from specifying the wire size, allowable capacitance, and attenuation characteristics. Specific details on selected wire types shall be included in applicable procurement specifications and assembly drawings.

3.2.2.1.2 SIGNAL TYPES REQUIRING CONTROLLED IMPEDANCE CHARACTERISTICS

Serial digital, data bus, video, and clock circuits operating below 4 megahertz (MHz) shall use controlled impedance wiring. RF circuits, including clock or data circuits with signal content of 4 MHz or above, shall use fiber–optic, twinaxial or triaxial cable to maintain the SSP requirements for isolation and single point references. Coaxial cable shall be permitted for signals with frequency content above 4 MHz where dc isolation is maintained.

3.2.2.1.3 SHIELD GROUNDING REQUIREMENTS

Shields shall be terminated at both ends and at intermediate break points directly to structure or chassis, through connector backshells or direct wire connection per the methodology specified in 3.2.2.4. See appendix C for exception (EMEP TIA–0180) to this paragraph.

3.2.2.2 IMPLEMENTATION OF CODING AND BUNDLING

All circuits routed together in a bundle shall be of the same classification. Circuits classified by sensitivity shall be analyzed to determine if the source voltage will be detrimental to other circuits in the bundle and if it is necessary to isolate such circuit wiring from other wires in the classification. See appendix C for exception (EMECB TIA–0113) to this paragraph.

3.2.2.3 IMPLEMENTATION OF BUNDLE INSTALLATION

The bundles which have been formed and coded shall be installed using the following requirements to provide the required electrical isolation between different signal levels.

3.2.2.3.1 PHYSICAL ISOLATION OF BUNDLES WITH DIFFERENT CODES

Each bundle type shall be physically isolated from all other bundles of a different bundle code. This separation provides electromagnetic coupling isolation between unlike bundles and circuits carrying different redundancy codes.

3.2.2.3.2 SEPARATION REQUIREMENTS

Each bundle type of one code shall be physically separated from other bundles to meet the 20 dB isolation requirement of SSP 30243. Metallic channel separation shall be permitted in lieu of physical separation, provided that the channel separator height is no less than the largest cable bundle diameter requiring separation and that analysis shows that the channels provide the required 20 dB isolation. The application of such metallic barriers in lieu of physical separation shall be identified on all wiring diagrams containing these circuits. Cable bundle placement in all wire trays shall also be determined using minimum–to–maximum voltage or sensitivity requirements of Table 3.2.1.1–1, e.g., EO and RF cable bundles shall have maximum separation in the placement of adjacent wire bundles. See appendix C for exception (EMECB TIA–0113) to this paragraph.

3.2.2.4 SHIELDS

Shielding within a flight element shall be identified in the EME Design Analysis report. System interconnections shall terminate overall cable shields peripherally.

3.2.2.4.1 TERMINATIONS

Radio Frequency Interference (RFI) backshells with individual shield grounding provisions shall be used for multiple RF shield terminations. The length of the termination–to–ground lead for RF circuits shall be the minimum practical and shall not exceed 3 inches. The preferred method is to connect the shield peripherally to the backshell of an RF connector. This requires a continuous low–impedance electrical bond path through both halves of the connector shell, the connector–to–chassis interface, and the chassis–to–ground. All electrical connectors not engaged during mission shall be covered with a conductive cap. High impedance wires shall be terminated with a low impedance. See appendix C for exception (EMECB TIA–0086) to this paragraph.

3.2.2.4.2 BREAKOUTS

Where RFI backshells with individual shield grounding provisions are required for multiple shield terminations, RF circuit shields shall be broken out such that no more than 2 inches of wiring is exposed; and, the wiring must be contained within the connector metal backshell covering.

3.2.2.4.3 GROUNDING OF RADIO FREQUENCY CIRCUIT SHIELDS

RF circuit shields shall be structure grounded as often as possible. This requirement can be satisfied by shield grounding to electrically conductive connector backshells at source and load and at any intermediate breakpoints.

3.2.2.4.4 INTERNAL EQUIPMENT SHIELDS

Shields originating and terminating within the same equipment shall be grounded therein.

3.2.2.4.5 GROUNDING

The shield ground shall be as specified in Table 3.2.1.1–1.

3.2.2.5 BRIDGE WIRE ACTUATED DEVICES

Bridge Wire Actuated Devices (BWAD) use the thermal properties of a heated element to perform a discrete function. BWADs can be categorized into two groups: electroexplosive devices and nonexplosive devices. BWAD firing circuits shall be classified RF in terms of shielding for maximum RF circuit protection. All BWAD interface circuits shall use shielded twisted pair wiring treatment with multipoint grounding of shields at source and load. The method of shield termination shall be via peripheral termination at all connector backshells. For routing purposes, the MO cable separation classification of Table 3.2.1.1–1 shall be applied to all BWAD firing circuits.

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 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 commercial laboratory acceptable to NASA or responsible IP agencies. NASA or responsible IP agencies reserves the right to perform any of the inspections set forth in the requirements document where such inspections are deemed necessary to assure supplies or services conform with prescribed requirements.

APPENDIX A ABBREVIATIONS AND ACRONYMS

ac	Alternating Current
BWAD	Bridge Wire Actuated Device
dc	Direct Current
EM	Electromagnetic
EMC	Electromagnetic Compatibility
EME	Electromagnetic Effects
EMECB	Electromagnetic Effects Control Board (superceded by EMEP)
EMEP	Electromagnetic Effects Panel
EMEEC	Electromagnetic Environment Effects Control
EMI	Electromagnetic Interference
EO	Arbitrary nomenclature to define circuit classes
FO	Arbitrary nomenclature to define circuit classes
GHz	Gigahertz
HO	Arbitrary nomenclature to define circuit classes
k	Thousand
kHz	Kilohertz
LLA	Low level analog
MDM	Multiplexer/Demultiplexer
MHz	Megahertz
ML	Arbitrary nomenclature to define circuit classes
MO	Arbitrary nomenclature to define circuit classes
MPG	Multiple Point Ground
mV	Millivolt
mW	Milliwatt
NASA	National Aeronautics and Space Administration
RF	Radio Frequency
RFI	Radio Frequency Interference

RF1	Radio Frequency Band 1
RF2	Radio Frequency Band 2
RTD	Resistance Temperature Device
SSP	Space Station Program
TW	Twisted
TWDS	Twisted Double Shielded
TWS	Twisted Shielded
USL	United States Laboratory
V	Volt

APPENDIX B GLOSSARY

CABLE, ELECTRICAL

Two or more solid or stranded conductors insulated from each other and routed together or enclosed by a common covering; or one conductor enclosed by but insulated from another conductor or a metallic shield.

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.

EXTERNAL INTERFACE CIRCUIT

Any circuit connected via electrical cable to another device or piece of equipment which has a secondary common separate from the circuit under consideration and is under the control of, or part of, another subsystem or equipment.

INTERCONNECTING CABLING

Power, control, and signal lines which interface with equipment or subsystems.

SUBSYSTEM

A collection of equipment designed and integrated to perform a single function where in any equipment within the subsystem is not required to function as an individual equipment.

SYSTEM

A collection of equipment, subsystems, skills, and techniques capable of performing or supporting an operational role. A complete system includes related facilities, equipment, subsystems, materials, services, and personnel required for its operation to the degree that it can be considered self–sufficient within its operational environment.

WIRE, ELECTRICAL

A single current–carrying conductor of one or more strands covered with a suitable insulating material.

APPENDIX C APPROVED TAILORING/INTERPRETATION AGREEMENTS

EMECB TIA–0066

C.3.2.1 CIRCUIT CLASSIFICATION

Exception: The PMA–1 (CI PMA 1 IFCA 3) to NODE 1 (CI NODE 1 IFCA 3) unbraided lines that interface Resistance Temperature Devices (RTD) to the Multiplexer/Demultiplexer (MDM) Low Level Analog (LLA) input terminals will comply with the intent of 3.2.1. While the twisted pair is unshielded by a braid, the shielding function is adequately accomplished by the wire bundle in which the transmission line is installed. The affected cables are: PMA1W0103, PMA1W0104, PMA1W0107, PMA1W0108, PMA1W0303, PMA1W0304, PMA1W0316, PMA1W0317, PMA1W0318, PMA1W0319, PMA1W1303, PMA1W1304, PMA1W1305, PMA1W1306, PMA2W0301, PMA2W0305, PMA2W1301, PMA3W1301, N1W0301, N1W0302, N1W0304, N1W0307, N1W0308, N1W0309, N1W0316, N1W0317, N1W0318, N1W0319, N1W0320, N1W0321, N1W0322, N1W0323, N1W0324, N1W0325, N1W0901, N1W0906, N1W0928, N1W0929, N1W0930, and N1W0933.

Rationale: The intent of the ML classification wire braid is to enhance transmission line interference coupling immunity. The potential interference to these identified sensor transmission lines was studied using mathematical model and confirmed by laboratory test. Interference coupling may be addressed in the following parts:

a. Bundle crosstalk: The twisted 22 AWG pair is terminated by a balanced and ungrounded resistive load on both the sensor and signal conditioner ends. RTD transmission lines are bundled only with other signal–level transmission lines. The wire pair twisting and the close proximity of the two conductors contribute to provide a transmission line that is relatively immune to the effects of magnetically coupled interference. The signal conditioner LLA is filtered to respond to a differential input of a few tens of hertz only. Both differential and common–mode interference induced by wire bundle crosstalk coupling is so low that it is difficult to measure in the laboratory.

b. RF Electromagnetic field coupled interference: Differential mode RF field induced voltage is low due to the conductor close spacing as well as the wire twisting effect. The LLA input filter further attenuates any coupled RF current. An unprotected twisted pair exposed to a high level impinging field (RS03) may exhibit a common–mode RF induced voltage of less than one volt peak to peak typically but may rise to as much as ten volts peak to peak at line resonance appearing equally on the two LLA input terminals. Placing the twisted pair in its bundle reduces the induced common–mode voltage to a small fraction of this voltage. The effect of this common–mode voltage is to produce an LLA output signal offset. This offset is not an input signal distortion but a more indirect effect of the LLA signal conditioner’s response to an unexpected common mode voltage. Investigation has shown that the inherent field coupling attenuation provided by the wire bundle is more than sufficient to prevent the common–mode voltage output error.

EMECB TIA–0086

C.3.2.2.4.1 TERMINATIONS

Exception: The Stage 2A 1553 data bus shield pigtails that are in the 90 degree connectors comply with the intent of the 3.2.2.4.1 requirement to have a length of 3 inches or less and do not need to be reworked. The connector numbers are as follows:

NZGA–JG–15–N–12
NZGA–JG–13–N–12Z
NZGA–JG–13–N–20Z
NZGA–JG–11–N–12Z
NZGA–JG–15–N–16Z
NZGA–JG–11–N–16
NZGA–JG–25–N–44Z

Rationale: Developmental tests at Huntsville, Test Report D684–10265–01, concentrated on 1553 data bus systems, demonstrated that 1553 data buses are robust to spec–level free–field and induced pulse environments even with purposely degraded shields, including open shields, which represent worse cases than 6–inch shield pigtails.

Therefore, the Stage 2A 1553 data bus pigtails are acceptable as installed and do not need to be reworked.

EMECB TIA–0087

C.3.2.1.1 FREQUENCY OR RISE/FALL TIME

Exception: The unshielded Stage 2A RTD–to–LLA wires in the inboard truss cables comply with the intent of 3.2.1 and do not require braid shields. Affected cables are shown in Table C3.2.1.1–1.

TABLE TIA–0087–1 UNSHIELDED STAGE 2A RTD–TO–LLA WIRES (PAGE 1 OF 3)

Ref. Des	Qty	Harness Assy Drawing Number	Rev Letter (3)	Wire List Drawing Number	Rev Letter
W4107	1	1F75180–1	A	1F75181–1	A
W4139	1	1F75514–1	(B)	1F75515–1	N
W4154	1	1F75342–1	B	1F75343–1	C
W4155	1	1F75344–1	(C)	1F75345–1	(D)
W4157	1	1F76506–1	A	1F76507–1	B
W4158	1	1F76508–1	A	1F76509–1	B
W4164	1	1F75538–1 (1F77165–3)	A	1F75539–1	A

TABLE TIA–0087–1 UNSHIELDED STAGE 2A RTD–TO–LLA WIRES (PAGE 2 OF 3)

Ref. Des	Qty	Harness Assy Drawing Number	Rev Letter (3)	Wire List Drawing Number	Rev Letter
W4165	1	1F75540–1 (1F77165–5)	A	1F75541–1	A
W4167	1	1F75546–1 (1F77165–7)	A	1F75547–1	A
W4306	1	1F75584–1	A	1F75585–1	B
W4208	1	1F75588–1	(A)	1F75589–1	A
W4211	1	1F75594–1	(A)	1F75595–1	(A)
W4212	1	1F75596–1	(A)	1F75597–1	(A)
W4301	1	1F75612–1	A	1F75613–1	A
W4302	1	1F75614–1	A	1F75615–1	A
W4303	1	1F75616–1	(A)	1F75617–1	New
W4304	1	1F75618–1	New	1F75619–1	New
W4305	1	1F75620–1	A	1F75621–1	A
W4306	1	1F75622–1	A	1F75623–1	A
W4307	1	1F75624–1	(B)	1F75625–1	(B)
W4308	1	1F75626–1	New	1F75627–1	New
W4312	1	1F75630–1	New	1F75631–1	New
W4313	1	1F75632–1	B	1F75633–1	B
W4314	1	1F75634–1	B	1F75635–1	A
W4316	1	1F76202–1 (1F77165–9) (IF77165–9)	A	1F76203–1	A
W4317	NA	1F77165–11	Instl	1F76573–1	New
W4318	NA	1F77165–13	Instl	1F76575–1	New
W4321	NA	1F77165–15	Instl	1F76581–1	New
W4325	NA	1F77165–21	Instl	1F76589–1	New
W4326	NA	1F77165–23	Instl	1F76591–1	New
W4327	NA	1F77165–25	Instl	1F76593–1	New
W4328	NA	1F77165–27	Instl	1F76595–1	New
W4502	1	1F75666–1	A	1F75667–1	A
W4503	1	1F75668–1	A	1F75669–1	A
W9104	1	1F75060–1	(C)	1F75061–1	(C)
W9141	1	1F75074–1	(B)	1F75075–1	(C)
W9321	1	1F75100–1	B	1F75101–1	B
W9322	1	1F75102–1	B	1F75103–1	B

TABLE TIA–0087–1 UNSHIELDED STAGE 2A RTD–TO–LLA WIRES (PAGE 3 OF 3)

Ref. Des	Qty	Harness Assy Drawing Number	Rev Letter (3)	Wire List Drawing Number	Rev Letter
W9371	NA	1F75818–5	Instl	1F75065–1	New
W9372	NA	1F75817–5	Instl	1F76451–1	New

Rationale: The intent of the ML wire braid classification and the ensuing braid shields is to reduce EM interference.

Stage 2A designs sufficiently reduce RTD–to–LLA EM interferences of concern and these designs were verified by the MDM qualification tests and a recent developmental test.

These designs and test results are summarized below.

Designs Sufficiently Reduce Common–Mode Interference:
The RTD–to–LLA pairs contained within the in–board truss cables are co–bundled with multiple conductors which in effect shield the RTD–to–LLA pairs from external EM fields, reducing their common–mode interference to acceptable levels.

Designs Sufficiently Reduce Differential–Mode Interference:
Several design features reduce differential–mode interference due to external EM fields on RTD–to–LLA pairs to acceptable levels.

First, the RTD–to–LLA pairs are twisted wires with the conductors in close proximity to one another which significantly reduces magnetically coupled interference. Second, they are terminated by balanced and ungrounded resistive loads on both sensor and signal conditioner ends reducing differential–mode interference. Third, RTD–to–LLA transmission lines are bundled only with other signal–level transmission lines. Fourth, LLA signal conditioners are filtered to respond to differential inputs of only a few tens of Hertz which further attenuates coupled RF interference.

Designs Sufficiently Reduce Bundle Crosstalk**:**
Several of the designs discussed above reduce bundle crosstalk. In addition, the LLA signal conditioner filters, passing differential inputs of only a few tens of Hertz, significantly reduce frequency–dependent bundle crosstalk.

These designs reduce bundle crosstalk to acceptable levels.

MDM Qualification Tests Verified Designs:
Passed MDM RS03 qualification tests with the RTD–to–LAA pairs unshielded, as they are installed on Stage 2A.

Boeing - Huntington Beach Test Verified Designs:
A recent developmental test, focusing on RTD–to–LLA interfaces, demonstrated RTD–to–LLA interfaces are robust as installed.

This test was conducted during April 7–9, 1998, using flight–like wire harnesses interfacing with an MDM from Honeywell. The interfacing wire harnesses were configured in the screen room to simulate their Stage 2A configuration. This included two loops. The effects of on–orbit electromagnetic fields were simulated by simultaneously illuminating (radiating) both loops and the MDM at the ISS RS03 specification levels, from 10 kHz to 15 GHz. No anomalies were observed. Thereafter, the illumination levels were increased to three times the specification level from 10 kHz to 200 MHz, and twice the specification levels from 200 MHz to 1 GHz. Again, no anomalies were observed.

EMECB TIA–0113

C.3.2.2.2 IMPLEMENTATION OF CODING AND BUNDLING AND
C.3.2.2.3.2 SEPARATION REQUIREMENTS

Exception: The ECOMM GFE Project and Boeing – Houston are allowed to install cabling into Node 1 that only partially meets the intent of 3.2.2.2 and 3.2.2.3.2, as depicted in SSP 684–10276, “Early Communications System Interface Control Drawing,” Figure 10A, “Cable Layout.” (Also see Boeing –HB Drawing 1F00308, “Patch Installation, Velcro – Node 1)

Rationale: Practical cable layout and runs in the Node, along with assembly–mission, early–ingress IVA considerations, and 2A flight crew preferences for cable bundling and routing preclude the possibility of complete cabling separation into like functions and classifications. All of the cables are shielded and this provides the electromagnetic shielding required. There were no anomalies noted during KSC Cargo Element 2A Testing in this configuration (May 18–20, 1998).

EMECB TIA–0122

C.3.2.1 CIRCUIT CLASSIFICATION

Exception: The unshielded PMA 3 RTD–to–MDM wires in the PMA 3 external wire harnesses comply with the intent of SSP–30242, paragraph 3.2.1, and do not require braid shields. The wire harness part numbers involved in this agreement are: 1F92885, 1F92959, 1F92895, 1F92891, 1F92897, 1F92893, 1F92899, 1F92901, 1F92903, 1F92905, 1F93312, and 1F93314.

Rationale: The intent of the ML wire braid classification and the ensuing braid shields is to reduce Electromagnetic (EM) interference. In TIA–087, the RTD was shown to be very insensitive to EM interferences. The RTD used on PMA 3 will be similarly insensitive to EM interferences.

The PMA 3 designs sufficiently reduce RTD–to–MDM EM interferences of concern and these designs were verified by the MDM qualification tests and a recent Stage 2A developmental test.

These designs and test results are summarized below:

Boeing–HB Designs Sufficiently Reduce Common–Mode Interference

The RTD–to–LLA pairs contained within the PMA 3 external wire harnesses are co–bundled with multiple conductors which in effect shield the RTD–to–LLA pairs from external EM fields, reducing their common–mode interference to acceptable levels.

Boeing–HB Designs Sufficiently Reduce Differential–Mode Interference

Several design features reduce differential–mode interference due to external EM fields on RTD–to–LLA pairs to acceptable levels.

First, the RTD–to–LLA pairs are twisted wires with the conductors in close proximity to one another which significantly reduces magnetically coupled interference. Second, they are terminated by balanced and ungrounded resistive loads on both sensor and signal conditioner ends reducing differential–mode interference. Third, RTD–to–LLA transmission lines are bundled only with other signal–level transmission lines. Fourth, LLA signal conditioners are filtered to respond to differential inputs of only a few tens of Hertz which further attenuates coupled RF interference.

Boeing–HB Designs Sufficiently Reduce Bundle Crosstalk

Several of the designs discussed above reduce bundle crosstalk. In addition, the LLA signal conditioner filters, passing differential inputs of only a few tens of Hertz, significantly reduce frequency–dependent bundle crosstalk.

These designs reduce bundle crosstalk to acceptable levels.

MDM Qualification Tests Verified Designs

Boeing–HB passed MDM RS03 qualification tests with the RTD–to–LAA pairs unshielded, as they are installed on Stage 2A.

Boeing - Huntington Beach Test Verified Designs

A recent developmental test, focusing on RTD–to–LLA interfaces, demonstrated RTD–to–LAA interfaces are robust as installed.

Boeing–HB conducted this test during April 7–9, 1998, using flight–like wire harnesses interfacing with an MDM from Honeywell. Boeing–HB configured the interfacing wire harnesses in the screen room to simulate their Stage 2A configuration. This included two loops. Boeing–HB simulated the effects of on–orbit electromagnetic fields by simultaneously illuminating (radiating) both loops and the MDM at the ISS RS03 specification levels, from 10 kHz to 15 GHz. Boeing–HB observed no anomalies. Thereafter, Boeing–HB increased the illumination levels to three times the specification level from 10 kHz to 200 MHz, and twice the specification levels from 200 MHz to 1 GHz. Again, Boeing–HB observed no anomalies.

EMECB TIA–0125

C.3.2.1 CIRCUIT CLASSIFICATION

Exception: The unshielded Segment S1 (end item no. 222220A) RTD–to–Thermostat Box wires in the in–board truss wire harnesses listed below comply with the intent of SSP–30242, paragraph 3.2.1, and do not require braid shields. The part numbers for the S1 wire harnesses are as follows: 1F80440, 1F80444, 1F82702, 1F82704, 1F82706, 1F82708, 1F82710, 1F82712, 1F82714, 1F82716, 1F82718, 1F82720, 1F82722, 1F82724, 1F82726, 1F82728, 1F82730, 1F82732, 1F82734, 1F82736, 1F82738, 1F82740, and 1F82742.

Rationale: The intent of the ML wire braid classification and the ensuing braid shields is to reduce EM interference. In TIA–087, the RTD was shown to be very insensitive to EM interferences. The RTD used on Segment S1 (and later on Segment P1) will be similarly insensitive to EM interferences.

The Segment S1 designs sufficiently reduce RTD–to–Thermostat Box EM interferences of concern and these designs were verified by the MDM qualification tests and a recent Stage 2A developmental test.

These designs and test results are summarized below:

Boeing–HB Designs Sufficiently Reduce Common–Mode Interference

The RTD–to–LLA pairs contained within the in–board truss cables are co–bundled with multiple conductors which in effect shield the RTD–to–LLA pairs from external EM fields, reducing their common–mode interference to acceptable levels.

Boeing–HB Designs Sufficiently Reduce Differential–Mode Interference

Several design features reduce differential–mode interference due to external EM fields on RTD–to–LLA pairs to acceptable levels.

First, the RTD–to–LLA pairs are twisted wires with the conductors in close proximity to one another which significantly reduces magnetically coupled interference. Second, they are terminated by balanced and ungrounded resistive loads on both sensor and signal conditioner ends reducing differential–mode interference. Third, RTD–to–LLA transmission lines are bundled only with other signal–level transmission lines. Fourth, LLA signal conditioners are filtered to respond to differential inputs of only a few tens of Hertz which further attenuates coupled RF interference.

Boeing–HB Designs Sufficiently Reduce Bundle Crosstalk

Several of the designs discussed above reduce bundle crosstalk. In addition, the LLA signal conditioner filters, passing differential inputs of only a few tens of Hertz, significantly reduce frequency–dependent bundle crosstalk.

These designs reduce bundle crosstalk to acceptable levels.

MDM Qualification Tests Verified Designs

Boeing–HB passed MDM RS03 qualification tests with the RTD–to–LAA pairs unshielded, as they are installed on Stage 2A.

Boeing – Huntington Beach Test Verified Designs

A recent developmental test, focusing on RTD–to–LLA interfaces, demonstrated RTD–to–LAA interfaces are robust as installed.

Boeing–HB conducted this test during April 7–9, 1998, using flight–like wire harnesses interfacing with an MDM from Honeywell. Boeing–HB configured the interfacing wire harnesses in the screen room to simulate their Stage 2A configuration. This included two loops. Boeing–HB simulated the effects of on–orbit electromagnetic fields by simultaneously illuminating (radiating) both loops and the MDM at the ISS RS03 specification levels, from 10 kHz to 15 GHz. Boeing–HB observed no anomalies. Thereafter, Boeing–HB increased the illumination levels to three times the specification level from 10 kHz to 200 MHz, and twice the specification levels from 200 MHz to 1 GHz. Again, Boeing–HB observed no anomalies.

EMECB TIA–126

C.3.2.1 CIRCUIT CLASSIFICATION

Exception: The unshielded Segment S0 (end item no. 222200A) RTD–to–MDM wires in the in–board truss cables listed below comply with the intent of SSP–30242, Space Station Wire and Cable Design Requirements, paragraph 3.2.1 and do not require braid shields. The part numbers for the SO wire harnesses are as follows: 1F75180, 1F75182, 1F75342, 1F75344, 1F75498, 1F75514, 1F76506, 1F76508, 1F75538, 1F75540, 1F75546, 1F75584, 1F75588, 1F75594, 1F75596, 1F75612, 1F75614, 1F75616, 1F75618, 1F75620, 1F75622, 1F75624, 1F75626, 1F75630, 1F75632, 1F75634, 1F76202, 1F77165–9, 1F77165–11, 1F77165–13, 1F77165–15, 1F77165–21, 1F77165–23, 1F77165–25, 1F77165–27, 1F75666, 1F75668, 1F75060, 1F75074, 1F75100, 1F75102, 1F75818, and 1F75817.

Rationale: The intent of the ML wire braid classification and the ensuing braid shields is to reduce Electromagnetic (EM) interference. In TIA–087, the RTD was shown to be very insensitive to EM interferences. The RTD used on Segment S0 will be similarly insensitive to EM interferences.

The Segment S0 designs sufficiently reduce RTD–to–MDM EM interferences of concern and these designs were verified by the MDM qualification tests and a recent Stage 2A developmental test.

These designs and test results are summarized below:

Boeing–HB Designs Sufficiently Reduce Common–Mode Interference

The RTD–to–LLA pairs contained within the in–board truss cables are co–bundled with multiple conductors which in effect shield the RTD–to–LLA pairs from external EM fields, reducing their common–mode interference to acceptable levels.

Boeing–HB Designs Sufficiently Reduce Differential–Mode Interference

Several design features reduce differential–mode interference due to external EM fields on RTD–to–LLA pairs to acceptable levels.

First, the RTD–to–LLA pairs are twisted wires with the conductors in close proximity to one another which significantly reduces magnetically coupled interference. Second, they are terminated by balanced and ungrounded resistive loads on both sensor and signal conditioner ends reducing differential–mode interference. Third, RTD–to–LLA transmission lines are bundled only with other signal–level transmission lines. Fourth, LLA signal conditioners are filtered to respond to differential inputs of only a few tens of Hertz which further attenuates coupled RF interference.

Boeing–HB Designs Sufficiently Reduce Bundle Crosstalk

Several of the designs discussed above reduce bundle crosstalk. In addition, the LLA signal conditioner filters, passing differential inputs of only a few tens of Hertz, significantly reduce frequency–dependent bundle crosstalk.

These designs reduce bundle crosstalk to acceptable levels.

MDM Qualification Tests Verified Designs

Boeing–HB passed MDM RS03 qualification tests with the RTD–to–LAA pairs unshielded, as they are installed on Stage 2A.

Boeing – Huntington Beach Test Verified Designs

A recent developmental test, focusing on RTD–to–LLA interfaces, demonstrated RTD–to–LAA interfaces are robust as installed.

Boeing–HB conducted this test during April 7–9, 1998, using flight–like wire harnesses interfacing with an MDM from Honeywell. Boeing–HB configured the interfacing wire harnesses in the screen room to simulate their Stage 2A configuration. This included two loops. Boeing–HB simulated the effects of on–orbit electromagnetic fields by simultaneously illuminating (radiating) both loops and the MDM at the ISS RS03 specification levels, from 10 kHz to 15 GHz. Boeing–HB observed no anomalies. Thereafter, Boeing–HB increased the illumination levels to three times the specification level from 10 kHz to 200 MHz, and twice the specification levels from 200 MHz to 1 GHz. Again, Boeing–HB observed no anomalies.

EMEP TIA–0180

C.3.2.2.1.3 SHIELD GROUNDING REQUIREMENTS

Exemption: The Node 2 cable harnesses Harness Manufacturing Units (PNs 602, 603, 612, 613, 623, 633, 636, 722, 724) are exempted from meeting the 3.2.2.1.3 shield grounding requirements by grounding their shields through connector pins and not to the connector backshells at break points.

Rationale: The 3.2.2.1.3 Shield Grounding Requirements states "Shields shall be terminated at both ends and at intermediate break points directly to structure or chassis, through connector backshells or direct wire connection…" Alenia interpreted direct wire connection to mean termination to pins at intermediate break points was acceptable. Additionally, Alenia's design practice of termination of shields to pins at production breaks facilitates troubleshooting of the harness should it become necessary. The cable harness design and procurement are under Alenia's control and not United States On–orbit Segment. The termination of the shields to pins instead of backshells for these cable harnesses does not represent a problem because they are not critical circuits.

EMEP TIA–0221

C.3.2.1 CIRCUIT CLASSIFICATION

Exception: The unshielded United States Laboratory (USL) (CI# 683400A) and Airlock (CI# 683C01A) RTD–to–MDM interface cables and pigtails comply with the intent of 3.2.1 and do not require braid shields. The part numbers for the wire harnesses are as follows:
USL: 683–20193, 683–22044, 683–22045, 683–22046, 683–22047, 683–22048, 683–22049, 683–22053, 683–22054, 683–22055, 683–22056, 683–22021, 683–22022, 683–22023, 683–22024, 683–22025, 683–22026, and Heat Exchanger wire harness 1F70130.
Airlock: 683–52086, 683–52031, and 683–52019.

Rationale: The intent of the ML wire braid classification and the ensuing braid shields is to reduce EM interference. In TIA–0126, the RTD was shown to be very insensitive to EM interference. The RTD wiring used on the USL and Airlock Modules will be similarly insensitive to the effects of electromagnetic coupling.

The USL and Airlock cable configurations sufficiently reduce RTD–to–MDM EM coupled interference; these designs were verified by the MDM qualification tests and a recent Stage 2A developmental test. The Thermostat RTD RF response to the effects of electromagnetic coupling can be considered similar or more benign to that of the MDM LLA response.

These designs and test results are summarized below:

A. Boeing–HB/Huntsville Designs Sufficiently Reduce Common–Mode Interference

The RTD–to–LLA and Thermostat pairs contained within the USL interface cables are co–bundled with multiple conductors which in effect shield the RTD pairs from external EM fields, reducing their common–mode interference to acceptable levels.

Most of the RTDs in the USL have shielded wire leads; all the RTDs in the USL connecting to a MDM have shielded wires. In the Airlock many of the RTDs had twisted wire unshielded pigtails which were connected to a shielded cable as soon as practical in the cabling design. For the wall heaters in both modules, the thermostat leads to the RTDs had shields and were run as far as feasible before dead–ending the shields and connecting the thermostat wires to the twisted wire pigtails of the RTDs.

The internal cabling is shielded from the external RF environment by the module structure and walls. The external wall heaters (Launch–to–Activation heaters) are shielded by the metal layers in the Meteoroid and Debris Shield and the metalized layers in the Multilayer Insulation blankets.

B. Boeing–HB/Huntsville Designs Sufficiently Reduce Differential Mode Interference

Several design features reduce differential mode interference due to external electromagnetic fields on RTD to LLA and Thermostat pairs to acceptable levels.

First, the RTD pairs are twisted wires with the conductors in close proximity to one another, which significantly reduces magnetically coupled interference. Second, they are terminated by balanced and ungrounded resistive loads on both sensor and signal conditioner ends reducing differential mode interference. Third, RTD transmission lines are bundled only with other signal–level transmission lines. Fourth, LLA signal conditioners are filtered to respond to differential inputs of only a few tens of Hertz, which further attenuates coupled RF interference.

C. Boeing–HB/Huntsville Designs Sufficiently Reduce Bundle Crosstalk

Several of the designs discussed above reduce bundle crosstalk. In addition, the LLA signal conditioner filters, passing differential inputs of only a few tens of Hertz, significantly reduce frequency dependent bundle crosstalk.

These designs reduce bundle crosstalk to acceptable levels.

D. MDM Qualification Tests Verified Designs

Boeing–HB passed MDM RS03 qualification tests with the RTD to LLA pairs unshielded, as they are installed on Stage 2A.

E. Boeing–Huntington Beach Test Verified Designs

A recent developmental test, focusing on RTD to LLA interfaces, demonstrated RTD to LAA interfaces are robust as installed.

Boeing–HB conducted this test during April 7–9, 1998, using flight–like wire harnesses interfacing with an MDM from Honeywell. Boeing–HB configured the interfacing wire harnesses in the screen room to simulate their Stage 2A configuration. This included two loops. Boeing–HB simulated the effects of on orbit electromagnetic fields by simultaneously illuminating (radiating) both loops and the MDM at the ISS RS03 specification levels, from 10 kHz to 15 GHz. Boeing–HB observed no anomalies. Thereafter, Boeing–HB increased the illumination levels to three times the specification level from 10 kHz to 200 MHz, and twice the specification levels from 200 MHz to 1 GHz. Again, Boeing–HB observed no anomalies.

EMEP TIA–0341

C.3.2.1 CIRCUIT CLASSIFICATION

Exception: The unshielded Cupola (CI 684EA2A, PN CP2102F) RTD to MDM wires in the Cupola wire harnesses comply with the intent of 3.2.1 and do not require braid shields.

Rationale: The intent of the ML wire braid classification and the ensuing braid shields is to reduce Electromagnetic Interference (EMI). In TIA–087 and TIA–122, the RTD to LLA interface was shown to be very insensitive to EMI. Cupola harness is interfacing with Node1 and PMA1 harnesses (Cupola RTD harness N1–WB0308) for which TIA–066 has already been accepted.

The Cupola design sufficiently reduces RTD to MDM EMI concerns and this design was verified by the MDM qualification tests. The design and test results are summarized below:

The Cupola design sufficiently reduces differential and common mode interferences.
The RTD to LLA 4–wires connection contained within the Cupola wire harnesses is cobundled with other RTD to LLA 4–wires conductors which in affect shield the RTD to LLA interface from electromagnetic fields, reducing the common mode interference to acceptable levels.

Several Cupola design features reduce differential mode interference due to external electromagnetic fields on RTD to LLA pairs to acceptable levels. First, the RTD to LLA 4–wires are made using two cables (with two twisted wires each) with the conductors in close proximity to one another. This significantly reduces magnetically coupled interference. Second, voltage measurement and excitation transmission lines are shorted together at the RTD. Bundling together excitation and voltage measurement transmission lines minimizes the loop which significantly reduces magnetically coupled interference. Third, the RTD to LLA 4–wires are terminated by balanced and ungrounded resistive loads on both sensor and signal conditioner ends reducing common mode interference. Fourth, RTD to LLA transmission lines are bundled only with other RTD to LLA transmission lines. Fifth, LLA signal conditioners are filtered to respond to differential inputs of less than 50 Hertz, which further attenuates coupled RF interference. Sixth, the Cupola RTD harness cables are running between the primary and the aluminum made secondary structure (close to the primary structure at about 0.2 cm of distance). Only about 10 cm of these cables are not shielded by the secondary structure and are directly exposed to the Cupola cabin field (the part of the cables approaching the window connectors).

The Cupola design sufficiently reduces bundle crosstalk. Several of the design features discussed above reduce bundle crosstalk. In addition, the LLA signal conditioner filters, passing differential inputs of less than 50 Hertz, significantly reduce frequency dependent bundle crosstalk. This reduces bundle crosstalk to acceptable levels.

The MDM qualification tests verified the design. The MDM passed RS03 qualification tests with the RTD to LAA pairs unshielded as they are installed on Stage 2A.

The Node 1 harness interfacing with the Cupola RTD harness is currently classified and designed as HO. The Node 3 harness interfacing with the Cupola RTD harness is currently classified and designed as HO for the "Excitation" signals and ML for the "Voltage Measurement" signals.

EMEP TIA–0404

C3.2.1 CIRCUIT CLASSIFICATION

Exception: The unshielded ITS P3 (CI# 222280A) and ITS S3 (CI# 222240A) remote terminal device to Space Station MDM wires in the in board truss wire harnesses listed below comply with the intent of 3.2.1 and do not require braid shields.

The part numbers for the ITS P3 wire harnesses are 1F84072, 1F84074, 1F83076, 1F83078, 1F84110, 1F84112, 1F84106, 1F54102, 1F84140, 1F84120, 1F84130, 1F97381, and 1F97332.

The part numbers for the ITS S3 wire harnesses are 1F84072, 1F84074, 1F86076, 1F86078, 1F86110, 1F86112, 1F86102, 1F86102, 1F86120, 1F86130, 1F97349, and 1F97336.

Rationale: The intent of the circuit class ML wire braid classification and the braid shields is to reduce EMI. In EMEP TIA–087, the remote terminal device was shown to be very insensitive to EMI. The remote terminal device used on ITS P3 and ITS S3 was similarly insensitive to EMI.

The ITS P3 design reduces the remote terminal device to SSMDM LLA EMI concern and the design was verified by the MDM qualification tests, a Stage 2A developmental test, and the successful flight experience with Stage 2A that has been in orbit for nearly two years.

The Boeing–Huntington Beach (HB) design reduces Common Mode Interference. The RTD to LLA pairs contained within the inboard truss cables are cobundled with multiple conductors that shield the RTD to LLA pairs from external electromagnetic fields reducing their common mode interference to acceptable levels.

The Boeing–HB design reduces differential mode interference. Several design features reduce differential mode interference due to external electromagnetic fields on remote terminal device to LLA pairs to acceptable levels. First, the remote terminal device to LLA pairs are twisted wires with the conductors in close proximity to one another, which significantly reduces magnetically coupled interference. Second, the pairs are terminated by balanced and ungrounded resistive loads on both sensor and signal conditioner ends reducing differential mode interference. Third, remote terminal device to LLA transmission lines are bundled only with other signal level transmission lines. Fourth, LLA signal conditioners are filtered to respond to differential inputs of only a few tenths of hertz that attenuates coupled RF interference.

The Boeing–HB design reduces bundle crosstalk. The LLA signal conditioner filters, passing differential inputs of only a few tens of hertz, which reduces frequency dependent bundle crosstalk to acceptable levels.

The Boeing–HB design passed the MDM RS03 qualification tests with the RTD to LLA pairs unshielded, as they are installed on Stage 2A.

A developmental test, focusing on remote terminal device to LLA interfaces, demonstrated that the remote terminal device to LLA interfaces are robust as installed. Boeing–HB conducted this test April 7–9, 1998, using flight like wire harnesses interfacing with a MDM from Honeywell. Boeing–HB configured the interfacing wire harnesses in the screen room to simulate the Stage 2A configuration. This included two loops. Boeing–HB simulated the effects of on–orbit electromagnetic fields by simultaneously illuminating (radiating) both loops and the MDM at the ISS RS03 levels, from 10 kHz to 15 GHz. No anomalies were observed. Boeing–HB increased the illumination levels to three times the specification level from 10 kHz to 200 MHz, and twice the specification levels from 200 MHz to 1 GHz. No anomalies were observed.

Stage 2A (Node 1 and Pressurized Mating Adapters) has been in orbit since December 1999. The Stage 2A remote terminal device to MDM LLA twisted pair cables have proven to be immune to on–orbit radiation field to cable coupling interference without additional shielding.