WFMOS PROJECT
80.60.00.00_REF
Version: 3

Construction Standards

Reference Document

Version:	**3**	**Date:**
Issued by:	S. Kleinman	28Aug08
Approved by:	**Subaru Manager:**	
	Gemini Manager:	
	Gemini Engineering:	

80.60.00.00_REF, Revision Control

Revision: 1, Scot Kleinman, Manuel Lazo, 27Aug08

Revision: 2, Scot Kleinman – added Manuel's section 3 and comments from J. Jensen. Plus other minor changes.

Revision: 3, Scot Kleinman – some formatting and other minor edits.

Contents

1. Introduction

This document describes the Gemini workmanship and safety requirements and guidelines. The phrase *the Instrument* is generically meant to refer to the Gemini Instrument being built as well as its individual sub-components.

2. Related Documents

Document Number	Document Name
80.60.40.05_REF	Safety Review Document Template

3. Electrical Grounding Practices and Requirements for Instruments Hardware

Partially adheres to Reliability Practice # PD-ED-1214; from NASA Technical Memorandum 4322A, NASA Reliability Preferred Practices for Design and Test.

3.1 Benefits

Grounding procedures used in the design and assembly of electrical and electronic systems will protect personnel and circuits from hazardous currents and damaging fault conditions. Benefits are prevention of potential damage to delicate instruments systems, subsystems and components, and protection of development, operations, and maintenance personnel.

3.2 Implementation Methods

3.2.1 System Grounding Requirements and Design Approaches

The design of electrical and electronic systems should comply with the following as a minimum: (1) a ground reference plane should be established that will hold the grounds for all systems, subsystems, equipment metallic components, surfaces, and electrical and electronic parts at the potential of the base structure; (2) within equipment, power should have dedicated returns; (3) except for a single-point reference, all electrical signal and power grounds should be electrically isolated from each other, and each separately derived electrical system should be electrically connected to structure at only one point; and (4) a dedicated power return should be used except where necessary to support system requirements.

The grounding within electrical or electronic enclosures is at the discretion of the circuit designer. The following design approaches should be considered for the design of these systems: (1) within equipment, conditioned electrical power should be DC-isolated from chassis and structure except at a single point; (2) within equipment, the single-point reference should be routed external to the equipment for termination to ground, or routed directly to the chassis for termination; (3) the control power bus return should be independent of the primary electrical power return and should be referenced to the return system at a single point; (4) secondary and tertiary electrical power should be single-point grounded and should be returned to that single reference ground point; (5) when all single-point grounds are not terminated to chassis or structure, secondary and tertiary electrical power should be dc isolated by a minimum of 1 megohm; (6) power conversion performed to supply conditioned power to several devices or functions should reestablish a single-point ground reference for the serviced equipment or functions; (7) equipment should not depend on other equipment for reference or grounding, either signal or power, unless it is also dependent upon the other equipment for its power; (8) signal circuits with frequencies below 2 MHz, with interfaces external to equipment, should be balanced and isolated from chassis; (9) all returns and references should be brought out of equipment on individual connector pins; (10) shield connections should be made to connector shells or to connector pins that are, or will be, grounded when mated; (11) single-ended circuits with the lowest frequency component equal to or above 2 MHz should be coupled by coaxial cable with the shield terminated 360 degrees at each end; and (12) external to an equipment, single-ended electrical signals should be prohibited for signal frequencies below 2 MHz except where electrical isolation is maintained.

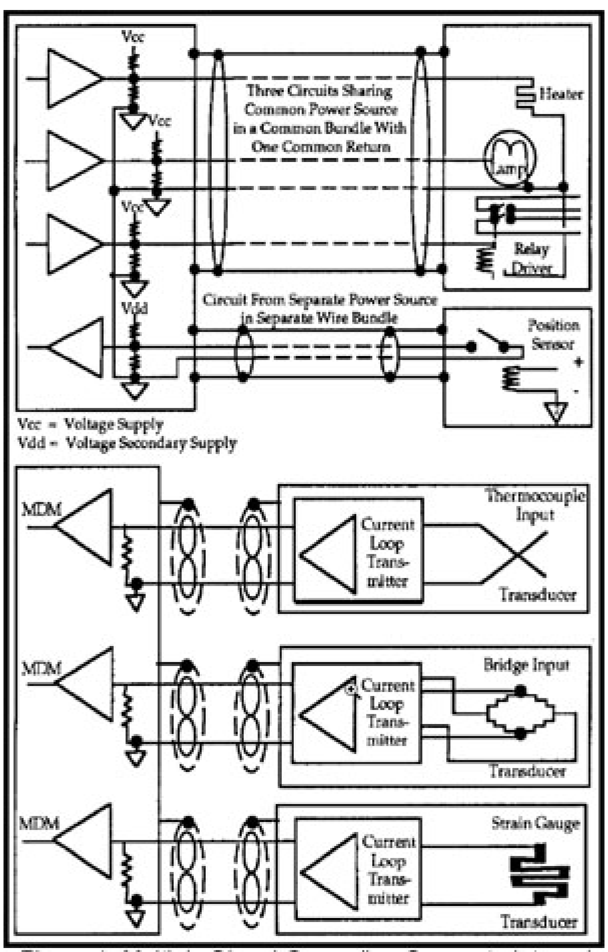

Figure 1. Multiple Signal Grounding Concepts Internal to Equipment (Below 2 MHz)

Schematic Examples:

An example of grounding implementation concepts is shown on Figure 1. This figure reflects the stated grounding requirements and design considerations and shows two feeder, cabling and load configurations. At frequencies below 2 MHz (Figures 1 and 2), the emphasis is on circuitry requiring internal grounding with interfaces to external equipment. For frequencies equal to and above 2 MHz, the emphasis is on external connections between equipment and the proper grounding of shielding to prevent electromagnetic coupling.

Single-Point/Multiple-Point Grounding:

Although the establishment of a ground reference plane requires a single-point ground, the actual practice of complying with this requirement in a system design is controversial. Modern electronic systems seldom have only one ground plane and, to reduce potential interference, as many ground planes as possible are sometimes used. From Figure 2, a grouping of ground planes connected by the shortest route back to a system ground point where they form an overall system potential reference, could be called a single-point ground system.

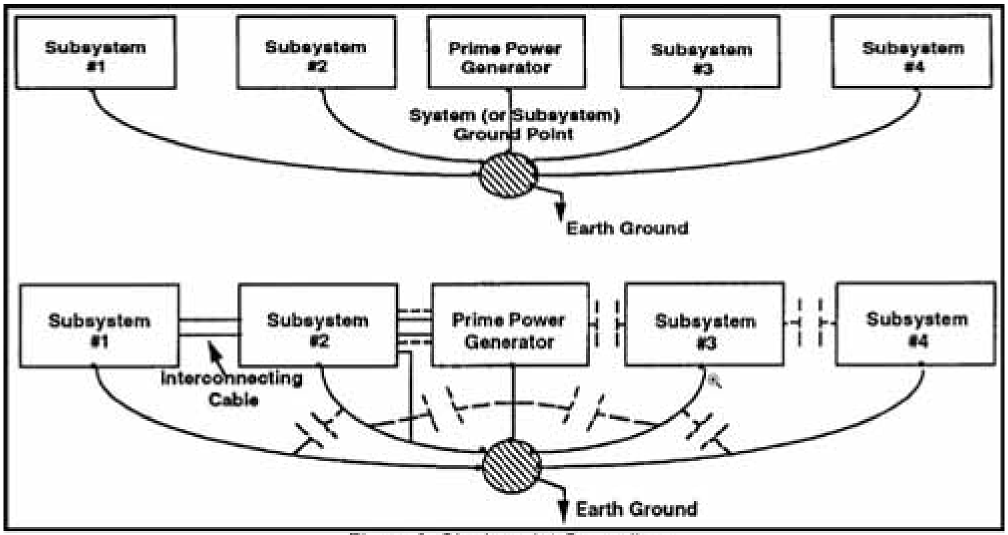

Figure 2. Single-point Grounding

However, problems with this scheme arise when interconnecting shielded cabling is used having significant lengths with respect to the wavelength of signal frequencies and parasitic capacitance exists between equipment housings or between subsystems and the grounds of other subsystems. It can be argued that a "multiple-point" ground system, which bonds each subsystem or equipment as directly as possible to a low impedance equipotential ground plane, can minimize these electromagnetic interference problems. An example of such a system is shown in Figure 3 where each subsystem is connected directly to a common ground plane, ideally a flat, equipotential plate.

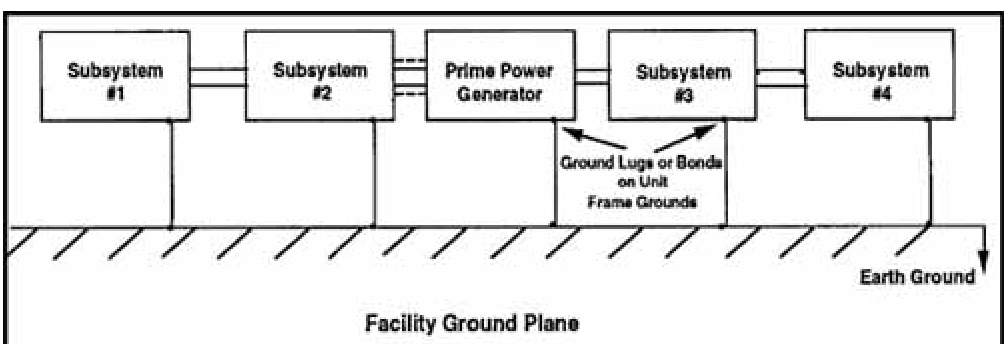

Figure 3. Multiple-point Grounding

In practice, the selection of a grounding scheme is dependent on the highest significant operating frequency of low-level circuits relative to the physical separation of the equipment. As shown in Figure 4, single-point grounding works best at low frequencies and small dimensions and multiple-point grounding works best at high frequencies and large dimensions. For transitional situations, one or the other may perform better as shown in Figure 4. For this crossover region, hybrid grounds perform best when portions of the low-frequency systems use single-point grounds and the high-frequency portions use multiple-point grounds.

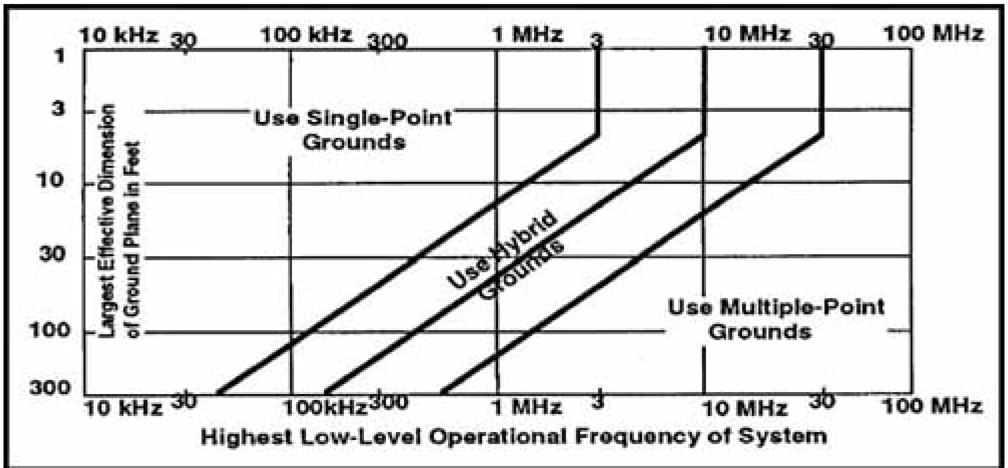

Figure 4. Cross-over Regions of Single-Point vs. Multi-Point Grounding

3.2.2 Shock Prevention

Proper grounding protects personnel from accidental contact with metallic elements that may have hazardous voltage potentials due to system faults or accidental contact between energized elements and equipment chassis, frame or cabinet structure. Case voltage rise is limited to reduce currents to levels that do not produce adverse reactions and possible secondary effects. Typically, case voltage rise is limited to prevent hazardous currents. Table 1 summarizes the alternating and direct currents and their shock effects.

Table 1. Summary Effects of Electrical Shock

Alternating Current (60Hz) (mA)	Direct Current (DC) (mA)	Reation
0.5-1	0-4	Perception
1-3	4-15	Surprise
3-21	15-80	Reflex action
21-40	80-160	Muscular inhibition
40-100	160-300	Respiratory block
> 100	> 300	Usually fatal

3.2.3 Bonding

The integrity of interconnected conductive elements is ensured by electrical bonding, a process in which components or modules are electrically connected to provide a low-impedance conductor. Bonding practices should comply with MIL-STD-5087B. Bonding procedures require the use of specified clamps, standard parts, bolt and screw attachments, washers and materials to ensure consistent bonding of equipment under various temperatures and corrosion environments. The use of jumper cables is discouraged except across movable vibration or thermal isolation joints.

Surface preparation for bonded joints should begin by removing all anodic film, grease, paint, lacquer, or other high-resistance properties from the faying surfaces. A typical bonding hardware configuration is shown in Figure 5. The use of scrapers, abrasives or chemical cleaning methods to provide a clean, smooth bonding surface is dependent on the type of joint (i.e., metal-to-metal, metal-to-nonmetal or nonmetal-to-nonmetal). Example bonding impedances for selected bonding classes are shown in Table 2.

Table 2. Example Bonding Impedances and Bonding Class

Bonding Class	Impedance
A (Antenna installation) H (Shock hazard) R (RF potentials) S (Static charge)	DC resistance < 2.5 milliohms DC resistance < 100 milliohms DC resistance < 2.5 milliohms Impedance < 100 milliohms up to 1 MHz <</u>1 ohm (conductive structure) <</u> 1000 ohms (composites) <</u> 1000 ohms (conductive subassemblies) 1 ohm (pipe and hose)

3.2.4 Cabling/Connector Grounding

Cabling extending outside grounded enclosures is vulnerable to radiated emissions if cable lengths are a significant portion of the wavelength of the systems' highest operating frequencies. Adequate shielding and grounding are required to ensure proper system operation. Figure 6 shows typical grounding practices for shielded cabling and connectors. Shield terminations at connectors are gripped by the connector back shell to provide a low impedance 360 degree connection. Soldered connections are not recommended due to the difficulty in repair and wiring changes, and the use of foil in some cable shielding. Where cabling enters enclosures, the box connector or partition penetration in Figure 6 may be used. For cabling where the overall shield ends in a terminal strip, the termination may look like the configuration shown in Figure 7.

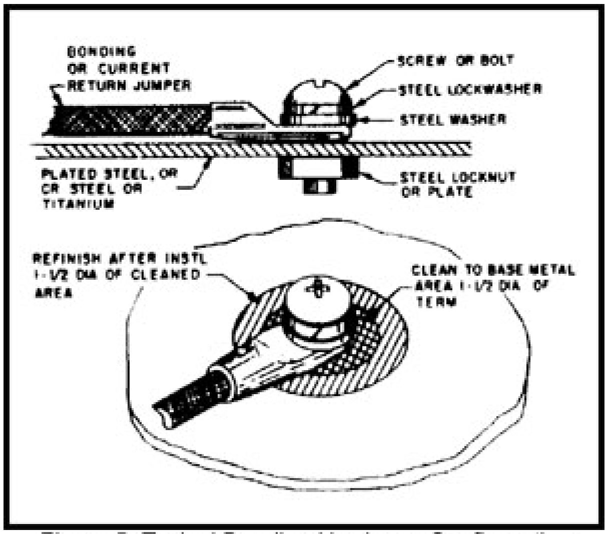

Figure 5. Typical Bonding Hardware Configuration

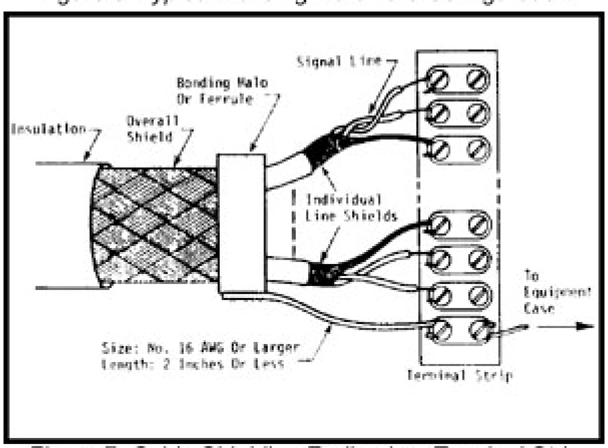

Figure 7. Cable Shielding Ending in a Terminal Strip

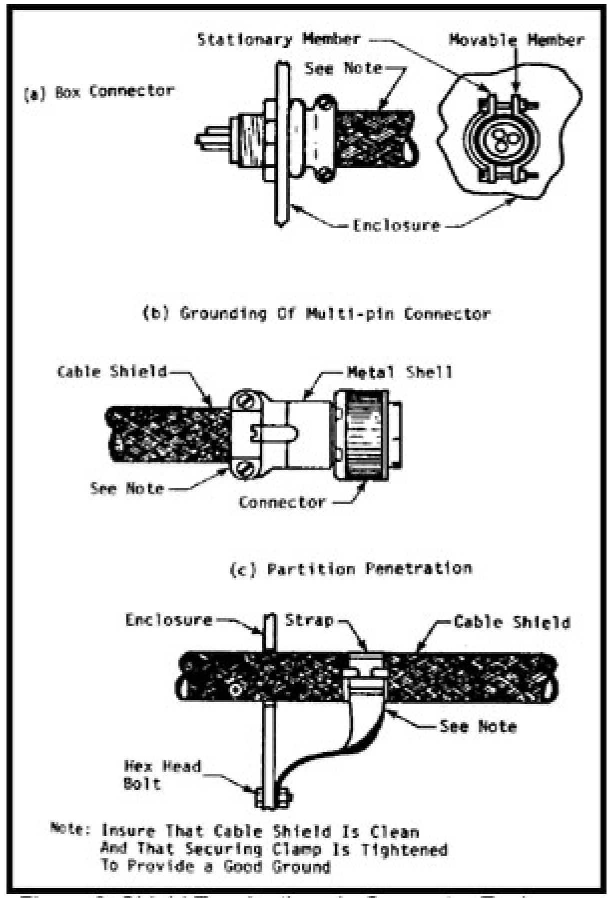

Figure 6. Shield Terminations in Connector Enclosures

3.2.5 Technical Rationale.

Gemini now has many years of experience in the design and fabrication of electrical circuits and electronic devices for Instruments. This practical experience is reflected in the standard procedures and techniques presented here that Gemini has seen result in safe, reliable circuits that present minimum hazard to personnel and equipment, while meeting our reliability and maintainability requirements.

3.2.6 References

•Reliability Preferred Practice No. PD-ED-1202, "High Voltage Power Supply Design and Manufacturing Practices," Lewis Research Center.
•Ott, Henry W., *Noise Reduction Techniques in Electronic Systems,* Second Edition, AT&T Bell Laboratories, 1988, Chapter 3.
•Weston, David A. *Electromagnetic Compatibility, Principles and Applications*, Second Edition, Revised and Expanded, 2001.
•MIL-STD-461C, "Electromagnetic Emission and Susceptibility," August 1986.
•MIL-STD-462, "Electromagnetic Interference Characteristics," July 1967.
•MIL-STD-463A, "Definitions and System of Units, Electromagnetic Compatibility Technology Interference," June 1966.
•Denny, Hugh W., *Grounding for the Control of EMI*, 1983.
•White, Donald R.J., *Electromagnetic Interference and Compatibility*, Vol.3, "A Handbook on EMI Control Methods and Techniques," 1973.

4. Instrument Reliability

4.1 Lifetime

The Instrument shall be designed for an operational lifetime of 10 years without a major overhaul. Components likely to affect the lifetime requirement shall be identified.

4.2 Downtime

The Instrument shall be designed to have a total downtime of at most 2%, with 1% as a goal. Downtime is defined as hours of available night-time when the instrument or any of its subcomponents are incapable of gathering data consistent with the instrument's normal operating specifications. Where possible, component failure shall result in gradual performance degradation. Single point failures that may result in significant downtime shall be determined and, where necessary, critical spares shall be identified.

4.3 Continuous Duty

The Instrument shall be designed and built for continuous operation. Continuous operation is defined as 12 night hours of standard operation for up to 30 consecutive nights, averaging 240 nights a year and 20 nights/month with *standard operation* being defined as detectors continuously active and mechanisms operated at regular intervals consistent with the instrument's normal operating modes. (For WFMOS, this means fiber re-positioning, spectrograph configuration and exposure readouts every 20minutes.) Modules containing moving parts shall be designed or selected to meet the Downtime requirement assuming continuous operation.

5. Maintainability and Serviceability

The Instrument shall meet the requirements for maintainability as outlined in the Statement of Work throughout its operating lifetime. Some annually scheduled downtime is acceptable, so long as it is consistent with the downtime requirements above. A list of spares necessary or advised to meet this requirement shall be provided.

To the extent possible, the Instrument shall provide visual indicators consistent with operating in a dark night-time environment of the status of the instrument power supplies. Access to test points of crucial signals and voltages of the Detector and Components Controller electronics enclosures that does not require major disassembly of the instrument or its electronics enclosures shall be provided.

5.1 Standard Components

Whenever possible, the Instrument shall use unmodified, commercially available, standard components, and components taken from designs of previous Gemini (and Subaru, in the case of WFMOS) instruments.

Notes and Comments

- When no standard components are found to satisfy this requirement, to the extent possible, customized boards or interfaces will be installed in standard electronics crates (Vector or similar type), avoiding mounting such boards horizontally inside open crates. Test points of important signals shall be provided at the board front panels.
- No wire wrap type boards shall be used.

5.2 Modularity

To the extent possible, the Instrument shall be designed to be modular in order to provide accessibility for testing and swapping components.

Power supplies and commercial and customized boards will be installed in standard electronics crates (Vector or similar type) to provide a high degree of modularity and provide for better sparing across multiple Gemini instruments.

5.3 Access

Access to components and subassemblies shall be considered in the Instrument design, particularly for those elements that are accessed frequently. Tool and hand clearances shall be considered, as well as space required to remove modules and gain visual access to components (or a means to feel their correct position and alignment, e.g., for electronic connectors).

The Instrument Detector and Components controller electronics enclosure doors shall be accessible and able to be opened without changing the position of the enclosures or removing them with the instrument mounted at any ISS standard instrument port (or in its nominal position within Subaru).

5.4 Alignment

Alignment of optical components shall be achieved to the extent possible by accurate machining of locating fixtures or surfaces. Adjustable mounts, while useful for final adjustment into position, are sensitive to vibrations and can also adjust themselves out of position. They should be used only when absolutely necessary.

5.5 Relative Equipment Arrangements

Equipment shall be located with due consideration of the sequence of operations involved in maintenance procedures. To the extent possible, the most accessible locations shall be reserved for the items requiring most frequent access.

5.6 Subassemblies

Subassemblies of the equipment that require more frequent service (inspection, adjustments, repair, or replacement) shall be configured as plug-in modules or, if in racks, as drawers that can be withdrawn easily.

5.7 Handling

Modules greater than 20 kg in mass shall have suitable handles for use in removing, replacing, and carrying them. Handles shall be located such that the vector sum of resultant handling forces shall pass close to the center of gravity of the unit.

5.8 Wiring and cabling

Standard wiring protocols with respect to proper gauge, color, etc. shall be used in Instrument construction. Wires and cables should be well secured and protected from accidental contact wherever possible. Where possible, wiring should be shielded and routed to minimize the chances of short circuits, ground loops, and interference or noise pickup. Cable lengths should be long enough to allow for maintenance and replacement, but otherwise no longer than necessary. Cables should be clearly labeled, correspondingly with their appropriate connectors. Two sets of cables that go to the ISS shall be provide, one each for the up-looking and side-looking ports.

5.9 Connectors

Connectors shall be well secured and consist of standard components wherever possible. Connectors shall be keyed and locking, or otherwise secured. To avoid confusion, different cables, or at least different cable types, should use different connectors. Connectors shall be well labeled and chosen to minimize the potential for accidental incorrect connections.

6. He, Coolant, and Air Lines

Glycol fittings should be made of stainless steel.
TBD

7. Network and Fiber Optic Cables

TBD

8. Safety

We consider Instrument safety to refer to both safety to the Instrument and to staff constructing, operating, maintaining, or otherwise associated with it. Design and construction of the instrument must take place in accordance with the institute's and host nation's own safety requirements and regulations. All component documentation shall include a Safety section that details potential risks to the Instrument and staff in performing any of the procedures described within.

The Instrument shall be designed in such a way that it will not present a safety hazard to personnel while being transported, attached to the ISS (or PFU/telescope for WFMOS), or during operation. Hazardous materials / environments in the instrument shall be appropriately marked and discussed with Gemini. No abnormally hazardous or poisonous substances shall be used in the Instrument. Placards in both English and Spanish will be attached to indicate areas were caution should be used. For WFMOS, placards shall be in both English and Japanese.

Reference document 80.60.40.05_REF is a Gemini template for Instrument Safety Review documentation.