Internal Electrostatic Discharge Tests of Micro-D Connectors for Planned Europa Mission

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I. Introduction

NASA has planned a mission to study Jupiter's moon, Europa. The mission would place a spacecraft into orbit around Jupiter, performing nominally 45 flybys of the moon. The suite of instruments onboard the spacecraft would investigate Europa's potential to sustain life, studying the moon's atmosphere, water-ice crust, suspected subsurface ocean, and rocky interior.

The radiation environment at Europa's orbit is severe and presents a significant threat to the spacecraft. There are several radiation effects that could be problematic, one of which is internal charging. Problems due to internal charging arise when high energy electrons penetrate the spacecraft and deposit within onboard dielectrics or floating metals. These charges can build up over time, generating electric fields that exceed the breakdown strength of materials in the region. A rapid discharge of the stored charges may occur, sending current pulses into electronics and potentially damaging them.

An Internal Electrostatic Discharge (IESD) design environment was created for the planned Europa mission [Kim et al, in press]. The IESD design environment is meant to characterize the part of the radiation environment that poses the largest threat to the spacecraft with respect to internal charging. The environment was based off of electron data gathered by the Galileo spacecraft.

Over the past year, the internal charging threat to several hardware components of the planned Europa Clipper spacecraft have been characterized using simulations and/or tests. The subject report documents one such test on Micro-D connectors.

II. Sample Preparation

Four mated M83513 Micro-D connector sets were IESD tested: a 9-Position Glenair, 9-Position ITT, 100-Position Glenair, and 100-Position ITT. The connectors were received and assembled by the Cable Shop at JPL. Each connector was populated, potted with Arathane 5753A/B, mated, and assembled with a backshell. The wiring of each connector was wrapped with both EMI tape and 3M 1181 conductive-adhesive copper tape. The coverage of EMI tape started approximately half-way along the neck of the backshell and extended a few centimeters along the length of the wires, and the coverage of copper tape started approximately half-way along the neck of the backshell and extended the full length of the wires. A photo of a 9-Position Glenair connector set is shown in Fig. 1. The EMI tape is hidden in the figure because it is beneath the copper tape.

The reason EMI tape was included on the samples was to make the connectors flight-like. The reason the copper tape was included was two-fold: the first reason was also to make the connectors flight-like, and the second reason was to shield the wire insulation from low energy scattered electrons. Charge deposition in the wire insulation was not desired because the purpose of this test was to isolate the response of the connectors.

The test chamber had 7 available feedthroughs. These feedthroughs were used to monitor voltages on the pins. As such, the pins on each connector were electrically tied into 7 groups according to the specifications in Fig. 2. This was accomplished by soldering the specified wires together on each end of the connector set, finishing the groups on one end with SMA connectors and on the other end with insulating shrink-wrap tubing (Fig. 3 and Fig. 4).

Each test except for the 9-Pin ITT test included a second connector set in the chamber for Total Ionizing Dose (TID) testing only. This connector was prepared the same way as the one being tested for IESD except that all pins on both ends of the connector were electrically tied together and finished with a ground lug. The ground lug was screwed onto the mounting plate for secure grounding. The TID connector was not monitored.

Figure 1. 9-Position Glenair Connector Set with EMI Tape (hidden) and Copper Tape

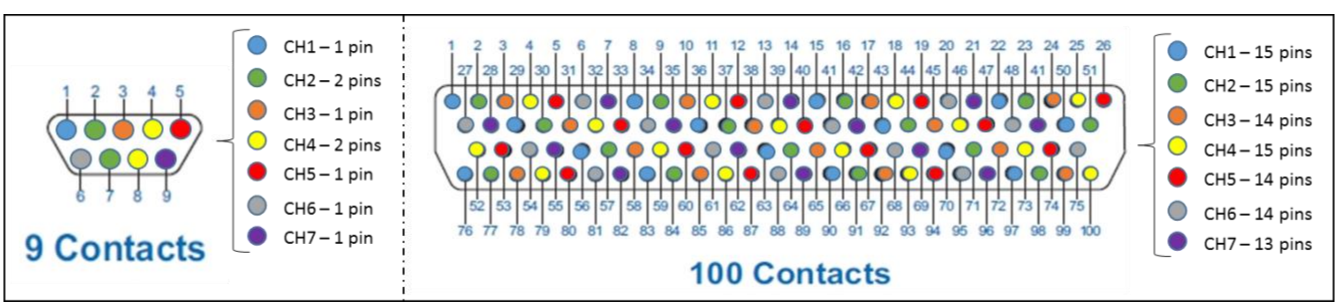

Figure 2. Pin-to-Channel Wiring Schemes for 9-Contact and 100-Contact Connectors

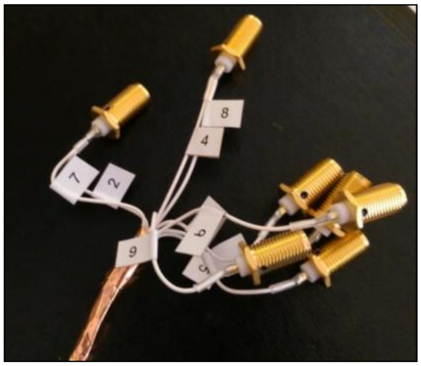

Figure 3. Monitored Side of 9-Position Glenair Connector Set. Pins 7 and 2 are tied together, as are pins 8 and 4.

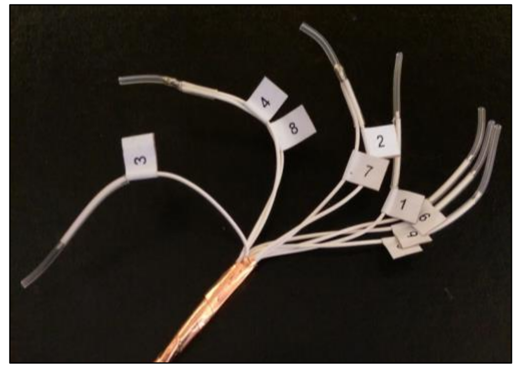

Figure 4. Insulated (Floating) Side of 9-Position Glenair Connector Set. Again, Pins 7 and 2 are tied together, as are Pins 8 and 4.

After the connectors were assembled, they were fixed to an aluminum mounting plate. Additional aluminum plates served to clamp the connectors to the mounting plate (Fig. 5). Again, the purpose of these tests was to isolate the IESD response of the connectors, which required prevention of charge deposition in the wiring. Therefore the aluminum clamping plates were also intended to shield the connector wiring insulation from high energy electrons.

Two thermocouples were fixed to the mounting plate with conductive-adhesive aluminum tape, and one more thermocouple was installed on the neck of a backshell between the aluminum plate and the backshell neck itself. The thermocouple locations are called out in Fig. 5.

The assembly was then mounted in the vacuum chamber against a cold plate. The cold plate is an aluminum plate through which liquid nitrogen (LN2) is fed to regulate the temperature of the sample. There was a hole in the center of the plate to accommodate a faraday cup for in situ current measurement. The pin and thermocouple leads were routed to the sides of the plate where they were connected to feedthrough cables and brought out of the chamber. The pin signals were then terminated with 50 Ω resistors, and the voltage across these resistors was probed and monitored by two nearby scopes (Fig. 6 and Fig. 7). The scopes themselves were monitored and controlled remotely in a nearby room via DVI and USB, respectively. Aluminum plates were installed in the chamber to shield the feedthrough wiring from the beam (Fig 8), then the chamber was closed and pumped down to approximately 10^{-7} Torr. See Fig. 9 for a diagram of the complete test setup.

III. Test Conditions

The test was performed at the Dynamitron facility at JPL. The Dynamitron is a continuous beam electron accelerator capable of beam energies of 600 keV to 1.7 MeV with current densities from 3 pA/cm^2 to 16 nA/cm^2. Ideally, the test would reproduce the charge and energy deposition rates expected in the sample during flight. However, because the Dynamitron produces a unidirectional, monoenergetic beam, this is not possible in general. By tuning the beam energy and flux, the charge or energy deposition rate can be matched at up to two depths in the sample. Because the effect of the energy deposition rate depends on material properties that were not known, the

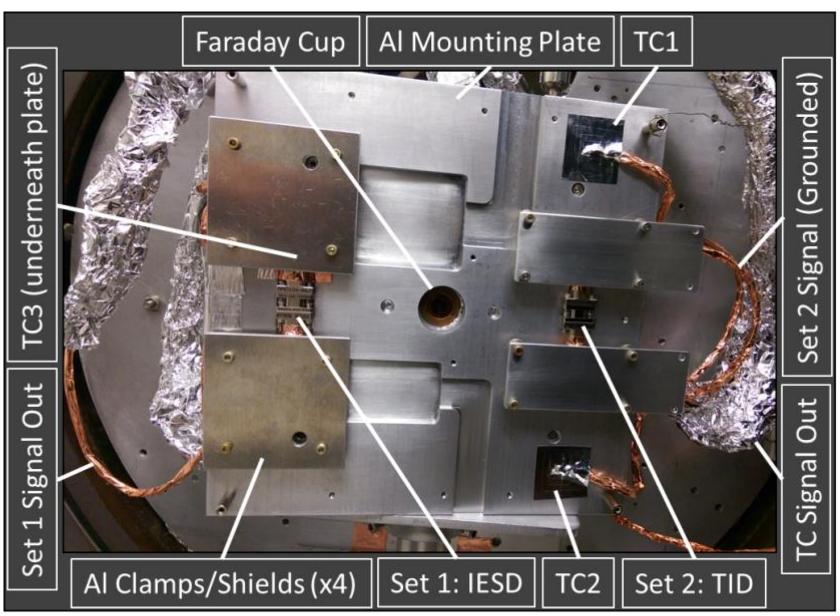

Figure 5. 9-Position Glenair Samples on Mounting Plate with Thermocouples. Assembled with Chamber before Chamber Beam Shields Installed.

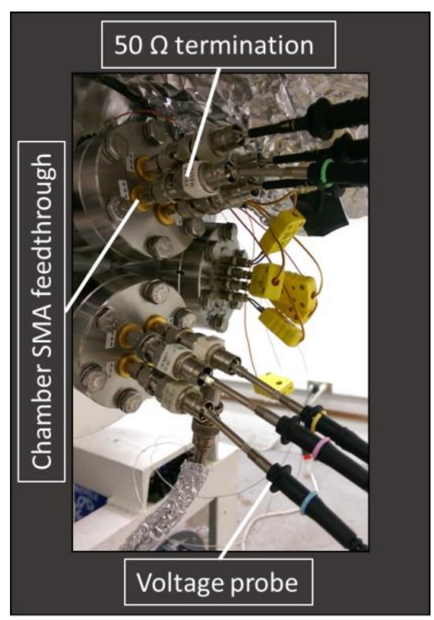

Figure 6. Exterior of Chamber Feedthrough with Terminations and Probes Installed

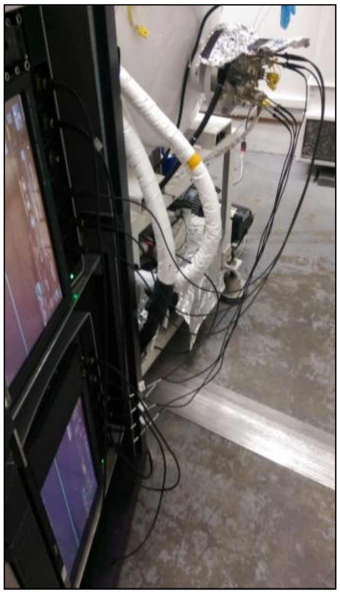

Figure 7. Probe and Scope Setup

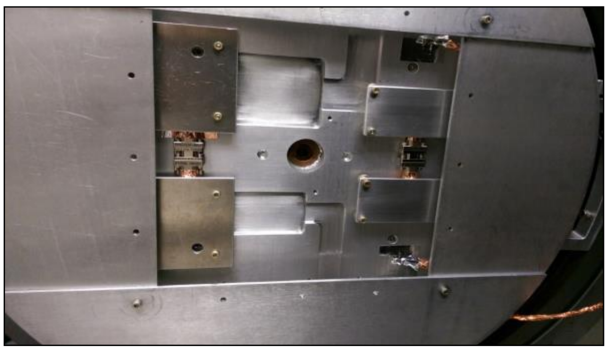

Figure 8. Samples Mounted in Chamber with
Aluminum Beam Shields Installed.

beam was tuned to match the charge deposition rate at the two depths of highest charging rate.

Test conditions were determined using TIGER 1D radiation transport tool. The connector geometry was approximated in 1D, and was simulated in the Europa IESD design environment to determine the expected charge deposition rate profile expected in the connector during flight. The two depths of highest charging rate were identified, then a series of unidirectional, monoenergetic beams were simulated to determine what Dynamitron beam energy and flux would most closely match those rates. The energy was calculated to be 1.7 MeV and the flux was calculated to be 6 pA/cm^2; however, the test was run at an accelerated 4x condition, so the test flux was increased to 24 pA/cm^2. The 4x accelerated condition reduces the exposure time from 40 hours as specified in the IESD Design Environment, to 10 hours during testing. 10 hour tests are more practical and affordable than 40 hour tests, and previous IESD testing of Europa cabling showed the 4x condition to be similar to, and slightly conservative relative to, the 1x flight condition [J. Chinn et al, unpublished]. Test conditions are shown in Table I.

The temperature of the cable during testing was controlled via a cold plate running LN2 behind the sample. A temperature controller started and stopped the flow of LN2 through the cold

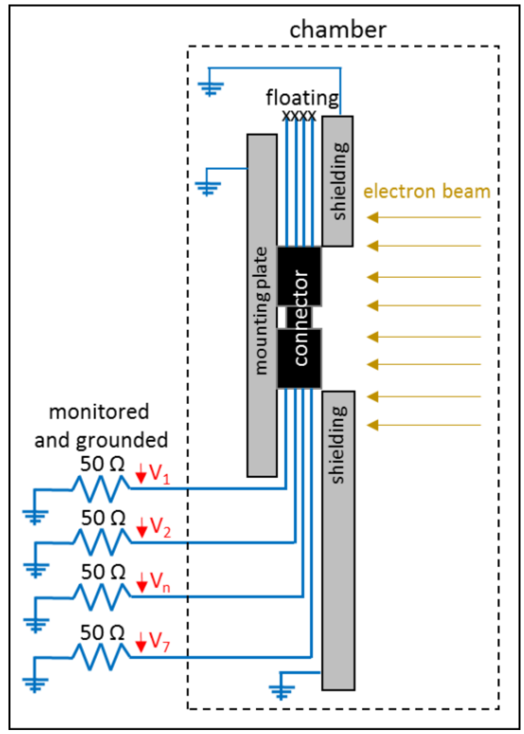

Figure 9. Diagram of the Test Configuration.
4 Channels Shown. Actual Configurations have 7 Channels.

plate in order to hold the temperature of the samples between -50 °C and -52 °C throughout the tests. This temperature is the expected temperature of the samples during flight.

Prior to testing, the chamber was pumped down to 10^{-7} Torr and held overnight, during which time the sample was baked for 8 hours at 100 °C. The vacuum was maintained throughout the bake out and tests.

IV. Test Data and Analysis

A summary of the test results is shown in Table II. One discharge was observed in the 9-Position Glenair connector test. Its amplitude was approximately 1.5 V (Fig. 11). Based on the negative response of Pins 4+8, the relatively large positive response of Pin 5, the relatively small positive response of Pin 3, and near-zero response of the other pins, it is suspected that this discharge originated just above and to the right of Pin 4 as shown in Fig. 13, and discharged into Pin 4.

Two discharges were observed in the 100-Position ITT connector, the largest of which had a maximum amplitude of 1 V (maximum discharge shown in Fig. 12). No discharges were observed in either the 9-Position ITT or 100-Position Glenair connectors. Only discharges greater than 250 mV were recorded (200 mV in the 100-Pin ITT case), and a trigger on any channel would trigger all channels on both scopes.

Table I. Test Conditions

Energy (MeV)	*Flux (pA/cm^2)*	*Temperature (deg C)*	*Duration (hrs)*
1.7	24	-50 to -52	10

TABLE II. TEST RESULTS SUMMARY

Connector Type	***Test Date***	***Number of Discharges***	***Largest Discharge Amplitude (V)***	***Energy (J)***	***Eq. HBM V - [V,E] (V)***		***Max HBM V (V)***	***Factor of Safety = 2***	***HBM Class Rating***
9 Pin Glenair	11/17/2016	1	1.5	2.14E-10	45	12	45	90	1A
9 Pin ITT	11/22/2016	0	-	-	-	-	-	-	1A
100 Pin Glenair	12/07/2016	0	-	-	-	-	-	-	1A
100 Pin ITT	12/14/2016	2	1	3.39E-10	30	14	30	60	1A

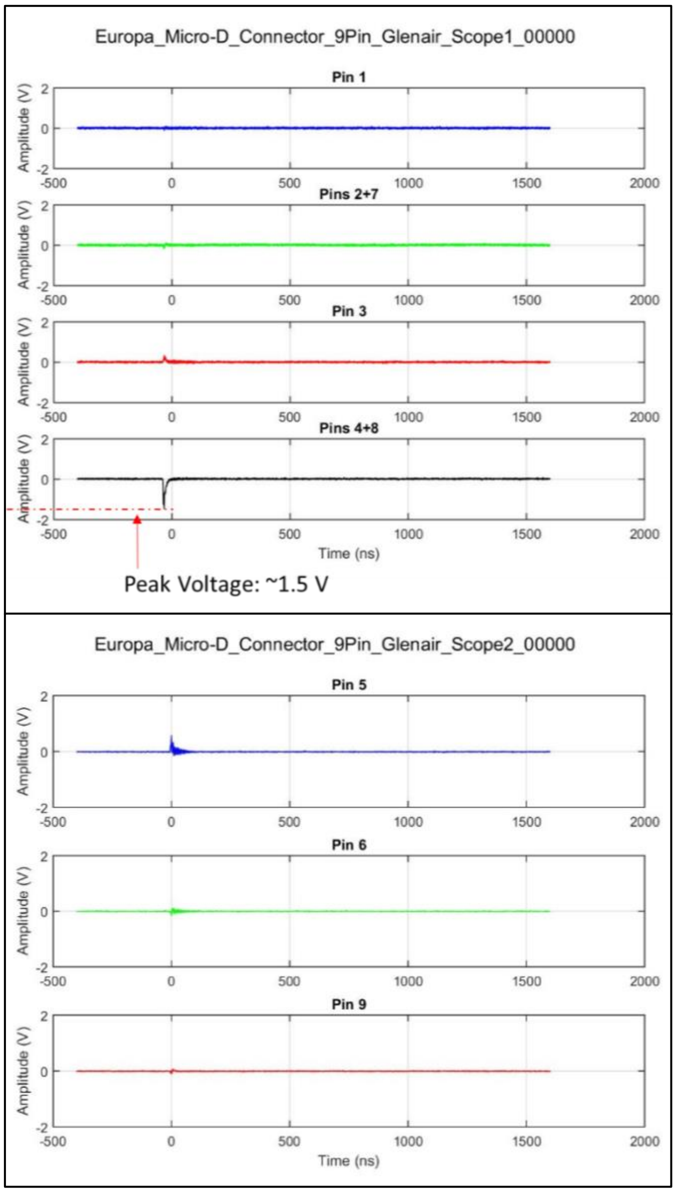

Figure 11. 9-Position Glenair Max Discharge

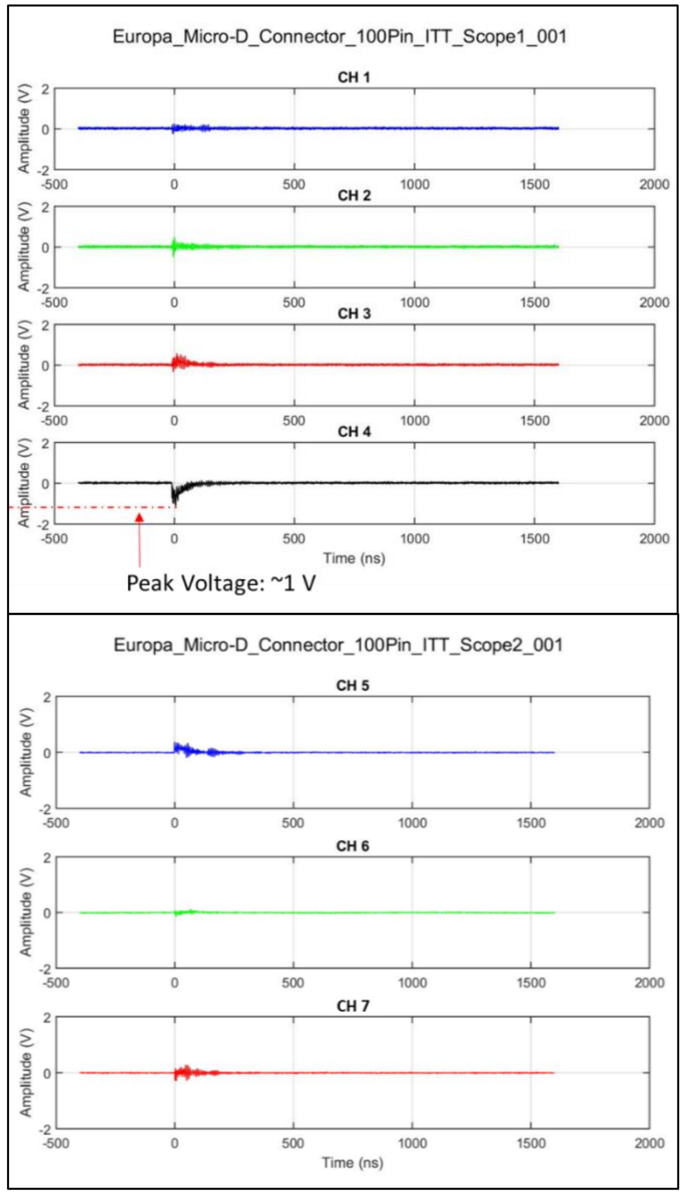

Figure 12. 100-Position ITT Max Discharge

A few columns in Table II deserve additional explanation. Column 5 “Energy (J)” lists the energy released into the termination resistor by the largest discharge. This is calculated by integrating the power dissipated in the termination resistor over the duration of the discharge:

$$E = \int \frac{V(t)^2}{R} dt \quad (1)$$

Where R = 50 Ω, V is the voltage measured across the termination resistor as a function of time, and the integral is evaluated over the duration of the discharge pulse.

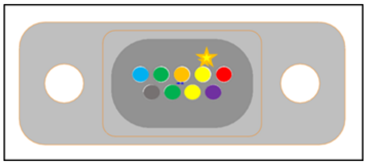

Figure 13. Suspected Discharge Location for Pulse Shown in Fig. 11. Star indicates Location.

Columns 6 and 7 list the Human Body Model (HBM) voltage of the discharge for an equivalent voltage calculation and an equivalent energy calculation. The Human Body Model of MIL-STD-883D Method 3015.7 is a standard for classifying the susceptibility of electronic parts to discharge pulses and is specified in detail in [DOD, 2006]. In brief, during a HBM assessment, electronic parts are connected to a circuit consisting of a 100 pF capacitor in series with a 1500 Ω resistor. The capacitor is charged to a specified voltage, and then discharged into the test part through the 1500 Ω resistor. The charged capacitor voltage (HBM V) that causes the test part to fail is recorded, and a HBM class rating is assigned to the part according to that voltage. Most parts used in JPL hardware are classified according to the HBM standard so it is useful to convert IESD pulses into equivalent HBM voltages and class ratings.

During the test, the voltage drop across the 50 Ω termination (load) resistor was measured. If it is assumed that this measured voltage drop instead came from a standard HBM circuit (described in the previous paragraph), the hypothetical HBM voltage of the capacitor in that circuit can be calculated. Because the profile of the IESD pulse is not necessarily the same as that of the HBM circuit pulse, the energy of the IESD pulse and the voltage of the IESD pulse may correspond to different capacitor voltages in the HBM circuit. Therefore, the equivalent HBM capacitor voltage is calculated using both an equivalent voltage method and an equivalent energy method. In a conservative approach to the analysis, the worst-case of these two methods is used to classify the discharge. This value is listed in column 8.

Column 9 applies a factor of safety of 2 to the worst-case value listed in column 8. This factor of 2 is standard practice at JPL for this type of test and is intended to increase reliability. Column 10 lists the minimum HBM class rating necessary for electronics to safely interface with the corresponding connector.

All four connectors tested are determined to safely interface with HBM Class 1A rated electronics.

It was discovered after completion of the tests that an unintended factor of 2 was included in the flux calculations, making the subject tests conservative. The flux and fluence were twice their intended values.

V. CONCLUSIONS

Four M83513 Micro-D connectors were tested to determine their IESD threat to electronics onboard the planned Europa Clipper spacecraft. The connectors were:

- 9-Position Glenair
- 9-Position ITT
- 100-Position Glenair
- 100-Position ITT

The connectors were exposed to an electron beam calibrated to induce in them a charging profile as similar as possible to that expected in the IESD design environment. The voltage of discharge pulses in the connectors were recorded and HBM voltages and class ratings were assigned to each connector.

All four connectors tested were determined to safely interface with HBM Class 1A rated electronics. The HBM Class 1A rating may be extended to other Micro-D connectors provided that they:

- Use the same dielectric material within the connector
- Have a minimum shielding thickness (housing and backshell) at least at thick as those in the tested connectors
- Have a maximum dielectric thickness (greatest distance between any point in the dielectric and nearest ground) at most as thick as those in the tested connectors

Connectors that do not meet these criteria will need to be evaluated separately.

ACKNOWLEDGMENT

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