# ESD challenges for NASA Astronauts in upcoming missions.

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**Introduction:** As NASA begins to send humans back to the moon and onto Mars, there are numerous challenges for future astronauts concerning ESD issues. One such issue of concern is the replacement of ESD sensitive parts and components while in the vacuum of space. Astronauts working outside of the International Space Station or Space Shuttle do not have access to common ESD mitigating techniques such as air ionization, electrical grounding, antistatic sprays, etc… Therefore, each ESD concern must be addressed prior to launch if possible in order for mission success.

One recent example examined by the Electrostatics and Surface Physics Laboratory (ESPL) at the NASA Kennedy Space Center in Florida was to assess the ESD hazards associated with the changing out an electronics board for an upcoming Hubble Space Telescope service repair mission. Since astronauts have never touched or exposed an electronic circuit board while in the vacuum of space, engineers were not sure what possible ESD concerns might exist. It was the role of the ESPL to identify those concerns and mitigate the risks if possible.

Current models such as the Human Body Model, Charge Device Model and the Machine Model do not address the ESD effects of highly charged ungrounded, insulators in vacuum. Therefore, the first measurements were taken to quantify the large electric fields generated on highly resistive materials such as the space suits when triboelectrically charged against common materials found within the payload bay of the orbiters. These tests would guide the astronauts as to which materials they should and should not come in contact with prior to board replacement. A second set of measurements were designed to assess whether discharges of any kind could result from contact with a ground probe with a highly charged insulator surface in vacuum. Such discharges, which are called brush discharges in air [1], would be sources of EMI which is well-known form of stress on sensitive components.

Tests were performed using a modified triboelectric test standard used at Kennedy Space Center for over 40 years [2]. This device, called a Tribot, shown in Figure 1 is able to rub two materials together and measure the surface potentials of both materials afterwards. The first material is attached to a rotating wheel that approaches and rubs against a second material for 10 seconds [Figure 1(a)]. The second material is held in place using a rod attached to the wheel assembly. After rubbing, both materials separate which allows the second material housed inside a special holder to fall down [Figure 1(b)]. The surface potentials of both materials are simultaneously measured for long periods using JCI (John Chubb Instruments, Inc.) fieldmeters [Figure 1(c)]. Finally, a grounded brass probe of ¾ inches diameter approaches the charged surface in order to extract any surface charge [Figure 1(d)]. This charge is monitored using a Keithley 6514 Electrometer. In order to get the correct values of charge exchanged the probe must be housed inside a Faraday cage before and after contacts with the test material.

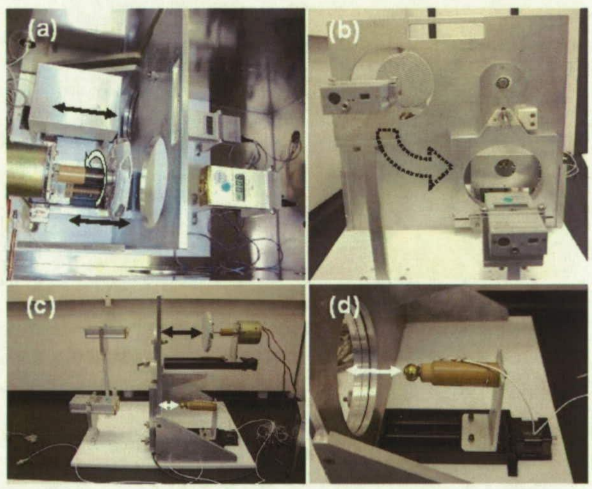


**Figure 1.** (a) The top view of the Tribot within the vacuum chamber. (b) The front view. (c) The side view. (d) The discharge electrode shown without the Faraday housing.

The materials tested included RTV (room temperature vulcanized) silicone used for the astronaut gloves; Ortho fabric (Kevlar®, Gortex® and Nomex®) and PTFE or Teflon® fabric, the space suit outermost materials; and a variety of payload bay materials including insulating materials such as floroethylenepolypropylene (FEP), as well as grounded conductors such as Chromate. Tests performed at vacuum conditions ($10^{-5}$

torr) are compared with those in low humidity ambient conditions.

**Results and Conclusions:** An excellent representation of the results is shown below in Figure 2. The highest recorded surface potential reading on space suit and glove material is presented against the materials they are expected to come in contact with. The top graphic shows the results for low humidity testing in air while the bottom graphic shows the high vacuum results. We note that the highest charge levels recorded were +20 kV for RTV rubbed with FEP and -22.6 kV Teflon® fabric rubbed against the grid side of Ortho. In both cases the charge dissipation or charge decay times were quite long and high surface potentials could easily last for several hours. None of the materials tested exhibited short decay times except for a well-grounded Ortho grid. Thus it should be assumed that all insulators will hold their charge for long periods of time.

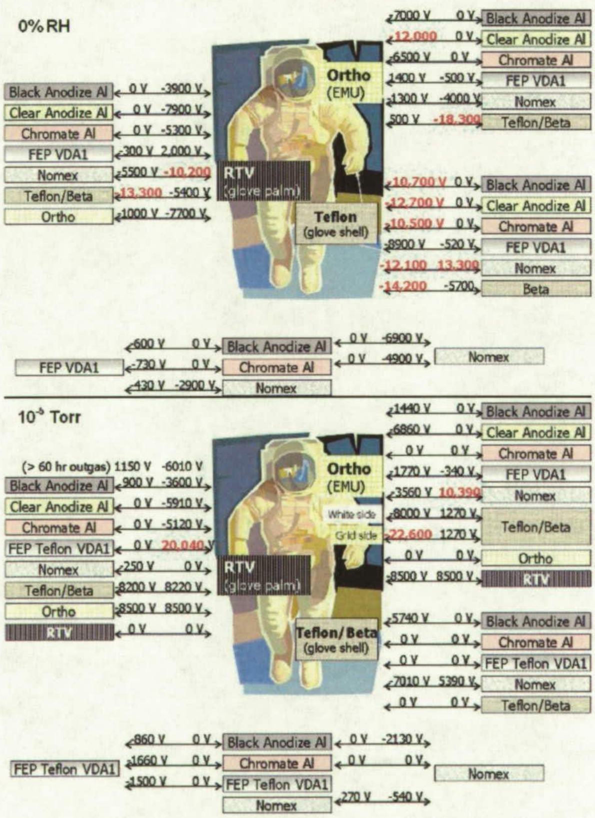


**Figure 2.** (top) Summary of test results for low humidity conditions at atmospheric pressure. (bottom) Summary of high vacuum test results.

Like materials were not able to charge each other under high vacuum conditions. This is completely opposite of what happens in air. Although not shown, data taken on materials in air show that like materials will electrostatic charge upon contact and separation. For example Vectran™ was able to charge up to -13.8 kV when rubbed against another sample of Vectran™ which is typical of insulator-insulator contact charging in air. Teflon®, Ortho, Nomex® and RTV all performed the same way by not self-charging under high vacuum conditions. Clearly the transfer of ions which dominates insulator-insulator contact charging in air is not present under high vacuum conditions.

Similarly, grounded metals such as Chromate which can deposit large amounts of charge on insulator surfaces in air, were unable to charge Teflon®, Nomex® and Ortho in high vacuum. However, Chromate was able to charge RTV and FEP. We do not know the amount of charge deposited onto the metals since they are grounded conductors and cannot be read using the fieldmeter from the backside 10 cm away.

Finally, for all materials tested, there were no recorded brush discharges under high vacuum conditions using the 3/4″ diameter grounded metal probe. All charge measurements were below the noise level of $10^{-12}$ pC. Unlike discharge testing in air which can be as high as several nanocoulombs, charge insulators in vacuum conditions did not discharge to a grounded metal. Thus the brushlike discharges that occur in air must be solely due to air breakdown and not emission from surface ions or electrons. This is opposite from highly charged metals in vacuum which can discharge due to field emission as electrons overcome the work function. Insulators without the benefit of free electrons cannot discharge and thus it may be impossible to form an EMI event caused by triboelectrically charged insulators in vacuum.

The results can now be used to allow engineers to choose between materials that should be used in conjunction with the space suit materials and which ones should not. All measured charge decay times are quite long and thus waiting for charge to dissipate is not an adequate mitigation strategy. Thus sensitive components must be shielded from large DC electric fields but they may not require EMI shielding which is commonly caused by the discharge of insulators to grounded surfaces.

**References:**

1. Britton, L.G., *Avoiding Static Ignition Hazards in Chemical Operation*. 1999, New York, NY: American Institute of Chemical Engineers.

2. Finchum, A., *Standard Test Method for Evaluating Triboelectric Charge Generation and Decay*. 1998, Kennedy Space Center Test Standard MMA-1985-98 (Revision 3).

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**14. ABSTRACT**
Electrostatic charging of insulators is well known to pose potential threats to electronic systems under terrestrial systems. We were asked to evaluate potential hazards associated with replacement of an electronics board in the vacuum of space during the upcoming Hubble Service Repair mission in September 2008. A device called a "tribot" was built to simulate triboelectric charging of several insulators that are capable of contact charging against astronaut's gloves and suit materials. Materials were evaluated as the extent of not only the magnitude of electric fields generated by the frictional action, but also any resulting discharge which would be a source of EMI. Experimental results are quite surprising and unexpected when compared with tests performed under ambient conditions under dry and humid air.

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