JUPITER ICY MOONS ORBITER
(An element of Project Prometheus)
LESSONS LEARNED NEWSLETTER

Exploring the habitable water worlds of Jupiter — Callisto, Ganymede, and Europa

JIMO Lessons Learned Newsletter

August Issue

The JIMO Lessons Learned newsletter provides a short synopsis of lessons learned that have potential benefit to the JIMO Project Team. Web links are provided to take the interested reader to the detailed article describing the situation and measures one should take to prevent or limit similar occurrences. The lessons are gathered from several sources including, but not limited to, the NASA Lessons Learned Information System (LLIS) that contains lessons learned from over forty years in the aeronautics and space business. The JIMO Lessons Learned Newsletter can also help you share your lessons learned. To submit a lesson learned contact Vyga Kulpa at 256-544-1383 or e-mail Vyga.Kulpa@nasa.gov.

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Cone Angle Anomaly in Canopus Star Tracker

Source: LLIS Database Entry: **0384**
Submitted by: K. Flynn / JPL

Description of Driving Event

Shortly after Voyager I Jupiter encounter, an anomaly occurred in the cone angle circuitry of the Canopus Star Tracker (CST). The cause of the problem was determined to be a base-emitter or collector-emitter leakage in a transistor circuit that drives the cone angle deflection plates. This problem was duplicated in a spare CST.

The most probable cause of the leakage path in the transistor circuitry is believed to be two-fold;
1) a Delrin insulating sleeve decomposed after exposure to Jupiter radiation fields and
2) development of a high resistance path through the Delrin by electrostatic discharge from an ungrounded tungsten radiation shield box.

Lessons Learned

1. Charging of internal elements to as high as several hundred volts can occur due to radiation fields.
2. Exposure to ionizing radiation can degrade spacecraft materials.
3. Availability of spare hardware is extremely useful in verifying in-flight failure modes.

Recommendations

1. All metal shielding boxes and metal masses on circuit boards should be grounded even though they are inside equipment housings.
2. All materials that could be exposed to ionizing radiation should be analyzed/ tested to insure that unacceptable degradation will not occur.
3. A set of spare hardware should be maintained to enable analysis of in-flight failures and validation of proposed corrective actions.

Link for further information - http://llis.nasa.gov/llis/cgi-push/view_lesson.cgi?num=0384&kw=database

Need for Early Reference Vehicle Conceptual Designs

Source: NGLT LL Report – R3

Driving Events

In the 2nd Gen RLV Program, the prime contractors developing the vehicle architectures held their proprietary design information very close. Subsystem-level technology developers, e.g., those focused on propulsion and thermal protection systems (TPSs), were forced to derive a broad set of performance requirements due to the lack of a focused vehicle architecture. It was difficult for the subsystem technology developers to determine an appropriate set of environments and performance/life cycle requirements.

Although NASA attempted to generate top-level requirements documents, a reference mission, and vehicle architecture, the information flow was slow and, in many cases, non-existent. In this case, the sub-element manager was forced to piece together design information from various prime contractors to arrive at a preliminary set of requirements encompassing all known vehicle architectures and environments.

Lessons Learned

System-and subsystem-level requirements should be developed early in the design phase to ensure a truly meaningful subsystem design and testing phase. Timely requirements flowdown from the prime contractors and lead NASA organization(s) must be improved. The late establishment of program-level requirements requires project restructuring, causing cost over-runs and schedule slips due to constant contract redirections.

Recommendations

A reference vehicle architecture, or clear performance specifications, should be in place prior to the initiation of technology development. A clearly defined process is required for both generating and fl owing down system requirements (e.g., associated flight environments) to the subsystem level.

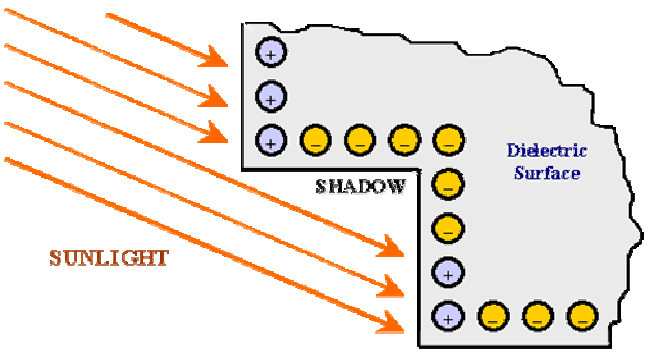
Space Charging of Composite Structures

Source: LLIS Database Entry: **1330**
Submitted by: R. Frederickson/ D. Oberhettinger - JPL

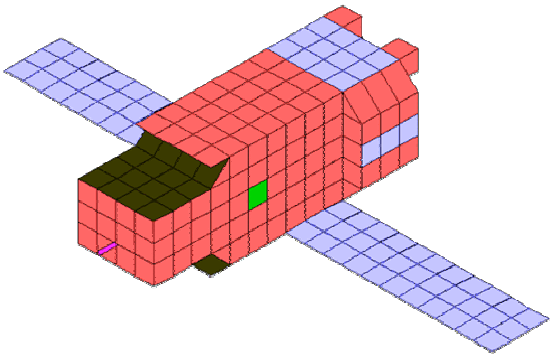
Abstract

Although graphite/polymer composites were thought to be immune to space plasma charging because the material is electrically conductive, it may actually retain a significant charge in places where the non-conductive resin pools.

Use a non-contact charge measuring device when testing the material's electrical resistance, and consider spacecraft designs that can accept worst-case electrical discharges.



Differential Charging due to Self-shadowing



NASA Charging Analysis Program (NASCAP) representation of FUSE satellite

Description of Driving Event

Differential electrical charging of the spacecraft surface due to its interaction with charged plasma particles may present unrecognized hazards with non-conductive surface materials such as non-metallic and ceramic-metallic composites. Although graphite/polymer composites were thought to be immune to space plasma charging because the material is electrically conductive, it may actually retain a significant charge. Laboratory testing with multi-kV electron beams has found substantial charging to occur.

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Space Charging of Composite Structures *(Continued from Page 4)*

Spacecraft structures made of graphite/polymer composites have proven capable of significant weight savings while maintaining structural performance requirements. Their excellent thermal performance has led to applications in spacecraft solar arrays, radiator panels, space telescope structures, and mirrors. For these reasons, this material is widely used in the structural components of the Space Interferometry Mission (SIM) spacecraft.

A surface resistance measurement of graphite composites made using an ohmmeter and flat probes would likely show zero resistance. The individual graphite fibers that penetrate the surface provide the conductive path between the probes. However, the non-conductive cyanate ester resin can be shown to accumulate voltage potentials in excess of 2000 volts when exposed to a wide-angle electron beam. Preferential charging occurs at locations within the composite matrix where the weave permits the resin to pool.

References: A flash animation of spacecraft charging and its effects may be found at http://www.eas.asu.edu/~holbert/eee460/spacecharge.html

Lesson Learned

Surface resistance measurements of a non-homogeneous composite material may not accurately characterize the material's susceptibility to surface charging.

Recommendations

Take precautions where any composite materials (such as graphite cyanate ester or epoxy resins) are used in exposed exterior spacecraft surfaces, and where flight electronics or other flight equipment is susceptible to degradation or damage from radiated or otherwise coupled electrostatic discharge (ESD) energy:

1. Use a non-contact charge measuring device when testing the material's electrical resistance under expected mission worst-case space plasma environment conditions.
   a. Conduct the first test as a measure of resistance in a vacuum, and use an electron beam to characterize the material's surface and in-depth ability to hold an electrical charge.
   b. If the charge does not bleed away, the material's resistivity is too high for analysis and the material may accumulate a potentially damaging charge in space. If, however, the charge bleeds away in a measurably short time, the material may be characterized and the potential for damage may be analyzed.

2. Results of such testing and analysis may warrant consideration of spacecraft designs that can accept worst-case electrical discharges. This may include pulse filters, the use of alternative materials and coatings, or methods to improve the ESD bleed path on the composite surface.

Provide Early, Comprehensive Test Facility Needs Definition

Source: NGLT LL Report – P5

Driving Events

In an effort to reduce duplicity and cost, NASA has evolved and consolidated its test facilities over the past 10 years. This reduction in duplicity makes it unlikely that similar facilities will be available for "fly-offs" required under a competitive environment. Additionally, test facility investment and sustainment is required to ensure that the facilities remain in a state of readiness to support program/project objectives. Relevant work in such facilities ensures retention of staff expertise for safety and for effective real-time management of the testing process. As an example, an independent assessment performed by the ARES Corporation determined that the test facilities available for RS-84 component and prototype testing were insufficient. In addition, during 2003, NGLT unsuccessfully attempted to execute multiple test programs at the Stennis Space Center's (SSC's) E1 Test Facility. These included the Integrated Powerhead Demonstrator's (IPDs) Oxidizer Turbopump (OTP), Fuel Turbopump (FTP), RS-84's Battleship Preburner (BSPB), and TR-107's Preburner (PB)/Thrust Chamber Assembly (TCA). Ultimately, the TR-107's PB/TCA testing was removed from the contract due to limitations in facility capability and capacity.

Lessons Learned

The processes that produce, maintain, and sustain test facilities—especially unique and high-energy facilities—are not as dynamic as the programs or projects they support. Typically, investments must be made long before the anticipated project need. Programs or projects have not been front-loaded to support the required facility build-up and therefore, have suffered from either a complete lack of facility capability or a severe schedule impact required to make ready facility systems. "Core" facilities should be identified, upgraded, and sustained to ensure that project formulation is not disproportionately driven by the available facilities. Limiting the amount of competition may be required if duplication of test facilities is prohibited. Detailed evaluation of test facility capabilities and capacities should be performed prior to contract negotiations. The evaluations should be performed with visibility into existing projects and pending contract awards that could impact planning for such test facilities.

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Provide Early, Comprehensive Test Facility Needs Definition *(Continued from Page 6)*

Recommendations

Limit test projects if required facility systems are not available. Avoid overly optimistic phasing of test facility projects and rely more heavily on historical capabilities. Allocate funding, as necessary, to allow for construction or modification of back-up facilities for mission-/schedule-critical tests. During proposal evaluation, incorporate a process/procedure for evaluating the test requirements against known capabilities and capacities. Verify that existing and future test projects are considered along with built-in contingencies to reduce the schedule risks associated with overlapping tests.

PREVIOUS LESSONS LEARNED (JIMO LL Newsletter Articles)

Avionics
ESD: An Enduring and Insidious Threat to Flight Hardware - NASA LLIS: **1317**
Commercial-Off-The-Shelf (COTS) Electronic Hardware Susceptibility to Radiation – NASA LLIS: **1333**

Communications
TDRS-H S-Band Multiple Access Antenna Performance Shortfall – NASA LLIS: **1180**

Instrumentation
Guideline for Developing Reliable Instrumentation for Aerospace Systems – NASA LLIS: **0761**
Magellan Star Scanner Unit False Star Sightings - NASA LLIS: **0269**

Management & Integration
Comet Nucleus Tour (CONTOUR) Mishap Investigation - NASA LLIS: **1385**

Operations
Emergency Response Planning Must Consider Radiological Hazards – DOE CLL Database: 2002-RL-HNF-**0018**

Propulsion
DS1 ION Engine Shut-Down Anomaly - NASA LLIS: **0639**

SUGGESTIONS SOUGHT

Your suggestions are valuable and will help make this a better communications tool. Submit your ideas and comments to Bruce Funderburg at Bruce.Funderburg@msfc.nasa.gov

LESSONS LEARNED DATABASES

- NASA Lessons Learned Information System (LLIS) – http://llis.nasa.gov
- JSC Lessons Learned Database – http://iss-www.jsc.nasa.gov/ss/issapt/lldb
- Flight Programs and Projects Directorate Lessons Learned Database (FPPDLL) – http://eo1.gsfc.nasa.gov/miscpages/fppd-ll-database.html
- EOS, the Earth Observing System – http://eos.gsfc.nasa.gov/eos-ll/index.html
- NASA Technology Portal – http://nasatechnology.nasa.gov/?ntpo=1&cfid=90684&cftoken=75170853
- Department of Energy Corporate Lessons Learned Database - http://tis.eh.doe.gov/ll/listdb.html