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

July 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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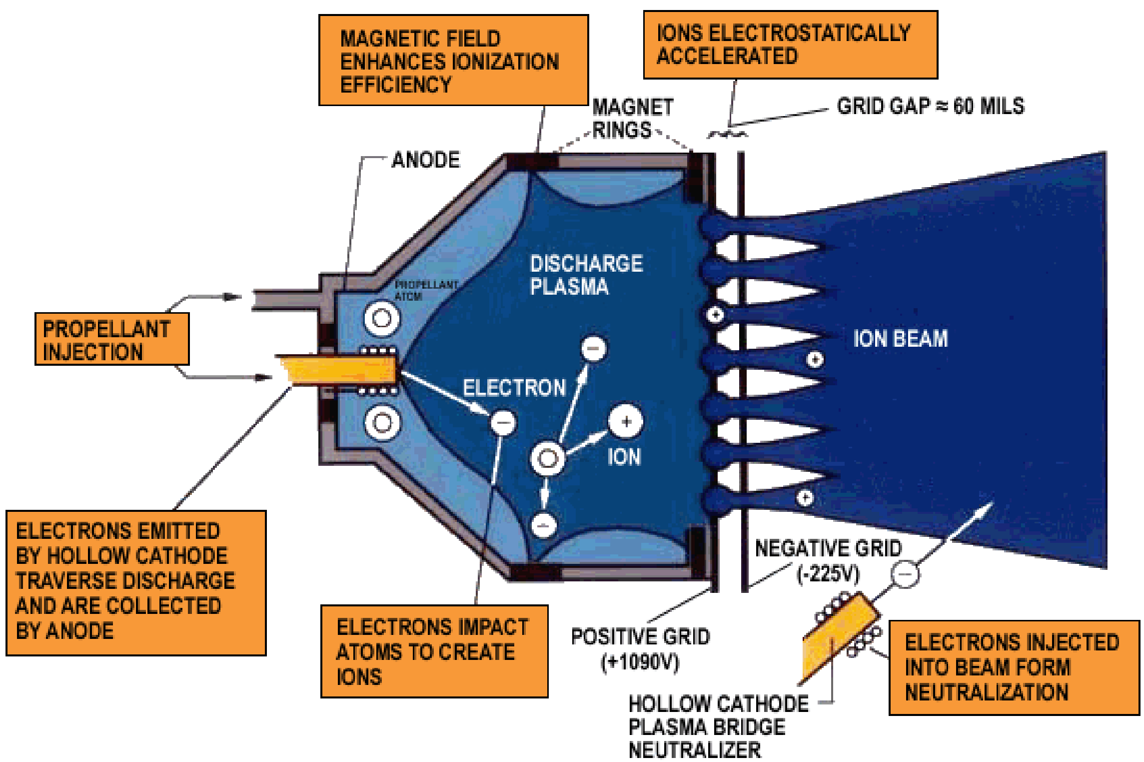
THIS MONTH:

<u>DS1 ION Engine Shut-Down Anomaly</u> (11-02-99)

[Propulsion]

Source: NASA LLIS Database Entry: **0639**
Submitted by: David J. Oberhettinger /JPL (818-542-6960)

Abstract: Shortly after the successful demonstration of solar electric propulsion (SEP) aboard Deep Space 1 began, the xenon ion engine shut down unexpectedly-- likely due to a "grid short." Although the engine was later restarted using other procedures, immediate use of a "grid clear circuit" was deemed as too risky. Since grid shorts are likely to occur during future missions that use SEP technology, conduct further study of grid clear circuits and provide a pre-planned operational procedure for detecting and clearing critical anomalies, including SEP grid shorts.



[D]
DS1 Xenon ION Engine

Lesson(s) Learned: The "grid clear" approach to recovery from a solar electric propulsion (SEP) grid short, a failure mode that is likely to occur during an extended mission, requires additional evaluation before it can be judged as an acceptable risk.

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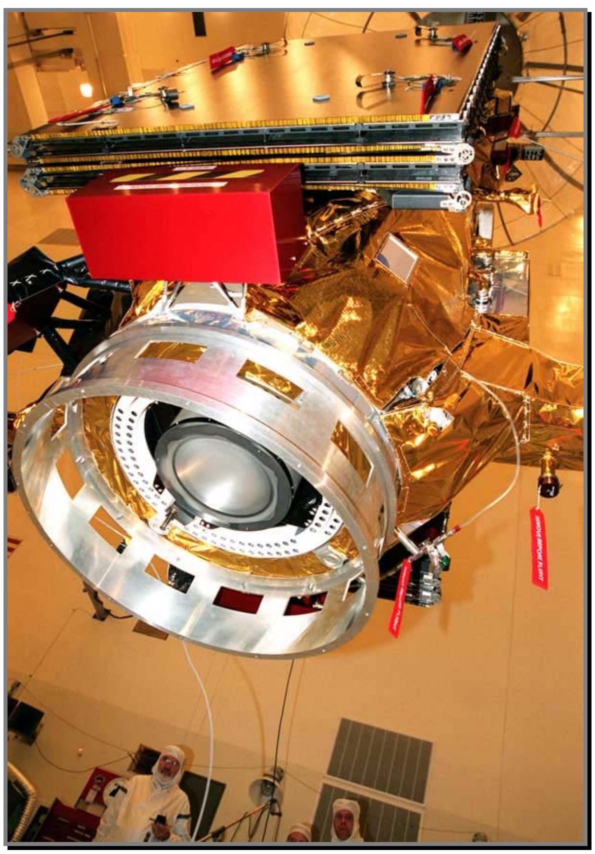
DS1 ION Engine Shut-Down Anomaly *(Continued from Page 2)*

Recommendation (s):

1. Provide a pre-planned operational procedure for detecting and clearing time-critical and mission-critical anomalies, including SEP grid shorts.

2. Perform a study to determine how well grid clear circuits work. The study should identify the amount of current needed to clear grid shorts caused by various materials.

3. Ensure that downlinked data on the operational condition of SEP systems include measurements of the current to the grids, and the voltage between them, to permit in-flight analysis of a possible grid short.



Deep Space 1 is lifted from its work platform, giving a closer view of the experimental solar-powered ion propulsion engine. The ion propulsion engine is the first non-chemical propulsion to be used as the primary means of propelling a spacecraft. Above the engine is one of the two solar wings, folded for launch, that will provide the power for it. When fully extended, the wings measure 38.6 feet from tip to tip.

Emergency Response Planning Must Consider Radiological Hazards (4-03-02) [Operations]

Source: DOE Database Entry: 2002-RL-HNF-0018

Lesson Learned Statement: To ensure adequate preparation and readiness to implement the Incident Command System during an emergency, facilities with radiological hazards must include radiological planning in selection, inventory, and surveillance of emergency equipment; development of procedures; and facility emergency response organization training.

Analysis: The involvement of multiple organizations (e.g., Emergency Preparedness, Operations, Radiological Control, and Environmental) in the management of the Emergency Program was considered a major factor in the inconsistencies identified - including overlapping and unclear roles and responsibilities.

Emergency Program requirements clearly identify comprehensive emergency response program requirements, including selection and management of emergency equipment and materials. Those requirements prescribe that emergency planning and preparation will evaluate postulated and credible facility emergencies considering all hazards, including chemical and radiological, and that those emergencies will be documented in the Facility Hazards Assessment.
Program requirements prescribe that facilities shall select emergency response equipment and supplies based on the results of the Hazards Assessment and that the required equipment will be listed in the Building Emergency Plan (BEP). Facilities are then required to develop routine surveillances, including inventories, of the equipment and materials listed in the BEP. Facilities are also required to provide annual training to ERO personnel (including HPTs) germane to their associated emergency response duties. Training should include facility specific details.

Weaknesses identified during assessments included:

- Radiological emergency kit inventories did not adequately consider the Facility Hazards Assessment and postulated facility emergencies.
- Some facilities relied on another facility for emergency response resources, yet clear understanding between the facilities was not formalized.
- Building Emergency Plans were inaccurate and inconsistent in listing Emergency Response Kits.
- Personnel interviews at the facility indicated many types of response kits are maintained, and although personnel interviewed clearly understood which kits they are responsible for during an emergency, they could not clearly communicate which kits were designated "emergency response equipment" (i.e., required by the Hazards Assessment and listed in the BEP).
- Facilities did not use appropriate rationale to determine when an emergency response kit is needed, and at times, too many emergency response kits were developed and maintained.

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Emergency Response Planning Must Consider Radiological Hazards *(Continued from Page 4)*

- Maintaining kits is resource intensive and facilities commonly keep redundant sets both inside and outside the facility. The number, location, and contents of kits needs to consider the two basic types of emergency scenarios - take cover, and evacuation. Typically, a take cover response co-locates response personnel (HPTs) with their routine-use equipment and materials, and therefore a kit may not be necessary in those areas. Another set of emergency kit(s) is commonly located away from the event scene where personnel would gather/report during evacuation emergency. Contents of those kits may rely upon routine-use equipment without considering the potential inability to re-enter the facility during an emergency.
- Surveillance programs did not clearly and consistently establish kit inventories or prescribe exchanging critical items with shelf-lives.
- ERO personnel (including HPTs) are required to receive annual training germane to their associated emergency response duties [DOE/RL 94-02, 12.2.2.1.3]. HPTs interviewed were not always aware of emergency kit locations or kit contents associated with emergency response. Some HPT's were not aware of facility boundaries defined by emergency response documents, facility specific Emergency Action Levels, or expected actions required to establish habitability of staging areas or other areas.
- Training for Emergency Response Organization - Support Personnel targets general employees and the operation of the Incident Command System.
- It includes only some of the information essential for HPTs. Facility Orientation, Facility Emergency
- Hazards Information Checklist (FEHIC) training, and newly developed facility specific ERO training did not contain HPT specific information essential or germane to facility specific HPT duties and emergency response.

Recommended Actions: DOE facilities with radiological hazards and Facility Emergency Response Organizations should assess compliance with the following emergency response objectives:

- Emergency equipment and supplies, including kits, are required to be developed as a result of postulated and credible emergencies in the Facility Hazards Assessment:
- Should be minimized
- Should be strategically located in case response personnel are isolated from routine use equipment. Locations should consider expected routes of travel and destinations
- Must be clearly labeled
- Contents must consider both decontamination of personnel and general emergency response surveys and monitoring needs
- Contents must consider radiological equipment identified by DOE/RL-94-02, 11.2
- Must be listed in the Building Emergency Plan (use caution in the level of detail included to avoid setting an audit trap should equipment be moved without updating the plan).
- Must be included in a surveillance program where inventories are listed and routinely inspected for readiness

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Emergency Response Planning Must Consider Radiological Hazards *(Continued from Page 5)*

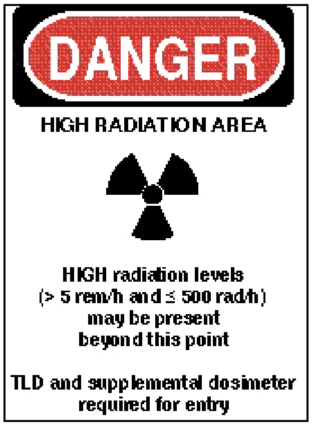
A. Facility Specific Emergency Response Organization Training must:

- Involve Health Physics Technicians
- Define facility specific Emergency Action Levels and radiological factors
- Identify facility specific boundaries and criteria to escalate emergency classifications
- Identify radiological kit locations and contents
- Identify special considerations for equipment locations, such as respirators or backup equipment or instrumentation not stored in kits
- Identify assistance or resources available from other facilities or support groups
- Identify primary and backup decontamination resources and stations
- Identify expected radiological monitoring to ensure habitability of the Incident Command Post, Event Scene, and Staging Areas.

B. Where one facility relies on another facility or group for emergency equipment/resource needs, Memoranda of Understanding should be developed to ensure all involved organizations clearly communicate and understand those relationships.

Watch for these signs!

The symbol above is called a "tri-foil." The tri-foil may be magenta or black on a yellow background and it is the international symbol for radiation.

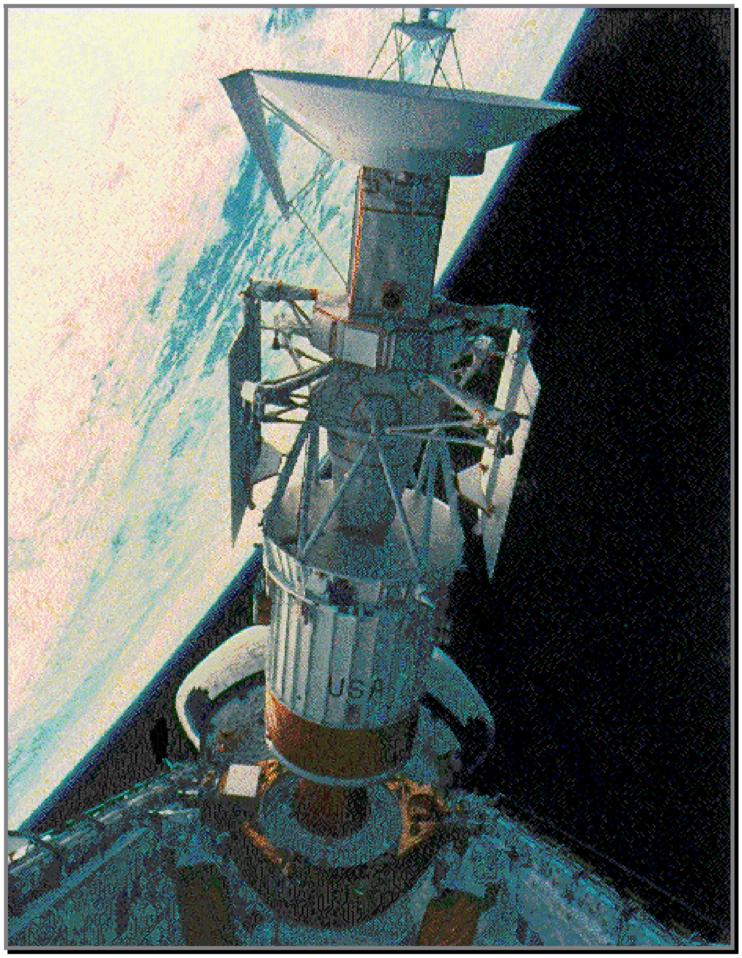


Although the reason why the tri-foil was chosen as the warning symbol remains unclear, its simplicity and distinctive appearance make it a good choice. The fallout shelter symbol is similar in design.

Magellan Star Scanner Unit False Star Sightings

[Instrumentation]

Source: NASA LLIS Database Entry: **0269**
Submitted by: J. O. Blosiu / JPL



Magellan Being Deployed from the Space Shuttle - 05/04/89

Abstract: False star sightings by the Magellan star scanner during cruise to Venus prevented spacecraft attitude updates and occasionally caused false updates. Two causes were identified: 1) high energy solar protons sensed by the star scanner detector, and 2) quartz particles ejected from thermal blankets due to thermal shock. Selection of spacecraft sensors should consider all environmental effects. Consider the tendency of spacecraft materials to shed particles. System design must take into account the limitations of sensor and spacecraft material performance and show that the risk is acceptable.

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Magellan Star Scanner Unit False Star Sightings *(Continued from Page 7)*

Lesson(s) Learned:

1. Spacecraft star scanner detectors can sense high energy solar protons as false stars.

2. Quartz particles ejected from spacecraft thermal blankets cloth, when illuminated by the sun, can be sensed as false stars by onboard detectors.

3. Selection of spacecraft sensors which will be unaffected by mission environments, and selection of spacecraft materials which will not shed particles, may not be fully achievable.

Recommendation(s):

1. Selection of spacecraft sensors should include a consideration of all environmental effects, including all sources of radiation.

2. The selection of spacecraft materials that will be exposed to solar and other environments should include consideration of their tendency to shed particles that would be detrimental to the sensors of the spacecraft's subsystems or instruments.

3. When the above selections cannot be fully attained, then system design must take into account the limitations and show that the risk is acceptable.

Commercial Off The Shelf (COTS) Electronic Hardware Susceptibility to Radiation (11-27-02)

[Avionics]

Source: NASA LLIS Database Entry: **1333**
Submitted by: Michael Doherty / GRC

Description of Driving Event: The Physics of Colloids in Space (PCS) experiment was launched on ISS Flight 6A in April 2001, was activated in EXPRESS Rack 2 on May 31, 2001, and was successfully operated on the International Space Station (ISS) until February 24, 2002. On February 24, 2002, at the onset of a scheduled operational run on ISS, the PCS flight system computer (within the PCS Avionics Section) failed to boot up. On-orbit recovery efforts were undertaken but were unsuccessful. The Avionics Section was removed and brought back on ISS Flight UF-2.

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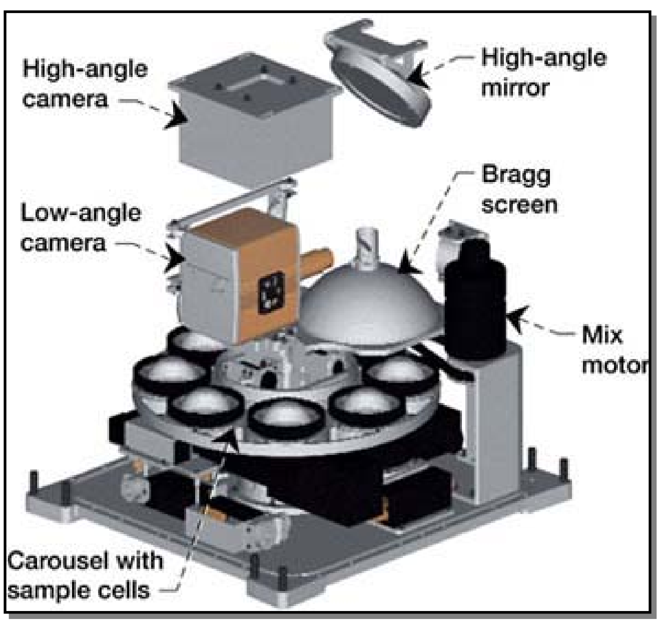
Commercial Off The Shelf (COTS) Electronic Hardware Susceptibility to Radiation *(Continued from Page 8)*

Lesson(s) Learned: A detailed hardware inspection and troubleshooting process was initiated on the Avionics Section. The Project asserts with a measure of confidence that the on-orbit failure of the PCS experiment was due to a Single Event Effect (radiation event) on the Single Board Computer's CMOS (i.e., the battery-backed Random Access Memory). Commercial Off The Shelf (COTS) electronic hardware memory devices deployed on ISS can be highly susceptible to space radiation effects.

Recommendation(s): One response to this lesson is, where vulnerabilities have been identified, to deploy radiation hardened solutions. For reflight, PCS will employ a Programmable Read-Only Memory (PROM) device for storage of Basic Input Output System (BIOS) application and parameters, a technology that is much less susceptible to Single Event Effects than either CMOS or flash memory technologies.
Specifically, the solution being pursued by the Project to reduce the vulnerability of the BIOS is to have the Original Equipment Manufacturer of the original Single Board Computer create a customized BIOS application that will force a boot-up using BIOS parameters stored in Programmable Read-Only Memory (PROM) technology. PROM memory technology is far less susceptible to radiation events than either CMOS or flash memory. The PCS BIOS program and the BIOS parameters themselves will be "burned" into a One Time Programmable-Programmable Read-Only Memory (OTP-EPROM) device. Storing all BIOS parameters in OTP-EPROM will then effectively bypass CMOS as a storage location for the PCS startup parameters and also provide a far less susceptible storage location than flash memory for the BIOS application itself.



Physics of Colloids in Space (PCS) test section features

PREVIOUS LESSONS LEARNED (JIMO LL Newsletter Articles)

Avionics
ESD: An Enduring and Insidious Threat to Flight Hardware - NASA LLIS: **1317**

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**

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

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