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Lesson Learned

Control Blow-By From Pyrotechnic Devices

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Abstract: Significant leakage or “blow-by” of combustion products past the seals within a pyrotechnic cable cutter was detected during pyroshock testing of Mars Exploration Rover. Optical flight instruments would likely have been contaminated had they been attached during the test. Test plans and procedures that involve the firing of pyros should include several suggested measures predicated on an assumption that hazardous blow-by will occur.

Description of Driving Event:

After a Mars Exploration Rover (MER) landed, but before the vehicle could rove the Martian surface, the rover had to be deployed from its compact mechanical configuration. This included the flight software-triggered firing of pyrotechnic cable cutters to sever restraints that had been placed on articulating assemblies. One such assembly was the Instrument Deployment Device (IDD), a mechanical manipulator mounted on the rover that carries the *in-situ* science instruments and positions them upon selected Martian terrain features.

During pyrotechnic shock (pyroshock) and deployment testing of the IDD, a bright flash was observed, accompanied by a loud report (Reference (1)). Examination of a high speed video recording of the test (Figure 1) revealed flame and sparks discharged from the target aperture end of the cutter assembly. This is indicative of excessive leakage or “blow-by” of combustion products past the seals within the pyrotechnic device (pyro). Some blow-by had been noted earlier during testing of similar cable cutters used to release the MER solar array and airbags. Following the IDD incident, all MER test and flight cable cutters were reworked to incorporate a JPL change to the pyro design that significantly reduced the leakage.

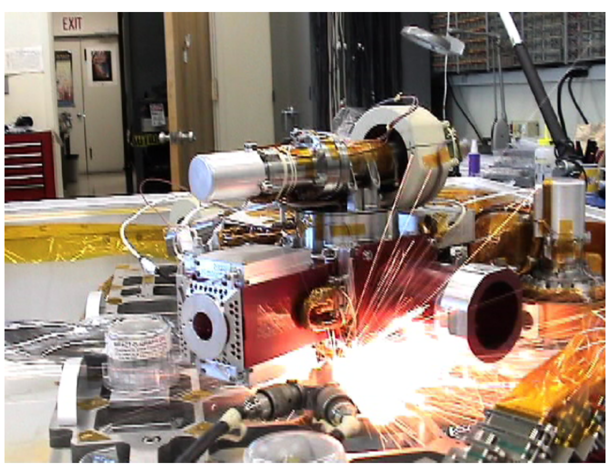

Figure 1. Blow-by from IDD cable cutter during 8/9/02 pyroshock test

+ View Video

Some blow-by (due to design tolerances) is typically considered inherent for pyrotechnic devices, the leakage is difficult to characterize or to measure, and it may be exacerbated by workmanship errors in their manufacture. Leakage is more pronounced at low temperature (Reference (2)). Post-incident examination and testing revealed no damage to the flight hardware, including the Rock Abrasion Tool (RAT) instrument that had been installed on the IDD for the test, and no evidence of contamination on any of the adjacent surfaces. There was no hazard to personnel because the testing was done remotely. However, had the optical flight instruments been attached to the IDD during the pyroshock test, significant contamination might have occurred.

References:

(1) "Excessive Blowby/Leakage During Deployment & Pyroshock Exposure Testing of the [MER] IDD," JPL Problem/Failure Report (PFR) No. Z77205, August 21, 2002.

(2) "Mars Exploration Rover (MER) Pyrotechnic Test Damage," Lesson No.1316, NASA Engineering Network, November 1, 2002.

(3) "Pyrovalve Blow-by May Interact Violently With Propellant," Lesson No.0591, NASA Engineering Network, May 14, 1998.

(4) "VO'75 Pressure Regulator Leakage and Work-Around Procedures," Lesson No. 0420, NASA Engineering Network, May 22, 1978.

Additional Key Words (JPL metadata field): blowby, NASA standard initiators (NSIs); pyrotechnic shock test, test mishap, test failure, test hazard, pyro hazard, system safety

Lessons Learned

Pyro events, including blow-by of particles and combustion products from pyro firing, are not uncommon hazards during flight hardware ground test and mission operations (References (1) through (4)).

Recommendations:

Test plans and procedures that involve the firing of pyros should include measures predicated on an assumption that hazardous blow-by will occur:

1. Always consider pyro venting a possibility and protect sensitive areas of the flight hardware against contamination.

2. The possible venting of particles that could harm critical hardware should always be a concern; consider appropriate protective measures such as moving adjacent hardware and providing barriers.

3. Pyrotechnic testing should always be done remotely so that there is never potential for personnel injury. (See Reference (2).)

4. The placement and orientation of pyro devices on flight hardware should always be done in conjunction with a venting analysis to assure that critical hardware will not be affected during initiation modes.

NEN Metadata Fields

NASA Field Center: JPL

Project: Mars Exploration Rover

Year of Event Occurrence: 2002

Evidence of Recurrence Control Effectiveness: JPL opened Preventive Action Notice (PAN) No. 1459 on April 14, 2006 to initiate and document appropriate Laboratory-wide action on the above recommendations.

Does the Lesson Relate to a Particular NASA Policy, Standard, Handbook, Procedure or other Document? Yes:

NPG 8715.3, "NASA Safety Manual"

From what **phase** of the program or project was this lesson learned captured?: Phase C

Categories that best describe the functional area to which LL applies:

Risk management; Power; Spacecraft and Spacecraft Instruments; Advanced planning of safety systems; Product Assurance; Energetic Materials - Explosive/Propellant/Pyrotechnic; Flight Equipment; Hardware; Parts, Materials, & Processes; Payloads; Risk Management/Assessment; Safety & Mission Assurance; Spacecraft; Test & Verification; Test Article

Mission Directorates: Aeronautics Research
Exploration Systems
Science
Space Operations

Does this Lesson Address a Safety Issue: Yes

Has this lesson been documented previously?: No

Are there any restrictions on the data contained in this submission?: No

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Alt Tags:

Figure 1 is a color photo of the stowed MER IDD, a complex mechanical assembly with the RAT instrument attached to the top, on a bench within a test facility. A bright flare of light issues from beneath the test article, with many sparks shooting in all directions from the flare. It is clear that the test article is taking the brunt of the apparent explosion, and no personnel are visible. The Figure 1 caption includes a link to a video clip from which the Figure 1 photo was extracted. The video shows the above-described test article in a steady state on the bench, until the blow-by event is visible for a fraction of a second.

Reviews (a “comment field” that archives reviewer comments)