National Aeronautics and Space Administration

NASA Case Study Epilogue SCSC-E-0113

So Close Yet So Far: The Jammed Airlock Hatch of STS-80

Final Decision

Neither engineers nor management personnel were able to determine a cause for the failed hatch based on video survey. With no ability to remove the hatch in orbit for further assessment, the Mission Management Team (MMT) decided not to risk damage to the hatch or seals and canceled both extravehicular activities (EVAs). The astronauts, although disappointed, went on to successfully complete all other mission objectives. STS-80 marked the first time two free-flying spacecraft were deployed and retrieved during a single mission.

Figure 4: Engineers continue testing on the interior side of the outer airlock hatch to identify malfunctions. NASA Image

During a post-landing inspection, engineers concluded a faulty actuator assembly was to blame for the malfunction. A new actuator assembly was installed on the orbiter and worked flawlessly. Upon further inspection of the faulty actuator, engineers discovered a screw lodged in between a planetary gear and ring gear in the gearbox. The loose screw originated from a clutch assembly and most likely fell between the gears during launch or once in orbit. A second screw from the clutch assembly was found loose, but caused no operational issues with the actuator.

Engineers also concluded that improper thread inserts were used with the screws, which allowed them to loosen over time and eventually back out of the clutch assembly; non-locking thread inserts were used when design specifications called for locking thread inserts to be used. Additionally, appropriate torque values were not included in the engineering drawings of the assembly.

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Thread Inserts

A thread insert is a tube shaped part that has both internal and external threads. It is threaded into a drilled hole in the structure/housing and mechanically locked into place. The screw or bolt used to assemble the parts then threads into the inner threads of the insert. Inserts are used so that if the threads get damaged or worn, the insert can be replaced without having to re-drill and tap the hole in the structure/housing. Shuttle requirements specify that there be two locking methods for all threaded fasteners. This is to reduce the chance of a fastener loosening over time due to vibration or cyclic loading. The torque on the fastener is considered the primary locking feature. The secondary feature is either something that physically prevents the fastener from being able to turn (like lock wire, epoxy, a locking tab, or some type of locking fixture) or by use of a locking nut or locking thread insert. In the case of the locking nut/insert, some of the threads are deformed so that the screw/bolt cannot freely turn. In other words there is resistance to rotate due to the fact that there is some interference between the treads of the screw/bolt and the threads of the nut/insert. For each fastener size, there is a required torque to rotate the fastener through the locking feature (referred to as running torque). When fasteners are removed and reinstalled, this running torque is required to be checked. Repeated removal/installation of a fastener results in lower running torque, as the deformed threads are straightened and there is less resistance to rotate. High re-use locking nuts/inserts have a limited life and have to be periodically replaced.

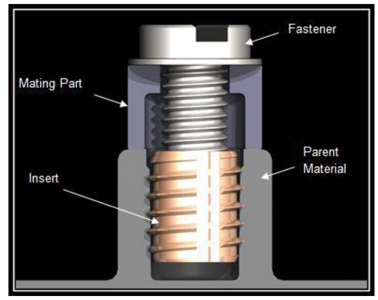

Figure 5: View of thread insert. Source: Google Images

Maintenance Investigation

A detailed maintenance investigation was completed for the faulty actuator. Results determined that the screws were removed and re-installed five times without replacing the proper thread inserts. Investigations performed on the rest of the fleet identified another 12 actuators with improper inserts (some with one locking and one non-locking insert), all of which contained loose screws. As a result, all orbiters were re-fitted with the proper thread inserts and engineering drawings were updated to include torque specifications.

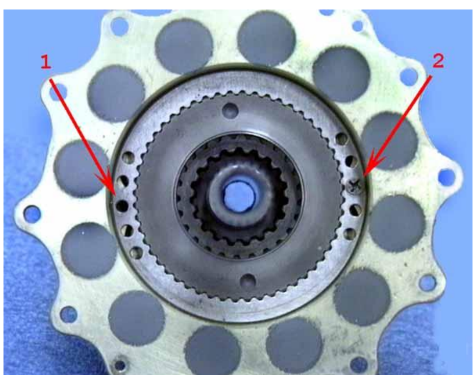

Figure 6: STS-80 actuator assembly showing missing and loose screws. NASA Image

In a 2010 interview with NASA's Lessons Learned Program Manager Michael Bell, Boeing engineer Albert K. Curry suggested that engineers should "keep the moving part[s] simple for these types of applications [3]." Regarding the design of new hatches, Curry, who spent much of his career dealing with these types of hatches, stated "…to simply…unlatch, open and then close and latch a hatch… should not require a hundred plus moving parts [3]." Curry believes that hatches should be fabricated in a similar fashion to the four bolt linkage systems of World War II submarine vessels, citing:

"…It locks, it performs its function, holds the sea water out. In this case we're trying to hold the vacuum of space out of a pressurized vehicle and its applications are very, very similar… in fact you know there is less pressure involved. So, to me a much simpler design is very feasible [3]."

STS-80 remains the first and only mission during the Shuttle Program's 30 year history to have an orbiter airlock hatch malfunction in space.

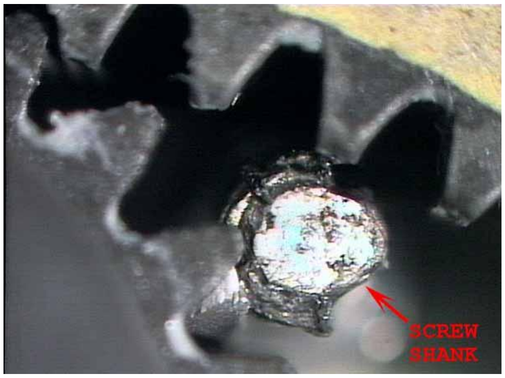

Figure 7: Close-up of jammed screw between ring and planetary gears. NASA Image

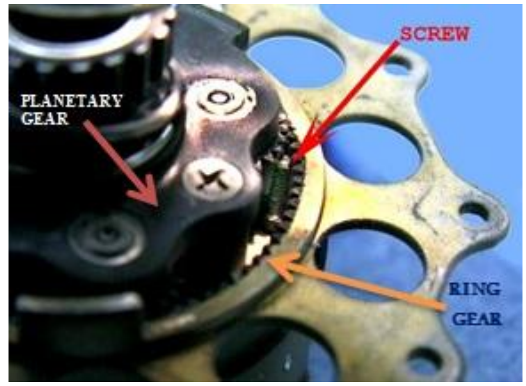

Figure 8: Screw lodged between planetary gear and ring gear. NASA Image

References

[1] Associated Press. "NASA deals with Space Jam," Toledo Blade, November 30, 1996. Accessed June 25, 2012. http://news.google.com/newspapers?nid=1350&dat=19961130&id=CmRPAAAAIBAJ&sjid=cQMEAAAAIBAJ&pg=3582,10037126.

[2] Boeing North America. "Corrective Action Record Closeout." Accessed July, 10, 2012. https://nen.nasa.gov/llis_lib/pdf/1035918main_upload_00008677.pdf

[3] NASA, "Lessons Learned Entry: 4417." Accessed June 13, 2012. https://nen.nasa.gov/web/ll/home/llis-doc-viwer?url=https://nen.nasa.gov/llis_content/imported_content/lesson_4417.html.

[4] NASA, "STS-80 Day 12 Highlights," Accessed June 14, 2012. http://science.ksc.nasa.gov/shuttle/missions/sts-80/sts-80-day-12-highlights.html

[5] NASA, "STS-80 Space Shuttle Mission Report." Texas: Lyndon B. Johnson Space Center, 1997, 5-6. Accessed June 11, 2012, http://ntrs.nasa.gov/archive/nasa/casi.ntrs.nasa.gov/19970011045_1997015729.pdf