MISHAP INVESTIGATION BOARD SUMMARY OF EXTRAVEHICULAR ACTIVITY 23: LESSONS LEARNED FROM A SPACEWALK CLOSE CALL

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ABSTRACT

The Space Station program convened a Mishap Investigation Board (MIB) to investigate a High Visibility Close Call which occurred during US Extravehicular Activity (EVA) 23 on July 16, 2013. The MIB established the specific cause for the potentially catastrophic water leakage inside the Extravehicular Mobility Unit (EMU), which was a clog inside the EMU Fan Pump Separator, caused by inorganic material that led to water spilling into the vent loop. Additionally, the MIB identified Root Causes as any of the multiple factors (events or conditions, that are organizational factors) that contributed to or created the proximate cause and subsequent undesired outcome. Root causes are ones that if eliminated or significantly modified, would have prevented the undesired outcome. Trouble-shooting also identified a catastrophic failure mode previously unknown to the ISS program. The lessons learned resulted in 49 separate recommendations to the ISS Program to correct these issues that led to this incident and prevent future such mishaps. Many of these recommendations were being implemented before the report was complete, and all of them are being specifically addressed by the ISS Program. Additional insights from NASA astronaut and EVA 23 spacewalker Christopher Cassidy are included to provide additional insight to the incident and the resulting lessons learned.

1. INTRODUCTION

On July 16, 2013, Christopher Cassidy (EV1) and European Space Agency (ESA) astronaut Luca Parmitano (EV2) exited the International Space Station US Airlock to begin U.S. Extravehicular Activity 23 (US EVA 23). Roughly 44 minutes into EVA 23, Parmitano reported water inside his helmet on the back of his head. The EVA ground team and the crew members were unable to identify the water's source. As Parmitano continued to work, the amount of water in his helmet increased and eventually migrated from the back of his head onto his face. EVA 23 was terminated early and the crew safely ingressed the airlock. A nominal rate was used to re-pressurize the airlock followed by an expedited suit removal. The water quantity introduced into his helmet was later determined to be almost 1.4 liters.

During the post-EVA debrief, Parmitano reported that he had impaired visibility and breathing, with water covering his eyes, nose, and ears. In addition, he had audio communication issues because of the water. When returning to the airlock, Parmitano had to rely on manual feel of his safety tether's cable for pathway directions.

The event was classified as a High Visibility Close Call and a Mishap Investigation Board (MIB) was created. A related concern occurred during a post-EVA 23 suit dry-out procedure. A vacuum cleaner was used and unexpectedly suctioned O_2 from the suit's secondary high pressure oxygen tank, causing a potentially hazardous mix of electricity and pure O_2, which could have ignited flammable materials in and around the vacuum cleaner, although fortunately no incident of this nature occurred. This paper will discuss the mishap, the results from the subsequent investigation, and lessons to be learned from the event.

The Mishap Investigation Board was commissioned by William H. Gerstenmaier, Associate Administrator for the Human Exploration and Operations Directorate at NASA Headquarters in Washington, D.C. on July 22, 2013. The final report, reference [1], was submitted on December 20, 2013. The MIB members appointed were Chairman Chris Hansen, Dr. Sudhakar Rajulu and Mike Foreman of the Johnson Space Flight Center, Joe Pellicciotti of the Goddard Space Flight Center, and Richard Fullerton from NASA Headquarters. The MIB investigation ran concurrently with an ISS Program investigation and relied on multiple experts to complete its work.

2. BACKGROUND

The International Space Station is located in low Earth orbit about 400 km (250 mi) above the Earth's surface. It serves as a microgravity and space environment research laboratory for the physical and natural sciences. The ISS is also a tested of spacecraft systems and equipment required for future missions to the Moon and Mars. ISS EVAs, or spacewalks, are performed outside the spacecraft to build and maintain the orbital laboratory: installing new components; re-wire systems, modules, and equipment; monitor, install, and retrieve scientific experiments. EVAs also provide critical contingency capability to assure ISS viability and crew safety.

Figure 1. Extravehicular Mobility Unit (EMU)

The current ISS Extravehicular Mobility Unit (EMU) (shown in Fig. 1), a complex spacesuit that provides protection from the extreme conditions of space, is a mobile life support system with an oxygen supply, electrical power, water-cooling equipment, ventilating fan, and an in-suit drink bag. The EMU was originally developed for use on the U.S. Space Shuttle to mitigate failure scenarios in which the Shuttle payload bay doors failed to close and lock properly prior to atmospheric re-entry. An additional postulated failure scenario involved achieving "rescue" of a disabled orbiter by EVA crewmembers entering a depressurized vehicle and accessing the flight deck. This particular risk mitigation approach required that the EVA suit and the Portable Life Support System (PLSS) assembly be sized—width and depth—to pass through the Shuttle hatch openings to the flight deck. The EMU has since evolved from a suit to mitigate Shuttle failure scenarios to one capable of deploying, capturing, and repairing satellites, and enabling astronauts to assemble, repair, and maintain the ISS.

As mission objectives expanded, the once single-mission EMU certification was incrementally extended to an operational life of multiple years on the ISS. The evolution of the suit over the years resulted in a long history of issues that led to many modifications to the EMU. The Quest Joint Airlock module in the U.S. segment of the ISS maintains the habitable environment when astronauts are exiting or entering the spacecraft for EVA operations. It consists of two main parts: the equipment lock and the crew lock. The equipment lock is where the EMUs are stored and preparations for spacewalks are carried out. The crew lock is depressurized during spacewalks. Continuous flight of the ISS requires spacesuits to be left on-board for longer periods of time than the suit's original Shuttle certification allowed.

At the beginning of the ISS Program, EMUs were delivered by the Space Shuttle; a complement of suits was left on ISS when the Shuttle Orbiter un-docked. On subsequent Shuttle missions, suits were replaced and returned to the ground for maintenance and refurbishment. Originally, the maintenance cycle for an individual suit was after each Shuttle flight. Suit requirements supported three EVAs before ground conditioning. In order to support continuous ISS operation, the period of EMU maintenance cycles was extended to one year or 25 EVAs. This maintenance period was extended to two years in 2002 and to three years in 2007. The current operational certification is 6 years. NASA's decision to retire the Shuttle fleet in 2011 required another change to the EMU operations concept. The complement of EMUs on ISS was increased from three to four. Additional ground processing is required for the EMU hardware to meet this longer 6-year maintenance interval. This processing includes cleaning or replacing water filters along with the stripping and recoating of areas with known susceptibility to corrosion.

3. EVENTS IMMEDIATELY LEADING UP TO MISHAP

Prior to EVA 23, Cassidy had completed five EVAs, totaling 29 hours and 43 minutes. Parmitano had completed one EVA (EVA 22), which was 6 hours and 7 minutes. On May 12, 2013, ISS crewmembers conducted US EVA 21. An EVA crewmember on this EVA wore EMU 3011, the EMU that experienced the close call on EVA 23. The crewmember did not experience water in the suit during EVA 21.

On July 9, 2013, just one week prior to EVA 23, Cassidy and Parmitano conducted US EVA 22 with the same EMUs that would be worn on EVA 23. When Parmitano removed his helmet post-EVA 22, he discovered between 0.5 and 1 liter of water in the helmet. Cassidy reported that when he was face-to-face with his partner at the airlock hatch prior to ingress, there was no visible indication of water in Parmitano's helmet. Therefore, the crew concluded that the water must have entered the helmet during re-pressurization activities. Also, during EVA 22 repress, Parmitano was looking down and leaning forward. It was concluded that he likely had pressed on the drink bag (shown in Fig. 2) with his chest and could have pinched the bite valve open with his chin, releasing water into his helmet. The ground team accepted the crew's drink bag leak suggestion and the presence of excessive water in the helmet was not investigated further. The crew cleaned up the residual water, and the ground team sent up procedure changes for EMU stowage to help the equipment dry out. The ground team instructed the crew to use a new drink bag for the upcoming EVA 23. There was no discussion of water in the helmet during EVA 23 pre-briefs which were held on July 11 and July 15.