

ISS EVA 23 Mishap Investigation Board

Media Briefing – 2/26/14

Chris Hansen, Mishap Investigation Board Chairman

Date of Mishap: 7/16/13

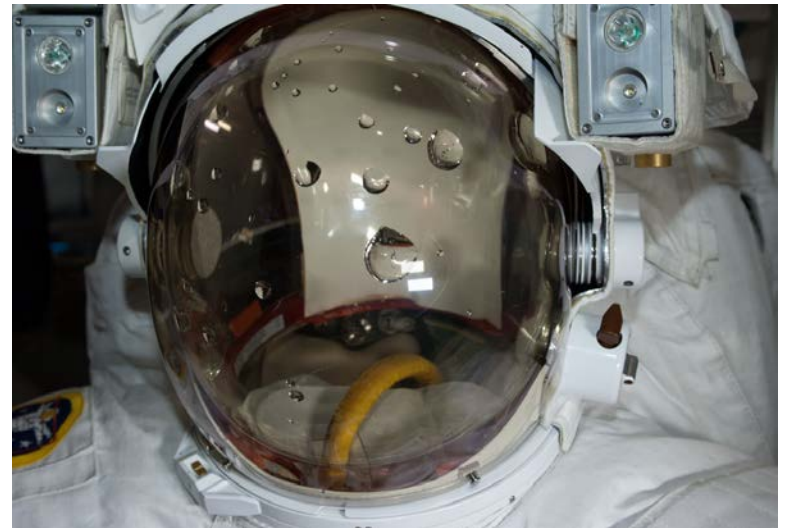
High Visibility Close Call - NASA IRIS Incident No. S-2013-199-00005

Mishap Summary

DATE: July 16, 2013

TIME: 1241 GMT (7:41am central time)

LOCATION: Outside the International Space Station,
on-orbit during US EVA 23



BRIEF DESCRIPTION:

- Roughly 44 minutes into EVA 23, Luca Parmitano (EV2) reported water inside his helmet, on the back of his head. The EVA ground team and EVA crew members were unable to identify the source of the water. As EV2 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. After the airlock was re-pressurized, the crew member's helmet was removed. The water quantity introduced into the helmet was estimated at about 1.5 liters.
- After the EVA was completed, it was learned that during his return to the airlock, Luca experienced intermittent loss of communication, his vision was impaired by water covering his eyes, and water had entered his nose making breathing more difficult.

Mishap Investigation Board Formation

- After the incident, NASA appointed a Mishap Investigation Board to perform an independent safety investigation to develop lessons learned and corrective actions necessary to prevent a similar occurrence in the future.
 - Chris Hansen, ISS Chief Engineer, NASA Johnson Space Center, MIB Chair
 - Mike Foreman, Astronaut, NASA Johnson Space Center
 - Joe Pellicciotti, Engineering Specialist, NASA Goddard Space Flight Center
 - Richard Fullerton, Safety and EVA Specialist, NASA Headquarters
 - Sudhakar Rajulu, PhD, Human Factors Specialist, NASA Johnson Space Center
- The MIB also had numerous experts supporting the investigation.

Unique Cooperation Between ISS and MIB

- Because the ISS is an operating, on-orbit laboratory, it could not be shut down during the investigation.
- In addition, there are certain ISS failures that, if they occurred, could require an EVA to safe the ISS despite the fact that the investigation was not complete.
- Because of this, the ISS Program quickly formed an investigation team to determine the cause of the water intrusion into the helmet, and develop its own corrective actions to the issues that were discovered.
- The MIB formed a very close, cooperative relationship with the ISS Investigation Team throughout the investigation.
- The spacewalks to repair the ISS pump module failure that occurred in late 2013 was planned with full cooperation between the ISS Program and the MIB.

Hardware Failure Investigation

- The MIB was formed to quickly investigate the factors that led to the incident and develop recommendations to help prevent similar incidents from occurring in the future.
- The actual cause of the mechanical failure in the spacesuit is still under investigation by the ISS Investigation Team. The system is very complex and investigation will take time to complete.
- When the root cause of hardware failure is determined, the MIB will assist NASA in evaluating corrective actions.
- The hardware failure has been traced to contamination in a portion of the spacesuit called the Fan Pump Separator, but the source of the contamination has not yet been determined
 - This contamination clogged several small holes that prevented water from flowing properly, causing water to back up and flow into the space suit's air system and enter the helmet.



Contamination found in Fan Pump Separator

Summary of Findings

- The MIB investigation sought to determine if there were ways to prevent this mishap from re-occurring, if there were ways to have minimized the risk to the crew once it occurred, and if there were ways it could have been prevented before it occurred.
- The MIB determined that the causes for this mishap evolved from:
 - Inorganic materials causing blockage of the drum holes in the EMU water separator resulting in water spilling into the vent loop.
 - The NASA team's lack of knowledge regarding this particular failure mode, which led to a delay in recognizing the severity of the event when it occurred.
 - Misdiagnosis of this suit failure when it initially occurred on EVA 22.
 - The MIB determined that the space suit actually suffered the same failure at the end of EVA 22, performed a week earlier, and this event was not properly investigated which could have prevented placing a crew member at risk a week later during EVA 23

Summary of Causes

- Three Proximate causes were identified contributing to the severity of the event:
 - P1:** The ISS Program conducted EVA 23 without recognizing the EMU failure which occurred on EVA 22.
 - P2:** EMU 3011 Helmet had a large quantity of water during EVA 23.
 - P3:** Flight Control Team/Crew did not terminate EVA 23 as soon as water was reported in the helmet.
- Ultimately these (P1 and P3) were caused by 5 Root Causes:
 - RC1:** Program emphasis was to maximize crew time on orbit for utilization.
 - RC2:** ISS Community perception was that drink bags leak.
 - RC3:** Flight Control Team's perception of the anomaly report process as being resource intensive made them reluctant to invoke it.
 - RC4:** No one applied knowledge of the physics of water behavior in zero-g to water coming from the PLSS vent loop.
 - RC5:** The occurrence of minor amounts of water in the helmet was normalized.

Summary of Findings and Recommendations

- 49 recommendations were developed by the MIB and put into priority order, with 3 levels of recommended importance:
 - Level 1:** Highest priority, these recommendations should be completed prior to a return to nominal EVA (16 recommendations).
 - Level 2:** Process should begin now, but not a constraint to returning to nominal EVA (16 recommendations).
 - Level 3:** Incorporate over the long term & complete within reasonable time (17 recommendations).

Summary of Findings and Recommendations

- **Level 1** recommendations will be discussed in this presentation.
- **Level 2** recommendations are contained in the report and cover areas related to:
 - Improved safety documentation and associated training
 - Better communication between ground control teams
 - Access to and documentation of flight hardware
 - Improvements in failure investigation processes
 - Review of EVA related hardware certifications

Summary of Findings and Recommendations

- **Level 3** recommendations are contained in the report and cover areas related to:
 - Organization and management structure improvements
 - Evaluation of applicability of lessons learned from this event to other similar ISS activities
 - Training improvements
 - Documentation improvements
 - Potential space suit hardware improvements

High Priority Recommendations

- **R1:** The ISS Program must reiterate to all team members that, if they feel that crew time is needed to support their system, a request and associated rationale must be elevated to the ISS Program for an appropriate decision.
 - The MIB did **not** find any evidence that fear, intimidation, or an unwillingness to raise safety concerns contributed to this event. Schedule pressure and pressure to maximize crew time used to perform science was so ingrained in the team that risks associated with their decisions to not request on orbit time for important activities were not always communicated to ISS managers
- **R6:** The ISS Program should ensure that all instances of free water and contamination in the EMU are documented and investigated, with corrective action taken, if appropriate.
 - Small amounts of water in the helmet had been normalized over time

High Priority Recommendations

- **R35 (O-23)** : The ISS Program and JSC EVA Office should improve technical and management coordination between their two organizations and ensure that all strategic and tactical decisions that are made by either organization are quickly and effectively understood, and officially accepted by both.
- **R4 (I-16)**: The ISS Program should ensure that updates are made to the EMU hazard reports to reflect the possibility of water in the helmet resulting in a catastrophic event due to asphyxiation.
- **R36 (O-24)**: The government officials and contract managers must put in place expectations and create a board environment that allows the EVA contractors to freely challenge technical decisions made by the governing boards when appropriate and encourage proactive participation.

High Priority Recommendations

- **R7 (I-15):** MOD must lead the development of appropriate flight rules and procedures to address the course of action to take in the event of water in the helmet.
- **R32 (O-19):** MOD should review all procedures with a “√ MCC” step and verify that rationale exists to explain the required actions to be taken by the flight control team if this step is reached.
- **R10 (O-4):** MOD should evaluate how personnel who are located in the Payload Operations Control Center facility and not part of the active flight control team interact with the active flight control team and ensure that lines of communication and the decision making chain is not compromised.

High Priority Recommendations

- **R33 (O-20):** The ISS Program should ensure appropriate connectivity between all relevant parties who participate in EVA activities to support real-time operations including talk/listen access to MCC Audio Loops.
- **R43 (O-28):** The ISS Program must define the roles and responsibilities of the engineering support teams and the Flight Control Teams to a level whereby each position, on either side, clearly understands their role and the role of their counterparts and mutual expectations must be established and agreed to.

High Priority Recommendations

- **R15 (O-8):** The EVA Office should ensure that all EMU procedures are consistent between all teams that perform operations with the EMU, and require that all contamination found during ground processing be evaluated by the engineering and quality teams.
- **R25 (O-13):** The ISS Program and the EVA Project Office should ensure that all procedures are validated on flight hardware if the procedure requires a functioning system versus a fit check.
- **R31 (O-18):** MOD should provide integrated EVA simulations with the possibility of ending the simulation early. These simulations must be scheduled for the full duration, but allowed to end early if required by the actions taken by the flight control team. Additionally, airlock ingress and repress should be routinely included as part of simulations that involve terminating an EVA with an EMU in an off-nominal configuration.

High Priority Recommendations

- **R34 (O-22):** MOD should strengthen training to emphasize the physiological effects of a rapid repress on the crew to aid in the decision making process in real-time.
- **R11 (O-5):** The ISS Program should perform testing and analysis to verify that use of the Helmet Purge Valve to remove free water from the helmet is safe and effective. Results of this testing should be made clear to the EVA community, including the flight control team and documented in hazard reports, flight rules and procedures.
- **R20 (O-10):** The ISS Program should institute a systematic process of monitoring water quality and chemistry aboard ISS to track changes that can affect critical ISS systems including the EMU, crew health, and multiple ISS systems that use water and are sensitive to its chemical makeup (the oxygen generation system, the water processor assembly, the common cabin air assembly, etc.). This process should include consideration of onboard monitoring capability. It should also include return of any removed hardware to the ground for evaluation.

Future Work

- Cross-agency engineering and ISS investigation continues to determine the root cause of the hardware failure.
- Key members of the MIB are involved in and will remain part of the hardware investigation team and its ongoing efforts to determine the root cause of the hardware failure.
- Many of the recommendations contained in the MIB report are either complete or in work due to a very proactive reaction by the ISS Program to the event.