By Stavros Georgakas

Contamination Risk During EVA

Astronaut Robert L. Curbeam, Jr taking part in an EVA during construction of the International Space Station. - Credits: NASA

Extra Vehicular Activity (EVA) is among the most dangerous space operations. Alexei Leonov's first ever spacewalk almost ended in tragedy when his space suit inflated, preventing him from reentering the spacecraft. Early Gemini spacewalkers experienced near-fatal episodes of exhaustion, sweating, foggy visors, and inability to grapple and move themselves around the spacecraft. The fortunate lack of fatal accidents may give the false impression that EVAs are a safe, almost routine activity, but the truth is that they occasionally expose astronauts to extremely hazardous and life threatening situations.

Toxic Leak Emergency

On February 10, 2001, during STS-98, NASA astronauts Robert L. Curbeam and Thomas D. Jones were exposed to toxic ammonia during an EVA. Their task was to connect cooling lines on the International Space Station for the Destiny Laboratory Module installation. A defective quick-disconnect valve released 5% of the ammonia coolant supply into space. The ammonia was essential for operation of the $1.4 billion laboratory, and a massive leak would have rendered the laboratory unusable. Ammonia is highly suitable as a coolant due to its low freezing point, but it is also highly toxic. On Earth, there have been many fatal industrial accidents due to hydrous ammonia contamination.

> "EVA is among the most dangerous space operations"

On this particular EVA, the escaping ammonia froze on Curbeam's spacesuit as he tried to close the valve by pulling on a locking device known as a bailer bar. Toxic ammonia crystals 2-3 cm thick covered parts of his helmet and spacesuit. Initially, Jones tried to brush off as much of the frozen ammonia as he could from Curbeam's spacesuit, but Mission Control quickly instructed them to remain outside the Shuttle for an entire orbit to allow the Sun to evaporate the frozen ammonia. Curbeam himself was not affected from a physical point of view, but the ammonia crystals were a contamination risk to the Shuttle cabin. Under different circumstances, a spacewalk with no demanding task to work on would be a great time for an astronaut, and a chance to enjoy the unique view. However, Curbeam remembers this interval as extremely unpleasant, having nothing to keep his brain busy, and worrying that he had lost his supervisors' trust.

Curbeam working on the Destiny module during the second EVA of the STS-98 mission in 2011. - Credits: NASA

Back inside the Shuttle

Upon returning to the airlock, the astronauts followed an exhausting procedure to avoid any further risks. The airlock was pressurized, vented and re-pressurized to remove any remnants of ammonia and safeguard the rest of the crew, after which they had to wear oxygen masks for 20 minutes to allow life-support systems to filter the air. Eventually, the entire cabin air volume had been circulated and they were allowed to remove their masks. The other team members were understandably worried, but fortunately no injuries resulted from the incident. No ammonia odor was detected and the procedures followed were deemed successful. Five hours after the leak, the astronauts were informed that the valve was faulty, and that they were not the cause of the accident. However, this incident demonstrated the unexpected risks that may occur even while performing routine operations.

The incident, described as a minor setback during the mission operation, is now recalled by the individuals involved as an important milestone in space safety, and a moment of high tension and adrenaline. A vivid recollection of the event can be found in Thomas D. Jones' book "Sky Walking: An Astronaut's Memoir" (Smithsonian Books, 2006).

> "Only careful planning, design and execution can reduce the risks to a minimum"

The Importance of Training

Only ten days before the flight, the crew had attended a briefing on shutting off ammonia lines during EVA. The briefing was crammed into the schedule and would not have taken place if there hadn't been a launch delay. Mission specialists and experts considered the possibility of a leak so remote that the standard procedures for that case were not included in the original training schedule. Curbeam reported that during debriefing they were told: "I really sincerely doubt you'll have a leaky valve, and I can tell you for sure you won't have a male Q.D. leak" —the exact kind of leak that actually occurred on their mission.

Luckily, Curbeam concluded the mission safely, and travelled into space for a third time in 2006, while still holding the world record for the highest number of EVAs on a single mission. But how can we ensure safety from such incidents in the future?

Crew exposure can be minimized through regular safety reviews and careful hardware engineering. The most effective method to minimize contamination risks like this remains prevention, but toxic substance handling is sometimes inevitable, due to operational and mission requirements.

An important aspect to ensuring safety is alerting the crew when protective action must be taken. Carbon monoxide detectors, Draeger tubes that sense the presence of specific chemicals, and the compound specific analyzer-combustion products (CSA-CP) device are used for this purpose.

Also, active measures must be applied, should the preventive actions fail. The crew must undergo focused simulation-based training and be prepared to actively intervene to ensure their safety. Active measures include the use of oxygen masks and decontamination procedures, and are an essential part of safety engineering design.

Only careful planning, design, and execution can reduce risks to a minimum and achieve optimal risk mitigation. Space is an extreme environment, with many associated risks and dangers. While some accidents cannot be predicted or prevented, good training and valid contingency planning will allow prompt recovery, even from potentially fatal situations.

Curbeam donning his spacesuit with the help of a technician in the Operations and Checkout Building. - Credits: NASA