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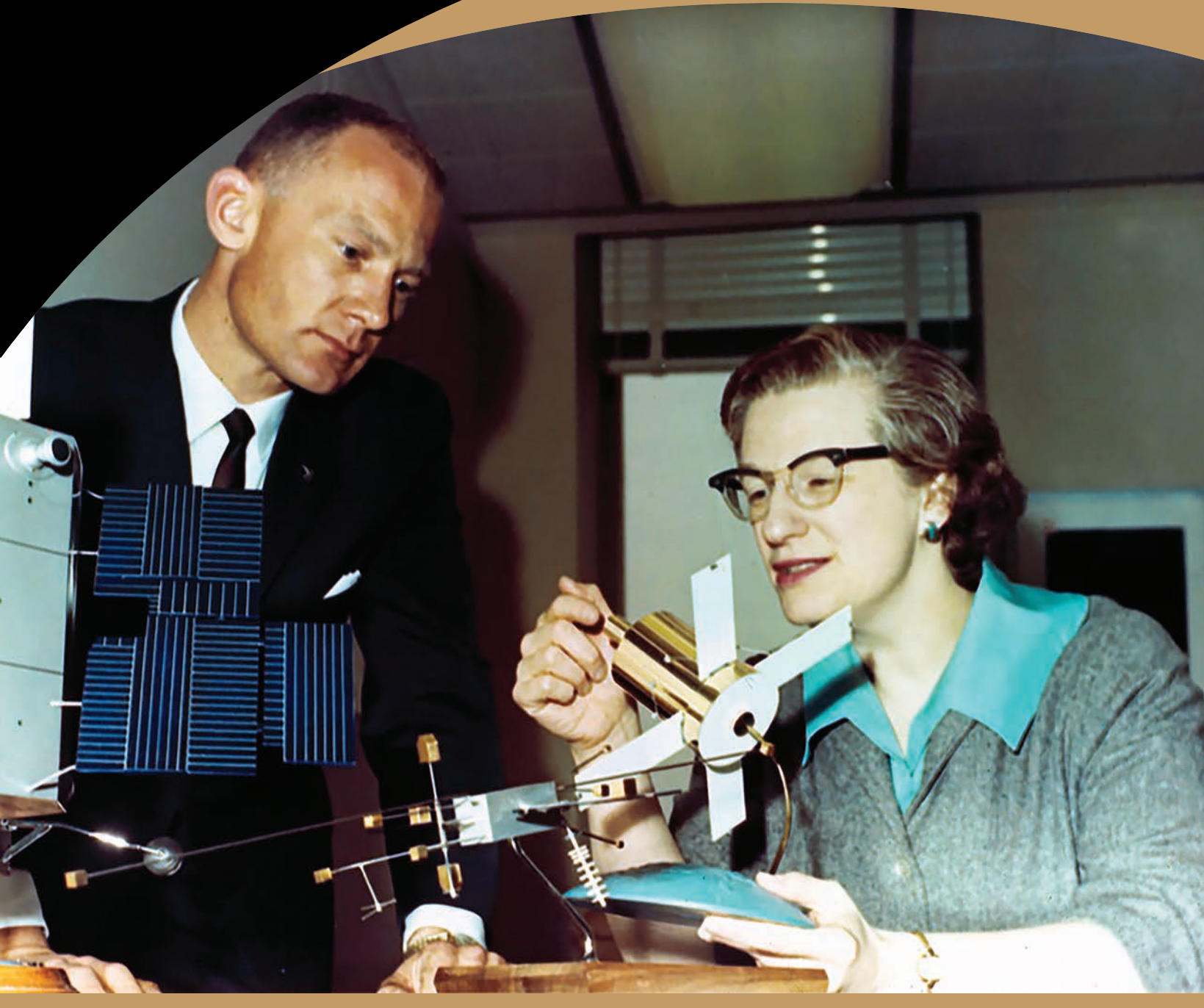

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Nancy Grace Roman explains the *Advanced Orbiting Solar Observatory* to astronaut Buzz Aldrin in 1965.
Credit: NASA

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The Historical Precedent of the *Expedition 8* EVA

BY SAMUEL MCKEE

Expedition 8 to the International Space Station (ISS) *was a two-person mission from 20 October 2003 to 29 April 2004. NASA's representative was British-born Dr. Michael Foale, while Roscosmos' cosmonaut was Aleksandr Kaleri. During the mission, maintenance of the* ISS, *as well as performing science in vacuum, required use of Russian ORLAN spacesuits in which Foale and Kaleri conducted the first ever extravehicular activity (EVA) on the* ISS *without anyone remaining inside the station or craft as a "watchman." There have only ever been two scheduled EVAs under such conditions (the others followed during* Expedition 9*), meaning Foale and Kaleri undertook a historic and risky precedent. Despite their historic EVA being cut short, this risky venture involved much exploration of how such an EVA could be done and it is unlikely that EVAs without a watchman will take place in the future.*

ISS *Expedition 8* crew: Aleksandr Kaleri (left). Michael Foale (right). Credit: NASA

Expedition 8

Following the Space Shuttle *Columbia* disaster on 1 February 2003, crews on the *International Space Station* (*ISS*) were reduced from three to two, so each space agency sent their most experienced astronauts and cosmonauts to manage the station. NASA's Michael Foale had flown five times and conducted three previous EVAs for 18 hours, whereas Roscosmos' Aleksandr Kaleri had flown three times for a total of 416 days and performed four EVAs.[1] Crews were required to travel to and from the station by Soyuz as the Shuttle would not fly again for more than two years. No EVA was conducted during *Expedition 7*, leaving Foale and Kaleri to undertake this historic exercise. Alongside maintenance of the station[2] and an important navigational installation for Automated Transfer Vehicle (ATV) dockings, expensive and important science experiments, including those from the European Space Agency (ESA), would necessitate at least one EVA.[3] *Expedition 8* lasted for 195 days[4] before the crew's replacement by Gennady Padalka and Michael Fincke.[5]

Although external construction of the *ISS* was not possible without the Shuttle, a strong schedule of internal development of the station was continued, alongside the science experiments delivered by the Progress and ATV vehicles.[6] Foale, Kaleri, and ESA Spanish Astronaut Pedro Duque launched from Baikonur Cosmodrome on 18 October 2003 and docked with the *ISS* two days

later.[7] They replaced *Expedition 7* commander Yuri Malenchenko and NASA's Ed Lu who returned to Earth with Duque on October 27. Duque had been sponsored by ESA to fly on the Soyuz for a short-duration stay on the *ISS* to conduct several science experiments,[8] and Roscosmos thought the *ISS* could accommodate short-term guests at this stage for a week at a time.[9] Following Duque, ESA's Dutch astronaut Andre Kuipers flew with the *Expedition 9* crew to the *ISS* and returned to Earth with Foale and Kaleri following their handover.[10]

Reporting on the circumstances of the flight for a medical report at Johnson Space Center, NASA physician Dr. Lars Ulissey wrote the following.

> "Shuttle missions were halted after *Columbia*. Suddenly *Expedition 6* needed that Soyuz lifeboat to get home and TMA-01 was it! The original plan was for a three-person crew to fly TMA-02 to the *ISS* and return a week later on TMA-01. Instead, TMA-02 would have to fly with a long duration crew. Yuri Malenchenko and Edward Lu were selected for the mission, making them the 7th expedition to the *ISS*. Until Shuttle flights resumed with STS-121, *Expedition 6* was the last time a three-person crew inhabited *ISS*. It was also the first time US astronauts landed in a Soyuz capsule (although Dennis Tito, a US space tourist, did so in 2001).
>
> While *Expedition 6*'s TMA-01 spacecraft appeared identical to earlier Soyuz models, it was actually the first flight for its class; it had new systems, software, and re-entry procedures. Due to some technical glitch, the descent track was steeper than usual, causing the spacecraft to make a ballistic re-entry, resulting in exceptionally high g-forces and the capsule landing 300 miles from the intended target area.
>
> Another first was accomplished by *Expedition 7* commander, Yuri Malenchenko, who became the first person to get married in space. His bride was in Texas, the definition of long distance—and where long-distance marriages were legal.
>
> No EVAs were conducted during *Expedition 7*, so by the time *Expedition 8* arrived with Commander Michael Foale and Flight Engineer Aleksandr Kaleri, the *ISS* was overdue for one. What was unusual is that there wouldn't be anyone inside the *ISS* to provide support in the event of a contingency pertaining to the EVA, or the *ISS* itself."[11]

Compounding the problem was Roscosmos' difficult financial situation. There were European experiments outside of the *ISS* in need of retrieval for completion without which they would not be paid. Therefore, an EVA was a necessity, yet the conditions would set the precedent of an EVA without a watchman.[12,13]

Conditions for the EVA

Due to the *ISS* containing only two crewmembers, if an emergency situation arose where the airlock could not be repressurized, the crew would need to go straight to the Soyuz lifeboat for an immediate return to Earth.

At the time, crew members had to pass through the Pirs module to access their Soyuz ferry. Pirs was launched in September 2001 and was connected to the Russian part of the station by a passageway. It included the airlock from which the EVA would embark,

Expedition 8 insignia. Credit: NASA

and was connected to the docking port for the Soyuz.

The EVA would utilize Russian ORLAN spacesuits designed for EVAs rather than US EVA spacesuits or Russian Sokol suits worn during ascent and descent operations in the Soyuz spacecraft.

Foale had completed an EVA in an ORLAN suit during his stay on *Mir* space station during the Shuttle-Mir program for five months in 1997. During his stay on the *Mir*, the Progress M-34 lost control and crashed into the station, puncturing the Spektr module and impacting several of the solar arrays. An EVA was necessary to externally assess the damage, and Foale conducted one alongside Commander Anatoly Solovyev. Since he had trained and used an ORLAN spacesuit, Foale performing a Russian EVA aboard the *ISS* wasn't a big stretch in 2004. He had gained a great deal of experience working alongside the Russians, had lived in Star City with his family, and had served as the chief NASA astronaut in the Russian office.

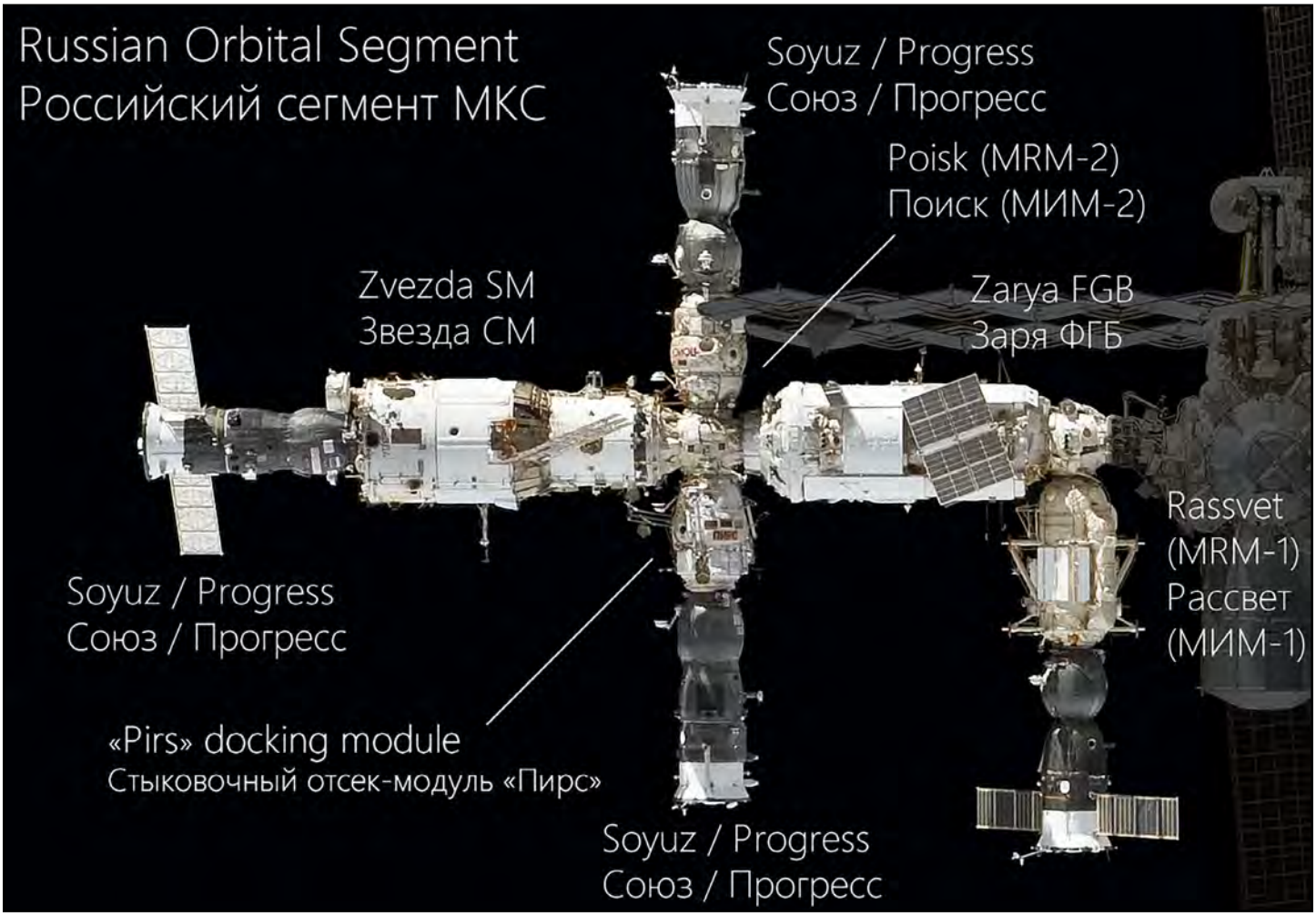
The requirements for a "watchman" during an EVA are numerous; from communication, safeguarding of the station, the extra eyes on the choreog-

raphy, as well as the potential piloting of a craft to rescue a stranded spacewalker. These possibilities were not available for this EVA without a third member, and it is now essential practice that no EVA take place without a watchman.

The Pirs module had been added to the *Station* in 2001 to serve as both an airlock and a docking port for Soyuz and Progress vehicles.[14] During assembly of the *ISS*, it was more common practice to egress for EVAs from the Space Shuttle airlock, so although the Pirs module was used, this was typically during the EVAs performed without the Shuttle docked and with a three-person crew. Two-person crews did not begin until *Expedition 7* and continued through *Expedition 13*, after which Shuttle flights had recommenced.

Challenges with the Pirs Docking Module and the Soyuz Hatch Plan

The junction hatchway between the airlock and the Soyuz was a small docking port. In the middle of the hatchway was a cone with a diameter of only 800 millimeters, conical and with latches, facing the space side of the Soyuz coming into the cone of the receiving docking port joining the airlock. On the Soyuz side, Foale and Kaleri were to pump air into the small space between the two vehicles and open up the Soyuz hatch, which opens inward toward the Soyuz along with the cone. On the airlock side of the Pirs module, there was a rotating docking adaptor receiver, which was a conical hole to receive the cone of the Soyuz. This swings out of the way to allow crew members to pass through Pirs from the Soyuz to the airlock and onward into the rest of the station. While crew members pass through Pirs often when the station is pressurized, such a passage had never been attempted before in an EVA situation. The complications began



Layout of the Russian orbital segment of the *International Space Station* in 2011, overlaid in English and Russian. Poisk and Rassvet were not yet attached to the *ISS* in 2004, when the *Expedition 8 EVA* took place. Credit: NASA, Wikimedia Commons

ISS Expedition 8 docking. Credit: NASA

because there was no one to operate hatches on their behalf in the absence of a backup airlock. Without a backup airlock, if one could not re-enter the module successfully or repressurize it to remove their suits, the crew members would be in serious danger.

On the side of the Pirs airlock there was a meter-wide hatch that opened up to space, but the door, as with the cones, opened inward. If the airlock door could not be closed, then the crew members could not pressurize the airlock. There was a hatch between the airlock and the small vestibule leading to the station, which is closed, but if this was to be opened with a depressurized airlock, then all the air in the station would escape, so the crew members would be stuck. In other configurations there was a second hatch close to the station where the vestibule could be used as an emergency airlock for one person at a time, but this was not possible for Foale and Kaleri. Therefore, they needed to set up the Soyuz as an emergency airlock and also for returning home in an emergency.[15]

Foale and Kaleri needed to open the Soyuz hatch, unbind it, but leave it closed on the Soyuz side, so that as they let the air out of the airlock and into space, the pressure of the Soyuz would push the hatch closed and against its rubber seal so that it was still pressurized inside. A command would be sent by Moscow to let the air out of the Soyuz living compartment so that then they could push through against the remaining air pressure to get into the living compartment of the Soyuz. (The hatch for the flight control module of the Soyuz is closed but not latched).

Articulating the problem in his report, Ulissey offered this assessment at Johnson Space Center.

> During planning, in the event Soyuz was needed as a backup airlock, the Russians wanted Foale and Kaleri to perform a test to see whether they could both squeeze through the docking hatch that connected the Soyuz Orbital Compartment to the ISS. It was unlikely for them to need a backup, but one scenario put forth was if the Pirs airlock had a large leak and couldn't regain an airtight seal post EVA, they might need a lifeboat. The problem was the docking hatch to Soyuz was narrow (much more narrow than anything on the USOS side), so the Russians wanted to make sure that Foale and Kaleri could squeeze through, while wearing their Orlan suits. NASA at the time was only loosely following script, which prompted Foale to raise a red flag. He asked management to push back on the Russian request. His concern was that if a problem developed while trying to pass through the hatch then they shouldn't both be suited. Eventually everyone got on the same page and the test was conducted with only Kaleri suited. Foale monitored and remained ready to assist.[16]

In an event that Foale and Kaleri could not close the Pirs airlock hatch they would use to enter the airlock, Moscow would send the command to evacuate the living compartment of the Soyuz, and once the pressure was released, the crew members could push the docking probe assembly aside, and go around the docking probe and into the living compartment of the Soyuz. Once both had gone around the docking probe and into the living compartment (which was very crowded and could barely fit two ORLAN suits inside) they would push this docking hatch closed.

Problems during the EVA

Two days before the scheduled EVA, Roscosmos mission control asked both Foale and Kaleri to get into their suits together inside the airlock in a pressurized environment. The suits were to be pressurized to .4 of an atmosphere of pressure above the usual pressure level in order to be as stiff as they would be if they were performing the EVA before attempting the pass by the docking probe that partially blocked the way to the Soyuz. During this rehearsal, Foale relayed reservations about this plan to the ground as it was immensely difficult for just one of them to carry out, let alone both of them. If they both became stuck, then there would be no way out and they would die. Speaking to the head of EVA planning in Moscow, Foale and Kaleri shared their fears over the docking probe obstacle in a call. Foale as Commander spoke on their behalf.

The following morning, Moscow ordered Kaleri to go first while Foale wore fewer layers of clothing inside his suit and followed behind Kaleri and they were eventually able to complete the rehearsal.

During the EVA on 26 February 2004, they encountered no issues with the airlock hatch. But the EVA was cut short after only three hours and 55 minutes[17] once Kaleri

reported increased temperatures in his suit and droplets of water accumulating in his visor.[18] The problems began at approximately three hours when Moscow called Kaleri for a status report. Despite his positive response, Foale noticed water on the inside of Kaleri's faceplate. Moscow inquired as to whether Kaleri's cooling system was functioning properly. Foale was ordered to complete Kaleri's tasks while he retreated to the airlock and stood by. However, not long afterward the EVA was called off. The crew were disappointed to cut short the EVA with work left to be completed and much having already been done, but Kaleri's condensation buildup was so great that he could hardly see, and his overheating was becoming severe.

The cooling system on the suit, known as the sublimator, evaporates water into space cooling the heat exchanger, which has interior water from the water loop of the suit passing through it. On the other side of the heat exchanger is water being flash evaporated into the vacuum to cool it down. It had become common for the flash evaporators to freeze ice on the outside against the vacuum, which stopped them working. Foale hypothesized that this had happened, and could identify it with ice on the outside of the suit.

Once they reentered the Pirs docking compartment and it was fully repressurized, Foale removed his suit and inspected Kaleri's.[19] The Flight Director in Moscow asked Kaleri to remain still as they ran diagnostics to assess the problem. The sublimator was working well until they closed the hatch. Foale opened Kaleri's suit and saw within Kaleri's pack that one of his two hoses was crimped (much as water through a garden hose flows less freely when crimped). Kaleri's suit was old and had been used 10-15 times. Unfortunately, a new suit had been sent up in a resupply vehicle but was not used for the EVA.

Medical officer Laurence (Lars) A. Ulissey relayed the following internal report of the EVA for the Johnson Space Center, which was passed on to me by Dr Michael Foale.

> "The test was successful, and the EVA proceeded as planned, starting on February 26th, 2004 at 21:17 hours GMT. They accomplished a good portion of their tasks, but due to a cooling failure in Kaleri's suit, the EVA was terminated early (at 3 hours and 55 minutes). The Orlan is designed for self-donning, and somehow during that process, one of the fluid lines in Kaleri's cooling garment got kinked. It was determined that he performed his EVA with virtually no cooling and a helmet that became overly fogged from excess heat and humidity, possibly due to a backup in water, not entirely unlike what happened to Luca Parmitano during EVA-23, but for different reasons and not nearly as severe."[20]

Video screenshot during *ISS Expedition 8*, EVA 2. Credit: NASA

Once both astronauts had returned inside the airlock, there was no way to re-attempt the EVA. The Russians do not recapture the air, and it is shunted into space when the airlock is evacuated. The Americans use a pump to push the air back into the station. Therefore, a lot of air was lost by the time the EVA was ended and the astronauts were back inside.

The EVA had initially been planned to be six hours in length. Most of the work had been completed, and the work with the most significant experiments that were

Video screenshot from an EVA on *ISS Expedition 8*. Credit: NASA

exposed to the exterior environment were taken care of. No external maintenance was carried out, and the planned work on the reflectors for assistance in ATV navigation was not able to be finished.

Aftermath

The EVA was treated as a practice for Michael Fincke for *Expedition 9*, who despite being on his first spaceflight was to learn much from it. Foale's very successful EVA on *Mir* had come without rehearsal on the ground due to the nature of the collision with the Progress resupply vehicle in 1997. Both NASA and Roscosmos acknowledged the fine job done by Foale.[21] Ultimately, Fincke and Malenchenko would perform four EVAs, before the exercise of performing EVAs without a watchman would be abandoned by *Expedition 11*, by which time the Space Shuttle was back in operation with the launch of STS-114 commanded by Eileen Collins. However, concerns around debris shedding during Shuttle launches returned following close study of the STS-114 launch where a large piece of debris narrowly missed the Orbiter, resulting in the Shuttle being grounded for another year while improvements were made. Nevertheless, with Shuttle missions to the *ISS* becoming regular again, there was no need to risk EVAs without a watchman, or to navigate the risks with the Soyuz hatch.

Hatch concerns continued to be raised in the aftermath of the *Expedition 8* EVA, much as they had been since Shuttle-Mir during the mid to late 1990s. As the *ISS* expanded, there was no need for the Soyuz hatch to be used as two airlocks were by then usable. The concept was shelved as a viable substitute without need for further consideration.

Upon landing, Foale had accumulated more time in space than any NASA astronaut at the time.[22] Kaleri would fly again six years later for *Expedition 25/26*. Both maintained significant record status in their space agencies to this day, with Foale inducted into the NASA Astronaut Hall of Fame in 2017.[23, 24]

The Pirs module was eventually replaced in 2021 by the Nauka module[25] which was larger and served broader purposes as well as both airlock and docking port.[26] Pirs was allowed to burn up on reentry into the atmosphere over the Pacific Ocean on 26 July 2021.[27]

Discussion

The need for these EVAs without a watchman was a necessity forced upon the space agencies due to the Space Shuttle *Columbia* disaster. The window for these practices extended only until the Shuttles were regularly flying again. The possibility of using the Soyuz as both hatch and lifeboat was an immense risk and yet only viable due to its design, which was an immense stroke of luck for the agencies. Without the design of the Soyuz as well as the ability to depressurize it from the ground then the astronauts would not have had the option of a second makeshift airlock. Nevertheless, the astronauts involved had their concerns and were fortunate that recourse to this action was not needed.

More could have been learned if the EVA was not cut short. Finke and Padalka experienced little trouble, yet it is not surprising that at the first opportunity, the possibility of an EVA without a watchman was abandoned. Though more could be achieved with three people conducting EVAs, the risks of operating without a watchman were not worth taking under any consideration and have not been taken again to this day.

NASA was also fortunate to have Dr. Michael Foale active and training for an *ISS* mission. His experience working with the Russians and within an ORLAN suit were an invaluable asset to call upon in the situation. With Foale being NASA's most experienced NASA astronaut at the time,

controllers were able to count on both Foale and Kaleri's experience for a six-month stay. One wonders if they would have been prepared to extend their stay if necessary, given the 12-month stays of the likes of Scott Kelly and Christina Koch in the years that followed.

About the Author

Samuel McKee is a PhD student in history and philosophy of science at Manchester Metropolitan University researching Sir Arthur Eddington's legacy. He is also a molecular biology researcher at the University of Reading and is on the committee of The Mars Society UK.

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