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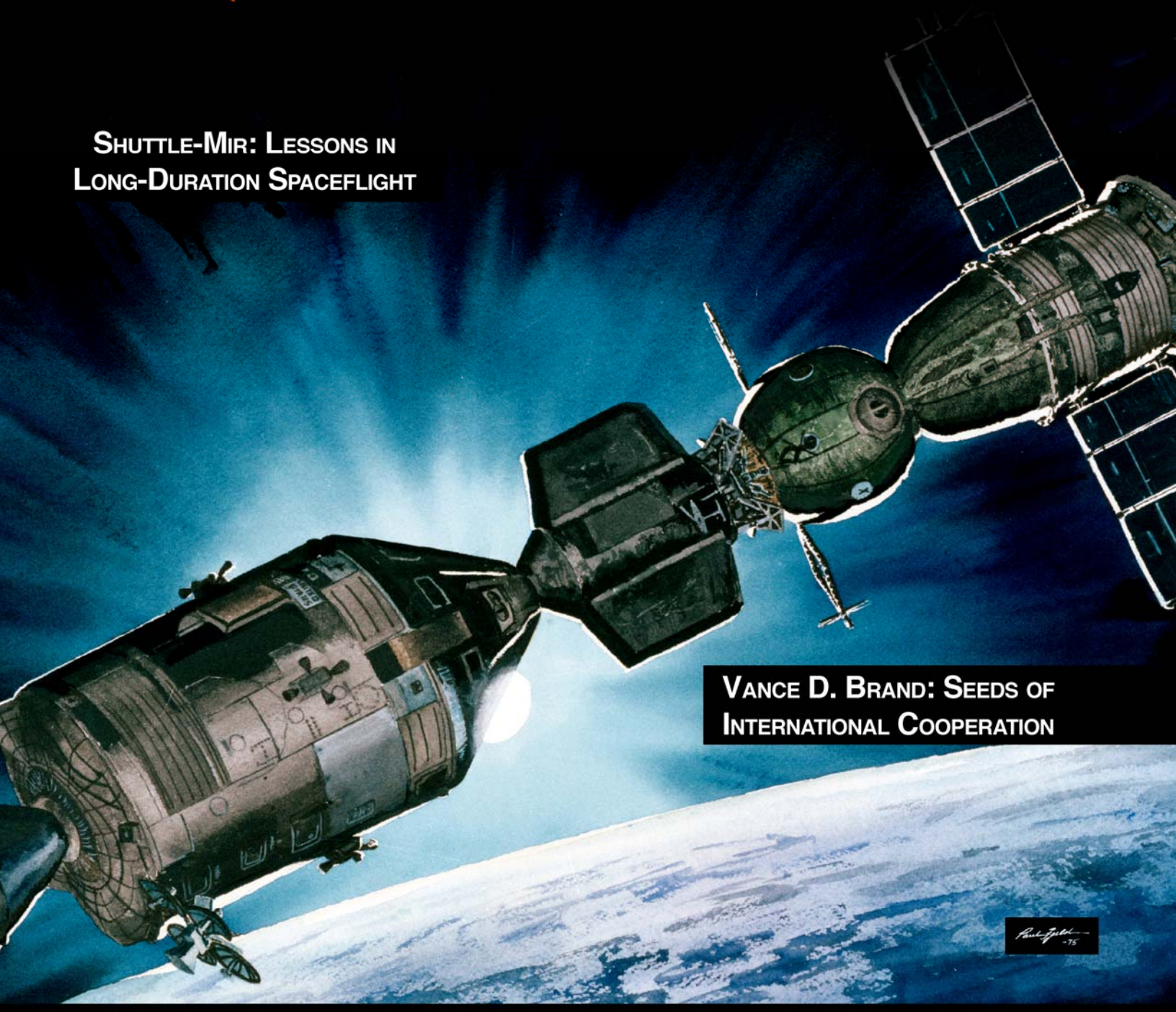

SHUTTLE-MIR: LESSONS IN LONG-DURATION SPACEFLIGHT

VANCE D. BRAND: SEEDS OF INTERNATIONAL COOPERATION

THE BEGINNINGS OF RESEARCH IN SPACE BIOLOGY

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Front Cover Caption

An artist's concept depicting the American and Soviet spacecraft docked in Earth orbit during the July 1975 Apollo-Soyuz Test Project mission. The Apollo Command/Service Module is on the left, the Docking Module is in the center, and the Soyuz spacecraft is on the right. The first docking of spacecraft from two different nations took place on 17 July 1975. The painting is by artist Paul Fjeld. Credit: NASA

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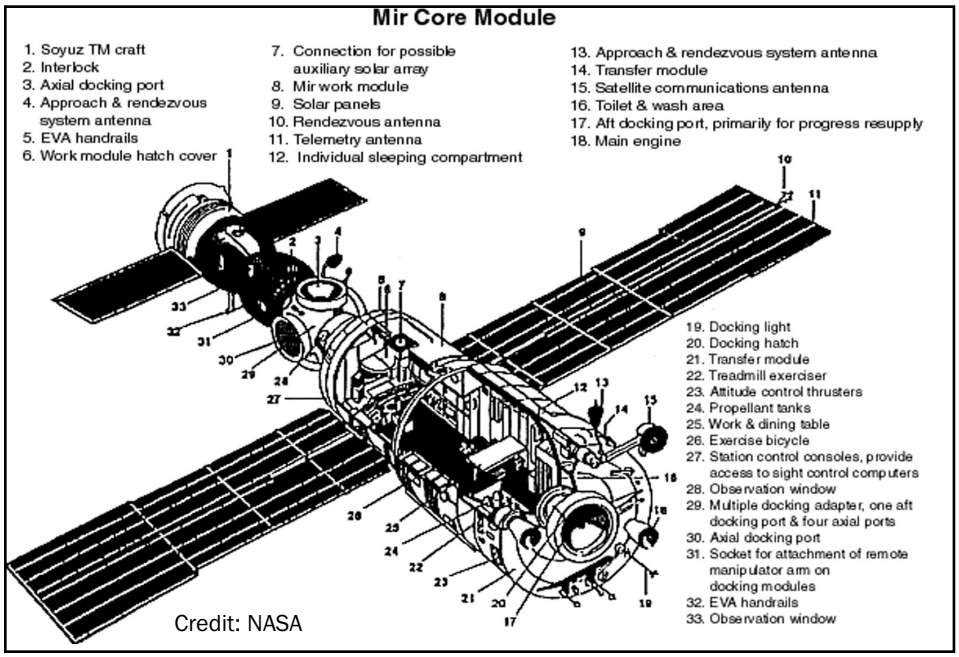
NASA's Lessons Learned in Long-Duration Spaceflight: The Shuttle-Mir Program

By Zack Hester

On 2 November 2000, two Russian Space Agency cosmonauts and one NASA astronaut arrived at the newly orbited *International Space Station* (*ISS*) and, thus, became the station's first occupants.[1] This event was a culmination of years of collaboration between multiple international partners and established a platform for NASA to conduct multiple long-duration human spaceflight missions. However, this mission was not the first time that Russian cosmonauts and American astronauts had undertaken a joint long-duration mission in low-Earth orbit. Russian and American astronauts had been working together in space for several years prior to the ISS's development onboard a Russian space station called *Mir*.

This historic collaboration in space resulted from the fall of the Soviet Union in 1991. After decades of Cold War-rivalry, the United States suddenly found itself in the position of trying to stabilize its former superpower rival, as a new Russian state struggled to support its massive government run infrastructure. Included in that infrastructure was the crown jewel of the Russian space program, the *Mir* space station.

The Russian word "Mir" translates roughly into "new world," "peace," or "community" depending on the context of its usage.[2] Assembly of the *Mir* space station first began in 1986 with the launch of the station's core stage. By 1991, *Mir* consisted of four pressurized modules with a regular rotation of cosmonaut crews. The Soviet Union



Credit: NASA

was well experienced in space station development from its previous successes at deploying seven small stations, Salyuts, between 1971 and 1982. Russian psychologists were the first to require that all Russian stations have "floors" and "ceilings" to provide cosmonauts a clear sense of up-and-down.[3] However, *Mir* was a much larger and complex design than any previous Soviet system. The station could connect multiple modules and had multiple docks for Russian Soyuz's to support larger expedition crews.[4] This Russian engineering knowledge and expertise gained from the *Mir* would prove valuable the development of the ISS.

In the early 1990s, NASA was at work designing its own space station, Space Station *Freedom*. The station was first approved in the mid-1980s and was pitched as international endeavor given the involvement of international partners in Europe and Japan. However, cost overruns and numerous station redesigns stalled development and nearly resulted in cancellation by Congress of the program in 1991. However, by early the 1990s, Presidents Bush and Clinton began to employ NASA as a diplomatic tool to maintain Russian space's infrastructure and technology talent following the Soviet Union's collapse. Out of such efforts the Shuttle-Mir program was born, which set the stage to bring Russia into the Space Station *Freedom* partnership, which was later renamed the *International Space Station* (*ISS*). The only other time the United States and Russia had previously undertaken a joint mission in space was the Apollo-Soyuz mission in 1975, when an Apollo spacecraft docked with a Russian Soyuz spacecraft in low-Earth orbit to symbolize stronger relations between the two superpowers.[5]

In 1995, Norm Thagard became the first American astronaut to train in Russia, launch into space on a Russian Soyuz, and the first to complete a residency aboard Mir, setting an American space endurance record of 115 days in orbit. Credit: NASA

This new era of collaboration began with what NASA called the Phase One program, also known as the Shuttle-Mir program. The program would send astronauts to live and work on *Mir* by utilizing the Space Shuttle to ferry astronauts. This would mark NASA's return to long-duration human spaceflight since the end of the Skylab program, an American space station that was operated in the mid-to-late 1970s. During the Shuttle-Mir program, eleven Shuttle flights were made to the *Mir* space station. Additionally, seven US astronauts lived and worked onboard the *Mir* station for months at a time between 1995 and 1998.[6]

Beyond the political benefits, the Shuttle-Mir program also provided NASA experience in long-duration human spaceflight before the development of ISS. Some at NASA, especially in the astronaut corps, would come to see the Shuttle-Mir program as a waste of NASA resources for little scientific payoff, while placing American astronauts in unnecessary danger on the aging *Mir* station. However, without NASA's $400 million pledge to Shuttle-Mir program, it is very likely that Mir would not have survived through the 1990s, which in turn would have crippled Russia's space program.[7] From the first mission with astronaut Norman Thagard in 1995 to seventh and final mission with Andy Thomas in 1998, NASA gained value experience as an institution in long-duration human spaceflight that is applicable to its current mission onboard the ISS and its future deep space ambitions.

The First NASA Astronaut on *Mir*—Norman Thagard

On 14 March 1995, after months of extensive training in Russia, Norman Thagard became the first American to ride a Russian rocket and the first of eventually seven astronauts to visit *Mir* for long-duration spaceflight missions. Naturally, NASA wanted to use this first mission to study the effects of long-duration spaceflight on the

human body. However, a series of setbacks derailed the scientific objectives of the mission. It started with Thagard's freezer for storing blood, saliva, and urine samples. The European-built freezer malfunctioned early in the mission. As NASA had no understanding of the freezer and was unable to figure out how to repair it, Thagard's samples soon spoiled.[8] With few experiments left to occupy his time and the refusal of his Russian crewmates to allow him to participate in station maintenance or operations, Thagard spent most of his 115-day mission floating around the station, reading, and watching the Earth out a station window. All Thagard could do was basic metabolic tests and measurements for medical events such as bone loss. However, these tests soon became tainted as ground controllers came to realize that Thagard had lost over seventeen pounds, including lean body mass, just a few weeks into the mission.[9] This had been the result of the strict diet NASA had set for Thagard in which only bar-coded food that was properly recorded could be eaten for the sake of medical research. Foods without bar codes included secondary rations like snacks, which required more paperwork to log. Ultimately, Thagard was more inclined to skip meals than deal with the paperwork and failed to notice his rapid weight loss.

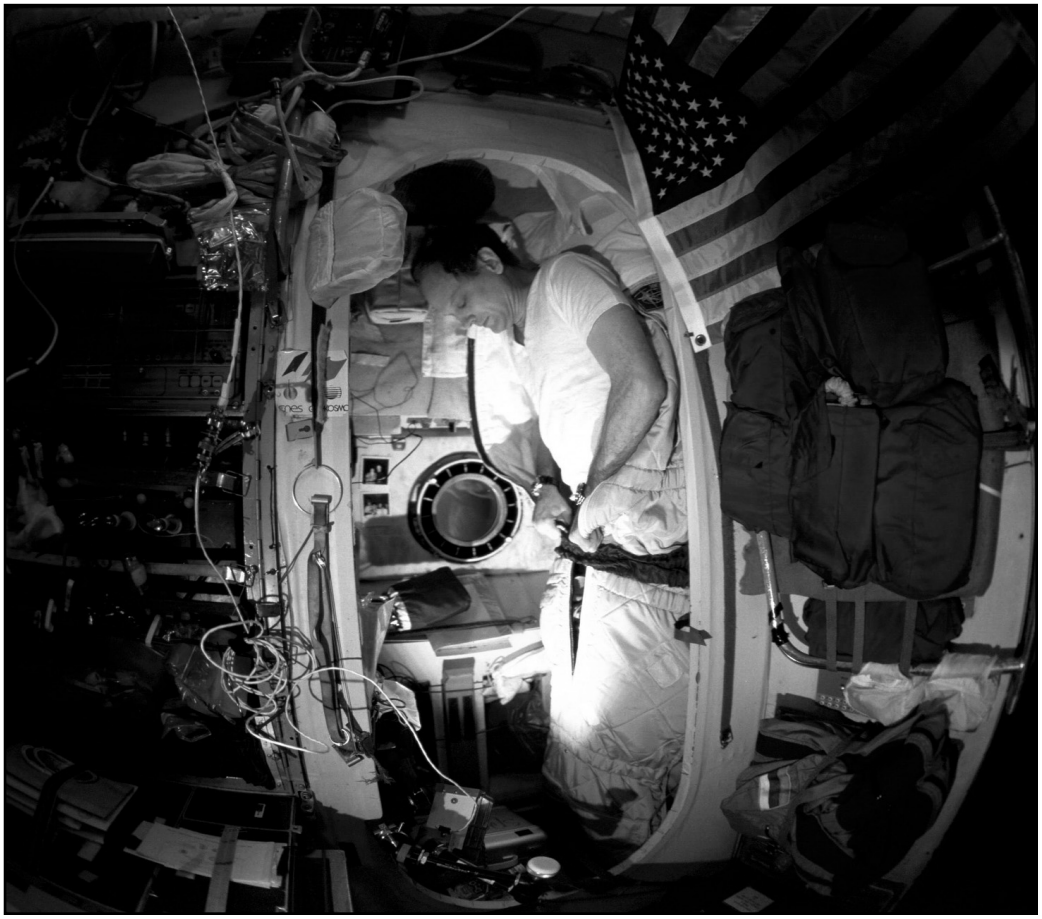
Thagard's mission to *Mir* also was the first time in decades that a NASA astronaut had an opportunity to exercise in microgravity to counter bone and muscle loss during a long-duration spaceflight mission. Here too Thagard and NASA stumbled out the gate. Shortly after his arrival, Thagard attempted to exercise with a set of Russian isometric cables that were onboard *Mir*. The cables are looped around one's feet for a hold and stretched over the back and neck to allow astronauts to perform knee bends. However, one of the cables slipped off Thagard's foot during an exercise and struck him in his right eye causing severe pain and sensitivity in that eye. When he told one of his Russian crewmates what had happened, the cosmonaut simply replied, "Oh, yes. Those things are dangerous. That's why I don't use them."[10] Russian doctors later diagnosed the injury as a possible corneal abrasion and prescribed him antibiotics and steroid drops. Eventually, Thagard's eye began to heal as a result of the medication.

On 24 February 1997, a routine ignition of an oxygen-generating canister caused a fire, which suddenly went out of control. Crew wore gas masks and eventually managed to extinguish the fire. Smoke filled part of the *Mir* space station, along with a Soyuz spacecraft, their only way to go home. Credit: NASA

The failure of Thagard's mission in terms of medical research was capped off with his return to Earth, where upon landing he walked out of the Shuttle rather than be carried off in a stretcher.[11] This show of astronaut bravado denied NASA medical personal the opportunity to study and conduct tests on Thagard's body before the act of standing, which initiates changes in the human body to react to the effects of gravity. Finally, before Thagard's post-flight medical examination, NASA Administrator Dan Goldin took Thagard to a press conference where Goldin presented Thagard with an ice cream sundae and a hot dog to welcome the astronaut home. Much to the chagrin of the NASA medical staff, this meal skewed Thagard's glucose levels before the post-mission medical tests. Ultimately, the mission clearly demonstrated that NASA as an institution was rusty at executing long-duration human spaceflight missions.

Extravehicular Activity (EVA) on *Mir*

During the Shuttle-Mir program, a total of 25 EVAs were conducted. Most consisted of installation and maintenance of station hardware. Unlike the Space Shuttle, which could be taken back to Earth for repairs and regular maintenance, *Mir* demonstrated the challenges of maintenance and repair in space, which have to be conducted through



Norm Thagard zips a sleep restraint in his sleep station in the Core Module of Russia's *Mir* Space Station. Credit: NASA

extensive EVAs. Crewmembers who went outside the station to work on *Mir* often reported skin injuries such as friction-induced sores, eroded fingernails, and friction abrasions on the ribcage after the completion of an EVA.[12] However, these injuries were consistent with those encountered in NASA's EVA trainings in Houston and ointments were readily available on *Mir* to treat the injuries. However, the simulations could not replicate the challenges of establishing one's orientation in microgravity during an EVA. One NASA astronaut, Jerry Linenger, suffered from extreme disorientation during his *Mir* EVA. There were a few times when he could not even move because of overwhelming disorientation.[13] Additionally, Linenger found it challenging to navigate around the massive solar panels on the *Mir* space station. Many NASA astronauts that lived aboard *Mir* noted that the patched-up *Mir* panels and modules bore sharp edges and snap points which made any EVA work precarious for first-time space walkers.[14]

Technical Challenges and Failures

By the time Norm Thagard arrived to *Mir* in 1995, the nearly ten-year-old station was already showing signs of aging. Additionally, there were constants gaps in communication signals between the ground and the station crew. Some days the crew would have only 42 minutes of communication time with the ground in a 24-hour period.[15] At this time, NASA had yet to establish the network of communications that could supplement Russian ground stations and provide station crews near continuous communications access with the ground. This would later cause major issues for ground controllers during times of crisis onboard *Mir* where the crew would be out of range for hours on end trying to handle an emergency without support.

One such emergency occurred during a scheduled crew rotation in 1997 when a fire broke out onboard

Mir. The cause of the fire was the use of solid-fuel oxygen generator that cosmonauts had employed to generate extra oxygen onboard the station during times of excess crew capacity. These canisters burned cassettes containing lithium perchlorate ($LiClO_4$), which then produced breathable oxygen.[16] It was one of these canisters that malfunctioned and generated a fire. Soon three-foot flames were erupting from the canisters melting nearby metal as smoke began to engulf the entire module. While the fire was soon contained, NASA was not informed of the fire until 12 hours after the emergency. Moreover, the incident revealed some disturbing issues to NASA.[17] During the fire, some oxygen masks did not properly inflate and some of the fire extinguishers malfunctioned. The fire also cut off the crew from one of the two Soyuz vehicles docked to the station. This meant that if the crew had been forced to evacuate, only half of the six-person crew could have safely escaped. Furthermore, there was no air analysis equipment onboard *Mir*, which made it difficult for ground controllers to clear the crew to take off their masks following the fire.

Not too long after the fire, a coolant leak was discovered. This issue led to long nights and endless hours of stress and work placed on the cosmonaut crew to find and seal the leak and lasted for nearly three months. At one point cosmonaut Vasily Tsibilyev actually flew into a basketball-sized blob of ethylene glycol floating in one of the modules while working on the leak. The toxic contact poisoned Tsibilyev's stomach to the point where he could not eat for three days. The leak was finally found and sealed but not after the crew had to fight and avoid the toxic contamination for months on end while not fully understanding the toxin's effect on their bodies.

Additionally, during a manual docking test of a Russian resupply ship, known as Progress, the cosmonauts and Russian ground controllers lost sight of the Progress ship on its approach to *Mir*. The result was that the supply ship actually struck the station and damaged Mir's solar arrays and punctured a small hole in a station module, Spektr, which led to a slow decompression.[18] The *Mir* crew eventually sealed off the damaged module. However, with the station suddenly in free drift from the collision, the solar arrays could no longer track the sun and generate power that led to crash of the *Mir* central computer. This crisis took weeks to resolve and almost led the United States Congress to cancel the entire program.

Psychological Stresses and Challenges

One area within NASA's human spaceflight organization that was greatly expanded as a result of the Shuttle-Mir program was the rise of the role of psychologists. For decades, psychologists were loathed by astronauts who did not like the idea of someone denying them the opportunity to fly because of perceived psychological issues. Additionally, since Shuttle flights were typically only two weeks in duration, issues such as personality conflicts and depression were often considered a moot point. The thinking at NASA was that anyone could endure dysfunctional group dynamics for two weeks and that such a timespan was too short for any onset of depression or mental fatigue to materialize. However, onboard *Mir*, NASA astronauts had to deal with months of mental stress and pressures that the ground operators had to address. Furthermore, Russia had a well-established team of psychologists in place for their cosmonauts.[19] This fact partly contributed to NASA's expansion of the role of psychologist in the human spaceflight program, as NASA sought to avoid American astronauts falling under Russian psychological observation and evaluation.

Dysfunction in station operations constantly arose as daily challenges with the *Mir*'s aging systems, a series of emergencies, and general fatigue from sleep deprivation led *Mir* cosmonauts and astronauts to develop an "us" versus "them" mentality with the controllers on the ground. For cosmonauts, there was a strong belief that Russian ground controllers would never abandon *Mir* even at the risk of the cosmonauts' lives in order sustain Russia's economic and national prestige interests in maintaining the station. Conversely, NASA astronauts often believed that the motives of the entire Shuttle-Mir program were purely political and that their scientific missions were a mere farce. Indeed, NASA struggled to find enough astronaut volunteers to participate in the Shuttle-Mir program because many in the astronaut corps did not see how the program would advance their careers. Often issues would arise when ground controllers drafted schedules for the astronauts. NASA's approach to astronaut schedules was very rigid with tasks allocated down to the minute. However, astronauts often struggled to keep up with the schedule as a result of *Mir*'s maintenance problems and the problems of finding equipment in the station's cluttered modules. At one point, NASA astronaut Jerry Linenger became so frustrated with NASA ground controllers over the NASA schedule and technical problems on *Mir* that he only communicated with them through email for a few days before returning to radio communications. NASA had also struggled with this issue of ground controllers and astronaut relations over schedule conflicts dur-

ing the Skylab station program in the 1970s. During the *Skylab IV* mission, NASA astronauts became so frustrated with NASA ground controllers over schedule disagreements that the astronauts actually shut off radio communications with the ground for an entire day.[20]

Furthermore, the third astronaut to live abroad *Mir*, John Blaha, would later admit that after a few weeks aboard *Mir*, he suffered from deep depression after the Shuttle that transported him to the *Mir* had left. He felt a great sense of disconnection from Earth. He would later tell the media, "I realized that I was clinging to Earth, so to speak. I psychologically cut the cords, if you will, with all those things that were on the planet that I couldn't have."[21] Unlike Shuttle flights, long-duration spaceflights require astronauts to work and operate in space, long after the novelty of living space wears off.

Finally, there were also personality conflicts between astronauts and cosmonauts during the four-year collaboration. Some of this was in part to cultural differences that were exacerbated by language barriers. Other points of conflict included Russian trainings and station procedures that were vastly different from that of the Shuttle program. All seven of the NASA astronauts in the Shuttle-Mir program had to undergo training at Russia's cosmonaut facility and undergo Russian medical examinations because *Mir* remained fully owned and operated by the Russian Space Agency. Russian medical procedures were a particular point of contention between astronauts and Russian ground controllers as it put the decision of whether or not an astronaut could fly into the hands of Russia, not NASA.

Andy Thomas—The Final Astronaut to *Mir*

By the time Andy Thomas, the seventh and final astronaut abroad *Mir*, arrived in 1998, he and NASA were much more well prepared in comparison to Norman Thagard's mission in 1995. With the knowledge of the setbacks and emergencies encountered by his predecessors fresh in his mind, Andy Thomas had one of the more successful missions onboard *Mir*. Communications between the ground and crew and between NASA and the Russian Space Agency had vastly improved by 1998 and would prove invaluable for the United States and Russia on the development of the ISS.[22] However, *Mir* continued to have technical problems including one small fire and issues maintaining the station's orientation.[23]

Despite the aging station's problems, Andy Thomas was able to complete a string of scientific experiments in Earth science, microgravity research, life sciences, and radiation research.[24] Thomas did report having some issues adapting psychologically to the isolation and confinement of the station as well as handling the rigorous schedule set on his time by NASA.[25] Thus, he faced a common problem that most long-duration astronauts face, finding time to complete all assigned scientific work while also achieving the recommended amount of exercise to counter the effects of microgravity. However, these issues appeared much less severe to Thomas than those encountered by Thagard, Blaha, and Linenger.

Conclusion

After more than 86,000 total orbits around the Earth, *Mir* was deorbited and destroyed on 23 March 2001 just a few months after the first crew arrived at the newly developed *ISS*.[26] The development and operation of the ISS relied on the lessons learned from the Shuttle-Mir program. As Frank Culbertson, former NASA astronaut and Phase One manager, stated, "Many of our lessons are repeats that were forgotten from Apollo-Soyuz."[27] The seven astronauts who lived and worked onboard *Mir* deepened NASA's understanding of the challenges of long-duration spaceflight to a new generation of NASA ground controllers and astronauts. These missions brought to light the importance of having procedures in place to help astronauts cope with psychological and physiological issues as they arise. Not all the problems onboard *Mir* were inherently the result of Russian technology or cultural conflicts. Many are problems that are simply inherent to long-duration spaceflight. Therefore, the Shuttle-Mir program should serve as a case study for what future long-duration missions might entail, especially as NASA seeks to embark on new long-duration spaceflight missions beyond low-Earth orbit. Deep spaceflight missions to asteroids, the Moon, and Mars will certainly entail challenges of technological failure, psychological stresses, and negative physiological effects of microgravity. All of which will have to be addressed far away from the confines of low-Earth orbit. NASA should use the Shuttle-Mir program as a reminder that it takes time along with some trial and error for an large and complex institution like NASA to properly prepare and execute new mission profiles.

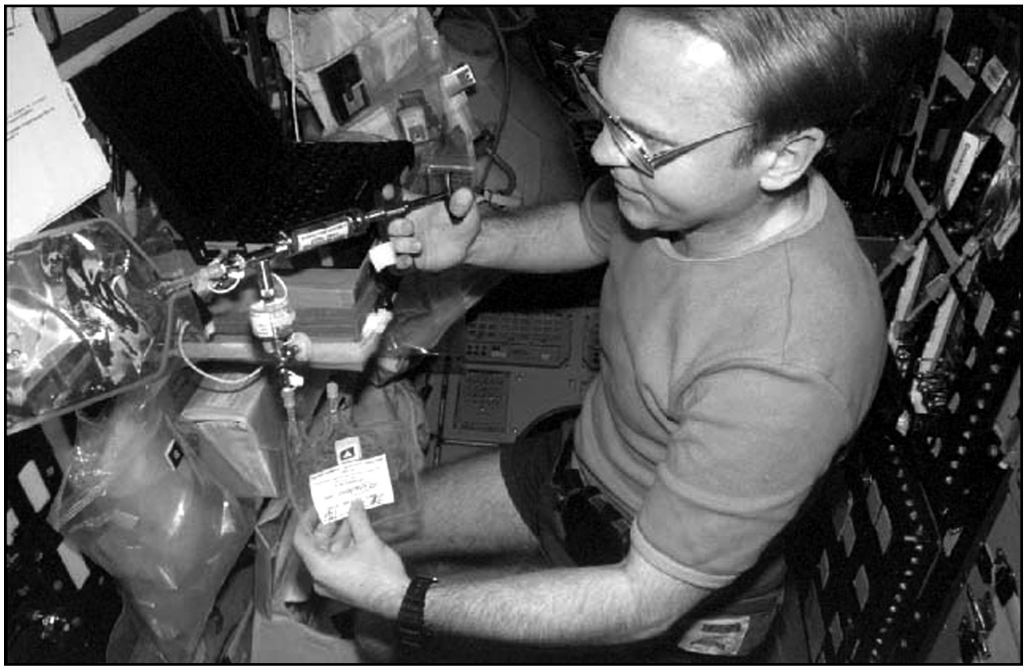
About the Author

Zack Hester is a graduate student at the George Washington University Space Policy Institute.

Notes

1 Garcia, Mark. "International Space Station." NASA. 2015. Accessed 14 April 2015. http://www.nasa.gov/mission_pages/station/expeditions/expedition01/index.html.

2 David M. Harland, *The Story of Space*



Mir-25 crewmember Andrew Thomas takes a Microbial Collection Device (MCD) sample for Water Experiment Kit VI using a syringe pump. Credit: NASA

Station Mir (Berlin: Springer; 2005), 141.

3 Harland, 145.

4 Bryan Burrough, *Dragonfly: NASA and the Crisis aboard Mir* (New York, NY: HarperCollins Publishers, 1998), 81.

5 Sarah Loff, "Apollo-Soyuz Test Project" (NASA: 2015), accessed 14 April 2015 from http://www.nasa.gov/mission_pages/apollo-soyuz/index.html

6 Brian Dunbar, "Shuttle-Mir" (NASA, October 19, 2007), accessed April 17, 2015 from http://www.nasa.gov/mission_pages/shuttle-mir/

7 Burrough, 81.

8 Burrough, 314.

9 John Holliman, "Report: Conditions on *Mir* Much Worse than Thought" (CNN, 1997), accessed 15 April 2015 from http://www.cnn.com/TECH/9709 /12/mir

10 "NASA-1 Norm Thagard" (NASA-1: Norm Thagard), accessed 17 April 2015 from http://history.nasa.gov/SP-4225/nasa1/nasa1.htm

11 Burrough, 324.

12 I.B., Gontcharov, I.V. Kovachevich, A.L. Navinkov, and M.R. Barratt, "Medical Care System for NASA-Mir Spaceflights," *Aviation, Space, and Environmental Medicine* 73: 1219 (2002), 693.

13 Burrough, 224.

14 Burrough, 227.

15 "NASA-1 Norm Thagard."

16 "Trial by Fire: Space Station Mir Onboard Fire" (NASA, 2011), accessed 22 April 2015 from https://sma.nasa.gov/docs/default-source/safety-messages/safetymessage-2011-11-07-spacestationmironboardfire-vits.pdf?sfvrsn=4

17 Burrough, 130.

18 Burrough, 391.

19 Jerry Linenger, *Off the Planet: Surviving Five Perilous Month Aboard the Space Station Mir*. (New York: McGraw-Hill, 2000) 129.

20 Vaughan Bell, "Isolation and Hallucinations: The Mental Health Challenges Faced by Astronauts," *The Guardian* (5 October 2014), accessed 21 April 2015 from http://www.theguardian.com/science/2014/oct/05/hallucinations-isolation-astronauts-mental-health-space-missions

21 Marcia Dunn, "Blaha Got the Blahs on His 4-Month Visit to the Russian Space Station," *Los Angeles Times* (30 March 1997).

22 "NASA-7 Andy Thomas: Smoother Sailing" (NASA History), accessed 17 April 2015 from http://history.nasa.gov/SP-4225/nasa7/nasa7.htm

23 "NASA-7 Andy Thomas: Smoother Sailing."

24 "Andy Thomas's Mission on Mir," Scientific American Frontiers (1998), accessed 13 April 2015 from http://www.pbs.org/safarchive/5_cool/5_mir/mir2.html

25 "NASA-7 Andy Thomas: Smoother Sailing."

26 "Mir Space Station" (NASA History), accessed 10 April 2015 from http://history.nasa.gov/SP-4225/mir/mir.htm

27 Frank Culbertson, "What's in a Name?" (NASA History, 3 October 1996), accessed 22 April 2015 from http://history.nasa.gov/SP-4225/documentation/mirmeanings/meanings.htm

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