

TROUBLE INTERNATIONAL

ON THE SPACE STATION

Next year marks two decades of continuous human occupancy of space, but things haven't always run smoothly...

Reported by James Romero

This achievement of political ambition, engineering execution and international collaboration has changed the nature of space exploration. Following the initial period of politically motivated, headline-grabbing forays into space and then to the Moon came a more settled, but no less important period of habitation.

"Because of the International Space Station, space exploration is no longer an up and down activity," says space historian Robert Pearlman, co-author of *Space Stations: The Art, Science and Reality of Working in Space*. Cited as the largest peacetime international effort in human history, in 2014 British astronaut Tim Peake was the latest to call for the ISS to receive a Nobel Peace Prize for bringing nations together.

If the station is seen as a beacon of peace and a testament to not just human ingenuity, but harmonious collaboration in pursuit of shared goals, the realities of life on board can be far more testing. As we enter a seemingly new era of human space exploration, with proposed lunar bases and crewed missions to Mars, the lessons learnt keeping the station's spacelarking residents safe, sane and secure are more vital than ever.

These lessons begin further back than the launch of the first ISS components back in 1998. This latest low-orbit residence followed on from smaller scale celestial real estate in the form of the US Skylab and a number from the Soviet Union which culminated in Mir, launched from 1986 to 2001.

These early forays into temporary orbital living went ahead in spite of a limited understanding of how such an alien living environment might affect the health of the crew. And while the ISS has made efforts to mitigate some of the adverse complications identified from these earlier missions, there is still a lot we

don't know. "Part of the reason the ISS exists is to learn how the human body reacts to extended periods of time in microgravity," says Pearlman.

Today those extended periods cover between six months and a year, which is a concern when we know that such lengthy periods in orbit produce serious muscle wastage. To combat this the space station is outfitted with its own gym equipment, and the crew work out for more than two hours each day to overcome this wastage. "The astronauts who return from the ISS are not crippled in any way," explains Pearlman. "They can walk within minutes of getting out of their spacecraft."

A less well-managed physical impact of space living comes from accounts of crew members experiencing visual impairment during their missions. "We don't know exactly what causes these changes," says Michael Stenger, lead of the Cardiovascular and Vision Laboratory at the Johnson Space Center, "but we have identified possible contributing factors. These include a build-up of pressure behind the retina, possibly brought about by weightlessness-induced headward fluid shifts."

Fortunately the complications seem to correct themselves once the astronauts are back on Earth. Indeed, current mission lengths don't seem to induce long-term changes in any physical traits. This was confirmed by a recent twin study led by clinician Francine Garrett-Bakelman, which compared changes in the molecular and physiological traits of astronaut Scott Kelly with his Earth-based twin brother Mark during, and in the weeks after, Scott's latest 340 days in space.

The study concluded that the majority of Scott's biological health variables remained stable, or returned to normal soon after landing. "The biology in our bodies can manage space travel," wrote Garrett-Bakelman. "You don't come back as the green blob. You're still human. Your lungs are working. Your heart is working."

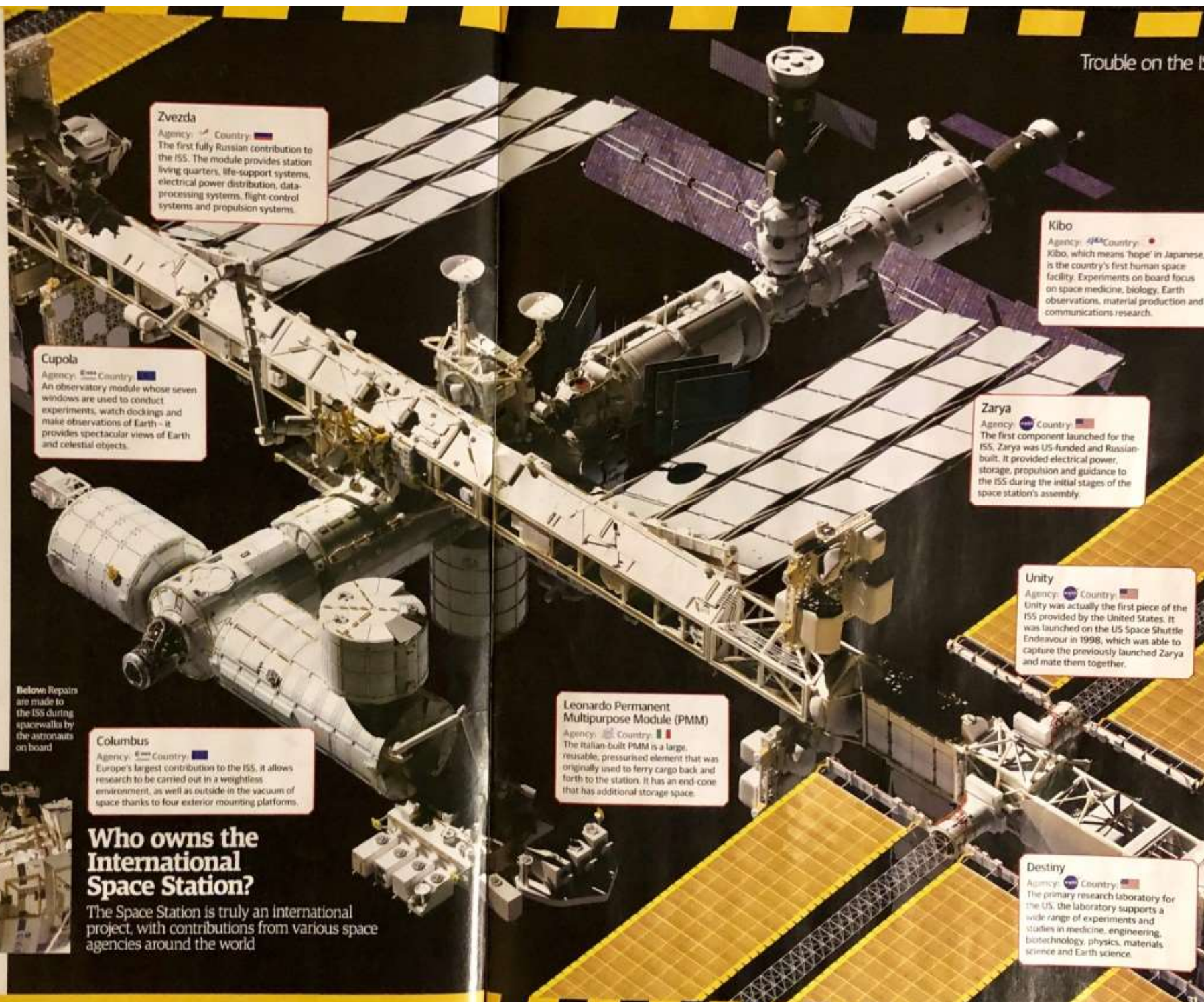
While the ISS has made us a home in space, other lifeforms also seem to have taken a liking to these pockets of low-gravity habitability. And that could prove bad news for crews on future missions. ISS astronauts have carried out experiments to see what the microgravity environment does for the growth of bacteria. They found species behind various ailments on Earth, such as urinary tract infections, endocarditis, salmonella and listeria, but one even more potent.

Other unwanted microorganisms have also stowed away on the station. Samples of mould and fungal species, brought in by the astronauts themselves or perhaps by their cargo, have been observed growing, and samples have been taken for analysis. "The longer a confined habitat is used, some moulds and fungi can accumulate, especially in moist locations," says Petra Rottberg from the Institute of Aerospace Medicine in Cologne. "This is not that important for crew health, but might result in damage to ISS surfaces due to biofilm formation, and might disturb the functionality of instruments."

It's a reminder that in such an extreme, isolated environment, dangers can come from unexpected places. This places extra pressure on the crew when the smallest malfunction or error in judgement can create threatening situations.

While no full station evacuations or serious medical emergencies have been reported, mishaps and close shaves do occur. Mir famously suffered both a collision with another spacecraft and a fire on board that were both life-threatening. While in 2013 Italian ISS resident Luca Parmitano almost drowned on a spacewalk. The water system inside his spacesuit started to back up and fill his helmet. By the time he had made his way back to the airlock, his helmet was almost completely filled with water and he could not see. "I experienced what it's like to be a goldfish in a fishbowl from the point of view of the goldfish," he told RIGO-TV upon his return to Earth.

Threats to the crew on the ISS don't just come from inside the space station. "Space debris has the potential to cripple the ISS and kill the crew," Robert Frost, instructor and flight controller at NASA, told spacenews.com. "These objects are travelling around the Earth at a speed ten times that of the average bullet from a gun. It is a tightly managed risk." To combat this threat more than 23,000 objects larger than ten centimetres, four inches across are tracked in orbit.



Zvezda
 Agency: Country:
 The first fully Russian contribution to the ISS. The module provides station living quarters, life-support systems, electrical power distribution, data-processing systems, flight-control systems and propulsion systems.

Cupola
 Agency: Country:
 An observatory module whose seven windows are used to conduct experiments, watch dockings and make observations of Earth - it provides spectacular views of Earth and celestial objects.

Columbus
 Agency: Country:
 Europe's largest contribution to the ISS, it allows research to be carried out in a weightless environment, as well as outside in the vacuum of space thanks to four exterior mounting platforms.

Leonardo Permanent Multipurpose Module (PMM)
 Agency: Country:
 The Italian-built PMM is a large, reusable, pressurised element that was originally used to ferry cargo back and forth to the station. It has an end-cone that has additional storage space.

Kibo
 Agency: Country:
 Kibo, which means 'hope' in Japanese, is the country's first human space facility. Experiments on board focus on space medicine, biology, Earth observations, material production and communications research.

Zarya
 Agency: Country:
 The first component launched for the ISS. Zarya was US-funded and Russian-built. It provided electrical power, storage, propulsion and guidance to the ISS during the initial stages of the space station's assembly.

Unity
 Agency: Country:
 Unity was actually the first piece of the ISS provided by the United States. It was launched on the US Space Shuttle Endeavour in 1998, which was able to capture the previously launched Zarya and mate them together.

Destiny
 Agency: Country:
 The primary research laboratory for the US, the laboratory supports a wide range of experiments and studies in medicine, engineering, biotechnology, physics, materials science and Earth science.

Who owns the International Space Station?
 The Space Station is truly an international project, with contributions from various space agencies around the world



About five per cent of those are active spacecraft and 95 per cent are spent rocket bodies, dead satellites, debris and other junk.

"If there is even a one in 10,000 chance of collision with an object bigger than a small grapefruit, we make plans to move," said Frost. These small debris avoidance manoeuvres take place several times a year, and are carried out by the space station's thrusters. However, this citrus fruit-scale surveillance still leaves an estimated 500,000 untracked objects out there larger than a marble, which could still cause significant damage. To prepare for the worst-case scenario of air depressurisation from a puncture there are sealable hatches between each ISS module, and the astronauts are trained to go through the process of closing those hatches, sealing off the safe areas from the damaged ones.

While the ISS has not yet been punctured from the outside, there was a recent situation where a drop in pressure was attributed to the discovery of a small hole in a Russian Soyuz capsule docked at the station. Some Russian news sources and officials speculated that the hole was the result of deliberate sabotage, though former ISS commander Alexander

Gerst told BBC Radio 4 earlier this year it was caused by a botched repair job prior to launch. This constant danger of meteorite punctures or malfunctioning components would cross the mind of even the most focused astronaut. However, the mental strain on those living above our skies for months on end generally comes from more recognisable places of isolation and distance from loved ones. Fortunately this was recognised from the outset of the ISS project, and there was a lot of talk about ways to maintain mental health, from the wall colours to agreeing on a single upwards orientation across the entire station.

Later there was recognition of the need for privacy, and so as soon as the ISS could support it, soundproof crew quarters were installed. This has been followed by a phone, weekly video calls, internet access and the inclusion of personal care packages on cargo missions, which have delivered freshly baked goods, ice cream and even sushi.

There have also been conservative efforts to build camaraderie with weekly all-crew sit-down dinners. Plus, with projects on board, movie nights have become a popular part of the social calendar. "They've developed traditions and a culture into

Problems on the International Space Station

Threats come from some surprising places when living in space

Micrometeorites and space debris

Space is not, as its name suggests, completely empty. Especially within low-Earth orbit, where micrometeorites and space debris such as active spacecraft, old rockets and parts from smashed-up satellites can be travelling around the Earth at ten-times the speed of the average bullet from a gun. To combat this threat, which in a worst-case scenario could see depressurisation of breathable air through a punctured hole, the space station is fitted with thrusters that can move it slightly in its orbit if an impact is anticipated.



A Russian spacewalk in 2007 discovered damage to a module's outer protective blanket caused by a micrometeoroid.

The dangers of faulty equipment

In 2013, Italian ISS resident Luca Parmitano almost drowned while on a spacewalk after a water system inside his spacesuit started to back up and fill his helmet. Another example came in 2018 when a drop in air pressure was attributed to a small hole in a Russian Soyuz capsule docked at the station. Some speculated that the hole was the result of deliberate sabotage, however, former ISS commander Alexander Gerst reported it was caused by a botched repair job prior to launch.



In 2018 a breach opened up in the Soyuz Orbital Module's hull, allowing a very small amount of atmosphere to leak into space.

The physical strain of space living

In space you don't have gravity pulling down on you, removing some of the everyday stresses put on your skeleton and muscular system. As a result, these muscles would start to degrade if not for the astronauts' daily workout regimes. Other reported health complications from space living include loss of eyesight, possibly as a result of a build-up of liquid pressure behind the retina.



ESA astronaut Thomas Pesquet wearing the Muscle Atrophy Inertial Exercise System (MAIES) in the Columbus Module.

The mental strain of space living

The dangers of space habitation, the sense of isolation and distance from loved ones puts a unique mental strain on those on board. This is made worse when astronauts experience loss during their stay. More than once an astronaut has experienced the death of a family member while on board, while the American astronaut Frank Culbertson was on the ISS on the day of the 9/11 terrorist attacks.



Peggy Whitson and Jack Fischer make a call using one of the ISS video phones, vital to connect astronauts to loved ones.

The threat of infection

ISS astronauts have carried out experiments to see what the microgravity environment does for the growth of bacteria. They found species behind serious ailments on Earth, such as urinary tract infections, endocarditis, salmonella and listeria, became even more potent. Other uninvited microorganisms have also stowed away on the ISS. This is not that important for crew health, but might disturb station instruments.



Inside the Microgravity Science Glovebox, ISS astronauts are growing bacterial colonies.

Right: Our planet is surrounded by thousands of chunks of space debris

Left: Teams of astronauts take part in scientific experiments



"We are seeing the very early stages of a new group of humanity" Robert Pearlman

itself. We are seeing the very early stages of a new group of humanity that we haven't seen before," says Pearlman.

"This sense of community, along with the creature comforts, reminders of home and access to medical and psychological support teams on the ground, are vital for when things get tough. More than once an ISS astronaut has experienced the loss of a family member while on board the space station. The inability to be with relatives at such a difficult time is a risk astronauts take when signing up to a mission, says Pearlman. "Before they fly they are asked if they want to know if someone close dies."

A similarly traumatic experience was reported by American astronaut Frank Culbertson on board the ISS on the day of the 11 September terror attacks. He has written extensively about his feelings of being off the planet and seeing smoke rising out of the former site of the World Trade Center. He later learned that a close friend, Charles Buntingham, was the pilot of the plane that struck the Pentagon.

Whatever the political situation down on the ground, astronauts and Russian cosmonauts have pointed out from the beginning that events on Earth should not impact life in orbit. Mi, which launched during the Cold War, still operated joint missions between US Space Shuttle crews and Russian cosmonauts. These were the founding principles of early space habitation and outlined everything that came after. "They view themselves as a single crew," insists Pearlman. "In general, space exploration has been viewed as a way of bridging the differences between our countries."

Going forward, it is this sentiment that is one of the key lessons from the space station era, and it becomes more important as the uncertain future

of the ISS comes into light. Engineering studies have only given the green light for it to continue operating until 2028, and the space station programme partners have only agreed to continue operation until 2024. The US in particular seems keen to free up resources to pursue missions beyond low-Earth orbit, back to the Moon and then on to Mars.

One nation that seems set to take up the international mantle is China. It's evidence again of that one planet, one people ideal that has so far underpinned this era of space occupation. While reducing the dangers and the physical and mental toll on the crew remains a priority, the idealism continues for space habitation to be a source of hope and comfort for both future astronauts calling these stations their home, and those on the ground looking up at these unique achievements of engineering and humanity. "I think the ongoing legacy of the ISS will be the idea that we do not go this alone," says Pearlman. "That once we leave Earth, we are one people. We are human and we work together, regardless of what apparent country we originate from."



The future of the International Space Station

The ISS might have less than a decade left, during which a lot could change



Taken private

As directed by the White House, NASA is currently assessing if and when a commercial or private entity might be able to take over operation of the US-operated segments of the ISS. Such a handover would need the agreement of the international partners, which include Russia, Canada, Japan and Europe.



Deorbited

If a commercial or private entity cannot be identified, or if the partners do not want to continue supporting the space station beyond an agreed-upon date, then it will need to be deorbited. The station was not designed to function without a crew on board for long stretches of time. The tentative plan uses visiting vehicles and the space station's thrusters to direct the complex into a controlled re-entry, destroying it over an ocean where any surviving pieces can fall without harm.



Replaced by a Chinese station

One nation that seems set to take up the international mantle is China, who are working towards finalising deployment of their own space station - the Chinese Large Modular Space Station - in the next few years. They've already invited other countries to send up experiments or crew members to their space station. ESA astronauts have responded by starting to take lessons in Mandarin.