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Hindustan Times
FIRST VOICE. LAST WORD.

FRONTIER LEAGUE

What came before the International Space Station? The answer is: quite a lot. The International Space Station (ISS) is about 25 years old, but we've had space stations for more than half a century. Who got there first? How did a space race end in Tranquility? Take a look.

Early musings

The idea of space stations can be traced, rather incredibly, to the mid-1800s. That's when astronomers and physicists first began asking: Could humans get something to orbit Earth in the same way that the planets glide around the Sun?

In Russia, Konstantin Tsiolkovsky, known as the father of modern space-flight, drew an outline for a "space station with a rotating section... Such a station could be used to investigate Earth and refuel ships," writes Jay Chladek, in his 2017 book Outposts on the Frontier: A Fifty-Year History of Space Stations.

MOL beginnings

When NASA was founded in 1958, it took over space exploration, which had until then been led by the US Air Force. But, amid the Cold War, the US military wasn't taking its eye off the skies. Plans took shape for a Manned Orbiting Laboratory (MOL), a series of 60-ft-long space stations in Low-Earth Orbit, built for military reconnaissance, to be occupied by two-man crews. Pilots were selected. A test flight was carried out in 1966 (left). Then, amid the Vietnam War and budget cuts, the project was abruptly ended. Some elements of design would later be used in Skylab. But first...

A Soviet Salyut

In many ways, Almaz (Russian for Diamond) was the Soviet Union's response to MOL. The space station was conceived, in 1964, as a three-man orbiter that would gather intelligence.

Then the Apollo 11 landed on the moon. The Soviet government wanted to give Russia something as thrilling to celebrate. So, in 1970, the USSR announced that it would build a "civilian" or research-focused space station.

Salyut (Russian for Greetings) was launched in 1971. The world's first space station was 66 ft long, or about the size of a large swimming pool. A series of Salyuts would be sent into space until 1982.

Watch this space

The International Space Station will soon be gone. In its place, private orbiting laboratories will compete, and hopefully collaborate. It is both an exciting and uncertain time. NASA is reviewing its role, after 25 years at the helm in Low-Earth Orbit. Where do India's plans fit in? How about China and Russia? How does one even decommission the largest object ever assembled in space? Where will ISS go? Take a look at future labs, ongoing research, and plans for the LEO landscape

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The idea was straight out of science-fiction: A post-Cold War US and Russia working on a joint mission to build a giant, rotating, Earth-orbiting laboratory in space.

The International Space Station (ISS) remains the largest manmade object outside Earth. It has hosted 279 people from 22 countries, including Saudi Arabia, Turkey and Belarus. (No Indians have spent time there yet, but a Gaganyaan astronaut currently in training for India's first manned mission to space may visit later this year.)

It has carried out thousands of studies, in areas ranging from Alzheimer's disease to bone loss, and water purification.

"It's been an invaluable platform for understanding how the human body reacts under different conditions," says Anil Bhardwaj, director of Physical Research Laboratory, a national research institute for space and allied sciences in Ahmedabad. "It has helped us understand how different materials and compounds behave, and the kind of properties they inherit, in zero-gravity and away from Earth's magnetic field."

For the world's then superpowers, ISS was a way for former enemies to improve relations and build trust. "It's one of the biggest feats of science diplomacy the world has ever seen," says Somak Raychaudhury, an astrophysicist and vice-chancellor of Ashoka University.

Twenty-five years in, it is set to be decommissioned. It will be gone from the skies by 2030, the US National Aeronautics and Space Administration (NASA) has said.

"It's an old horse," Raychaudhury adds. "It was conceived and designed in the 1980s, when computers could still only hold a few KB of data. It is becoming economically unviable to keep up with repairs and replacements (it costs $4 billion a year to run, according to NASA). The miniaturisation of electronics and the power of computing have revolutionised technology here on Earth. There's no doubt that the ISS needs an upgrade."

> There's going to be competition over space tourism, over mining asteroids and using space for publicity.
> **SOMAK RAYCHAUDHURY,** astrophysicist and vice-chancellor of Ashoka University

The upgrade will also mark the dawn of a new order.

In less than a decade, the Low-Earth Orbit or LEO landscape will be dotted with private space endeavours.

The American company Axiom Space is likely to have the first private space station in orbit, with the first module likely to be put in place by 2026.

The Orbital Reef Space Station, built in a collaborative effort between a number of private companies, including Jeff Bezos's Blue Origin and the aviation giant Boeing, will serve as a combined research and tourism centre.

Boeing's European rival Airbus and the American space-technology company Voyager have announced a joint venture to develop a research station called StarLab.

The Russian government is developing an orbital space station that President Vladimir Putin says will be operational by 2027.

India has announced plans to launch the Bharatiya Antariksha Station, a 25-tonne modular structure that will be built in India and operated as a laboratory, by the Indian Space Research Organisation (ISRO).

NASA astronaut Josh Cassada photographs Earth from ISS's seven-window cupola or viewing deck, in 2022. NASA

The one country that was never invited onto the ISS was China. So, in 2021, China started assembling its own space station, Tiangong. At 75 tonnes, it is a fraction of the size of ISS (which weighs over 420 tonnes), but is reportedly a cutting-edge facility. "China successfully demonstrated capability," says Raychaudhury. "But the world remains unclear about the larger intent of their scientific research, since they haven't published anything and haven't specified their goals."

Now, as private players look set to dominate the future of space exploration, scientists are beginning to express concern that the opacity that has shrouded China's experiments only foreshadows what most space exploration, particularly in Low-Earth Orbit, might look like.

"There's going to be competition over space tourism, over mining asteroids and using space for publicity. The private companies may not even make their research public, in the way that NASA, the European Space Agency, Japan Aerospace Exploration Agency, ISRO and others have done in the past," Raychaudhury says.

This could alter how technology is released into the world, he adds.

After all, mock meats, digital cameras and the computer mouse all started out as NASA experiments originally meant for use by astronauts.

There will be advantages to having multiple space stations orbiting Earth. They could potentially serve as invaluable refueling posts on manned journeys towards the Moon, Mars and the outer solar system. They could allow experiments to be conducted in tandem; results verified. They could allow humans to study microgravity in far greater depth.

They could also set a new standard for collaborative work in space, Raychaudhury says, serving as training grounds for more astronauts, and provide greater mission continuity... assuming that collaboration is more profitable than competition.

"It's difficult to say, right now, exactly how the private space stations will work with each other," Raychaudhury says. "But as they come up, so will new ideas and experiments."

The first module of ISS was launched in 1998. It took about 40 trips, over the following 10 years, to assemble its frame. It has been inhabited continuously, including during the pandemic, since 2000. It will take significantly less time for ISS's 16 pressurised modules to be unlocked and deorbited.

A Russian propulsion system keeps the craft in orbit; American-made systems are responsible for electricity and life-support. The two sides (the space station is divided into two porous halves) have no choice but to cooperate with each other.

The end of ISS will mark the end of a unique experiment, and the end of an era. "Science has been better off for it," Raychaudhury says.

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{ DOWN TO EARTH } THE RE-ENTRY PLAN

It ISS a final farewell

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As ISS inches towards retirement, "our final frontier is moving out," says Jonathan McDowell, an astrophysicist with the Harvard-Smithsonian Center for Astrophysics (one of the largest astronomical research institutes in the world).

The Moon and Mars, and the outer solar system, are the new two-tiered frontier for human and robotic space exploration.

"Living, working and experimenting on ISS has given us the confidence to survive in space, to venture beyond Low-Earth Orbit (LEO). And by the time the ISS retires, LEO will just be another place where humans hang out," he adds

As it happens, the decommissioning of the space station comes at a time when the US National Aeronautics and Space Administration (NASA) — which oversaw its installation and will oversee its deorbiting — is readying for a new age in which its role will be vastly altered. NASA is already signing deals as a facilitator in the growing commercial space-exploration economy.

> NASA IS ALREADY AT WORK ON GATEWAY, WHICH WILL BE HUMANITY'S FIRST LUNAR-ORBIT SPACE STATION. IT WILL HELP WITH EXPLORATION OF THE LUNAR SOUTH POLE

The American company Axiom has finalised a contract that will allow it to attach at least one habitable commercial module to ISS by 2026. There will eventually be four such units. After ISS is gone, the modules will coalesce and become the Axiom Station.

NASA has meanwhile signed agreements with US-based companies such as Blue Origin, Nanoracks and Northrop Grumman, to help design and build independent commercial space stations and space destinations.

"The agency is committed to continuing to work with industry with the goal of having one or more stations in orbit to ensure competition, lower costs, and meet the demand of NASA and other customers," Angela Hart, manager of NASA's Commercial LEO Development Program, said in January.

Why must ISS go?

It was only meant to serve for 15 years but, as with so much space technology, has exceeded expectations to last nearly 26. "It would have been nice to leave it out there, like an in-orbit museum," says McDowell. "But it would become steadily more battered, unstable and out of control."

Disposing it is expected to cost about $1 billion, in an operation that will take months.

To begin with, the space station will slowly be allowed to lose altitude. At about 200 miles above Earth's surface, a special deorbit vehicle will attach itself and provide the final pull. ISS will then be guided towards a remote point in the Pacific Ocean, at a pace that will allow as much of the space station to burn away on re-entry as possible.

Nothing this big has ever re-entered the

Skylab

By 1965, NASA was having a bit of an identity crisis. A lunar landing was well within reach, but after that, what? There were calls for the organisation to devote more resources to scientific research. There were also calls for it to justify and reduce its massive budgets.

At the same time, NASA engineers in Alabama were looking at ways to use spent Saturn rockets. If they were left in orbit, could they be turned into a space lab that could be gradually expanded?

This seemed like an economical way to compete with the Soviet Union too. And so, Skylab (left) was launched, in 1973.

Mir

By the early 1980s, the world was a different place. Mikhail Gorbachev had taken the reins in a post-Cold War Russia. Peace was on the cards. Russia's new space station, launched in February 1986, was accordingly named Mir (left; Russian for Tranquility).

Mir would be occupied for over a decade, visited by astronauts from various countries. An American astronaut visited in 1992. As it became clear that the two giants of space exploration could work together, a new plan took shape. In 1993, the two countries announced plans for a revolutionary project that would be called, simply, the International Space Station.

atmosphere. But based on the re-entry of two other space stations, the Russian Mir in 2001 and NASA's Skylab in 1979 (ISS is four to five times larger than these), the space agency expects the skin of the modules to blaze away first, leading the internal hardware to rapidly melt. What is most likely to survive re-entry are denser, heat-resistant components such as the scaffolding or truss sections.

Where will it go?

Space debris of this kind is typically guided to a specific remote point in the Pacific Ocean called Point Nemo, or the Oceanic Pole of Inaccessibility (because it is one of the furthest points from land; there is another in the Indian Ocean).

Nicknamed the Space Cemetery, Point Nemo sits about 2,700 km from New Zealand to the west, South America to the east and Antarctica to the south.

Bits of titanium, stainless steel, aluminium and parts containing cryogenic fuel are usually what make it to the ocean floor in this freezing stretch, says space archaeologist Alice Gorman. Because of its depth and remoteness, there is little to no data on what happens to these remains, or on the impact on marine life here.

But it needn't be all bad news. "Many shipwrecks end up fostering rich marine communities," Gorman says. "Could these rocket bodies turn into habitats for sea creatures? I like to hope they can."

Onward

NASA, meanwhile, is already at work on its next. Gateway will be humanity's first lunar-orbit space station. It will reportedly be crucial to the exploration of the lunar South Pole. Assembly is expected to begin in 2028.

Gateway will make it easier to plan NASA's Artemis series of crewed orbiter and lander missions, McDowell says. "After that, it's Mars and the outer solar system."

READ: What were the early days on ISS like? Read an excerpt from Outposts on the Frontier: A Fifty-Year History of Space Stations by Jay Chladek

{ COSMIC EXPERIMENTS } NO SMALL MATTER

Notes on the future, from a a floating lab

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At 400 km above the surface of Earth, a very different rulebook for physics kicks in.

In the absence of gravity and oxygen, fire behaves differently, as does water. Materials acquire new melting points. Atoms clump together, in ways that hold new hope for quantum technology.

The International Space Station (ISS) has served as a laboratory for all this and more. How does the human body react to time in space? How can recycling systems be refined? Can plant life be supported off-planet (it turns out it can be, relatively easily; if one can find the water for it). Here's a quick look at key ongoing experiments.

Fire: Thousands of flames have been lit in a series of experiments on board ISS, to investigate the underlying physics of flame structure and behaviour, from flame growth and decay to fire-extinction in space.

On Earth, gravity pulls cooler, denser air towards the ground, while hot gases rise, creating the classic shape of a flickering flame. In microgravity, small flames tend to be rounder. Experiments on ISS also led to the discovery of steadily burning cool flames, which burn at extremely low temperatures (a feat that is nearly impossible to accomplish on Earth).

"In the reduced gravity of space, fire can behave unexpectedly and could be more hazardous," Paul Ferkul, a scientist at NASA's Glenn Research Center, has said.

From spacesuits and spacecraft to habitats on the Moon or Mars, and power plants and boilers here at home, the implications are vast and varied.

Water: It has been intriguing and enjoyable for humans on Earth to watch water behave completely out of character on ISS. But how water behaves in space is also a perplexing problem that has implications for vital systems ranging from life-support to fuel tanks. Researchers are now studying exactly what causes water droplets to merge when and as they do.

Answers wouldn't just solve a long-standing mystery. They would help humans plan better, when it comes to storage, leaks and losses over years-long journeys.

Sleep: With no day or night, up or down, and multiple sunrises and sunsets in each 24-hour period, most astronauts on ISS have trouble sleeping.

Two ongoing experiments are currently using fresh tools to seek solutions.

The first, titled Circadian Light, uses a special lamp to simulate the calming reds of a sunset and blues of a morning sky, in attempts to induce more regular sleep cycles. The second, Sleep in Orbit, uses an in-ear device to measure astronauts' brain activity through the night, with a view to assessing the quality of sleep, and finding ways to enhance it.

ISS astronauts captured a view of the Sarychev volcano in Japan, as they floated above it in 2009. Over the years, images from ISS have helped track the onset and impact of natural disasters, weather systems, and the climate crisis. NASA

Planet monitoring: The space station offers a unique perspective across more than 90% of inhabited regions on Earth. A number of instruments on board monitor changes in oceans, air (and energy cycles), vegetation, geological hazards, seasons. Footage has helped track and assess the impacts of floods, wildfires, superstorms, tsunamis and volcanic eruptions. Images taken via the space station now form an archive of climate-change impact, as maps see their outlines shift.

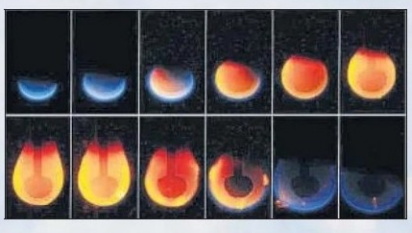
A fifth state of matter: In 2018, scientists aboard the ISS generated the fifth state of matter (in addition to solid, liquid, gas and plasma), Bose-Einstein Condensate (BEC).

BEC occurs when atoms are cooled to near-absolute zero and clump together, behaving like a single entity that exists between the physical world and the quantum world.

BEC was first achieved on Earth 25 years ago, but the microgravity and super-low temperatures of space make it exponentially easier to create and study them in an environment such as the ISS Cold Atom Lab.

They take less power to produce, and survive longer there, lasting for over a second, compared to a few hundredths of a second here on Earth.

Why does any of this matter? Studying BEC, physicists believe, could be a key to unlocking new quantum technologies.

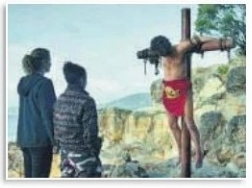


Researchers on ISS have been studying how fire behaves in space. On Earth, gravity helps shape a typical flame. In zero-gravity, small flames tend to be rounder. NASA

culture

Who hid the smoking gun?

The detective-fiction genre remains popular on screens, even though it is increasingly difficult to find a good film or show to watch. Tech is the villain of the piece, says K Narayanan. How good can a detective show be in a world of surveillance and AI profiling?



Stills from the 2017 retelling of Agatha Christie's Murder on the Orient Express; and the new but rather dead-end tale, Deadloch.

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Every detective story has the same components. The crime, the investigation, the disclosure. The motives are usually drawn from the same catalogue: envy, rage, greed, lust and, in the case of serial killers, gluttony.

Which makes telling a truly innovative crime story that much more difficult.

One sees the struggle play out on screens today: retellings of old stories featuring French detectives and luxury trains; or new ones featuring gizmos and time travel. New twists are attempted, but fail to land (an island of women, a dead man on the beach... but then what? The 2023 series Deadloch simply finds nowhere to go.)

Why has it become so much harder?

Well, the crimes themselves have changed. Murder alone hasn't been enough for a while.

In 1946, George Orwell published an essay titled The Decline of the English Murder. "Our great period in murder, our Elizabethan period, so to speak, seems to have been between roughly 1850 and 1925, and the murderers whose reputation has stood the test of time are the following: Dr Palmer of Rugeley, Jack the Ripper, Neill Cream, Mrs Maybrick, Dr Crippen, Seddon, Joseph Smith, Armstrong, and Bywaters and Thompson," he wrote, adding: "in at least four cases respectability (was the motive) — the desire to gain a secure position in life, or not to forfeit one's social position by some scandal such as a divorce."

Orwell was examining the shift away from the "murder for respectability", contrasting killers of this order with the earliest examples of the killing spree, such as the so-called "cleft chin murder", in which an 18-year-old English waitress and a 22-year-old American deserter tried to kill two women and killed a taxi driver, over six days, in 1944. The spree killing would feature, over and over, in headlines in the real world, and in fiction created through the 20th and 21st centuries.

Charles Starkweather and Caril Ann Fugate's killing spree — the 19-year-old and his 14-year-old girlfriend killed 10 people, including her entire family, over nine days in 1958 — inspired the films The Sadist (1963), Badlands (1973), Guncrazy (1992), Kalifornia (1993), Natural Born Killers (1994) and Starkweather (2004).

Then this was no longer enough, and we got the mass murderers: sadists, school shooters, thrill killers, and now, social-media slayers who livestream their crimes and hold the viewer complicit.

A victim is lowered into a vat of acid, based on the number of likes that flow in; someone else is drawn across a rack. It is lurid, messy, and asks nothing of the viewer. When the law bursts in, it is often at least a bit unclear how they joined the dots. And one is left not with a wish to review clues, but a sense of relief that it is over.

Death by tech

Technology is the elephant in the room.

How effective can a detective be, in a world of near-constant surveillance and AI-led profiling? And how skilfully can a tale be crafted, in a voracious industry that simply wants another season released?

Orwell called the murders for respectability, products of "a stable society where the all-prevailing hypocrisy did at least ensure that crimes as serious as murder should have strong emotions behind them".

For better and worse (after all, stability is only ever stability for the lucky few, isn't it?), no one would call ours a stable society.

And so, in place of the gentlemanly French detective and the masterful English sleuth, whose formulae all add up and whose science is verifiable, we have shows such as Criminal Minds, in which it is likely a case would never be solved without Penelope's fictional technology. We have the murderous and unreasonably attractive Dexter, which tells a most improbable tale, that soon spirals into sameness.

Perhaps the way forward is back, to a time of killers who plan "with the utmost cunning, and only slip up over some tiny unforeseeable detail... With this kind of background, a crime can have... tragic qualities which make it memorable and excite pity for both victim and murderer." (Orwell again.) Of course, this would be easier in a period setting, and it would explain the lasting popularity of Sherlock Holmes and Hercule Poirot.

READ: Stuck on the same level: K Narayanan on why videogames make such bad movies

{ THE SPORTING LIFE }

Rudraneil Sengupta

Shooting stars

It takes courage, and effort, to rebound after losses as severe as those of the Tokyo Olympics. India's shooters aren't just back, ahead of Paris; they're better than before

It's been a record-setting year for Indian shooters.

At the end of the Paris Olympics qualification stage, 20 have won quotas for the Games from a maximum of 24 possible quota slots per country. That's the most won by any nation except the sport's undisputed powerhouse, China, which has 22. It's two more than the sport's other powerhouse, USA. And it is a new record for India, surpassing the 15 shooters who made it to the Tokyo Olympics in 2021.

This comes as no surprise to those within the fraternity, because Indian shooters have been doing brilliantly for two years, building capability patiently and purposefully towards Paris, and shrugging off the demoralising, medal-less showing in Tokyo.

That last bit must have taken serious work. Credit is due to the shooters, their coaches, and the National Rifle Association of India (NRAI). A debacle such as 2021 might have sunk the sport. Instead, they have rebounded with spirit.

Before the record quota-winning spree, there was the unprecedented medal haul at the Asian Games last year. Winning 22 medals (including seven golds) in Hangzhou was a statement of intent.

How did Indian shooting engineer this turnaround?

First, the federation did not get sucked into a negative spiral. NRAI found ways to admit that it could have done better, without shifting the blame onto the athletes, as many federations would have done.

NRAI and the coaches spoke in one voice, identifying the great disruption caused by the pandemic as the root of the problem. The lockdowns left most Indian shooters without competition time, training time or equipment. It forced many to improvise, building makeshift ranges at home. This took a toll on a generation of promising teenagers with limited experience of big events — almost all of whom then appeared at their first-ever Olympics, in Tokyo.

Second, the federation trusted the now-deep culture of shooting in the country, sparked by Abhinav Bindra's 2008 Beijing gold, and developed and sustained by shooting academies set up by some of India's finest former shooters. (Gagan Narang, for example, runs a clutch of high-performance centres across the country.)

It relied on committed state programmes such as those at the Madhya Pradesh State Shooting Academy in Bhopal, to keep the movement alive. Combined with easy accessibility to high-end guns and ammunition (a marked shift from the situation ahead of the 2016 Rio Games), what we have is a world-class ecosystem for the sport.

It's an ecosystem that is growing too. The domestic scenario has reached a level of competitiveness that will see, for the first time, quota winners in this sport having to earn their place at the Olympics via selection trials, to be held in May.

When the Indian contingent arrives at the picturesque, medieval town of Chateauroux (about 300 km from Paris), where the shooting events will be held, "they will be better prepared, better equipped, and much more familiar with the pressures of a big competition than ever before," in the words of national rifle coach Suma Shirur.

I think the family of world-record holder and Asian Games gold-medallist Sift Kaur Samra said it well too. Their response when she quit an MBBS course to follow the sport was a slogan we can all get behind: "Don't worry... Tum bas goli chalao! (Just take aim and fire)."

India's Manu Bhaker and Saurabh Chaudhary with Bomi Kim of Korea, during the 10m air pistol mixed-team qualification round at the Tokyo Olympics. GETTY IMAGES