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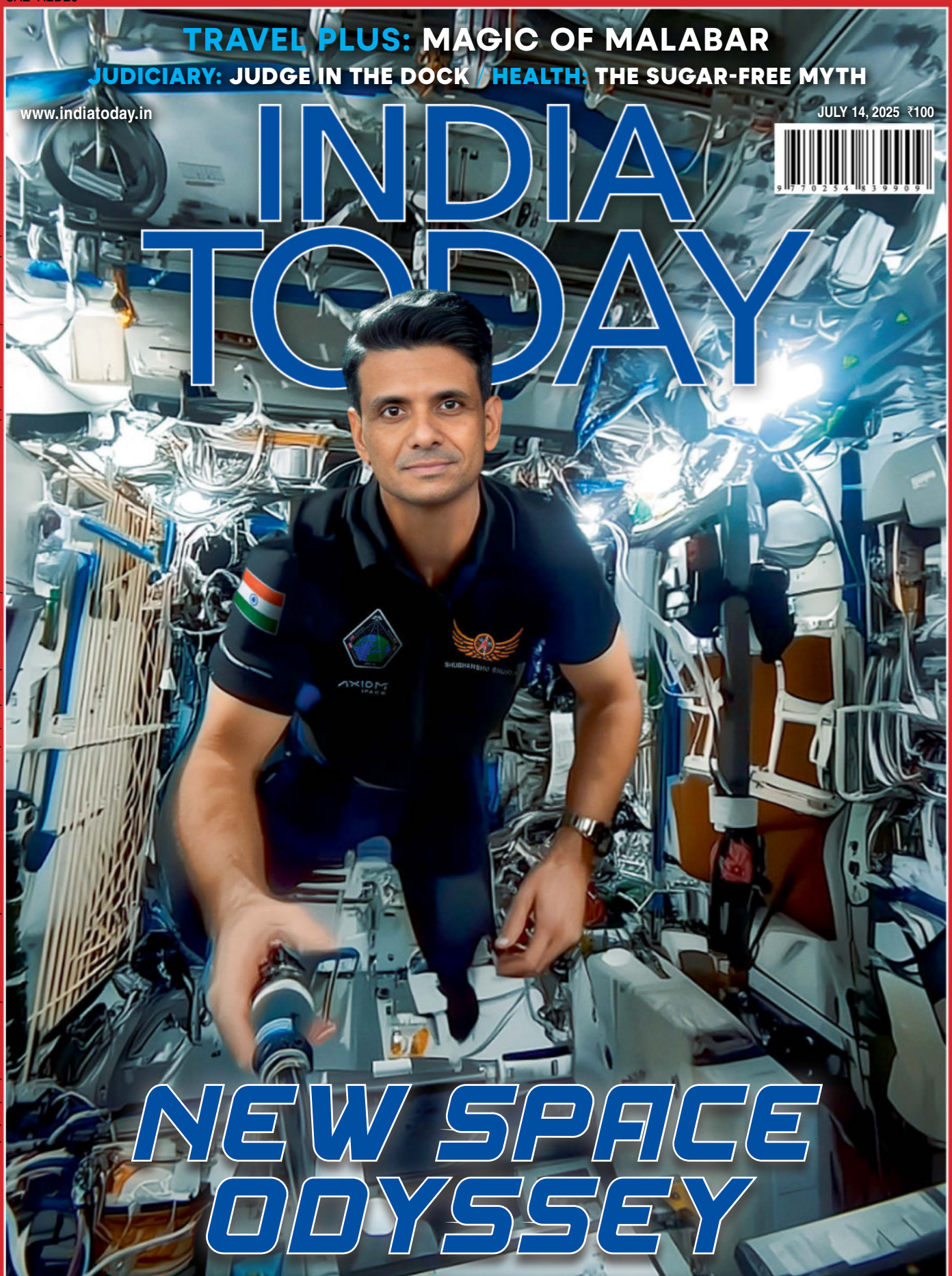

NEW SPACE ODYSSEY

SHUBHANSHU SHUKLA'S VOYAGE SIGNALS INDIA'S AMBITION TO JOIN THE TITANS OF HUMAN SPACE EXPLORATION

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OUR MAN IN SPACE
Group Captain Shubhanshu Shukla speaking with PM Narendra Modi from ISS, Jun. 28

“The first thought was the feeling of oneness of the Earth—there were no boundary lines or borders of countries. The second was when I saw India for the first time. It looked very big and grand, not like the 2-D paper maps of it”

—SHUBHANSHU SHUKLA
Indian astronaut

THE NEW SPACE ODYSSEY

ASTRONAUT SHUBHANSHU SHUKLA'S VOYAGE SIGNALS INDIA'S AMBITION TO JOIN THE BIG LEAGUE OF HUMAN SPACE EXPLORATION

BY RAJ CHENGAPPA

When Group Captain Shubhanshu Shukla floated into the International Space Station (ISS) from the Crew Dragon capsule that had docked with it on June 26, he wasn't feeling too good. Despite being a test pilot in the Indian Air Force, like most astronauts on their maiden flight into orbit, Shukla admitted that his head felt heavy and he was slightly disoriented. That's because he was still adjusting to the near-zero gravity conditions he endured during the 28-hour space flight that brought him and his three compatriots to the ISS, which orbits the earth at a height of 400 km. Dr Brigitte Godard, a former spaceflight surgeon at the Cologne-based European Astronaut Centre who was in Delhi recently, describes the effect this way: "Despite the lack of gravity, the heart continues to pump at the same rate as it does on earth and blood tends to rush to the head, and the face and tongue swell up. All these are symptoms of motion sickness. The body takes anything between 24 and 36 hours to adjust to zero gravity."

AI-RECREATED IMAGE

Soon after lift-off from the Kennedy Space Center in Florida, USA, Shukla also experienced the tremendous gravitational force or G-force that Rakesh Sharma, India's first astronaut, talked about when his Soviet Soyuz T-11 spacecraft took him to space in April 1984. Sharma recalled, "Because you are seated in the spacecraft looking upwards for lift-off, the G-force that you feel on your rib cage is four times the amount you feel on your waist. It presses against the spine, leaving very little space for the lungs to expand. So, breathing becomes difficult."

By launch day on June 25 , Shukla was only too eager to get off the ground. He had waited a month in quarantine and then faced several postponements of the Crew Dragon's launch for technical reasons. "When I was sitting in the capsule on the launch pad," he says, "the only thought on my mind was: let's just go this time. When the ride started, I kept getting pushed back strongly in the seat. Then, suddenly, I felt nothing. There was silence and we were floating in vacuum. What a ride—it was amazing." Far below, in the computer-lined control room of Launch Complex 39A, his mother, Asha Shukla, who anxiously watched the spacecraft's ascent on a screen, wiped the tears from her eyes and broke out into a huge smile of joy and relief.

When he reached the ISS, Shukla brushed aside the motion sickness and smiled a lot. Along with his three team members on Axiom Mission 4, he hugged the seven astronauts who had come to the space station earlier. Shukla joked, "I am learning like a baby, how to walk, speak and eat in space." Ax-4 mission commander Peggy Whitson fixed a silver pin on the lapel of his deep blue overalls, designating Shukla as astronaut number 634—the 634th human to have orbited in space. The ISS is a multinational collaborative effort, involving the US, Russia, Europe, Japan and Canada, and was built in phases from 1998 to 2011. It is now an orbiting space laboratory the size of four tennis courts. So far, 280 astronauts from 23 countries had spent time at the ISS. Shukla is the first Indian astronaut to live on the ISS and only the second Indian to go into orbit after Rakesh Sharma's historic feat 41 years ago. Aware of the weight of the moment, Shukla said, "It is a privilege to be among the few who have had the chance to see Earth from this vantage point."

Two days later, when Prime Minister Narendra Modi spoke to him, Shukla had to strap his legs to the ground to stop bobbing around. How was the view from ISS, Modi asked. Shukla's words were as resonant as Sharma's in 1984. "The first thought was the feeling of oneness of the Earth—there were no boundary lines or borders of countries," he said. "The second was when I saw India for the first time. It looked very big and grand, not like the 2-D paper maps of it." A smiling Modi then told Shukla that he is giving him some homework, saying, "We have to take Mission Gaganyaan (India's indigenous human space exploration programme) forward, we must build our own space station and also have to land Indian astronauts on the moon. Your experiences will be very helpful for these missions."

MEN ON A MISSION
From left, Wearing dark suits, members of the Ax-4 Mission relax after reaching the ISS: Slawosz Uznanski-Wisniewski (Poland), Peggy Whitson (US), Shukla and Tibor Kapu (Hungary), Jun. 26

Shukla's trip to ISS cost Rs 500 crore, but it will give India the exposure and experience needed for human interface processes in its own crewed spaceflight missions

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NO FREE RIDE

Modi was also disarmingly telling the Indian Space Research Organisation (ISRO), which sponsored Shukla's Rs 500 crore trip, that there were no free lunches or, in this case, space rides. Not that ISRO needed much goading. In

We have to take Mission Gaganyaan forward, build our own space station and also land Indians on the moon. Your experiences will be very helpful

—NARENDRA MODI
Prime Minister of India, talking to Shubhanshu Shukla in space

the past five decades, it has fulfilled its objectives of indigenously building rocket launchers and satellites for development purposes at reasonable cost. These include satellites for telecommunication, remote sensing, navigation and even defence. Now, the prime minister wants India to venture to the final frontier by joining the big league, putting crewed missions in space.

Since Yuri Gagarin's historic first spaceflight on April 12, 1961, in a Soviet Vostok 1, only three countries—US, Russia and China—have had their own crewed spacecraft. While the US and Russia are veterans, China joined this exclusive club on October 15, 2003, when it launched Shenzhou-5, its first crewed spacecraft. Since then, China has launched 13 other crewed missions and established the Tiangong-1 space station, a permanently crewed research platform, in 2011. When it completed its three modules in 2022, the new Chinese space station, also called Tiangong, measured about half the length of the ISS. The country has also set an ambitious goal to land its astronauts on the moon by 2030.

India, on its part, had initially focused on sending unmanned missions to the Moon and Mars. However, in his first term, Modi decided India must make the big leap towards human spaceflight and exploration. He sanctioned the Gaganyaan project in December 2018 to send up a crewed orbital mission by the first quarter of 2027. Simultaneously, Modi cleared the building of the first module of the Indian orbiting space station—Bharatiya Antariksh Station or BAS-1—by 2028. The combined cost of Rs 20,193 crore is among the single largest budgets set aside for an ISRO programme.

The prime minister didn't stop at that and enunciated a longer-term vision for a project that will facilitate the landing of Indian astronauts on the moon by 2040. Shukla, in that sense, is the first Gaganyatri in India's new space odyssey. As Modi told Shukla, "Today, I can say with confidence that yours is the first chapter of success of India's Gaganyaan mission. India is opening the doors of new possibilities of space for the world. India will not just fly, but will prepare the platform for new flights in the future."

Conscious of the nation's enormous expectations of ISRO, Dr V. Narayanan, its chairman, who had just returned to the space headquarters in Bengaluru after participating in the launch of the Ax-4 mission, told INDIA TODAY, "Gaganyaan is a national project that not only involves ISRO but also the Indian navy and air force, apart from a whole host of industries in the public and private sector."

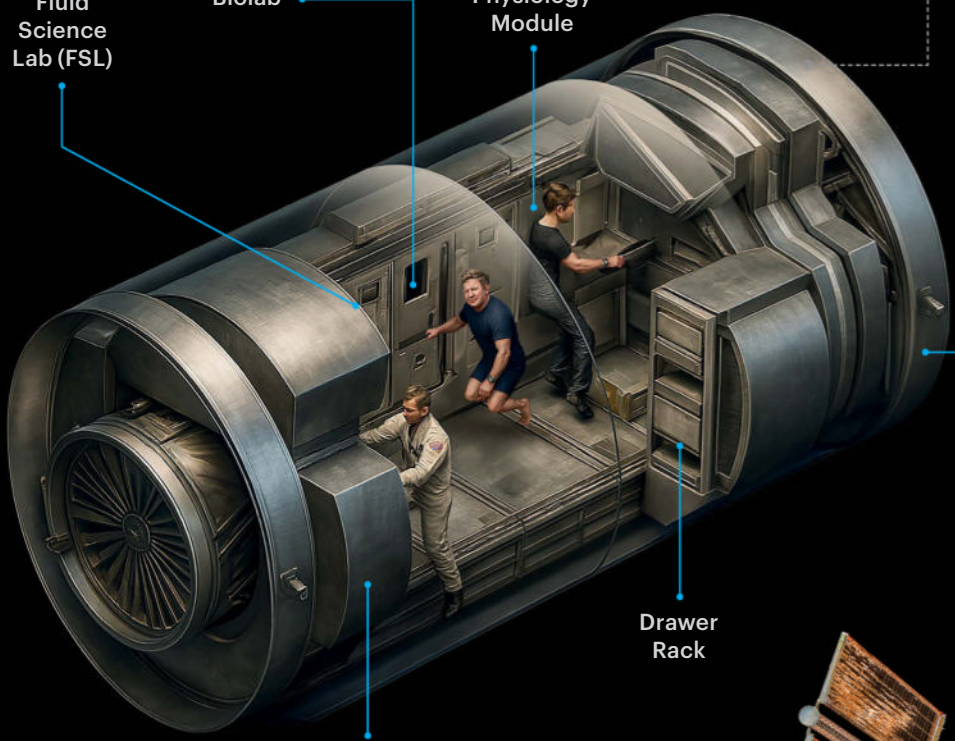
Wonders of an Orbiting Lab

Indian astronaut Shubhanshu Shukla's two-week sojourn in the International Space Station is full of new learnings and experiments

Graphic by **NILANJAN DAS**

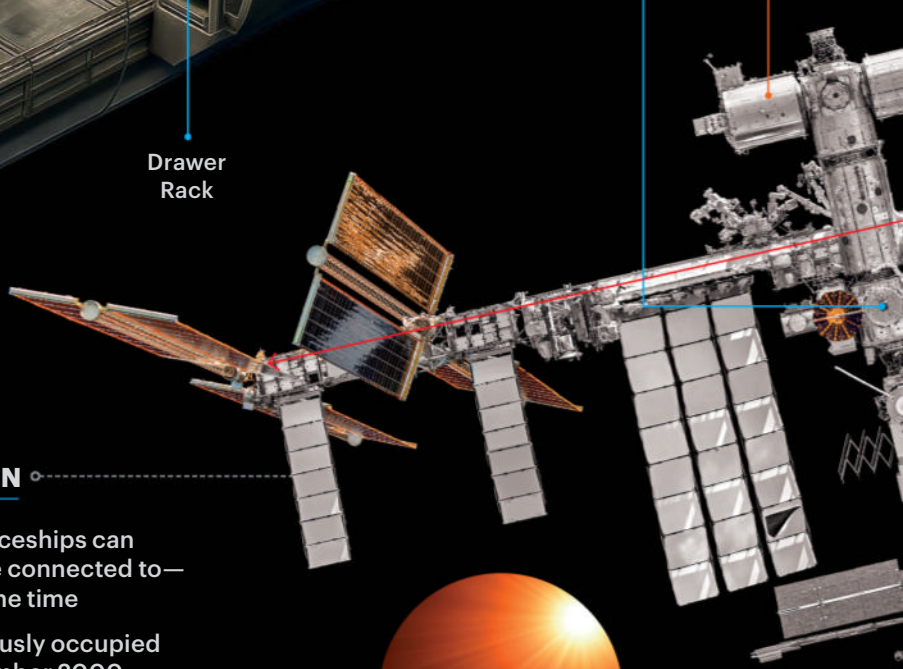
THE UNITY MODULE

- Second module in ISS, delivered to orbit by US space shuttle Endeavour in December 1998
- Provides living and working space; contains over 50,000 mechanical items, over 100 external and internal electrical cables
- It has six berthing ports, and has been connected to several other modules



US MODULES

EUROPEAN MODULE



INTERNATIONAL SPACE STATION

- The ISS is a permanently crewed orbital laboratory placed in low earth orbit (Avg altitude: 400 km)
- Orbits the Earth at a speed of 7.66 km/ sec, completing an orbit in 90 minutes or around 16 orbits a day
- The space station was set up between 1998 and 2011 after an initial US-Russia agreement in 1993
- It is a collaboration of 5 space agencies: NASA (US), Roscosmos (Russia), ESA (Europe), JAXA (Japan) and CSA (Canada)
- Eight spaceships can dock—or be connected to—the ISS at one time
- Continuously occupied since November 2000; counting Shukla et al, has hosted 280 astronauts from 23 nations
- ISS is composed of 16 pressurised modules: six Russian, eight American, one European and one Japanese
- Each module has diverse functions—scientific research, crew habitation, storage and spacecraft control

16

NUMBER OF SUNRISES AND SUNSETS VIEWED DAILY FROM THE ISS

With its velocity, it completes 16 orbits of the Earth in 24 hours

28,000

KMPH

APPROXIMATE SPEED OF THE ISS AS IT COMPLETES AN ORBIT OF THE EARTH IN ABOUT 90 MINUTES

400

KM

ALTITUDE OF THE ORBIT OF ISS ABOVE EARTH

INDIAN EXPERIMENTS IN ISS

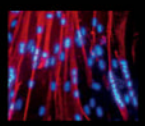
Group Captain Shubhanshu Shukla travelled to the ISS with three other astronauts in the Ax-4 mission on June 25. He is assisting in these microgravity research experiments proposed by Indian scientists in R&D laboratories across the country

- Impact of microgravity radiation in ISS on edible microalgae

- Sprouting salad seeds in space—relevant for crew nutrition

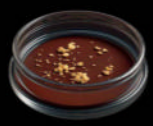
- Impact of microgravity on food crop seeds

- Analysing human interaction with electronic displays in microgravity

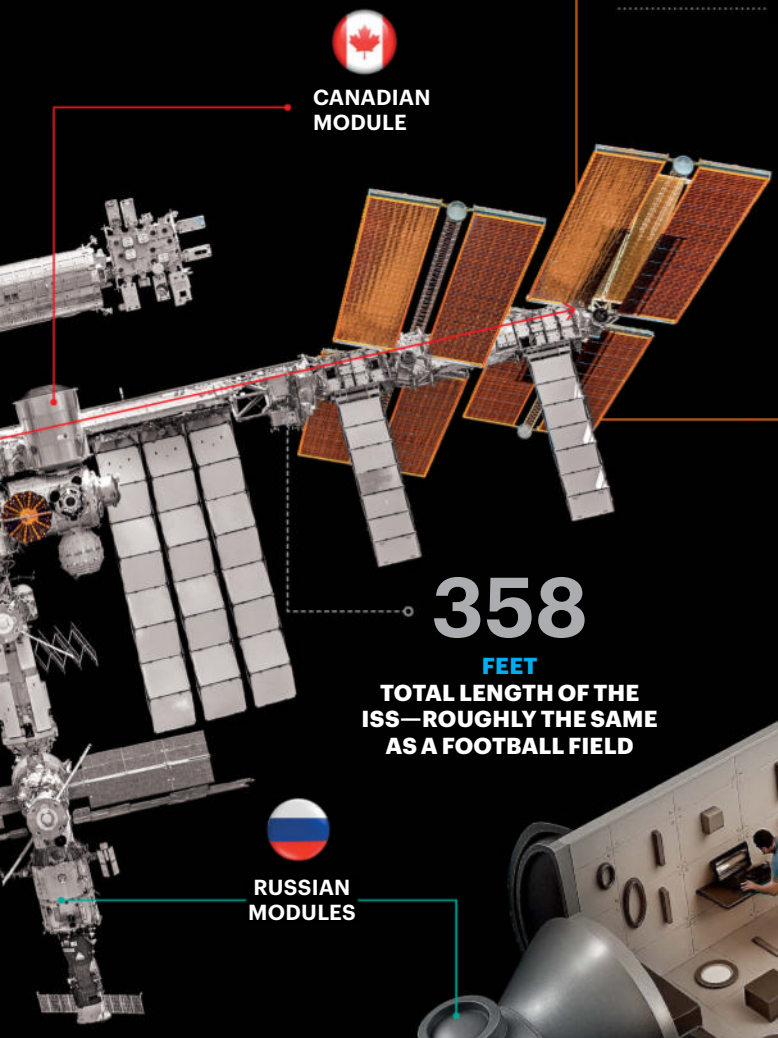


- Effect of metabolic supplements on muscle regeneration under microgravity

- Survival, reproduction, RNA transcripting of Eutardigrade Paramacrobiotus, a microscopic aquatic animal



- Growth, proteomics (specific cell proteins) responses of cyanobacteria on urea/ nitrate in microgravity



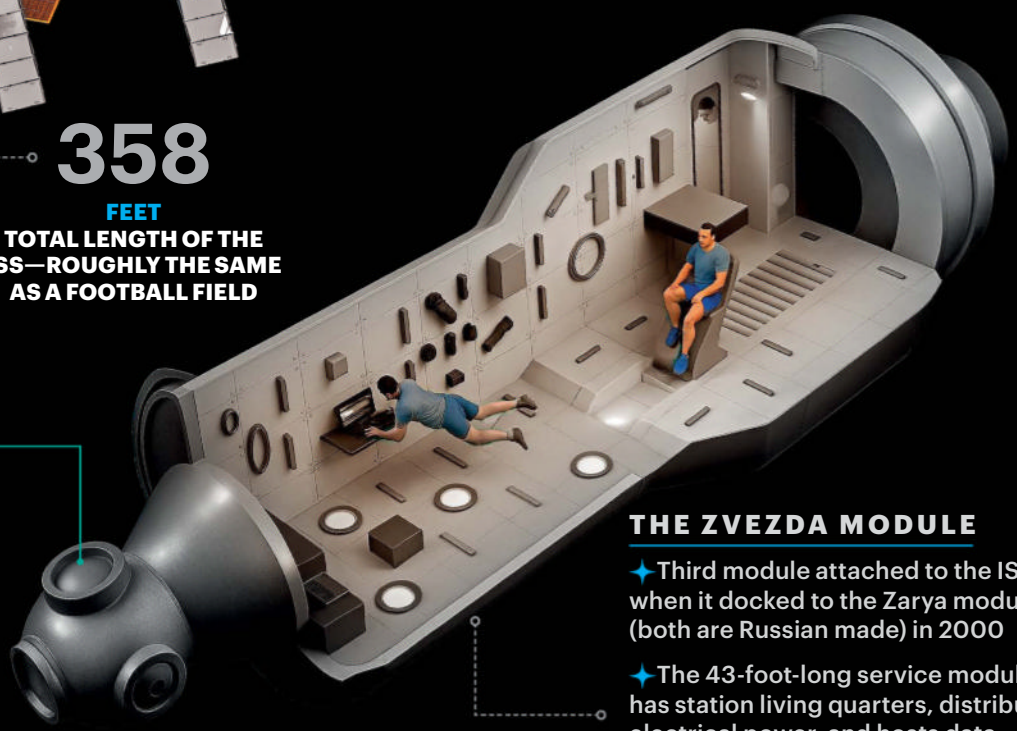
CANADIAN MODULE

358

FEET

TOTAL LENGTH OF THE ISS—ROUGHLY THE SAME AS A FOOTBALL FIELD

RUSSIAN MODULES



THE ZVEZDA MODULE

- Third module attached to the ISS when it docked to the Zarya module (both are Russian made) in 2000
- The 43-foot-long service module has station living quarters, distributes electrical power, and hosts data processing, flight control and propulsion system
- Provides communication system that includes remote command capabilities from ground flight controllers, docking port for Russian Soyuz and Progress spacecraft

THE BIG TASKS BEFORE ISRO

With Shukla going up in space, what India gains is the good exposure and experience needed for human interface processes, which is important, but only one part of the entire programme. India not only has to build and validate a suitable launch vehicle but also orbital and crew modules. This is in addition to training astronauts and ensuring their safety at launch, in space and on their return to earth. "It's a whole new and challenging game for us, but our scientists and collaborating institutions are up to it," says Narayanan.

Among the first things ISRO did was to build Launch Vehicle Mark3, or LVM3, which would be capable of lifting heavy payloads of 10 tonnes to low earth orbit. To make these launch vehicles human-rated, numerous test firings will be needed. The redundancies, too, have been trebled so that if one system fails, there are enough back-ups to prevent a catastrophe. Narayanan says, "When there is human life involved, we have to be thrice as careful. We have to score 100 out of 100 when it comes to safety protocols." In fact, at the Ax-4 mission involving Shukla, it was Narayanan who refused to give his clearance for launch after mission control reported a slight glitch. His insistence saw the Axiom technicians discover a hairline crack in one of the engines that could have proved disastrous on flight. Only after it was rectified did Narayanan give his consent.

Back home, on its own projects, what ISRO had to do from scratch was build a crew module that can carry three or four astronauts with adequate Environmental Control and Life Support Systems (ECLSS). These maintain comfortable room temperatures, the right cabin pressure and adequate oxygen levels, apart from food, living quarters and waste disposal. Former ISRO chairman S. Somanath points out, "These are essentially 'do it yourself' or DIY technologies. Initially we thought we could just buy these and then later develop them. But they didn't materialise because they came at a high cost and were unable to meet our schedules." ISRO also had to develop the technologies for the re-entry of the crew vehicle, then the soft landing at sea using parachutes, and recovery by the armed forces. It has also tested the crew escape system where the crew module is ejected at a safe distance in case of rocket failure on the launchpad or during lift-off.

The other systems ISRO has to perfect are communications, navigation and a high degree of automation. As important is the selection and training of astronauts. The first four astronauts for Gaganyaan, including Shukla who went up in Axiom, are all Indian Air Force pilots selected after a range of tough tests. Besides developing an astronaut training centre in Bengaluru that currently focuses on physical and mental fitness, the astronauts have been sent to the cosmodrome in Moscow for rigorous tests, including a sub-orbital flight to experience zero gravity briefly. The test is called vomit-comet because, invariably, the trainees throw up on their first attempt.

INDIA'S BIG LEAP

Two missions, each a stepping stone for the next, symbolise India's grand bid to be a spacefaring nation

GAGANYAAN

AIM: Launch a crew of three Indian astronauts into space and bring them back safely

TARGET: 2027

PRECURSORS

- Three uncrewed missions, beginning by the end of 2025
- The first will have Vyommitra, a female humanoid robot, on board

LESSONS FROM SHUKLA'S TRIP

Rakesh Sharma recalls that no amount of training on the ground helps you prepare for all that happens in orbit, including withstanding G-force or motion sickness. Shukla himself revealed that he found "drinking water, walking, sleeping a big challenge—you can sleep on the roof, or the walls and on the ground". Aboard the ISS, astronauts sleep in compartments the size of a phone booth and equipped with sleeping bags that are secured to the walls of the spacecraft, so that they don't float away. They cannot use showers to bathe as water doesn't flow in microgravity. Instead, as Sharma did 40 years ago, they use wet wipes, rinseless shampoo and liquid soap. Shukla seemed to have dispensed with shaving as well, sporting a thick stubble within days of arrival. Going to the toilet, as Sharma recalls, "is a well-practised art because even your bodily effluents are weightless just as you are. So, you have to make sure that they are captured effectively. It does take some practice." Space food, though, has evolved and moved beyond the food tubes that Sharma snacked on. Shukla can choose between vacuum-packed, freeze-dried, dehydrated or canned items. He has also carried some *gajar ka halwa*, *moong dal halwa* and

BHARATIYA ANTARIKSH STATION

AIM: Establish India's space station for microgravity research

TARGET: 2035

PRECURSORS

- Sending five modules by as many launchers; first in orbit by 2028
- Docking of the modules to build the space station

CREWED LUNAR MISSION

AIM: Land first Indian astronaut on the moon

TARGET: 2040

PRECURSORS

- Chandrayaan-4, with expected launch in 2027-28, to bring back lunar samples
- Chandrayaan-5, a joint mission with Japan, to study the moon's potential to host humans

"From a follower, India intends to be a frontliner in space. India is now an equal partner in global space endeavours"

—JITENDRA SINGH
Union MoS for science & technology, earth sciences and space

aamras to share with fellow astronauts. Fortunately, as Godard points out, microgravity has no bearing on the peristaltic movement (muscle contraction and relaxation) of food down the digestive tract. Meanwhile, Shukla is busy absorbing the celestial joy of witnessing 16 sunrises and sunsets daily at the ISS as the spacecraft's speed of 28,000 kmph means it orbits the Earth once every 90 minutes.

Shukla's observations, therefore, will prove valuable not only in understanding some of the challenges faced aboard the ISS but also the rigorous protocols to be observed for a human spaceflight. ISRO is taking no chances with its first crew spaceflight: it is planning three unmanned tests that will fully validate all the critical systems (including a robot called Vyommitra on board as a substitute) and ensure they are all error-free before it attempts one with the selected astronauts aboard.

Shukla's experience will also be crucial in the construction of India's first space station, the BAS-1. While the first module of BAS-1 was sanctioned along with the Gaganyaan project, the ultimate aim is to have five modules in space, including the living quarters for astronauts and orbiting laboratories. Already, the technology for docking spacecraft with BAS-1 has been validated with the Space Docking Experiment (SpaDeX) earlier this year, using two satellites as a demonstration. Autonomous rendezvous apart from docking and undocking capabilities were validated and these would be used for future space endeavours, including in BAS-1. Of course, the technology needs to be human-rated and would require many more SpaDeX tests. "It will not be like a five-star hotel," says

GAGANYAAN MISSION

TOWARD INDIA'S FIRST HUMAN SPACEFLIGHT

All that has been done and what more needs to be done

LAUNCH VEHICLE

Human-rated LVM-3: For delivery of the Orbital Module into a 400 km low-earth orbit (LEO)

- Height: **43.4 m**
- Mass: **640 tonnes**
- Stages: **3 (solid, liquid, cryogenic)**
- Payload capacity: **10 tonnes**

STATUS: *Human-rating completed for all propulsion systems (i.e. certifying the vehicle is capable of safely transporting humans)*

CREW MODULE

Houses astronauts in Earth-like environment

Environmental Control & Life Support System (ECLSS)

- Maintains cabin pressure, humidity, temperature etc. in the module
- Maintains oxygen level, and removes carbon dioxide and trace contaminants

Cabin pressure: **98-116 kPa**

Humidity: **60-70%**

Temperature: **23±3°C**

Humancentric products

- Indigenous space suit
- Customised space food
- Ergonomically designed seating

STATUS: *Development/ testing in advanced stages*

CREW ESCAPE SYSTEM

Purpose

Rapid astronaut evacuation during launch emergencies

Components

- Solid motors for quick pull-away
- Autonomous activation for crew safety

STATUS: *Successful demonstration using test vehicle*

ORBITAL MODULE

It comprises two main parts

- **Crew Module (CM):** Houses astronauts in Earth-like environment

Mass: **5.3 tonnes**

- **Service Module (SM):** Supplies propulsion, power and thermal control to CM

Mass: **2.9 tonnes**

STATUS: *Development/ testing in advanced stages*

CREW SELECTION & TRAINING

On Feb. 27, 2024, India got its four designated 'Gaganyatris'—all Group Captains in the IAF

- Shubhanshu Shukla
- Prasanth Nair
- Ajit Krishnan
- Angad Pratap

Only three will be part of the first crewed mission

STATUS
Physical, psychological and generic training completed; Shukla travels to the ISS on Axiom-4 mission

CREW RECOVERY OPERATIONS

Recovery Team
ISRO + Indian Navy

Post-landing in sea

- Divers retrieve crew and module
- Medical checkups onboard recovery vessels
- Transport to mainland for debriefing

STATUS:
Validation of CS deceleration, flotation system, parachute drop tests completed

Narayanan. "Within the minimum space, we aim to provide maximum comfort and utility so that it will be cost-effective."

India is keen to use its own upcoming space station for many cutting-edge experiments, some of which Shukla is already conducting in his two-week sojourn aboard the ISS. These include examining human interaction with electronic displays in microgravity and identifying any musculoskeletal dysfunctions in Zero-G as well as the effects of metabolic supplements. There are many studies designed for Shukla to analyse the impact of microgravity on cultivating food crops like moong dal, methi sprouts and on edible microalgae. There is also an indepth experiment on tardigrades—microscopic

"Gaganyaan is a national project that not only involves ISRO but also the Indian navy and air force, apart from a whole host of industries in the public and private sector"

—DR V. NARAYANAN
Chairman, ISRO

aquatic animals—and their functioning in such harsh conditions. All these experiments have been devised by key scientific institutions across the country and many more would be done when BAS-1 comes up. The idea is to prepare for the exploitation of lunar resources and possibly Mars in the near future.

JOINING THE TITANS

All these programmes segue neatly into the long-term strategy of India becoming a major player in the lunar race. After ISRO successfully demonstrated its capability of landing a spacecraft on the moon surface and operating a rover in August 2023, the Modi government sanctioned the ambitious Chandrayaan-4 project in September 2024. It involves the development of technology to land a spacecraft on the moon, collect rock samples and then fly them back to Earth for analysis. Estimated to cost upward of Rs 2,000 crore, Chandrayaan-4 is expected to be launched in 2027-28, and will demonstrate foundational technological capabilities for an Indian astronaut landing on the moon by 2040 and returning safely to the earth. It will be followed by Chandrayaan-5, a joint mission with Japan that will have a

AN ADVENTURE BECKONS
Shubhanshu Shukla (2nd from left) and fellow crew members aboard the SpaceX Dragon spacecraft before lift-off, Jun. 25

powerful, long-lasting rover to explore resources for human sustenance on the lunar surface.

In doing so, India will join the global Moon Rush, with the US sanctioning the Artemis projects, which will mark American astronauts' return to the moon after a hiatus of over 50 years. China has been actively exploring the Moon, even robotically collecting lunar samples and flying them back for analysis. Half a dozen other countries, including Russia, Japan and South Korea, have joined the lunar bandwagon with ambitious flights. This coincides with the increasing interest within countries to establish space stations of their own. Russia has announced its withdrawal from the ISS and plans to develop its own Russian Orbital Service Station (ROSS). Apart from India and China, there are three major private players who are keen to develop commercial space stations. These include Orbital Reef, a joint project by Blue Origin and Sierra Space; Starlab by Voyager Space and Airbus; and Axiom. Jitendra Singh, the Union minister of state for science and technology, earth sciences and space, says, "From a follower, India intends to be a frontliner in space. India is now an equal global partner in space endeavours."

To trigger an unprecedented boost in private participation in Indian space, the Modi government in June 2020, in the thick of the Covid pandemic, ended ISRO's monopoly to build and launch rockets and satellites. It not only allowed entry to private players but also opened up ISRO facilities for them to use on payment. Subsequently, it also allowed 100 per cent FDI in the space sector. Close to 200 space start-ups have come up in the past four years, and many of them have been extremely successful. This is in keeping with the international trend of private giants like Elon Musk's Space-X and Jeff Bezos's Blue Origin, competing with established giants like Boeing and Lockheed Martin.

India's space market was worth $8.4 bn (Rs 71,800 cr.) in 2024, just 2% of the global market. The Modi government plans to grow it to $44 bn (Rs 3.75 lakh cr) by 2033, or 8% of global share

India's space market was worth $8.4 billion (Rs 71,800 crore) in 2024, just 2 per cent of the global space market, way below its potential. The Modi government is pushing for an aggressive target of reaching $44 billion (Rs 3.75 lakh crore) by 2033, accounting for 8 per cent of the global share, with its ambitious human space exploration mission being a major driver. Up in space, Shukla's advice to youngsters is, "There is no one path to success, but there is one common thing—Never Stop Trying." That is something India, too, can follow in its giant ambitions for human spaceflight in the wake of Shukla's sojourn. ■