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Space Stations: Promises & Challenges

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Executive Summary

- The next decade is likely to witness the launch and operation of multiple space stations by both states and commercial entities.
- While some of these stations may fail technologically or commercially, the development of space stations could help develop, validate, and mature technologies required to maintain a continuous human presence in space.
- India will remain far behind the US, Russia, and China in these efforts even if it meets its deadlines for human spaceflight in 2023 and the launch an experimental space station in 2030.
- Instead of pursuing these capabilities independently, India must actively seek out collaborations with both states and commercial entities. It must also encourage its own commercial enterprises to participate in the low earth orbit economy.

Introduction

The idea of a permanent or continuous human presence in space took shape in the United States in the early 1980s, with senior NASA officials billing it as "the next logical step" in space exploration. At this time, the United States only had experience launching and operating the short-lived Skylab space station. The Soviets had accumulated more than a decade of experience with the Salyut series of space stations, which were also temporary orbital craft like Skylab.

Mir

In 1986, the Soviets launched the core segment of the Mir, the world's first modular space station. Over the years, five research modules would be added to Mir. In the aftermath of the Cold War, Mir also opened up the opportunity for Russia-US space cooperation, with NASA providing some of the scientific gear for two of the research modules. American space shuttles also ferried personnel to and from Mir. Indeed, for a decade between September 1989 and August 1999, Mir was continuously inhabited. Cosmonauts and astronauts on the Mir conducted scientific experiments and engaged in the three longest spaceflights to date (between 366 and 438 days). Mir was deorbited in 2001 after being in operation for 15 years.

International Space Station (ISS)

The ISS is a multinational effort led by the US and Russia. It came into existence on 20 November 1998, when a Russian Proton rocket launched the Zarya Control Module. It was joined two weeks later by an American module. The station received its first visitors on 2 November 2000, and has been continuously inhabited ever since. The ISS continued to add new modules until 2011, making it the

largest artificial structure or craft in space. That same year, the US space shuttle programme ended, leaving the task of transport to and from the ISS to Russia's Soyuz spacecraft and as well as the Dragon-series of spacecraft operated by US-based company SpaceX.

As of 8 December 2021, the ISS had received 251 visitors from 19 countries. Out of these, 155 were from the US and 52 were from Russia. The ISS has so far enabled about 3,000 scientific experiments that require microgravity environments in fields ranging from biology to Earth sciences. However, despite its impressive record, the ISS is now ageing, and is unlikely to remain in operation beyond 2030. NASA's current plan is to deorbit the station in January 2031, allowing it to crash in a remote spot in the Pacific Ocean. The future of humanity's continuous presence in space will depend on a new generation of space stations.

Space Station Programmes

The United States

The US has approved funds for the International Space Station to operate until 2024. However, on 31 December 2021, President Joe Biden's administration committed the US to continuing operating the ISS until 2030. This was not surprising: in the past, NASA has asserted that the station would remain viable until at least the end of the decade. NASA administrator Bill Nelson had also previously indicated that the station was capable of remaining in operation until 2030.

NASA is keen to keep the ISS in operation because it does not have a replacement for it yet. The US has chosen to place its bets on commercial enterprise. The first step has been to commercialise transport to the ISS. Following the end of the space shuttle programme in 2011, NASA struck deals with SpaceX and Boeing to transport personnel to the ISS and back. Boeing received $4.2 billion and SpaceX received $2.6 billion in fixed-price contracts that obligate both companies to send between two and six crewed missions to the ISS each. In May 2020, SpaceX Dragon craft began transporting crews to and from the ISS. Boeing is presently behind SpaceX, with its Starliner spacecraft only expected to go on a test voyage to the ISS later in 2022. SpaceX has also been ferrying cargo to and from the ISS since 2012, using an uncrewed version of its Dragon spacecraft. Another company moving cargo for the ISS was Orbital Sciences Corporation (OSC), which Northrop Grumman acquired in 2018. The OSC/ Northrop Cygnus spacecraft began ferrying cargo in 2013, much like the Dragon. Unlike the Dragon, however, Cygnus craft can only conduct destructive reentries.

NASA's second step has been to support the operation of commercially owned space stations before the ISS is decommissioned in 2030. According to NASA's official blog, its goal is to now "enable a seamless transition of capabilities in low-Earth orbit to one or more commercially owned and operated destinations in the late 2020s." In July 2021, NASA released a request for proposals for space stations through its Commercial Low Earth Orbit Development (CLD) programme. NASA considered 11 proposals and selected three of them: Nanoracks, Blue Origin, and Northrop Grumman.

Nanoracks will receive $160 million to develop its Starlab station in collaboration with Voyager Space and Lockheed Martin. Starlab will feature an "inflatable habitat" developed by Lockheed Martin that will house a lab with a crew of four. The station will also have a docking node, a propulsion unit, and a robotic arm.

Jeff Bezos' Blue Origin will get $130 million to develop a commercial station it calls Orbital Reef. The station will be designed along with a startup called Sierra Space, while Boeing is to design a research module. Orbital Reef is touted as a "mixed use business park" in low earth orbit that will be made available to researchers and commercial customers. The station is to be nearly as large as the ISS and house up to 10 people, with Boeing's Starliner providing transport.

Northrop Grumman is to receive $125.6 million for the development of its space station, which it says will use "flight-proven elements" and take advantage of the experience gained from operating the Cygnus series of spacecrafts. In its initial stage, the station is to have the capacity to house a crew of four, which will expand to eight as more modules are added over the station's planned 15-year lifespan.

Besides these three candidates, other companies are pursuing space station projects on their own. For example, in 2020, NASA awarded the company Axiom a contract to build a commercial module for the ISS. Axiom also plans to build its own stand-alone station.

The Privatisation Imperative: NASA has three key motivations for encouraging the growth of a commercially viable low earth orbit economy. One, the creation of a financially sustainable system, could help maintain a continuous human presence in space. Two, NASA expects to save about $1.3 billion in 2031, with that figure going up to $1.8 billion by 2033. Three, the funds saved through commercialisation will allow NASA to focus on more ambitious projects such as the Artemis programme, which plans to return humans to the Moon.

However, NASA's plan hinges on the private companies overcoming the significant technological hurdles of spaceflight and habitation. It also depends on the development of a commercially sustainable economy in low earth orbit. At present, both of these outcomes are uncertain. Transport spacecraft such as the Boeing Starliner and planned launch systems such as the Blue Origin are behind schedule in their development. Some of the novel space station designs currently being pursued are also untested. Besides the challenges of technology, would-be operators of space stations will also need to find customers besides governments, whether they be research institutions, companies, or tourists. Those customers may not materialise in sufficient numbers for many years. In 2018, a report by NASA's own auditors concluded that commercial operators would be dependent on government support for longer than previously anticipated. If the creation of a self-sustaining ecosystem is delayed, NASA may find itself having to divert resources to fund space stations.

Russia

For over two decades, NASA and Russia's state space corporation, Roscosmos, have productively collaborated to build, crew, and maintain the ISS. However, in April 2021, the head of Roscosmos, Dmitry Rogozin, said Russia would build its own space station, possibly by 2030. There are three reasons for Russia to take its own path into low earth orbit.

One, the returns from collaboration with the US are diminishing. The ISS is an ageing craft that requires regular maintenance. NASA is also now much less dependent on Roscosmos to run the ISS. There are no new modules for Russia to build. NASA is also no longer solely reliant on Russia's Soyuz spacecraft to transport crews to the ISS, thanks to the SpaceX Dragon capsules. Soyuz launches had been especially lucrative for Russia, allowing Roscosmos to charge up to $90 million for every astronaut transported to the ISS.

Two, US-Russia ties have been fraying, making cooperation more difficult. The ISS was conceived in the aftermath of the Cold War, at a time when post-Soviet Russia and the US enjoyed much common ground. Following the 2014 Ukraine crisis, ties began to worsen. Rogozin himself was personally sanctioned by both the US and the European Union (EU), while the US put two Russian firms with connections to Roscosmos - TsNIImash and Progress - on a restricted list for their military ties. US sanctions have also disrupted Russia's space programme, with launches delayed because components have been made unavailable. In June 2021, this prompted Rogozin to threaten to leave the ISS by 2025 if sanctions were not lifted. Finally, Russia's decision to conduct a destructive antisatellite missile test on 15 November 2021, drew criticism from US officials including NASA administrator, Bill Nelson. While Russia is unlikely to conduct another such test in the near future, it highlights the decline in relations.

Three, Russia is enhancing space cooperation with China. The two states are working together on the ambitious International Lunar Research Station (ILRS) project that is a rival to the US-led Artemis lunar exploration programme. Russia and China are also collaborating on a mission to collect samples from a Near-Earth Asteroid called Kamo'oalewa. Collaborating with China could give Russia's space programme access to much-needed finance in return for Russian know-how. However, any Russia-China space cooperation will limit Russia's ability to collaborate with the US. This is because of a 2011 US legislation called the Wolf Amendment, which bars NASA from collaborating with China without prior approval from the US Congress. The Wolf Amendment effectively bans US-China cooperation in space, and will thus impose limitations on NASA's ability to work with Roscosmos.

Russia's Space Station - Plans and Prospects: The state-run Energia Space Rocket Corporation is working on the "first basic module" for Russia's own space station. The craft has been called Russian Orbital Service Station (ROSS) and is to be ready by 2025. While details about the planned space station are not yet clear, Rogozin has said the station will be more efficient than the ISS, with features such as extravehicular robots, that reduce the need for crewmembers to leave the station and engage in spacewalks for routine maintenance. Another senior space official has mentioned the possibility of a "squadron of satellites" that will surround the station at distances of 100-200 kilometres.

Russia enjoys obvious advantages in its pursuit of a new space station. It is a pioneer in the field, having operated the early Salyut stations, as well as the first modular space station, Mir. Roscosmos has also been NASA's most important partner in the ISS. It has built modules for the ISS and has provided transport for crewmembers and cargo. Most recently, on 16 February 2022, a Progress MS-19 spacecraft delivered 2.5 tons of cargo to the ISS. This deep experience and expertise means Russia can build, launch, and operate ROSS providing it gets the funding it needs. To acquire that financial support, Russia could turn to other states like India, and possibly China.

China

In 2011, the China National Space Administration (CNSA) launched its first experimental space station, Tiangong-1, to an altitude of about 300 kilometres. The next year, the Shenzhou-9 capsule docked with the station, transferring a crew of three who stayed onboard for about two weeks. This feat was repeated again the following year with the Shenzhou-10 vehicle. In 2018, the defunct space station re-entered the Earth's atmosphere and disintegrated.

China's next prototype station was the Tiangong-2, which went into orbit in 2016. A crew of two taikonauts worked onboard for a month and the station was eventually deorbited in 2019.

Launching and operating two temporary spacelabs in orbit, gave CNSA the experience to begin the process of putting together China's permanent and modular space station, Tiangong. The core module of the station, Tianhe, was placed in orbit in May 2021. In October, the Shenzhou-13 docked with the module, transferring a crew of three who are to stay onboard for six months. China intends to keep the station continuously crewed for ten years. CNSA plans to launch the two remaining modules in 2022 and complete assembling the space station. The first module, called Wentian, will serve as the space lab and feature an airlock for spacewalks.

With a total of just three modules, the Tiangong will be a much smaller space station than the 16-module ISS. However, the Tiangong will serve several important functions. The process of running a space station will impart expertise and experience to CNSA's scientists and engineers, validate technologies, and provide learnings. Besides being a potent demonstration of China's growing technological prowess, the Tiangong will also serve as a springboard for China's future exploration plans on the Moon and on Mars.

India

While India has proven expertise at launching satellite payloads into orbit, it is new to the tasks of human spaceflight and the construction of space habitats. In January 2020, then-chief of the Indian Space Research Organisation (ISRO) said India would build a space station once it completed the first human spaceflight. In December 2021, Union minister for science and technology, Jitendra Singh said India would launch this space station by 2030. Sivan had indicated that the station was envisaged to

have a mass of about 20 tons and orbit the Earth at an altitude of about 400 kilometres - the same altitude as the ISS. The station would also be able to house a small crew for 15-20 days. While few other details are available, it would seem India's planned space station will resemble the temporary spacelabs first launched by the Soviets, Americans, and Chinese.

Human spaceflight is a key hurdle India will have to overcome on its path to launching a space station. In 2022, ISRO plans to complete the first two uncrewed phases of the Ganganyaan human spaceflight programme. The first launch will serve to test the space vehicle and its escape system. The second will feature a humanoid robot. In 2023, ISRO plans to send the first human into space.

Conclusion

Despite uncertainty about the future of the ISS, the next decade is likely to witness a number of attempts by both states and private entities to establish space stations and enable a continuous human presence beyond the Earth. At present, India remains far behind the US, Russia and China in these efforts. Even if it were to meet its deadline of launching a space station by 2030, India could do so at a time when multiple space stations are already in low earth orbit and providing customers a range of services.

Instead of seeking to independently pursue human spaceflight and continuous presence in space, India must actively seek out international collaborations and encourage the involvement of its private sector. India should use collaborations to absorb know-how and technical expertise in building, fabricating, launching, deploying and maintaining permanent outposts in low earth orbit. As partners, it must seek out both state entities like Roscosmos and NASA, and commercial enterprises. Such collaborations will offer India the best chance it has to maintain a continuous presence in space and unlock the commercial potential of low earth orbit.