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A Quad Space Station?

Examining the Opportunities and Challenges for India's Human Spaceflight Programme

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This discussion document examines the possibility of the Quad countries collaborating on building a space station. It provides a novel framework to analyse large-scale space cooperation between various countries. Further, it identifies five policy options India can pursue to realise its interests in space. Finally, the document provides recommendations on the steps India must take to strengthen its human spaceflight programme.

Executive Summary

India's human spaceflight programme formally took shape in August 2018 when Prime Minister Narendra Modi announced the *Gaganyaan* programme. The natural next step for India is to pursue long-term human habitation in low-Earth orbit (LEO) by constructing a space station.

This document examines the collaborative potential between the Quad countries by comparing the countries' space policy priorities, technological capabilities and the degree of past cooperation. The document also posits that commercial entities will play a significant role in the race to build space stations.

The analysis points to a strong collaborative potential between India, Japan and Australia. In this arrangement, India and Japan can be symmetric partners. Australia, in this case, can contribute to the project as a minor partner.

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The potential for collaboration with the US is low, as it prioritises its space policy to reach the Moon and beyond. However, India might collaborate with private players in the US who are playing a prominent role in developing space stations.

India can also collaborate with other partners, such as European spacefaring countries. On the other hand, India might build a space station indigenously without the help of foreign partners. This option, however, would be very expensive and impose opportunity costs on the country.

Finally, India can forgo the construction of a space station entirely. In this case, India can continue its human spaceflight programme by purchasing commercial services from other entities.

1. Introduction

Can the Quad countries — namely Australia, India, Japan and the United States — collaborate to launch a space station into orbit? Should India proceed with a space station project, with or without partners? And what are the options available for India to continue its human spaceflight programme? This document argues that India, Japan and Australia have the most substantial potential for collaborating on a space station project. However, India can also pursue other alternatives, such as partnering with non-Quad countries, partnering with a commercial entity, pursuing an independent space station or buying commercial services from other entities without investing in its own infrastructure. None of the options mentioned above can be considered the best. Each alternative available to India brings its own set of benefits and trade-offs. Therefore, carefully examining all options is necessary to set the course for India's space programme.

For more than 20 years, the *International Space Station (ISS)*, operated by a partnership between the United States (US), Russia, Japan, Europe and Canada, has been a symbol of international collaboration in the Earth's orbit. Its time in orbit, however, is running short for technical and political reasons. The first module of the *ISS* was launched in 1998 and is reaching the limits of its operational capacity.[1] The retirement of the *ISS* was initially slated for 2024, but the National Aeronautics and Space Administration (NASA) of the US plans to extend its life through 2030.[2] Moreover, international cooperation with Russia has grown increasingly strenuous after the country’s invasion of Ukraine in February 2022.[3] In July 2022, Yuri Borisov, the director-general of Russia’s space agency, Roscosmos, announced his country’s intention to end its partnership with the ISS before the end of 2030 and pursue efforts to launch Russia’s own space station.[4]

Amidst the uncertainties highlighted above, the question remains: what will replace the *ISS*?[5] Currently, China is the only country operating a fully indigenous space station. In parallel, the start-ups and private companies of the NewSpace-era have also risen to the occasion to fulfil the need for building cost-effective and reliable space systems, making their proposals appear as a viable option to replace the *ISS*.[6]

India has announced its intention to develop and launch its own space station by 2030.[7] The programme is an outgrowth of the *Gaganyaan* human spaceflight endeavour, which was formally announced in 2018.[8] Indeed, the then Chairman of ISRO, Dr Kailasavadivoo Sivan, said that India's human spaceflight programme would not have a conclusion in the absence of a space station. He further stated that India's space station would sustain human life for 15 to 20 days in orbit.[9] India's attempt to build a space station, even on a small scale, is certainly ambitious. But taking the space station path also means India's policymakers will give lower priority to increasing the country's satellite capacity and ground-based assets. At the same time, in an attempt to pursue the construction of a fully indigenous space station, India might be closing its doors to gaining access to critical technologies and eschewing an opportunity to strengthen its relationship with like-minded partners.

A space station can be defined as any infrastructure in low Earth Orbit that can support human habitation for a period of 30 days or longer.

This document aims to interrogate the possibility of a partnership between the members of the Quad. Since its revival in March 2017, the Quad has been an informal but nevertheless significant feature in India's approach to international diplomacy. It has evolved from a working-level group to a full-fledged partnership, with cooperation ranging from maritime and cyber security to disaster response and vaccine distribution.[10] Indeed, the Quad already consists of a working group on space to promulgate collaboration between partners. During the Quad Leaders' Summit in May 2022, the four countries agreed to establish the Indo-Pacific Partnership for Maritime Domain Awareness (IPMDA).[11] The initiative also involves sharing satellite data to track illegal fishing activities conducted by China.[12]

Further, India's bilateral space cooperation with Australia, Japan and the United States has improved significantly in recent years, setting the political precedent for deepening space cooperation.[13] On the technological front, Japan and the US have well-established space programmes, while Australia is at the early stages of its space endeavour. While India has not been as enthusiastic as its Quad partners in joining US-led initiatives such as the Artemis lunar exploration programme, disagreements among the members can exist even while they cooperate on other fronts of outer space.[14] Therefore, analysing the possibility of a Quad space station is an exercise that is necessary to determine the future of India's human spaceflight programme.

The Quad is not a military alliance. However, it is an informal partnership whose actions focus on countering China's growing influence.

China's rising influence in outer space could provide the impetus to increase the degree of space cooperation between the Quad countries.

Building on the Takshashila Institution's previous work on this subject,[15] this document introduces a framework for assessing the potential for large-scale space cooperation among countries and private entities. The document also posits that the commercial space sector will play a prominent role in developing Low Earth Orbit (LEO) space stations, thus, having significant implications for state-to-state space collaboration. Further, it provides a comprehensive list of options for India to pursue the construction of a space station.

The rest of this document proceeds as follows. The second section will briefly outline why countries build space stations and the advantages of pursuing international cooperation. The third section will provide a framework for evaluating the possibility of international cooperation on a space station project. The fourth section evaluates the space policies of the US, Japan and Australia to understand the viability of a Quad space station. The fifth section delves into India's options for pursuing cooperation on a space station project. The final section provides recommendations on how India can enable a greater degree of Quad civilian space cooperation.

2. Rationale for space stations and international cooperation

Going to space is extraordinarily difficult, even for countries with the available knowledge and resources. Deciding to place a sizeable habitable structure in orbit is all the more challenging. Why do countries decide to go for space stations? Based on the history of space station decision-making (see Appendix), we can extract the key reasons why countries undertake such expensive projects.

2.1: The pursuit of space stations

The overarching reason for pursuing a space station pertains to where a country wishes to place itself in the hierarchy of the space club.[16] Space programmes are extremely expensive and risky national (or private) undertakings. They symbolise a country's scientific and technological prowess, with human space flight at the top of the club's hierarchy.[17]

The four main reasons why countries pursue space station goes as follows:

Diplomatic value: Countries might see space stations as lucrative investments to boost relations with non-space powers and smaller neighbours. Offering free rides to countries with little or no space capabilities might strengthen diplomatic relations.[18] In unique cases, countries may pursue a partnership to prevent a potential partner from undertaking competing projects or, to prevent a country from sharing sensitive dual-use technologies with adversarial countries.[19]

Competitive pressures: Presently, only countries with vast economic resources have pursued the construction of space stations. The competitive pressures of the international system are one of the reasons why the US and the Soviet Union launched *Salyut* and *Skylab* during the Cold War.[20] Similar competitive pressures may force countries to widen their access to space through indigenous space stations.

Leverage in international space negotiations: The presence of long-term infrastructure in the Earth's orbit might give a country greater room for negotiating terms of international agreements in their favour.[21] A country can signal normative behaviour and raise concerns about safety and security in outer space.[22]

Technological benefits: A country might view space stations as a project which can foster innovations within a short period. Further, countries might also see advantages in using microgravity conditions to conduct experiments on new technologies in the areas of material science, medicine and education.[23] Since experiments conducted in space take several years to trickle down to usable technologies, it is difficult to measure a space station's tangible advantages.

Commercial benefits: Countries might view space stations as a platform for inviting space agencies of other countries and private entities to send scientific experiments or purchase private missions to the space station.[24] The commercialisation of space infrastructure is viewed as having the potential to bring in much-needed revenue to recoup part of the space station investment.[25]

Quantitatively measuring the benefits of a space station is difficult because both material and non-material benefits take several years to be of prominence.[26] Hence, space stations may not always seem economically advantageous at the onset. As we have observed previously, political and strategic interests are the primary drivers of space projects, even when the economic benefits are limited. ***Space stations, therefore, are the products of politics wrapped in the narrative of scientific and technological benefits.***

2.2: The advantages of international collaboration

Space stations are expensive.[27] Building a fully indigenous space station for a country with a small budget is a high-risk undertaking with no foreseeable benefits if partners or friendly countries are doing the same. This is especially true for a country like India, which has a nimble space programme operating on constrained budgets and no substantive human spaceflight experience. Under these circumstances, how can international cooperation benefit countries?

First, international cooperation with like-minded partners reduces the risk of undertaking expensive projects indigenously, as the risk associated with building and construction is spread among partnering members. Second, the cooperating countries within a partnership will be able to focus their efforts on areas of competitive strength rather than pursue unfamiliar technologies. Third, a less-advanced partner can access the critical know-how of carrying out long-duration human spaceflight missions and potentially gain access to advanced technologies through non-exchange of funds technology transfers.

International cooperation can help reduce the overall cost of constructing a space station. It allows collaborating countries to focus on competitive strengths, such as robotics and in-space construction, instead of innovating in technologies that are already pioneered by others.

But international cooperation in space does not manifest itself automatically. Collaboration between potential partners results from the relative distribution of power, political context and alignment of interests. The next section, therefore, provides a framework for assessing the viability of long-term space collaboration between the Quad countries.

3: A framework for assessing international cooperation in space

Why do countries cooperate in space? What are the drivers of international cooperation in space, and what are the conditions that give rise to cooperation on projects such as the construction of a space station? The previous section put forward a history of space station decision-making. This section puts forward a framework for assessing whether it is possible for India to take forward comprehensive space cooperation with other Quad countries.

3.1: Existing frameworks of international cooperation in space

Several scholars have put forward models of international cooperation which are extrapolated from historical case studies. The seminal international space cooperation framework is provided by Sadhe et al., who argue that cooperative space outcomes are determined by three critical factors: initial conditions, political actors and the mediating structures.[28]

Initial conditions, according to the authors, are determined by rational calculations such as the degree to which countries assess the economic, scientific and technological benefits of space exploration missions. Politics, which according to the authors, comprises both domestic and international political conditions, is also an important constituent of the initial conditions as they determine whether countries will go forward with international cooperation. Political actors are individuals and groups like scientists, national organisations or bureaucrats who bring their own set of preferences that enable or constrain cooperation.[29]

The authors argue that the interaction between the initial conditions and political actors can give rise to four models of international cooperation: [30]

- Institutional bargaining process can give rise to multilateral institutions like the ESA.
- Epistemic community processes bring together groups with shared interests to undertake space science cooperation.
- Structural conditioning, where hegemonic powers undertake policies to bring public goods.
- Converge of norms which foster cooperation between countries with shared beliefs and interests.

Although the authors classify *ISS* as a model of cooperation under structural conditioning and convergence of norms, the history of space station cooperation reveals that the national space organisations of partnering countries must also share a degree of epistemic convergence.[31] Further, the model proposed by Salhe et al. does not consider the order of priority that a country might place on the political and economic/scientific benefits when pursuing international cooperation.

Even though competitive dynamics of international politics might still be a prevalent factor that determines the patterns of international cooperation in space,[32] countries like the US, with a thriving private space industry, might choose to prioritise their own commercial private sector and reap the benefits of selling space missions.[33] Moreover, even if political, economic and epistemic conditions strongly align between potential partners, misalignment of national space strategies and roadmaps will likely prevent cooperation.

In order to forecast the possibility and the viability of international cooperation in space between two or more countries, we must analyse the individual space policies, strategies and roadmaps of countries that intend to cooperate and assess the convergence of conditions, interests and technological capabilities.[34]

Parameters for evaluating space station cooperation

Since the objective of this document is to evaluate the possibility of bilateral or multilateral cooperation on a space station, a framework for assessment must be limited to consider how countries can achieve collaboration on long-term niche and critical path projects.[35]

Further, the framework presented here assumes that the political conditions already exist for space cooperation between the Quad countries as the partnership has cooperated on space-related matters in the past. However, the international political conditions for an optimistic scenario of space cooperation do not exist, and competitive dynamics of international politics will still determine the outcome of collaboration.[36] Therefore, the parameters chosen are as follows:

Space Policy Priorities: What are the types of missions that countries aim to undertake within a five or ten-year period, and what are the objectives set for these missions? Cooperation between countries on civilian space missions is highly contingent upon each partnering country's goals. Since budget allocations are decided years before the beginning of a mission, countries can not commit to working with partners when the mission schedules and objectives are misaligned. The space policy priorities are coded on three scales:

I. Beyond Earth Orbits: Countries commit to long-term Cislunar and Mars missions as a high priority.[37] While these countries may also have an interest in maintaining Low-Earth Orbit (LEO) infrastructure, it is low on the priority list.

These countries are less likely to cooperate on a space station project.

II. Geocentric Orbits: Countries prioritise establishing a medium and long-term presence in space by increasing the number of space assets in LEO, MEO and GEO. A country may also aim to through the launch of crewed spacecraft and the eventual operation of a space station.

III. Mission-support: Countries with limited technological capabilities or relatively small space programmes prioritise the support of large-scale missions through international cooperation. Such countries utilise the competitive advantages of their domestic industries for international cooperation in space.

Technological Capabilities: What capabilities do countries possess that allow for international collaboration on a space station project?[38] A symmetric partnership is possible when partnering countries have similar capabilities to launch crew modules and spacecraft. At the same time, countries with asymmetric capabilities may also choose to cooperate to form an asymmetric partnership, where the more technologically capable country takes the lead in the space station project. Technological capabilities are coded on three scales:

I. Advanced: The countries that possess heavy-lift launch vehicles, capabilities to design, develop and launch modular space laboratories and technologies to sustain long-term missions in outer space. In addition, countries can leverage the capabilities of their private sector to advance their space policy priorities.

II. Competitive: Countries in this category possess the capabilities to launch satellites into LEO, MEO and GEO. These countries may also have the technological know-how to carry out human spaceflight but are yet to carry out missions. The private space sector in these countries may be nascent or oriented towards specific fields.

III. Nascent: These countries specialise in space technologies such as robotics, satellite fabrication and ground support for space missions. However, they do not possess independent launch capabilities or undertake large-scale space infrastructure manufacturing. The private space sector in

A thriving ancillary industry is essential for countries with advanced, competitive or nascent capabilities,

Ancillary industries can be defined as the private sector that supports the space industry by producing subcomponents, machine tools and analytical and software support for national space institutions.

these countries may have the capacity to undertake more demanding space missions.

Degree of past cooperation: Cooperation between counties — especially on large-scale collaborations such as a space station — do not take place in the absence of a prior history of cooperation. As the previous records of space station collaborations have demonstrated, partnering countries had some form of small-scale cooperation in the past to enable cooperation on large-scale projects.[39] Past epistemic community interaction, therefore, is endemic to international cooperation in space.[40] Interaction between epistemic communities of partnering counties is coded as follows:

I. High: The degree of past cooperation between partners is said to be high when the partnering countries have collaborated on large-scale space projects such as jointly launching interplanetary missions, constructing space stations or sending and training astronauts from either country.

II. Medium: The degree of past cooperation between partners is said to be at a medium scale when the partnering countries have collaborated on projects such as the construction of satellites in LEO and GEO. Countries may have also pursued joint development of space launch vehicles and their constituent components, such as boosters or rocket engines.

III. Low: The degree of past cooperation between partners is said to be low when the partnering countries do not have any history of collaborative research, development and construction of space technologies or any undertaking of substantive scientific missions in space.

While the partnering counties may purchase components for their spacecraft and ground stations from each other, this does not constitute a higher degree of cooperation or interaction.

The interplay between the three parameters will produce four types of cooperative outcomes for a space station in LEO. They are as follows:

I. Asymmetric collaboration: This form of collaboration arises when one country within a partnership possesses advanced technological capabilities while the other partners possess competitive and nascent capabilities. Collaboration between partners who possess asymmetric capabilities is possible when all partnering countries prioritise space activities in geocentric orbits.

II. Symmetric collaboration: A symmetric pattern of collaboration between partnering countries arises when two or more partners share similar space policy priorities and technological capabilities. Countries must possess a medium to a high degree of past cooperation to achieve symmetric collaboration on a space station.

III. Low collaboration: The conditions for collaboration between two or more countries will not arise if they have no shared history of cooperation in space. Further, a LEO space station collaboration will not be possible if the countries do not share similar space policy goals.

IV. Commercial collaboration: A unique pattern of collaboration that has become prominent only recently is the potential for partnership between private sector entities or between private entities and a country. A commercial collaboration on a space station can take two forms: 1.) Two or more private space companies based out of different countries can partner to build sections of a space station. 2.) A private space company based out of one country can partner with a national space agency or state-led entity of another country, giving rise to a public-private partnership.

Commercial collaboration does not include cases where countries and private entities purchase commercial services from a company. Since purchasing commercial services does not involve any commitment from a country to build hardware, any country that buys services from a private entity is simply a customer rather than a partner. A thriving private space industry or a competitive public space sector is necessary for commercial collaboration on a space station. The nature of collaboration can be symmetric or asymmetric depending on the degree to which a country or private entity wishes to be involved in the commercial partnership.

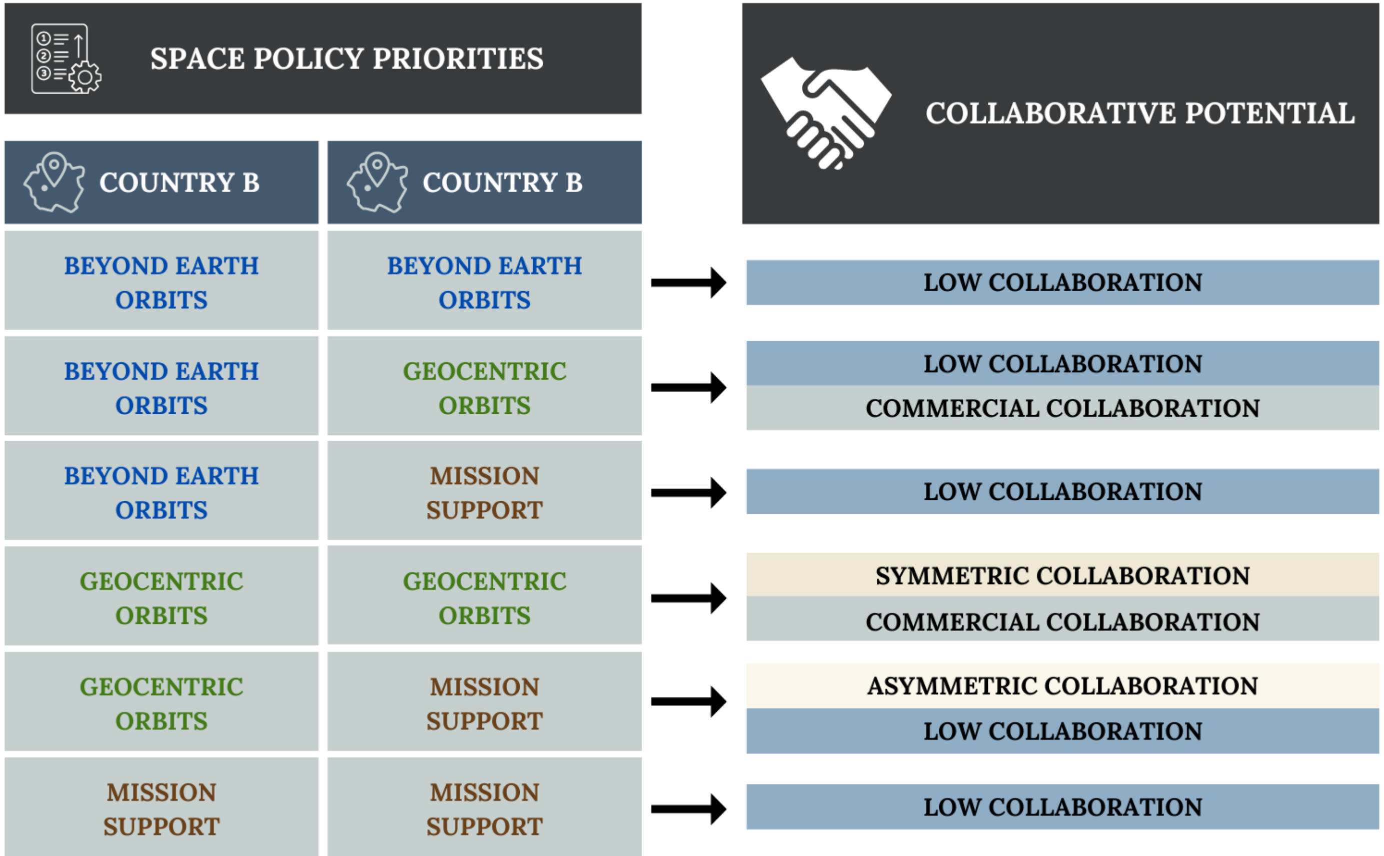

Figure 1: Space policy priorities and collaborative potential between countries

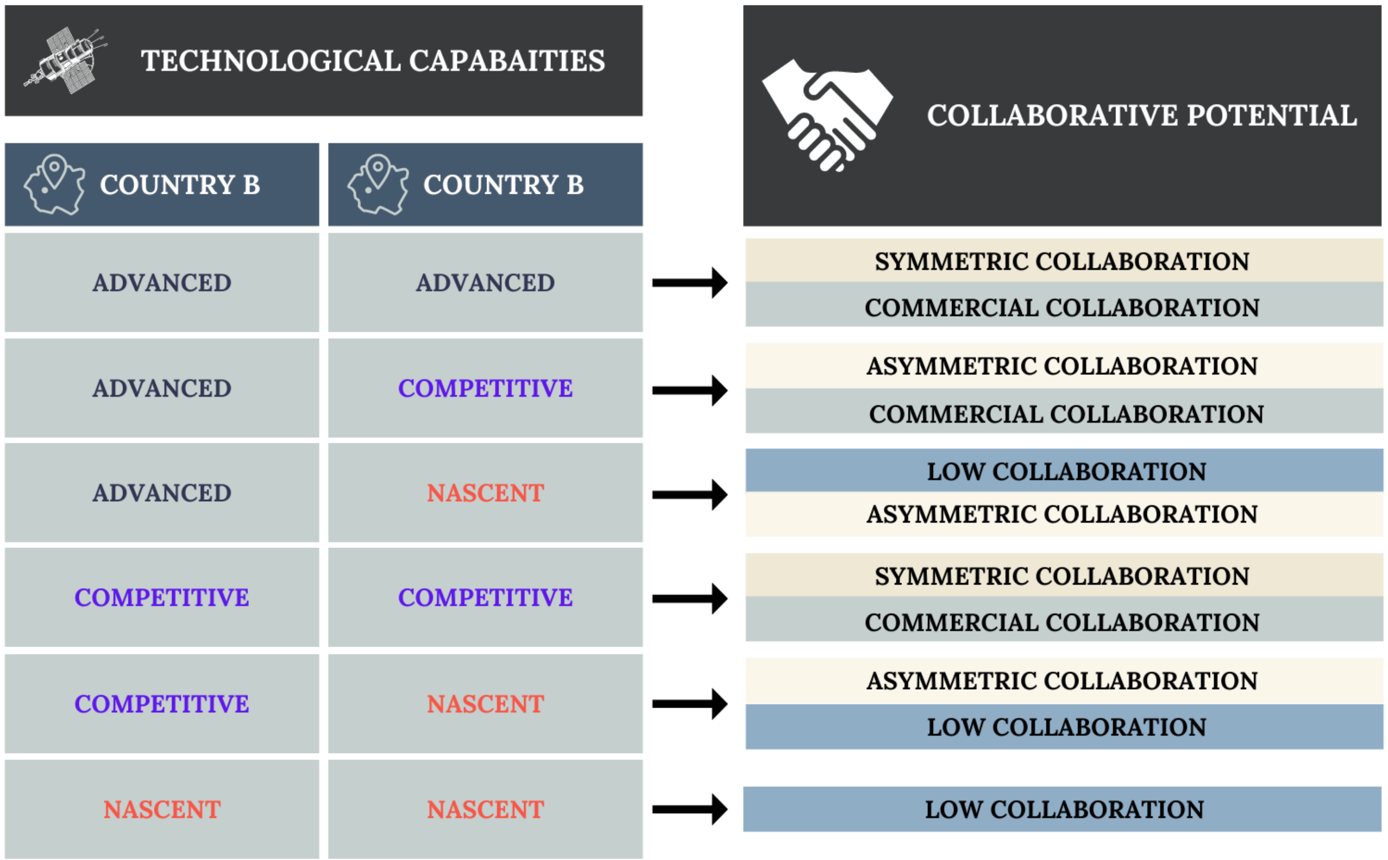

Figure 2: Technological capabilities and collaborative potential between countries

4. Space policies and capabilities of Quad countries

What are the space policies of India's partnering Quad countries, namely, the US, Japan and Australia? Are these policies conducive to international cooperation on a space station? Using the framework provided in the previous section, this section will analyse the space policies of the Quad countries to evaluate the potential for cooperation.

4.1: United States

4.1.1: The Orientation of US Space Policy

The US is the leading partner in the *ISS,* and it has operated the massive space structure in LEO for over 20 years. In fact, the *ISS* has cost NASA an average of $1.4 billion every year for maintenance and research. These costs do not include the crew and cargo launch expenses, which cost an average of $ 1.8 billion annually.[41] Although the US has committed to operating the *ISS* till at least 2028, its attention towards LEO began to diminish in the early to mid-2000s. After the *Columbia* Space Shuttle accident in 2003, President George W. Bush announced the retirement of the Space Shuttle by 2010 and proposed a plan to return Americans to the Moon.[42] The Bush vision resulted in NASA's Constellation programme in 2006,[43] which would meet its end under the Obama administration.

The Constellation Program was the second attempt by the United States to return to the moon. An earlier attempt under the George H.W. Bush administration, known as the Space Exploration Initiative, lasted between 1989 and 1993.

After the Space Shuttle's retirement, the US was left with no viable human spacecraft to carry crew to the *ISS* and became solely dependent on Russia for ferrying its astronauts. Ballooning costs of the Constellation programme and the lack of independent human spaceflight capability led the Obama administration to cancel the Constellation programme and re-orient the US space programme to bolster the private sector.[44] The Constellation pro gramme, however, would not meet its conclusive end. The US Senate passed the National Aeronautics and Space Administration Authorization Act of 2010, which mandated NASA to develop the Space Launch System (SLS) by utilising the contracts from the Constellation programme.[45] This firmly set US space policy objectives to return to the Moon and beyond. The US policy goals were further refined under the Donald

Trump administration in 2016, which set firm the goal of sustaining human exploration beyond Earth orbits.[46]

At present, the US-led *Artemis* programme consists of three components to achieve near-term objectives. First, the SLS rocket and the Orion capsule will carry astronauts to the Moon. The second component is the Lunar Gateway — a US-led lunar space station built in partnership with the Canadian Space Agency (CSA), European Space Agency (ESA) and the Japan Aerospace Exploration Agency (JAXA). The Human Landing System (HLS) is the final component of the *Artemis* programme, with SpaceX chosen as the prime contractor.

Although the US made *Artemis* its primary space policy goal, it still maintains an interest in LEO. Under the Commercial LEO Development (CLD) programme,[47] NASA aims to commercialise LEO activities by opening the *ISS* for commercial activities and transition to carry out research on commercially-owned space stations by 2030.[48] Under the new CLD programme, NASA has funded three commercial entities to develop a private space station:[49]

- Blue Origin (with Sierra Space) for the Orbital Reef space station: $130 million.
- Nanoracks (with Voyager Space and Lockheed Martin) for the Starlab space station: $160 million.
- Northrop Grumman for a free-flyer space station: $125.6 million.

Further, NASA has also contracted Axiom Space for $140 million to develop and build a commercial module for the ISS over a seven-year period.[50] The company, Axiom Space, hopes to detach its modules from the *ISS* and operate a fully-independent space station in the near future.[51]

4.1.2: Technological capabilities

The launch and human spaceflight capabilities are provided in the table below. As the table shows, the US has significant capabilities in the above-mentioned areas, and therefore, the country has the option to forgo any form of collaboration with foreign partners.

Launch Capabilities	Human and Cargo Spacecraft
Falcon 9	Cargo Dragon Crew Dragon
Falcon Heavy	
Antares	Cygnus Starliner Dream Chaser*
Atlas V	
Vulcan Centaur*	
New Glenn*	
SLS	Orion
Starship*	

* *Hardware yet to be tested or fully operationalised.*

4.1.3: Overall Assessment

The current space policy of the United States prioritises missions in cislunar orbits and on the Moon's surface. It possesses the technological capabilities to achieve its goals and has partnered with long-time allies to enhance its presence on the Moon. The US has also bet on commercial space stations to fill the gap in long-term LEO capabilities.

But the CLD programme is not without risks. A 2021 report by NASA's Inspector General warned that the CLD programme vastly underestimates the costs of developing commercial space stations and that NASA has set itself the ambitious goal of transitioning to private space stations by 2028.[52] Indeed, it was only in FY2022 that the US Congress approved the level of funding for the CLD programme as requested by NASA.[53] Although the Americans have minimal incentive to cooperate with other countries in LEO, uncertainties regarding the future of the CLD programme might prompt the US government to reconsider.

While NASA's Inspector General has clearly outlined sceptism about the success of the CLD programme, the private entities remain confident.

Axiom Space has signed MOUs with Canada, Hungary, New Zealand, Saudi Arabia, Turkey and the United Arab Emirates (UAE) to send astronauts to the space station.

Voyager Space, on the other hand, has agreed to work with Hilton Hotel as the official partner for the Starlab commercial space station.

4.2: Japan

4.2.1: The Orientation of Japan's Space Policy

Japan's space policy is essentially a dual-use policy which aims to balance the country's civilian space ambitions and national security requirements. Although it was in 2008 that Japan's Space Basic Space Law made an explicit emphasis on the military aspects of space,[54] the shift from a purely civilian policy to a dual-use policy has taken place over several years.[55]

The fourth Basic Plan on Space Policy released in 2020 highlights Japan's space policy priorities for the next decade.[56] Japan's revised policy envisions four goals: 1.) Ensure space security; 2.) Disaster management and national resilience; 3.) Knowledge-creation through space science and exploration; and 4.) Use space for economic growth and innovation.[57] The first two goals are the most relevant for our analysis. However, Japan's geocentric orbital priorities are clearly focused on security. Over the next ten years, Japan hopes to spend big on earth-observation surveillance satellites, command, control and communication assets. Further, it hopes to collaborate with the US to improve missile early-warning functions of space assets.[58]

The second major priority for Japan is a collaboration with the US on the *Artemis* programme to conduct exploration beyond the Earth's orbit. The new policy calls for exploring the Moon and beyond "habitation technology, resupply supply and lunar surface mobility where Japan has technological advantages."[59] Japan was among the first signatories of the Artemis Accords.[60] It is also a partner in constructing and operating the US-led Lunar Gateway.[61] Further, Japan has also committed to launching the Smart Lander for Investigating the Moon (SLIM) mission as a part of *Artemis*.[62] The planned missions and the budget allocated for space exploration clearly reflect Japan's cislunar priorities.[63]

Japan has been active in LEO human spaceflight and exploration activities since the 1980s, beginning with the NASA and National Space Development Agency of Japan (NASDA) collaboration to launch the standalone Japanese microgravity experiment mission called Skylab-J.[64] Japan's contribution to the *ISS* is on three fronts:[65]

1. Japanese astronaut missions to the space station.
2. Operation of the Japanese Experiment Module (JEM), also known as *Kibō.*
3. Providing cargo delivery service through the H-II Transfer Vehicle (HTV).

In this context, Japan may have limited incentives to pursue the construction of yet another space station in LEO, as it has already gained experience and knowledge of long-term crewed operations and microgravity science. However, the current space policy also mentions the country's interest in maintaining a presence in LEO even after the retirement of the *ISS*.[66] Therefore, there is still a possibility that Japan could partner with other countries to continue operations in LEO and to develop new technologies.[67]

4.2.2: Technological Capabilities

Japan's space launch and cargo delivery capabilities are provided in the table below. Although Japan does not possess a diverse set of capabilities like the US, it has instead amassed highly tailored launch capabilities to meet its LEO, GEO and interplanetary requirements.

The Japanese Experiment Module (JEM) or *Kibō* consists of smaller modules and a manipulator arm, resembling a mini-space station.

Launch Capabilities	Cargo Spacecraft
H-IIB	H-II Transfer Vehicle
H-III*	

**Hardware yet to be tested or fully operationalised.*

Japan's private industries are the heavy lifters of JAXA's space projects. Japan's space launch vehicles are manufactured and operated by Mitsubishi Heavy Industries (MHI), which also played a major role in the development of the *Kibō* module of the *ISS*. The company has already set a precedent for commercial collaboration as MHI, and Sierra Space (Blue Origin's partner in developing the Orbital Reef space station) jointly signed an agreement to study space station technologies.[68] If Japan is indeed more receptive to maintaining LEO capabilities through commercial entities, then Tokyo may also accept international collaboration with competitive and like-minded partners.[69]

4.2.3: Overall Assessment

Japan's space policy priorities are in the beyond Earth orbits. The country is deepening space collaboration with long-time ally and partner, the United States, to bolster its status as a space power. On the technological front, Japan has also transitioned from possessing competitive capabilities to advanced technologies in the last decade.

These strides were achieved through the experience gained from the *ISS* partnership, which Japan now hopes to leverage in the *Artemis* programme. Japan might still wish to hold on to its interest in LEO and make conditions conducive for a new international space station collaboration.

4.3: Australia

4.3.1: The Orientation of Australia's Space Policy

Australia's space policy stands out among the rest of the Quad countries. The Australian Space Agency was set up in 2018, and the country had placed minimal emphasis on a full-fledged space programme in the prior years and chose to prioritise the ground segment of space applications.[70]

The new space road map adopted by Australia is unique, as it hopes to leverage the capabilities of the private sector to realise space policy goals. Australia's ambitions hinge on the degree to which it can collaborate with international partners to gain access to outer space.[71] Australia's current space priorities are to increase its space assets in LEO, particularly focused on increasing position navigation and timing (PNT), communications and Earth-observation satellites.[72] Further, Australia also hopes to leverage its domestic industry in robotics to provide services for LEO and cislunar space stations.[73]

Australia also has its eyes set beyond the Earth's orbits as it hopes to support long-term cislunar and Mars missions. Indeed, Australia has already signed an agreement with NASA to send a rover to the Moon as part of the *Artemis* programme.[74] Naturally, the country has also signed the Artemis Accords.

4.3.2: Technological Capabilities

Australia does not have an independent launch capability. The country's launch market is nascent, with several start-ups in their early stages of launch vehicle development.[75] While Australia has a highly developed communications and robotics sector, it is not easy to extrapolate the degree to which these capabilities will come of use as space technologies.[76]

4.3.3: Overall Assessment

Australia's space policy priorities are predominantly in LEO. Australia currently possesses mature ground-segment capabilities which are suited for mission support. However, the country also aims to advance its capabilities and use outer space to make strides in science and technology. Australia will likely function as a minor partner in future international collaboration projects in outer space.

5. India's policy options for space station collaboration

The previous section has provided an assessment of the space policy goals and technological capabilities of the Quad countries. The section delves into India's space policy and the options at its disposal to pursue international cooperation for a space station. This section also asks an important question regarding India's space policy: should India build a space station at all? Although India has committed to a human spaceflight programme, such a large-scale project comes with opportunity costs. India's options for international collaboration, therefore, must be taken in the context of India's strategic requirements and the opportunity costs imposed by various forms of collaboration.

5.1: Assessing India's space policy goals and technological capabilities

5.1.1: The Orientation of India's Space Policy

On August 15, 2018, Prime Minister Narendra Modi announced that India would place its first astronauts in orbit in 2022, thus kicking off the *Gaganyan* human spaceflight programme.[77] A human spaceflight programme was always on the cards, as India had demonstrated its capabilities to launch payloads into the Earth's orbits. India began conducting capsule re-entry experiments in 2007, beginning with the Space Capsule Recovery Experiment.[78] A second test, called the Crew Module Atmospheric Re-entry Experiment (CARE), was conducted in December 2014. Indeed, ISRO remained on the fence about carrying out a human spaceflight mission as it waited to test critical technologies.[80] While the original deadline of launching Indian astronauts into orbit in 2022 could not be met, Union Minister Jitendra Singh said that the *Gaganyaan* mission will begin by the end of 2023.[81]

India's policymakers see the pursuit of an indigenous space station as a natural next step in the human spaceflight programme.[82] In February 2021, the Department of Space published the draft Humans in Space policy which stated that sustained human spaceflight would be used as “an instrument for development, innovation and foster collaborations in alignment with national interests."[83] The real question, however, is whether an indigenous space station — or any collaborative space station project — will yield the tangible benefits that Indian policymakers hope to gain. These gains must be measured against the cost of not pursuing other programmes that are urgently in need.

India’s space policy trajectory has traditionally been aimed at programmes that achieve its developmental goals and harness socio-economic benefits.[84] India’s pursuit of Moon and Mars missions in recent years has created a debate about whether India has veered off course to pursue missions that created clout and prestige rather than real scientific and socio-economic benefits.[85] Moreover, there is an innate fear that India’s policymakers pay less attention to the country’s lack of civilian and weather satellites,[86] particularly in the context of China’s rapidly growing strategic space capabilities.[87]

Given the stringent constraints on India's space expenditure, some consider human spaceflight missions a distraction that can syphon off much-needed funds from strategic necessities. India's policymakers are yet to lay down a policy for pursuing a space station. Without a detailed roadmap detailing the goals that India's space station hopes to achieve, ISRO's long-term human spaceflight programme may fall well short of the perceived scientific, technological and diplomatic benefits.

5.1.2: Technological Capabilities

For over two decades, India has successfully demonstrated its ability to launch payloads into LEO, sun-synchronous and geostationary transfer orbits at a low cost using the Polar Satellite Launch Vehicle (PSLV) series of rockets. Moreover, India had developed the GSLV Mark I and Mark II series of rockets which could carry 2.2 tons and 4.4 tons of payload to geostationary orbits, respectively.

ISRO is planning to replace the PSLV rocket with a fully reusable launch vehicle named the Next-Gen Launch Vehicle. The status of its development is, however, unclear.

India's GSLV Mark III, also known as Launch Vehicle Mark 3 (LVM3), is currently the country's only heavy-lift rocket capable of carrying payloads of up to 10 tons to LEO and 4.3 tons to GEO. The development of the GSLV Mark III began as early as 2002 and conducted its first sub-orbital test in December 2014. The rocket has conducted only four fully operational flights to date. The Mark III will carry the crew and service modules of the Gaganyaan mission, though as of this writing, ISRO is yet to carry out its first human-rated test flight. While ISRO has been provided grants to study the rendezvous and docking of spacecraft,[88] its ability to build long-term habitable modules can only be assessed once human spaceflights have been conducted.

India's private space industry is relatively nascent.[89] Apart from industrial manufacturers by the likes of Larsen & Toubro (L&T), Godrej Aerospace and Walchandnagar Industries, India's start-ups are yet to mature to a stage where they can fully support ISRO in its human spaceflight commitments. The newly formed space activities regulatory body, Indian National Space Promotion and Authorisation Centre (IN-SPACe), promises to nurture and promote India's NewSpace industry and provide access to ISRO's facilities.[90] Since IN-SPACe began full-fledged operations in 2022, realising the full potential of the country's space start-ups may take many more years.

5.1.3: Overall Assessment

India's space policy priorities are in geocentric orbits. Although India has carried out lunar and Mars, they are comparatively small in scale. What is unclear, however, is the direction in which India wants to take its geocentric orbital priorities.

The *Gaganyaan* mission is all set to send India's first astronauts into LEO, but long-term plans for sustained human spaceflight remain obscure. Without a clearly outlined roadmap, India's space programme is in danger of neglecting other areas of strategic space interests, such as the need for more communication, Earth observation and space situational awareness capabilities.

On the technology side, India is yet to fully demonstrate its ability to sustain human spaceflight. India is yet to undergo full indigenisation to prepare for a human spaceflight programme.[91] ISRO is yet to make the GSLV Mark II and Mark III heavy-lift launch vehicles fully reliable for launching humans and large assets into orbit.[92] India currently depends on Russia to fulfil its astronaut training and space suit supply requirements.[93] With India's ancillary space industry in its early stages of maturity, it may take several years before the country can be fully prepared for a space station programme.

5.2: Assessing India's collaborative potential

What are the patterns of collaboration that emerge when India's space policy goals and technological capabilities are compared with those of the respective Quad countries? The previous section analysed space policies and capabilities of the US, Japan and Australia. This sub-section uses the framework in Section 2 to analyse the patterns of collaboration that emerge between India and its potential Quad partners.

5.2.1: India–US space station partnership

The partnership between the two democracies has historically been intermittent. During the early days of India's space programme, the United States provided India with sounding rockets and limited technical assistance.[94] India's INSAT-1 series of satellites were built in partnership with the Ford Aerospace and Communication Cooperation (FACC), marking the 1970s as the peak of Indo-US Cold War cooperation in space.[95] Cooperation on space exploration and technology witnessed a steady decline after India tested its first series of rockets, beginning with the Space Launch Vehicle-3 (SLV-3). The relationship worsened with the cryogenic engine debacle in 1993 when the US stopped Russia from supplying cryogenic engines, an incident which still sparks mistrust towards the US and Western countries.[96]

The mid-2000s was an era of reset for Indo-US relations. The Next Steps in Strategic Partnership laid down new ground for taking forward cooperation between the two democracies. Cooperation on space issues also intensified.[97] The Chandrayaan-1 Moon mission of 2008 carried the Miniature Synthetic Aperture Radar (Mini-SAR) from Johns Hopkins University's Applied Physics Laboratory (APL) and Moon Mineralogy Mapper (M3) from Brown University and NASA's Jet Propulsion Laboratory (JPL).[98] NASA also provided deep space communication assistance with the Mars Orbiter Mission.[99]

The NASA-ISRO Synthetic Aperture Radar (NISAR) project is by far the most prominent collaborative effort between the two countries in recent years. India and the US signed an agreement on the sidelines of the International Astronautical Congress 2014 in Toronto,[100] and the satellite is set to launch in 2023.[101] Most recently, India and the US agreed to share space situational awareness data to monitor space debris.[102] The table below indicates the cooperative abilities of India and the US.

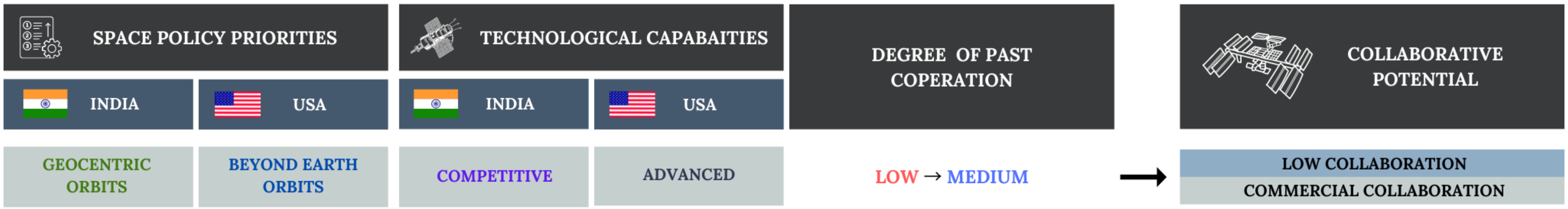

Figure 3: Overall collaborative potential between India and the United States

Given the disparity in space policy priorities and technological capabilities, an Indo-US state-led collaboration on a space station is unlikely. The American shift to the commercialisation of long-term LEO activities reduces the incentives to cooperate even further. However, the commercialisation of LEO activities is also an opportunity as India can collaborate with a US-based private company to achieve its long-term human spaceflight mission.

5.2.2: India–Japan space station partnership

The cooperation between India and Japan can be summarised as stable and healthy. Japan propelled itself as a major space power by partnering with the US. Thus, the lack of cooperation between India and Japan in the early years can be explained by the US-Japan space alliance and the mistrust towards India. However, the India-Japan cooperation in space did not take off even after the Cold War, seemingly due to one of two reasons, or a mix of both. First, the competitive dynamics among Asian powers;[103] and second, the divergence of space policy trajectories.[104]

This trend of non-cooperation did not last long. Indo-Japanese space cooperation has witnessed a steady rise in the last decade. In December 2015, Prime Minister Modi and Japanese Prime Minister Shinzo Abe laid down the roadmap for Indo-Japanese cooperation in the areas including but limited to space and advanced material.[105] In 2017, the two countries announced the Lunar Polar Exploration Mission, under which JAXA and ISRO will send a Moon rover by no later than 2025.[106] The two countries held the first Space Dialogue in

2019 and the second edition in 2021.[107] The table below indicates the cooperative abilities of India and Japan.

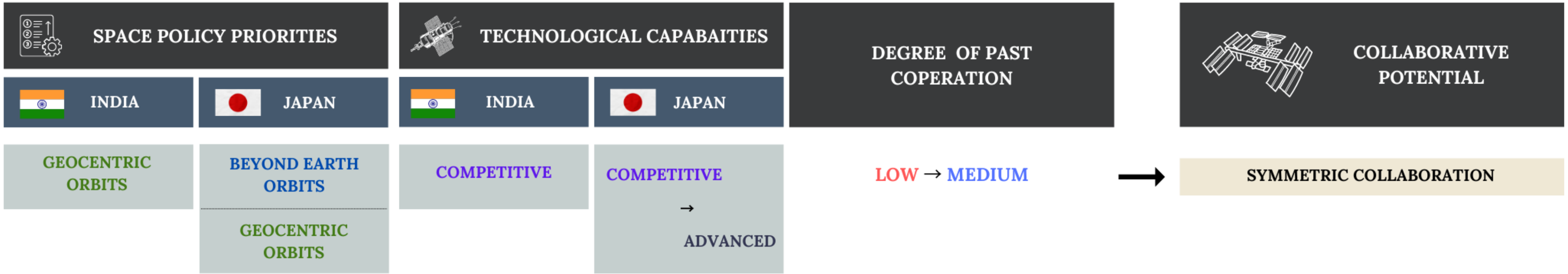

Figure 4: Overall collaborative potential between India and Japan

India and Japan will be on the same technological footing when the *Gaganyaan* mission is successfully completed. Indo-Japanese space cooperation is remarkable since the two countries had little cooperative experience in previous years. If they manage to sustain the current pace of cooperation, then a collaboration on a future space station in LEO is not far from reality.

5.2.3: India-Australia space station partnership

The Indo-Australian space cooperation has been minimal due to Australia's absence from the global space market. Yet, establishing the Australian Space Agency has allowed the two countries to cooperate more extensively. Australia has already agreed to support India's *Gaganyaan* mission by establishing a transportable terminal.[108] In September 2022, the two countries deepened cooperation even further when start-ups from both sides signed six MOUs on the sidelines of the Bangalore Space Exposition.[109] The table below shows the cooperative abilities of India and Australia.

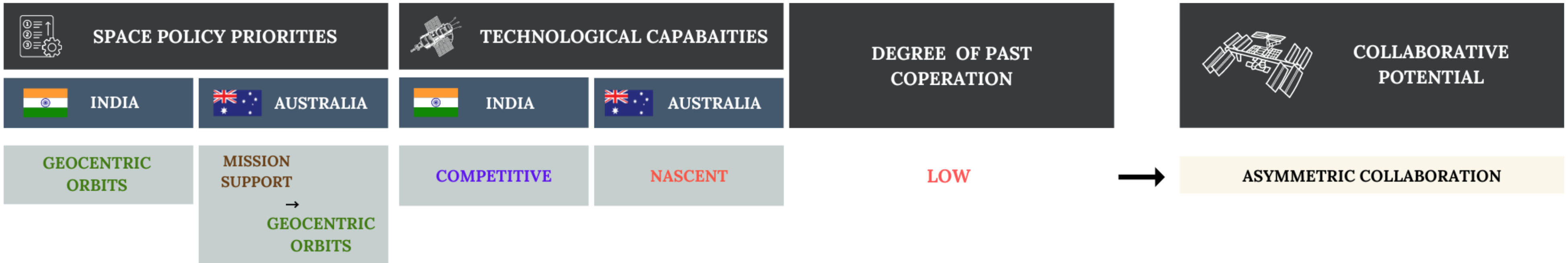

Figure 5: Overall collaborative potential between India and Australia

Since the two countries have yet to collaborate on building space hardware, the cooperation between India and Australia is still low. Hence, Australia may only play the role of a minor partner in a future space station collaborative effort.

5.2.4: India's space station partnership with other countries

The Quad countries are not the only potential partners for a space station. Other partners, old and new, could be up for a significant undertaking, such as a new space station in LEO. A brief examination of potential partners is provided below.

Russia: India and Russia have an intimate relationship in space cooperation. India sent its first astronaut, Rakesh Sharma, to work aboard the *Salyut-7* space station in April 1984. The two countries also collaborated to supply the KVD-1 cryogenic engine for the initial flights of the GSLV Mark I and have agreements to share GLONASS services.[110] However, Indo-Russian collaboration hit rough terrain when Russia could not provide India with a rover for the *Chandrayaan-2* mission.[111]

While cooperation continues on the human spaceflight front, the countries have stayed away from collaborating on jointly developing space hardware. In April 2022, Russia unveiled a mock-up of the planned Russian Orbital Service Station (ROSS), which is said to be operational by 2028 but has yet to indicate whether it is open for collaboration.[112] Further, it is also unclear whether Russia can meet the stringent deadline. Russia does not need India to fulfil its space policy goals. Any partnership with Russia, therefore, will be asymmetric.[113]

Europe and the European Space Agency: Major cooperation between India and Europe dates back to the 1970s when France offered to launch India's Ariane Passenger Payload Experiment (APPLE) satellite on the first orbital launch of Ariane.[114] The Indo-French cooperation continued when France offered to licence the Viking engine to India through a no-transfer-of-funds deal in 1974.[115] In 2005, the ESA agreed to place its instruments on *Chandrayaan-1* and share data retrieved from the experiments.[116] ESA and ISRO have also collaborated to launch satellites from the Ariane-5 and PSLV rockets, respectively.[117]

Although the ESA is a partner in the Lunar Gateway project,[118] it has not given up its interests in LEO. The interest was explicitly expressed in a November 2021 document which called for the study of a SciHab (Science and Habituation) concept, which aims to lay down the options for the ESA after the retirement of the *ISS.*[119] In February 2022, the head of ESA's Washington office, Sylvie Espinasse, stated that the idea of purchasing commercial services from American companies in the future would not be a fully acceptable option for European partners.[120]

However, some European countries are more receptive to commercial collaboration than others. In 2021, for example, the European aerospace company, Thales Alenia Space, signed a $130 mission agreement with US-based Axiom Space to build two pressurised modules for the future private space station.[121] More significantly, Italy and Axiom signed an MOU to expand commercial space cooperation, including the development of space infrastructure.[122]

Although such inconsistencies remain within the ESA, India's space station ambitions strongly align with ESA's need for an independent space station. The ESA, therefore, could function as a major or symmetric for a future space station project.

South Korea: The space programme of South Korea is relatively nascent.[123] Despite having a strong heavy-machines and electronics industry, the country could not build powerful rockets due to the restrictions on missile technology placed by the US. However, with missile technology restrictions lifted,[124] South Korea can not only go ahead with its missile programme but also pursue a robust space programme.[125] Indeed, South Korea's space ambitions are on the rise, as the new President, Yoon Soon-yeol envisions his country to be a space power by 2035.[126] India and South Korea have partnered to jointly manufacture military hardware and hope to strengthen their bilateral relationship in other areas such as cyber and space.[127] With India's expertise in space technologies, South Korea could join India as a minor partner on a space station project to fulfil its LEO ambitions.

5.3: India's options for a space station collaboration

From the analysis presented in the previous sub-section, it is clear that India does not have a single best option to collaborate with the rest of the Quad members at its disposal. Instead, India can choose from a variety of paths that can advance the country's human spaceflight programme and strategic interests in outer space. The domestic and international constraints leave India with five options to choose from, which are as follows:

Option 1: India-Japan-Australia space station

Under this arrangement, India and Japan might function as symmetric partners and contribute to the construction of space station modules. Australia being a country with nascent capabilities might choose to contribute to the partnership by supplying communication and robotic components. Traditionally, multilateral space infrastructure partnerships are formed through non-transfer-of-funds agreements. It is often the most preferable, as non-transfer-of-funds allow all partners to maintain a high degree of autonomy through financial independence, even while sharing the critical know-how of long-term habitation in space. However, the partnering countries may also seek other forms of agreements that involve the transfer of funds if such arrangements seem more favourable.

Option 2: India collaborates with other potential partners

Under this arrangement, India and Japan might function as symmetric partners and contribute to the construction of space station modules. Australia being a country with nascent capabilities might choose to contribute to the partnership by supplying communication and robotic components. Traditionally, multilateral space infrastructure partnerships are formed through non-transfer-of-funds agreements. It is often the most preferable, as non-transfer-of-funds allow all partners to maintain a high degree of autonomy through financial independence, even while sharing the critical know-how of long-term habitation in space. However, the partnering countries may also seek other forms of agreements that involve the transfer of funds if such arrangements seem more favourable.

Option 3: India collaborates with a commercial entity

The third option at India's disposal is to collaborate with one of the US-based companies on the space station project. Since Axiom Space is already collaborating with private industries in Japan and Europe, other companies might be open to such a partnership. Under this option, India's space station module will function as a part of a commercial space station, operating with a high degree of autonomy while making use of the services of the space station architecture.

Option 4: India pursues an independent space station

India's fourth option — and perhaps most expensive — is to pursue a fully independent space station. If it were to choose this path, the road to a fully modular space station would take over a decade as ISRO and its domestic partners must master several technologies which have been perfected by other countries several years prior.

Option 5: India purchases time and services on other space stations

Under the final option, India might choose to abandon its space station ambitions entirely and continue its human spaceflight programme by paying for time and services on a space station run by another country or private entity. While abandoning the space station project will allow India to focus on other areas of space capacity-building, the option will also restrict the country's access to space.

The best option for India is to pursue a collaboration with Japan and Australia, who are established partners in the Quad. Ultimately, India's choice will depend on the priorities that its policymakers and scientific community set for the space programme. If India wants to forge a collaboration with Quad members, it must navigate the murky waters of space governance that balances international cooperation with the West while maintaining its national interests. Killing the human spaceflight programme is politically infeasible or, at best, widely unpopular. On the contrary, India must establish the competitiveness of its existing projects before pursuing more ambitious goals. While India's strategic competitor, China, is achieving over 40 launches yearly,[128] India struggles to launch ten rockets in the same period.[129]

The next section provides recommendations on how the stakeholders of India's space programme can sustain the country's human spaceflight programme and the steps that must be taken to advance India's national interests.

6: Recommendations

The question of whether India must pursue the construction of a space station has major implications for the future of India's human spaceflight programme. It will determine the country's space policy priorities for the long-term trajectory of India's space programme. Since the *Gaganyaan* programme is already underway, India's policymakers and scientific community must take the following steps to ensure that the country's space policy goals do not go astray.

- The Department of Space and ISRO must draw up a robust roadmap for the future of the *Gaganyaan* programme, which highlights the economic, scientific and technological goals it hopes to achieve in the next decade. The *Gaganyaan* programme will be unsustainable in the absence of a clear vision for the future.

- Irrespective of what path is chosen, India's policymakers must view the human spaceflight programme as a whole-of-nation effort. Therefore, it is imperative that the Department of Space, ISRO and IN-SPACe include India's private sector as a key element in the human spaceflight and space station endeavour. A strong ancillary industry is key to the success of a nation's space programme.

- India must use the opportunities that are opened by the *Gaganyaan* programme to improve space cooperation with other countries. For example, the docking of India's human capsule with other countries' crew capsules and docking with the *ISS* are objectives that ISRO can achieve with relative ease. Docking missions also open up opportunities for future space station collaborations.

- If India chooses to collaborate with other countries or private entities on a space station project, it must do so through a public-private consortium led by NewSpace India Limited (NSIL). Such an arrangement will allow ISRO and the Indian government harness the full potential of India's space sector and allow India's private space sector to innovate as a collective entity.

- India’s space policymakers must clarify the country’s space policy to create conditions that are conducive to bringing the private sector into the fold of the human spaceflight programme. Clarifying India’s space policy also removes uncertainties about India’s international space diplomacy and space cooperation preferences.

- Policymakers and the scientific community must view India’s space policy in the broader ambit of India’s technology strategy — where technology serves as a means to advance national goals that bring peace and prosperity to all citizens.

Appendix: A History of Space Station Decisions

The appendix provides a brief history of space stations that have existed since the beginning of the Space Age. It outlines the decisions that led to their creation and the lessons learnt from each project. Since the dawn of the space age, scientists, engineers and experts like Wernher von Braun envisioned the space station as a permanent habitation for humans and a gateway for humanity to travel across the solar system.[130] None of these concepts made it beyond paper. There has never been a single imperative to build a space station, as the decision to carry out expensive space programmes has often been a bargain struck to balance budget constraints, leadership preferences, bureaucratic politics and the pressures of international competition.

The MOL and early ideas of a space station

By the late 1950s, space technology had come into fruition to be of practical use, and the space station came to be viewed as an object of military utility. The US Department of Defense (DoD) studied several options for reconnaissance missions over an adversary's territory.[131] In early 1962, the DoD and the US Air Force began pursuing two crewed space programmes. The first was the X-20 Dyna-Soar, a hypersonic space plane designed to carry two pilots. And the other project was a two-person space station derived from the Gemini rocket. Both programmes were simultaneously competing with the CORONA spy satellite).[132]

By mid-1963, however, the fate of the Dyna-Soar was hanging in the balance. The DoD and NASA jointly agreed to study the objectives of an orbital space station, giving birth to the Manned Orbital Laboratory (MOL). Dyna-Soar ultimately lost the battle, and the DoD aimed to place the newly-announced MOL in orbit by early 1968 under the Lyndon B. Johnson administration.[133] The MOL's permanent presence in orbit was not to be, as the ballooning budgets and doubts about the space station's reconnaissance utility[134] led to the programme's cancellation in June 1969.[135] A single mock-up test of the MOL was carried out in November 1996. However, the MOL project's benefits permeated to other NASA programmes, and several subsystems of the MOL were used on Skylab and the Space Shuttle.[136]

The *Salyut* series of space stations

The Soviet Union, on the other hand, took a two-pronged route as it decided to pursue both civilian and military versions of a space station. The dynamics of interpersonal in-fighting within the Soviet military-industrial complex gave rise to two different programmes.[137] The development of a military space station was formally approved in 1964, with full responsibility for its development handed to Vladimir Chelomei's OKB-52 bureau, which was designing its own version of a military space station called the *Almaz.*[138] The programme took an abrupt turn in 1969 after the Soviets lost the Moon race to the Americans. To achieve success before the American launch of *Skylab*, the Soviet Secretary for Defence and Space, Dmitry Ustinov, ordered the transfer of *Almaz* hulls to a rival design bureau headed by Vasily Mishin.[139] The transferred hulls were fitted with subsystems from the

Soyuz spacecraft, ultimately giving birth to the Long-Duration Orbital Station (DOS), creating two completely different space station missions.

Both the DOS and *Almaz* were launched in parallel under the title of *Salyut* to conceal the military nature of the *Almaz* mission. The Soviet Union conducted seven *Salyut* missions, three of which (*Salyut-2, Salyut-3* and *Salyut-5*) were used by the military. The *Almaz* series of piloted missions, which were cancelled in 1978, taught the Soviets what the Americans learnt much earlier — manned space stations are of limited military utility when compared to reconnaissance satellites.[140] The civilian DOS series of missions, however, proved relatively more successful. First, the DOS missions proved that long-duration crewed and uncrewed scientific experiments could be carried out in orbit.[141] Second, *Salyut* proved that a space station had diplomatic value as the Soviets collaborated with the French space agency, CNES (Centre national d'etudes spatiales) to host astronaut Jean-Loup Chrétien (and his backup, Patrick Baudry) on board *Salyut-7.*[142] Although the *Salyut* series of missions faced several setbacks, the lessons learnt from *Salyut* would go on to be implemented on *Mir,* the first modular space station.

An American workshop in space

In June 1969, *Apollo-11* took the first humans to the Moon, and the US had achieved a stern victory in the space race. The next natural step was a mission to Mars. In parallel, NASA also pursued the Apollo Applications Program, which aimed to make use of *Apollo* and Saturn V rocket hardware. The orbital workshop, *Skylab*, was born out of this program. *Skylab* was designed for a crew of three and used the third stage (S-IVB) of the Saturn V along with the Apollo Telescope Mount.[143] But with dwindling political and public interest in interplanetary human exploration, Richard Nixon slashed the NASA budget and cut any hopes of future *Apollo* or Mars missions.[144] Nonetheless, Nixon retained *Skylab* within the budget to retain employment within the aerospace industry post-*Apollo.*[145]

Skylab was launched into orbit on May 14th, 1972, and faced problems soon after launch, as it lost part of its main solar panel along with the station's micrometeoroid shield. Nonetheless, activities on the station moved forward, with three crewed missions launching between May 1973 and November 1973. The final crewed mission lasted for 84 days. Similar to what the Soviets learnt from *Salyut* missions, the Americans gathered valuable lessons on the long-term effects of orbital flight on humans and the challenges of sustaining a space station in orbit. *Skylab* crews also conducted several scientific experiments, many of which were proposed by students and universities.[146]

Apollo-Soyuz, Mir and the beginning of US-Soviet space cooperation

During the early to mid-1970s, the US and the Soviet Union had stuck a new chord in their relations. In this era of *détente*, the US and Soviet Union extended cooperation in a number of areas, most prominently in the limitation of nuclear arms through the signing of the Anti-Ballistic Missile (ABM) Treaty in 1972.[147] In this regard, cooperation between the rivals also extended to outer space. After returning from his visit to Moscow in 1969, astronaut Frank Broam floated the idea of a US-Soviet docking mission.[148] In February 1972, President Nixon gave the go-ahead to pursue negotiations on comprehensive space cooperation,[149] resulting in the *Apollo-Soyuz Test Project* (ASTP).[150]

The ASTP was not merely an exercise of space-handshake, as it gave way to a number of breakthroughs in bilateral space cooperation. First, it allowed both sides to gain an understanding of each other's space programmes.[151] Second, it set the foundation for deeper space cooperation between the two superpowers. Finally, the ASTP opened the doors for engineering breakthroughs, such as the standardisation of the docking adapter on the Space Shuttle and *Mir.*[152]

After the limited success run of *Salyut*, the Soviet Union launched a third-generation re-design of the DOS station in February 1986. The *Mir* was the first modular space station and consisted of seven modules by 1996. *Mir* demonstrated the soft power value of permanent habitation in the Earth's orbit. Over the course of its lifetime, the *Mir* hosted astronauts from Austria, Afghanistan, Bulgaria, Canada, France, Germany, Japan, Slovakia, Syria, the United Kingdom and the US.[153] *Mir* also became a platform for deeper US-Soviet cooperation through the Shuttle-*Mir* programme, leading the way to cooperation on the *ISS*.[154]

The *ISS* and the birth of long-term space cooperation

Unlike previous space stations' stories, the story of the *ISS* is unique for two reasons. First, the *ISS* is the first comprehensive space project that brings together a truly international group of participants. Second, the policies that shaped the *ISS* project in the initial years took a markedly different turn in the final years before the launch of the first module.

In 1982, President Ronald Reagan announced the intention to place a permanent human presence in the Earth's orbit, prompting NASA to begin work on Space Station *Freedom*. The policy gears shifted in June 1985 when Reagan invited Canadian, European and Japanese partners to cooperate on space station *Freedom*.[155] The reason for such an international outreach was two-fold: one, the US saw foreign policy benefit in bringing together allies and partners for peaceful cooperation on the scale of a space station; two, to a lesser extent, divert funds from projects that could compete with US commercial interests.[156]

The precedence for international cooperation already existed. Canada had already contributed to the Space Shuttle programme by constructing its flagship robotic arm called Canadarm.[157] The European Space Agency (ESA) sponsored the *Spacelab* pressurised laboratory for the Space Station in exchange for carrying European astronauts. Similarly, Japan had also sponsored a *Spacelab* mission.[158] Negotiations with partners began in late 1984, intending to sign independent Memorandum of Understandings (MOUs) with Canada, ESA and Japan between 1984 and 1990.[159] By 1992, however, the *Freedom* project was eating up allocated funds with no hardware in sight. The Bill Clinton administration laid down three options for the future space station. Option A was to build a simplified version of the space station, derived from the *Freedom* design. Option B was to increase funding and complete the space station construction in its existing form. The final implicit option was to scrap the programme altogether.[160]

The collapse of the Soviet Union raised concerns about the poor state of Russia's space sector. President Clinton had a strong inclination to deepen collaboration with Russia, and like his predecessor George H.W. Bush, President Clinton wished to expand the ongoing space collaboration. Under these circumstances, a compromise option was born in late 1993 when Russia was invited to join as the fourth partner in the *ISS* project.[161] Thus, it became a strategic priority for the US to infuse money into the ailing Russian space industry, keep scientists and engineers employed, and prevent a brain drain towards adversarial or rogue countries.[162]

The final result is reflected in the International Space Station Intergovernmental Agreement (IGA), which outlines the partnership's structure and each partner's roles and responsibilities.[163] Further, NASA also signed individual MOUs with partnering agencies which detail the specific role of each *ISS* partner.[164] The *ISS* partnership is inherently unequal, as outlined in the IGA. But over the past 20 years, the *ISS* has hosted thousands of microgravity experiments and education programmes. And despite the growing animosity between US and Russia, cooperation onboard the *ISS* managed to survive.[165]

China's palace in the heavens

The imagination of a Chinese human spaceflight programme dates back to the late-1960s when Premier Zhou Enlai commissioned a series of feasibility studies for sending humans to orbit. The early programme, titled Project 714, was officially cancelled in 1973 after Mao Zedong declared that the needs of Earth needed priority.[166] The quest to send humans to orbit was rejuvenated in the 1980s amidst the rapid progress in space technology and human spaceflight, particularly driven by the US decision to pursue the Strategic Defense Initiative (SDI) and build a permanent space station. Program 863 began in 1986 with the imperative of advancing space technology in heavy-lift rocketry, space transportation systems and space stations.[167]

However, the decision to go ahead with the human spaceflight programme was far from straightforward. A section of the scientific community expressed scepticism towards human space flights as the US and the Soviet Union space station programmes could not recover any significant military and scientific benefits. But the leadership also recognised that the final decision would be a political one rather than a purely technological imperative.[168] The decision to commit to a human spaceflight programme solidified in September 1992, after a three-step strategy to develop competence in uncrewed and crewed orbital flights and eventually place a space lab in orbit.[169]

Under Project 921, China successfully placed its first astronaut in orbit in October 2003. The *Tiangong-1* space laboratory was launched in September 2011, and an improved version of the lab, *Tiangong-2*, was placed in orbit in 2016. The experience gained through the two mini space stations set the ground for the fully modular space station.[170] China's space station, simply called the *Tiangong*, consists of three modules and can support a crew of six.

China's space station is a part of its larger strategy to enhance its space power and technological capabilities.[171] While the country's human spaceflight priorities were set in the 1990s, it was driven to pursue a fully independent project due to its inability to cooperate with the established space powers. China's space station will not only help establish the country as a major power in LEO but also provide China with the experience to pursue missions beyond Earth orbits.

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