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Does Asymmetry Challenge Stability? Governance Design in Multinational Space Cooperation

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Abstract

Large-scale multinational space projects involve complex political, economic, and institutional interests, making equitable collaboration between partners a persistent challenge, especially at program level. Lunar missions in particular have reflected power asymmetries between established spacefaring nations and emerging space actors, often yielding imbalanced decision-making structures and unequal distribution of benefits. Such imbalances are not inherently problematic; contribution-based differentiation can be both rational and functional. However, the critical question is under what conditions these asymmetries generate unequal effects, such as reduced partner commitment, limited capacity development, constrained influence in decision-making, or long-term dependency structures. This paper examines the governance frameworks underlying past and ongoing multinational space programs to identify structural factors behind unequal partnerships. Focusing on the interaction between key international agreements, treaties, and policy instruments, we analyze how legal language, institutional design, and political norms have shaped partner roles and obligations. The study pays particular attention to the position of emerging space nations and the mechanisms through which their interests are translated into multinational collaborations. The paper applies a structured scoring framework to four cases: the International Space Station (ISS) Intergovernmental Agreement, the Artemis Accords and their Lunar Gateway implementation core, the International Lunar Research Station (ILRS), and India's Chandrayaan-3 mission, and complements this with twelve semi-structured expert interviews. These use cases are well-suited for analysis and comparison because they all represent long-standing multinational programs. Their institutional architectures offer empirical insight into how asymmetries can be structured to sustain cooperation over decades. Comparing these cases helps identifying how different governance architectures shape partner roles and influence. The comparative analysis is supported by a systematic literature review and qualitative expert interviews involving space governance specialists and project managers from space missions. By identifying the benefits and drawbacks of asymmetries in existing governance architectures, this paper proposes recommendations for designing more inclusive and balanced frameworks for future multinational space projects. The findings support the development of future treaty structures and partnership models that enable fairer participation of emerging space nations in global space exploration initiatives.

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1. Introduction

The space sector is undergoing a profound transformation. Once dominated by a small number of established spacefaring nations operating through government-led programs, it is increasingly characterized by the participation of emerging space nations, commercial actors, and multinational partnerships [1]. As ambitions shift towards sustained lunar exploration and future missions beyond Earth orbit, the financial, technological, and institutional demands of these programs have made international cooperation a strategic necessity. Governance frameworks like the Intergovernmental Agreement (IGA) developed for the ISS have demonstrated that long-term collaboration can be sustained despite differences in national priorities and capabilities. More recent initiatives, including the Artemis program and the ILRS, reflect an evolving geopolitical landscape in which new governance models are emerging alongside a broader and more diverse community of space actors [2, 3]. These partnerships are usually inherently asymmetric since partners differ in financial resources, technological capabilities, industrial capacity, operational experience, and political influence. While differentiated responsibilities can improve efficiency and enable complex programs, they may also create unequal participation, dependency, and challenges to long-term cooperation [4]. Consequently, understanding how asymmetry can strengthen or undermine collaboration and how governance structures can influence and guide multinational projects is an important challenge for future space exploration.

This paper aims to address this challenge by examining how governance design shapes the relationship between asymmetry and stability in multinational space cooperation. Comparing governance frameworks such as the IGA for the ISS, the Artemis program, and the ILRS provides a structured assessment of embedded asymmetries and the mechanisms that support resilient partnerships. Expert interviews explore how multinational cooperation is experienced and managed in practice. The findings are used to derive governance design principles for balanced multinational space cooperation and are discussed in relation to recent successful missions by emerging space nations, such as India's Chandrayaan program.

Much of the existing literature on space governance reflects the perspectives of established European and other long-standing space nations, potentially prioritizing their experiences over emerging partners. While this study incorporates newer perspectives through case selection and expert interviews, the broader academic discourse remains dominated by established space powers.

2. Background

Understanding how governance design influences multinational space cooperation requires considering the broader context in which contemporary space programs are developed. International partnerships are shaped not only by formal governance arrangements, but also by the evolving landscape of global space activities, the growing participation of emerging space nations, and the political, economic, social, and technological motivations that drive collaboration [5–7]. Together, these factors influence how responsibilities, decision-making authority, and resources are distributed among partners, ultimately shaping the effectiveness and longevity of international cooperation [7, 8]. In the context of this study, *stability* refers to the ability of a multinational cooperation framework to sustain effective collaboration and achieve its intended objectives over time, despite changes in political priorities, partner capabilities, funding, or other external conditions. *Asymmetry* refers to differences among partners in capabilities, resources, decision-making authority, and dependencies. Such differences are not inherently detrimental but reflect the varying contributions of participating actors. The following sections provide the conceptual background for the subsequent analysis, covering the evolution of space governance models, the changing composition of the global space sector, principal drivers of international collaboration, and the role of asymmetry in multinational partnerships.

2.1 Multinational Cooperation Models

Space program governance refers to the set of formal and informal systems—rules, institutions, agreements, and practices that guide how space activities are planned, funded, and executed. It encompasses decision-making structures, accountability mechanisms, risk-sharing arrangements, and coordination processes among stakeholders. These frameworks are particularly critical in multinational programs, since differences in legal systems, industrial capabilities, political priorities, and organizational cultures can otherwise create friction. A well-defined governance structure establishes shared procedures, clarifies roles and responsibilities, and provides mechanisms for conflict resolution. This is especially important given that space programs are typically long-term, capital-intensive endeavors spanning decades. There are different types of governance models, including multinational cooperation for space projects. These can be categorized according to different approaches. A widely used way to categorize space governance is through a historical lens, distinguishing three major phases [1]:

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1. **Legacy Space Model (~1957–1975)**: In this phase, governments fully owned, funded, and controlled space infrastructure. Programs were vertically integrated within state institutions, often with strong military involvement. Examples include early NASA programs and Soviet space missions.

2. **Transitional Space Model (~1975–2005)**: During this period, dedicated space agencies became the primary operators of space systems, while governments retained the role of principal sponsors. International cooperation began to expand, as seen in programs like Spacelab and early ISS agreements. Governance became more distributed but remained largely intergovernmental.

3. **New Space Model (~2005–present)**: The contemporary phase is characterized by the growing role of private actors (such as SpaceX and Blue Origin) as developers, operators, and sometimes owners of space infrastructure, while governance act as customers, regulators, and co-investors, integrating public–private partnerships and commercial contracts alongside state oversight.

An alternative way to categorize governance models focuses on the level of political organization involved. Four levels can be distinguished [9]:

- **National level**: Central governments and national space agencies defining strategy, funding priorities, and regulatory frameworks.

- **International level**: Global governance involving actors and institutions that operate across regions and the international system as a whole. This includes United Nations bodies such as the United Nations Committee on the Peaceful Uses of Outer Space (COPUOS), as well as international treaties, agreements, and other global governance mechanisms, such as the Outer Space Treaty.

- **Regional level**: Cooperation among multiple states within a geographically defined region. This level includes regional intergovernmental organizations and other regional cooperation mechanisms such as the European Space Agency (ESA), the Asia-Pacific Space Cooperation Organization (APSCO), and the African Space Agency (AfSA).

- **Sub-national level**: Governance below the national level, involving cities, states, provinces, and other subnational governments, as well as local and regional space clusters and innovation ecosystems (e.g., space hubs, launch sites, and technology clusters).

These levels interact rather than operate independently. For instance, a single mission may involve national funding, regional industrial participation, and compliance with international legal norms. This multi-layered governance structure reflects the inherently global nature of space activities. While analytical distinctions between governance models are useful, in practice they overlap and evolve dynamically [10]. Legacy and New Space actors frequently collaborate — for example, National Aeronautics and Space Administration (NASA) contracting private firms for launch services, or ESA partnering with commercial providers for satellite development. This coexistence leads to hybrid governance arrangements that combine hierarchical control (e.g., state oversight), market mechanisms (e.g., competitive procurement), and network-based coordination (e.g., international partnerships). As a result, modern space governance is best understood not as a linear progression but as a complex ecosystem of interacting models and partners [9]. Initially, a few countries led space activities. Recently, more nations establish space agencies and are emerging as space partners.

2.2 Emerging partners

Traditionally, the United States (US) and the Soviet Union were the earliest nations to establish themselves as major spacefaring powers. Over time, the distribution of influence within the space sector has evolved, with the principal actors now including the US, Russia, China, Japan, and ESA [11]. Advances in technology and greater accessibility have also enabled a broader range of countries to participate in space-related activities, making the domain increasingly relevant globally. Whereas only around 20 nations operated spacecraft in orbit in 1985, more than 20 countries have established national space agencies during the past decade alone [12]. Furthermore, the number of countries possessing at least one satellite in orbit increased from 50 to 82 within a single decade, as of 2019 [13, 14]. Recently established space agencies include those of Egypt, the Philippines, Portugal, and Türkiye. Additional indicators of a country's growing presence in the space sector include the establishment of a national space program supported by a dedicated budget and multiple projects, the development of domestic technological and industrial capabilities for the deployment and operation of space systems, and active participation in international space initiatives [15, 16]. Table 1 highlights some emerging space nations and their recent milestones.

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Table 1: Emerging Spacefaring Nations

Nation	Key Milestone (Last 5 Years)
South Korea	Successfully launched the **Nuri (KSLV-II)** rocket in 2022/2023, becoming the 7th nation to independently launch a satellite.
United Arab Emirates (UAE)	Launched the **Hope Probe** to Mars (2021) on its first attempt. Established a dedicated Ministry of Space.
India	**Chandrayaan-3** lunar landing (2023); opened sector to private companies (IN-SPACe).
United Kingdom	Established spaceports (Cornwall/Scotland); backed **OneWeb** constellation; post-Brexit space strategy.
New Zealand	Became the primary launch hub for **Rocket Lab** (Electron rocket).
Israel	Attempted lunar landing (Beresheet); strong private defense/satellite technology sector.
Iran & North Korea	Successfully placed satellites in orbit using ballistic missile-derived technology.

The increasing number of spacefaring nations over the last decade represents a fundamental shift in the perception of space. Once the exclusive domain of superpowers, space is now viewed as critical infrastructure indispensable to economic security, national defense, and technological sovereignty. Consequently, investment for space activities of emerging partners is predominantly led by national governments and defense ministries, though a rapidly growing private sector is gaining traction through deregulation and venture capital [17]. This shift toward a multipolar space environment is driven by several factors, and the reasons for expanding space activities depend heavily on a country's political and socioeconomic situation. The following section presents the different drivers and their implications.

2.3 Drivers for Collaboration

To analyze the motivations behind national space activities, this paper utilizes the *PEST* framework, focusing on *P*olitical, *E*conomic, *S*ocial, and *T*echnological factors. Although additional dimensions such as legal regulations, environmental sustainability, and specific security doctrines significantly influence the sector, they fall outside the scope of this examination. The following section concentrates on the primary socio-economic and political drivers that define the strategic landscape for space nations.

2.3.1 Political factors

The growing involvement of emerging nations and the continuous interest of established nations in space activities has been partially driven by strong political motivations. Space serves simultaneously as a symbolic arena for prestige and as a strategic infrastructure domain critical to national sovereignty, security, and foreign policy [18].

First, the pursuit of national sovereignty and strategic autonomy constitutes a core political driver. Space-based infrastructures such as satellite communications, navigation, and Earth observation have become indispensable to public administration, economic activity, disaster response, and military operations. Dependence on foreign space systems exposes states to political leverage and vulnerabilities during diplomatic crises or conflicts. For emerging space nations, developing domestic space capabilities is therefore seen as a means to reduce external dependence and enhance autonomy in national decision-making [19].

Second, security imperatives and the acquisition of dual-use capabilities play a central role. Many space technologies possess dual-use characteristics, enabling both civilian and military applications. Earth observation and communication satellites can support disaster management and economic development while simultaneously enabling intelligence, surveillance, and command-and-control functions. As outer space is increasingly recognized as an operational domain alongside land, sea, air, and cyberspace, states perceive space capabilities as integral components of national defense and security strategies [20].

Third, the enhancement of international status and diplomatic influence represents another major political incentive. Possessing space capabilities serves as a visible demonstration of technological sophistication and state capacity, reinforcing national prestige and international recognition. Participation in international space missions and cooperative programs also functions as an important diplomatic instrument, strengthening bilateral and multilateral relationships, expanding soft power, and supporting aspirations for regional or global leadership [21].

Fourth, specifically emerging space nations seek to secure voice and influence within international space governance frameworks. International rules governing orbital access, frequency allocation, space debris mitigation, and resource utilization have historically been shaped by established space powers. States that lack practical space activities face significant limitations in their ability to influence norm-setting and rule-making processes. Consequently, investments in national space programs are often motivated by the desire to participate meaningfully in future governance arrangements [18].

2.3.2 Economic factors

Historically, space activities relied on structures fully controlled by governments, who acted as the sole planners and owners of the infrastructure. This "Legacy Space"

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paradigm was driven primarily by national sovereignty and military competition, using cost-plus contracts to insulate the underlying industry from the immense financial risks associated with space exploration [1]. Under this model, the state carried the burden of failure while directing every implementation stage, creating high entry barriers that limited participation to few state-backed industrial giants [22].

Over the past few decades, however, government agencies shifted towards positioning themselves as customers rather than sole operators, ceding direction and implementation to industry. This transition led to the emergence of a "New Space" era, where advances in technology and digital infrastructure have lowered costs and opened opportunities for a more diverse array of commercial actors [23]. Nowadays, Public-Private Partnerships (PPPs) have become the rule, shifting implementation and operation risks to the private sector through fixed-price and milestone-based contracts [1]. This shift has undeniably accelerated innovation and expanded the space market, which has grown into a multi-billion-dollar global domain [13]. Most notably, it has drastically reduced launch costs by forcing firms to prioritize efficiency to maintain profitability. This has significantly lowered entry barriers for emerging spacefaring nations with lower gross domestic product and enabled them to engage in space activities and even partially establish a market around them. Nevertheless, the financial power of a country influences the extent to which a player can be involved in space activities.

2.3.3 Social factors

Another important driver for countries to increase their efforts in space activities is socially motivated. Space achievements are still closely associated with technological sophistication and geopolitical relevance, such that space missions can serve as powerful symbols of national capability and leadership [24]. Governments frequently emphasize the practical benefits of satellite applications, such as environmental monitoring, disaster management, agricultural planning, and telecommunications infrastructure. National space programs often serve as highly visible symbols of modernization, long-term development planning, and political leadership. The establishment of national space agencies and flagship missions can foster national pride, support social cohesion, and strengthen governments' perceived legitimacy by projecting an image of competence and strategic vision. By framing space programs as tools that directly benefit society, policymakers can justify public investment in space technology while simultaneously addressing domestic development challenges [25].

Moreover, developing space assets can help promote education and human capital development. National space initiatives are frequently justified as mechanisms for stimulating interest in science, technology, engineering, and mathematics (STEM) fields. By investing in satellite development, research infrastructure, and scientific missions, governments can create opportunities for universities and research institutions while simultaneously encouraging students to pursue technical careers [26].

2.3.4 Technological factors

Technological and scientific objectives are deeply intertwined in national space strategies, serving as both a means of capacity building and a driver of discovery. Nations prioritize developing indigenous launch capabilities and satellite technologies to ensure technological sovereignty, foster industrial innovation, and enable critical downstream applications such as secure communications and Earth observation. Simultaneously, these technological advancements facilitate profound scientific inquiries, ranging from climate monitoring to deep-space exploration missions [27].

Participation in space activities allows countries to strengthen domestic research institutions, promote technological innovation, and stimulate high-technology industries. Investments in aerospace engineering, robotics, remote sensing, and data analysis frequently produce technological spillover effects that benefit other sectors of the economy. Historically, space programs have contributed to advancements in materials science, telecommunications, computing, and medical technologies [28]. Emerging space nations, therefore, often view investments in space research as part of broader strategies aimed at technological modernization and industrial development.

Additionally, technological development is closely tied to the political goals of strategic autonomy and national resilience: developing domestic capabilities in satellite manufacturing and data processing directly reduces dependence on foreign providers [29].

In sum, the expansion of space activities by emerging nations is not driven by a single factor but a complex interplay of different incentives. The political drive for geopolitical prestige and strategic autonomy, alongside the economic pursuit of satellite-enabled commercial growth and national development, serves as a catalyst for expansion. This momentum is reinforced by social aspirations to inspire STEM education and unify national identity, while technological advancement and strategic international partnerships provide the essential infrastructure to transform these ambitions into operational reality.

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2.4 Asymmetry

As discussed above, states engage in space development based on their own political, economic, social, and technological motivations, which increasingly led states to pursue space development through collaborative frameworks. However, such cooperation does not necessarily imply equality among participating actors, but is often influenced by significant asymmetries in technological capabilities, financial contributions, institutional experience, and decision-making authority. These asymmetries shape not only the structure of cooperation itself, but also the governance mechanisms through which space activities are planned and implemented.

Within the broader framework of international governance, asymmetry is a defining feature of international cooperation. It refers not only to unequal capabilities and resources but also to a relational structure that shapes how actors perceive one another, define their interests, and behave [30]. Stronger actors are generally less dependent on their partners and less vulnerable to disruptions, whereas weaker actors face greater constraints and have a stronger interest in maintaining stable relationships [31]. This creates self-reinforcing systems of dominance that limit participation. While established space powers can reduce commercial risk through state support and research funding [30], emerging nations often depend on external providers, face information asymmetries regarding regulatory processes, and struggle to access affordable financing, increasing reliance on costly capital and volatile venture investment [1, 23].

Technological complexity further entrenches these advantages because advanced capabilities are cumulative and difficult to replicate [32]. Over time, established space nations have shaped technical architectures and institutional frameworks that later entrants largely adopt rather than influence [33, 34]. Network effects reinforce this process by increasing the value of widely adopted systems and strengthening the position of those who have traditionally controlled them. As a result, asymmetries are not only maintained but often deepened over time [35]. These inequalities may also be institutionalized through forms of "legalized asymmetry," in which formally equal agreements create differentiated modes of participation and governance [31, 36, 37].

Consequently, cooperation often follows a *hub-and-spoke* model: established space nations often coordinate projects, define standards, and provide core infrastructure, while other partners contribute specialized or modular components [37, 38]. Although this structure can create barriers to entry, it also enables managed inclusion by allowing emerging space nations to participate, benefit from knowledge transfer, and gradually develop capabilities without building a complete space ecosystem from the outset [23, 35, 39]. Thus, the existence of asymmetry in governance can be understood as both a facilitating factor and a source of tension in space development initiatives. On the one hand, unequal distributions of resources and expertise may enable large-scale projects to proceed efficiently; on the other hand, they may also generate imbalances in influence and participation among partner states.

To examine how asymmetries in space projects emerge and operate in practice, the following section outlines three specific governance frameworks established as case studies, two specifically for lunar exploration.

3. Lunar Governance Architectures

The Moon is a unique use case for analyzing multinational space governance because it serves as a focal point where strategic value, technological barriers, and evolving legal frameworks intersect. This section outlines why lunar exploration exposes the structural obstacles to symmetric partnership in multinational cooperation.

The Moon concentrates significant resources, most notably water ice in permanently shadowed regions, which is essential for life support and fuel production [40]. Beyond physical resources, the Moon offers exceptional positioning for deep space exploration and holds high symbolic value for national prestige. However, these features transform the Moon into a common-pool resource domain. The concentration of valuable resources at specific sites, such as the lunar south pole, creates risks of resource depletion, orbital debris, and interference between competing missions. Without robust governance, the pursuit of these strategic benefits threatens the long-term sustainability of the lunar environment [35].

Lunar cooperation is defined by extreme asymmetries in both capability and capital. Established space powers like the US, China and Russia possess decades of institutional knowledge and massive budgets, while emerging actors like India are rapidly developing their own strategic roadmaps for lunar presence. High technological and financial thresholds widen this gap, limiting access to a few nations and wealthy commercial entities. This capability asymmetry, which the scoring framework in Section 4.1.1 specifically measures, is tested in the following cases to see if it translates into instability

The modern lunar landscape also reflects a shift from purely state-led initiatives to a mix of agencies and commercial actors. Currently, lunar governance is being actively shaped by competing frameworks, most notably the

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US-led Artemis Accords and the Roscosmos- China National Space Administration (CNSA)-led ILRS. These architectures reflect different visions for international cooperation and resource utilization: the Artemis Accords operate as a non-binding, soft-law regime that permits commercial resource extraction, while the ILRS is a lead-state-controlled structure through which China extends access to emerging actors [41, 42]. The emergence of these parallel structures highlights the urgent need for governance design that can manage inherent power imbalances while ensuring that emerging nations are not left to secondary roles. Lunar projects, therefore, allow a direct comparison of how governance design mediates the relationship between asymmetry and stability. The following subsections examine three governance frameworks through their main programs: the IGA, whose use case is the ISS and which serves as the benchmark treaty from which the lunar frameworks depart; the Artemis Accords, implemented through the Lunar Gateway; and the bilateral Memorandum of Understanding (MOU) model of the ILRS.

3.1 The ISS Intergovernmental Agreement

A representative approach to conducting large-scale space development projects through international cooperation is the conclusion of an Intergovernmental Agreement (IGA), which establishes the overarching legal and institutional framework for collaboration between participating states. A prominent example is the IGA for Space Station Cooperation that governed the International Space Station (ISS), which was signed in 1998 by the US, Russia, Japan, Canada, and participating European states. This IGA establishes the rights and obligations of the participating partners and provides the legal basis for issues including jurisdiction and control, intellectual property, liability, and the allocation of responsibilities. Thus, the ISS IGA, which structured one of the most technologically, politically, and operationally complex international space programs to date, serves as a reference point for analyzing subsequent models of international space cooperation.

Under the IGA, each partner retains jurisdiction and control over the modules and personnel it provides. This principle allows states to participate without relinquishing sovereign authority, while still committing to collective objectives. The IGA is supplemented by bilateral and multilateral MOUs between NASA and partnering space agencies, which define operational, technical, and managerial responsibilities in greater detail. By adopting a two-tier structure consisting of the IGA and the MOUs, technical and operational changes could be implemented with greater flexibility, without requiring the amendment or conclusion of a new international treaty. Since the MOUs are concluded bilaterally between NASA and each participating space agency, the resulting arrangement effectively takes the form of a NASA-centered *hub-and-spoke* structure, reflecting the asymmetry inherent in the ISS governance framework. It has also been argued that assigning NASA a leading role and allowing it to occupy a *first among equals* position helps prevent deadlock in deliberations and facilitates smoother decision-making [43].

In this way, the IGA established for the ISS became one of the most prominent examples transitioning from Cold War-era international competition to space cooperations. However, with the advent of the lunar exploration era, a need emerged for new governance arrangements beyond the traditional model centered on intergovernmental treaties and sovereign states as primary actors.

3.2 The Artemis Accords

The Artemis Accords, consisting of 13 Sections, represent a fundamental change in the architecture of international space cooperation, moving away from the comprehensive, centralized treaty models of the 20th century toward a modular, norm-based, and soft-law framework [41]. While the program is officially presented as an inclusive global endeavor, an analysis of its governance structures, rooted in the text of the Artemis Accords [37], reveals a clear center-versus-periphery model that institutionalizes a tiered operational structure.

The Artemis Accords [37] function as a non-binding framework of principles intended to coordinate among all 52 signatories. Section 1 establishes the purpose of the Accords as creating a *"shared vision for creating a safe and transparent environment"*. Section 2 describes the following instruments as the mechanism for implementation, establishing the cooperation through *"bilateral or multilateral instruments"*, effectively fragmenting the legal landscape into individual agreements between the lead, in this case, NASA, and each partner.

The operational core of the Accords is found in Sections 3 through 9. These sections mandate peaceful purposes (Section 3), transparency through the *"public release of scientific data"* (Sections 4 and 8), and the emergency assistance of personnel (Section 6). However, Section 5 addresses interoperability, stating that *"the use of open interoperability standards [...] is vital"* and committing signatories to "rely on existing interoperability standards". While phrased as "open", these standards are derived from the lead partner's technical heritage, thereby requiring partners to adopt the lead partner's interfaces [33].

Sections 10 and 11 clarify the management and conflict

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resolution, interpreting the extraction of Lunar resources as not contradicting the Outer Space Treaty, *"the extraction of space resources does not inherently constitute national appropriation"*, and *"operationalize the use of safety zones"* as a tool for deconfliction under the duty to avoid harmful interference. The two remaining sections address orbital debris mitigation and periodic checks among signatories.

Throughout the Accords, an emphasis on the voluntary coordination is made, rather than the institutionalized interdependence observed in previous treaties [41].

The Artemis architecture, therefore, operates across three distinct layers with different degrees of legal force. Beneath them, individual program elements are implemented through bilateral MOUs that create operational obligations on a much smaller group of contributing agencies. Beneath those, commercial services are procured under fixed-price contracts with private providers. Only the middle layer generates enforceable program commitments.

At this layer sits the Lunar Gateway, which serves as a clear example of the Accords implementation, and due to its resemblance to the ISS, it offers a direct comparison between the fundamental differences of the ISS IGA and the Artemis Accords. Unlike the ISS, which relied on deep technical interdependence for life support and propulsion, the Gateway uses the specialized modularity, where the lead partner acts like the anchor customer by purchasing services and hardware from the different partners through MOUs rather than a single treaty [1]. In this scheme, the anchor customer position corresponds to NASA, and already established partners like ESA and Japan Aerospace Exploration Agency (JAXA) provide high-value and critical infrastructure. It moves from a functional interdependence to a service-level integration. The Gateway, therefore, sits in the middle of the three Artemis layers identified above: the commitments it creates are operational and binding on the contributing agencies, but they are established bilaterally with the lead partner and are not themselves anchored in the Accords. ESA contributes the International Habitation Module (I-Hab), Lunar View and Lunar Link, together with three guaranteed European astronaut seats. These constitute the largest non-lead hardware commitment in the architecture and, unlike the ISS modules, are procured under a bilateral arrangement rather than treaty rights. JAXA contributes a pressurized lunar rover, and the Canadian Space Agency (CSA) contributes robotics. Each element is architecturally dependent on the lead partner's interfaces and mission profile, as the European Service Module (ESM) is dependent on Orion. What the arrangement does not establish is joint ownership of core systems, any obligation to consult partners before altering the architecture, or any compensation mechanism should their contributions be stranded. This is a critical implementation gap [44]. Section 5.2 assesses what followed when the lead partner's priorities changed.

3.3 The International Lunar Research Station (ILRS)

The ILRS is a China-led lunar base initiative, jointly announced with Russia. It is defined as a *"comprehensive scientific experiment base"* designed for long-term autonomous operations on the lunar surface or in lunar orbit [45]. This framework represents a significant shift in the landscape of space governance, as it establishes a *"competing system of world public order"* that operates parallel to the US-led Artemis Accords [37, 41]. The initiative's origins lie in Sino-Russian space cooperation that intensified from 2017 onward; a joint working group was established by 2020, the formal MOU between the CNSA and Roscosmos was signed in March 2021, and a joint roadmap presented at the Global Space Exploration Conference in June 2021 outlined a three-phase development plan: reconnaissance (2021-2025), construction (2026-2035), and utilization (from 2036 onward) [45].

The governance of the ILRS is fundamentally based on the exercise of "structural power," which allows the lead nations to shape the frameworks and rules that govern the participation of others. Unlike the US, which relies on a long-established network of international alliances, China utilizes the ILRS to build a new network of partners [33]. This structural power is exercised by offering lunar access to nations, particularly emerging space actors that may be marginalized from the Artemis Accords [9].

Institutionally, the ILRS operates within a multilevel governance environment, where decision-making is distributed across different levels of state and agency cooperation [9]. This creates an architecture where leading partners maintain architectural control over critical technological and logistical capabilities [33]. To institutionalize the program, China announced in April 2023 the establishment of the International Lunar Research Station Cooperation Organization (ILRSCO), intended to coordinate and manage the project, with founding members promised "more favorable terms, more rights and more results" [46]. China aimed to complete the founding-member agreements by the end of 2024, though the current status of this timeline has not been publicly confirmed.

In resource terms, the ILRS is overwhelmingly dependent on Chinese state capacity. China's space budget, which is widely estimated at US$14–16 billion annually [39], though exact figures are not published, dwarfs that of every other ILRS partner combined, and the pro-

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gram's critical infrastructure is entirely Chinese-built: the Chang'e series missions for the reconnaissance and construction phases, the Long March 5/9/10 launch vehicles, the Queqiao-2 relay satellite for lunar far-side communications, and the planned Tiandu cislunar navigation constellation. Russia, the nominal co-lead, has contributed declining resources since 2022, and the Luna 25 failure eliminated its most tangible near-term lunar contribution. The emerging partners contribute negligible resources in absolute terms; Pakistan's ICUBE-Q CubeSat, flown on Chang'e-6 in 2024, is the most substantive junior-partner contribution to date, yet it represents a payload opportunity provided by China rather than an independent resource input. Notably, there is no published cost-sharing framework and no equivalent of the IGA principle "no exchange of funds".

The institutional design of the ILRS creates inherent risks for emerging partners due to the structural imbalances of the partnership. As under the Artemis Accords, junior partners rely on the infrastructure of the lead nations, placing them in a position of dependency [33]. This means that mission-specific investments are highly sensitive to the political and budgetary stability of the core partners. Without the protections of a binding, multilateral legal regime, junior partners face a potential gap in governance where their contributions could be marginalized if the lead nations unilaterally redirect their national priorities [41, 44].

4. Methodology

In order to strategically analyze the governance framework in past space projects and develop recommendations for future multinational activities, this paper applies a mixed-methods approach consisting of a comparative case study analysis and a series of expert interviews. The two methods address complementary aspects of the research question, namely whether asymmetry challenges stability in multinational space collaboration and how governance design influences this relationship.

The comparative case study provides a structured assessment of asymmetry at the program level for past space collaborations such as the ISS IGA and the Artemis Accords. Through a quantitative scoring framework, it aims to evaluate the distribution of capabilities, resources, governance influence, and dependencies among participating actors. This enables a systematic comparison of governance architectures across selected lunar programs to address the question: How asymmetric is a given program?

The expert interviews complement the case studies by examining how asymmetries are experienced and managed in practice. Rather than measuring asymmetry itself, the interviews were designed to identify the mechanisms through which asymmetry affects trust, dependency, cooperation, and long-term program stability, as well as the governance practices that may coordinate these effects.

By combining program-level structural analysis with expert perspectives, the methodology enables both the identification of asymmetries and an evaluation of their implications for governance and stability in multinational space collaboration. The combined findings will be translated into governance design recommendations aimed at program managers, identifying practices that allow asymmetry to support rather than undermine stable cooperation.

4.1 Comparative Case Study Analysis

To systematically compare the governance architectures of the selected past and present multinational space programs, we employ a structured scoring framework that evaluates the capability, governance position, dependency, and vulnerability of each member state or organization within a program. We operationalized the background discussion by translating the paper's core dimensions of governance design, partner asymmetry, and differentiated roles into comparable analytical criteria.

4.1.1 Scoring System

The scoring system enables a quantitative assessment of asymmetries between partners, providing a basis for cross-program comparison consistent with comparative case study methods that rely on structured within- and cross-case comparisons from the literature [47, 48]. The unit of analysis is the set of participating states with an identifiable role in the program, rather than all political signatories. Non-state organizations are noted qualitatively but excluded from scoring. Fixing this unit consistently is essential because inequality measures are sensitive to the composition of the populations being compared [49]. Each criterion is scored on a scale from 0 to 5, as defined in Table 2. If no concrete data can be found for a given criterion and country, an expert assessment is conducted based on other available information.

The unit of analysis is defined according to the level of the governance framework being assessed. For multinational membership frameworks, the coalition-level analysis includes all sovereign states formally participating in the framework at the selected temporal cut-off. This is necessary to capture the distribution of capabilities between both established and emerging actors and to avoid conditioning the inequality analysis only on states that have already obtained major operational roles. Where formal membership

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Table 2: Score scale for partner assessment.

Score	Meaning
0	No capability; no presence
1	Minimal capability; negligible impact
2	Limited capability; heavy dependence
3	Meaningful capability; some independence
4	Significant capability; partially autonomous
5	Dominant capability; fully autonomous

does not itself create a specific operational commitment, a secondary implementation-core analysis is conducted. This distinction is particularly relevant to the Artemis Accords, since signature of the Accords does not itself initiate a specific cooperative space activity, while individual Artemis projects are implemented through separate bilateral or multilateral instruments [50]. Coalition-level and implementation-core results are therefore reported separately rather than treated as a single population.

4.1.2 Comparison Criteria

The criteria to be identified for the different use cases are organized into three clusters, each capturing a distinct dimension of a partner's position within a program.

Cluster A: Capability & Resources evaluates the tangible capabilities and resources that each partner brings to the program. The criteria and their scoring definitions are presented in Table 3.

Cluster B: Governance Position & Influence assesses the influence each partner exercises within the program's governance structure. The criteria are defined in Table 4. Scores on the normative/diplomatic influence criterion are cross-checked against published network-centrality metrics for cislunar cooperation, in which the US shows a markedly higher degree, closeness, and eigenvector centrality than other actors, providing an external quantitative anchor for an otherwise qualitative judgment [42].

Cluster C: Dependency & Vulnerability captures a partner's exposure to risks arising from its reliance on the program or other partners' infrastructure and geopolitical positioning. The criteria are presented in Table 5.

4.1.3 Program-Level Asymmetry Evaluation

To evaluate the degree of asymmetry at the program level, two aggregate measures are computed, combining a dispersion measure with a concentration measure commonly used to summarize inequality distributions [49]:

1. **Standard deviation (SD) of member scores on each criterion:** For each criterion, the SD measures the dispersion of member scores around their program-specific mean, identifying specific dimensions that drive asymmetry. Because all criteria are scored from 0 to 5, the SD is expressed in the same units: an SD of 0 indicates identical member scores, whereas larger values indicate greater member-level differences and, therefore, greater asymmetry.

2. **Gini coefficient across partners' Cluster A scores:** This captures the concentration of resources among the partners. The Gini coefficient is calculated as:

$$G = \frac{\sum_{i=1}^{n}\sum_{j=1}^{n}|x_i - x_j|}{2n^2\mu}, \tag{1}$$

where $|x_i - x_j|$ is the absolute difference between every pair of scores, n is the number of members, and μ is the mean score across all members. The resulting value ranges from 0 to 1. $G = 0$ represents perfect equality in the distribution of capabilities among partners, and $G = 1$ represents maximum concentration, where all capabilities are held by a single actor. Higher values, therefore, indicate a stronger concentration of resources and a greater degree of asymmetry within the partnership.

After individual calculations for each case, the SDs and Gini coefficients of each program are compared across the selected case studies to identify which governance architectures exhibit higher or lower levels of structural asymmetry. The two measures are complementary: the standard deviation captures dispersion on a single criterion, while the Gini coefficient captures concentration of the material base, which is why it is applied to Cluster A only. Since Cluster A contains four criteria and Clusters B and C three each, the summed total weights capability slightly more heavily; this is deliberately retained, as material capability is the primary axis of asymmetry, but it is acknowledged when interpreting totals. The ordinal 0-5 scale is treated as interval for these calculations, an approximation commonly accepted in applied research on Likert-type scales when interpreted with caution, though its reliability remains limited at small partner counts [51].

4.2 Expert Interviews

Alongside the quantitative analysis of asymmetry in multinational space projects, we conducted interviews with experts involved in space projects to assess their subjective

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Table 3: Cluster A – Capability & Resources: criteria and scoring definitions.

Criterion	Definition	Scoring
Space budget scale	Total civil space budget	0 = no dedicated budget 1 = < 50M US$ 2 = 50M – 500M US$ 3 = 500M – 2B US$ 4 = 2B – 10B US$ 5 = > 10B US$
Industrial base & system integration capability	Level of the domestic space industry; ability to independently design, build, and integrate space systems	0 = no space industry 1 = can assemble using imported components 2 = can build small satellites 3 = can build large spacecraft (e.g. GEO satellites) 4 = full value chain from spacecraft, ground, to services 5 = system integrator for mega programs; architecture definer
Independent launch access	Ability to independently launch payloads into orbit	0 = no launch program 1 = sub-orbital only 2 = in development 3 = operational small LV (LEO-capable) 4 = operational medium/heavy LV (e.g. GTO-capable) 5 = operational super-heavy LV (comparable to Saturn V)
Human spaceflight experience	Operational experience with human spaceflight	0 = no experience in crewed program 1 = astronauts flew on others' vehicles 2 = notable hardware contribution to crewed systems (e.g. life support) 3 = independent crewed program 4 = sustained crewed program (i.e. space station) 5 = crewed program beyond LEO

Table 4: Cluster B – Governance Position & Influence: criteria and scoring definitions.

Criterion	Definition	Scoring
Decision-making power in the program	Formal role in program governance (program-specific)	0 = signatory only 1 = member with no governance role 2 = contributes hardware/payloads but no decision-making role 3 = contributes critical components;participates in coordination mechanism 4 = core partner with major governance role 5 = program lead who defines architecture, timeline, standards, and partner selection
Contribution criticality	Level of non-substitutability to achieving program objectives & schedule	0 = no contribution 1 = symbolic contribution 2 = contribution that can be easily replaced 3 = significant contribution that would cause delay or cost increase if withdrawn 4 = critical contribution that would substantially degrade the program if withdrawn 5 = indispensable contribution that would terminate the program if withdrawn
Normative/ diplomatic influence	Ability to shape norms, rules, and standards of the program or broader space governance	0 = no international space diplomacy presence 1 = participates in COPUOS but does not lead initiatives 2 = participates in multilateral norm discussions 3 = shapes norms regionally or within specific technical domains 4 = significant norm initiator (proposes frameworks) 5 = sets frameworks that define the program

perceptions of the balance between partners using meaningful questions that were designed for this study.

4.2.1 Interview Process

The interviews were conducted as semi-structured interviews with 12 specialists in space governance and project managers with experience in multinational programs, selected to capture both leading- and non-leading-partner perspectives. Each interview lasted 45–60 minutes and followed the question set in Appendix A, combining open-ended questions (Q1-Q4) with a structured rating block (Q5). Interviews were conducted either online or in person, depending on the interviewee's availability, and recorded or documented through notes, with the given consent of the participants. All data was stored and subsequently analyzed in an anonymized manner [52].

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Table 5: Cluster C – Dependency & Vulnerability: criteria and scoring definitions.

Criterion	Definition	Scoring
Alternative pathway availability	Whether credible alternatives exist if the program fails, is canceled, or the partner is excluded	0 = complete dependence on this program for access to the domain 1 = could theoretically seek alternatives, but none are realistic in the near term 2 = has one alternative that would require significant realignment 3 = has at least two alternatives 4 = has multiple alternatives and could sustain relative independence 5 = can pursue objectives with full autonomy
Exposure to export control / geopolitical constraints	Degree to which participation is constrained by export controls, sanctions, or geopolitical stances	0 = fully constrained (under heavy sanctions or legal prohibitions by major space nations) 1 = severe constraints (effectively locked into one bloc) 2 = significant constraints (participation in one bloc materially limits options in another) 3 = moderate constraints (needs to navigate export controls for specific components but generally unaffected) 4 = minor constraints (subject to export controls but with license exceptions) 5 = no constraints (fully self-sufficient or exempt from restrictions)
Infrastructure dependency	Degree of dependence on partners' infrastructure (e.g. launch sites, LVs, relay satellites, ground stations) to conduct its own activities within the program	0 = no independent infrastructure relevant to program; complete reliance on lead partners for all access 1 = depends on partners for all mission-critical infrastructure 2 = depends on partners for launch, comms, and PNT 3 = has own ground infrastructure but depends on partners for launch/comms 4 = mostly independent but uses partners' infrastructure for convenience 5 = fully independent infrastructure

4.2.2 Evaluation

The expert interviews were evaluated using a mixed qualitative and quantitative approach.

The open-ended questions (Q1-Q4) were analyzed qualitatively by using thematic analysis to identify recurrent patterns across interviews [53]. The frequency with which individual themes occurred across interviews was recorded to identify common patterns and areas of expert consensus.

The rating questions (Q5) were analyzed quantitatively. For each factor and governance measure, the mean score across all respondents was calculated using the provided five-point scale, following the common practice of treating Likert-type response categories as approximate intervals for descriptive statistical purposes [51].

The interview findings are not converted into program-level asymmetry scores and therefore cannot be directly compared with the standard deviations or Gini coefficients derived from the case study analysis. Instead, the interview results are used to interpret and contextualize the case study findings by identifying the conditions under which asymmetry contributes to or challenges program stability.

5. Case Study Evaluation

The comparative scoring system was applied to the selected case studies, which are characterized by different governance frameworks. For the rating, the Clusters presented in Section 4.1.2 are used as comparison criteria. Within the rating, European states are aggregated under ESA wherever ESA is the contracting party, as in the IGA, the Gateway implementation core, ground support, because in those frameworks Europe functions as a single institutional partner with shared rights and obligations [54, 55]. In the Artemis Accords coalition and the ILRS, sovereign signatories are scored individually because signature is a state act. The following sections first present the individual analysis for the separate case studies, before drawing a comparison across all investigated governance frameworks. The numerical scores are presented in Appendix B.

5.1 ISS IGA Evaluation

Applying the comparative scoring system to the IGA established for the ISS in 1998, the five formal partner countries that structured the program's establishment were rated: the US, Russia, Japan, Canada, and ESA. Since this paper evaluates the asymmetry of establishing mega space projects rather than their mature operational phase, 1998 is used as the benchmark year as it is highly representative of the ISS build-up phase, defined by the signing of the IGA and partner MOU, the formal allocation of responsibilities, and the launches of *Zarya* and *Unity* [56].

Applying the scores defined in Table 2 to the different criteria of the Clusters A (Tab. 3), B (Tab. 4), and C (Tab. 5), we calculate a score for each partner. The resulting scores are summarized in Table A1 and visualized in Figure 1, reporting the 1998 baseline scores by cluster, with 2026 updates in brackets where scores have changed.

As described in Section 4.1.3, we can use Equation 1 to calculate the Gini coefficient for Cluster A, which captures

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a partner's concentration of resources. The resulting coefficient for Cluster A in the IGA framework for 1998 amounts to 0.173, indicating a build-up architecture that was slightly asymmetric but not highly concentrated in a single lead actor. The US and Russia together account for 52.2% of all capability and resource scores in the 1998 partner set in Cluster A. ESA and Japan occupy a substantial second tier with 13 points each. This broader capability distribution is also reflected in the criterion-level dispersion visible in the standard deviation (SD) presented in Table 6. In practical terms, only Canada scored 0 on independent launch access in 1998, while all five partners already possessed identifiable human spaceflight roles, astronaut corps, or station-facing operational capabilities. By 2026, the Gini coefficient for Cluster A declines further to 0.147, i.e., the asymmetry is reduced, indicating that operational maturity diffused capabilities somewhat beyond the original US-Russia core, especially through ESA and Japan reflected in the higher scores seen in Table A1.

The distribution of Cluster B scores in Table A1 shows that the ISS build-up phase was hierarchical, but not unipolar. The US and Russia shared the top score in 1998, reflecting their joint control over architecture, assembly sequencing, propulsion, and core station systems, while ESA, Japan, and Canada retained meaningful bargaining power because their program rights were anchored in treaty and memorandum structures and tied to specific hardware or operational contributions [54, 55]. Therefore 1998 is the representative year for evaluating establishment asymmetry: by then, the governance architecture had crystallized, partner obligations had been allocated, and physical assembly had started, but the mature routines of later station operations had not yet diluted the founding bargains. The 2026 updates show that this hierarchy persisted but evolved: the US consolidated its lead, ESA strengthened slightly, and Russia's governance position declined, visible in the changed Cluster B scores.

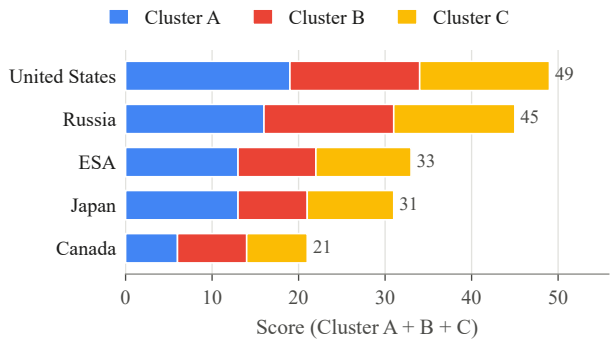


Fig. 1: ISS country-level scores by cluster. Only the 1998 baseline year data is being shown.

Cluster C (Tab. A1) results show that the interdependence in the IGA for the ISS was deep but institutionalized. In 1998, the partners were mutually dependent, yet that dependence was reciprocal rather than concentrated almost entirely in a single architect state. The US, Russia, and ESA all entered the build-up phase with substantial infrastructural roles, while Japan and Canada, although more dependent, still held protected access through dedicated modules, robotics, logistics functions, and utilization rights [55]. The 2026 comparison shows that vulnerability did not disappear; rather, it shifted. Russia's Cluster C score falls sharply from 14 to 9, and ESA's score declines slightly from 11 to 10, indicating that the contemporary ISS IGA is more exposed to geopolitical fracture and continuation-path uncertainty than the original build-up bargain would suggest.

Taken together, the scores evaluating the IGA framework established for the ISS characterize the program as a case of managed asymmetry under deep interdependence. The 1998 baseline shows a mega-project whose establishment depended on a clear hierarchy, but one moderated by treaty-based obligations, the distribution of mission-critical hardware, and formalized partner rights. This helps explain why the IGA for the ISS proved comparatively resilient over time: junior and mid-tier partners were not merely symbolic participants but structurally embedded contributors. As a benchmark case, the IGA establishes the paper's reference point for a mega-project in which asymmetry is real, but buffered by institutional thickness and reciprocal contribution structures, even though the 2026 updates also show that long-lived cooperative programs remain vulnerable when geopolitical cohesion erodes.

5.2 The Artemis Accords Evaluation

The Artemis case requires a distinction between the broad political coalition established by the Artemis Accords and the considerably smaller group of actors holding major operational responsibilities within the architecture. Restricting the scoring population to the principal Lunar Gateway partners alone would measure asymmetry within the implementation core but would exclude the large number of emerging and smaller states whose positions within multinational space cooperation are central to the present study. For the coalition-level assessment, the unit of analysis therefore consists of all sovereign states that had signed the Artemis Accords by the end of the selected baseline year, which includes 52 states as of December 2024 [57].

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An important distinction is nevertheless required between formal membership and operational participation. The Artemis Accords are a non-binding framework of principles, and signature does not itself initiate a specific cooperative space activity. The Signatories Group provides an inclusive forum in which participating states have an equal and valued voice, while specific Artemis activities are implemented through separate bilateral or multilateral instruments [50]. All three clusters were scored for the full coalition and are reported in Table A4. However, the coalition-level interpretation is confined to Cluster A, since governance position and contribution criticality are only meaningful for states holding operational roles, which are assessed separately as the implementation core.

Cluster A was therefore evaluated across the complete 52-state coalition using the four capability criteria defined in Table 3: space-budget scale, industrial-base and system-integration capability, independent launch access, and human spaceflight experience. The resulting distribution is shown in Figure 2, where signatories are ranked by their total Cluster A score.

The 2024 assessment produces a Cluster A Gini coefficient of 0.366. The corresponding criterion-level standard deviations are 1.166 for space-budget scale, 1.045 for industrial-base capability, 1.299 for independent launch access, and 0.849 for human spaceflight experience. The distribution, therefore, demonstrates substantial heterogeneity within the Artemis Accords coalition: participation in the framework extends well beyond the small number of states possessing large space budgets, mature system-integration capabilities, independent orbital launch access, or extensive human spaceflight experience. This capability asymmetry is not, by itself, interpreted as evidence of instability; rather, it establishes the structural distribution of resources within which the governance framework operates.

A separate operational-core assessment is retained for the partners holding major implementation responsibilities within the Lunar Gateway architecture. By the 2024 baseline, five space agencies were making significant contributions to Gateway: NASA, ESA, JAXA, Canadian Space Agency (CSA), and the Mohammed Bin Rashid Space Centre (MBRSC) of the United Arab Emirates [58]. The United Arab Emirates (UAE) is included because an implementing arrangement concluded in January 2024 assigned MBRSC responsibility for the Gateway Crew and Science Airlock [59]. The Cluster A scores of these five partners are reported in Table A5; ESA is scored as a single institutional partner, as in the IGA case, and therefore does not appear in the signatory-level population of Table A4. Applying Equation 1 to those totals (NASA 20, ESA 17, JAXA 14, CSA 11, MBRSC 7) produces a Gini coefficient of 0.186. The corresponding criterion-level standard deviations are 0.894 for space-budget scale, 0.748 for industrial-base capability, 1.789 for independent launch access, and 1.356 for human spaceflight experience. These values describe the distribution of capabilities within the Gateway implementation core and is therefore reported separately from the coalition-wide Artemis Accords value.

This two-level result reveals an important characteristic of the Artemis governance architecture. The Accords provide broad political participation to states with widely different levels of national space capability, while major operational responsibilities remain concentrated in a much smaller implementation group. Formal inclusion and operational influence should therefore not be treated as equivalent dimensions of participation.

The 2024 scores are retained as the establishment baseline. In March 2026, NASA announced its intention to pause Gateway in its existing form and redirect greater emphasis toward infrastructure for sustained lunar-surface operations [60]. The consequences of this change are treated as a subsequent temporal shock rather than incorporated into the 2024 baseline through parenthetical scores. Any post-2026 revisions are reported separately and identify explicitly which partner and criterion are affected.

Applying the framework to the post-March-2026 position, ESA's Cluster B score falls from 12 to 10 as its governance role over the stranded orbital elements lapses, and CSA's from 12 to 10 as Canadarm3's Gateway-specific criticality dissolves. ESA's Cluster C score falls from 12 to 11 on the alternative-pathway criterion, since no near-term European route to lunar orbit exists outside the host program. JAXA's and NASA's scores are unchanged, because the pressurized rover transferred to the surface architecture. Cluster A is unaffected, so the Gateway-core Gini coefficient remains 0.186: the loss registers in governance position and dependency, not in resources (Tab. A5).

Because the governance of the Gateway is based on bilateral MOUs rather than a binding multilateral treaty, the lead partner retains the power to terminate the program with minimal legal penalty or to suspend it indefinitely. The cancellation of the Exploration Upper Stage removed the transport path on which several Gateway elements depended, and ESA, JAXA, and CSA, whose combined hardware investments exceeded several billion dollars, were under no consultative arrangement: with no obligation on the lead partner to consult or compensate them [61].

ESA contributes to the Gateway with the International Habitation Module (I-Hab), which is architecturally dependent on NASA's specific interfaces and mission, as the

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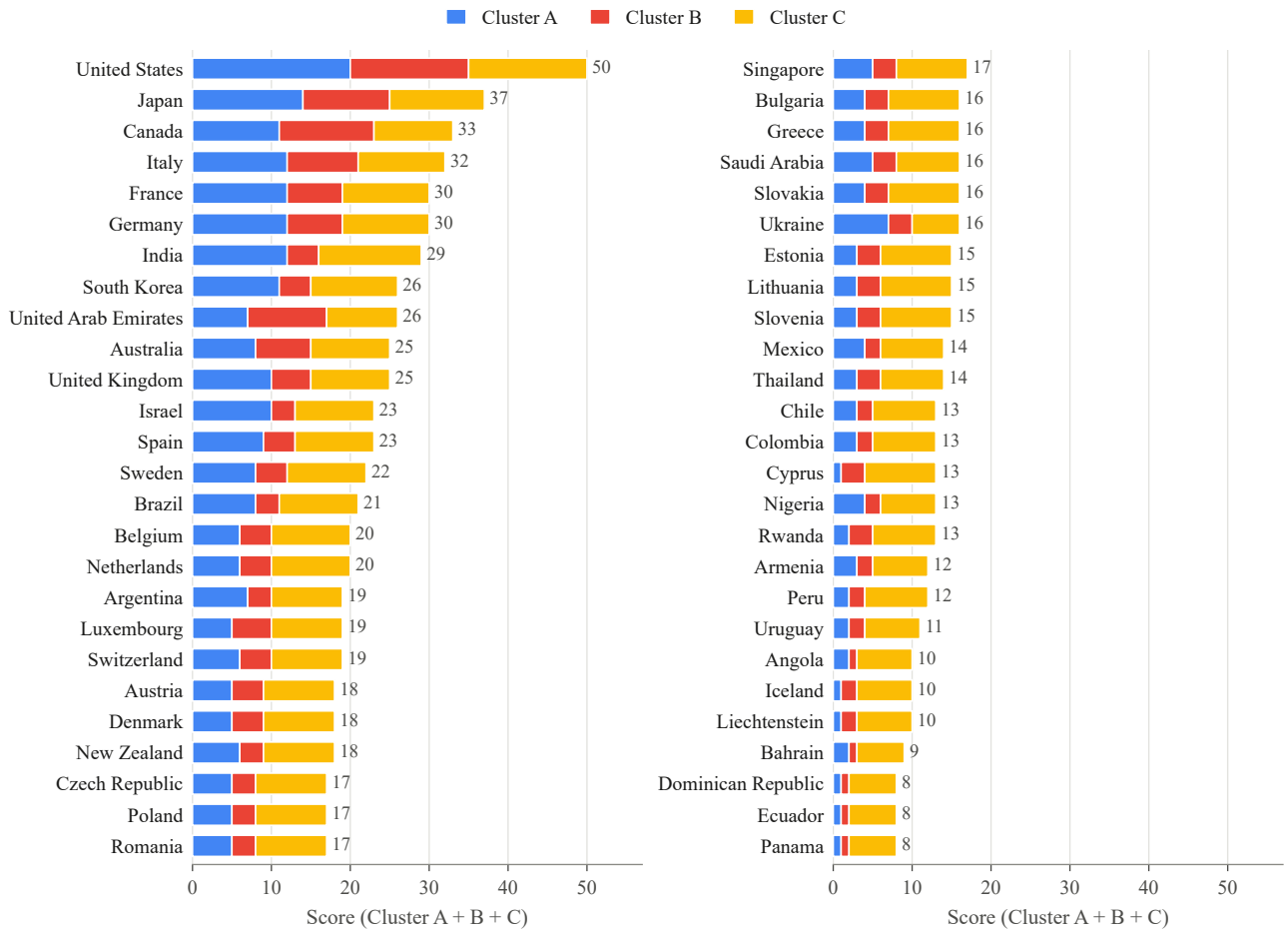


Fig. 2: Artemis Accords country-level scores by cluster.

ESM is to the Orion Spacecraft. The pause compromised these developments, because the operational utility of these modules is architecturally contingent on the lead partner's mission profile [1]. ESA's two further Gateway elements, Lunar View (refueling and logistics) and Lunar Link (communications), were similarly affected. At its 347th Council on 17 June 2026, ESA resolved to take I-Hab only through its critical design review before deciding whether to repurpose it, to assess Lunar Link for reuse as a standalone lunar communications satellite, and to slow Lunar View while retaining the technology for future deep-space use [62]. That decision is itself instructive: the repurposing path was created unilaterally by ESA at its own cost, because no provision in the Gateway arrangements obliged the lead partner to fund or negotiate one. Three guaranteed European astronaut seats on Gateway missions were left in limbo, pending renegotiation.

JAXA's contribution to the program is materialized with a pressurized lunar rover, which is specifically designed for integration into the Artemis surface architecture. Because it targets the lunar surface rather than the orbital station, the rover was absorbed into NASA's new surface-first architecture and survived the pivot. The contrast is the analytical point: contributions tied to the lead partner's orbital design were stranded, while those transferable to its redirected priorities were retained, in both cases at the lead partner's discretion, not the contributors'.

5.3 ILRS Evaluation

The comparative scoring system was also applied to the ILRS framework. A country-level assessment was conducted for sovereign-state participants that could be publicly identified in official ILRS reporting up to April 2025; for this evaluation, 13 states were identified and scored,

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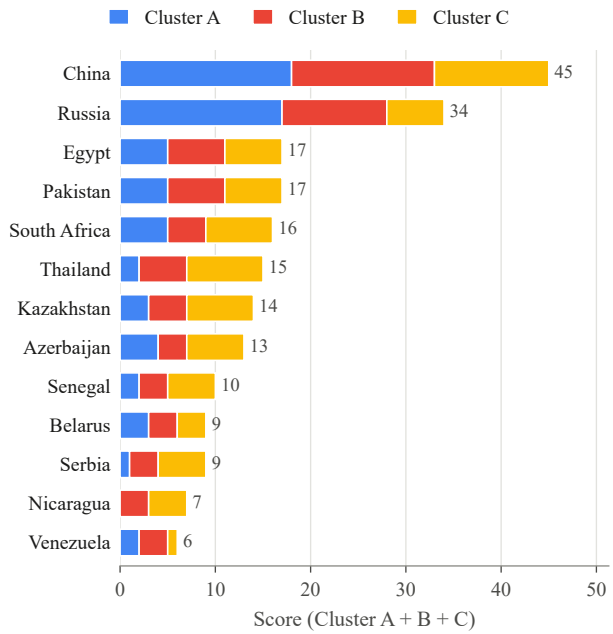


Fig. 3: ILRS country-level scores by cluster.

while non-state organizations were excluded. Table A2 reports the aggregate results by cluster, and Figure 3 illustrates the country-level Cluster scores and their total score.

The resulting ILRS Gini coefficient for Cluster A is 0.496, indicating a high concentration of capability and resources within the program. China and Russia alone account for 52.2% of all capability and resource scores in the assessed partner set (Cluster A). This concentration is further reflected in the criterion-level dispersion visible in the SD presented in Table 6.

The distribution of Cluster B scores shows that the ILRS is not merely a technically asymmetric coalition but also a governance hierarchy. China clearly occupies the architect role, while Russia remains the only other actor with system-level influence [63]. Among junior partners, Pakistan and Egypt emerge as the strongest secondary participants because both are linked to identifiable mission contributions, while Thailand also achieves a comparatively higher governance score through instrument-level participation on Chang'e-linked missions [64]. By contrast, most other partners remain politically relevant but technically substitutable, which limits their bargaining power within the program even when their formal participation expands the coalition's diplomatic reach. While these partners have limited influence on the program, they can still participate and use the ILRS to expand their space technology capability and gain experience in space exploration, which they may not have otherwise.

Cluster C results indicate that dependence and vulnerability are strongly uneven among the junior partners and are integral parts of the program. Thailand, Egypt, South Africa, Azerbaijan, Kazakhstan, and Serbia retain somewhat broader diplomatic room for maneuver than Belarus, Venezuela, Nicaragua, and Pakistan, yet even the more flexible partners remain dependent on Chinese and, to a lesser degree, Russian transport, communications, and surface infrastructure for meaningful participation [41, 45]. This suggests that ILRS inclusion can support capacity building and political visibility for emerging actors, but does not yet redistribute the program's core infrastructural levers.

Taken together, the results characterize the ILRS as a highly asymmetric architecture anchored by Chinese system integration capacity, with Russia functioning as a diminished but still important co-core partner. From a stability perspective, this architecture may be efficient in the short term because it lowers entry barriers for emerging participants. However, it also means that long-term program resilience is strongly contingent on the strategic continuity, financing, and technical delivery of the lead partners, above all, China [33].

5.4 Comparative Analysis

The comparison between the governance frameworks is based on the Gini coefficients for Cluster A of each program and the standard deviations across the different criteria (Tab 6). In addition, the Cluster B and C scores are used qualitatively to extend the analysis to "soft" criteria, beyond resources and capabilities.

Two Artemis values are reported in Table 6 and they answer different questions. The implementation-core value (0.186) is the appropriate comparator for resource concentration among contributing partners and is indistinguishable from the IGA (0.173). The coalition value (0.366) measures breadth of political inclusion across 52 signatories, most of which hold no operational role; it is reported to characterize the Accords as a membership framework, not to compare them with the IGA.

Comparing the IGA and the Artemis Accords shows that the Artemis Accords are based on many contributions of partner countries with resources and capabilities. However, in contrast to the IGA, there is only one dominating country, especially when taking the human spaceflight experience into account, which is the US.

Looking at the Gini coefficient of Cluster A, the resources in the Artemis Accords case are more asymmetric than with the IGA. Seeing the Cluster A Gini coefficient

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Table 6: Cluster A Gini coefficient and criterion-level standard deviations for the comparative cases.

Framework	*n*	Gini	SD Budget	SD Capability	SD Launch	SD Human SF
IGA (1998)	5	0.173	1.020	0.748	1.600	1.744
Artemis Accords (2024)	52	0.366	1.166	1.045	1.299	0.849
ILRS (2025)	13	0.496	1.389	1.476	1.435	1.328
Gateway core (2024)	5	0.186	0.894	0.748	1.789	1.356
Chandrayaan-3 (2023)	3	0.116	0.816	0.471	0.471	1.700

of 0.366 for the Artemis Accords in comparison to 0.173 indicates that resource distribution was less asymmetric with the IGA. Using the standard deviations per criterion for Cluster A shows us where the main asymmetries arise. While the SD for the budget and the capability is higher for the Artemis Accords than for the IGA, the situation is reversed for the SD of the launch and human spaceflight experience criteria. The most prominent difference is with the SD of the human spaceflight experience criterion, which is a little over half the value for the Artemis Accords (0.849) than for the IGA (1.744).

Looking at Cluster B, which shows the governance position and influence of a partner country, reveals many similarities between the Artemis Accords and IGA partner countries. While more countries have higher scores similar to the lead country, the majority scores much lower. This can be interpreted as a dominance by a few countries. However, it should be kept in mind that the number of partner countries for the Artemis Accords is substantially higher, pointing to a more inclusive program that allows the participation of countries with less capability and, consequently, less influence. Nevertheless, this still reveals a higher asymmetry for the Artemis Accords than for the IGA.

Looking at Cluster C, which shows the dependency and vulnerability of a partner country, more similarities between the IGA and the Artemis Accords become apparent. For the IGA case, there are two, and for the Artemis Accords, there is a single lead country. However, there are also other partners with only slightly lower scores. For the Artemis Accords, there is a significant share of partner countries that score lower than the lead country. This shows these countries' dependence on the program. Cluster C scores for signatories without an operational role reflect general geopolitical position rather than program dependency and should not be read as exposure to Artemis decisions.

Comparing the IGA with ILRS shows that both programs were initially centered around the contributions of two major partner countries. Coincidentally, in both programs the two major partners provide exactly 52.2% of the Cluster A score (35 of 67 points). However, with the IGA, the contributions of the non-major partners were more significant, and the major partners relied on them more than in the ILRS case. The Gini coefficients of Cluster A shows that the resources in the ILRS case are much more asymmetric than with the IGA. Based on the Cluster A Gini coefficient of 0.496 of ILRS, the asymmetry profile is much steeper than the IGA benchmark with a Cluster A Gini coefficient of 0.173. Using the standard deviations per criterion for Cluster A allows us to see where the main asymmetries come from. While the SD for the budget and the capability is higher for ILRS than for the IGA, the situation is reversed for the SD for the launch and human spaceflight experience criteria. The most prominent difference between the two programs is with the SD on the capability criterion, which is nearly twice as high for ILRS than for the IGA.

Looking at Cluster B, representing the governance position and influence of a partner country, similarities between the IGA and ILRS become visible as both programs are centered around two defining countries. However, the non-major partners score lower on ILRS, indicating a stronger program asymmetry.

Looking at Cluster C, which shows the dependency and vulnerability of a partner country, the difference between the IGA and ILRS becomes obvious. For the IGA the partner countries all have high values, except for Canada. With ILRS, only China has a high score, and none of the other partner countries. These scores reveal the defining character of the Chinese contribution and the dependence of other partner countries on China, as well as their vulnerability.

Taken together, the comparison shows many similarities between the IGA and ILRS, including the presence of two major partner countries. However, there are also significant differences, such as the asymmetry in available resources and the much more pronounced dependence of the non-major partners on China for ILRS. Relative to the IGA benchmark, the ILRS program is therefore better understood as a model of managed inclusion with thinner

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reciprocal foundations: it is broad enough to attract a politically diverse coalition, but the underlying resource and infrastructure base remains with the lead states [9].

Comparing the Cluster A number directly between the Artemis Accords and ILRS shows that, despite the much larger number of participating countries, the Gini coefficient and the SD for each criterion are lower for the Artemis Accords than with the ILRS. The consistently lower values of the Artemis Accords for Cluster A, representing the capabilities and resources of a partner country, indicate that the ILRS has a consistently higher asymmetry.

6. Interview Evaluation

As described in the methodology section 4.2, the interviews were conducted in a semi-structured way with 12 specialists. Below, we summarize all interview evaluations, with most common answers listed for each qualitative question (see Appendix A, Q1-Q4), and a quantitative analysis of the rating questions (see Appendix A, Q5).

The interview sample consisted primarily of program and project managers, complemented by technical leads, systems engineers, domain specialists, and academic experts. Participants represented a diverse range of organizations, including major space agencies, research institutes, industry, and academia. The sample included perspectives from both established space powers and emerging space actors, covering organizations involved in international cooperation through agencies such as NASA, ESA, JAXA, DLR, and CNES, as well as representatives with experience in countries seeking to expand their space capabilities. This diversity ensured that the interviews captured both leading-partner and non-leading-partner perspectives on asymmetry, governance, trust, and capability development in multinational space programs.

6.1 Type of Asymmetry (Q1)

What types of asymmetries have you observed in multinational space programs, and what are their primary sources?

- **Experience, Competence and Heritage:** Differences in experience and knowledge on hardware, processes and documentation, often resulting in newer actors depending on more experienced partners
- **Budget and Funding:** Differences in available budget, funding mechanisms, cost underestimation, and dependency on state funding, leading to financial imbalance between partners.
- **Technological Capability:** Differences in technical capabilities and expertise, limited testing ability.
- **Power and Size:** Differences between large and small partners, dominant agencies such as NASA, "small partner of a small partner" situations, big countries versus small countries, established suppliers versus inexperienced customers, or smaller institutions depending on larger actors.
- **Culture and Communication:** Differences in language, terminology, documentation practices, communication style, work ethic, hierarchy, decision-making culture.

6.2 Impact of Asymmetry (Q2)

Under what conditions do asymmetries between partners begin to influence dependency, interpersonal trust, and long-term cooperation?

- **Trust is critical:** Asymmetry increases reliance on trust. Trust enables collaboration despite unequal power, resources, expertise, or contractual positions. Personal contacts, transparency, reliability, long-term relationships help stabilize asymmetric partnerships.
- **Dependency between partners:** Less experienced or less capable partners depend on stronger partners for technology, expertise, infrastructure, transportation, suppliers, or program success.
- **Decision-making power unevenly distributed:** Larger or more experienced actors gain greater influence over project decisions. This may reduce the influence of smaller partners and create dependencies on dominant actors.
- **Knowledge and experience transfer:** Collaboration with stronger partners accelerates learning, capability development, heritage building, and competence growth. Asymmetry can therefore be a mechanism for capacity building.
- **Requires clear governance:** Asymmetry makes explicit allocation of authority, responsibilities, escalation paths, and decision rights necessary to avoid confusion and inefficiencies.

6.3 Role of Emerging Space Nation (Q3)

Which factors and mechanisms determine whether emerging space actors can build capabilities and influence within a program, rather than remaining dependent on more experienced partners?

- **Capability builder and learner:** Emerging nations are primarily viewed as actors seeking to develop capabilities. Their participation is often motivated by

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learning, acquiring heritage, and gaining autonomy through practical experience.

- **Future independent space actors:** Emerging nations are seen as progressing along a maturity path, gradually reducing asymmetry, increasing autonomy, building ecosystems, and eventually becoming independent contributors or leaders.
- **Recipient of knowledge and technology transfer:** Established partners are expected to transfer expertise and experience to emerging nations through collaboration, mentoring, workshops, reviews, and participation in projects.
- **Source of innovation, flexibility and agility:** Several respondents attribute greater creativity, flexibility, and willingness to try new approaches to emerging actors, who are often less constrained by legacy systems and established procedures.

6.4 Suggestion of Change (Q4)

What governance, management, or relational practices have you found effective in managing asymmetry while maintaining efficiency and ensuring program success?

- **Open communication and information sharing:** Partners should communicate openly, exchange information transparently, discuss issues early, and ensure all stakeholders remain aligned.
- **Clarify roles and responsibilities:** Clearly defining who is responsible, who decides, who communicates with whom, and how governance functions reduces confusion and potential conflict arising from asymmetries.
- **Build trust through personal relationships:** Personal meetings, informal interactions, regular exchanges, relationship-building are essential for overcoming organizational, cultural, and capability gaps.
- **Align expectations early and continuously:** Partners should explicitly discuss objectives, expectations, project scope, schedules, responsibilities, learning goals, and partnership models at the beginning and revisit them regularly.
- **Support and mentor less experienced partners:** Experienced partners should actively help emerging actors through guidance, coaching, reviews, and practical support rather than expecting them to learn independently.

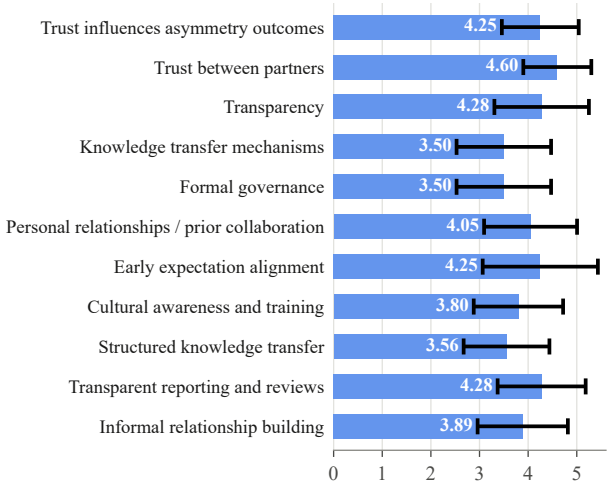


Fig. 4: Mean expert ratings for Q5 questions (1–5 scale).

While less frequently mentioned, several minority suggestions were retained because they provide complementary perspectives on managing asymmetry and may be particularly relevant in specific program contexts, organizational environments, or stages of program maturity:

- **Establish long-term strategic partnerships:** Formal partnerships, MOUs, and long-term commitments can provide stability and facilitate capability development.
- **Joint risk management and shared ownership:** Technical and management teams should collaboratively manage risks to create common ownership and avoid asymmetric burdens.
- **Quick adaptation of partners' responsibilities:** Flexibility to adapt responsibilities as partners' capabilities evolve, as such multinational programs may have a long timeline

6.5 Asymmetry Rating Questions (Q5)

Figure 4 summarizes the ratings provided by the interview participants. Trust was consistently identified as an important factor in managing asymmetry, both in terms of its influence on program outcomes (M=4.25 ± 0.79) and as the highest-rated factor for successfully managing asymmetry (M=4.60 ± 0.70). Transparency, personal relationships, early expectation alignment, and transparent reporting and reviews also received high ratings, while formal governance arrangements and knowledge transfer mechanisms were rated lower, although still positively. Overall,

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the results suggest that respondents consider trust, transparency, and expectation management to be more important for managing asymmetry in multinational programs than formal governance mechanisms alone.

7. Discussion

7.1 Evolution of Space Governance Frameworks

Across the three analyzed frameworks (the ISS IGA, the Artemis Accords, and the ILRS), a consistent direction is visible. The IGA for the ISS bound partners through a single ratified instrument that allocated rights and obligations jointly; the Artemis Accords replaced that with political commitments coordinated bilaterally; the ILRS dispenses with a multilateral instrument altogether. Each step lowered the cost of entry and widened participation; 5 partners, then 52 signatories, then a coalition assembled bilaterally by a single lead state. Each step also removed something: the obligation to consult, the joint ownership of core systems, and the reciprocal criticality that made withdrawal expensive for the withdrawing party as well as the remaining ones. The breadth of participation and the depth of protection have moved in opposite directions.

The ISS case showed that deep interdependence and treaty-anchored rights can buffer asymmetry, fostering resilience even through geopolitical turbulence. In contrast, the Artemis Accords and ILRS frameworks revealed that asymmetry, when coupled with weak institutional protections and concentrated decision-making power, can lead to significant vulnerability, particularly for non-lead partners whose contributions are architecture-specific and easily marginalized by a single partner's strategic pivot.

The scored results express this quantitatively. The ISS in 1998 and the Gateway implementation core in 2024 register almost identical Cluster A concentrations (0.173 and 0.186), yet one sustained cooperation for more than twenty-five years, while the other stranded partner contributions within two years of the baseline. Measured resource asymmetry does not separate them. Instead, what sets them apart is whether the governance layer on top converted that asymmetry into protected interdependence or into unprotected dependency. Asymmetry, on this evidence, does not challenge stability; governance design that leaves dependency unprotected does.

The analysis showed that the ILRS framework resembles the IGA in structure, with two lead partners holding the same 52.2% share of Cluster A points, but is far more concentrated overall (0.496 against 0.173). However, it differs in governance and influence of the partner countries, as well as their dependence and vulnerability. The data clearly shows a lead-state-centric governance model of ILRS. This can be interpreted as the ILRS program being centered on China and used to solidify China's dominant position. On the other hand, it can also be interpreted as China fostering collaboration among partners and providing development opportunities to countries that do not have, or have only limited capabilities in space technology so far. In contrast, the IGA was limited to countries with substantial resources and solid space technology capabilities.

The contrasting fates of the ESA and JAXA contributions in section 5.2 show that the specialized modularity pursued in the Artemis Accords, while more efficient than the technology interdependence of previous treaties, creates long-term dependency structures for any non-lead partners that lack autonomy to operate independently of the others [9]. Thus, it can be concluded that the current lunar governance is not providing a safety net for asymmetric partners. This is the paper's central claim in observed form: asymmetry did not challenge stability while the lead partner's priorities held, but did so the moment they shifted. In the scoring framework, this is what a low Cluster C (dependency/alternative-pathway) score means in practice: ESA's and JAXA's lunar-orbital ambitions had no near-term alternative once the host program was withdrawn. This finding opposes the interview results, where respondents ranked formal governance among the least important factors; Section 7.3 returns to that tension.

7.2 Successful Missions of Emerging Partners

The preceding comparative analysis of governance frameworks ranging from the treaty-based interdependence of the IGA to the hub-and-spoke dynamics of the Artemis Accords and the lead-state-centric model of the ILRS has revealed a critical insight: structural asymmetry is an inherent and often necessary feature of multinational space cooperation. The scoring framework applied in Section 5 demonstrated that while all programs exhibit some degree of capability concentration, the nature of that asymmetry and the governance mechanisms surrounding it are decisive in determining long-term stability.

It is within this analytical context that the successful execution of the Chandrayaan-3 mission on August 23, 2023 emerges as a particularly powerful and instructive example case for how emerging space nations can navigate and challenge existing structural asymmetries. By becoming the first nation to achieve a soft landing near the lunar south pole, the Indian Space Research Organisation (ISRO) demonstrated that "meaningful capability" can be established through a unique synergy of scientific ambition and cost-effective engineering. Unlike the three previously outlined governmental frameworks, Chandrayaan-3 was not

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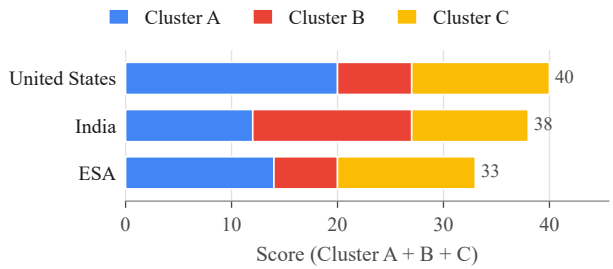


Fig. 5: Chandrayaan-3 country-level scores by cluster.

implemented under a multilateral governance framework, thus offering a unique benchmark for lunar access outside of multinational lunar programs.

Chandrayaan-3 exemplifies a shift to a hybrid, commercially integrated architecture, driven by cost minimization through indigenous design and local sourcing. The mission cost approximately $77 million, a fraction of the typical budget of established space powers, which was achieved by leveraging India's "New Space" sector via IN-SPACe to open the industry to private companies. A critical pillar of India's strategic roadmap is independent launch access. The mission was launched using the LVM3-M4, India's heavy-lift vehicle, which reinforces the nation's standing as an actor capable of reaching lunar orbit without relying on the launch infrastructure of its other partners. Chandrayaan-3 illustrates how emerging nations manage the multipolar space environment to avoid structural marginalization. By signing the Artemis Accords in 2023, India achieved managed inclusion by aligning with international norms while maintaining an autonomous architecture. This functional interdependence is evident in the use of NASA and ESA tracking networks without sacrificing sovereign authority. The mission served as a powerful tool for national identity and prestige. The naming of the landing site as "Statio Shiv Shakti" and the declaration of August 23 as "National Space Day" underscore the mission's role in fostering social cohesion and demonstrating India's rising status as a global technology powerhouse.

To quantify how the success of Chandrayaan-3 was achieved, we apply our previously developed scoring system, where scoring was restricted to the three entities with documented operational roles: India (ISRO) as owner and operator of all flight segments, the US (NASA) providing the Laser Retroreflector Array as payload, and ESA giving ESTRACK ground-segment support. Consistent with the establishment-phase logic applied to the IGA, 2023, the year of mission execution, was used as the benchmark. Figure 5 visualizes the results for the Cluster scoring, while the detailed values can be found in Table A3.

The resulting Gini coefficient for Cluster A is 0.116, which is noticeably lower than those of all previously analyzed governance frameworks. The reason for this is not because the program is egalitarian, but because all three entities function like established space actors. The distinctive result is the combination of this low resource asymmetry with total governance concentration (SD 1.414 on both decision-making power and contribution criticality) vested in the *least*-resourced actor of the set, and with uniformly low dependency scores (Cluster C SDs of 0.471-0.816): India used partner ground assets as coverage augmentation rather than mission-critical infrastructure, while its partners' contributions were marginal to their own programs.

Consequently, Chandrayaan-3 exemplifies how an emerging nation can leverage autonomy to overcome structural imbalances. This case provides a vital counterpoint to the multilateral models analyzed earlier, demonstrating that stability can be achieved through national control and strategic foresight rather than formal governance frameworks. It marks a boundary condition in the asymmetry-stability relationship: complete governance asymmetry generated no instability because no partner held marginalizable stakes. Thus, the mission serves as a strategic blueprint for how emerging partners can thrive in a multipolar space environment.

7.3 Practical Expert Insights

The interview findings of this study provide important context for the case study analysis. The interviews showed that asymmetry is common in multinational space programs and is not necessarily a problem. Differences in experience, resources, funding, and technical capability are often expected and can even help programs succeed. However, some interviewees noted that asymmetry becomes a challenge when it creates strong dependencies, reduces trust, or leaves partners with little influence over decisions.

Trust, transparency, and clear communication were mentioned repeatedly as key factors for successful cooperation. Interviewees highlighted the importance of defining roles and responsibilities early, keeping expectations aligned, and ensuring that partners understand how decisions are made. Building personal relationships and regular communication were also seen as important to avoid misunderstandings and maintain long-term cooperation.

The interviews also showed that asymmetry can help emerging space actors gain experience and develop capabilities when more experienced partners actively provide support, guidance, and opportunities for participation. Rather than trying to eliminate asymmetry, future

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programs should focus on reducing critical dependencies, supporting capability growth, and ensuring that all partners can contribute in a meaningful way. Read against the case evidence, the interview ranking is not a contradiction but a division of labor. Respondents rated formal governance lowest and trust highest because they were describing routine program operation, where day-to-day friction is resolved interpersonally and the governing instrument is rarely invoked. The case studies capture the opposite regime: a lead-partner pivot, where no amount of accumulated trust protected ESA's Gateway contributions, and the only variable that would have was the instrument itself. Trust governs the median week of a program; the instrument governs its worst one. Governance design should be judged by the second, not the first.

8. Recommendations

The findings from both the comparative case studies and the expert interviews indicate that asymmetry is an inherent feature of multinational space programs rather than a governance flaw. Differences in resources, capabilities, and experience are both expected and, to some extent, necessary for the delivery of complex missions. However, the analysis suggests that program success depends not on eliminating these asymmetries, but on managing them through governance structures that promote transparency, trust, and meaningful participation. Across the case studies, governance frameworks that combined differentiated responsibilities with inclusive decision-making and opportunities for capability development were associated with more resilient long-term partnerships. The expert interviews further emphasized that perceived fairness, rather than formal equality, is the key determinant of sustained partner commitment. Based on these findings, the following recommendations are proposed for the effective long-term governance of multinational space programs, addressing both formal governance structures and interpersonal dimensions of cooperation.

Manage Asymmetry Constructively Asymmetry in large-scale space programs is inherent to the structure and should be managed rather than avoided. Well-managed asymmetry can yield mutual gain for the partners involved: Smaller partners gain access to experience and funding and can increasingly "grow" into contributing to space missions. Larger partners, in turn, can benefit from the drive and rapid movement of the smaller ones and may be challenged to question long-standing beliefs and structures. This same hierarchy should establish a natural flow of information and a clear delegation of responsibilities, with each party owning a specific area rather than overlapping claims to the same domain. Likewise, financial contributions should scale with capacity, so that larger partners may contribute more than smaller ones. However, funding must never buy influence or participation, and the exact amount each partner contributes need not be publicly rank-ordered. At the same time, asymmetry in power also scales responsibilities, meaning that larger partners establishing as leaders should formalize access in MOUs, assign partners to tasks that match their scale, and document decision-making authority up front so that the benefits of asymmetry are captured intentionally rather than left to ambiguity.

Integrate Emerging Partners Gradually Program leaders should involve emerging partners and start-ups early but stage their involvement. Thus, missions should not directly depend on small, first-time space partners for success, but rather involve them with small, non-mission-critical contributions initially and increase responsibilities as trust, experience, and capability build across successive milestones. To enhance the growth of new space nations, capability development should be built into program planning: knowledge transfer, joint technical activities, and training enable emerging partners to expand their skills over time, thereby reducing long-term dependency on established actors. To fully leverage the benefits of including emerging partners in space projects, they should be integrated into reporting and documentation structures from an early stage. Such structures should be designed proportionately, with sufficient documentation to monitor progress and transparency, without imposing excessive administrative burdens on partners with limited institutional capacity. This can facilitate the assessment of partners' capabilities and contributions while also periodically reassessing the relevance of established norms and procedures.

Structured Adaptability to Program Change Since circumstances can change over the course of a long-term space project, cooperation frameworks should remain adaptable and evolve in response to new technological capabilities, institutional developments, and contributions from emerging partners. However, lessons from the Lunar Gateway and insights from the expert interviews also highlight the need to protect partners when program structures change. Significant changes to the architecture or technical design can affect partners' planned contributions and investments. Future agreements should therefore include consultation obligations before major architectural changes, giving affected partners an opportunity to assess the consequences and participate in the decision-making process. Where an existing contribution can no longer

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be used as originally planned, agreements could also provide for compensation or alternative use of that contribution. These provisions would reduce the risk that emerging partners bear disproportionate costs as a program evolves, while providing greater certainty and stability for long-term participation.

Separate Influence from Responsibility Governance structures should ensure that a partner's financial or technical contribution does not directly determine its influence on strategic decisions. One way to achieve this is through a two-level model: an open strategic forum in which all partners can contribute to discussions on the program's overall direction, and a smaller decision-making body in which voting rights are linked to technical responsibilities rather than financial contributions. ESA already operates a version of this model, with one vote per member state in Council for mandatory activities and contribution-weighted participation in optional programs, and it has sustained a twenty-three-member agency across very unequal contribution levels. This approach allows all partners to have a voice while ensuring that those responsible for specific technical areas retain an appropriate role in related decisions. To prevent a single partner from becoming a critical point of failure, cooperation frameworks should establish a multi-sourcing framework, e.g., using multiple suppliers for essential infrastructure, standardizing interfaces, and diversifying funding and expertise. In this way, political or technical problems affecting one partner are less likely to disrupt the entire program. Governance should also be designed to adapt over time. Periodic reviews can be scheduled, with additional reviews triggered by unforeseen events such as the entry of a new partner, a change in capabilities, or a significant shift in funding. Thus, partner roles can be adjusted as capabilities, priorities, and program needs change.

Build Trust through Cultural Integration Especially for large multinational space projects, cultural differences should be taken into account from the beginning. Cross-cultural training and early in-person interaction should be included in the program schedule, as trust develops through sustained engagement rather than being assumed. This can be organized in three stages: First, co-located workshops can combine cultural training with face-to-face collaboration, allowing partners to build relationships and identify differences in communication styles. Second, during program execution, periodic in-person meetings and rotating host locations can help maintain these relationships and strengthen cooperation over time. Third, partners should explicitly agree on shared values and ethical standards. A common ethical baseline can help partners better understand each other's actions, particularly when disagreements or pressures arise. Together, these measures can improve communication and cooperation, but trust still needs to be actively built through repeated personal interaction, shared problem-solving, and commitment from all partners.

Ensure Transparency through Governance From the outset, partners should document the decision-making process, including defining who can propose and approve decisions and how those decisions are recorded. Partner responsibilities should be clearly defined, while financial and technical contributions should be reported at an appropriate level rather than necessarily disclosed in full detail. Transparency should focus on ensuring that all partners understand their roles, obligations, and the factors that influence major decisions. This can be supported through regular reporting on program progress, risks, and overall contributions, as well as shared information structures that give emerging partners the same visibility as established ones. A staged conflict-resolution process, such as referral first to a joint committee and then to neutral mediation, should also be agreed in advance. This approach reduces uncertainty and builds the trust needed for partners to make stronger commitments over time.

9. Conclusions

International space cooperation is becoming increasingly important as emerging space nations develop their capabilities. Differences in economic resources, technical capabilities, and political influence make such cooperation inherently asymmetric, often creating dependence among smaller partners on established nations for resources and influence over decision-making. The stability of space cooperation does not, however, depend on removing that asymmetry; it depends on how the asymmetry is shaped.

The scored comparison gives this a precise form. The score of the ISS in 1998 and the Gateway in 2024 show almost identical resource concentration (Gini 0.173 and 0.186), yet one sustained cooperation for over 25 years and the other stranded partner hardware within two years. What separated them was not asymmetry but whether the governing instrument converted dependency into protected interdependence. Chandrayaan-3 marks the boundary of the relationship: complete governance asymmetry with no instability, because no partner held a strandable stake.

Our study showed that fair and effective cooperation does not require all partners to contribute equally. Instead, governance should ensure that financial or technical contributions do not automatically determine strate-

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gic influence, thereby reducing one-sided dependence and improving stability. Clear responsibilities, appropriate transparency, shared access to information, and predefined conflict-resolution processes can reduce uncertainty and build trust. Cultural differences should also be considered through early interaction, cross-cultural training, and sustained personal engagement.

Cooperation frameworks should be designed to adapt over time. Regular reviews and diversified funding, expertise, and infrastructure can help programs respond to changing capabilities and reduce dependence on individual partners. For European partners in particular, whose contributions to lead-partner architectures are typically high-value, architecture-specific elements, the practical implication is that consultation, repurposing, and exit provisions belong in the founding instrument rather than being improvised afterwards. By combining inclusive governance, transparency, trust, and adaptability, future space agreements can give emerging partners a more meaningful role while strengthening international space cooperation as a whole. Future work should develop a protection or exit-exposure indicator alongside the Gini coefficient, so that the variable this study identifies qualitatively can be scored.

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Appendix A. Expert Interview Questions

1. Type of Asymmetry: What types of asymmetries have you observed in multinational space programs, and what are their primary sources (e.g., experience, institutional frameworks, expectations, or cultural factors)?

2. Impact of Asymmetry: Under what conditions do asymmetries between partners begin to influence dependency, interpersonal trust, and long-term cooperation? Please reflect on both risks and potential strategic benefits.

3. Role of Emerging Space Nation: Which factors and mechanisms determine whether emerging space actors can build capabilities and influence within a program, rather than remaining dependent on more experienced partners?

4. Suggestion of Change: What governance, management, or relational practices have you found effective in managing asymmetry while maintaining efficiency and ensuring program success?

5. Asymmetry Rating Questions:

   - To what extent does trust influence the impact of asymmetry on program outcomes? (1 = no influence, 5 = strong influence)
   - How important are the following factors for successfully managing asymmetry in multinational programs?
     (1 = not important, 5 = very important)
     - Trust between partners
     - Transparency (e.g., pricing, communication)
     - Knowledge transfer mechanisms
     - Formal governance (contracts, SoW)
     - Personal relationships / prior collaboration
   - Based on your experience, how effective are the following measures in managing asymmetry?
     (1 = not effective, 5 = very effective)
     - Early expectation alignment
     - Cultural awareness and training
     - Structured knowledge transfer
     - Transparent reporting and reviews
     - Informal relationship building

Appendix B. Comparative Case Study Scoring Data

Section 5 presents the score for each partner country per Cluster in bar graphs. The data behind the graphs is in Tables A1 to A5. The complete per-criterion tables are not reproduced due to their size but remain available at [65].

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Table A1: ISS partner scores by Cluster with 1998 baseline and 2026 updates in parentheses.

Partner	Cluster A	Cluster B	Cluster C	Country Total
United States	19 (20)	15	15	49 (50)
Russia	16 (17)	15 (13)	14 (9)	45 (39)
Japan	13 (15)	8	10	31 (33)
Canada	6 (7)	8	7	21 (22)
ESA	13 (17)	9 (10)	11 (10)	33 (37)
Cluster Total	67 (76)	55 (54)	57 (51)	179 (181)

Note: green values indicate an increase and red ones indicate a decrease.

Table A2: ILRS country-level scores by cluster.

Country	Cluster A	Cluster B	Cluster C	Country Total
China	18	15	12	45
Russia	17	11	6	34
Pakistan	5	6	6	17
Egypt	5	6	6	17
South Africa	5	4	7	16
Azerbaijan	4	3	6	13
Kazakhstan	3	4	7	14
Thailand	2	5	8	15
Belarus	3	3	3	9
Venezuela	2	3	1	6
Senegal	2	3	5	10
Serbia	1	3	5	9
Nicaragua	0	3	4	7
Cluster Total	67	69	76	212

Table A3: Chandrayaan-3 partner scores by Cluster (2023).

Partner	Cluster A	Cluster B	Cluster C	Country Total
India	12	15	11	38
United States	20	7	13	40
ESA	14	6	13	33
Cluster Total	46	28	37	111

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Table A4: Artemis Accords signatory scores by Cluster (2024 baseline, 52 signatories). The post-pause 2026 revisions are reported separately in Section 5.2 and are not applied to these baseline values.

Partner	**Cluster A**	**Cluster B**	**Cluster C**	**Country Total**
United States	20	15	15	50
Japan	14	11	12	37
Canada	11	12	10	33
Italy	12	9	11	32
France	12	7	11	30
Germany	12	7	11	30
India	12	4	13	29
South Korea	11	4	11	26
United Arab Emirates	7	10	9	26
United Kingdom	10	5	10	25
Australia	8	7	10	25
Israel	10	3	10	23
Spain	9	4	10	23
Sweden	8	4	10	22
Brazil	8	3	10	21
Belgium	6	4	10	20
Netherlands	6	4	10	20
Argentina	7	3	9	19
Switzerland	6	4	9	19
Luxembourg	5	5	9	19
New Zealand	6	3	9	18
Austria	5	4	9	18
Denmark	5	4	9	18
Czech Republic	5	3	9	17
Poland	5	3	9	17
Romania	5	3	9	17
Singapore	5	3	9	17
Ukraine	7	3	6	16
Saudi Arabia	5	3	8	16
Bulgaria	4	3	9	16
Greece	4	3	9	16
Slovakia	4	3	9	16
Estonia	3	3	9	15
Lithuania	3	3	9	15
Slovenia	3	3	9	15
Mexico	4	2	8	14
Thailand	3	3	8	14
Nigeria	4	2	7	13
Chile	3	2	8	13
Colombia	3	2	8	13
Rwanda	2	3	8	13
Cyprus	1	3	9	13
Armenia	3	2	7	12
Peru	2	2	8	12
Uruguay	2	2	7	11
Angola	2	1	7	10
Iceland	1	2	7	10
Liechtenstein	1	2	7	10
Bahrain	2	1	6	9
Dominican Republic	1	1	6	8
Ecuador	1	1	6	8
Panama	1	1	6	8
Cluster Total	299	204	464	967

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Table A5: Gateway implementation-core partner scores by cluster, 2024 baseline with post-pause 2026 updates in parentheses. The Cluster A totals are the population used for the implementation-core Gini coefficient reported in Section 5.2.

Agency	**State / organization**	**Cluster A**	**Cluster B**	**Cluster C**	**Partner Total**
NASA	United States	20	15	15	50
ESA	European Space Agency	17	12 (10)	12 (11)	41 (38)
JAXA	Japan	14	11	12	37
CSA	Canada	11	12 (10)	10	33 (31)
MBRSC	United Arab Emirates	7	10	9	26
Cluster Total		69	60 (56)	58 (57)	187 (182)

Note: values in parentheses report the post-March-2026 score only where it differs from the 2024 baseline; red indicates a decrease. The five agencies are those holding major Gateway implementation responsibilities at the 2024 baseline [58, 59]. ESA is scored as a single institutional partner, consistent with its treatment in Table A1, and therefore does not appear in the signatory-level population of Table A4. The Cluster A totals in this table are the population from which the implementation-core Gini coefficient is computed; they are not a subset of the coalition-level totals in Table A4.

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