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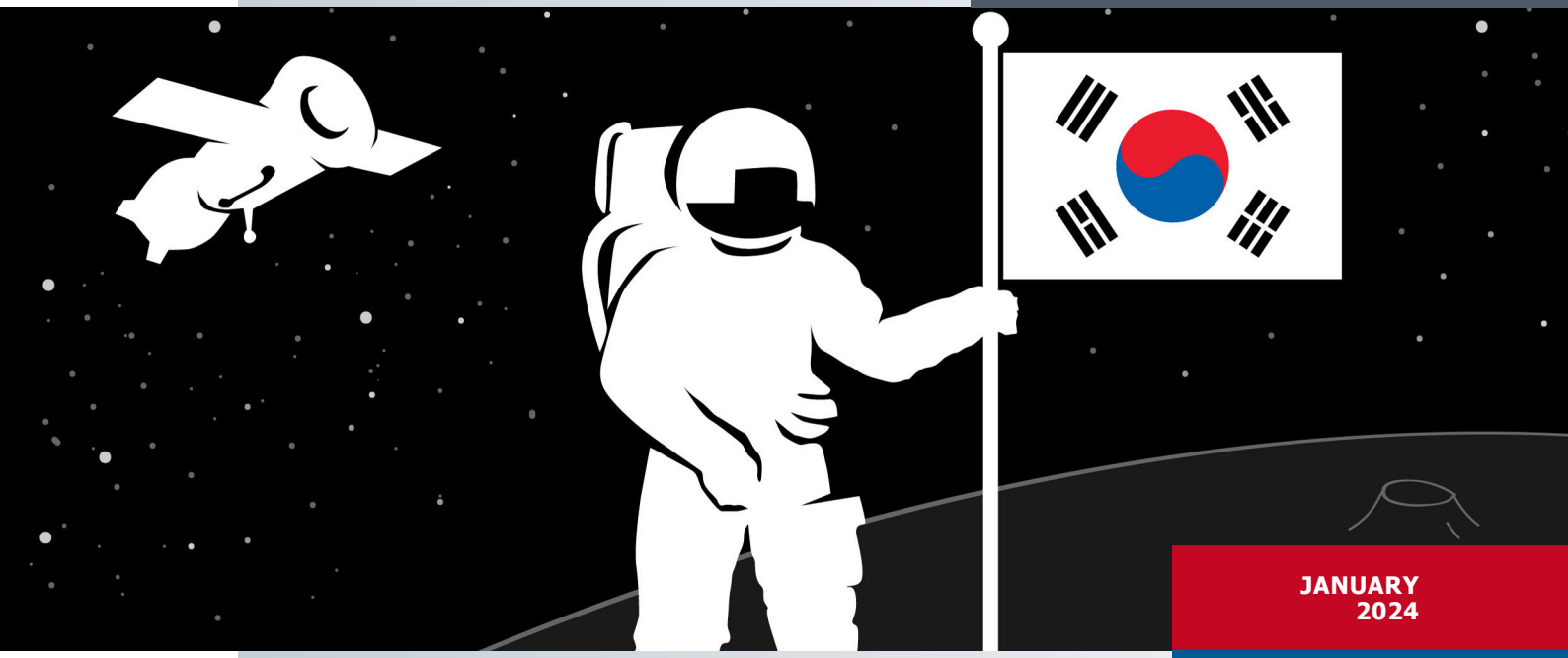

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Evolution and Dynamics of the Space Industry in South Korea

Center for Asian Studies

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Abstract

This paper comprehensively examines South Korea's strategic approach to its space industry, covering growth patterns, governmental policies, and international positioning.

First, while discussing recent legislative changes and the Korean Aerospace Agency (KASA) establishment, we focus on the space industry ecosystem to highlight a shift to a market-oriented model for sustained growth. The shift in the space industry in South Korea hinges upon various factors, such as well-established governance, the private sector's capital investment, and legal reforms.

Second, South Korea's evolving space strategy, spanning three phases and aiming for global space economic power by 2045, is incorporated in the "Space Development 2.0" initiative that outlines goals to integrate space exploration with economic infrastructure. Also, South Korea's military space strategy, outlining a three-stage plan for enhanced capabilities and institutional restructuring, has emerged as a new component of South Korea's space strategy. The international cooperation strategy, including a strengthening space alliance with the U.S. and collaborations with emerging space nations, underscores South Korea's commitment to a global and collaborative approach.

In conclusion, the paper provides a multifaceted analysis, offering insights into South Korea's trajectory as a critical player in the evolving space landscape, covering legislative, economic, technological, and international dimensions.

Table of contents

Introduction

The advent of the 21st century has witnessed the rise of the space industry as a pivotal arena of technological innovation, economic opportunity, and geopolitical significance. Amidst this global landscape, South Korea has emerged as an increasingly influential player in space exploration and technology. This paper offers an in-depth examination of South Korea's space industry, encapsulating its historical evolution, current state, and future prospects in a global context.

The strategic importance of the space industry to South Korea transcends its technological and economic facets, extending into realms of national security and diplomatic influence. As a sector that fosters cutting-edge technological development, it also serves as a vital cog in the nation's economic engine, mainly through advancements in satellite technology, launch capabilities, and related areas. Moreover, the space industry's role in national security and South Korea's international standing is paramount.

This paper traces the genesis and growth trajectory of South Korea's space endeavors. It starts from the foundational stages, marked by establishing institutions like the Korea Aerospace Research Institute (KARI), and spans through various phases of satellite development, launch missions, and international collaborations. These historical insights provide a backdrop for understanding the present dynamics of South Korea's space sector.

Currently, the South Korean space industry is characterized by a multifaceted ecosystem of government entities, academic institutions, and burgeoning private companies. This intricate network operates under the aegis of significant government investment and supportive policies. However, it navigates through many challenges, including technological development hurdles, global competitive pressures, and intricate policy landscapes. Concurrently, the industry stands at the cusp of manifold opportunities, notably in the domains of international partnerships, market development, and technological breakthroughs.

This paper aims to comprehensively analyze South Korea's strategic approach to its space industry. This includes scrutinizing the growth patterns of the sector, evaluating the effectiveness and impact of governmental policies, and assessing South Korea's position and role within the international space community. Additionally, this paper seeks to identify the pivotal challenges and opportunities for South Korea in this domain.

The paper is structured to provide a systematic exploration of these aspects. Following this introduction, the subsequent sections delve into the historical overview of South Korea's space industry, analyze the current

state of affairs, and then project future trends and possibilities. This approach ensures a holistic understanding of South Korea's space industry, contributing significantly to the scholarly discourse on space technology's role in national development and global competition.

Space development in South Korea

A brief history

South Korea initiated its space development program in the early 1990s. Although the start was thirty to forty years behind the advanced space-developing countries, the past thirty years have seen substantial progress due to bold government support and vision, setting the stage for South Korea to become an emerging leader space-faring nation.[1]

In 1986, the Astronomical Space Science Research Institute (affiliated with the Korea Electronics and Telecommunications Research Institute) was established. Then, in 1989, the Korea Aerospace Research Institute (KARI), specializing in research and development in the aerospace sector and affiliated with the Mechanical Engineering Research Institute, was founded.[2]

Concurrently, establishing the Satellite Research Center at KAIST (Korea Advanced Institute of Science and Technology), a research-focused educational institution, laid the foundation for space development.[3] The 1990s saw an acceleration in space development efforts. In 1992, the country developed its first experimental small science satellite, Wooribyul 1. In 1999, it successfully launched Arirang 1, the country's first practical satellite, marking the beginning of a phased satellite development program. Additionally, in 1993, developing the small science rocket KSR-I and then the medium science rocket KSR-II in 1999 helped South Korea acquire foundational technology in the solid rocket field.[4]

In the 2000s, South Korea's space research and development was strengthened with the establishment of space-related laws and advancements in launcher and satellite technologies. In 2003, the development of the Science and Technology Satellite 1 and the Multipurpose Practical Satellite 2 marked an essential maturation in satellite technology. This period also saw the development of the liquid-propellant science rocket KSR-III, whereby

1. The Ministry of Science and ICT, *2006 Space Development White Paper*, 2006 (in Korean). The Ministry of Science and ICT, *2020 Space Development White Paper,* 2020 (in Korean).
2. J.-B. Kim, "The History of Space Policy and Administration in Korea*", Aerospace Industry Technology Trend*, 16(1), 2018, pp. 14-21.
3. C. Y. Hwang, "Space Activities in Korea: History, Current Programs, and Future Plans", *Space Policy*, 22(3), 2006, pp. 194-199.
4. J. C. Moltz*, Asia's Space Race: National Motivations, Regional Rivalries, and International Risks*, New York, Columbia University Press, 2011.

foundational technology for liquid rockets was acquired. Additionally, enacting the Space Development Promotion Law in 2005 laid the legal groundwork for space development. In 2008, South Korea produced its first astronaut. The 2010s further established the country's position as an emerging space development nation.[5]

In 2010, South Korea's entry into the exclusive group of geostationary satellite operators was marked by the successful deployment of the Chollian satellite. This milestone was further augmented by the launches of the Multipurpose Practical Satellites 3, 5, and 3A, which much enhanced the nation's capability to acquire high-resolution Earth observation imagery and signaled the commencement of multi-satellite operations. A pivotal moment in South Korea's space exploration journey was achieved with the successful launch of the Naro-1 (KSLV-I) rocket, firmly establishing the country as a member of the global space-launching community.

South Korea has made significant strides in its space program in recent years, mainly due to a more favorable policy and regulatory environment. Notably, in 2020 and 2021, South Korea and the United States agreed to lift restrictions on South Korean missile and space launch vehicle capabilities.[6] This change marked a pivotal shift, granting South Korea greater autonomy and flexibility in its space launch endeavors. In a landmark achievement, in June 2022, South Korea successfully deployed a satellite into orbit using its indigenously developed three-stage Nuri rocket. The rocket, a product of the government's KARI, symbolizes South Korea's entry into the exclusive group of nations capable of independent orbital launch. This advancement not only signifies a technological leap but also reflects the nation's evolving role in the global space landscape.[7]

The recent policy developments surrounding the Missile Technology Control Regime (MTCR) have significant implications for South Korea's space sector, particularly its collaboration with the United States. Reports from March indicate a potential easing of the licensing process for US satellite-related technologies to MTCR member countries.[8] While maintaining rigorous export controls on space launch vehicles, this amendment could markedly advance the prospects for exporting US satellite technology or entire satellites to South Korea.

5. J. Lee and S. Chung, "Space Policy for Late Comer Countries: A Case Study of South Korea", *Space Policy*, 27(3), 2011, pp. 227-233.
6. S.-H. Choe, "South Korea Launches Satellite with Its Own Rocket for the First Time", *The New York Times*, June 21, 2022, available at: www.nytimes.com.
7. E. J. Lee and C. G. Yi, "Improvement for Performance Management of Korean Space Launch Vehicle Development Project by Using a Logic Model", *Journal of Korea Technology Innovation Society*, 23(4), 2020, pp. 815-840 (in Korean).
8. T. Hitchens, "Commerce Eases Satellite Exports to MTCR Partners; South Korea a Key Focus," *Breaking Defense*, March 16, 2023, available at: www.breakingdefense.com.

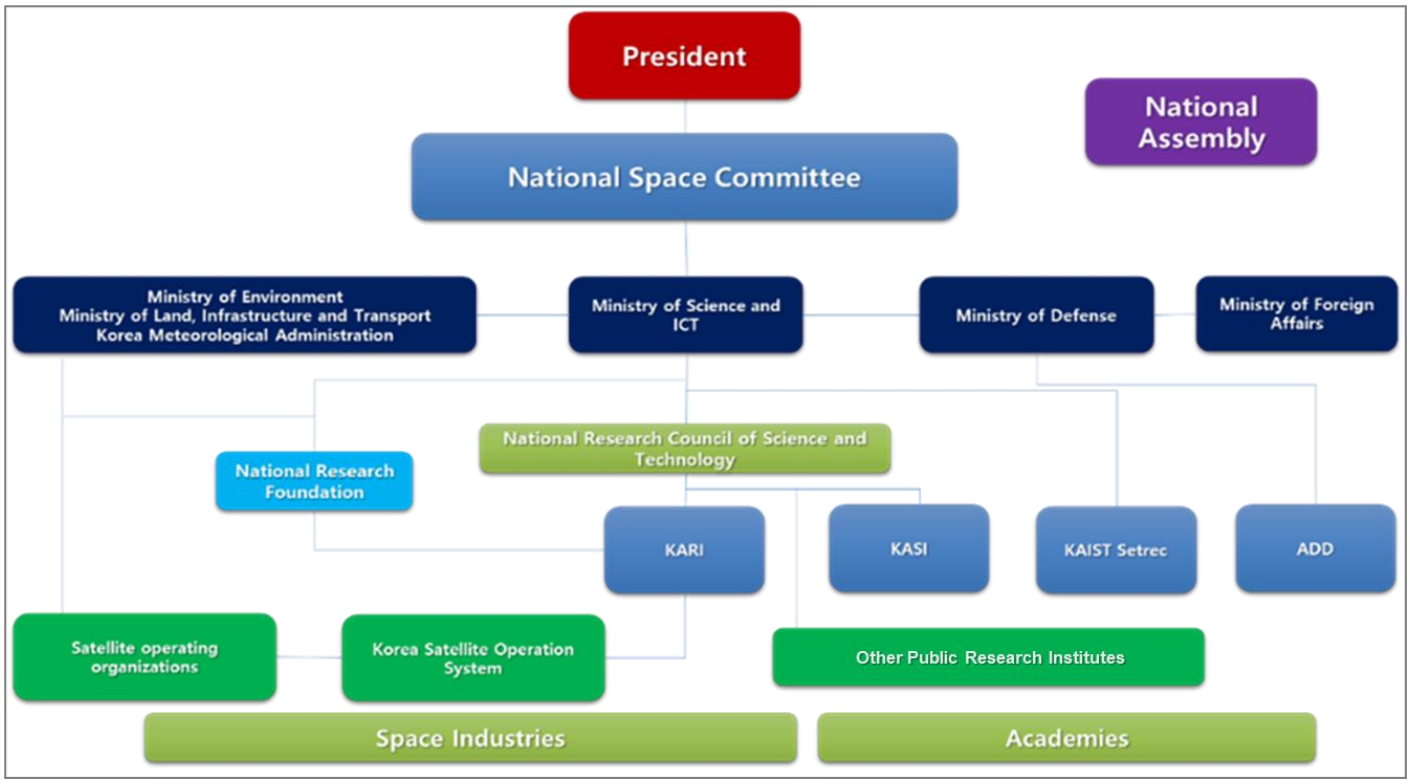
This topic was prominently featured during a high-level diplomatic meeting in April 2023, where South Korean President Yoon Suk Yeol and US President Biden met in Washington. The joint statement from this summit highlighted a shared commitment to strengthen US-ROK commercial space collaboration. It specifically commended the US for its recent revisions to export control policies regarding satellites and satellite components, acknowledging these alterations as a robust foundation for future expanded bilateral commercial and governmental space initiatives.

Key players

The current structure of South Korea's space development program is complex and involves numerous organizations and departments. It includes:

- the National Space Committee, directly under the President;
- seven ministries, including the Ministry of Science and ICT, Ministry of National Defense, Ministry of Foreign Affairs, Ministry of Economy and Finance, Ministry of Land, Infrastructure and Transport, Ministry of Environment, and the Korea Meteorological Administration;
- two research institutions under the Ministry of Science and ICT: the National Research Council of Science & Technology and the affiliated Korea Aerospace Research Institute and Korea Astronomy and Space Science Institute;
- the Agency for Defense Development under the Ministry of National Defense;
- the Korea Advanced Institute of Science and Technology (KAIST) and its satellite research center, under the Ministry of Science and ICT;
- other government-funded research institutes;
- department-specific research management organizations and satellite operation/utilization agencies.

Figure 1: Space programs and actors in South Korea



Source: authors' creation.

This decentralized system has led to debates over consistency and unity in policy implementation, as well as difficulties in securing and efficiently using budgets. Recently, there has been discussion about establishing a dedicated space agency in South Korea, leading to amendments to the Space Development Promotion Act in November 2021 and June 2022. These amendments aim to reorganize the existing government structure related to space.

As a result of these changes, the Prime Minister has become the chair of the relevant committee, and the Minister of Science and ICT serves as the vice-chair. Other members include the Minister of Economy and Finance, the Minister of Foreign Affairs, the Minister of National Defense, the Minister of Trade, Industry and Energy, the Director of the National Intelligence Service, and experts in the space field with extensive knowledge and experience, appointed by the President, as outlined in Article 6, Paragraph 4 of the Space Development Promotion Act.[9]

9. The Ministry of Science and ICT, *The Fourth Basic Plan for the Promotion of Space Development*, 2023 (in Korean).

The Fourth Basic Plan delineates an ambitious trajectory for the national space program, targeting a twofold increase in its budget by 2027 relative to the fiscal allocations of 2022. Central to this strategic framework is a substantive reconfiguration in the governance mechanisms governing space activities. The National Space Committee, historically presided over by the Prime Minister as the deputy head of government, is to undergo a notable transformation. Under the new plan, the chairmanship is elevated to the presidential level, a modification that mirrors the Yoon administration's strategic elevation of space endeavors as a matter of national priority. This elevation of the committee to a presidential purview signifies enhanced engagement of senior governmental echelons in formulating and executing space policy, a dynamic that is expected to persist beyond the tenure of the current administration. The committee's mandate extends beyond merely charting the national space agenda; it encompasses the imperative to foster synergistic collaborations among the principal space development entities, including the Agency for Defense Development (ADD) and the Korea Aerospace Research Institute (KARI). Additionally, the plan advocates the inception of a new space agency, the Korean Aerospace Agency (KASA), a proposal championed by President Yoon. Establishing KASA represents a strategic augmentation of the nation's space exploration and technological development capabilities.[10]

Budget and programs

The South Korean government is steadfastly increasing its investment in space programs, allocating an unprecedented KRW 874.2 billion (approximately US$ 724 million) to space development in the current fiscal year. This figure marks a 19.5% increase from the KRW 731.6 billion allocated in 2022. The most significant portion of the budget, KRW 586.2 billion, is dedicated to nurturing the space industry, followed by KRW 148.2 billion for space transportation, KRW 95.4 billion for space security, KRW 34.4 billion for space science, and KRW 10 billion for space exploration.

10. KASA, originally slated for establishment by 2023, is currently experiencing delays as discussions in the National Assembly continue.

Figure 2: Space budget in Korea by year

(unit: KRW 100 million)

Source: The Ministry of Science and ICT (2023).

Regarding fostering the space industry, the government primarily focuses on expanding the development of public satellites, including small satellites, geostationary satellites, telecommunication satellites, next-generation medium-sized satellites, and the Korean Positioning System (KPS). The strategy aims to lay the foundation for the growth of the private space industry by increasing the supply of public satellites, thereby enhancing the quality of satellite information services applicable to the land, maritime, environmental, meteorological, and forestry sectors.

For this purpose, from this year until 2026, the government plans to invest KRW 48.7 billion in strengthening the national satellite integrated operation and calibration infrastructure. Additionally, KRW 12 billion will be invested from this year through 2028 to increase the domestic production rate of space-related components and parts. The government is also initiating substantial support for space-related startups, earmarking a budget of KRW 5 billion for this year. In the space transportation sector, the third launch of the Nuri rocket (KSLV-2) and the development of the next-generation launch vehicle (KSLV-3) are essential. The third Nuri launch, scheduled between May and June, will carry KAIST's next-generation small satellite 2 and seven CubeSats selected through a public competition. The specific launch schedule will be announced in April.

The successor to the Nuri rocket, the next-generation launch vehicle, is being developed, with an inaugural launch targeted for 2030. Test launches are planned for 2030 and 2031, and in 2032, the rocket is expected to launch South Korea's first domestically developed unmanned lunar lander. The development of this next-generation launch vehicle, spanning from this year to 2032, will see an investment of approximately KRW 2 trillion. The development will be a joint effort between the Korea Aerospace Research Institute and a "system integration company" to be selected from the private sector in September. Additionally, improvements to the launch site

facilities are underway, with KRW 47.6 billion allocated from this year to 2025, including the construction of facilities for launching private rockets.

Meanwhile, the government is beginning to focus on developing technologies for asteroid exploration and entering the orbital service market. Core technologies include rendezvous and docking, robotic arms, and active control of space objects. Active control refers to extending the mission lifespan of space assets by altering their position or orbit, refueling, repairing, or towing them in orbit. This market is expected to grow with the expansion of the space economy.

The technology development will proceed in three phases. The first phase, from 2023 to 2027, aims to develop and demonstrate precursor technologies necessary for rendezvous and close proximity flight in space. The second phase, from 2028 to 2032, will further refine these technologies and undertake missions to retrieve objects from space and return them to Earth.

In the third phase, starting in the 2030s, South Korea plans to offer actual services in Earth orbit using its developed technologies. During this phase, missions are also planned to retrieve soil samples from the Moon, asteroids, or Mars and return them to Earth.

Key characteristics of the space industry ecosystem

In the era of newspace, it is essential first to examine the extent to which a commercial market is well established in the domestic space industry sector to leverage market functions in the space industry effectively. This paper will focus on the market from three perspectives: demand, supply and institutional framework.

Demand side

First, the importance of demand stems from the concept of fixed costs. The high research and development investment costs are predominantly fixed in advanced science and technology industries like the space sector. As more units of a developed product are produced, the unit cost of development (or production) diminishes. Hence, the "scale of the industry", including market demand, becomes a critical condition for establishing the industry. The high fixed costs necessary for research and development are considerable as set-up costs in the context of industry establishment, as described by Alfred Marshall in 1890.[11] This concept holds substantial importance in formulating policy for fostering advanced technology industries, such as the space industry.

Globally, governments are the primary customers in the space manufacturing sector; the situation in South Korea is no different. Table 1 compares the number of satellites launched by various countries over the last decade, from 2013 to 2022. Regarding satellites launched by private and government entities (including defense), the figures stand at 4,165 for the United States, 419 for the United Kingdom, 315 for China, 161 for Russia, 71 for Japan, and 48 for India. In contrast, South Korea has launched a total of 12 satellites to date, averaging less than one satellite per year.

The insufficiency of governmental demand for satellite development in South Korea extends beyond the confines of the satellite industry alone, directly affecting the entire demand within the space equipment manufacturing sector, encompassing launch vehicles and ground stations. This situation necessitates a critical evaluation of whether the government's demand for satellite development constitutes a market of adequate scale to sustain many local enterprises specializing in space equipment manufacturing.

11. A. Marshall, *Principles of Economics*, London: Macmillan [8th ed.], 1890 [1920].

Table 1: Number of satellites by country (2013-2022)

Country	Number of satellites
USA	4165
United Kingdom	419
China	315
Russia	161
France	71
Japan	71
India	48
Luxembourg	29
Germany	28
Uruguay	25
European Space Agency (ESA)	24
Canada	23
Finland	17
Australia	14
Brazil	13
South Korea	12
Spain	11
United Arab Emirates	11
Italy	10

Source: UCS Satellite Database, available at: www.ucsusa.org.

In an analytical report, the Korea Institute of Science and Technology Evaluation and Planning (2020) underscored the difficulties encountered in industrial commercialization via mass production. This challenge has resulted in a diminished incentive for industry participation, an issue that remains unaddressed within the current national research and development project framework. The institute emphasizes the imperative for a coherent and detailed strategy, focusing on long-term public satellite demand, which includes identifying key participants and allocating appropriate budgetary resources.[12]

12. Korea Institute of S&T Evaluation and Planning, *2020 Technology Level Evaluation*, 2020.

Considering the entry into foreign export markets, a substantial domestic demand of a specific scale is indispensable. This is particularly evident in the launch vehicle market, where the American SpaceX is a pertinent example. SpaceX's ability to supply launch vehicles globally at much lower costs can be partly attributed to the economic benefits derived from the scale of the US domestic launch service demand. While it's true that SpaceX's successful development of reusable launch vehicles further reduced launch costs, this technological breakthrough was underpinned by the economic advantage gained from the reduced average costs due to the economies of scale provided by the vast US market. These gains enabled SpaceX to reinvest in developing reusable launch vehicle technology and further cost-reduction strategies. The market dominance achieved by SpaceX allowed for reinvestment in high-risk, cost-reducing technologies like reusable launch vehicles.

Conversely, if the domestic market is not sufficiently large, establishing the industry becomes challenging, and entering the export market is not easy. Therefore, the global competitiveness of a national space industry is intricately linked not only to technological capabilities but also to the size of its domestic market.

Given the current situation of insufficient domestic demand, expecting active market participation and investment from companies is challenging. Additionally, from the government's perspective, it is difficult to find economic advantage in procuring satellites from industry players rather than developing them in-house, especially when only a single new satellite is being developed. For instance, if the costs associated with materials, labor, and technology levels are similar, there would be little difference in the budget required for satellite development. When considering factors like responsibility for development failures or the continuity and reliability of the project, direct government development might even prove more advantageous. This is because government-led development can mitigate risks and ensure long-term project stability, often essential in satellite development's high-stakes and technologically complex field.

Supply-side

The current status of the space development workforce in the South Korean industry can be summarized as follows, based on data from 2021. The number of employees in industrial firms in the space equipment manufacturing sector is 2,225, in research institutions 727, and in universities 352. Additionally, the workforce in research institutions and universities has increased by approximately 2.5% and 12.7%, respectively, compared to the previous year, while the workforce in companies has increased by about 24.7%.

Despite this growth, when comparing these numbers to international standards, particularly with companies like SpaceX in the United States, which employs around 10,000 individuals, the absolute scale of the South Korean space industry workforce seems relatively small. This comparison highlights a significant gap in workforce scale, which could limit the overall capacity and competitiveness of the domestic space industry. The relatively smaller workforce in South Korea might also reflect limitations in industry size, research and development capacity, and the scope of space projects undertaken domestically.

The current state of capital investment in the South Korean space industry, as indicated in the data for 2021, reveals a relatively low level of investment by companies involved in this sector. These companies' total investment in the space sector amounted to KRW 205.8 billion. Of this, the largest proportion, 73.1%, was allocated to research and development, amounting to KRW 150.5 billion, while facility investments totaled around KRW 54.6 billion.

Table 2: Number of workforce in upstream in 2020 and 2031

Sector	2020				2021				YoY(%)			
	Total	Firms	Research institute	University	Total	Firms	Research institute	University	Total	Firms	Research institute	University
Satellite	1,476	1035	240	201	1,614	1,178	276	160	8.6	12.1	13.0	-25.6
Launch vehicle	1,194	824	248	122	1,521	1,069	259	193	21.5	22.9	4.2	36.8
Ground station	382	276	102	4	485	361	124	-	21.2	23.5	17.7	
Launchpad	307	231	71	5	380	312	68	-	19.2	26.0	-4.4	
Insurance	39	39	-	-	35	35	-	-	-11.4	-11.4		
Total	**3,398**	**2225**	**709**	**308**	**4,035**	**2,955**	**727**	**353**	**15.8**	**24.7**	**2.5**	**12.7**

Source: Korea Space Industry Survey 2022.

This data suggests that, while there is a focus on research and development in the space industry, the overall investment level is modest, especially when compared to the scale of investments in leading space industries globally. This disparity in investment could influence the pace of technological advancements and the ability of South Korean companies to compete on the international stage. The relatively smaller investment in facilities might also reflect limitations in manufacturing and testing capabilities, which are crucial for scaling up space operations and manufacturing more advanced space equipment and vehicles.

Table 3: Investment in space in 2021

	Firms		Research institute		University		Total	
	Cost	%	Cost	%	Cost	%	Cost	%
Total	**205,826**	**100.0**	**57,726**	**100.0**	**1,264**	**100.0**	**264,816**	**100.0**
R&D investment	150,522	73.1	28,848	50.0	1,114	88.1	180,484	68.2
Facility investment	54,634	26.6	28,804	49.9	86	6.8	83,524	31.5
Education and training	670	0.3	74	0.1	64	5.1	808	0.3

(unit: KRW million)

Source: Korea Space Industry Survey 2022.

In assessing the actual capital investment scale of companies in the space industry, it is necessary to focus on facility investment rather than research and development (R&D) expenses. This is because a significant portion of the corporate R&D investment amount compiled in the space industry status survey appears to include parts of the government's space development budget, counted as corporate R&D expenses due to R&D agreements. Therefore, viewing these R&D expenses as the companies' own investment amounts is questionable. The total facility investment by approximately 400 companies in the space sector is only about KRW 26 billion, which differs from the combined facility investment of 25 research institutions, predominantly related to the Korea Aerospace Research Institute. This suggests that domestic capital investment in the space sector remains very low.

On the other hand, the reason for the low level of capital investment by domestic companies is not deemed to be due to difficulties in raising funds from the private capital market. This is because, until recently, investment by venture capital in space sector startups has been relatively active, and equity investments – such as acquisitions and mergers of domestic and foreign space companies by large corporations – have also been notably brisk. Between 2018 and 2021, domestic startups such as Contec, Nara Space, and Perigee Aerospace raised about KRW 84.4 billion from private venture capital. Additionally, domestic conglomerates' substantial investments in space companies have begun to surface, including Hanwha Systems' US$ 300 million investment in OneWeb, Hancom's acquisition of InSpace, and Hanwha Aerospace's acquisition of Satrec Initiative. While direct comparison with foreign investments is difficult, it is evident that venture capital and large corporations in Korea have been actively investing in the space sector.

Meanwhile, the level of technology is a critical element in understanding the supply sector of the space industry. Regarding the current status of domestic development ratios for each technical element of practical-grade government satellites, one of the most commercially mature areas of domestic space technology, Table 4 indicates that payload technology is less mature than the main body technology. Additionally, according to the Korea Institute of Science and Technology Evaluation and Planning (2020), while the localization rate (in terms of number and cost) of parts/items is improving, technological elements such as the main body and payloads have long depended on overseas purchases. It identifies the primary reasons for the low localization rate: the demand from departments for high project success probability, the increase in part performance conditions and unit cost according to development difficulty, and the preference for proven acquisition methods due to issues such as the development period. Therefore, it can be seen that, even in the case of the most commercially mature satellite development, a significant portion of core components, including payloads and main bodies, still relies on foreign companies. This situation underscores the continuous need for efforts in developing original technologies for these core components.

Table 4: Domestic R&D in satellite development in Korea

	Subsystem	COMPSAT		GEO-COMPSAT	CAS500
		COMPSAT-5	COMPSAT-3A	2A/2B	1, 2
Bus	Structure	4/4	4/4	5/6	2/3
	Thermal control	3/6	4/7	4/6	2/4
	Attitude and orbit control	2/7	2/6	2/7	2/6
	Propulsion	3/4	3/4	0/8	2/7
	Electrical power	3/5	3/5	3/6	3/5
	Telemetry, command & ranging	3/7	3/7	1/4	3/5
	Software	n/a	n/a	6/6	2/2
	Data Management	n/a	n/a	2/6	n/a
	total	18/33	19/33	23/49	16/32
Payload		SAR Electronics (0/6) SAR Antenna (0/4) Data Transmission (0/3) Payload Module (1/4)	Optical System (2/3) Structural System (1/1) Imaging Electronics (4/7) Data Transmission (2/6)	Meteorological Payload (0/4) Space Weather Payload (4/4) Marine Payload (0/3) Environmental Payload (0/4)	Optical System (3/3) Structural System (2/2) Imaging Electronics (3/4) Data Transmission (4/4)
	Total	1/17	9/17	4/15	12/13

Source: KISTEP (2020).

On the other hand, apart from the technologies developed by the government, companies have begun to develop satellites and small launch vehicles independently in anticipation of future domestic and international demand. Some of these companies have already entered the export market in areas like Earth observation satellites and satellite antenna manufacturing. Therefore, it can be seen that these companies' technology levels are growing rapidly.

Concerning the space technology levels of these companies, it is necessary to mention the uniqueness of the space sector. Especially in space equipment manufacturing, testing in the space environment is essential to prove the technology's performance, leading to various practical constraints in developing components and sub-components. Introducing a support policy that regularly launches government technology demonstration satellites, which can test components developed by the industry in space, would be of great help in growing these companies' domestic space technology.

Institutional framework

To harness market functions for space development, demand and supply must find a smooth equilibrium through the establishment of systems like pricing and competitive markets. Particularly in the space sector, where the government is a primary consumer, products and services are not freely traded in the market and are subject to various legal and regulatory constraints from development to launch. Recent improvements in transactions between corporations and the government, such as government procurement contracts and R&D agreements, as well as various legal regulations like licenses and permits necessary for businesses to operate in the space industry, play a vital role in market formation.

Traditionally, government space development projects have established satellite development plans through departmental demand surveys, followed by preliminary feasibility studies to finalize the development plans before commencing the projects. Such an approach, where the government plans the development of satellites or launch vehicles and assigns research and development tasks to public institutions or industrial entities, is unsuitable for industrialization. This is because the long-term demand is uncertain, making it difficult for companies to plan for the future and invest proactively. Moreover, this approach does not encourage companies to introduce new ideas or technologies or to develop new products and services. It also fails to adequately reflect rational pricing or cost reduction for space products and services. Although future defense budgets and mass production projects will undoubtedly contribute substantially to the quantitative growth of the domestic space industry, a shift in perspective as well as legal reforms are essential to achieve the goal of civilian-led space development, similar to in other advanced countries. It

is necessary to revise laws related to various licenses and permits to allow companies more freedom to test and produce space products and services and to introduce more flexible legal systems so that the government can support and purchase new space products and services developed by domestic space startups.

A shift in approach is required from a research and development service-centered model to a market-oriented perspective to establish and grow the space sector as an industry driven by private enterprises. This would involve the government purchasing necessary space infrastructure and services from industrial entities at reasonable prices. Under the current system, even if an industry develops space technology under government contracts, the initial stages of development often do not adequately consider aspects like exportation or commercial utilization. This lack of foresight can lead to a scenario where technologies must be redeveloped from scratch for cost reduction when entering export markets.

It is now crucial for the government to focus on long-term demand and target performance for the space infrastructure and services it requires. This involves defining the space products and services needed by various government agencies and supporting their acquisition from industry at fair prices through long-term planning and establishing related laws and regulations. Such policies can mitigate the uncertainty in demand for the space industry, encouraging participation from companies and spontaneous investment from private capital. In this process, cost reduction and technological innovation driven by the companies themselves can create new products and services that were previously unavailable. In cases where the development of critical technologies, such as specific payloads for unique missions, is required, collaborative efforts between government research institutions, universities, and industries are essential. The strengths and weaknesses of research institutions, universities, and enterprises should be considered to enable their effective participation in diverse space development projects.

As previously mentioned, a regulatory framework is necessary for the government to procure space products and services developed by emerging domestic space startups flexibly. Startups like Inno Space and Nara Space Technology are developing small launch vehicles and nanosatellites. Still, the current national space development project structure lacks the flexibility for the government to purchase and use these technologies promptly upon their successful development. Without sufficient domestic demand, these space startups risk not making it through the “valley of death”, leading to the potential loss of their developed technologies.

Additionally, regarding new ventures in the space sector, various safety-related regulations and permits will be required. Business operations can be delayed if relevant systems are not established in time. This has been observed in the mobility industry with car-sharing services and drones,

where conflicts with laws and regulatory issues have hampered business operations. Specifically, the small launch vehicle business faces potential delays due to safety and regulatory various problems related to licensing and permits. Such delays can be particularly detrimental for startups attempting to get through the “valley of death”.

The changing space policy landscape and South Korea's space strategy

Space development strategy

South Korea began to formulate a systematic space strategy in the mid-1990s and put an implementation framework in place. The space strategy has been implemented in three phases. Phase I began in April 1996 by establishing the "Mid- and Long-Term Basic Plan for Space Development." The plan served as the basic framework for South Korea's space strategy; it was revised and supplemented three times, in November 1998, December 2000, and May 2005.[13] The plan set the indigenous development of low-orbit satellites and launch vehicles as a critical goal of the space strategy by 2010. The Korean government also sought to lay the groundwork for developing liquid-fueled engines and multi-purpose commercial satellites.

South Korea upgraded to the 2nd phase of its space strategy in 2007 by establishing the "Basic Plan for the Promotion of Space Development."[14] This plan was revised four times (2012, 2014, 2018, and 2021) to reflect changes in the domestic and international environment. Based on the Basic Plan, South Korea succeeded in developing indigenous launch vehicles such as the Naro (KSLV-I) in January 2013 and the Nuri in 2022, as well as high-performance multi-purpose satellites.[15] Based on these achievements, South Korea has developed plans for lunar exploration and participated in the commercialization of space, mainly in the satellite sector.

With the finalization of the "Fourth Basic Plan for the Promotion of Space Development" in December 2022, South Korea's space strategy entered its 3rd phase. In this plan, unveiling a vision of "Aspiring to Be a Global Space Economic Power by 2045', South Korea set policy goals in areas such as expanding space exploration, increasing investment in space development, and creating a private space industry.[16] By expanding its

13. The Ministry of Science and Technology, Ministry of National Defense, and Ministry of Industry and Energy, *Mid- and Long-Term Basic Plan for Space Development Amendment*, 2005 (in Korean).
14. The Ministry of Science and Technology et al., *The First Basic Plan for the Promotion of Space Development*, 2007 (in Korean).
15. Korea Aerospace Research Institute, "Naro, Korea's First Space Launch Vehicle", 2023, available at: www.kari.re.kr (in Korean); Korea Aerospace Research Institute, "Nuri, the Korea Launch Vehicle", 2023, available at: www.kari.re.kr (in Korean).
16. *The Fourth Basic Plan for the Promotion of Space Development,* op. cit. (in Korean).

space exploration plans, creating a private sector-led space ecosystem, and pursuing the development of leading-edge technologies, South Korea plans to become a space power.

These goals reflected the assessment that changes such as the expansion of newspace, full-scale space exploration, intensifying global competition, and the increasing value of space development would promote the advent of the space economy era. First, the active use of private capital and technology in space development, traditionally dominated by the public sector, revolutionizes how space is developed. New services such as reusable launch vehicles, space debris removal, low-orbit satellite internet, and space tourism are expected to multiply. Second, not just the US, which plans to establish a manned base on the Moon in 2028 through its Artemis program, but China, Russia, India, and Japan are competitively pursuing plans to explore the Moon and Mars. Third, these countries are establishing new space policies and expanding their space budgets to commercialize the space industry and successfully promote space exploration. Fourth, satellite information, combined with AI and big data, has the potential not only to facilitate the development of related industries but also to respond to global issues such as climate change and natural disasters.[17]

Based on this forecast, in December 2022, the National Space Commission (NSC) finalized a space plan with three goals: (1) expanding the space exploration area with the goal of landing on the Moon in 2032 and Mars in 2045, (2) doubling the government's investment in space development by 2027, and (3) creating a private space industry to expand the space industry's share of the global market. In space exploration, South Korea has set key targets for a lunar landing and surface mission in 2032 and a Mars landing in 2045. In space development, the Korean government's investment will increase from KRW 0.73 trillion to KRW 1.5 trillion in 2021. Regarding the creation of a private space industry, the goal is to increase South Korea's share of the global space industry from 1% in 2021 to 10% in 2045.[18]

To realize these goals, the Korean government believes it is time to shift to "Space Development 2.0", which is differentiated from existing policies.[19] First, Space Development 2.0 sets five long-term space development missions as strategic goals to propose two action plans. The plans aim to maximize the economic and social impact of space development by pursuing long-term missions that integrate space exploration with expanding space economic infrastructure. This is based on the judgment that challenging missions can only be achieved by integrating

17. J.-B. Im, "Issue Analysis: Changing Space Policy Trends and Implications for Major Countries", *Science, ICT, Policy and Technology Trends*, No. 238, 2023, pp. 1-15 (in Korean).
18. "Doubling the Space Development Budget in 5 Years ... Building the Space Triangle", *The Science Times*, December 22, 2022 (in Korean).
19. *The Fourth Basic Plan for the Promotion of Space Development*, op. cit. (in Korean).

existing strategies that focus on technology development in individual fields with the establishment of space infrastructure. The plans also conceive technology development as an essential element for space development missions and the creation of new industries. Similarly, the Korean government believes that it is crucial to foster technological innovation by expanding infrastructure such as industry, governance, international cooperation, and training specialized personnel. In short, at the core of Space Development 2.0. is the creation of a virtuous cycle between securing advanced space technology capabilities and expanding space economy infrastructure.

The detailed strategy for achieving the new strategic goals consists of five pillars: (1) expanding space exploration (promoting independent space exploration), (2) perfecting space transportation (i.e., space transportation service capabilities and infrastructure), (3) creating a space industry (fostering the space industry as a major industry), (4) establishing space security (i.e. space and ground security support systems), and (5) expanding space science (promoting leading research led by domestic capabilities). The detailed strategy is based on the judgment that expanding the scope of space activities is essential to nimbly respond to changes in the space world order.[20]

First, in envisaging space activities to broaden South Korea's economic territory, the plan aims to secure the capability to conduct manned and unmanned activities in deep space. Against this backdrop, South Korea has set specific goals of landing on the Moon in 2032 and Mars in 2045. To this end, the Korean government thinks pursuing advanced space technology in parallel with building a space economy is essential. This is a departure from the previous space strategies, prioritizing indigenous development of launch vehicles and satellites. Instead, the Fourth Basic Plan focuses on a balanced approach to strategy between subfields such as launch vehicles, infrastructure, satellite services, space exploration, and science. The Korean government expects that this balanced approach will facilitate constructing a space industry ecosystem and establishing national-level space governance.

Second, South Korea aspires to nurture its space transportation capacity to become the "Asian Space Transportation Hub" in the space economy era in preparation for the surge in demand for space transportation of people and logistics. Specifically, the plan aims to achieve an unmanned hydrogen capability by 2030 and a manned transportation capability by 2045. The government seeks the establishment of a private sector-oriented space industry cluster since implementing these plans will require various capabilities, including various orbital transport launch vehicles, multiple launch sites, space system manufacturing infrastructure, and unmanned and manned transport vessels.

20. Ibid.

The third pillar is to promote the space industry as a flagship industry in South Korea. In October 2022, the Korean government designated 12 national strategic technologies, including semiconductors, secondary batteries, advanced bio, and aerospace.[21] In this initiative, the government plans to foster the space industry as one of its ten flagship industries by 2045. The core of the strategy is to build a private sector-led space industry ecosystem to explore overseas markets in line with the global trend of commercialization of the space industry. In the initial stage of the space ecosystem, the government is attempting to create a domestic market by using public-private partnerships and then taking a sequential approach to enter the global market by accumulating competitiveness in the manufacturing sector, such as in space materials, parts, and equipment, and in the service sector, such as in satellite navigation and satellite communication.

The fourth pillar is to establish space security to ensure the safety of people on the ground and in outer space through the protection of space assets. The Korean government prioritizes building a domestic infrastructure by upgrading surveillance, prediction, and space cybersecurity capabilities in 2030. In addition, it aims to secure capabilities on a par with advanced countries by building an active protection system by 2040. The government stresses that it is crucial to increase the number of satellites needed to secure disaster observation data and the observation equipment required to establish a space surveillance system, including space situational awareness and traffic management. Through these efforts, the Korean government is expected to improve its response capabilities concerning space debris and other space threats, for which it currently has only basic technology, and to operate satellites to remove space debris.

By expanding space science research, the fifth pillar aims to contribute to realizing the universal human goal of expanding knowledge while enhancing South Korea's international status. The key goals are to increase research capacity through a multidisciplinary approach to space science in 2030 and to take the lead in significant space science missions by 2040. Specifically, the plan is to participate in international collaborations to study the origin of the universe and life in space in the short term, to conduct independent tests using space stations in the medium term, to link them with manned space programs in the long term, and to identify and lead large international space programs. In pursuing these strategies, the Korean government expects to preemptively develop future space exploration technologies and realize goal-oriented space missions by establishing a long-term vision for space exploration and cooperative space development between industry and academia.

21. Office of the Secretary of Science and Technology, Presidential Office, "12 National Strategic Technologies, Responsible for Korea's Technological Sovereignty", October 28, 2022 (in Korean).

Military space strategy

As witnessed in the Russian-Ukrainian war, space has become increasingly important as the 5th war domain. Moreover, given the constant security threats from North Korea and the intensifying military space race between neighboring countries, South Korea needs urgently to improve its military space capabilities. However, the security landscape South Korea faces poses a daunting challenge. While South Korea works on a satellite surveillance system to monitor North Korea, it suffers from an absolute lack of indigenous space assets for surveillance. Since North Korea has advanced its nuclear and missile launching capabilities, South Korea needs to develop early-warning capabilities for North Korean ballistic missile threats and independent satellite surveillance systems for reconnaissance of the North Korean region. This requires South Korea to increase investment and manpower and embark on restructuring institutions and organizations governing space strategies and operations.

The South Korean government has developed a three-stage plan to overcome these limitations. The first stage is to enhance its space surveillance capabilities and space intelligence support capabilities by 2025. The second stage is to strengthen its space operations capabilities by 2030. Finally, in the third stage, the government will build a space strategic investment capability, if not full-scale. Based on the step-by-step plan, the Ministry of National Defense (MND) developed a plan to develop defense space capabilities and set the long-term goal of "securing the ability to conduct space operations led by the Korean military".[22]

The Korea-US Missile Guidelines, which limited the range and warhead weight of missiles, was an obstacle to the development of South Korea's space capabilities. However, the revision of guidelines in 2021 paved the way for South Korea to upgrade its space development capabilities and strengthen its space military capabilities. Finally, the MND is working to improve its space strategy, including reconnaissance satellites, and establish a system for conducting joint space operations. In terms of governance, South Korea established the Security Space Development Working Committee under the National Space Commission in November 2022, creating an institutional foundation for strengthening defense space capabilities in conjunction with the National Space Development System.

In accordance with the MND's direction for the construction of defense space power, the Defense Acquisition Program Administration (DAPA) established a plan to develop space weapons systems through the Master Plan for the Development of Space Defense Business. A total of five military reconnaissance satellites will be developed and deployed, led by DAPA and

22. S.-J. Park, "Advancing the Defense and Space Security System", *Space Policy Research* 7, 2023, pp. 30-61 (in Korean).

the Agency for Defense Development (ADD). The first of these, Military Reconnaissance Satellite 1, will be launched in 2023 aboard a Falcon 9 from Vandenberg Air Force Base in the United States.[23]

In June 2021, ADD also established the Defense Space Technology Center (DSTC), a multi-faceted effort to advance technology and foster industry in the defense space sector. In parallel with DAPA's strategy for defense space technology development and industrialization, the DSTC is expected to play a significant role as a provider and leader of defense space technology and to promote the research and development of defense space power rapidly.[24]

23. Defense Acquisition Program Administration, "Military Reconnaissance Satellite 1 Launched in November ... Demonstration of 'AI Pilot' This Year", *Yonhap News*, February 17, 2023, available at: www.yna.co.kr (in Korean).
24. "Completed Reorganization, Including Launch of Defense Science Laboratory and Defense Space Technology Center", *Defense Today*, June 22, 2021, available at: www.defensetoday.kr.

International cooperation strategy

Bilateral cooperation with the United States is the primary source of South Korea's strategy for space cooperation. The signing of the Korea-US Space Cooperation Agreement in April 2016 was a catalyst for deepening and expanding bilateral cooperation. Considering that, as of 2016, only 11 countries, including Russia, Canada, and France, had signed the US Space Cooperation Framework Agreement, the signing of the Korea-US agreement signaled that the United States had recognized South Korea's space technology and the bilateral relationship was upgraded to a strategic alliance. In this agreement, the two countries agreed to cooperate in various fields such as space science, earth observation, and space exploration, an opportunity to develop Korea's space industry capabilities. The Korea Aerospace Research Institute (KARI), Korea Astronomy and Space Science Institute (KASSI), Korea Meteorological Administration (KMA), Korea Agency for Infrastructure Technology Advancement (KAIA), and Korea Advanced Institute of Science and Technology (KAIST) were designated as implementing agencies to ensure effective implementation of the agreement.[25] In June 2021, South Korea became the 10th country to join Artemis, culminating in the strengthening of Korean-US space cooperation. South Korea expanded its involvement in Artemis to participate in the Commercial Lunar Payload Services (CLPS) and by deploying the NASA-built ShadowCam on board Danuri, the Korea Pathfinder Lunar Orbiter (KPLO), South Korea's first lunar orbiter.[26]

The bilateral summit between President Yoon Suk Yeol and President Joe Biden in 2023 was a watershed in Korea's space cooperation. The two leaders agreed that the two countries would further elevate the bilateral relationship to a "space alliance." Following the summit, the South Korean Ministry of Science, ICT, and NASA agreed to identify cooperation projects in various fields, including lunar exploration programs, global positioning systems, and space exploration.

25. "[Korea-U.S. Space Cooperation Agreement Signed] South Korea Gains Foothold in 350 Trillion Won Global Space Market", *Dong-A Science*, March 1, 2016, available at: www.dongascience.com (in Korean).

26. "South Korea Becomes the 10th Country to Join the Artemis Covenant, an International Collaboration for Manned Lunar Exploration", *Korea Policy Briefing*, May 27, 2021, available at: www.korea.kr (in Korean).

South Korea has tried to broaden space cooperation to include emerging space countries. In 2017, it signed a space cooperation MoU with Australia to collaborate on atmospheric observation, lunar exploration, and deep-space exploration. South Korea also signed a Space Cooperation MoU with Australia in December 2021 to establish a comprehensive and strategic partnership in space, following the signing of a Science and Technology Cooperation Agreement in 1999.[27] In January 2023, South Korea revised its space cooperation MoU with the United Arab Emirates Space Agency to expand cooperation to include peaceful space exploration, satellite communications, satellite navigation, space science and technology, and experimental verification.[28]

South Korea also signed a space cooperation MoU with Luxembourg in November 2022, which is expected to open a new chapter in Korea's international cooperation in space. Luxembourg's space policy and governance strengths, as evidenced by its unique Space Resources Development Law, are highly complementary to Korea's manufacturing capabilities. Moreover, Luxembourg has established a cooperation system with major European space development organizations such as the European Space Agency (ESA) and the European Space Resources Innovation Center (ESRIC), which is expected to serve as a bridgehead for South Korea to expand space cooperation.[29]

South Korea is also strengthening space cooperation with France. In May 2023, the South Korean Ministry of Defense signed a "Letter of Intent for Defense Space Cooperation" with the French Ministry of Defense. The two countries agreed to participate in international space exercises organized by France and conduct joint research on space policy.[30] The signing of the letter of intent with France, a traditional space leader, marks an expansion of the frontiers of South Korea's space cooperation in terms of expanding military cooperation and diversifying space cooperation.

South Korea's traditional international space cooperation focused on acquiring technology to develop satellites and launch vehicles. Since the 2010s, South Korea has rapidly expanded the number and scope of its space cooperation partners by leveraging its growing space industry capabilities, including the successful launches of the Nuri and Danuri. South Korea is simultaneously developing its capabilities to explore the Moon and Mars and pursuing international cooperation to build a manned station and

27. The Ministry of Science and ICT, "Press Release: Korea-Australia Memorandum of Understanding (MoU) on Space Cooperation", December 13, 2021 (in Korean).
28. "Amended Memorandum of Understanding on Space Cooperation between Korea and the United Arab Emirates", *Economic Diplomacy Portal*, January 15, 2023, available at: www.president.globalwindow.org (in Korean).
29. "Korea-Luxembourg Sign MoU for Cooperation in the Space Sector (11.28)", Korea-EU Research Center, February 15, 2023.
30. "MND Signs Letter of Intent for Defense Space Cooperation with France, a Leading European Space Power", *Korea Policy Briefing*, May 31, 2023, available at: www.overtherainbow.korea.kr (in Korean).

manned exploration base. It is also seeking international cooperation for disaster and disaster response services in the Asia-Pacific region by 2030. It actively participates in the process of shaping international norms for space surveillance systems.

South Korea has also used international cooperation as a strategy to expand its space industry into the global market. The Korean government provides overseas expansion one-stop services to help domestic space companies expand into global markets by conducting overseas demand surveys and helping them respond to regulations in key countries. Furthermore, the Korean government uses official development assistance (ODA) and reciprocal trade to support South Korean space companies in expanding overseas markets.

Accomplishments and future challenges

South Korea became the 7th country in the world to explore the Moon when Danuri, the Korea Pathfinder Lunar Orbiter (KPLO), successfully landed in lunar orbit in December 2022.[31] In the past, South Korea made significant strides in acquiring critical space systems, as well as indigenous satellite and launch vehicle manufacturing capabilities. In this period, the public sector took initiatives to enhance research capabilities and continuously expand infrastructure. Based on its achievements, South Korea is preparing to take a new leap forward to become an emerging space power in the newspace era. It seeks to expand the scope of its space policy from technology development to space exploration and science and to establish space development missions. To become a global space economy powerhouse by 2045, private sector participation in the space industry is essential.[32]

While South Korea has the basic capabilities to pursue space development independently, a significant gap exists between South Korea and the most advanced space nations. While it has succeeded in developing its own satellites and small and medium-sized launch vehicles, such as Naro, Nuri, and Danuri, in a relatively short period, it has not yet been able to use them to create economic effects and address social challenges. Also, private companies' ability to develop new markets and form a self-sustaining space industry ecosystem is still lacking.

South Korea has sought to strengthen the governance of its space policy, reflecting the expansion of the space policy domain to include space exploration, the space industry, and space diplomacy, as well as the increasing number and diversification of actors involved in space development. Strengthening policy coordination is a key to space policy governance. For this, the government is currently working on establishing the Space and Aeronautics Agency to address this issue, reflecting the need for a dedicated space development organization that can oversee and execute space policy. Also, the establishment of the Space and Aeronautics Agency is expected to consolidate space R&D capability.

31. Korea Aerospace Research Institute, "Danuri, South Korea's First Lunar Rover", 2023, available at: www.kari.re.kr (in Korean).
32. The Ministry of Science and ICT, "Fourth Space Development Promotion Basic Plan: Realization of a Space Economy Powerhouse by 2045", 2022 (in Korean).

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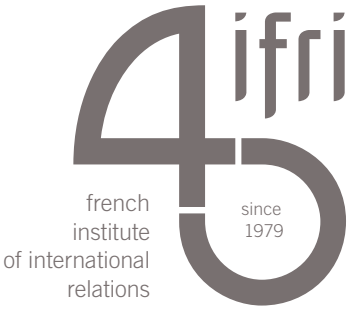

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