

Suggestions on Measures to Strengthen South Korea-India Space Cooperation in the New Space Era

Geunho Song

Abstract

This study explores ways to strengthen space cooperation between South Korea and India to enhance Korea's space power while discerning the cutting-edge space exploration capabilities of India, which recently succeeded in landing a moon rover on the moon's south pole for the first time in the world. Along with the United States, Russia, and China, India is recognized for its state-of-the-art space technology. It is the sixth country in the world to launch a practical satellite on its own in 1980 and the fourth country in the world to successfully send a lunar probe in 2008. India's success of Chandrayaan-3 landing on the south pole of the Moon in August 2023 surprised the world once again. Until now, there has been little international space cooperation between Korea and India when compared to the extent of South Korea's space cooperation with the United States, Russia, and European countries. South Korea must find ways to increase its national space power in the era of the space economy through space cooperation with India, an emerging powerhouse with advance technology, which continues to advance its space technology through international cooperation. Thus, South Korea's space cooperation with India can help improve Korea's space science technology in the future, including successful moon landing and Mars exploration.

Key Words: *Space cooperation, Chandrayaan-3, India Space Research Organization (ISRO), Korea Aerospace Agency (KASA)*

Introduction

On August 26, 2023, India's Chandrayaan-3 Moon Lander successfully landed on the moon's south pole. India is the fourth country in the world to land on the moon, following the United States, the Soviet Union, and China. The success of the moon's landing on the south pole was India's first remarkable achievement in the world, although India has a long history of space activities as an advanced country in space development. India's lunar exploration marked a milestone for mankind's exploration and settlement of the moon and its establishment an outpost for future Mars exploration through the study of icy water on the moon's south pole.

In November 2022, President Yoon Suk Yeol released a roadmap for the future space economy that included plans to successfully land the moon by 2032 and send a probe to Mars by 2045, which would help the Republic of Korea become a space economy powerhouse. It proposed policies that would allow Seoul to explore the moon and Mars, leap to become a space technology power house, foster the space industry, cultivate space talent, realize space security, and strengthen international cooperation in the direction of six major policies.¹⁾ It announced plans to expand Korea's economic sphere to the space domain and strengthen international cooperation with advanced space powers to enhance Korea's space power.

In the era of New Space, where the private sector has emerged as a subject of space technology innovation and rocket launch costs have decreased significantly, major space-advanced countries are creating innovative space technologies through cooperation between the private sector and government to strengthen their space industry competitiveness and building space military forces to strengthen security.²⁾ In addition, global companies are using artificial intelligence and IT technology developing into the fourth industrial revolution to compete for new areas in the space market such as space Internet and space tourism services, which would provide new space services such as reusable space rockets and space debris removal.³⁾ Korea has been enhancing its space power through international cooperation and technological exchanges with countries such as the United States, European countries, and Russia while undertaking its own space development plans. South Korea must recognize the necessity of international cooperation in the era of new space as it seeks to become an advanced space powerhouse.

1) Presidential Office, "President Yoon Announces Future Space Economy Roadmap," Nov. 28, 2022, <https://www.korea.kr/news/policyNewsView.do?newsId=148908812>(accessed on Oct. 27. 2023).

2) Hague Centre for Strategic Studies, "The New Space Era," <https://hcss.nl/space/>(accessed on Oct. 26. 2023).

3) Ahn Hyun-joon and Park Hyun-joon. 2021. "A plan to expand public-private cooperation to enhance the competitiveness of the space industry in the new space era." *STEP Insight*, No. 273.

Until now, research on Indian space activities has focused on analyzing India's development of space launch vehicles, such as its evolution and history of rocket development. Reviewing India's rocket development trends, Yoo Jae-han analyzed the types and development process of space launch vehicles in India.⁴⁾ Han Young-min examined the ability to develop space launch vehicles, concluding that India's space programs developed satellites and space launch vehicles on its own with a focus on direct space development that would provide convenience for their citizens.⁵⁾ While analyzing India's space development budget, Lee Jun noted India's current interests in satellite communication, satellite navigation, space exploration, Earth observation, and space launch vehicle, as well as major space project plans.⁶⁾ Scholars overseas have studied India's international space cooperation. In one of the seminal works on the subject, Khalid pointed out that the United States and India have been in space cooperation since 1962 to deal with the common security threat of China. Khalid added that US aerospace companies are conducting various space development cooperation programs with ISRO.⁷⁾ Grupurasad paid attention to India's space development cooperation with advanced countries such as the United States, Russia, France, Germany, the United Kingdom, Japan, and Israel. India has improved its space technology through international space cooperation. Recognized as a major partner in international space development and commercial benefits, India has successfully carried out the national space program, which is internationally recognized for excellent space technology.⁸⁾ Sourbès-Verger emphasized the importance of space in a number of global security areas, including defense, climate change, natural disasters, environmental and water management, while recognizing space as an important area in security. Through space cooperation, India and the EU can achieve the goals of both countries, such as promoting mutual interests in the international community.⁹⁾ Samson said that the United States and India, major space powers,

4) Yoo Jae-han. "Rocket Development Trends in India." 2021 Spring Conference of the Korean Society for Propulsion Engineering (2021): pp. 1-2.

5) Han Young-min et al., "History and development trends of space launch vehicles in India." *Aerospace Technology Development Trends* Vol. 9, No. 2, (2011), pp. 128-137.

6) Lee Joon et al., "Trends in Government Space Programs 2016." *Current Industrial and Technological Trends in Aerospace*, vol. 15, no. 2, (2017), pp. 57-58.

7) Munazza Khalid, "India-US space cooperation: Implications for the South Asian strategic stability," *Journal of Humanities, Social and Management Sciences (JHSMS)*, Vol. 2, No. 2(July-December 2021), pp. 55-66, <https://ideapublishers.org/index.php/jhsms/article/view/475> (accessed on Nov. 24. 2023).

8) B. R. Guruprasad, "Understanding India's International Space Cooperation Endeavour: Evolution, Challenges and Accomplishments," *India Quarterly*, Volume 74, Issue 4, December 2018, pp. 455-481, <https://doi.org/10.1177/0974928418802077> (accessed on Nov. 24. 2023).

9) Isabelle Sourbes-Verger, "EU-India Cooperation on Space and Security," *IAI(Instituto Affari Internazionali) Working Paper 16*, 2016. pp. 1-20,

have long cooperated in the private space sector but less in space security. India claimed that it could contribute to strengthening U.S. space security while insisting on promoting the strategic partnership between the two countries in space.¹⁰⁾

The review of the previous studies reveals that there has been little research by Korean scholars on international cooperation between Korea and India; if any, most of the studies were about India's satellites, rocket development, and space programs. However, overseas research is often concerned with India's space cooperation with major advanced space countries. Through their cooperation with India, developed countries are strengthening their space security and updating space technology. It is imperative to research international space cooperation between Korea and India as advanced countries in space actively cooperate with India.

India emphasizes the importance of international cooperation in space development in its 2023 space policy. India, which has emerged as a space powerhouse, is strengthening international cooperation to promote patriotism of the people and provide convenience to people's lives by securing advanced space technology. In the face of increasing international space cooperation, South Korea must strengthen its space power through international cooperation with advanced space countries. This study aims to discover the areas for space cooperation between Korea and India and to establish ways to strengthen their cooperation in space development. By comparing and analyzing the space capabilities of both countries to identify strengths, weaknesses, and complementary factors, South Korea and India will be able to strengthen their relationship as partners in space cooperation and strengthen their space capabilities in the future.

International trend of cooperation in space cooperation

Changes in the World Space Activity Environment

In the era of new space, the private sector has become the main body of space technology innovation and development, as its role in traditional government-led space development has been greatly expanded due to the development of private capital and high-tech capabilities. Competition in space exploration has become fierce worldwide as developed countries plan on manned exploration to the moon

<https://css.ethz.ch/content/dam/ethz/special-interest/gess/cis/center-for-securities-studies/resources/docs/IAI-EU-India%20Cooperation%20on%20Space%20and%20Security.pdf> (accessed on Nov. 24. 2023).

10) Victoria Samson, "U.S.–India strategic partnership in space, A path toward cooperation," *The future of U.S.–India security cooperation*, 30 Mar 2021, <https://www.manchesterhive.com/display/9781526155160/9781526155160.00018.xml> (accessed on Nov. 24. 2023).

and Mars. Since its launch in 2022, South Korea's lunar orbiter has been in operation and getting ready to explore lunar resources. Space-advanced countries have established and promoted space activity policies with an emphasis on expanding space exploration and fostering the private space industry. It promotes a shared understanding of space and creates new values and economies through new technologies. Particular areas for international cooperation include space exploration, satellite navigation systems, and space security, which require large budgets, because international cooperation enables the continuous operation of space programs and safe space services. The international community is working together to solve the common problems of mankind: major disasters, climate change, food security, and space threats. As space technology improves the quality of life and becomes a key factor in social and economic development, international cooperation in outer space will increase.¹¹⁾

Areas and targets of international space cooperation

In the era of new space where private companies lead space activities, Korea can develop advanced space technology and develop Korea's space power through international cooperation with advanced space technology countries. Among a variety of space activities, we identify the following four areas where South Korea's space cooperation with India will greatly enhance South Korea's space power: 1) satellite navigation and the use of satellite information; 2) space exploration; 3) space transportation services; 4) and the training of experts in the space sector necessary for the development of Korea's space power. The first is satellite navigation and satellite utilization. India successfully launched and operated the Indian Regional Navigation Satellite System (IRNSS) satellite from 2013 to 2018, providing navigation and location information to the public. South Korea began to build the Korean Positioning System (KPS) in 2022. Technical cooperation with India, which has experience in developing regional navigation satellite systems, will no doubt help South Korea build its own.

Second, space exploration of the moon and Mars, resource discovery, and solar system research should be conducted. South Korea should have the ability to respond to the space exploration competition of advanced countries through its cooperation with India in space exploration, operating the U.S. Shadow Cam to shoot permanent shadow areas with NASA.

Third is the provision of space transport services. As an advanced country in the area of space launch vehicles, India has recently been conducting research on reusable launch vehicles and providing many services to the commercial space launch market. South Korea needs to secure technology to reuse space launch

11) Jeong Heon-joo, Baek Yu-na and Jeong Yoon-young. "Space and international development cooperation: an exploratory analysis of the achievement of sustainable development goals using space technology." *Social Science Research* 33, no. 2 (2022): p. 129.

vehicles to lower the cost of space launch vehicles and secure the ability to develop small launch vehicles to meet the demand for small satellite launches.

Fourth, training professional space personnel is a key component of the development of advanced space technology. Thus, Korea should promote international educational cooperation to train experts in science, technology, engineering, and mathematics (STEM) through exchanges with advanced space and IT talents in India.

As an analysis tool for the development of Korea's space power in this study, the scope and targets of space cooperation between Korea and India are as follows.

<Table 1> Areas and Contents of South Korea-India Space Cooperation

Category	Space cooperation field	Details
Korea-India Space Cooperation	Satellite navigation and satellite application	Regional satellite navigation service, satellite imagery analysis using AI and producing satellite information
	Space exploration	Space exploration and resource exploration activities such as lunar landing technology and Mars exploration
	Space transport service	Development of small SLVs, cooperation in the development of recycled SLV technology
	Training space experts	Cooperation in human exchange and STEM field education, internship program

Korea-India Space Policy and Space Power

Indian Space Policy and Space Power

Indian Space Policy

India's space development policy aims to support the people with space services, manage its large land efficiently, generate profits from space development, and strengthen its space status around the world through space exploration.¹²⁾

In a new Indian space policy issued by the Indian Space Research Organization (ISRO) in May 2023,¹³⁾ India announced that it would focus on promoting private enterprise's participation and high-tech R&D in the space sector as it enters a new

12) Ahn Hyunjoon, "A Proposal of National Space Governance Reform according to Expansion of Space Development," *Policy Research* 2022-24, (2022): p.3.

13) ISRO, "Indian Space Policy 2023," April 6th, 2023, https://www.isro.gov.in/media_isro/pdf/IndianSpacePolicy2023.pdf (accessed on Oct. 24. 2023).

space era. India's space policy is expected to play a major role in establishing standards for the domestic space industry, promoting space activities, and expanding the space ecosystem. This revised the role of ISRO to focus on advanced space development research.

To overcome the limitations of India's space development, the new space policy focuses on promoting industrialization of space development by encouraging private activities and re-establishing the role of various organizations in the development of advanced space technology. It aims to expand India's space economy value from the current 2% to 10%, reduce dependence on foreign countries, and strengthen India's independent economic system.¹⁴⁾ It also sets a vision to enable, encourage, and develop a thriving commercial presence in space, acknowledging that the private sector is an important stakeholder in the overall value of the space economy.

India's newly announced space policy defined the role of ISRO in private-led space development. It emphasized the activities of various government departments and agencies to allow more private companies to participate, focused on high-tech research and development, and adjusted the scope of responsibilities that no longer require it to manufacture repetitive satellites and SLVs. According to ISRO, in the future, it will focus only on high-tech R&D while IN-SPACe (Indian National Space Promotion and Authorization Centre) will be in charge of India's space ecology development.¹⁵⁾ India recognized the limitations of government-led space development and specified its direction to become a space powerhouse through participation in private companies.¹⁶⁾

India also stressed the importance of the space domain in national security and announced its first national security strategy in 2019, saying it would develop military deterrence against possible conflict in space and protect India's space assets.¹⁷⁾

Indian Space Power

India began space development in earnest when it established the Indian Space Research Organization (ISRO) in 1969. To improve people's lives by developing satellites and space launch vehicles with its own technology, space development was carried out with national support. In 1980, India successfully launched a satellite using an Indian-developed Satellite Launch Vehicle (SLV) developed and successfully launched the Polar Satellite Launch Vehicle (PSLV) in 1994. In 2014, it successfully developed a Geosynchronous Satellite Launch Vehicle (GSLV)

14) ISRO, "Indian Space Policy 2023," pp. 5-6.

15) ISRO, "Indian Space Policy 2023," pp. 6-8.

16) Lee Seung-gi, "India's Upgraded Space Policy," *KOTRA Overseas Markets News*, 2023.5.15., https://dream.kotra.or.kr/dream/cms/news/actionKotraBoardDetail.do?MENU_ID=2430&pNttSn=202512# (accessed on Oct. 24. 2023).

17) India's National Security Strategy, March 2019, p. 41, https://manifesto.inc.in/pdf/national_security_strategy_gen_hooda.pdf(accessed on Oct. 24. 2023).

capable of putting satellites into a geostationary orbit that operates telecommunications and meteorological satellites. Korea's Uri Star 3 satellite was successfully launched by India's PSLV. PSLV succeeded in 50 out of 59 launches while GSLV succeeded 9 times out of 15 launches. The GSLVM-3 is the largest rocket in India's rockets, which improved the performance of the payload by improving the thrust of boosters and engines in the GSLV. The GSLVM-3 has succeeded in all seven of its seven launches, demonstrating the high reliability and superior rocket technology of India's space launch vehicle.¹⁸⁾

Since India participated in the international satellite launch market and, particularly, helped Algeria launch a satellite in 2010, it has maintained its competitiveness in the international satellite launch market. India is preparing to launch manned spacecraft and undertake space exploration. While developing space technology to secure independent technology, India's pace of scientific and technological innovation through international cooperation was accelerated, and its achievements in space activities were made possible through private-led technological innovation.

India began lunar exploration in 2008 with the development of the Chandrayaan-1 Orbiter. Chandrayaan-1, which used NASA's payload, contributed to confirming the existence of water on the moon. Although Chandrayaan-2's Vikram Lander crashed due to an operational failure of the thrusters, caused by a software error during a lunar landing descent, ISRO solved the problem by analyzing the cause of the crash.

Chandrayaan-3, an Indian unmanned lunar probe, made the world's first landing on the moon's south pole on Aug. 23, 2023.¹⁹⁾ Immediately after landing on the moon, the Pragyaan rover (exploration robot) mounted on the Vikram Lander explored 100m of the lunar surface and found traces of sulfur and metal. Before India landed on the moon, ISPACE, a Japanese private space company, crashed into the lunar surface due to an altitude recognition error, and Russia's Luna 25 failed to land. Therefore, India's successful landing on the moon was welcomed news around the world.²⁰⁾

The Moon's south pole is considered a critical area of lunar exploration as a large amount of water is likely to exist in ice. If water exists in the lunar south pole, it will be possible to obtain drinking water and oxygen, as well as hydrogen, which can be used as rocket fuel. Such a discovery will reduce the difficulty of exploring Mars and the outer planets of the solar system. In addition, the lunar south pole is rich in helium

18) ISRO, LVM3(Geosynchronous Satellite Launch Vehicle Mk III), https://www.isro.gov.in/GSLVmk3_CON.html (accessed on Oct. 22. 2023).

19) Lee Joon-ki, "Independent development, cost-effectiveness..." "Like Space Innovation India," *Digital Times*, 2023.8.2. (accessed on Oct. 20. 2023).

20) Nature, "India's Moon landing is a stellar achievement — and a win for science," Aug. 24, 2023, <https://www.nature.com/articles/d41586-023-02685-4> (accessed on Oct. 22. 2023).

isotopes (Helium-3) (the fuel for nuclear fusion) and rare mineral titanium, which increases the economic value of lunar resource mining.²¹⁾

India's Mars orbiter, Mangalyaan (Mars Craft), succeeded in entering Mars' orbit in September 2014. Mangalyaan orbited Mars, photographed the surface of Mars, collected atmospheric information, and sent it to Earth. India became the first Asian country and the fourth country in the world to send a probe to Mars, following the United States, the European Union, and Russia.²²⁾ As such, India is solidifying its status as an advanced space country in all areas of space, including space launch vehicles, satellite production, and space exploration.

Indian Prime Minister Modi announced his plan to send Indian astronauts to the moon by 2040.²³⁾ India is also developing a manned space development program to send Indian astronauts into Earth's 400 km orbit under the Gaganyaan Project, which has carried out major tests and plans to build a space station by 2035.

The Korean Government's Space Policy and Space Power

South Korea's Space Policy

In the era of New Space, where private companies lead the space industry, it is very important for Korea to expand the private sector's participation in space development projects. The Yoon Suk Yeol government has released a roadmap for the Republic of Korea to become a space economy powerhouse, which includes the policy direction until 2045. The six policy directives were proposed to lead the exploration of the moon and Mars, become a space technology power, foster the space industry, develop space talent, realize space security, and form international cooperation.

In December 2022, the National Space Development Commission reviewed and confirmed the 4th Basic Plan for the Promotion of Space Development. The 4th Basic Plan for the Promotion of Space Development is a major plan for the implementation of Korea's space economy roadmap in the future. To grow into a global space economy powerhouse by 2045, Korea has set five long-term space development missions for its space economy, seeking to expand investment in space activities and increase Korea's share of the global market from 1% to 10% by 2045.²⁴⁾

The first mission is to expand space exploration. The South Korean government

21) Park Jeong-yeon, "India's unmanned lunar lander successfully landed 'Moon's south pole for the first time in mankind." Dong-A Science, 2023.8.24.

<https://www.dongascience.com/news.php?idx=61326> (accessed on October 22, 2023).

22) NASA, "Mars Orbiter Mission," <https://science.nasa.gov/mission/mom/> (accessed on Oct. 22. 2023).

23) Sharmila Kuthunur, "India wants to land astronauts on the moon in 2040," Oct 19, 2023, <https://www.space.com/india-land-astronauts-moon-2040> (accessed on Oct. 27. 2023).

24) Ministry of ICT, "The 4th Basic Plan for the Space Development Promotion ('23-27)," <https://www.msit.go.kr/publicinfo/view.do?sCode=user&mPid=62&mId=63&publicSeqNo=3&publicListSeqNo=3&formMode=R&referKey=3,3> (accessed on Oct. 22. 2023).

announced its goal of successfully landing on the moon by 2023 and landing on Mars by 2045 to promote its independent space exploration plan to expand the space economy territory. It plans to secure unmanned exploration capabilities independently and strategically promote human space exploration, space stations, and exploration bases through international cooperation. Second, Seoul seeks to enhance space transport capability and build a space transport base as a hub for Asian space transport. By 2030, it plans to build unmanned transportation capabilities by improving launch capabilities and develop manned transportation rockets by 2045. Third, South Korea plans to grow the space sector into a major industry and build a world-class space industry ecosystem. Fourth, South Korea will establish space security. To ensure public safety, the South Korean government plans to build a space strategy that facilitates international cooperation by building the ability to respond to risks in space, such as collisions and falls of space objects, and by equipping Korea's space assets to ensure national security. Fifth, South Korea aims to expand space science. It plans to lead space research globally by cultivating space science talents, strengthening research capabilities, and introducing long-term space science research programs.

Discussions are underway on the establishment and operation of the Korea Aerospace Agency, which will serve as a control tower for Korean space activities. Providing initiatives to develop the aerospace industry by utilizing technologies such as electronics, electricity, and batteries as well as SLVs and satellite technologies will contribute to Korea's emergence as a powerhouse in the new space era.²⁵⁾ The Korea Aerospace Agency should play a major role in establishing and implementing the national space policy in the future.

South Korea's Space Power

On May 25, 2023, Korea successfully launched the next-generation small satellite-2 manufactured by KAIST into orbit by the Korean space launch vehicle(KSLV II), Nuri. With the success of the third launch of Nuri, South Korea has the ability to land a domestic practical satellite into space orbit. With the success of the third launch, along with the improvement of the reliability of the KSLV-II Nuri, Korea has secured its own space transport capabilities and gained independent national space development capabilities.²⁶⁾

South Korea has been operating satellites for various purposes since 1999. It

25) Kim Hyundai, "We must not miss the launch window of the Korea Aerospace Exploration Agency," *Maeil Economy*, 2023.10.20., <https://www.hankyung.com/article/2023102041351>(accessed on Oct. 22. 2023).

26) Ministry of Science and ICT, "Our own technology 'Nuri Lake' has been successfully launched for the third time... New Space Era Opens in earnest", *Policy Briefing*, May 26, 2023, <https://www.korea.kr/news/policyNewsView.do?newsId=148915600> (accessed on Oct. 22. 2023).

operates the multipurpose practical satellite (KOMPSAT), which is tasked with Earth observation missions, to provide remote sensing data to the public. Multi-purpose satellites contribute to national land monitoring, geological information, agricultural information, and disaster response by collecting various satellite information such as earth observation information using various sensors such as optics, infrared, and radar in low-Earth orbit.²⁷⁾ In the earth's geostationary orbit at an altitude of 36,000km, weather and environmental satellites are operated to produce weather, marine, and environmental information over the Korean Peninsula and provide public service.

Korea uses navigation services using GPS from the United States, but Korea does not have its own navigation satellite system. Accordingly, the Korean government began a project on the development of a satellite navigation system, the Korean Positioning System (KPS), in 2022 that would provide the location, navigation, and time (PNT) information essential for the operation of key national infrastructure such as transportation, communication, and finance. The KPS project will develop major KPS systems by 2035 and deploy and operate a total of eight satellites over the Korean Peninsula and geostationary orbit. Korea needs international cooperation with Japan and India as well as the United States and Europe to establish and operate its own satellite navigation system.²⁸⁾

In April 2023, President Yoon Suk Yeol proposed the establishment of the Korea Aerospace Agency (KASA), also known as the Korean NASA, to lead the country's space activities in general. In Korea, the establishment and operation of the Korea Aerospace Agency is essential to actively respond to the new space era in which private companies lead space activities and international cooperation. In the future, the Korea Aerospace Agency, a control tower for space development, should play an important role if Korea seeks to become an advanced space country.

About the global space program budget, the U.S. has the highest budget at \$61.97 billion, China has \$11.94 billion, France has \$4.20 billion, Germany has \$2.53 billion, and India has \$1.93 billion. By comparison, Korea has a very small space budget of \$724 million.²⁹⁾ It is very important to expand the space budget to support research and development in the aerospace field, implement the national space development plan, and improve Korea's national space technology.

27) KARI, "Korea Multipurpose Satellite (Arirang),"

https://www.kari.re.kr/kor/sub03_03_01.do (accessed on Oct. 22. 2023).

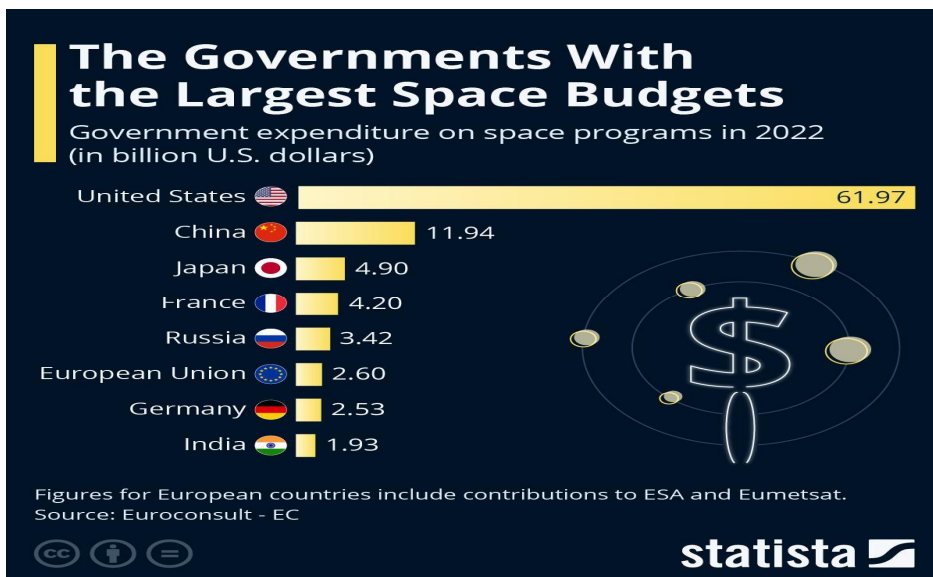
28) Ahn So-hee said, "The development of a Korean satellite navigation system is just around the corner... Leap Towers a Space Power", *Dong-A Ilbo*, 2022.9.20,

<https://www.donga.com/news/article/all/20220919/115518383/1> (accessed on Oct. 22. 2023).

29) Euroconsult, "Government Space Programs", 2021,

<https://www.euroconsult-ec.com/press-release/new-record-in-government-space-defense-spending-driven-by-investments-in-space-security-and-early-warning/> (accessed on Oct. 24. 2023).

<Figure 1> Governments with the largest space budgets



Source: Martin Armstrong, "The Governments With the Largest Space Budgets," Mar 7, 2023, <https://www.statista.com/chart/29454/governments-with-the-largest-space-budgets/> (accessed on Oct. 24, 2023).

System and Strategy for Strengthening Korea-India Space Cooperation

Korea-India Space Development Cooperation System and International Cooperation Status

The launch of the Korean Star 3 satellite using an Indian launch vehicle in 1999 highlighted the need for space cooperation between South Korea and India. In 2010, the Korea Aerospace Research Institute (KARI) signed an MOU with the Indian Space Research Organization (ISRO) for space cooperation in remote exploration, communication and navigation, space science, and manpower exchange. In addition, the Implementing Arrangement (IA) was signed between KARI and ISRO in 2014 to cooperate in space science and utilization, facilitate mutual cooperation in education and training, share space exploration scientific data, and hold joint workshops. In 2019, with the Indian prime minister's visit to Korea, a bilateral agreement was signed to promote cooperation between the two countries in space exploration and implement joint efforts to undertake space exploration.³⁰⁾ In the meantime, the MOU and IA on space cooperation between Korea and India have been concluded. Unfortunately, tangible results such as

long-term joint research projects, space exploration between the two countries, and space technology exchanges related to satellite utilization services were limited. Such a disappointing outcome was due to the lack of funds that supported the space cooperation project between Korea and India; a low level of South Korea's interest in space cooperation with India did not help. However, the leaders of the two countries agreed to strengthen space cooperation at the G7 meeting in Hiroshima in May 2023 and the G20 summit in India in September 2023, laying the foundation for future space cooperation between the two countries.

India and the United States are pushing to expand space cooperation between the two countries, led by the U.S. National Aeronautics and Space Administration (NASA) and the Indian Space Research Organization (ISRO). At the 2+2 Ministerial Dialogue held in April 2022, the two countries signed a memorandum of understanding on expanding space cooperation and planned to continue to cooperate on various projects, including the NASA-ISRO Synthetic Aperture Radar (NISAR) satellite scheduled to be launched in 2024.³¹⁾ In addition, India is collaborating with Japan on Lunar Polar Exploration (LUPLEX) to explore space resources on the moon. India will build a lunar lander, which Japan will launch with an H3 rocket, and Japan's Rover will explore the existence of water on the lunar surface.³²⁾

In order for Korea to strengthen space cooperation with India, Korea can analyze India's international cooperation cases and develop space cooperation programs and joint research fields.

South Korea's space development cooperation with India has been limited when compared to its cooperation with other advanced space countries such as the United States and Europe. South Korea's development of satellites was thanks to its technical cooperation with the United States, Israel, France, and Italy, while the development of rockets resulted from its technical cooperation with Russia and Ukraine. South Korea is recognized for its excellent space technology demonstrated by a number of Earth observation satellites and communication satellites and Nuri, the world's seventh-largest spacecraft to carry more than 1.5 tons of payloads. However, it lacks satellite transport and space exploration capabilities in geostationary orbit that other advanced space countries possess.

Instead of cooperating with India, South Korea has focused on space cooperation with the United States, Europe, and Russia. In addition, Korea's space cooperation with India was limited because it evaluated that India had cooperating on space programs such as SLV, navigation satellites, and manned spaceflight

30) Ministry of ICT, Space development white paper(2022), p. 296.

31) Congressional Research Service, "India-U.S. Relations: Issues for Congress" June 16, 2023, p.11, <https://crsreports.congress.gov/product/pdf/R/R47597> (accessed on Oct. 24. 2023).

32) JAXA Space Exploration Center (JSEC), "Lunar Polar Exploration (LUPLEX) Project Underway," <https://global.jaxa.jp/activity/pr/jaxas/no092/02.html> (accessed on Oct. 24. 2023).

while introducing rocket and satellite technologies from the Soviet Union.³³⁾

India began space development more than 30 years before South Korea did. India installed the world's first space ministry in 1972 and is an advanced space development country that developed space launch vehicles and satellites on its own. India, which focuses on private-led space development, has a lot of know-how in space development for Korea to learn from. India invests three times more in space budget than Korea, and ISRO has 10 times more space development personnel than KARI. Korea and India can identify various space fields for cooperation, starting from lunar exploration technology to future resources, private SLVs using science rockets, and joint science and technology talent training programs. Korea should enhance its space power and establish and implement plans for future space cooperation with India, which has the world's best space technology and IT talents. Recently, Korea was reported to have low participation in the Artemis program led by the United States. Thus, it is necessary to further develop Korea's space capabilities and space technology to play a main role in NASA's Artemis missions

In order for Korea to become a space powerhouse, Korea should participate as an indispensable partner country through continuous joint cooperation with advanced countries in space development and strive to recognize Korea as a major country in the international space community.

South Korea-India Space Cooperation Task and Strategy

Both India, an advanced space technology powerhouse, and South Korea regard each other as an ideal partner for space cooperation. At the 2023 summit between Korea and India, the two countries agreed to strengthen space cooperation. Since India actively attracts foreign direct investment in the private sector and wants to cooperate with Korea's excellent electronics and manufacturing companies in the private sector, cooperation between Korea and India in space, such as satellite development and utilization and ground test facilities, can be expanded.³⁴⁾ In the future, combining Korea's cutting-edge IT technology with India's world-class R&D capabilities through space cooperation

33) Namrata Goswami, "The Lunar Race Between India and Russia: What's at Stake?," August 17, 2023, *The Diplomat*, <https://thediplomat.com/2023/08/the-lunar-race-between-india-and-russia-whats-at-stake/> (accessed on Dec 5, 2023); Aditya Pareek, Dr. Andrey Gubin, "India-Russia Space Cooperation: A Way Forward," *Takshashila Discussion Document 2021-7*, October 13, 2021, <https://static1.squarespace.com/static/618a55c4cb03246776b68559/t/622866005041cb42e02390f5/1646814722652/India-Russia-Space-Cooperation-A-Way-Forward.pdf> (accessed on Dec 5, 2023).

34) Lee Gye-hyuk, "Moon's South pole Landing Successful Indian Space Administration Needs Cooperation with Korean Companies," *KBC*, Oct. 15, 2023, <http://www.ikbc.co.kr/article/view/kbc202310130025>(accessed on Dec 5, 2023).

between Korea and India will provide an opportunity to create great synergy in space development.³⁵⁾

The possible areas of mutual cooperation between Korea and India are satellite navigation and satellite utilization, space exploration and space observation research, space transport services, and space expert education. International space cooperation between Korea and India is very important for South Korea to secure space science and technology, which will help South Korea become a space power.

Satellite navigation and satellite utilization

India has developed and operated the Indian Regional Navigation Satellite System (IRNSS) successfully. For the Korean Positioning System (KPS) construction project, Korea has been implementing with India and the EU on satellite navigation since 2015. In order to develop and operate KPS, Korea should successfully carry out the KPS project by sharing important technologies, system development with India, and operation know-how of India's regional navigation satellite system.³⁶⁾

Satellite utilization is a field of greater economic value than satellite manufacturing and launch vehicle services. Recently, there has been an increase in international cooperation related to satellite utilization, such as artificial intelligence technology, global satellite Internet network construction projects, and space information sharing using big data. Since South Korea is able to predict climate change and disasters through satellite image analysis, using artificial intelligence and big data analysis, it will be able to strengthen international cooperation with India by boosting investment and exchanges in satellite utilization with India, the world's leading space technology and IT powerhouse.

Space exploration and space observation research

1) Space exploration

After successfully launching the Danuri lunar probe into lunar orbit in 2022, South Korea plans to operate it over the next three years. Space exploration is no longer just a story of other advanced space countries. Since Korea plans to launch a lunar lander in 2032, cooperation in space exploration with India is essential. India's successful landing on the moon's south pole in 2023 could greatly help South Korea's moon landing plans. India's successful landing on the lunar south pole for the first time in the world amid a series of failures of Japanese and

35) Ji Cha-soo, "Korea Institute of Engineering, 'Space Development' theme, 6th Korea-India workshop held," *Segye Daily*, August 28, 2023, <https://www.segye.com/newsView/20230828509267?OutUrl=naver> (accessed on Dec 5, 2023).

36) ISRO, "Satellite Navigation Services- Navigation with Indian Constellation (NavIC)," <https://www.isro.gov.in/SatelliteNavigationServices.html> (accessed on Oct. 24, 2023).

Russian lunar landers exhibited the world's best lunar landing technology India possessed. However, India's Vikram lander and Pragyan rover have switched to sleep mode, which changes day and night every 14 days, but have not been able to communicate with the cold of the night above minus 100 degrees Celsius on the lunar south pole.³⁷⁾ In the future, for a joint lunar landing program with India, Korea could utilize its excellent satellite production capabilities to develop the lander's thermal insulation and improve durability.

2) Space observation research

On September 2, 2023, the Indian Space Research Organization (ISRO) launched Aditya L1, a solar observation satellite, that will travel around the sun and study the sun's atmosphere.³⁸⁾ Aditya L1 will study not only the solar atmosphere but also the solar magnetic storm and its effects on the Earth's surrounding environment.³⁹⁾ In the past, the Korea Astronomy and Space Science Institute (KASI) has collaborated with NASA on solar coronagraphs. Thus, space cooperation between South Korea and India on solar observation research is a real possibility.

Space transport service

The operation of Space X's reusable space launch vehicle in the United States has shortened the satellite launch cycle and reduced launch costs. As an advanced country in space launch vehicle development, recently, India began to conduct research on reusable space launch vehicles with a plan to expand India's service area to the commercial space launch market. South Korea is trying to develop reusable SLV technology while carrying out the next-generation Korean SLV project (KSLV-III). It would benefit South Korea if it cooperates with India on technology to reuse space launch vehicles for space development purposes. It is also very important to develop small space launch vehicles and provide space services to meet the global demand for small satellite launches. India has advanced technology while developing long-term scientific rockets. It is imperative that South Korea cooperate with India on the development of small space launch vehicles. South Korea should develop space vehicle reuse technology through cooperation with India on space transport service technology to secure the ability

37) Hannah Ellis-Petersen, "Hopes fade for India's moon lander after it fails to 'wake up' following lunar night," *The Guardian*, Sep 26, 2023, <https://www.theguardian.com/world/2023/sep/26/india-chandrayaan-3-vikram-lander-pragyan-sleep-mode-failure> (accessed on Oct 24, 2023).

38) Nature, "India's first Sun mission will investigate the origins of space weather," <https://www.nature.com/articles/d41586-023-02811-2> (accessed on Oct 24, 2023).

39) Geeta Pandey, "Aditya-L1: India successfully launches its first mission of the Sun" BBC, Sep. 2, 2023, <https://www.bbc.com/news/world-asia-india-66643805> (accessed on Oct 22, 2023).

to build small SLVs, lower the cost of space vehicles, and meet the demand for small satellite launches.

Space expert education

The field of outer space requires advanced science and technology capabilities. Training human resources with advanced technological capabilities, such as artificial intelligence, software, and autonomous driving, is essential to successful space activities. India is the world's leading IT powerhouse. In Bengaluru, India, also known as the Silicon Valley of Asia, the world's top IT companies, such as Google, IBM, and Microsoft, have moved in, and the IT industry is booming thanks to Indian scientific talent. It was also selected as the most dynamic city in the world in 2017 and 2019.⁴⁰⁾ The Seoul Metropolitan Government and Gyeonggi Province are investing in joint IT development between Korea and India through the IT Development Center in Bengaluru. Korean students and start-ups can enhance Korea's international status by participating in the development of cutting-edge technologies in India through international exchanges in the IT and space sectors.⁴¹⁾ Developing international space education programs and providing opportunities for mutual exchange between Korean and Indian students amid the recent high interest of young people around the world in Korea will promote international exchanges related to cutting-edge space education such as space technology, space launch vehicles, propulsion systems, and space flight mechanics.

Korea should promote cooperation with India systematically and strategically. The exchange of manpower should be improved so that India's young talent can be attracted to Korea and participate in Korea's space development.⁴²⁾

Expected Effects of Korea-India Space Cooperation

Both Korea and India have developed space technology and successfully carried out national space programs through space cooperation with other space-developed countries. Space cooperation between South Korea and India can only continue if the two countries build trust through international space cooperation and identify common interests they share. It is necessary to analyze the strengths and weaknesses of Korea and India in the space field and identify the areas of research and cooperation that can complement each other. Space

40) Pavithra Dennis, "How Bangalore became Asia's Silicon Valley," Jun 24, 2020, <https://thescalers.com/how-bangalore-became-asias-silicon-valley/> (accessed on Oct 24, 2023).

41) Indian National Space Promotion and Authorization Centre(IN-SPACe), "IN-SPACe vision," 2023. p. 4.

42) Song Chiwoong, "Why to Embrace India's Young Talent," *e-newspaper*, July 12, 2023, <https://www.etnews.com/20230712000002> (accessed on Oct 24, 2023).

cooperation between Korea and India is expected to render the following effects.

First, in terms of national interests, as major countries in the Indo-Pacific region, Seoul and New Delhi can develop national space power and strengthen diplomacy between the two countries while maintaining national security through space cooperation and implementing major national space plans. Second, thanks to the artificial intelligence technology and advanced IT talents possessed by Korea and India, the two countries can increase profit creation in the space utilization field such as satellite imaging and communication services in the global space market. Third, Korea's advanced production capabilities of electronic components can be utilized to contribute to the space exploration missions in India. Fourth, taking advantage of major talents in the space field who can carry out joint research projects, the two countries can facilitate exchanges between professionals and strengthen science and technology research cooperation between them. Fifth, Korean space companies will be able to contribute to boosting local investment in India by entering India and conducting joint technology research.

Conclusion and Policy Recommendation

South Korea can use the lack of space cooperation with India as a new opportunity. To successfully implement the lunar lander project in 2032, South Korea must consider that India's Chandrayaan-3 lunar lander failed to withstand the extreme cold of the lunar South Pole and , learn the know-how of developing lunar landers by participating in India's lunar exploration project, and use Korea's satellite production technology to contribute to improving the performance of the lunar probe built by India. Through upward technological exchanges in international cooperation, Korea will emerge as an important partner for India in space development.

India has participated in space development since 1960 and succeeded in developing space launch vehicles and satellites with its technology. It is now one of the world's top space powerhouses. India has succeeded in building a commercial space industry that launches satellites from other countries, using its own space launch vehicles, and has space exploration technologies needed for moon and Mars exploration. In order to strengthen space cooperation between Korea and India, this study intends to present the following policy suggestions.

First, in the new space era, Korea should develop advanced space technology through international cooperation with advanced space countries and strengthen partnerships with space powers. India is a space power whose role in the global space market continues to grow. Korea should establish and implement measures to reinforce Korea's space capabilities by analyzing India's space development with its technological capabilities and small budget and drawing lessons applicable to the

case of South Korea.

Second, the South Korean government should review India's latest space policy and space program, identify the potential areas of cooperation with India, and reflect them in its space development plan. India has provided space-based services to the Indian people through space development and focused on the development of space technology and commercial profits of private companies. Korean space start-ups should be given the opportunity to participate in space technology development projects with world-class IT companies in Bengaluru, India, as well as Korea, and grow into technology-recognized companies in the global market.

Third, it is imperative that South Korea participate in international education programs with excellent space technology and IT talents in India to cultivate and secure excellent scientific personnel in Korea. Domestic and international space education programs can help train space-related personnel, but it takes a long time to develop such programs. India operates an international space education program, which will provide opportunities to facilitate human exchanges between the two countries' top talents through the development and participation of international education programs and serve as a stepping stone for Korea's top personnel to enter the world.

Fourth, South Korea and India should promote cooperation in the defense sector to jointly respond to threats in outer space. India has built space power to respond to China's threats and inspired patriotism among its people. Space cooperation between South Korea and India should begin in the private sector, but in the future, they should consider space cooperation in the defense sector. India is also planning a defense space program, recognizing the importance of space in terms of military. Notably, its diplomatic and military relations with the United States in the Indo-Pacific region have been reinforced. This year marks the 50th anniversary of Korea-India diplomatic relations, and both countries' collaborative efforts in space development in the private and defense sectors will multiply as the two countries promised to strengthen strategic communication and cooperation as key partners in the Indo-Pacific region through the G20 summit.

Fifth, Korea should establish and operate the Korea Aerospace Agency (KASA) as soon as possible to promote international cooperation with space organizations in the advanced space countries. The agreement on the opening of the KASA is delayed until the second half of 2023, which may hamper opportunities for international cooperation. The establishment of the Korea Aerospace Agency is essential to promote Korea's space cooperation with advanced space development countries and lead Korea's space activities. The Korea Aerospace Agency (KASA) should be in charge of overall international cooperation, as well as establishing and developing Korean aerospace policies, fostering domestic private space companies, and nurturing space professionals.⁴³⁾ The establishment and operation of the Korea Aerospace Agency will promote international space cooperation and play a leading

role in space activities.

[Received: October 30, 2023; Revised: November 9, 2023; Accepted: December 4, 2023]

43) Yoon Jeong-hyun and Lee Sung-hoon, "Changing Public-Private Cooperation in the New Space Era and Exploring the Direction of Korean-style Development," *National Strategy* 29, no.3 (2023), p. 199.

References

- Ahn Hyun-joon, "A Proposal of National Space Governance Reform according to Expansion of Space Development," *Policy Research* 2022-24.
- Ahn So-hee said, "The development of a Korean satellite navigation system is just around the corner... Leap Towers a Space Power", *Dong-A Ilbo*, 2022.9.20, <https://www.donga.com/news/article/all/20220919/115518383/1> (accessed on Oct. 22. 2023).
- Congressional Research Service, "India-U.S. Relations: Issues for Congress," June 16, 2023, p.11, <https://crsreports.congress.gov/product/pdf/R/R47597> (accessed on Oct. 22. 2023).
- Euroconsult, "Government Space Programs" 2021, <https://www.euroconsult-ec.com/press-release/new-record-in-government-space-defense-spending-driven-by-investments-in-space-security-and-early-warning/> (accessed on Oct. 22. 2023).
- Geeta Pandey, "Aditya-L1: India successfully launches its first mission of the Sun" *BBC*, Sep. 2, 2023, <https://www.bbc.com/news/world-asia-india-66643805> (accessed on Oct 22, 2023).
- Guruprasad B. R., "Understanding India's International Space Cooperation Endeavour: Evolution, Challenges and Accomplishments," *India Quarterly*, Volume 74, Issue 4, December 2018, pp. 455-481, <https://doi.org/10.1177/0974928418802077> (accessed on Nov. 24. 2023).
- Hague Centre for Strategic Studies, "The New Space Era," <https://hcss.nl/space/> (accessed on Oct. 26. 2023).
- Han Young-min et al., "History and development trends of space launch vehicles in India." *Aerospace Technology Development Trends* Vol. 9, No. 2, (2011), pp. 128-137.
- Hannah Ellis-Petersen, "Hopes fade for India's moon lander after it fails to 'wake up' following lunar night," *The Guardian*, Sep 26, 2023, <https://www.theguardian.com/world/2023/sep/26/india-chandrayaan-3-vikram-lander-pragyan-sleep-mode-failure> (accessed on Oct 24, 2023).
- Nature, "India's first Sun mission will investigate the origins of space weather," <https://www.nature.com/articles/d41586-023-02811-2> (accessed on Oct 24, 2023).

- India's National Security Strategy, March 2019, p. 41,
https://manifesto.inc.in/pdf/national_security_strategy_gen_hooda.pdf
(accessed on Oct. 24. 2023).
- Indian National Space Promotion and Authorization Centre(IN-SPACE),
"IN-SPACE vision," 2023. p. 4.
- ISRO, "Indian Space Policy 2023," April 6th, 2023,
https://www.isro.gov.in/media_isro/pdf/IndianSpacePolicy2023.pdf (accessed
on Oct. 24. 2023).
- ISRO, LVM3(Geosynchronous Satellite Launch Vehicle Mk III),
https://www.isro.gov.in/GSLVmk3_CON.html (accessed on Oct. 22. 2023).
- ISRO, "Satellite Navigation Services- Navigation with Indian Constellation
(NavIC)," <https://www.isro.gov.in/SatelliteNavigationServices.html> (accessed
on Oct. 24. 2023).
- JAXA Space Exploration Center (JSEC), "Lunar Polar Exploration (LUPEX)
Project Underway," <https://global.jaxa.jp/activity/pr/jaxas/no092/02.html>
(accessed on Oct. 24. 2023).
- Jeong Heon-joo, Baek Yu-na and Jeong Yoon-young. "Space and
international development cooperation: an exploratory analysis of the
achievement of sustainable development goals using space technology."
Social science research 33, no. 2 (2022).
- Khalid Munazza, "India-US space cooperation: Implications for the South
Asian strategic stability," *Journal of Humanities, Social and Management
Sciences (JHSMS)*, Vol. 2, No. 2(July-December 2021), pp. 55-66,
<https://ideapublishers.org/index.php/jhsms/article/view/475> (accessed on Nov.
24. 2023).
- Kim Hyundai, "We must not miss the launch window of the Korea
Aerospace Exploration Agency," *Maeil Economy*, 2023.10.20.,
<https://www.hankyung.com/article/2023102041351>(accessed on Oct. 22. 2023).
- Lee Seung-gi, "India's Upgraded Space Policy," *KOTRA Overseas Markets
News*, 2023.5.15.,
[https://dream.kotra.or.kr/dream/cms/news/actionKotraBoardDetail.do?MENU_
ID=2430&pNttSn=202512#](https://dream.kotra.or.kr/dream/cms/news/actionKotraBoardDetail.do?MENU_ID=2430&pNttSn=202512#) (accessed on Oct. 24. 2023).
- Lee Joon-ki, "Independent development, cost-effectiveness..."Like Space
Innovation India," *Digital Times*, 2023.8.2. (accessed on Oct. 20. 2023).

Lee Joon et al., “Trends in Government Space Programs 2016.” *Current Industrial and Technological Trends in Aerospace*, vol. 15, no. 2, (2017), pp. 57-58.

KARI, “Korea Multipurpose Satellite(Arirang),”
https://www.kari.re.kr/kor/sub03_03_01.do (accessed on Oct. 22. 2023).

Ministry of ICT, Space development white paper, 2022.

Ministry of ICT, “The 4th Basic Plan for Space Development Promotion (’23-27),”
<https://www.msit.go.kr/publicinfo/view.do?sCode=user&mPid=62&mId=63&publicSeqNo=3&publicListSeqNo=3&formMode=R&referKey=3,3>
(accessed on Oct. 22. 2023).

Ministry of Science and ICT, “Our own technology ‘Nuri Lake’ has been successfully launched for the third time...”*New Space Era Opens in earnest*, *Policy Briefing*, May 26, 2023,
<https://www.korea.kr/news/policyNewsView.do?newsId=148915600>
(accessed on Oct. 22. 2023).

NASA, “Mars Orbiter Mission,”
<https://science.nasa.gov/mission/mom/>(accessed on Oct. 22. 2023).

Nature, “India’s Moon landing is a stellar achievement — and a win for science,” Aug. 24, 2023, <https://www.nature.com/articles/d41586-023-02685-4>
(accessed on Oct. 22. 2023).

Park Jeong-yeon, “India's unmanned lunar lander successfully landed 'Moon on the moon’s south pole' for the first time in mankind.” *Dong-A Science*, 2023. 8. 24. <https://www.dongascience.com/news.php?idx=61326>
(accessed on October 22, 2023).

Pavithra Dennis, “How Bangalore became Asia’s Silicon Valley,” Jun 24, 2020, <https://thescalers.com/how-bangalore-became-asias-silicon-valley/>
(accessed on Oct 24, 2023).

Presidential Office, “President Yoon Announces Future Space Economy Roadmap,” Nov. 28, 2022, <https://www.korea.kr/news/policyNewsView.do?newsId=148908812>
(accessed on Oct. 27. 2023).

Samson Victoria, "U.S.–India strategic partnership in space, A path toward cooperation,” *The future of U.S.–India security cooperation*, 30 Mar 2021
<https://www.manchesterhive.com/display/9781526155160/9781526155160.0018.xml> (accessed on Nov. 24. 2023).

- Sharmila Kuthunur, "India wants to land astronauts on the moon in 2040," Oct 19, 2023, <https://www.space.com/india-land-astronauts-moon-2040> (accessed on Oct. 27. 2023).
- Song Chiwoong, "Why to Embrace India's Young Talent," *e-newspaper*, July 12, 2023, <https://www.etnews.com/20230712000002> (accessed on Oct 24, 2023).
- Sourbes-Verger Isabelle, "EU-India Cooperation on Space and Security," *IAI(Instituto Affari Internazionali) Working Paper 16*, 2016. pp. 1-20, <https://css.ethz.ch/content/dam/ethz/special-interest/gess/cis/center-for-security-studies/resources/docs/IAI-EU-India%20Cooperation%20on%20Space%20and%20Security.pdf> (accessed on Nov. 24. 2023).
- Yoo Jae-han. "Rocket Development Trends in India," *Spring Conference of the Korean Society for Propulsion Engineering*(2021): pp. 1-2.
- Yoon Jeong-hyun and Lee Sung-hoon, "Changing Public-Private Cooperation in the New Space Era and Exploring the Direction of Korean-style Development," *National Strategy* 29, no.3 (2023), p. 199.