2022년도 장기일반과정
국외훈련 훈련결과보고서

2024년 5월

방위사업청
여 창 동

차 례

국외훈련 개요

1. 훈련국 : 영국

2. 훈련기관명 : 엑시터 대학교 (University of Exeter)

3. 훈련분야 : 공공행정 석사 과정
(과정 명: MPA Master of Public Administration with applied Study)

4. 훈련기간 : 2022.8.29. ~ 2024.6.28.

훈련기관 개요

1. 훈련기관

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Tel. +44 1392 661000

2) St Luke's Campus

University of Exeter, St Luke's Campus, Heavitree Road, Exeter, EX1 2LU

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3. 기관 소개

엑시터 대학은 영국 남서부의 엑시터(Exeter)와 콘월(Cornwall)에 위치한 캠퍼스에서 세계적인 연구와 뛰어난 학생 만족도를 결합하고 있음. 해당 대학은 러셀 그룹(Russell Group)의 회원이자 Teaching Excellence Framework(TEF)의 골드 상을 수상한 소수의 대학 중 하나로, 교육과 연구의 탁월함에 대한 국제적인 평판을 입증하고 있음.

엑시터 대학은 1851년 엑시터 예술 및 과학 학교가 설립된 이후 교육을 통해 발견하고 삶을 변화시키기 위해 헌신해 옴. 1922년에 남서부 대학교(University College of the South West)로 명칭을 변경하여 1955년에는 허가를 받아 완전한 대학으로 승격되어 엑시터 대학교가 되었습니다. 또한 1978년에 설립된 세인트 루크스 교육 대학(St Luke's College of Education)(1840년 설립)과 2004년에 콘월의 고등 교육 제공을 확대하기 위해 펜린 캠퍼스(Penryn Campus)를 개설하여 합류함.

동 대학은 130개국에서 온 25,000명 이상의 학생과 183개국에 걸쳐 125,000명 이상의 졸업생을 보유하고 있으며, 이를 통해 교직원, 학생 및 방문 연구원으로 이루어진 학술 공동체에게 진정한 글로벌 경험과 다양하고 포용적인 환경을 제공함. 우리의 전략적 파트너십은 세계적인 학술인들과 우수 대학의 자원을 결합하여 전 세계적인 지속 가능성 및 웰빙과 같은 주요 글로벌 도전에 변혁적 영향을 전달함.

엑시터 대학교 연구의 최근 성과에는 드론 조사와 컴퓨터 모델링을 활용하여 극지방의 극단적인 침식을 지도하는 것, 암과 당뇨병의 진단 및 치료를 개선하는 것, 그리고 경제 개혁을 통한 기후

비상 대응을 위한 7단계 계획 개발이 포함됨. 또한, 대학의 과학자들과 임상 의사들은 데본(Devon) 환자들의 바이러스를 서열화하여 질병 bekämpen에 도움을 줄 수 있도록 대학의 최첨단 장비를 활용하여 코로나 바이러스 전파와 싸우기 위해 2천만 파운드(GBP)의 투자에 참여하고 있음.

동 대학은 모든 캠퍼스에 걸쳐 과학, 기술, 공학, 수학 및 의학뿐만 아니라 인문학과 과학을 위한 탁월한 교육 및 연구 시설 및 실험실을 보유하고 있음. 이러한 시설로는 펜린(Penryn) 캠퍼스의 환경과 지속 가능성 연구소, 스트릿햄(Streatham) 캠퍼스의 리빙 시스템(Living System) 연구소와 디지털 인문학 랩, 그리고 로얄 데본 및 엑시터 병원의 연구, 혁신, 학습 및 개발 센터(Research, Innovation, Learning and Development Centre, RILD)가 포함됨.

<Title>

Analysis of Korea's Space Development Policy and Recommendations for Improvement Strategies

1. Introduction

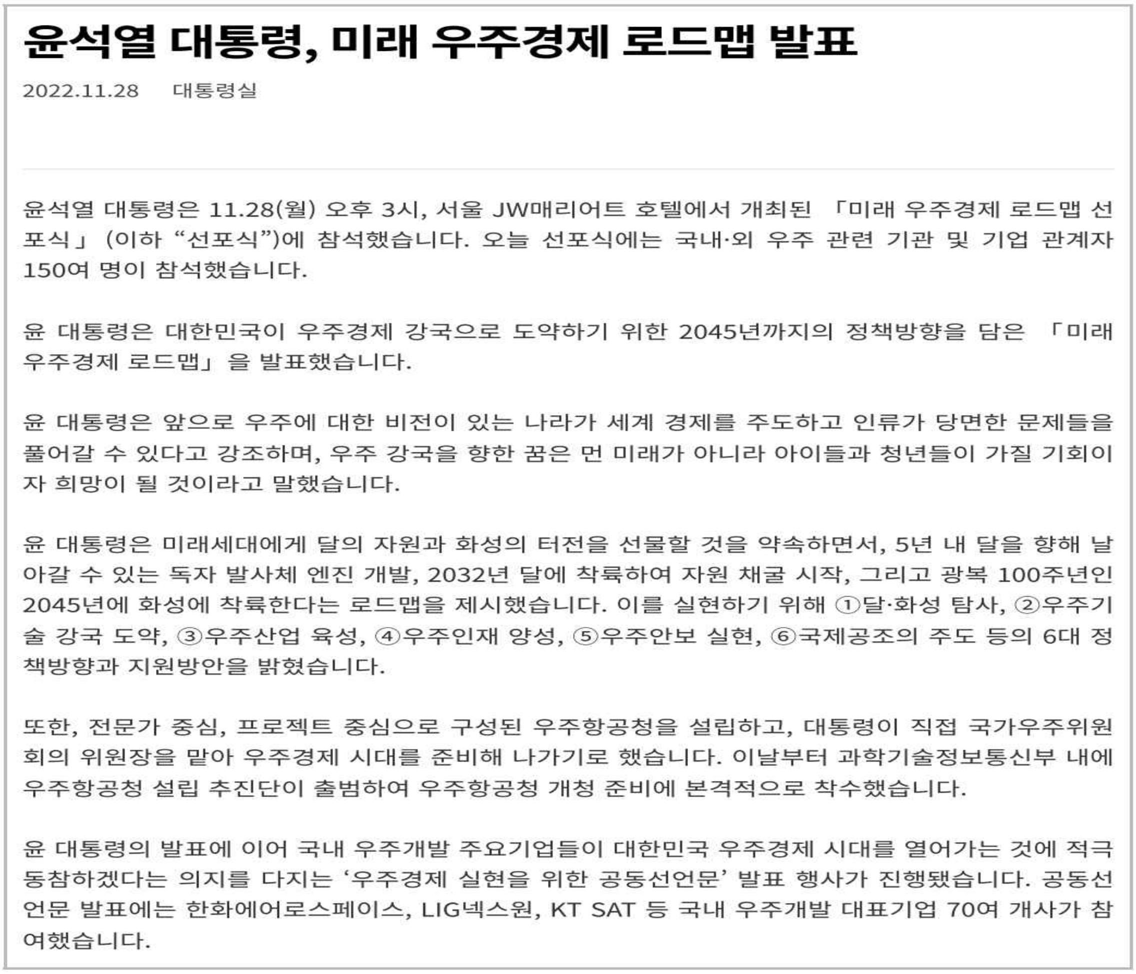
In November 2022, President Yoon Suk-yeol of South Korea (hereinafter "Korea") attended the Future Space Economy Roadmap Declaration and publicly disclosed Korea's "Future Space Economy Roadmap" to the public (Presidential Office, 2022)[1]. The Future Space Economy Roadmap contains policy directions for South Korea to leap into a space economic powerhouse by 2045 (see Figure 1).

President Yoon expressed his ambition, stating, "I will open wide the era of Korea's space economy in the future." He emphasized that countries with a vision for space will lead the world economy and solve the problems facing humanity. He added that the dream of becoming a space powerhouse is not a distant future but an opportunity and hope for children and young people.

President Yoon's remarks sound like a preview of a paradigm shift from the technology-focused space policy pursued by the Korean government for over 30 years to the next stage. While the space economy is now considered one of the hottest

1) 대통령실 (2022) *윤석열 대통령, 미래 우주경제 로드맵 발표* [online] (28 November 2022). Available at: https://www.korea.kr/briefing/presidentView.do?newsId=148908818

keywords in global economic trends as the next-generation growth engine, the reality is that the space economy worldwide is still far from being perceived as a profitable sector. To commercialize the space sector and create profits, it is essential to first secure relevant technologies, which are currently monopolized by some advanced countries. Particularly, technologies for manufacturing essential components like rockets and satellites, crucial for forming space industry infrastructure, are strictly controlled between nations due to security concerns. Consequently, most countries have had to prioritize self-reliance in securing space development technologies, resulting in the formation of the space economy primarily from a



윤석열 대통령, 미래 우주경제 로드맵 발표

2022.11.28 대통령실

윤석열 대통령은 11.28(월) 오후 3시, 서울 JW매리어트 호텔에서 개최된 「미래 우주경제 로드맵 선포식」 (이하 "선포식")에 참석했습니다. 오늘 선포식에는 국내·외 우주 관련 기관 및 기업 관계자 150여 명이 참석했습니다.

윤 대통령은 대한민국이 우주경제 강국으로 도약하기 위한 2045년까지의 정책방향을 담은 「미래 우주경제 로드맵」 을 발표했습니다.

윤 대통령은 앞으로 우주에 대한 비전이 있는 나라가 세계 경제를 주도하고 인류가 당면한 문제들을 풀어갈 수 있다고 강조하며, 우주 강국을 향한 꿈은 먼 미래가 아니라 아이들과 청년들이 가질 기회이자 희망이 될 것이라고 말했습니다.

윤 대통령은 미래세대에게 달의 자원과 화성의 터전을 선물할 것을 약속하면서, 5년 내 달을 향해 날아갈 수 있는 독자 발사체 엔진 개발, 2032년 달에 착륙하여 자원 채굴 시작, 그리고 광복 100주년인 2045년에 화성에 착륙한다는 로드맵을 제시했습니다. 이를 실현하기 위해 ①달·화성 탐사, ②우주기술 강국 도약, ③우주산업 육성, ④우주인재 양성, ⑤우주안보 실현, ⑥국제공조의 주도 등의 6대 정책방향과 지원방안을 밝혔습니다.

또한, 전문가 중심, 프로젝트 중심으로 구성된 우주항공청을 설립하고, 대통령이 직접 국가우주위원회의 위원장을 맡아 우주경제 시대를 준비해 나가기로 했습니다. 이날부터 과학기술정보통신부 내에 우주항공청 설립 추진단이 출범하여 우주항공청 개청 준비에 본격적으로 착수했습니다.

윤 대통령의 발표에 이어 국내 우주개발 주요기업들이 대한민국 우주경제 시대를 열어가는 것에 적극 동참하겠다는 의지를 다지는 '우주경제 실현을 위한 공동선언문' 발표 행사가 진행됐습니다. 공동선언문 발표에는 한화에어로스페이스, LIG넥스원, KT SAT 등 국내 우주개발 대표기업 70여 개사가 참여했습니다.

Figure 1 Presidential Office Briefing Material on the Future Space Economy Roadmap Announcement government-led research and development perspective, funded by substantial government budgets.

The purpose behind nations worldwide seeking to secure space technology on their own is not solely to utilize it as the foundation for fostering the space industry ecosystem, but also to gain positive secondary effects through technology transfer to other industries. Looking at the case of the United States, the leading country in space development, NASA (National Aeronautics and Space Administration) is directing efforts to expand the overall technological base within the country by transferring space technology acquired by NASA into various domestic industrial fields. NASA has been transferring technology acquired since the 1970s at an average rate of dozens of cases per year, particularly actively in the fields of manufacturing products and computer technology (see Figure 2) (OECD, 2021)[2]. Particularly noteworthy is the considerable

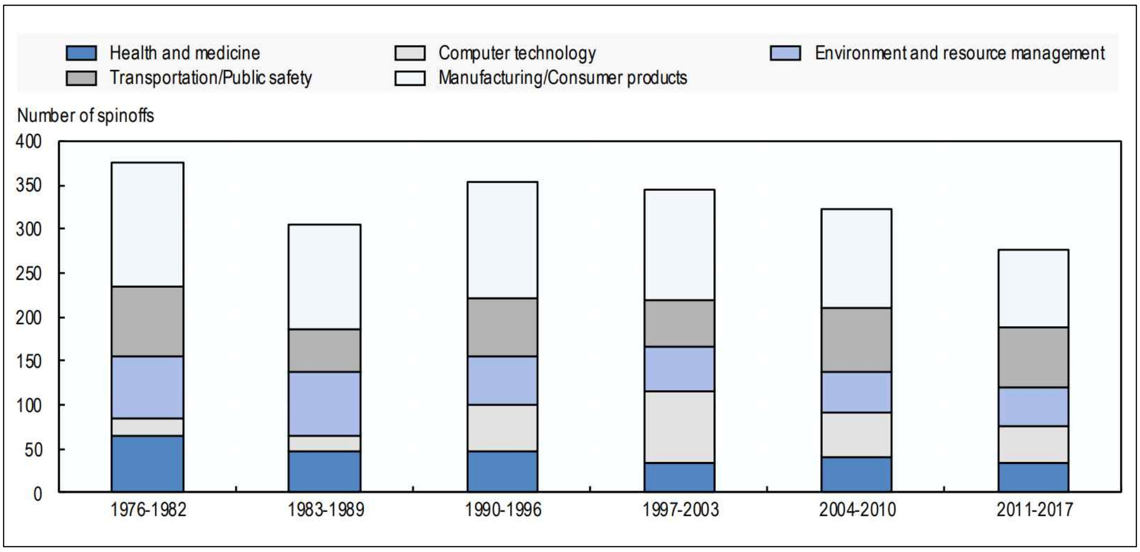


Figure 2 The number of technologies spinoffs by NASA to various industries within the United States.

2) OECD (2021) *Space technology transfers and their commercialisation, OECD Science, Technology and Industry Policy Papers,* No.116 (July 2021). Available at: https://www.oecd.org/sti/space-technology-transfers-and-their-commercialisation-0e78ff9f-en.htm

activity in technology transfer to the fields of health and medicine, as well as environment and resource management, suggesting that securing space technology can incentivize overall societal technological advancement and ultimately lead to an improvement in the overall quality of life for the nation.

The Korea Aerospace Research Institute (KARI), responsible for space development in Korea, is also actively engaged in technology transfer and knowledge sharing to domestic companies. According to the OECD in 2021[3], from 2001 to 2018, KARI conducted a total of 265 technology transfers and 61 knowledge transfers. Particularly noteworthy is the increasing number of knowledge transfers over time, indicating a growing pool of personnel with extensive experience and knowledge in space development. This is highly promising in terms of securing domestic space experts (see Figure 3).

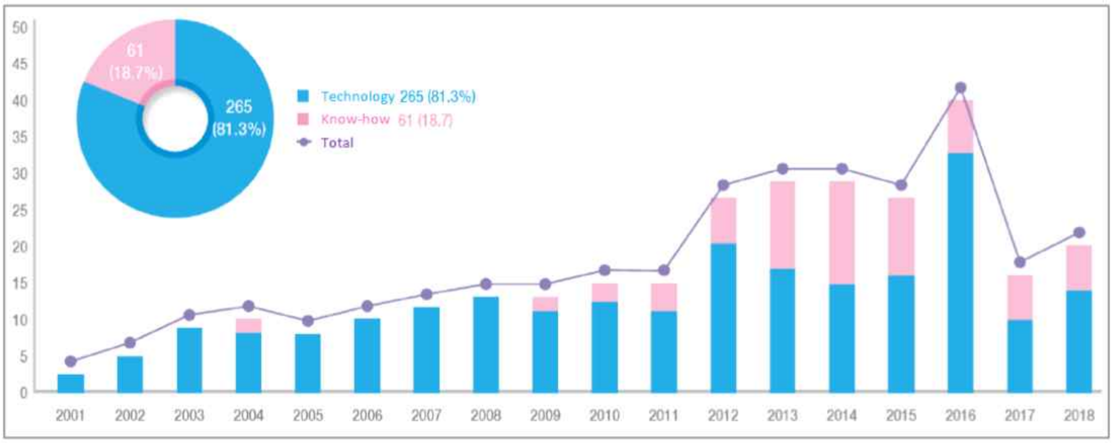


Figure 3 The number of technologies and know-how transferred by the Korea Aerospace Research Institute (KARI) to various industries within Korea.

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3) OECD (2021) *Space technology transfers and their commercialisation, OECD Science, Technology and Industry Policy Papers,* No.116 (July 2021). Available at: https://www.oecd.org/sti/space-technology-transfers-and-their-commercialisation-0e78ff9f-en.htm

Thus far, the demand for space development has largely been generated from governments capable of providing substantial funding, focusing solely on securing technology for public use. In contrast, private companies have been limited to participating in sporadic research and development projects commissioned by the government for technology development, resulting in limitations on the conditions for creating a space industry ecosystem centered around profit-generating private enterprises that consider price competitiveness and efficiency.

As such, the concept of space development, which was previously heavily influenced by governments' public tendencies in areas such as national security and economy, underwent significant changes with the emergence of private space companies like Space Exploration Technologies Corporation (SpaceX) and Blue Origin Federation in the early 2000s, along with companies like Virgin Galactic in the UK. These companies have steadily secured substantial private capital and technical experts, enabling them to independently acquire groundbreaking space technologies while simultaneously developing various commercial service models by reducing launch costs. Among these models, the provision of space tourism services has garnered interest from millionaires worldwide. It's worth noting that the first civilian to travel to lunar orbit aboard SpaceX's Starship has already been selected (Euronews, 2022)[4]. Moreover, SpaceX has achieved substantial financial gains by commercializing the reusable Falcon 9 rocket, drastically reducing launch costs and earning significant monetary returns

4) Euronews (2022) *Elon Musk's SpaceX signs up world's first space tourist for Starship flight around the Moon* [online] (13 October 2022). Available at: https://www.euronews.com/next/2022/10/13/elon-musk-spacex-signs-up-first-space-tourist-dennis-tito-starship-flight-around-the-moon

through satellite launch contracts from around the world (Kuhr and Islam, 2024)[5].

As a result, the intensified interest of global private companies in the profit potential of space development has led to the advent of the so-called New Space era, where private enterprises, rather than governments, take the lead in space development. In other words, unlike the Old Space paradigm where governments dictate development requirements and a few specialized aerospace companies develop and deliver technology accordingly, in the New Space era, private companies proactively assess market demands and produce products and services. Governments then purchase what they need from these offerings as necessary, while private companies earn revenue. (Kerolle, 2015)[6]. For example, according to NASA's 2023 Annual Procurement Report[7], NASA contracted with SpaceX on the second-largest scale in the space sector by 2022. This highlights SpaceX's significant influence in both the private and public sectors, reaching a formidable level of impact.

Korea also appears to have clear plans to nurture and grow the space industry as a new source of future growth. President Yoon Seok-yeol, in light of the successful launch of Korea's first lunar orbit spacecraft, the "Danuri," in 2022, self-evaluated that Korea has entered the ranks of the world's top seven space

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5) Kuhr, J. and Islam, M. (2024) *Estimating SpaceX's 2023 Revenue* [online[(24 January 2024). Available at: https://payloadspace.com/estimating-spacexs-2023-revenue/

6) Kerolle, M. (2015) *NewSpace – Is this the Advent of the Second Space Age?* [online] (23 November 2015). Available at: https://www.spaceboard.eu/articles/space-out/newspace-is-this-the-advent-of-the-second-space-age-

7) NASA (2023) *The Annual State of NASA Procurement Report: Fiscal year 2022 in review* [online]. Available at: https://oiir.hq.nasa.gov/asap/documents/ASAP_2022_Annual_Report.pdf

powers. He now aims to further advance this by targeting to become one of the top five space powers (Presidential Office, 2024)[8]. As a latecomer in space development, the Korean government must formulate effective policies within limited time, budget, and manpower to narrow the gap with established space powers and foster the domestic space industry ecosystem.

	Old Space	New Space
Objectives	National goals (military, security, economic development, scientific knowledge, enhancement of national status)	Commercial goals (market expansion)
Development period	Long-term	Short-term
Development entity	National research institutions, large corporations	SMEs, startups, ventures
Development cost	High	Low
Primary funding sources	Government (public capital)	Private (commercial capital)
Management approach	Government-led	Autonomous competition
Characteristics	Conservative, risk-averse, reliability	Innovation, risk-taking, high-risk
Representative cases	Apollo project, space shuttle	Reusable rocket, asteroid mining
Major markets	Hardware	Reusable rocket, asteroid mining, space tourism
Leading companies	NASA, Boeing	SpaceX, Planetary Resources

Table 1 Comparison between Old Space and New Space

(source: 과학기술정책연구원 (2018) 우주항공 기술강국을 향한 전략과제, STEPI Insight, 제226호 (20 November 2018))

8) 대통령실 (2024) *尹 대통령, 우주산업 클러스터 출범행사 참석해 5대 우주 강국을 향한 위대한 여정의 시작 축하,* 브리핑 [online] (13 March 2024). Available at: https://www.president.go.kr/newsroom/briefing/BeWTCuHr

In this training report, I will first examine Korea's key achievements in space development and the Korean government's recent space development policies to assess their effectiveness. I will also explore how these policies have evolved into the latest space development policies. Furthermore, I aim to identify areas of deficiency and improvement necessary to achieve the objectives of the latest space policies. I will investigate specific policy directions that Korea is pursuing and compare them with policies of other countries to determine where the Korean government should focus its efforts to become a true space power aligned with the New Space era.

2. Approach

In this training report, the analysis of Korea's space development policies will be based on the Space Development Promotion Basic Plan announced by the Ministry of Science and ICT. The first to third iterations of the Space Development Promotion Basic Plan, spanning from 2007 to 2022, outline the direction of space development policies during that period. The fourth iteration of the plan aims to present a new vision for space economic development until 2045 while addressing deficiencies in the existing space development policies. I will examine the trajectory of Korea's space policy and achievements from the first to third basic plans and explore how the fourth policy direction was formulated based on these. Additionally, through comparative analysis with space policies of countries such as Japan, Canada, Luxembourg, and the UAE, I aim to identify the validity and shortcomings of current Korean space policies and propose directions for improvement and development.

3. Context

Since the 1990s, the Korean government's space development policy can be broadly categorized into three areas: 1) acquisition of satellite development technology, 2) generating profits through satellite utilization, and 3) acquisition of launch vehicle development technology.

3.1. Acquisition of satellite development technology

Korea's interest in space development began in the 1990s, significantly later than advanced spacefaring nations. While space technology development during the Cold War era was competitively pursued between the United States and the Soviet Union to secure strategic military superiority, in the post-Cold War era, it was actively utilized for fostering advanced industries to expand national interests. The acquisition of space development technology in the 1990s aimed not only to enhance the technological competitiveness of domestic industries and improve national competitiveness but also to promote the development of human society by diversifying limited resources and energy sources on Earth, creating future technologies and industries, and advancing communication and information processing. This era was considered a crucial period from a national perspective, recognizing space technology as an important technological field (Kim, 1996)[9]. Following this trend,

9) 김광남 (1996) *우주개발 중장기 기본계획*, The Journal of the Korean Institute of Communication Sciences v.13 no.8, pp.27-34. Available at: https://scienceon.kisti.re.kr/commons/util/originalView.do?cn=JAKO199611920560010&dbt=JAKO&koi=KISTI1.1003%2FJNL.JAKO199611920560010

Russia, the United States, Japan, China, France, and other advanced nations took their first steps in space development by developing and launching artificial satellites. Likewise, Korea launched its first artificial satellite, the Korean Institute of Technology Satellite-1 (KITSat-1[10]), in 1992, followed by the launch of the first low-earth orbit small satellite, KITSat-2, in 1993. At that time, the ultimate goals of Korea's space development were: i) Securing independent space development capabilities through the development of core space technologies, ii) Entering the top 10 in the global aerospace industry market through the expansion of the space industry into the global market, iii) Enhancing the quality of life of citizens through securing space domains and utilizing space, and iv) Boosting national pride through successful space development (Kim, 2006)[11]. In pursuit of these goals, the Korean government established the 「Mid- and Long-term Master Plan of Space Development」 in 1996, which outlined systematic space development policies. The primary objective of this master plan was to develop and launch a total of 19 artificial satellites by 2015. This underscores Korea's space development strategy, which aimed to promote the nation's economy, welfare, and convenience by prioritizing the acquisition of advanced space technology, particularly satellite development technology, to contribute to national interests.

Since the establishment of the Mid- and Long-term Master Plan of Space Development in 1996, as a result of government

10) 우리별 1호

11) 김종범 (2006) *한국 우주개발의 이념*, Current industrial and technological trends in aerospace, v.4 no.2, pp.3-9. Available at: https://scienceon.kisti.re.kr/commons/util/originalView.do?cn=JAKO199611920560010&dbt=JAKO&koi=KISTI1.1003%2FJNL.JAKO199611920560010

investment and focused nurturing centered around satellite development, by 2007, a total of six satellites had been successfully developed and launched (refer to Table 2). A total of 1.7 trillion Korean won of government budget was allocated from 1996 onwards. Initially, around 500 billion Korean won was invested, but by 2007, the investment budget had increased to approximately 3 trillion Korean won. This not only indicates an absolute increase in the budget size over the years but also a growing proportion of space development R&D budget relative to the government's overall R&D budget, reflecting the positive outcomes of continuous government investment and nurturing. Furthermore, with the increased budget size, the workforce in space development has steadily grown. As of 2005, Korea had secured over 1,300 space development personnel. Additionally, by securing domestic proprietary technology for small satellites for Earth observation with a resolution of 2.5 meters, Korea achieved exports of small satellites to countries such as Malaysia and the UAE. Moreover, Korea successfully developed and launched the Multi-purpose Satellite-1 (KOMPSAT-1[12]), which provides high-resolution images comparable to those of advanced satellite countries since 1999, leading to the achievement of satellite technology self-reliance at the practical satellite level under domestic leadership. Consequently, Korea demonstrated visible achievements relatively early in satellite development technology acquisition, in line with the Korean government's policy implementation, providing impetus for the government to continue prioritizing the acquisition of core satellite technology as a key policy focus.

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12) 아리랑위성

Satellite	Mission	Year of Launch	
Korean Institute of Technology Satellite (우리별 위성)	Acquisition of satellite development technology and cultivation of specialized personnel	KITSAT-1	1992
		KITSAT-2	1993
		KITSAT-3	1999
Korea Satellite (무궁화 위성)	Overseeing satellite communication and satellite broadcasting businesses	KOREASat-1	1995
		KOREASat-2	1996
		KOREASat-3	1999
		KOREASat-5	2006
		KOREASat-6	2010
		KOREASat-7	2017
		KOREASat-5A	2017
Korea Multi-Purpose Satellite (아리랑 위성)	Precision surveillance using precision optics	KOMPSAT-1	1999
		KOMPSAT-2	2006
		KOMPSAT-3	2012
		KOMPSAT-5	2013
		KOMPSAT-3A	2015
Communication, Ocean, and Meteorological Satellite (천리안 위성)	Weather forecasting services and maritime/environmental monitoring	COMS-1	2010
		COMS-2A	2018
		COMS-2B	2020
Science and Technology Satellite (과학기술위성)	Observation of celestial bodies and Earth's spectra in the ultraviolet region	STSAT-1	2003
		STSAT-2A	2009
		STSAT-2B	2010
		STSAT-2C	2013
		STSAT-3	2013
Next Generation Satellite (차세대소형위성)	Scientific missions and verification of key space technologies	NEXTSat-1	2018
		NEXTSat-2	2023
Compact Advanced Satellite 500 (차세대중형위성)	Diverse public-wide observation and cartography	CAS500-1	2021

Table 2 History of Korean Satellite Launch

(source: Author edited research results of the website)

Meanwhile, the Korean government enacted the Space Development Promotion Act in 2005 with the aim of systematically promoting space development and efficiently utilizing/managing space objects. Under this law, the existing Mid- and Long-term Master Plan of Space Development was renamed as the Master Plan for Promotion of Space Development, and the first phase of the promotion plan was established in 2007. According to this plan, the policy continued to prioritize the acquisition of core space development technologies, with a primary goal of achieving self-reliance in satellite technology development, including the independent development of precision observation satellites. The Korean government's consistent investment in core satellite technology acquisition and independent satellite production bore fruit, as by the early 2010s, the technology for manufacturing low-earth orbit observation satellites had reached a global standard, and independent satellite development has continued to the present day. Especially in August 2022, with the successful launch and lunar orbit insertion of Korea's first lunar orbiter, Danuri, a new era in Korean space development was ushered in. Danuri, as part of NASA's Artemis program, carries the United States' Shadow Camera to identify optimal future lunar base construction sites, while also performing various lunar observation missions in pursuit of Korea's own space development goal of lunar landing by 2031.

Since the early 1990s, the Korean government has consistently maintained the goal of acquiring satellite technology development. Over a relatively short period of about 30 years, it has steadily secured state-of-the-art satellite design, analysis, assembly, and testing technologies, while continuously generating demand for satellite development for public purposes. The government-funded research institution, KARI, has not only been involved in space-related research and development but has also been directly responsible for designing and manufacturing satellites. It has accumulated technology for developing low-earth orbit observation satellites and geostationary satellites at a global level. Recently, it has been actively involved in transferring satellite development technology accumulated to private industries within the country to promote the growth of the domestic private satellite industry. As a result of continuous satellite manufacturing efforts, the number of satellite manufacturing companies, research institutions, and universities increased from just 22 in 2007 to a total of 94 in 2021. Similarly, the workforce engaged in satellite manufacturing increased significantly from 569 individuals to 1,614 individuals during the same period. Moreover, the total activity amount in the satellite manufacturing field increased substantially from 196.4 billion Korean won to 531.5 billion Korean won during the same period. Consequently, the economic impact can be observed with the satellite manufacturing sector's revenue increasing from approximately 240.7 billion Korean won to 341.2 billion Korean won (MSIT, 2023)[13].

3.2. Generating profits through satellite utilization

The satellites developed in the 1990s were aimed at meeting various public demands alongside securing advanced technology.

13) 과학기술정보통신부 (2023) *MSIT Launches the K-Network 2030 Strategy* [online] (20 February 2023). Available at: https://scienceon.kisti.re.kr/commons/util/originalView.do?cn=JAKO199611920560010&dbt=JAKO&koi=KISTI1.1003%2FJNL.JAKO199611920560010

Korea Satellite (KOREASat), the first broadcast communication satellite launched in 1995, aimed to satisfy diverse citizen needs and bridge cultural gaps between regions. Similarly, the Multipurpose Satellite (KOMPSAT), launched in 1999, was designed for applications in public sectors such as weather/environmental observation and precise surveying to accumulate satellite technology expertise. The Science and Technology Satellite (STSAT), launched in 2003, was intended for space environment experiments, space observation, equipment testing, and training specialized personnel in the space field. The electronic-optical camera mounted on the Multipurpose Satellite 1 (KOMPSAT-1) was particularly instrumental in producing detailed maps of the Korean Peninsula at a scale of 1/25,000, facilitating various applications such as land management, terrain surveying, and regional surveillance. Multipurpose Satellite 2 (KOMPSAT-2), on the other hand, possessed black-and-white imagery with a resolution of 1 meter and color imagery with a resolution of 4 meters. It was utilized for land management, environmental/marine pollution analysis, disaster management, and also proved effective for national security purposes, such as capturing images of North Korea's nuclear tests and long-range rocket experiments in 2013 (Park, 2015)[14].

The successful development of satellites and the resultant applications in Korea paved the way for the government to establish satellite-based industrialization as a key space policy. According to the First Master Plan for Promotopn of Space Development (2007), the strategy included utilizing the outcomes

14) 박근태 (2015) *굿바이, 아리랑2호... 9년 만에 임무 종료*, 한국경제 (5 October 2015). Available at: https://www.hankyung.com/news/app/newsview.php?aid=2015100525341

과제 3 | 우주개발 산업화 역량 강화

□ 독자적 우주개발 및 세계시장 진출 가능한 기술적·가격적 경쟁력 확보

○ 위성개발의 '틈새시장' 이고, 우주선진국 대비 경쟁력이 확보된 저가 소형위성의 수출 산업화 촉진 및 이를 위한 정부차원의 지원책 강구

□ 국책 기술개발 결과를 산업화로 연계하기 위해 기존 기업체 활성화 지원 및 벤처기업(연구소기업) 설립 장려

○ 국책연구기관의 우주기술을 산업화 하기 위해 '대덕연구개발특구 등의 육성에 관한 특별법'에 따른 연구소기업 설립 추진

○ 중장기적으로 다목적실용위성 위성영상의 해외수출, 우주전자 부품의 산업화를 위한 벤처기업(연구소기업) 설립 방안 검토

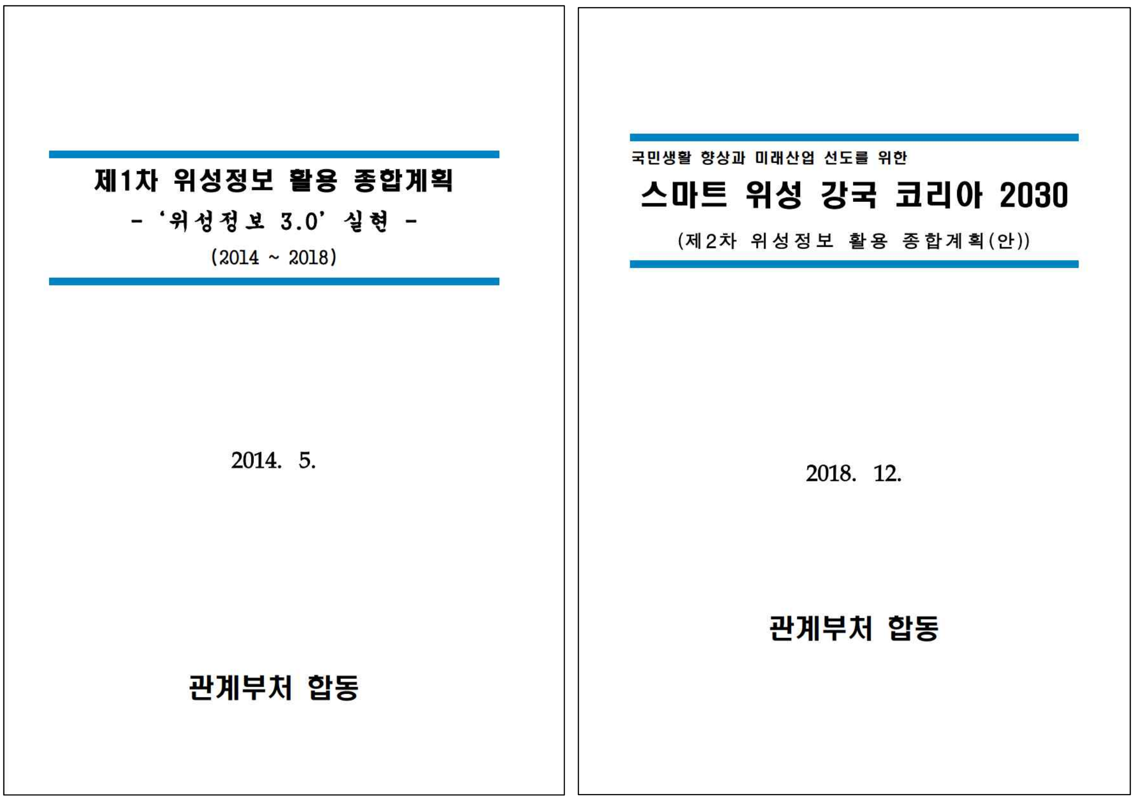
□ 민간 산업인력에 대한 우주개발기술 교육을 실시하여 우주기술 저변확대 및 관련 산업분야의 접목 유도

Figure 4 Proposal for strengthening space development industrialization as a space development promotion policy
(source: excerpt from the First Master Plan for Promotion of Space Development)

of satellite operations to benefit public interests and enhance the quality of citizens' lives. In the short term, the plan aimed to secure a competitive advantage in low-cost small satellites for export compared to space-faring nations (refer to Figure 4). Additionally, in the medium to long term, the plan proposed actively supporting the overseas export of satellite imagery from multipurpose satellites and providing domestic private companies with satellite imagery at affordable prices, thereby incentivizing the creation of new related industries using the acquired space development outcomes to stimulate the domestic space industry.

Thanks to these government policies, domestic private companies like Satrec Initiative have leveraged their accumulated technological expertise from participating in the government's public satellite development efforts to export self-produced small satellites to countries such as Malaysia, the United Arab Emirates, Spain, and others. Furthermore, they have demonstrated the potential for generating corporate profits in the space sector by exporting high-resolution satellite cameras to Singapore and Turkey (Song, 2010)[15].

Meanwhile, the Korean government has established a separate comprehensive plan for utilizing satellite information to promote industrial development in the space sector (refer to Figure 5). This comprehensive plan, covering a five-year period, was first formulated in 2014, with a second plan developed in 2019. The key contents of these plans are broadly as follows: i) Actively


제1차 위성정보 활용 종합계획
- '위성정보 3.0' 실현 -
(2014 ~ 2018)

2014. 5.

관계부처 합동

국민생활 향상과 미래산업 선도를 위한
스마트 위성 강국 코리아 2030
(제2차 위성정보 활용 종합계획(안))

2018. 12.

관계부처 합동

Figure 5 Covers of 1st and 2nd Comprehensive Plans for Utilizing Satellite Information

15) Song, J. (2010) *Setrec Initiative: Sky is no limit for small satellite maker*, FINANCIAL TIMES (10 November 2010). Available at: https://www.ft.com/content/9d208c90-eb8a-11df-bbb5-00144feab49a

utilizing diverse satellite information in the public sector to generate import substitution effects and contribute to the lives and safety of the people, ii) Creating a new industrial ecosystem that directly utilizes satellite information, including image sales/export, processing, and analysis services. In particular, to pioneer the export market for domestic companies' satellite imagery data, the government has spared no effort in predicting the demand for satellite imagery in promising export markets such as Central Asia, Southeast Asia, Africa, and South America and creating an export-friendly environment by actively supporting satellite imagery technology in these countries. From 2008 to 2012, the overseas sales revenue from satellite imagery amounted to approximately 20.3 billion Korean won, averaging about 4 billion won annually (Yoon & Kim, 2015)[16].

In relatively recent years, in 2018, under the full support of the Korean government, contracts for the export of national satellite imagery were signed with SIIS (Satrec Initiative Image Service), a domestic and international sales agent for satellite imagery, with the Philippines and India respectively (Song, 2018)[17]. These contracts involve the sale of territorial imagery captured by Korea's multipurpose satellites. With the Philippines, the export volume amounted to approximately 1.98 million US dollars (about 21 billion Korean won) for one year, while with India, it was about 4 million US dollars (about 43 billion Korean won) for two years. The government and KARI recognized the

16) 윤형식, 김용승 (2015) *위성영상 수출산업화 전략(성장동력 확보를 위한 상용체재 강화 방안)*, 항공우주산업기술동향 제13권 제1호 (1 July 2015). Available at: https://www.kari.re.kr/download/viewer/1621833466404/index.html

17) Song, J. (2018) *South Korea Exports Its First High-Resolution Satellite Images to Philippines and India*, Korea IT News (21 February 2018). Available at: https://english.etnews.com/20180221200001

high demand for ultra-high-resolution radar imagery in the tropical region of the Philippines, where frequent cloud cover makes ground situation assessment difficult, and consistently promoted the superiority of Korean satellite technology to the Philippines (Yoon, 2018)[18]. Similarly, in the case of India, KARI and SIIS established a foundation for exports by providing technical support since 2013, ultimately surpassing leading companies from China, Canada, the United States, and France to finalize the contract.

3.3. Acquisition of launch vehicle development technology

Since the early stages of space development, the Korean government has pursued the capability to independently develop satellites while concurrently seeking to establish autonomous capabilities for launching satellites into space. The reason behind this was to launch satellites developed domestically with rockets developed independently. The first-stage Science Observation Rocket (KSR-I), launched in 1993, was the first rocket developed jointly by KARI and industry, academia, and research institutions in Korea. This initial science observation rocket carried a payload of 150 kg and performed missions to explore the atmosphere at altitudes of 35-75 km and observe the ozone layer in the skies above the Korean Peninsula. Subsequently, the development of the two-stage Medium-sized Science Observation Rocket (KSR-II, launched in 1997) secured the technology for separating the rocket's second stage. Moreover, by successfully developing the Science Observation

18) 윤신영 (2018) *아리랑위성 영상 필리핀-인도에 64억원 받고 수출*, 동아일보 (21 February 2018). Available at: https://www.donga.com/news/article/all/20180220/88764781/1

Rocket (KSR-III, launched in 2002) using liquid propulsion instead of solid propulsion, the foundation was laid for the subsequent development of more sophisticated launch vehicles. These successful development achievements smoothly transitioned into the comprehensive development of launch vehicles, including the establishment of essential infrastructure such as launch sites and ground control centers required for launching rockets.

After successfully developing and launching three Science Observation Rockets, Korea decided to develop a launch vehicle capable of placing a 100kg-class small satellite into low Earth orbit. However, as late as the year 2000, Korea's rocket technology was so lacking that it could not even determine the conceptual design of a launch vehicle. Despite this, due to concerns about military applications, the transfer of rocket technology between countries was strictly prohibited. In this situation, Korea managed to conceive independent development solely based on existing experiences. However, when Korea joined the Missile Technology Control Regime (MTCR) in 2001, cooperation on rocket development with other countries became possible through technology transfer. In 2004, Korea and Russia initiated full-scale development of a launch vehicle by signing a space technology cooperation agreement (Kim, 2013)[19]. By subcontracting the conceptual design of the satellite launch vehicle and analysis of the propulsion system to Russian institutions, Korea was able to acquire advanced rocket development technology and experience, as well as key technologies such as system design, integrated technology, and

19) 김승조 (2013) *우주 강국 향한 나로호 발사 성공 - 나로호 발사와 그 이후, 나로호 발사 성공 소감과 향후 계획*, The Science & Technology, 46-50 (30 January 2013). Available at: https://koreascience.kr/article/JAKO201359149931710.pdf

launch operation technology during the development process. The Korean Space Launch Vehicle-I (KSLV-I), latter named Naro, resulting from this collaboration, dramatically improved Korea's rocket development technology, as it not only gained experience in successful rocket development through close technological cooperation with Russia, but also secured a considerable number of key rocket development technologies. In fact, through the development of Naro, Korea's rocket technology level improved from 46.3% to 83.4% compared to advanced countries (KARI, 2023)[20].

Despite the successful launch of Korea's first space launch vehicle, the Naro, in a relatively short period, some argued that Naro could not be considered a completely independent development because the core engine of the first stage was directly imported from Russia. In response, KARI began development of a launch vehicle capable of placing a 1.5-ton-class practical satellite into orbit solely using domestic technology in 2010. After several years of development, the completed vehicle, later named Nuri, Korean Space Launch Vehicle-II (KSLV-II), holds significant value in that unlike the previous Naro, all core components, including the engine, were designed and manufactured using pure Korean technology. This means that regardless of the launch schedule of other countries' launch vehicles, Korea can secure its own launch vehicle when needed and launch satellites at the optimal time, thereby ensuring national security and improving the quality of life for its citizens as planned by the government. For example, Korea's multipurpose satellite, KOMPSAT-6, was initially planned to be launched using a Russian launch vehicle in mid-2022. However,

20) 한국항공우주연구원 (2023) *Naro, Korea's first space launch vehicle*. Available at: https://www.kari.re.kr/eng/sub03_04_02.do

Vehicle	Objective	Development Period	Development Cost (B KRW)	Launch date
KSR-I (과학관측 로켓-I)	Development of the first-stage unguided scientific observation rocket	Jul 1990 - Oct 1993	2.85	1st 4 Jun 1993 2nd 1 Sep 1993 3rd
KSR-II (과학관측 로켓-II)	Development of the second-stage solid-fueled scientific observation rocket localization	Nov 1993 - Jun 1998	5.2	1st 9 Jul 1997 2nd 11 Jun 1998 3rd
KSR-III (과학관측 로켓-III)	Independent development of liquid-fueled rockets and acquisition of small satellite launch vehicle core technology	Dec 1997 - Feb 2003	78	1st 28 Nov 2002 2nd - 3rd
KSLV-I (나로호)	Development of a launch vehicle capable of placing a 100kg-class artificial satellite into low Earth orbit	Aug 2002 - Apr 2013	502.5	1st 25 Aug 2009 2nd 10 Jun 2010 3rd 30 Jan 2013
TLV (시험 발사체)	Development of a test launch vehicle for verifying the performance of a 75-ton liquid engine to be used in the Nuriho	Aug 2015 - Nov 2018	-	1st 28 Nov 2018 2nd 3rd
KSLV-II (누리호)	Development of a launch vehicle capable of deploying a 1.5-ton class practical satellite into low Earth orbit	Mar 2010 - Oct 2022	1,957.2	1st 21 Oct 2021 2nd 21 Jun 2022 3rd 25 May 2023

Table 3 History of Korean Rocket Vehicle Development

(source: Author edited research results of the website)

due to Russia's invasion of Ukraine, the use of Russian launch vehicles was restricted, resulting in a delay in the launch schedule until early 2025 due to administrative procedures such as sourcing, negotiation, and contracting of alternative launch vehicles. Nevertheless, with the practical impossibility of utilizing Russian launch vehicles due to international sanctions against Russia, Korea recently finalized negotiations for the termination of the satellite launch service contract with Russia and signed a new launch contract with the EU's Arianespace (MSIT, 2023)[21]. Such delays in satellite launches not only result in simple time losses but also incur significant additional costs, such as the shortening of the operational period of satellites that have already been manufactured. Furthermore, delays in acquiring operational data from satellites in space inevitably delay the acquisition of domestic satellite technology. As observed above, there has been a national consensus on the importance of securing independent launch capabilities, and the success or failure of Nuri, developed entirely with domestic technology, has received even greater attention.

The first launch of Nuri in 2021 ended in final failure due to premature ignition of the third-stage engine. However, in the second launch in June 2022, the performance verification satellite was successfully placed into orbit, finally receiving a final successful launch verdict, making Korea the 10th country to possess independent production and launch capabilities for its own launch vehicle. Particularly, as a launch vehicle capable of carrying practical satellites weighing over one ton, Korea now ranks as the 7th country following Russia, the United States, Europe, China, Japan, and India (Kim, 2023)[22]. In the third

21) 과학기술정보통신부 (2023) *다목적실용위성6호, 차세대중형위성2호 관련 러시아와의 환급 협상에 최선* (10 October 2023). Available at: https://www.korea.kr/briefing/actuallyView.do?newsId=148921127

launch in May 2023, by successfully launching an actual satellite, Korea's launch vehicle development capability was objectively proven. Securing independent space transportation capabilities holds significant importance as it signifies Korea's attainment of autonomous national space development capabilities.

22) Kim, N. (2023) *Fast facts about S. Korea's Nuri space rocket*, Yonhap News agency (25 May 2023). Available at: https://en.yna.co.kr/view/AEN20230524004700320

4. Problem Analysis

Since the 1990s, I have examined the direction and specific achievements of Korea's space development policy. It is no exaggeration to say that securing key technologies for the production of satellites and launch vehicles has been the top priority of space development. Recognizing the far-reaching impact and importance of space technology early on, efforts were made to secure independent production technologies through international cooperation, notably with Russia. Since the 2010s, Korea has successfully developed and launched satellites and launch vehicles solely with its own technology. This achievement, accomplished in a relatively short period compared to only a few countries worldwide, has earned recognition for Korea's outstanding space development capabilities. Alongside achieving technological independence in development, I have also observed the creation of new industrial sectors utilizing satellite utilization outcomes as one of the important policy directions of the Korean government. As a result, with the ability to acquire geographic information independently through domestic satellites, significant monetary benefits have been achieved by fully utilizing acquired imagery data for domestic public purposes. Furthermore, by identifying the demand from developing countries where self-acquisition of satellite data is not feasible and selling imagery data, Korea has also succeeded in opening up new avenues for revenue generation.

Korea can now be considered to have largely achieved its past top priority of securing core technologies to produce satellites and launch vehicles independently. Therefore, it is now necessary to pay attention to the next steps of the Korean government regarding space development. So far, it is true that core technology acquisition has been primarily achieved through budget allocation by the Korean government and technology development centered around government-funded institutions such as KARI. However, the private companies in the space sector, which should be the main players in the era of NewSpace, have remained in a position where they indirectly acquire technology through collaboration with KARI. This seems far from the vision of the NewSpace era, which advocates for a space ecosystem where commercial profits can be generated under private leadership. As we prepare for the upcoming era of NewSpace, it is necessary to examine the current direction of space development policy put forward by the Korean government and how it differs from the past.

4.1. Current Space Development Policy Direction

4.1.1. Enhancement of the maturity of acquired technology

1) Performance Improvement and Subsequent Development of Existing Satellites

According to the Fourth Master Plan for Promotion of Space Development established by the Korean government in 2023, it is expected that government-led repetitive satellite development will continue for the time being. The plan involves producing improved successor satellites considering the lifespan of currently operational satellites, thereby enhancing the maturity of the technologies already secured. As of 2024, there are a total of 10 government-developed satellites in operation, including three multipurpose satellites (KOMPSAT), three Communication/Ocean/Meteorological satellites (COMS), one Compact Advanced Satellite 500 (CAS500), two Next Generation Satellites (NEXTSat), and one performance verification satellite for the Nuri launch vehicle. Subsequent satellites are being developed to continue precision observation, disaster response, and national security missions in preparation for the aging of currently operational multipurpose utility satellites. Among these subsequent satellites, 7A is under development as the successor to 6 and 7, which have been completed but are currently experiencing launch delays, and the production of 9 is also planned. These successor satellites are equipped with improved resolution for more precise Earth observation. The Communication/Ocean/Meteorological satellites, which perform continuous observation missions of the Korean Peninsula at the same speed as the Earth's rotation under the name "Cheollian," are expected to be developed with upgraded performance. Following the three satellites currently in operation (1, 2A, and 2B), the next satellite, scheduled for launch in 2027 as Cheollian 3, is planned to provide comprehensive public services such as nationwide public disaster communication services, flood prevention monitoring, and rescue communication. Whether Cheollian 5 and 6 will proceed with the project will be determined through feasibility assessments.

Meanwhile, for the purpose of scientific missions, orbit verification of space core technologies, and the development of leading space technologies, the successor to the 100kg-class Next Generation Satellite (NEXTSat) has been developed not as a single satellite but in the form of a cluster of more than 10 satellites. This successor, named the Micro Satellite Cluster

System, aims to enhance the speed and accuracy of national security and disaster response by operating a total of 11 microsatellites weighing less than 100kg in a cluster. Operating as a cluster offers the advantage of more frequent and wider observation of the same location at the same time. The prototype satellite equipped with a 1-meter resolution electro-optical camera is planned to be launched in 2024, followed by the launch of the remaining 10 satellites in 2026 and 2027. Such microsatellites are expected to encourage the participation of small to medium-sized private companies and academia, as they require lower development costs compared to medium-sized satellites, thus alleviating the financial burden of satellite development. The Korean government anticipates that the development of microsatellite clusters will lead to the creation of 14,000 jobs and generate an economic ripple effect of 30 trillion Korean won.

The successor satellites of the multipurpose satellites and Communication/Ocean/Meteorological satellites will be led by the government agency KARI, as before. The Next Generation Satellites will be designed and manufactured by SatReC (Satellite Technology Research Center), an artificial satellite research institute affiliated with KAIST (Korea Advanced Institute of Science and Technology), a government-funded research institution.

Meanwhile, the Compact Advanced Satellite 500 (CAS500), a 500kg-class low-earth orbit observation satellite, was originally designed with the intention of private sector-led mass production. The currently operating first unit was developed overall under the auspices of KARI, but KARI established a joint design team with the research personnel of Korea Aerospace Industries (KAI), a Korean aerospace private company, to facilitate a natural transfer of satellite development technology. In this process, KAI acquired independent satellite development capabilities, leading to the successful completion of the second unit of the CAS500, which was led by KAI with participation from 67 domestic companies. Originally planned to be launched using a Russian rocket vehicle in 2022, the launch schedule was postponed due to reasons similar to those of the Multi-Purpose Satellite 6. Currently, the contract with Russia for the launch has been terminated, and a substitute launch contract with SpaceX of the United States has been signed, scheduled for launch in 2025 (Yang, 2023)[23]. Additionally, KAI is set to lead the development of the 3rd to 5th units in the future, and is also preparing for the era of private sector-led space by pursuing satellite export industrialization through a strategy that integrates aircraft and various satellite platforms.

2) Reliability and performance improvement through repeated launch of the KSLV-II

The Korean government is planning repeated launches to ensure the reliability of the Korea Space Launch Vehicle-II (KSLV-II), which has only had three launch attempts and succeeded twice. According to the Fourth Master Plan for Promotion of Space Development, concrete plans for up to the sixth launch by 2027 have been established, and there are plans to carry out launches at an average of more than once per year even after 2028 to

23) 양기섭 (2023) *KAI, 차세대중형위성 2호 대체발사 계약*, 경남매일 (4 December 2023). Available at: http://www.gnmaeil.com/news/articleView.html?idxno=531031

meet the requirements for performance testing of domestically developed components (refer to Figure 6). Furthermore, after the fourth launch of the Nuri, which was developed under the leadership of the KARI, a launch vehicle system integrator will be selected to oversee the production and assembly of flight models, thereby naturally spreading launch vehicle development technology to the private industry. Additionally, rather than simply manufacturing launch vehicles with the same performance as before, there are plans to improve the performance of the launch vehicle itself through the development of large fairings, engine performance enhancements, and vehicle lightweighting to diversify the missions of the launch vehicle. In particular, improvements will be made to allow heavier satellites to be carried, hinting at future developments in next-generation launch vehicle development. Through such improvements in launch

2 누리호 신뢰성 확보를 위한 반복 발사 및 성능 개선('22~')

- **(신뢰성)** '27년까지 **4회 반복 발사**를 추진하고 다양한 임무 수행을 위한 주·**부탑재 위성을 탑재**하여 발사
  - **'28년 이후**에도 공공수요 중심*으로 평균 **연 1회 이상 발사 추진**
    - * 국내 부품·탑재체 우주 성능 시험을 위한 기술검증플랫폼위성 지속 발사 ('28,'29,'30)
- **(체계종합기업육성)** 누리호 주요 **기술**(설계·제작·시험 등) **이전**을 통해 향후 **누리호의 제작·조립·발사 등**을 총괄 수행할 **민간기업 육성**
  - **체계종합기업**은 출연연과 함께 **누리호 4차~6차** 비행모델 **제작·조립 총괄 관리 및 발사 공동 운용** 등 역할 수행
- **(성능개선)** 임무다변화를 위한 **대형페어링 개발, 엔진 성능개량, 기체 경량화** 등 지속적인 성능 개선 추진
  - **출연연** 중심으로 **반복발사 과정** 중 **대형페어링 개발** 등 착수, **반복발사 이후 체계종합기업 중심** 성능 개선 및 안정성 확보 추진
  - 누리호 **최적화**(무게, 발사 운용 등)를 통해 **경쟁력 있는 발사체로 개선**

Figure 6 Plan for repeated launches and performance improvements to ensure the reliability of the KSLV-II

(source: excerpt from the Fourth Master Plan for Promotion of Space Development)

vehicle performance and reliability, there is cautiously anticipated potential to establish a revenue generation system akin to that of SpaceX in the United States, which profits by launching satellites from other countries. Moreover, this could lay the foundation for the ambitious future space transportation business proposed by the Korean government. Additionally, with the government announcing ongoing launch plans, various academic and industrial sectors involved in satellite development may find it easier to obtain opportunities for validation in actual space environments, thereby positively influencing continued efforts in challenging satellite development.

4.1.2. Development of new concept of satellite and launch vehicle

1) Development of new satellite systems

While developing successor satellites to existing satellite systems, the Korean government also plans to establish new satellite systems for various purposes. One notable example is the Korea Positioning System (KPS), a Korean satellite navigation system. The satellite navigation system provides Positioning, Navigation, and Timing (PNT) information through satellites, aiming to establish Korea's independent ultra-precise 5-centimeter-level positioning/navigation services. Development began under the leadership of KARI in 2022, with plans to launch a total of eight satellites starting in 2027 and commence services from 2035. Currently, Korea heavily relies on the commercial GPS signal from the United States, which has an inherent accuracy of about 10 meters. However, due to Korea's urban and mountainous terrain, there are areas with poor GPS signal quality, limiting the application of precise location information in new industries such as aviation mobility and autonomous driving. Furthermore, while there are no constraints on using GPS signals under normal circumstances, any technical flaws in the GPS signal or interruptions due to international disputes could potentially paralyze critical systems within Korea. There is also a constant concern about the possible commercialization of GPS signal provision. For these reasons, advanced countries have already established and operate independent satellite navigation systems for national security reasons in anticipation of similar scenarios: GPS (USA), GLONASS (Russia), Galileo (EU), BeiDou (China), QZSS (Quasi-Zenith Satellite System, Japan), and IRNSS (India).

[3] 4차 산업혁명의 핵심인프라 KPS 위성 개발

ㅇ **초정밀 위치·항법·시각(PNT)** 서비스에 필요한 **한국형 위성항법시스템(KPS)**을 구축*하여, **교통·통신** 등 **인프라 안정성** 확보 및 **新산업** 창출

* 사업 착수('22) → 위성 첫 발사('27) → 시범서비스('34) → 위성 배치 완성('35)

- 정지궤도 3기, 경사지구동기궤도 5기 등 **총 8기 위성시스템 개발**
- **항법메시지**를 생성하여 위성에 전달하는 **지상시스템*** **개발**

* 통합운영센터, 위성관제센터, 안테나국, 감시국, 서비스별 임무제어국 등으로 구성

- **KPS 운영** 및 다양한 사용자에게 필요한 **사용자시스템*** **개발**

* 연구개발용, 시험평가용, 감시국용, 일반사용자용 수신기 등

< KPS 위성 개발 계획(안) >

구 분	4차 계획(~'27년)	5차 계획('28~)	비 고
한국형 위성항법시스템(KPS)	사업 착수('22년) 1호기 발사('27년~)	2~8호기 발사(~'35년)	해외발사체

Figure 7 Plan for KPS(Korea Positioning System) Satellite development
(source: excerpt from the Fourth Master Plan for Promotion of Space Development)

Although the KPS development project is primarily driven by the government with a strong focus on national security, the Korean government plans to expand participation opportunities for the industry through wide-ranging involvement of businesses, academia, and research institutions. According to the third Master Plan for Promotion of Space Development, the KPS development project is expected to generate significant economic effects, including a production-induced effect of 17.798 trillion Korean won and an additional value-induced effect of 11.295 trillion Korean won, along with an employment effect of 18,000 people, through direct government investment. Furthermore, the indirect effects through the operation of the KPS with ultra-high resolution are substantial. The market benefits from various centimeter-level services expected to be developed could amount to 6.6536 trillion Korean won over 10 years, with an anticipated employment effect of 57,349 people. The development of navigation satellites, which is different from traditional Earth observation satellites, will provide participating private companies with opportunities to acquire new satellite development technologies and experiences, thereby enhancing their space development capabilities and enabling them to become more independent in the space ecosystem.

The Ministry of Science and ICT continues to maintain close cooperation with countries operating existing satellite navigation systems. In 2023, it launched the KPS-GPS Technical Working Group with the United States, followed by a cooperation agreement with Japan in 2024 regarding regional satellite navigation system interoperability between KPS and QZSS (Jo, 2024)[24]. As Korea seeks to operate its own independent

24) 조승한 (2024) *"KPS-QZSS 협력 논의" 한일 위성항법 분야 협력 약정*, 연합뉴스 (26 March 2024). Available at: https://www.yna.co.kr/view/AKR20240326075700017?input=1195m

satellite navigation system, ensuring coexistence and interoperability with existing systems is crucial. Therefore, there are plans to further expand international cooperation with Europe and India in the future.

Not only KPS, but the Korean government has also decided to move beyond the development of medium-sized satellites operating independently with a mass of over 500kg, opting instead to develop new clusters of ultra-small satellites weighing less than 100kg. The plan involves operating a large number of smaller satellites in conjunction with existing medium-sized multi-purpose satellites to monitor crisis situations in the waters surrounding the Korean Peninsula, with applications in maritime security, law enforcement, and disaster prevention. Among these ultra-small satellites, those designed for Earth observation, such as the ultra-small SAR (Synthetic Aperture Radar) satellites, represent an underexplored domain, with only two entities, Finland's ICEYE[25] and the United States'

[2] 국민체감 서비스 향상을 위한 저궤도 지구관측 역량 고도화

- **(다목적실용위성)** 공공수요(정밀관측, 재난대응, 국가안보 등)에 필요한 **초고해상도 영상레이더 및 광학 위성* 개발**
  ※ (7호, 7A호, 7B호) 광학+적외선, (8호) 영상레이더, (9호) 광학+적외선
- **(차세대중형위성)** 표준플랫폼(500kg급)을 기반으로 **민간주도 위성*** 개발 및 활용 **분야별 공공서비스**(국토, 농업, 산림, 수자원 등) **기반 구축**
  * (1·2호)국토관리·공간정보 / (3호) 과학기술 / (4호) 농업·산림 / (5호) 수자원 등
  ※ 지속적인 임무 수행 필요성 등 타당성 검토를 거쳐 추진
- **(초소형군집위성)** 고빈도·정밀관측(신속 재난대응 포함)을 위한 **군집형 초소형위성(100kg급) 및 관련 활용시스템을 개발**

Figure 8 Plan for clusters of ultra-small satellites development
(source: excerpt from the Fourth Master Plan for Promotion of Space Development)

25) https://www.iceye.com/

Capella Space[26], currently possessing such technology to a limited extent. Therefore, if successful, the impact of their development is expected to be significant (Ahn, 2020)[27].

These ultra-small satellites offer a significant advantage in terms of lower development costs compared to medium and large satellites. Therefore, they have the potential to stimulate participation in satellite development by small and medium-sized private companies and academia, which previously faced difficulties in bearing the financial burden of developing large-scale satellites. Moreover, efforts will be made to address the shortcomings typically associated with traditional ultra-small satellites, such as low resolution and reliability, while also overcoming disadvantages like high weight and long development periods. The Korean government anticipates that the development of clustered ultra-small satellites will lead to the creation of 14,000 jobs and have a ripple effect of 30 trillion won in economic impact. This project, overseen by the Agency for Defense Development (ADD) since 2023, involves collaboration with various private companies such as Hanwha Systems, Soltaip, and Satrec Initiative. Through this collaboration, the government aims to facilitate the transfer of small satellite development technology to the private sector.

26) https://www.capellaspace.com/

27) 안승회 (2020) *미래 전장은 어떤 모습일까? 작지만 강한 K-초소형 군집위성으로 그물망 감시정찰*, 국방홍보원 (8 September 2020). Available at: https://post.naver.com/viewer/postView.nhn?volumeNo=29370536&memberNo=37344293&vType=VERTICAL

2) Development of the next-generation launch vehicle, KSLV-III

The Korean government plans to develop the next-generation launch vehicle (KSLV-III) based on the technology secured through additional launches and performance improvements of the Nuri launch vehicle. This new launch vehicle will utilize a two-stage configuration incorporating a staged combustion cycle engine (a technology that re-burns residual thermal energy in the form of black smoke generated during the engine thrust process by burning oxidizer and fuel). With a total project budget of 2.132 trillion Korean won, the development of the next-generation launch vehicle commenced in 2023. It is expected to significantly enhance Korea's space transportation capabilities for future large satellite launches and space exploration missions. While the previous Nuri launch vehicle was

[3] 우주탐사 등 대형 우주수송을 위한 차세대 발사체 개발('23~'32)

○ **(성능) 7톤 저궤도위성**(태양동기궤도(SSO)) 및 **3.7톤 정지궤도위성**(정지천이궤도(GTO)) 투입**성능 확보 후, 본격적 우주탐사를 위한 성능확장**

※ '32년까지 지구저궤도 대형위성 발사 및 1.8톤급 달탐사선 발사 가능한 기본형 개발 후, 3~4톤 이상 달착륙선, 2~3톤 이상 화성탐사선 등 발사 가능한 확장형 단계적 개발

○ **(전략)** 누리호를 통해 확보한 기술을 기반으로 **다단연소사이클 엔진** 적용 **2단형 형상**(누리호 3단형 → 차세대 발사체 2단형*)으로 **발사체 개발**

* 1단부 100t 이상 엔진 5기, 2단부 10t 이상 엔진 2기 형상, 재사용발사체 기반기술(재점화, 추력조절)이 탑재된 다단연소사이클 엔진 적용

- **(기술고도화) 재사용 발사체 전환**을 고려한 기술 개발* 및 향후 추진될 대형임무를 고려한 **성능 확장 가능 형상**으로 개발** 추진

* 홀수의 1단 엔진 클러스터링 형상 및 1단 엔진 재점화/추력조절 기능을 기반으로 향후 재사용 발사체 기술개발 연계 가능

** 부스터 장착이 가능하도록 추진 계통의 발사체 내부 배치, 대형 페어링 개발 등

- **(민관협업)** 체계종합기업의 역할을 기존 제작참여·기술이전에서 **공동설계 참여까지 확대**하여 민간기업의 발사체 개발역량 강화

Figure 9 Plan for next-generation launch vehicle (KSLV-III) development
(source: excerpt from the Fourth Master Plan for Promotion of Space Development)

capable of carrying payloads of 1.5 to 2 tons, the goal for the next-generation launch vehicle is to carry payloads of more than three times that amount into low Earth orbit. Additionally, engine reignition and thrust control technologies will be applied to enable potential reuse of the launch vehicle in the future. Three launches are planned by 2032. The first launch in 2030 will carry a satellite for lunar orbit insertion performance verification to confirm the performance of the launch vehicle. In 2031, a preliminary model of a lunar lander will be launched, followed by the launch of the final model of the lunar lander in 2032.

Meanwhile, as of March 2024, Hanwha Aerospace, a private company in Korea, has been selected as the preferred negotiation partner for the overall management and production of the next-generation launch vehicle development project, and contract negotiations are currently underway (Hanwha, 2024)[28].

4.1.3. Space exploration

1) Landing on the Moon and securing a lunar base

As the development independence of satellites and launch vehicles became somewhat feasible, the Korean government began to turn its attention to space exploration. From the Third Master Plan for Promotion of Space Development in 2018, lunar exploration was actively pursued as one of Korea's space

28) 한화 (2024) *한화, '차세대발사체 사업자' 선정.. "도전적 과제, 책임감으로 완수할 것"* (20 March 2024). Available at: https://post.naver.com/viewer/postView.naver?volumeNo=37509868&memberNo=1972196&vType=VERTICAL

development strategies. As a preliminary action plan, the development of a 550kg-class lunar orbit probe for securing and verifying the basic technology of space exploration was decided.

3-1 달 탐사 본격 착수

□ 1단계 달 탐사 임무 완수

ㅇ (목표) 우주탐사 기반기술 확보·검증을 위한 국제협력 기반의 550kg급 시험용 달 궤도선 개발(~'20)

- 총 중 량: 약 550kg급
- 임무수명: 약 1년
- 개발내용: 궤도선 시스템·본체 및 탑재체 개발, 심우주지상국 구축, NASA와 국제협력 등 추진

< 시험용 달 궤도선 형상 >

Figure 10 Lunar orbit probe development plan
(source: excerpt from the Third Master Plan for Promotion of Space Development)

The KARI, the leading agency for the development of lunar orbit probes, focused on securing core technologies. KARI took the lead in the design, production, assembly, testing, and launch of the lunar orbit probe, while also receiving support for deep space flight, control, and navigation technologies through international cooperation with NASA. Key objectives included navigation guidance control technology for lunar orbit landing, large-capacity propulsion system technology, establishment of large antennas for deep space communication between Earth and the Moon, and securing communication/control technology. The developed lunar probe was launched aboard a SpaceX Falcon 9 rocket in August 2022 and successfully landed in lunar orbit in December of the same year, elevating Korea to the seventh position among countries with lunar exploration capabilities

(KARI, 2022)[29].

The lunar probe named "Danuri" was tasked with missions such as capturing high-resolution images of the lunar surface, geological and resource exploration of the Moon, and acquiring magnetic field maps of the surface and nearby areas. Among these, the high-quality images of the permanently shadowed regions of the lunar polar regions captured by the Shadow Camera developed by the United States are crucial data for selecting optimal lunar base construction sites. This is expected to significantly contribute to the Artemis project led by the United States. Originally, Danuri had a short-term mission plan for one year until 2023. However, due to significant fuel savings during the lunar orbit insertion process, it was decided to extend the mission operation until 2025 (MSIT, 2023)[30]. During the additional period, Danuri will not only capture additional images of over 50 potential lunar landing sites but also perform full-scale imaging of the mid-latitude regions and conduct tests to verify the performance of the payload. The newly assigned tasks are planned to be utilized as important foundational data for future space development.

Following the lunar orbit exploration previously discussed, the development plan for a 1.8-ton unmanned lunar lander for substantial lunar utilization has been formalized in the 4th Master Plan for Promotion of Space Development.

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29) 한국항공우주연구원 (2022) *다누리 마침내 달, 품에 안겼다 '세계 7번째 달 탐사국'* (29 December 2022). Available at: https://blog.naver.com/karipr/222969397524

30) 과학기술정보통신부 (2023) *우리 달 궤도선 '다누리' 임무기간 2025년 말까지로 2년 연장* (27 June 2023). Available at: https://www.korea.kr/news/policyNewsView.do?newsId=148916901

[2] 달 탐사의 본격 시작

○ **(달 궤도 임무)** **'다누리'**를 통한 달 궤도 탐사 **과학·기술검증 임무 완수***

* 자기장 측정기, 감마선 측정기, 고해상도 카메라, 광시야 편광카메라, 영구음영지역 카메라 등의 과학 임무와 우주 인터넷의 기술검증 임무

- 미국 협력 기관 등과 **과학자료 공유 및 지속적 공동 연구 수행**

○ **(달 착륙 임무)** 본격적인 달 활용을 위한 **첫 단계**로 달 표면 탐사 및 기술 검증을 위한 **달 착륙선 발사**('32)

< 『달 착륙선』 개발 사업(안) >

※ 예비타당성 조사 결과에 따라 변동 가능

◇ **사업기간 / 사업비 :** '24년 ~ '33년(10년) / 약 6,286억원

◇ **사업내용 :** 1.8톤급 달 착륙선 독자 개발, 달 표면 연착륙 실증, 과학기술임무 수행

- **(사업범위)** 착륙선, 지상시스템, 탑재체, 연착륙 기술 시험/검증
- **(개발성능)** 발사중량 1,800kg, 직접 또는 위상 전이궤도 달 표면 연착륙

Figure 11 Lunar lander development plan
(source: excerpt from the Fourth Master Plan for Promotion of Space Development)

At this point, specific project plans have not yet been finalized, but given the Korean government's emphasis on long-term space exploration as a significant space policy, the decision on whether to proceed with the project is expected to be made early. According to the current project schedule, development is set to begin in 2024, with the lunar lander planned to be launched aboard the next-generation launch vehicle in 2032. Unlike lunar orbit exploration, the lunar lander requires the use of powered descent systems to achieve a soft landing on the lunar surface, a technology known to be highly challenging, with only the United States and China possessing it independently. If the lunar lander is developed as planned, it will be equipped with a rover for surface exploration, a lunar regolith volatile extractor, and a small nuclear power unit to extract and analyze lunar soil samples or extract oxygen and hydrogen from the soil.

The plan is to construct a manned lunar base consisting of landing sites, habitats, and energy facilities necessary for long-term and sustained manned and unmanned exploration after successful lunar surface landing. However, at present, this is merely a declarative goal, and the achievement of this goal is only presented as a target for securing the level of In-Situ Resource Utilization (ISRU) technology.

1. 우주탐사 확대 : "우주로 경제영토 확장"

□ **임무 정의**

▶ 임무개요 : **인류 우주활동영역 확대**에 따른 국제질서 재편에 대응하여 **심우주 유·무인 활동을 주도적으로 추진**할 **핵심 역량 확보**

▶ 핵심 목표 : **'32년까지 달 착륙 → '45년까지 화성 착륙**

- **(달 탐사)** '32년 무인 착륙 및 표면 임무 → '40년대 달 기지 확보
- **(화성 탐사)** '35년 궤도 탐사 → '45년 착륙 및 표면 임무 수행

▶ 추진 전략 : **달·화성 탐사의 독자적 역량 확보**와 동시에 **국제협력**을 통한 **유인·정거장·탐사기지 등의 전략적 추진**

- 발사체, 무인 궤도선, 착륙선, 운송선의 독자적 능력 확보
- 궤도정거장, 달·화성 표면 기지 등의 분야에서는 국제협력 강화
- 현지자원활용(ISRU) 기초 기술을 확보하고 지상의 산업 역량 적극 활용
- 유인 우주 관련 선행 기술 개발 및 국제협력을 통한 유인탐사 참여

Figure 12 Expansion plan for space exploration
(source: excerpt from the Fourth Master Plan for Promotion of Space Development)

ISRU refers to the technology of producing necessary materials using local resources on celestial bodies such as the Moon or Mars, as continuously supplying materials from Earth is considered inefficient and is deemed essential for space exploration. However, the multilateral ISRU business agreement signed by six government-funded agencies including the Korea Institute of Energy Research (KIER), KARI, and aerospace company Hanwha Aerospace in 2021 represents the progress made in this regard so far (Hanwha, 2021)[31].

2) Orbital exploration and surface landing on Mars

Along with lunar exploration plans, the Korean government also plans to initiate preparations for future Mars exploration in earnest. Mars, as widely known, exhibits the greatest similarity to Earth among the planets in our solar system in terms of its rotational speed, axial tilt, surface features, and more. This is why Mars is considered a crucial planet in expanding the scope of human activities into space in the distant future.

In line with this, Korea has established plans to achieve unmanned spacecraft landing on the surface of Mars by approximately 2045 as a goal. By 2035, development of Mars orbiters is planned, aimed at observing Mars' atmosphere composition and terrain. To successfully achieve this ambitious plan, Korea is formulating strategies for specific Mars exploration missions and technological developments, while considering the technical challenges of lander missions. Development planning and research for both Mars orbiters and landers are planned to be conducted simultaneously until 2024. Although specific missions on Mars have not yet been

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31) 한화 (2021) *한화, 국내 최초 6개 정부출연 연구소와 우주 현지자원활용(ISRU) 관련 협약* (9 September 2021). Available at: https://post.naver.com/viewer/postView.naver?volumeNo=32336222&memberNo=1972196&vType=VERTICAL

confirmed, the plan is to carry out missions primarily for scientific exploration, including investigations into space environments, atmospheres, geology, astrobiology, and potential utilization of local resources. The success of Mars exploration plans depends on securing the development capabilities of orbiters and landers planned for lunar exploration, making the acquisition of cutting-edge technology a decisive factor in

③ **화성 탐사의 준비**

○ **(기획연구)** 우리나라 화성탐사 임무 발굴 및 기술 개발을 위한 전략을 마련하고, **화성 궤도선 및 착륙선 개발 기획 연구 수행***('23~'24)

※ 착륙선의 기술적 난이도, 임무 연계성을 고려해 궤도선과 착륙선 동시 기획

- **(궤도선)** 달 궤도선 및 착륙선 개발 역량을 기반으로 화성 궤도에 진입하여 화성의 대기 조성 및 지형 관측('35)
- **(착륙선)** 화성 궤도 진입과 진입하강착륙 기술을 적용하여 화성 대기, 지질, 생명의 흔적 탐사(~'45)

※ 차세대발사체 확장형을 활용하여 화성 궤도선 발사('35) 및 화성 착륙선 발사(~'45)

○ **(임무발굴)** 국내·외 **과학기술 커뮤니티**를 통해 과학·기술적 **행성탐사 역량** 및 영향력 있는 **과학 지식 창출**을 위한 **독창적 임무** 발굴

< 화성 탐사 임무(안) >

◇ **과학적 임무(안)**
- **(우주환경)** 화성의 자기권 및 이온층 분포 및 태양풍과의 상호작용
- **(대기)** 화성 대기의 수평·수직 분포, 구성 성분 및 중력장
- **(지질)** 화성의 내부구조, 표면의 지형 및 지질, 토양 및 광물자원
- **(우주생물학)** 생명체의 존재여부 및 생명체 거주공간으로서의 환경
- **(현지자원활용)** 에너지 생산, 기지 구축, 생명 유지를 위해 필요한 자원 탐색

◇ **기술적 임무(안)**
- **(항행)** 행성 간 비행 및 화성궤도 진입 또는 착륙하는 궤도 설계 및 운용
- **(통신)** 달에 비해 천배 이상의 거리에서 정밀 궤도 결정 및 통신 시스템

구 분	4차 계획(~'27년)	5차 계획('28~)	비 고
전략 도출	- 화성 탐사 전략/임무 발굴		
궤도선/착륙선	- 기획연구 수행 - 궤도선 개발 사업 시작	- 착륙선 개발 사업 시작 - 궤도선('35), 착륙선('45) 발사	궤도선/착륙선 동시 기획

Figure 13 Preparation plan for Mars exploration
(source: excerpt from the Fourth Master Plan for Promotion of Space Development)

determining the success of Korea's space policies related to Mars.

Meanwhile, the Ministry of Science and ICT (MSIT) of Korea held the 3rd Space Exploration Symposium, engaging in in-depth discussions with experts from academia, industry, and research institutes about Korea's potential and strategies for Mars exploration (MSIT, 2023)[32]. At this event, MSIT emphasized the value of Mars exploration, discussed research and development strategies, and exchanged opinions on development plans for Mars orbiters and landers. There was a consensus on the need to establish a clear roadmap for Mars exploration, develop key technologies, and formulate execution plans. Additionally, there was considerable interest in nurturing the next generation of talent for sustainable space exploration mission development. While Mars exploration is still in the early planning stages, it is deemed essential to establish systematic strategies for it to lead to substantive exploration success in the future.

4.1.4. Expand the share of Korean companies in the global space market from 1% in 2021 to 10% by 2045

According to the State of the Satellite Industry Report (2023)[33] by the Satellite Industry Association (SIA), the total size of the global space economy in 2022 was estimated to be

32) 과학기술정보통신부 (2023) *이제는 달을 넘어 화성으로! 대한민국 화성 탐사 필요성 및 전략 논의를 위한 제3회 우주탐사 심포지엄 개최*. 보도자료 (30 October 2023). Available at: https://www.msit.go.kr/bbs/view.do?sCode=user&mId=113&mPid=238&bbsSeqNo=94&nttSeqNo=3183609

33) Satellite Industry Association (2023) *State of the Satellite Industry Report*. Available at: https://sia.org/news-resources/state-of-the-satellite-industry-report/

approximately 384 billion USD. Of this, the satellite-related industry, excluding non-satellite industries such as government space budgets, amounted to around 281 billion USD (73%). Within this satellite industry, the ground equipment sector accounted for the largest share at 145 billion USD (52%), with GNSS equipment alone representing the largest revenue share in the entire space industry at 112 billion USD. GNSS stands for Global Navigation Satellite System and includes satellites and all equipment transmitting and receiving PNT information on the ground. Following ground equipment, satellite services accounted for 113 billion USD (40%), with consumer satellite services such as satellite TV, radio, and broadband accounting for 93 billion USD. Satellite manufacturing followed at 15.8 billion USD (6%), with launch services at 7 billion USD (2%) (see Figure 14).

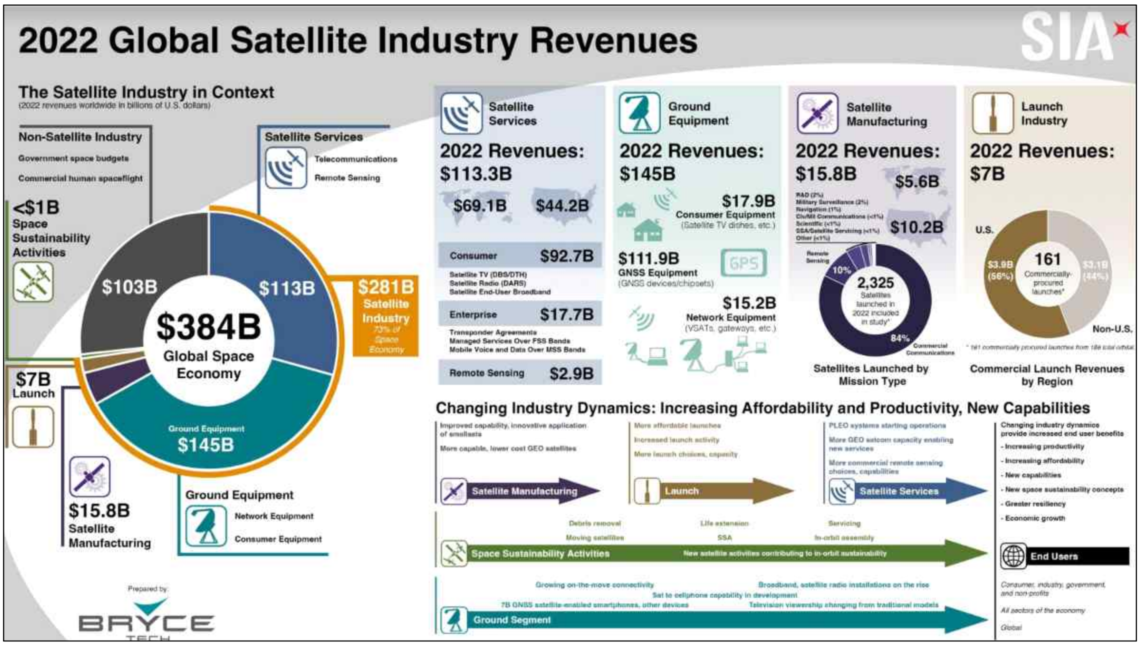

Figure 14 2022 Global Satellite Industry Revenues
(source: 2022 State of the Satellite Industry Report, SIA)

Looking at the size and composition of South Korea's space industry, in 2022, the total revenue of South Korea's space industry, based on the sales of 442 participating companies, amounted to approximately 2.9519 trillion Korean Won (approximately 2.13 billion USD), an increase of approximately 382.2 billion Korean Won compared to the previous year (MSIT, 2023)[34]. This size is only about 0.76% of the global satellite industry size, excluding government budgets, which is approximately 281 billion USD.

The size of the Korean space market by year reached its peak in 2017 at 3.3931 trillion Korean Won (approximately 2.7 billion USD) and has been steadily decreasing since then, but showed signs of recovery in 2022. The main factor contributing to the decline in revenue over the years was attributed to the decrease in sales in the satellite broadcasting and communication sector, which recorded a significant decrease from 2.6146 trillion Korean Won in 2017 to 1.278 trillion Korean Won in 2021, representing a 51% decrease. The government attributes this decline primarily to the reduced demand in the satellite set-top box and navigation industries due to the expansion of the OTT(Over-the-Top) industry market. On the other hand, the increase in sales of satellite communication antennas in the satellite broadcasting and communication sector contributed to the revenue growth in 2022 (refer to Figure 15).

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34) 과학기술정보통신부 (2023) *2023년 우주산업실태조사 보고서* (29 December 2023). Available at: https://www.msit.go.kr/bbs/view.do?sCode=user&mId=244&mPid=243&bbsSeqNo=65&nttSeqNo=3017412

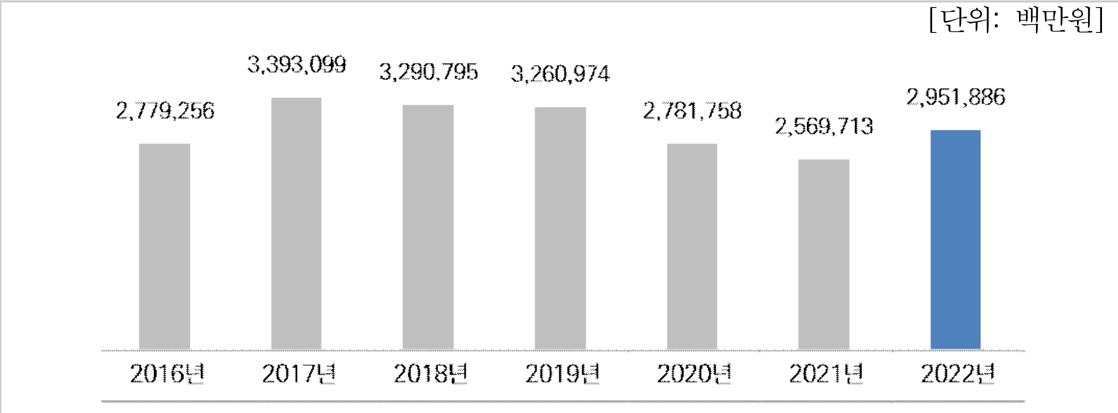

Figure 15 Space Industry Scale in Korea by Year
(source: Space Industry Survey in 2023, MSIT)

Looking into the details of the Korean space industry in 2022, satellite utilization services and equipment accounted for the largest share at 2 trillion 310 billion 600 million won (78.3%). Following this, satellite manufacturing stood at 408 billion won (13.8%), ground equipment at 115.7 billion won (3.9%), and launch vehicle manufacturing at 103.7 billion won (3.5%). Among these, satellite utilization services and equipment are further categorized into remote sensing, satellite broadcasting and communications, and satellite navigation, with satellite broadcasting and communications occupying the majority of the share.

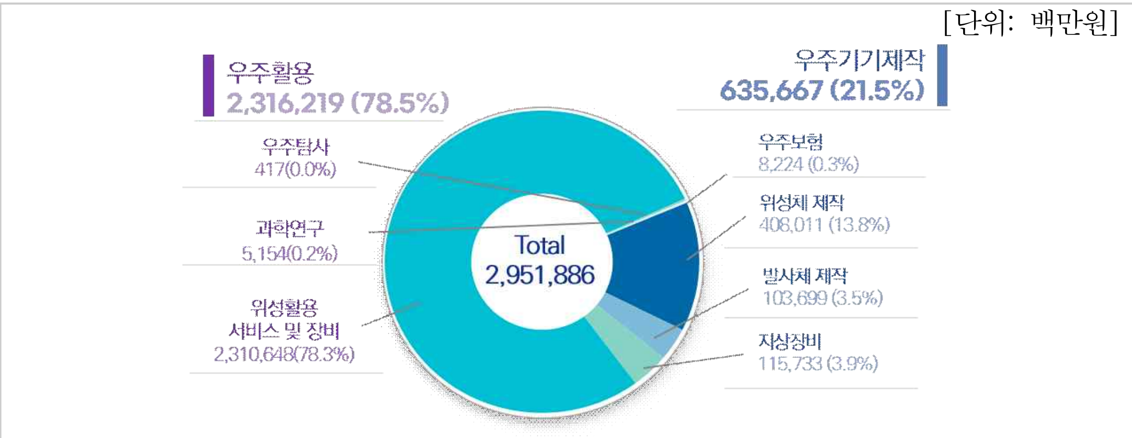

Figure 16 Revenue Status by Sector
(source: Space Industry Survey in 2023, MSIT)

As previously discussed, Korea has thus far held less than 1% of the global space industry market. However, the government aims to expand this to 10% by 2045. The Fourth Master Plan for Promotion of Space Development envisions the establishment of a globally competitive private-led space industry ecosystem through organic collaboration between the private sector and the government. It sets forth the goal of establishing a self-sustaining industrial ecosystem by 2030 and positioning the space industry as one of the top 10 leading industries in South Korea by 2045 (see Figure 17). To achieve these objectives, the plan proposes the creation of early markets through active cooperation between the public and private sectors and the exploration of new private-led industries aligned with South Korea's strengths.

In addition, the Ministry of Science and ICT (MSIT) is expressing its ambition to localize key space materials/parts and expand the market size through long-term overseas exports via the "Space Pioneer Project" (NRF, 2024)[35]. Recently, Perigee

Figure 17 Expansion Goal of the global space industry market share
(source: excerpt from the Fourth Master Plan for Promotion of Space Development)

35) NRF(한국연구재단) (2024) *스페이스파이오니어사업.* Available at: https://www.nrf.re.kr/biz/info/info/view?menu_no=378&biz_no=466

Aerospace, a domestic space-specialized company, has been making efforts to enhance its capabilities in small satellite launch vehicle development by signing memorandums of understanding with participating companies including NDT Engineering, Danam Systems, and Hanyang I&C under the Space Pioneer Project. These efforts aim to elevate the capabilities and value of domestic companies in the global small satellite transportation market (Jeju Ilbo, 2024)[36]. However, beyond this, the Korean government has not yet presented concrete feasible implementation strategies and currently remains confined to declarative goals.

Figure 18 Explanation of Space Pioneer Project
(source: NRF website)

36) 제주일보 (2024) *페리지, 스페이스파이오니어 사업 MOU... 우주발사체 개발 역량 강화* (16 January 2024). Available at: https://www.jejunews.com/news/articleView.html?idxno=2208159

4.2. Analysis of the issues in Korea's Space Policy

4.2.1. A space policy limited to satellite and launch vehicle development technology acquisition necessitates the creation and nurturing of strategies for fostering and leading in specialized fields that Korea can excel in

Upon detailed examination of Korea's recent space policy, it becomes evident that the country's space policy has been primarily focused on securing advanced technology through government-led satellite and launch vehicle development. This is illustrated by the fact that in 2022, Korea's government allocated a total of 615 billion Korean Won (approximately 483 million USD) for space development, with 34% allocated to satellite development and 31% to launch vehicle development. While goals for space exploration to the Moon and Mars, as well as expanding the domestic commercial space market, have been set, the establishment of detailed implementation strategies for these goals remains somewhat inadequate, with only rough objectives being outlined.

The policy oriented towards independent development of satellite and launch vehicle technologies seems to have limitations, especially considering the recent global shift towards space exploration-focused space development. The biggest concern is the possibility of being at a disadvantage in future international cooperation with space-faring nations. The Korean government has made efforts to enhance international cooperation in the space sector, starting with the signing of the Artemis Accords, a U.S.-led international space exploration program, in May 2021[37]. Additionally, during the Korea-U.S.

summit in May 2022, discussions were held to enhance bilateral cooperation in space technology and the space industry[38]. However, it is questionable whether these international cooperation efforts have yielded tangible results. For instance, in the case of the Artemis Accords, besides incorporating the United States' ShadowCam into Korea's lunar orbit probe, Danuri, no further new roles have been assigned.

International cooperation can only be achieved when mutual benefits are expected. However, the problem lies in the fact that Korea's capabilities in satellite and launch vehicle development, which are the only assets it can offer, have already been secured by advanced space-faring nations decades ago. With only the current satellite and launch vehicle development technologies at its disposal, it is becoming increasingly difficult for Korea to lead international cooperation with space-faring nations, and it will inevitably become more challenging to exert significant influence in the international community. Expecting Korea to unilaterally benefit from international cooperation, which requires mutual benefits, seems far-fetched. Furthermore, in missions such as asteroid mining, where international cooperation is essential, the varying levels of technological capabilities among nations and political, economic, and regional differences may lead to unequal outcomes in asteroid mining among countries. Therefore, the decisive role that countries can play in future international

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37) 과학기술정보통신부, 외교부 (2021) *한국, 미국 주도 아르테미스 약정(Artemis Accords) 가입*, 보도자료 (26 May 2021). Available at: https://www.msit.go.kr/bbs/view.do?sCode=user&mId=113&mPid=238&bbsSeqNo=94&nttSeqNo=3180282

38) 임성호 (2022) *[한미정상회담] 우주, 사이버, 양자기술, 바이오 등 협력 강화*, 연합뉴스 (21 May 2022). Available at: https://www.yna.co.kr/view/AKR20220521052700017

cooperation relationships may become increasingly important (Fan et al., 2023)[39].

From this perspective, it is an uncomfortable reality that there are nations which, despite lacking independent satellite or launch vehicle manufacturing technologies, maintain a dominant position in space international cooperation by leveraging their unique technologies and capabilities. This fact necessitates careful consideration by the Korean government. Canada, with its unparalleled expertise in space engineering, and Luxembourg, focusing on space mineral mining, are prime examples of such nations.

Let's first take a closer look at Canada's space development policy direction and focus. Despite having a long history of space development spanning over 60 years, Canada, which became the third country in the world to launch the Alouette I satellite in 1962 following the Soviet Union and the United States, is finding it difficult to find its place among the so-called space powers in recent times. Despite lacking indigenous launch vehicle development technology and even a domestic launch site, Canada is still considered a key participant

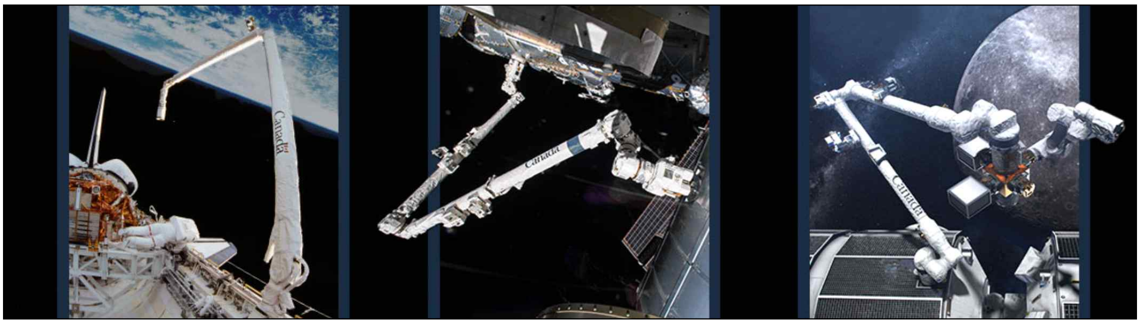

Figure 19 The operation of the Canadarm
(source: Canada Space Agency)

39) Fan, R., Zhang, H. and Gao, Y. (2023) *The global cooperation in asteroid mining based on AHP, entropy and TOPSIS.* Applied Mathematics and Comutation, 437, p.127535

in global space development projects. This is primarily due to the fact that Canada is the sole developer of the 'Canadarm', a robotic manipulator essential for delicate operations in space.
The Canadarm, with a history dating back to 1974 when NASA commissioned Canada to develop the Shuttle Remote Manipulator System (SRMS), is a 15-meter-long robotic arm capable of lifting payloads of up to 266 tons with minimal power in the virtually gravity-free environment of low Earth orbit. It is a product of cutting-edge robotic engineering, allowing for extremely precise control.

Canadarm-1, mounted on US Space Shuttles, successfully performed missions in space for 30 years since 1981, including delivering satellites into orbit, capturing satellites for repair, and assembling the International Space Station (ISS). The successful development and operation of Canadarm played a pivotal role in shaping Canada's space development strategy towards robotics engineering. Subsequently, in 2001, Canada's robotics engineering prowess was further demonstrated with the installation of Canadarm-2 and Dextre on the ISS. Dextre, short for Special Purpose Dexterous Manipulator, is a robotic hand attached to Canadarm-2, capable of intricate movements similar to human hands. It performed tasks such as installing or replacing small devices like cameras and battery packs on the exterior of the space station. Space robotic manipulators can conduct activities with minimal risk and in a more efficient manner than manned systems, making them essential for future space exploration endeavors (Mane, 2023)[40].

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40) Mane, S. (2023) *Space Robotics for Future Applications*, International Journal of All Research Education and Scientific Methods, Volume 11, Issue 6. (June 2023). Available at: https://www.researchgate.net/publication/371811598_Space_Robotics_for_Future_Applications

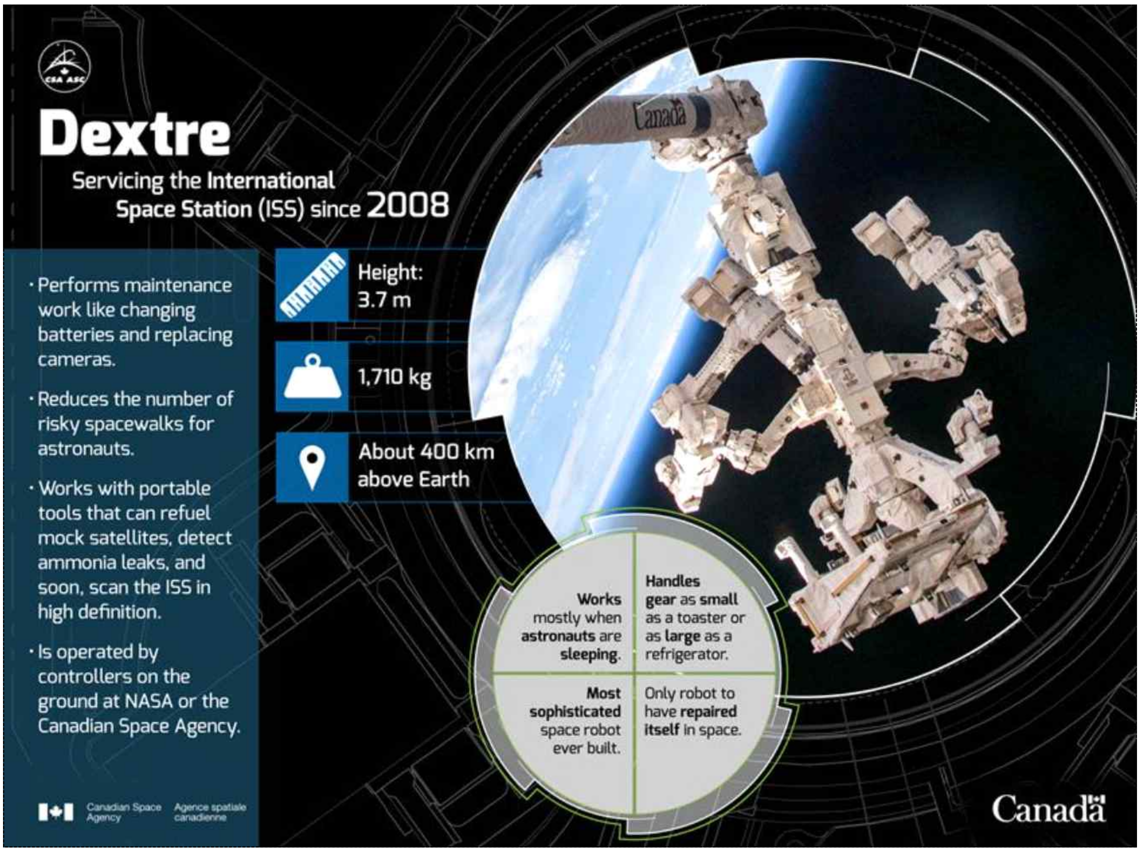

Figure 20 Illustration of the Dextre
(source: Canada Space Agency)

The development and success of Canadarm in Canada had a significant impact on the country's aerospace industry. According to a report[41] by the Aerospace Industries Association of Canada (AIAC), MacDonald, Dettwiler and Associates (MDA)[42], the manufacturer of Canadarm, received an initial investment of 110 million CAD through the Canadarm-1 development contract and generated approximately 786 million CAD in revenue through the contract. Even after delivering the equipment, MDA continued to

41) AIAC (Aerospace Industries Association of Canada) (2010) *Impact of the Canadian Aerospace Industry,* AIAC Phase 2 Report (October 2010). Available at: https://aiac.ca/wp-content/uploads/2015/11/AIAC-Phase-2-Report_FINAL.pdf

42) https://mda.space/

secure support contracts with NASA for space shuttle robotic engineering, earning an annual revenue of 20 million CAD since the early 1980s, totaling 40 years. Additionally, exports related to Canadarm to the United States, Europe, and Japan amounted to over 700 million CAD. Furthermore, from 1990 to 2009, participation in the Canadarm program created employment for over 100 individuals, and during the contract period for Canadarm-2, over 125 jobs were created.

With the significant positive economic impact brought by Canadarm, the Canadian Space Agency (CSA) places even greater emphasis on formulating space development policies. According to the space policy[43] released by CSA in 2019, Canada aims to maintain its status as a spacefaring nation by participating in the Lunar Gateway program led by the United States, delivering the state-of-the-art Canadarm-3. The Lunar Gateway is a multi-purpose lunar orbit space station that enables various space experiments, including lunar exploration, while stationed in space. Canadarm-3 is expected to be utilized for maintenance tasks on the Gateway as well as for intricate maneuvers required for spacecraft docking and assisting astronauts during spacewalks. Additionally, to ensure adaptability in scenarios where there are no humans on the Lunar Gateway or communication with Earth is disrupted, Canada plans to incorporate its own artificial intelligence technology into the development, with the goal of launching in 2028 (Swartman, 2020)[44].

43) CSA (Canadian Space Agency) (2019) *Space Strategy for Canada* (18 March 2019). Available at: https://www.asc-csa.gc.ca/eng/publications/space-strategy-for-canada/

44) Swartman, L. (2020) *MDA Announces Contract for Canadarm3,* MDA (8 December 2020). Available at: https://mda.space/article/mda-announces-contract-for-canadarm3/

In addition to contributing to the advancement of the Canadian space industry, Canadarm has provided the Canadian government with another important opportunity to formulate a strategic approach to space development: the cultivation of space talent. As the significance of Canadarm-1 grew during the Space Shuttle program, NASA permitted a Canadian astronaut to fly aboard the Space Shuttle. Building on this legacy, the development of Canadarm-3 has secured seats for two Canadian astronauts on Artemis 2 as compensation[45]. The achievements of Canadian astronauts inspire interest in space among Canadian children and youth, ultimately providing the impetus for sustained space development in Canada. Seizing this opportunity, the Canadian Space Agency (CSA) organizes nationwide competitions like "Junior Astronauts" and promotes visits to schools by Canadian astronauts to foster scientific understanding and inspire enthusiasm for space among many children[46]. The Canadian government's flexible approach, utilizing indispensable indigenous technology, in cultivating talent—an area where achieving results through mere investment and policy-making is challenging—is noteworthy.

45) CSA (Canadian Space Agency) (2024) *About Canadarm3* (12 March 2024). Available at: https://www.asc-csa.gc.ca/eng/canadarm3/about.asp

46) Canadian Association of Science Centres (2024) *Junior Astronauts.* Available at: https://www.canadiansciencecentres.ca/Junior-Astronauts

Figure 21 Description of Junior Astronauts
(source: captured at Canadian Association of Science Centres website)

Furthermore, the precision robotic engineering technology secured through the development of Canadarm has had a significant impact not only on the space industry but also on technological advancements in other industries within the country, particularly in the field of health science. 'NeuroArm', the world's first robot capable of performing brain surgery inside an MRI machine, is a product developed by MDA engineers in close collaboration with physicists, scientists, and nurses at the University of Calgary. It has enabled precise surgeries that were previously deemed impossible[47]. NeuroArm

47) CSA (Canadian Space Agency) (2018) *Robotic arms lend a healing touch: neuroArm and its legacy* (21 June 2018). Available at: https://www.asc-csa.gc.ca/eng/canadarm/neuroarm.asp

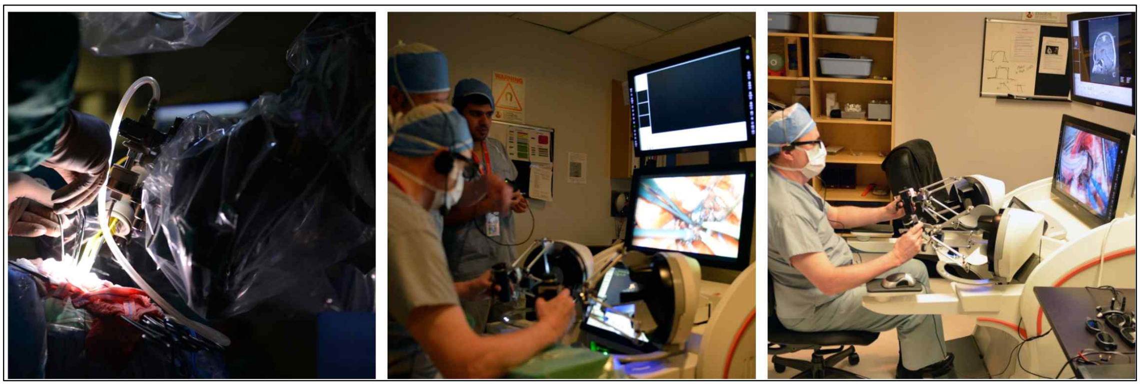

Figure 22 Operation of NeuroArm
(source: captured at neuroArm website (https://neuroarm.org/neuroarm)

utilizes miniaturized tools such as laser scalpels with pinpoint accuracy and can perform tasks such as soft tissue manipulation, needle insertion, suturing, and cauterization.

Another notable example is the Image-Guided Autonomous Robot (IGAR). IGAR is an automated surgical robot that executes operations based on instructions provided by medical personnel[48]. In the context of breast cancer treatment, IGAR is anticipated to enhance accessibility, precision, and dexterity, leading to highly accurate and minimally invasive procedures.

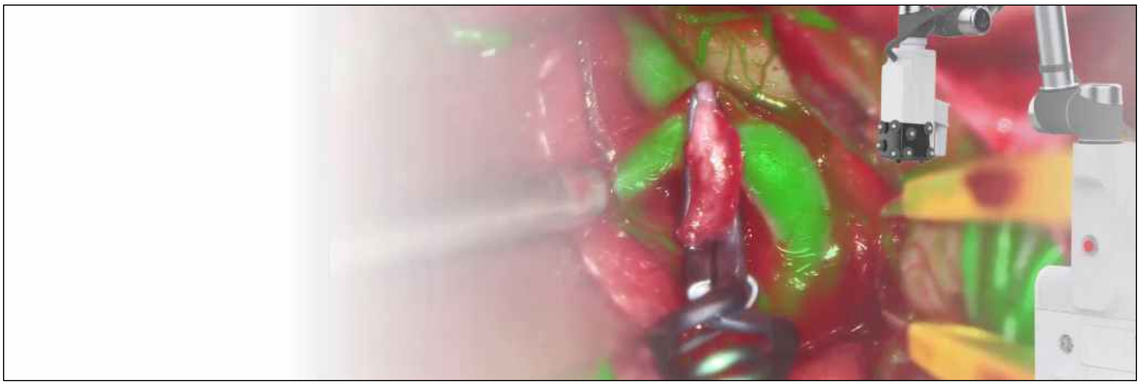

Figure 23 Description of Modus V
(source: captured at Synaptive website (https://www.synaptivemedical.com)

48) CSA (Canadian Space Agency) (2018) *Robots from space lead to one-stop breast cancer diagnosis and treatment* (31 October 2018). Available at: https://www.asc-csa.gc.ca/eng/canadarm/igar.asp

Additionally, Modus V is a product derived from technology originating from Canadarm2. Modus V is a robotically controlled digital microscope designed to offer advanced visualization during surgeries. Similar to Canadarm2, Modus V is a highly adaptable tool capable of assisting in delicate surgical procedures conducted within a uniquely challenging environment.

The Canadarm technology has influenced not only the medical field, as previously discussed, but also the nuclear industry. MDA (then 'Spar Aerospace') developed the Light Duty Utility Arm (LDUA) system, which can inspect and analyze radioactive waste in underground storage tanks (Carteret, 1994)[49].

As observed, Canada's space policy appears to be heavily reliant on the Canadarm product from start to finish. However, this singular product has been indispensable in current and future space development and exploration, enabling Canada to maintain a significant position in the global space market for an extended period. Moreover, the technology behind Canadarm has led to groundbreaking advancements in other industries and ultimately contributed significantly to the improvement of Canadians' quality of life. Consequently, what the Canadian case illustrates is that even without the capacity for independent satellite and launch vehicle development, a country can occupy a superior position in future international space development cooperation if it possesses specialized technology that other nations cannot replicate. Therefore, it seems crucial to devise policies that actively leverage specialized technologies to expand the domestic space market while also yielding positive spin-off

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49) Carteret, B.A. (1994) *Light duty utility arm system applications for tank waste remediation* (No. WHC-SA2669). Westinghouse Hanford Co.

effects for other industries.

Next, let's examine the case of Luxembourg. As a small country in Western Europe, Luxembourg has the highest contribution to national GDP in the space sector in Europe today, making space industry a national priority (LSA, 2019)[50]. The Ministry of Science and ICT (MSIT) of Korea also evaluates Luxembourg as one of the leading space powers in Europe, highlighting its strengths in policy and institutional aspects such as the establishment of independent space resource development laws, attracting foreign venture companies, and building a cooperation framework with major space development agencies in Europe. Luxembourg is considered significant enough for Korea to even sign a memorandum of understanding for space cooperation aimed at mutually complementary cooperation (MSIT, 2022)[51].

As mentioned earlier, Luxembourg adopts a space development strategy that focuses on attracting and incentivizing private companies in the space sector. In its 2023-2027 national space strategy[52] announced by the Luxembourg Space Agency (LSA), sustainability is emphasized as the main keyword, highlighting the space development as a new market with significant commercial perspectives and providing a favorable framework to

50) LSA (Luxembourg Space Agency) (2019) *Space Policy and Strategy* (23 September 2019). Available at: https://space-agency.public.lu/en/agency/mission-vision.html

51) 과학기술정보통신부 (2022) *한-룩셈부르크 우주협력 양해각서(MoU) 체결* (28 November 2022). Available at: https://www.msit.go.kr/bbs/view.do?sCode=user&mId=113&mPid=238&bbsSeqNo=94&nttSeqNo=3182411

52) LSA (Luxembourg Space Agency) (2022) *2023-2027 National Space Strategy: Focus on Sustainability* (13 December 2022). Available at: https://space-agency.public.lu/en/news-media/news/2022/nationalspacestrategy-2023-2027.html

attract private investment. This indicates a more aggressive approach to encouraging the attraction of space-related businesses than before. To achieve this goal, the strategy outlines focusing on financial activities, talent development, international cooperation, the development of legal and regulatory frameworks, and the establishment of LSA data centers and space campuses. Luxembourg's strategy contrasts with Korea's emphasis on securing independent manufacturing technology, yet it effectively maintains a significant position in the international community's space development efforts.

Specifically, the LSA supports domestic private space companies and actively attracts new companies through various financial support programs[53]. One notable program is LuxIMPULSE, which provides research and development funding to companies established in Luxembourg to bring innovative ideas to the market. Additionally, they operate the Fit4Start program, which provides financial support to startups established outside of Europe to establish themselves in Europe and demonstrate their capabilities. Selected startups receive initial funding of 50,000 Euros for commercializing their ideas, along with office space and professional coaching for a four-month period. Upon successful completion of the program and raising a minimum of 50,000 Euros in private capital, startups receive an additional 100,000 Euros in grants. Through these diverse programs, LSA successfully attracts space industry startups from around the world, fostering the domestic space ecosystem and promoting overall economic development, including job creation and increased domestic consumption, beyond the space sector.

53) LSA (Luxembourg Space Agency) (2019) *National Programmes* (9 September 2019). Available at: https://space-agency.public.lu/en/funding/funding-space.html

Furthermore, Luxembourg is a pioneer not only in attracting and supporting private space companies, as discussed earlier, but also in terms of ownership of space resources. The LSA prioritized the establishment of a legal framework for the exploration and use of space resources rather than focusing solely on technological development for resource extraction. As a result, in 2017, Luxembourg enacted the Law on the exploration and use of space resources, making it the second country in the world, after the United States, to do so[54)]. This law primarily recognizes the ownership rights of companies that mine space minerals[55)]. Currently, most space resource mining is conducted for scientific purposes, eliminating the need for disputes over ownership. However, as commercial space projects and mining become feasible in the future, there will be a need to clearly define the rights of miners to consume and commercialize the materials they discover. Therefore, by providing legal clarity and ensuring stability for companies involved in future space resource mining activities, Luxembourg is creating a favorable environment to attract companies in this field. This approach aims to provide companies with rights to resources extracted from space and guarantee their stability, thereby facilitating the attraction of companies engaged in related activities.

The cases of Canada and Luxembourg clearly demonstrate an

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54) LSA (Luxembourg Space Agency) (2024) *Legal Framework* (1 March 2024). Available at: https://space-agency.public.lu/en/agency/legal-framework.html

55) LSA (Luxembourg Space Agency) (2019) *Law of July 20th 2017 on the exploration and use of space resources* (18 November 2019). Available at: https://space-agency.public.lu/en/agency/legal-framework/law_space_resources_english_translation.html

important insight. If a country deeply cultivates expertise in a specific yet essential area that other space-faring nations have not fully covered, it can firmly establish itself as a desirable partner for international collaboration. As the trend in space development gradually shifts towards space exploration, cooperation among multiple countries becomes increasingly indispensable. For countries like Korea lacking exceptional capabilities beyond manufacturing technology, the merit as a future international cooperation partner may diminish.

Certainly, securing independent satellite and launch vehicle development capabilities is crucial from a national security perspective. However, from the perspective of international cooperation, the importance of possessing unique assets to the extent that other countries would seek assistance first from Korea becomes even more pronounced in the long-term development strategy of space.

4.2.2. Insufficient justification for space exploration policy implementation

When we think of space exploration, we often imagine the investigation of the origins of the universe or the discovery of new extraterrestrial intelligences, which may seem distant from everyday life for those outside the scientific community. Clearly, one of the biggest barriers to the advancement of space exploration is the lack of a compelling motivation to justify the necessary investment (Bainbridge, 2009)[56]. Nevertheless, despite this challenge, the Korean government is allocating significant

56) Bainbridge W.S. (2009) *Motivations for space exploration.* Futures, 41(8), pp.514-522.

budgets towards space exploration, focusing on developing high-performance launch vehicles, landers, and transport ships as a means to achieve this goal. Additionally, plans include enhancing international collaboration, particularly with the United States' Lunar Gateway project and lunar surface base construction efforts. Furthermore, Korea aims to secure its own lunar base by researching basic In-Situ Resource Utilization (ISRU) technology, developing space energy utilization methods, and establishing interstellar networks.

The decision of the Korean government to prioritize space exploration as one of top space policies task for the future raises questions about its underlying motivations. Is it driven by the academic or scientific value of space exploration, or is it merely following the latest space policy trends of advanced spacefaring nations like the United States? Regardless of the reasons and objectives that the government presents for space exploration, it is crucial that there is a certain level of socio-economic benefit assured while implementing space exploration plans. Whenever substantial budgets are allocated for a space exploration endeavor, there must be some degree of societal and economic benefit to justify the expenditure. Limited budget spending always comes with opportunity costs and demands justification. Therefore, without clear and tangible national benefits, not only will there be resentment from the general public over the expenditure of public funds, but also the momentum for policy implementation may wane over time.

It appears that the Korean government has introduced tasks such as lunar and Martian exploration and lunar base construction somewhat abruptly, without providing detailed explanations of why space exploration is necessary and what benefits it will bring. At present, the rationale seems to revolve around scientific exploration and acquiring space resources. However, in terms of scientific exploration, given that Korea lags behind spacefaring nations by 10 to 20 years or more, it is evident that the basic scientific curiosity will likely be significantly satisfied by the time Korea embarks on space exploration. Moreover, other countries, leveraging their experience in exploration, are likely to introduce more advanced exploration equipment to explore further into space.

Given this scenario, it seems unrealistic to expect Korea, which significantly lags behind spacefaring nations in terms of scientific exploration experience and accumulated know-how, to uncover highly valuable new facts through space exploration. Therefore, it may be more appropriate for space exploration policy to focus on generating tangible benefits rather than solely on securing academic value. In other words, if the government fails to provide a solid rationale for space exploration, it may inevitably face criticism for budget wastage.

Certainly, even the United States, the most advanced spacefaring nation, may not be able to clearly demonstrate the economic benefits of space exploration. In fact, it remains uncertain whether there are usable resources on the Moon or asteroids, let alone whether they can be efficiently utilized on Earth or what level of efficiency they would offer as resources. However, for spacefaring nations like the United States, Russia, and China, space exploration is not just a means of economic benefit. If a country is backed by abundant national budgets, it may prioritize enhancing its status as a pioneer in space exploration, thus elevating its national prestige in the space race.

However, the situation is different for Korea. The policy of prioritizing the acquisition of satellite and launch vehicle development technologies as a latecomer in space has been well executed so far, primarily because it had a clear rationale that even ordinary citizens could understand: establishing national security and improving the quality of life. Without clear objectives and effects that ordinary citizens can recognize, momentum for policy implementation can be lost. This would eventually affect budget allocation, leading to long-term challenges in implementing space exploration policies.

Therefore, in conclusion, the Korean government needs to establish specific objectives for its space exploration policy and contemplate how these objectives will generate national interests. Only then can the space exploration policy gain legitimate justification from the public and be pursued with confidence.

4.2.3. The absence of detailed strategies for expanding the participation of Korean companies in the global space market

The Korean government has set a goal to increase the domestic space market, which currently represents about 1% of the global space market, to the 10% range by 2045 (refer to Figure 17). However, specific measures to achieve this goal are not readily available. The current policy, which focuses primarily on the development of satellites and launch vehicles, is largely aimed at achieving public objectives rather than expanding the scale of the private space industry. As seen earlier, the scale of Korea's space market is dominated by satellite utilization services and equipment, accounting for 78.3%, while satellite and launch vehicle manufacturing combined only accounts for a mere 17.3% (refer to Figure 16). Furthermore, in the global space market in 2022, the share of satellite and launch vehicle manufacturing is only around 8% (refer to Figure 14). This indicates that, similar to Korea, companies worldwide find it more advantageous to explore other sectors rather than focusing solely on satellite and launch vehicle manufacturing to generate revenue.

However, the problem lies in the current space development policy of Korea, which focuses on satellite and launch vehicle manufacturing. This means that Korea's space development policy is not aligned with the goal of increasing the share of domestic companies in the international space market. Korea's space policy is geared towards continuously generating demand for satellite and launch vehicle development and transferring the development technology held by KARI (Korea Aerospace Research Institute) to private companies through public-private partnerships. Unfortunately, even if this process is successful and Korean companies' manufacturing technology advances significantly, the revenue generated from satellite and launch vehicle manufacturing itself is relatively small. As a result, it is difficult to significantly increase the share of Korean companies in the international space market.

Is there a separate policy direction for expanding the private space market in addition to the policy direction focused on securing satellite and launch vehicle development technologies for public purposes? There seems to be only a hopeful goal of expanding the private space market in line with the concept of the New Space era, without any specifically pursued strategy. There is no clear direction on whether to further activate the satellite utilization services sector or to expand the market in the manufacturing sector by leveraging sustained demand for production. This reality is evident even in the allocation of Korea's space development budget. In 2021, Korea's space development budget was only 0.4 billion USD (6.15 trillion KRW), which is less than the budgets of the United States (59.8 billion USD), Japan (3.5 billion USD), India (1.7 billion USD), and Italy (0.5 billion USD) (MSIT, 2023)[57] (see Figure 24, 25).

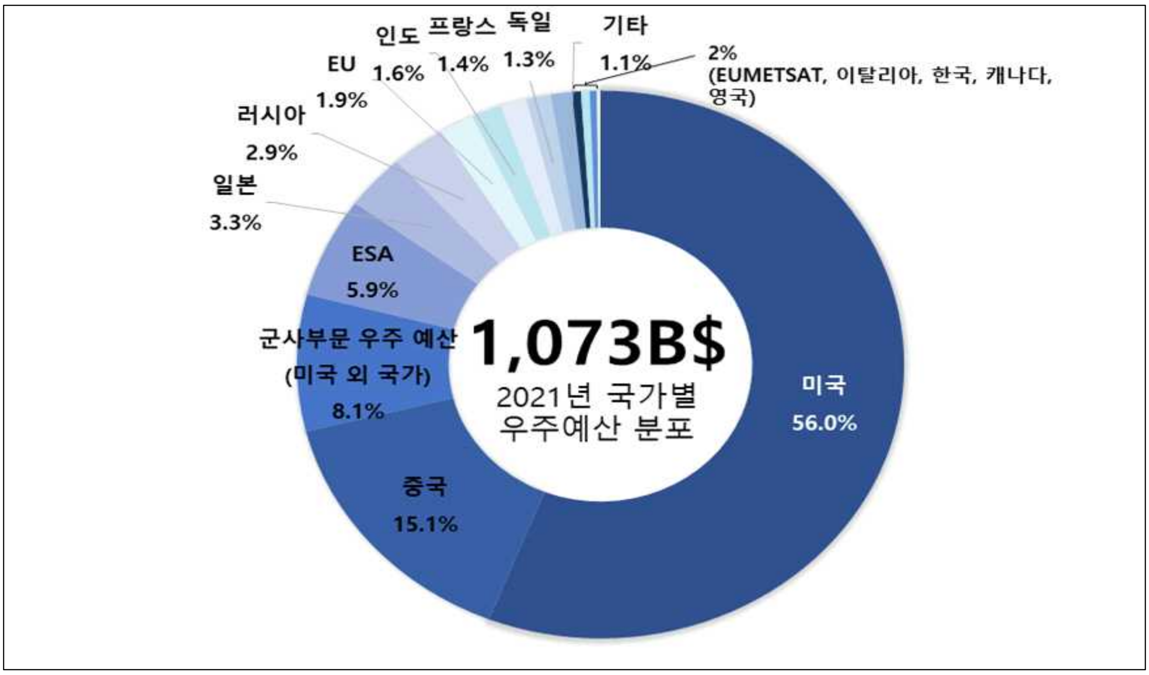

Figure 24 Distribution of space budgets by major countries and agencies in 2021 *(source: Space Industry Survey in 2022, MSIT)*

57) 과학기술정보통신부 (2023) *2022년 우주산업실태조사 보고서* (29 December 2023). Available at: https://www.msit.go.kr/bbs/view.do?sCode=user&mId=244&mPid=243&bbsSeqNo=65&nttSeqNo=3017412

국가/기관	2021 ($B)	2020-2021 변화율	예산 출처
미국	59.8	▲17.7%	美 정부 공개 자료
중국	16.1	▲23.4%	추정치
유럽우주국 (ESA)	6.3	▲8.8%	유럽우주국(ESA)
일본	3.5	▲14.6%	일본 우주항공연구개발기구 (JAXA)
러시아	3.1	▲9.3%	TASS Russian News Agency
유럽연합 (EU)	2.0	▲14.1%	유럽 우주산업 연합회 (Eurospace)
인도	1.7	▲35.6%	인도 재무부
프랑스*	1.5	▲34.4%	프랑스 국립 우주 센터(CNES)
독일*	1.4	▲4.5%	독일 연방 정부예산
유럽기상위성 개발기구 (EUMETSAT)	0.5	▼3.3%	유럽 우주산업 연합회 (Eurospace)
이탈리아*	0.5	▲101.2%	이탈리아 우주국 (ASI)
한국	0.4	▼22.8	ALIO
캐나다*	0.3	▲34.1	캐나다 우주국 (CSA)
영국*	0.2	▲37.2	영국 우주국 (UKSA)
기타	1.2	▲13.6	
군사부문 우주 예산 (미국 이외 국가)	8.6	▲33.7	추정치
미국 이외 국가	47.5	▲23.7%	
총예산	**107.3**	**▲18.8%**	

Figure 25 The current status of space budgets by major countries in 2021
(source: Space Industry Survey in 2022, MSIT)

Compared to other countries, Korea's space development budget is relatively small in absolute terms. However, a closer look at the detailed composition of Korea's space development budget reveals that 34% is allocated to satellite development and 31% to launch vehicle development. This allocation suggests a focus on ensuring the reliability of existing equipment, developing follow-up models, and concentrating on the development of new concept satellites and launch vehicles. In contrast, only a mere 5% of the total budget (approximately 35 million USD) has been allocated for fostering the space industry and creating jobs.

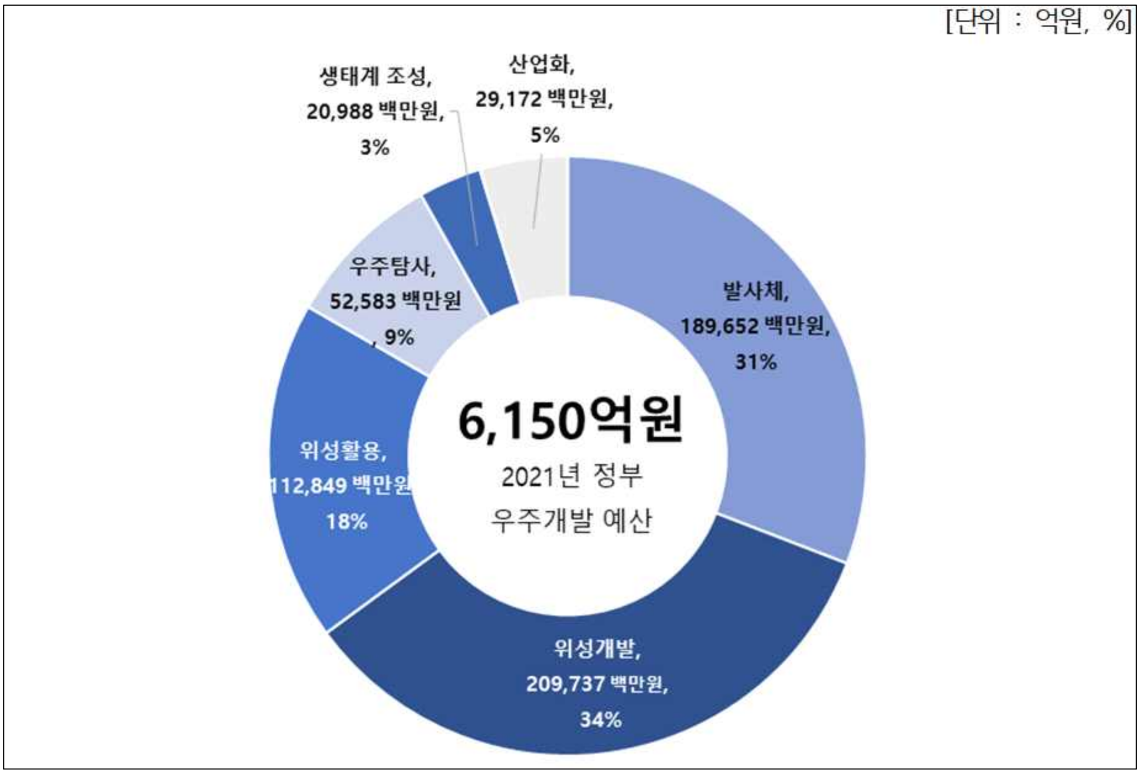

Figure 26 Distribution of government space development budgets by sector in 2022 *(source: Space Industry Survey in 2022, MSIT)*

The budget allocated to the space industry nurturing and job creation sector is designated for the "Space Pioneer Project" aimed at securing foundational space technology and the "Space Industry Talent Development Project" for training space professionals. However, upon closer examination, these projects diverge somewhat from the intended purpose of fostering the space industry budget.

The Space Pioneer Project[58], spanning from 2021 to 2030 with a total investment of 211.5 billion Korean Won over ten years, aims to promote domestication in 16 core areas of small launch vehicles and satellites, intending to reduce the high dependence on foreign space parts and thereby prevent cost increases and project extensions. The primary objective of this project seems to focus more on domestic utilization in future government-led development projects rather than directly expanding the domestic space market.

On the other hand, the Space Industry Talent Development Project aims to train 150 master's and doctoral level professionals over five years through the development of low-cost, low-orbit satellite technology, establishing relevant education programs, and supporting various theoretical and practical courses (Hwang, 2023)[59]. However, this project also appears somewhat detached from the fundamental goal of nurturing the space industry.

58) 과학기술정보통신부 (2020) *첨단 우주부품 국산화 통해 우주산업 육성 가속화* (28 April 2020). Available at: https://www.msit.go.kr/bbs/view.do?sCode=user&mId=113&mPid=238&bbsSeqNo=94&nttSeqNo=2851079

59) Hwang, B. (2023) *경남도, 우주분야 전문인력 양성사업 올해도 이어간다,* 연합뉴스 (1 April 2023). Available at: https://www.yna.co.kr/view/AKR20230331142500052

5. Policy Recommendations

5.1. A strategic approach to space development in Korea necessitates integration with industries where Korea holds strengths.

The strategy that the Korean government, having achieved its goal of securing core technology, should adopt to achieve two new objectives in future space development—leading international cooperation and expanding the Korean space market—is what? Hints can be obtained from Japan's space policy, which is about a decade ahead of Korea in space development.

The Japan Aerospace Exploration Agency (JAXA)[60] has established the Implementation Plan of the Basic Plan on Space Policy to promote systematic development of space science and exploration. Since the first implementation plan in 2013, the fourth implementation plan in June 2020 announced the basic direction for space development over the next 20 years (Cabinet Office, 2020)[61]. According to this plan, Japan's space exploration adopts a distinctive strategy of focusing on medium-sized missions rather than large-scale missions, unlike the United States and Europe. Representative medium-sized projects in Japan include the development of the XRISM (X-ray Imaging and Spectroscopy Mission) satellite[62], which observes space

60) https://global.jaxa.jp/

61) Cabinet Office (2020) *Implementation Plan of the Basic Plan on Space Policy* (30 June 2020). Available at: https://www8.cao.go.jp/space/english/basicplan/basicplan.html

62) https://www.xrism.jaxa.jp/en/

structures and dark matter, and the Smart Lander for Investigation Moon (SLIM)[63] developed by the private company ispace for lunar landing.

These projects are characterized by careful planning to maximize the utilization of key technologies identified by the Japanese government in advance. The Japanese government distinguishes major technologies required for space exploration into core mission technologies, domestically advantageous technologies, and technologies with broad applicability and selects five technologies that meet these criteria to be utilized in various projects. These five key technologies include ultra-small probe technology, transportation system technology, satellite and planetary probe technology, celestial surface activity technology, and space cooling system technology (Toukaku & Ozaki, 2019)[64]. By planning projects based on the country's capabilities and ripple effects rather than developing them randomly, the Japanese government demonstrates efforts to maximize efficiency in time and budget utilization. As the Korean government moves on to the next stage of space development, it is also a crucial moment for the government's seasoned planning capabilities to be demonstrated. Lee *et al.* (2021)[65] also analyzed that an SO strategy utilizing Korea's unique strengths and opportunities is most appropriate as a strategy for the development of Korea's space industry. They highlighted

63) https://www.isas.jaxa.jp/en/missions/spacecraft/current/slim.html

64) Toukaku, Y., Ozaki, N. (2019) *Planetary Exploration and International Collaboration,* Institute of Space and Astronautical Science Japan Aerospace Exploration Agency (Septermber 2019). Available at: https://h2061-tlse.sciencesconf.org/data/pages/3.1_Naoya_Ozaki_JAXA_Space_Program.pdf

65) Lee, J., Kim, I., Kim, H. and Kang, J. (2021) *SWOT-AHP analysis of the Korean satellite and space industry: Strategy recommendations for development.* Technological Forecasting and Social Change, 164, p.120515.

hardware and software development as strengths and presented the existence of continuous domestic satellite launch plans and the potential for convergence with information and communication technology as opportunities. The semiconductor and information and communication technology sectors are undoubtedly industries where Korea excels and can be continuously utilized in satellite/launch vehicle manufacturing and space exploration.

5.1.1. Space-grade semiconductor

Investing astronomical amounts to launch a satellite, only to find it malfunctioning in space, would render all efforts and costs futile. Once a satellite is launched, there's no way to repair it if it malfunctions, making highly reliable components essential for normal operation even in the extreme space environment. Especially for advanced equipment, the reliability of the semiconductor components responsible for equipment control, commands, and data processing is paramount. Therefore, aerospace-grade semiconductors are designed to withstand extreme temperatures, pressures, and shocks in space. Moreover, considering that approximately 30% of semiconductor failures in space are attributed to high levels of radiation emitted by the sun, they must be designed to withstand high radiation levels. Aerospace-grade semiconductors must endure such extreme conditions while also employing low-power designs to maximize equipment operational duration (Leonard, 2023)[66].

66) Leonard C. (2023) *Challenges for Electronic Circuits in Space Applications* (16 November 2023). Available at: https://www.theengineer.co.uk/content/product/challenges-for-electronic-circuits-in-space-applications/

The demand for high-reliability semiconductors for aerospace applications is expected to increase over time, in line with the space exploration plans of various countries worldwide. Therefore, the market size is expected to expand over time. According to an analysis by Transparency Market Research (TMR) in 2022[67], the market size of high-reliability semiconductors is projected to grow from 6.4 billion USD in 2021 to 10.1 billion USD in 2031, with an average annual growth rate of 5.5%.

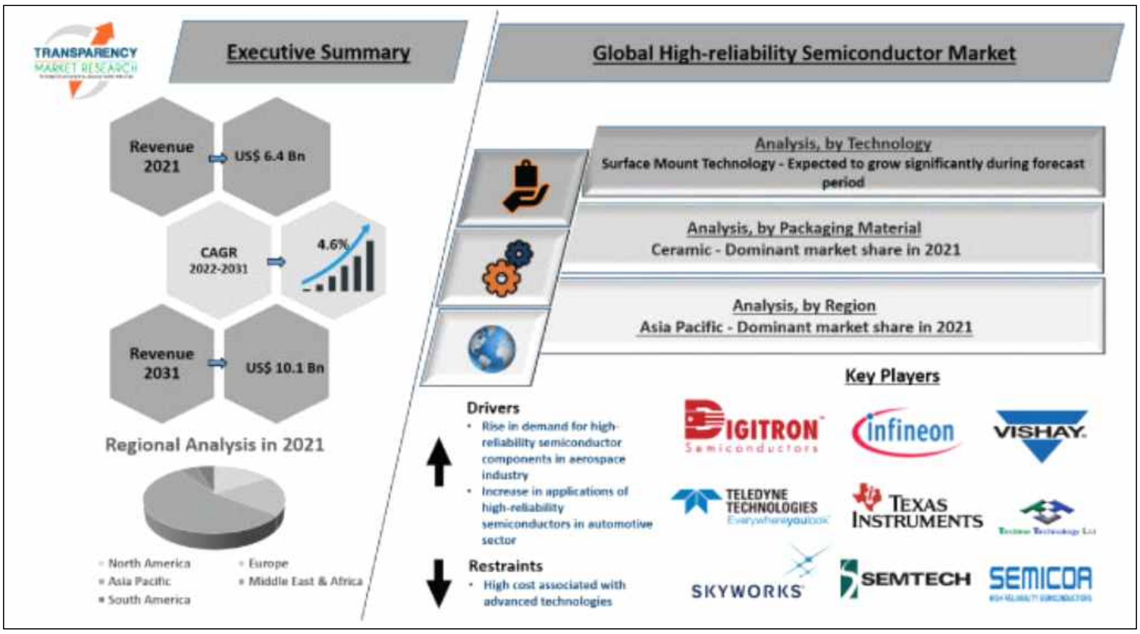

Figure 27 Analysts' viewpoint on high-reliability semiconductor market scenario *(source: TMR website)*

The aerospace semiconductor market, which is expected to continue growing, is already dominated by companies from the United States and Europe. For instance, Texas Instruments (TI) in the United States supplies over 80,000 diverse products in

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67) TMR (Transparency Market Research) (2022) *High Reliability Semiconductor Market.* Available at: https://www.transparencymarketresearch.com/high-reliability-semiconductors-market.html

Figure 30 Promotional photo of high-reliability space-grade supply products *(source: TI website)*

fields such as aerospace control, engine control, radar, and communication[68].

Infineon from Germany provides products for motor control, RF communication semiconductors, memory, and its F-RAM products, which operate normally even in high radiation environments, are widely used in satellite manufacturing[69]. Teledyne in the United States also possesses excellent radiation-hardened packaging technology and supplies memory products with storage density reduced to less than half

68) Texas Instruments (TI) (2022) *TI expands xpace-grade product portfolio with radiation-hardened and radiation-tolerant plastic packages for missions from new space to deep space* (28 November 2022). Available at: https://news.ti.com/2022-11-28-TI-expands-space-grade-product-portfolio-with-radiation-hardened-and-radiation-tolerant-plastic-packages-for-missions-from-new-space-to-deep-space#assets_all

69) Infineon (2024) *Radiation tolerant memories*. Available at: https://www.infineon.com/cms/en/product/high-reliability/new-space/memories/

compared to competitors.

Meanwhile, Korea is a semiconductor powerhouse represented by Samsung Electronics and SK hynix. Semiconductors are broadly classified into memory semiconductors and non-memory (system) semiconductors. Korea has consistently shown strength in the memory semiconductor sector, accounting for 56.9% of the global memory market as of 2020. Even when considering the entire semiconductor market, including memory, it holds a 18.4% market share globally, ranking second after the United States (Park, 2023)[70]. However, unfortunately, Korean semiconductor companies show little interest in the development of aerospace-grade semiconductors. Samsung Electronics, in its new environmental management strategy announcement in 202 2[71], declared its commitment to developing ultra-low-power semiconductors for climate crisis mitigation and participating in carbon neutrality, but there was no mention of aerospace-grade semiconductors apart from plans to expand semiconductor manufacturing infrastructure. SK hynix's situation is not significantly different.

So, why aren't leading semiconductor companies in the domestic market investing in aerospace semiconductor development, which is expected to expand in the future global market? From the perspective of businesses, the most realistic reason is likely marketability and profitability issues. First of all, the demand for aerospace-grade semiconductors within the country is too low.

70) Park, D. (2023) *Semiconductor*, Invest Korea. AVailable at: https://www.investkorea.org/ik-en/cntnts/i-312/web.do

71) 삼성전자 (2022) *삼성전자, '新환경경영전략' 선언* (15 September 2022). Available at: https://semiconductor.samsung.com/kr/news-events/news/samsung-electronics-announces-new-environmental-strategy/

Unless there is a guarantee of substantial demand for aerospace semiconductors domestically, similar to SpaceX's Starlink project in the United States, private companies are not incentivized to invest significant funds in long-term research and development or infrastructure construction. Even if they attempt to generate profits through exports, as mentioned earlier, American and European companies have already dominated the market for a long time. Therefore, it would be more practical for them to seek ways to generate greater profits within their current revenue models rather than investing in uncertain profitability in new fields.

Moreover, the barriers to entry into the aerospace semiconductor market are particularly high. This is because even a single semiconductor failure in the space environment can have more catastrophic consequences than in other fields. As a result, only products with proven performance and reliability are selected. Aerospace-grade semiconductors undergo rigorous reliability testing in various environmental conditions, and these tests alone can take a long time. Therefore, newly developed semiconductors face a challenging reality if they lack solid quality assurance results and real-world usage records to support them, making it very difficult for them to translate into actual sales.

However, these obstacles can also be adequately addressed through the government's strategic approach. Issues related to reliability can be resolved through ongoing domestic satellite and launch vehicle development in Korea. Since the Korean government currently purchases all aerospace semiconductor components from abroad, it has positioned the localization of key components as a keyword for achieving complete aerospace technology independence. Initiatives such as the Space Pioneer Project by the Ministry of Science and ICT and the Materials and Component Technology Development Project by the Ministry of Trade, Industry and Energy are being pursued to localize essential aerospace components. Additionally, ironically, there are reports that a Korean private company, QRT, is expanding its business to include reliability assessment of aerospace semiconductors to support the enhancement of domestic aerospace industry technology. Establishing a foundation for reliability assessment domestically is quite significant, as conducting reliability assessments overseas can lead to increased development periods and decreased product competitiveness due to cost escalation (Lee, 2022)[72].

In summary, the development of space-grade semiconductors in Korea aligns perfectly with the direction of space development envisioned by the Korean government, and support systems for this purpose are being established by the private sector itself. Furthermore, it is an environment where it is easy to obtain real-world usage data for products loaded onto domestic satellites or launch vehicles. Therefore, the issue of ensuring product reliability, which was seen as a hurdle for emerging companies entering the space-grade semiconductor market, can be adequately addressed.

Moreover, in terms of profitability, aerospace-grade semiconductors can be expanded for use in advanced industries such as defense, nuclear power, and healthcare, where high

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72) Lee, N. (2022) *큐알티, 우주 반도체 부품 영역 확장..국책과제 수행,* 산업경제 신문 (18 November 2022). Available at: https://www.ebn.co.kr/news/view/1555493

reliability is crucial, as they guarantee performance even in extreme environments. By expanding demand in domestic markets to other fields besides the aerospace industry, such as defense, nuclear power, and healthcare, it is possible to secure price competitiveness naturally through economies of scale. From the perspective of semiconductor performance, STMicroelectronics' latest aerospace-grade CPU, the C65SPACE[73], is produced using a 65nm process, whereas Samsung Electronics currently possesses semiconductor manufacturing technology precise enough to mass-produce using a 3nm process. Here, the term "nanometer" refers to the width of the electrical circuit through which electrical signals pass within the semiconductor, and a smaller number indicates significantly higher technological prowess. Generally, smaller nanometer semiconductor technology results in reduced power consumption and heat generation while enhancing performance, despite occupying a smaller area. Therefore, based on current technological capabilities, if aerospace-specific environmental conditions are met, it is expected that products with superior performance can generate global revenue.

In this way, with the strategic implementation of government policies and active support, the entry of Korean companies into the aerospace-grade semiconductor sector, which has significant potential to become a blue ocean, appears promising. If this can be realized, it is expected to not only expedite the domestic production of satellites and launch vehicles but also lead to an expansion of the presence of domestic companies in the global space market.

73) STMicroelectronics (2024) *C65SPACE, Rad hard 65nm CMOS technology platform for space applications.* Available at: https://www.st.com/en/space-products/c65space.html

5.1.2. Space Communications

Korea is also a global leader in the field of information and communication technology. It was the first country to establish a nationwide 5G network and has been developing research on the next generation, 6G, since its commercialization in 2019 (MSIT, 2023)[74]. The Korean government is considering leveraging the technological capabilities of private telecommunications companies such as SK Telecom, KT, and LG Uplus, which dominate the private communication market, to enter new markets, such as space information communication, which are expected to have continuous demand in the future. Furthermore, as mentioned earlier, these telecommunication companies are already moving quickly towards the commercialization of satellite communication, indicating a high level of interest among companies in space-related activities. However, Korea's pursuit of space information communication should go beyond satellite communication to the next stage of space networking. In this regard, it is necessary to pay attention to the recent activities of Nokia, a telecommunications company from Finland.

In 2020, as part of the Tipping Point program, NASA signed a contract with Nokia to build the first wireless LTE/4G network on the lunar surface (Hall, 2020)[75]. The Tipping Point program aims to develop fifteen advanced technologies necessary for creating an environment on the moon where humans can reside, including establishing a lunar base by 2028. Among these

74) 과학기술정보통신부 (2023) *MSIT Launches the K-Network 2030 Strategy* (20 February 2023). Available at: https://www.msit.go.kr/bbs/view.do?sCode=eng&mId=4&mPid=2&bbsSeqNo=42&nttSeqNo=783

75) Hall, L. (2020) *2020 NASA Tipping Point Selections*, NASA (14 October 2020). Available at: https://www.nasa.gov/technology/2020-nasa-tipping-point-selections/

technologies, Nokia is tasked with developing a network capable of voice and video communication, exchanging remote sensing and biometric data, and controlling robots. Finland, following Korea, is the second country in the world to deploy a nationwide 5G network, and is recognized for its network development capabilities.

While the reasons for NASA choosing Nokia for this mission are not known, it may be somewhat disappointing from Korea's perspective. This marks the first time that an independent network outside of Earth is being established without relying on Earth-based infrastructure. Missing out on this initial opportunity could pose a barrier to entry into this field in the future. However, since NASA also has plans to establish a 5G network after deploying the 4G communication network, there is still potential for the Korean government and domestic telecommunication companies to enter the field. Furthermore, a Finnish economic delegation, including Nokia, led by Timo Harakka, Minister of Transport and Communications of Finland, recently visited Korea in early 2023 and proposed economic cooperation initiatives (MTaC, 2023)[76]. The two countries discussed strengthening cooperation not only in 6G and quantum technology but also in the space sector. Korea cannot afford to miss this opportunity. There is still a chance for Korea to acquire independent weapons such as Canada's Canadarm beyond satellite/launch vehicle production.

In summary, I have examined the need for integration between

76) Ministry of Transport and Communications (2023) *Minister Harakka to lead a Team Finland delegation to visit South Korea* (27 January 2023). Available at: https://valtioneuvosto.fi/en/-/1410829/minister-harakka-to-lead-a-team-finland-delegation-to-visit-south-korea-1925112

Korea's internationally competitive semiconductor and telecommunications sectors and space development. The Korean government can achieve the goal of expanding the domestic space market by providing concentrated support for the development of space-grade semiconductors in the continuous development process of satellites and launch vehicles, along with the localization of satellites/launch vehicles. Furthermore, comprehensive government support is required to enable Korea to quickly seize opportunities in the space information communication sector. This requires substantial budget investments by the government, and to achieve this, it is necessary to complement and strengthen the "Space Pioneer Program," which the government has been promoting with the goal of localizing satellites and launch vehicles. Under this program, the government has allocated a total budget of 211.5 billion Korean Won (approximately 167 million USD) over ten years from 2021 for the localization of 16 satellite/launch vehicle components. However, the amount of support provided to companies for localizing one component is only about 1.3 billion Korean Won per year (approximately 1 million USD) on average. Moreover, as mentioned earlier, the targeted localization is at the component level rather than the part level, including propulsion tanks, optical gyroscopes, and infrared detectors, which are developed in the form of finished products with the assumption of being installed on Korean satellites/launch vehicles in the future. This raises concerns that the development may end with one-time projects. Furthermore, since the detailed components used in each component are likely to be imported from abroad as before, it is difficult to consider the achievement of true localization. To foster private space companies along with localization, it seems more conducive to promote localization at the component level rather than at the part level and to expand the scale of support, facilitating the continuous development of the space ecosystem rather than one-time projects.

5.2. Necessary for establishing a clear purpose of space exploration

In considering the justification or legitimacy of space exploration that the government should review, it is worth referring to the space policy status of the UAE, which is planning Mars exploration without lunar exploration. After setting its sights on Mars exploration in 2014, the UAE achieved a significant milestone in 2021 with the successful arrival of its Mars orbit probe, "Hope," into Martian orbit (Strickland, 2021)[77]. The UAE has aggressively invested in the space industry to diversify its economy, which is predominantly centered around the petroleum industry, and as a result, it has risen to become the fifth Mars exploration nation in the world, following the United States, the Soviet Union, Europe, and India. If the UAE had planned Mars exploration after lunar exploration like many other countries, the scientific value of the exploration might not have been significant. However, the UAE's remarkably bold decision-making and swift actions have provided legitimacy to space exploration for scientific inquiry purposes. In other words, regardless of social and economic benefits, the UAE's space exploration policy gains sufficient legitimacy solely based on scientific inquiry

77) Strickland, A. (2021) *The UAE's Hope Probe has successfully entered orbit around Mars*, CNN (9 February 2021). Available at: https://edition.cnn.com/2021/02/09/world/uae-hope-probe-mars-mission-orbit-scn-trnd/index.html

purposes.

However, it is evident from an interview with Sarah Al Amiri, the Minister of State for Advanced Technology and Chairwoman of the UAE Space Agency (UAESA), conducted by the US-based CSIS (Center for Strategic & International Studies), that the UAE government also has a clear intention to generate socio-economic benefits from Mars exploration beyond scientific inquiry. In the CSIS interview (2021)[78], Minister Sarah Al Amiri described space development, including Mars exploration, as a catalyst for the UAE's economic growth and industrial diversification. She emphasized focusing on the domestic industrial ripple effects rather than the space industry itself. Additionally, she outlined the role of the UAESA in facilitating UAE's space exploration to be linked with various commercial data, products, services, and satellite development projects. This linkage aims to actively utilize the information and data obtained through these activities to foster non-space industries.

The UAE government's steadfast determination to contribute to national economic development beyond the petroleum industry has now led to the announcement of asteroid exploration plans, going beyond Mars exploration (Chang, 2023)[79]. According to the UAE's announcement, the plan involves launching an asteroid probe in 2028 to explore seven asteroids between Mars and

78) CSIS (Center for Strategic & International Studies) (2021) *A Mission to Mars: A Conversation with Her Excellency Sarah Al Amiri, UAE Minister of State for Advanced Technology* (9 September 2021). Available at: https://www.csis.org/analysis/mission-mars-conversation-her-excellency-sarah-al-amiri-uae-minister-state-advanced

79) Chang, K. (2023) *The United Arab Emirates is Heading for the Asteroid Belt*, The New York Times (29 May 2023). Available at: https://www.nytimes.com/2023/05/29/science/uae-asteroid-mission.html

Jupiter over several years. The mission aims to analyze the surface composition, geology, internal density, temperature, and thermal-physical characteristics of multiple asteroids to study surface evolution and history. The ultimate goal is to land on the seventh asteroid, Eustatia, in 2034[80]. Asteroid exploration is a highly challenging mission that, until now, only the United States, Europe, China, and Japan have attempted. Despite the considerable challenges involved, the UAE government's firm policy drive to pursue this goal and achieve innovation in its domestic economic structure through it has garnered attention from many countries. Minister Sarah Al Amiri stated in a statement that the Emirates Asteroid Mission (EMA) is a key element of UAE's space strategy, prioritizing the creation of viable and rewarding employment opportunities for young Emiratis for future generations (Foust, 2023)[81].

As seen earlier, UAE has a firm purpose and goal in space exploration, unlike Korea. By linking space exploration to the revival of the national economy, UAE has a shape with strong driving force for policy implementation. Similarly, the Korean government, which aims for space exploration, should clearly emphasize this point and use it as a basis for continuous and robust policy implementation. Korea should not simply emulate the policies of advanced space-faring nations like the United States and China. They already have the status and ample national budget to use space exploration as a means of national

80) Times Aerospace (2024) *UAE Space Agency unveils milestones in Emirates Mission to Asteroid Belt* (23 February 2024). Available at: https://www.timesaerospace.aero/news/space/uae-space-agency-unveils-milestones-in-emirates-mission-to-asteroid-belt

81) Foust, J. (2023) *UAE outlines plans for asteroid mission,* SpaceNews (3 June 2023). Available at: https://spacenews.com/uae-outlines-plans-for-asteroid-mission/

elevation. On the other hand, Korea should not be satisfied with merely being the nth country to explore the moon, nor should it be content with the nominal achievement of increasing national brand value. Given the limited resources, Korea must carefully establish substantive goals to achieve tangible outcomes within the domestic atmosphere.

6. Conclusion

As seen above, since the 1990s, Korea has shown remarkable achievements in space development within a relatively short period. Through concentrated investment and nurturing, it has secured independent capabilities in satellite and launch vehicle development with relatively few failures. This was possible due to the effectiveness of Korea's consistent space development policy since the 1990s, coupled with the public nature of its objectives. Moreover, with KARI, a government agency, leading technology development and production in most programs, it appears that stronger government-led policy implementation was achievable.

With a history of strong government-led space policies, Korea has adopted a new direction for space development in the face of a new era led by the private sector. However, many aspects of this new direction still appear unclear. Although the public purpose is significant, policy focusing mainly on repeated satellite and launch vehicle development seems to hinder the development potential in other space sectors from the outset. Particularly in the global space market, where the production of satellites and launch vehicles forms a small portion, solely relying on this may not be suitable for achieving the goal of expanding the domestic space market. Moreover, with launch services already transitioning to private companies like SpaceX, the profit potential for latecomers seems limited. Examining the space industry and policies of Canada and Luxembourg underscores the importance of securing outstanding expertise in specific fields. Therefore, the Korean government needs to establish a dual strategy of developing its own expertise in addition to the current public-purpose satellite/launch vehicle development policy. Especially, integrating Korea's strengths in semiconductor and information communication fields into the space sector seems to be the best approach. Through this dual strategy, Korea can pioneer its unique expertise in the space industry, contribute to maintaining smooth international cooperation relationships, and simultaneously contribute to the expansion of the domestic private space market.

On the other hand, Korea's proposed space exploration as one of the future space development endeavors seems to lack adequate means compared to its ambitious goals. Furthermore, as space exploration commences later compared to spacefaring nations, Korea needs to present other purposes that justify allocating a significant budget for space exploration, rather than just scientific exploration, to gain traction for its space exploration policy. In this regard, the case of UAE confirms their clear purpose in space exploration. However, due to the limited achievements in space exploration as of yet, there are limitations in clearly proposing the justifiability of space exploration tailored for Korea. Additionally, various studies have failed to present the benefits of space exploration beyond scientific exploration or the utilization of mineral resources, indicating the need for further research.

[붙임] 룩셈부르크의 Law on the exploration and use of space resources 전문

Law of July 20th 2017 on the exploration and use of space resources.

Unofficial English translation,
French version shall prevail.

⊖ Article 1.

Space resources are capable of being owned.

⊖ Article 2.

(1) No person can explore or use space resources without holding a written mission authorisation from the minister or ministers in charge of the economy and space activities (hereinafter "the ministers").

(2) No person shall be authorised to carry out the activity referred to in paragraph 1 either through another person or as an intermediary for the carrying out of such activity.

(3) The authorised operator may only carry out the activity referred to in paragraph 1 in accordance with the conditions of the authorisation and the international obligations of Luxembourg.

(4) This Law shall not apply to satellite communications, orbital positions or the use of frequency bands.

⊖ Article 3.

The authorisation shall be granted to an operator for a mission of exploration and use of space resources for commercial purposes upon written application to the ministers.

⊝ Article 4.

The authorisation for a mission shall only be granted if the applicant is a public company limited by shares (*société anonyme*) or a corporate partnership limited by shares (*société en commandite par actions*) or a private limited liability company (*société à responsabilité limitée*) of Luxembourg law or a European Company (*société européenne*) having its registered office in Luxembourg.

⊝ Article 5.

The authorisation is personal and non-assignable.

⊝ Article 6.

The application for authorisation must be accompanied by all such information as may be useful for the assessment thereof as well as by a mission program.

⊝ Article 7.

(1) The authorisation shall be subject to the production of evidence showing the existence in Luxembourg of the central administration and of the registered office, including the administrative and accounting structures of the operator to be authorised.

(2) The operator to be authorised shall have a robust scheme of financial, technical and statutory procedures and arrangements through which the exploration and utilization mission, including the commercialisation of space resources are planned and implemented. The operator to be authorised shall furthermore have a robust internal governance scheme, which includes in particular a clear organisational structure with well defined, transparent and consistent lines of responsibility, effective processes to identify, manage, monitor and report the risks it is or might be exposed to, and adequate internal control mechanisms, including sound administrative and accounting procedures, as well as control and security arrangements for its technical systems and applications.

(3) The arrangements, processes, procedures and mechanisms referred to in this article shall be comprehensive and proportionate to the nature, scale and complexity of the risks inherent to the business model of the operator to be authorised as well as to the mission for which the authorisation is sought.

⊖ Article 8.

(1) The authorization shall be subject to the communication to the ministers of the identity of the shareholders or members, whether direct or indirect, natural or legal persons, that have direct or indirect holdings of at least 10 per cent of the capital or of the voting rights in the operator, and of the amount of such holdings or, if such 10 per cent threshold is not met, the identity of the twenty largest shareholders or members.

The authorisation shall be refused if, taking into account the need to ensure a sound and prudent operation, the suitability of those shareholders or members is not satisfactory.

(2) The concept of sound and prudent operation is assessed in accordance with the following criteria :

a) the good repute of the operator to be authorised and the shareholders and members referred to in paragraph 1 ;
b) the good repute, knowledge, skills and experience of any member of the management body of the shareholders or members referred to in paragraph 1 ;
c) the financial soundness of the shareholders and members referred to in paragraph 1 ;
d) whether there are reasonable grounds to suspect that money laundering or terrorist financing is being or has been committed or attempted in relation to the proposed exploration mission or the proposed utilization of space resources or that such exploration mission or such utilization could increase the risk thereof.

The good repute of the members of the management body of the shareholders or members referred to in paragraph 1 shall be assessed in accordance with the terms of article 9, paragraph 1, second sentence.

⊖ Article 9.

(1) The authorisation shall be subject to the condition that the members of the management body of the operator shall at all times be of sufficiently good repute and possess sufficient knowledge, skills and experience to perform their duties. Such good repute shall be assessed on the basis of police records and of any evidence tending to show that the persons concerned are of good repute and offer every guarantee of irreproachable conduct.

(2) At least two persons must be responsible for the management of the operator. Those persons must be empowered to effectively determine the direction taken by the business. They must possess adequate professional experience by virtue of their having previously carried out similar activities at a high level of responsibility and autonomy in the space industry or in a related sector.

(3) Any change in the persons referred to in paragraph 1 shall be communicated in advance to the ministers. The ministers may request all such information as may be necessary regarding the persons who may be required to fulfil the legal requirements with respect to good repute and professional experience. The ministers shall refuse the proposed change if these persons are not of adequate professional repute or do not have sufficient professional experience or where there are objective and demonstrable grounds for believing that the proposed change would pose a threat to the sound and prudent management of the operation.

(4) Granting the authorisation implies that the members of the management body shall, on their own initiative, notify in writing and in a complete, coherent and comprehensive form, to the ministers any change regarding the substantial information on which the ministers based their investigation of the application for the authorisation.

⊖ Article 10.

(1) The application for the authorisation must be accompanied by a risk assessment of the mission. It shall specify the coverage of these risks by personal financial means, by an insurance policy of an insurance undertaking not belonging to the same group than the operator to be authorised or by a guarantee of a credit institution not belonging to the same group than the operator to be authorised.

(2) The authorisation shall be conditional upon the existence of financial bases that are appropriate to the risks associated with the mission.

⊖ Article 11.

(1) The authorisation shall be conditional on the operator to be authorised having its annual accounts audited by one or more *réviseurs d'entreprises agréés* who can show that they possess adequate professional experience.

(2) Any change in the *réviseurs d'entreprises agréés* must be authorised in advance by the ministers.

(3) The rules in respect of commissaires, which may form a supervisory board as laid down in the Law of 10 August 1915 on commercial companies, as amended, only apply to operators where the Law on commercial companies mandatorily prescribes it even if there is a *réviseur d'entreprise*.

⊖ Article. 12.

The authorisation shall describe the manner in which the operator to be authorised fulfils the conditions of articles 6 to 11, paragraph 1. It may in addition include provisions on :

a) the activities to be carried on within the territory of the Grand Duchy or out of such territory ;
b) the limits that could be associated with the mission ;
c) the modalities for the supervision of the mission ;
d) the conditions for ensuring compliance by the operator to be authorised with its obligations ;

⊖ Article 13.

For each application for an authorisation, a fee shall be set by the ministers in order to cover the administrative expenses incurred in relation to the processing of the application. Such fee shall range from 5.000 to 500.000 euros depending on the complexity of the application and the amount of work involved.

A Grand-Ducal regulation shall determine the procedure applicable to the collection of such fee.

⊖ Article 14.

(1) The authorisation shall be withdrawn if the conditions for the granting thereof are no longer met.

(2) The authorisation shall be withdrawn if the operator does not make use thereof within thirty-six months of it being granted, renounces to it or has ceased to carry out its business for the preceding six months.

(3) The authorisation shall furthermore be withdrawn if it has been obtained through false statements or through any other irregular means.

⊖ Article 15.

The ministers are in charge of the continuous supervision of the missions for which an authorisation has been granted.

⊖ Article 16.

The operator that is granted an authorisation for a mission is fully responsible for any damage caused at the occasion of the mission, including at the occasion of all preparatory works and duties.

⊖ Article 17.

The granting of an authorisation for a mission does not dispense from the need to obtain other approvals or authorisations.

⊖ Article 18.

(1) Any person who contravenes or attempts to contravene the provisions of article 2 shall be punished by a term of imprisonment of between eight days and five years and a fine of between 5.000 and 1.250.000 euros or either one of those penalties.

(2) Any person who contravenes or attempts to contravene the provisions of articles 5, 9 paragraph 3 subparagraph 1, 11 paragraph 1 or 2 or that contravenes the terms and conditions of the authorisation shall be punished by a term of imprisonment of between eight days and one year and a fine of between 1.250 and 500.000 euros or either one of those penalties.

(3) Without prejudice to paragraphs 1 and 2, the court to which the matter is being referred, may declare the discontinuance of an operation contravening the provisions of the present law, under a penalty the maximum of which shall not exceed 1.000.000 euros per day of infringement found.