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THESIS

**CHARTING A PATH TOWARD A SUSTAINABLE ROK
SPACE PROGRAM**

by

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December 2016

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CHARTING A PATH TOWARD A SUSTAINABLE ROK SPACE PROGRAM

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ABSTRACT

This thesis seeks to trace the origins and initial Republic of Korea (ROK) strategy in space policy and to analyze the prospects and challenges of building effective and sustainable civil, commercial, and military space capabilities. To better understand the factors involved in developing a sustainable ROK space program, two sets of comparative case studies, both internal and external cases, are examined. The internal case studies consist of the ROK automobile and semiconductor industries, and the external case studies are of Israel's and Australia's space programs. The ROK space program exhibits considerable differences from the internal and external case studies in terms of policy direction, R&D investment, and human resources. Based on these findings, this thesis derives several conclusions. In order to take a path toward a sustainable space program, the ROK should redefine national needs and aspirations for its space activities; plan to expand private investment, especially in space R&D; invest in the space sector with a long-term vision; and continue to strengthen ties with international partners, especially its main ally, the United States.

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LIST OF ACRONYMS AND ABBREVIATIONS

ASB	Australian Space Board
ASC	Australian Space Council
ASO	Australian Space Office
ASERA	Australian Space Engineering Research Association
ASRI	Australian Space Research Institute
AMOS	Israeli Afro-Mediterranean Orbital System
CRCSS	Cooperative Research Centre for Satellite System
CSIRO	Commonwealth Scientific and Industrial Research Organization
EROS	Israeli Earth Resources Observation Satellite
GDS	Gross Domestic Spending
GEO	geostationary orbit
IAI	Israel Aircraft Industry
ISA	Israel Space Agency
KAI	Korea Aerospace Industries, LTD.
KAIST	Korea Advanced Institute of Science and Technology
KAMD	Korean Air and Missile Defense
KARI	Korea Aerospace Research Institute
KIET	Korea Institute for Industrial Economy and Trade
KIMM	Korea Institute of Machinery and Materials
KIST	Korea Institute of Science and Technology
KISTEP	Institute of Science and Technology Evaluation and Planning
KMA	Korea Meteorological Administration
KMPR	Korea Massive Punishment and Retaliation
KOMPSAT	Korea Multi-purpose Satellite
KSLV	Korea Space Launch Vehicle
KSR	Korea Sounding Rocket
LEO	low-earth orbit
MOST	Ministry of Science and Technology
MOTIE	Ministry of Trade, Industry, and Energy
MSIP	Ministry of Science, ICT, and Future Planning

MTCR	Missile Technology Control Regime
NASA	National Aeronautics and Space Administration
NCSR	National Committee for Space Research of Israel
NOAA	National Oceanic and Atmospheric Administration
ROK	Republic of Korea
RTA	Revealed Technological Advantage
SAR	Synthetic Aperture Radar
SCC	Space Coordination Committee of Australia
SSA	Space Situation Awareness
STL	Space Technology Ladder
STSAT	Science and technology satellite
UNIDO	United Nation Industrial Development Organization
WGS	Wideband Global Satellite

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I. INTRODUCTION

A. MAJOR RESEARCH QUESTION

The primary question addressed in this thesis is: What are the challenges and opportunities facing the Republic of Korea (ROK) in policy-making and investment for establishing a sustainable space program in a highly competitive region and international space marketplace? This thesis seeks to identify and explain the origins and initial strategy behind the space policies and programs of the ROK and the prospects and challenges of building a set of effective and sustainable civil, commercial, and military space capabilities.

B. SIGNIFICANCE OF THE RESEARCH QUESTION

The space program of the ROK began in the late 1980s in earnest. Its starting point lagged behind those of other space-faring nations by almost 30 years; however, despite its late beginning, the ROK's civil space development has proceeded rapidly. To date, the ROK has launched twenty objects successfully by foreign rockets and one of its own into outer space since 1992.¹ Without a doubt, the ROK is a new player in space activity, and according to James C. Moltz, "[it] has arguably been even more dynamic [than others] over the past two decades," in its space development.² While other space-faring nations started their space programs or were concerned about space in the 1950s, the ROK could not afford to start a space program at that time. The ROK's economic, educational, and technological status also held the ROK back. After the 1970s, the ROK was able to invest in efforts to build up its infrastructure for scientific and technological industries. The ROK's investment was initially made possible due to its own domestic development plans, such as the Five-Year Economic Development Plan, and international support,

¹ United Nations Office for Outer Space Affairs, "Online Index of Objects Launched into Outer Space," United Nations Office for Outer Space Affairs, accessed March 4, 2016, http://www.unoosa.org/oosa/osoindex/search-ng.jsp?lf_id=#?c=%7B%22filters%22:%5B%7B%22fieldName%22:%22en%22object.launch.stateOrganization_s%22,%22value%22:%22Republic%20of%20Korea%22%7D%5D,%22sortings%22:%5B%7B%22fieldName%22:%22object.launch.dateOfLaunch_s1%22,%22dir%22:%22desc%22%7D%5D,%22match%22:%22%22,%22termMatch%22:%22korea%22%7D.

² James Clay Moltz, *Asia's Space Race* (New York: Columbia University Press, 2011), 136.

especially from the United States. Recently, the Korea Aerospace Research Institute (KARI), which took the lead in the ROK's aerospace science and technology development, announced that it "successfully launched a small satellite in low-earth orbit (LEO) on January 30, 2013,"³ plans to "develop an independent space launch vehicle into LEO"⁴ through the Korea Space Launch Vehicle (KSLV-II) before March 2021, and will launch a lunar lander in 2020 and a Mars lander in 2030. Furthermore, the ROK seeks to establish a stable commercial program and develop military space capabilities to ensure its security from possible external threats.

Yet the future of the ROK's space development does not all glitter like gold. While the ROK is considered as one of the leading world industrial powers, there are obvious obstacles blocking the ROK's path toward sustainable growth and development in space. First, the ROK has fewer budgetary and human resources than neighboring countries, such as China, Russia, and Japan. Next, the international space marketplace has high barriers to entry due to its small size and tough price competitiveness. Moreover, restrictions imposed by space superpower nations on sharing space technologies, such as the Missile Technology Control Regime (MTCR) and missile range restrictions, have been a barrier to the ROK's development of space capabilities, so the ROK cannot enjoy advantages similar to what Japan and China once received from the United States and the Soviet Union.

In this context, this research on sustainability of the ROK's space development is significant for three reasons. First, the ROK's sustainable entry into space could contribute to regional and international security and stability. East Asia is a region with a dilemma that cooperation coexists with competition among nations in terms of politics, economy, and society as well as space. Moreover, the region consists of world's leading powers, including China, Japan, and Russia. By presenting its space development objectives clearly, an unnecessary space arms race could be prevented, and peaceful space development could be promoted.

³ Korea Aerospace Research Institute, "First Korean Space Launch Vehicle Narocho (KSLV-I)," accessed March 4, 2016, http://www.kari.re.kr/eng/sub03_03_02.do.

⁴ Korea Aerospace Research Institute, "Korea Space Launch Vehicle KSLV-II," accessed March 4, 2016, http://www.kari.re.kr/eng/sub03_03_01.do.

Second, the ROK could play a significant role by sharing the high-cost burden of space-based operational information as one side of the ROK-US alliance based on enhancement of mutual space military capabilities. To date, the ROK has received major support from the U.S. in space operations. The ROK's military power has been increased considerably due to space information, such as reconnaissance imagery and weather data provided by the U.S. and by the utilization of GPS satellites for military purposes.

Finally, the ROK's space development could provide an example for other states to follow in developing a model of sustainable space activities. A number of developing space countries have increased their space activities through rockets and satellites, built space systems and supporting infrastructure to defend themselves from space threats, and pursued the leading spacefaring nations with their technology development and competitive market edge. However, like the ROK, several nations overstate their future space potential. Thus, the ROK's development of an effective and sustainable space development plan could serve as an example for them.

C. LITERATURE REVIEW

1. Definition of Sustainability

Most studies regarding space sustainability focus on challenges to the peaceful and enduring use of space.⁵ For example, the Secure World Foundation defines space sustainability as follows:

Space sustainability is ensuring that all humanity can continue to use outer space for peaceful purposes and socioeconomic benefit now and in the long term. This will require international cooperation, discussion, and agreements designed to ensure that outer space is safe, secure and peaceful.⁶

The U.S. National Aeronautics and Space Administration (NASA) also uses a similar meaning for space sustainability. According to NASA's Sustainability Portal, the objective of NASA's sustainability policy is as follows:

⁵ "Space Sustainability 101," Secure World Foundation, accessed June 4, 2016, <http://swfound.org/space-sustainability-101/>; Timiebi Aganaba-Jeanty, "Space Sustainability and the Freedom of Outer Space," *Astropolitics* 14, no. 1, 10–11.

⁶ "Space Sustainability 101," Secure World Foundation.

NASA's sustainability policy is to execute NASA's mission without compromising our planet's resources so that future generations can meet their needs. Sustainability involves taking action now to enable a future where the environment and living conditions are protected and enhanced.⁷

In order to achieve this objective, NASA stresses the fact that "NASA seeks to use public funds efficiently and effectively, promote the health of the planet, and operate in a way that benefits our neighbors."⁸

However, these studies' concept of space sustainability is focused on the activities of major space powers. Developing countries' concerns about space activities are focused more on their ability to enter the international system and space marketplace and to stabilize their position in the system. Their interests are more dynamic and focused on development rather than the sustained use of a stable system that has been established already.

The report of the World Commission on Environment and Development created by the United Nations General Assembly, "Our Common Future," provides a definition of sustainable development as follows:

Sustainable development is development that meets the needs of the present without compromising the ability of future generations to meet their own needs ... In essence, sustainable development is a process of change in which the exploitation of resources, the direction of investments, the orientation of technological development; and institutional change are all in harmony and enhance both current and future potential to meet human needs and aspirations.⁹

This thesis draws on this concept of sustainable development to examine the space activity of the ROK, whose program is not yet mature enough to have effects on broader space sustainability. The sustainability of space development is defined here as a process of setting policy objectives, capital investment, and development of human

⁷ "Sustainability 101," NASA's Sustainability Portal, accessed June 4, 2016, <http://www.nasa.gov/agency/sustainability/#.V1OSkiTrtFQ>.

⁸ Ibid.

⁹ Gro Brundtland, Mansour Khalid, Susanna Agnelli, et al., "Our Common Future," the U.N. General Assembly, *The World Commission on Environment and Development Report*, May 21, 1987, 27–28. http://www.channelingreality.com/Documents/Brundtland_Searchable.pdf.

resources to meet the needs of a nation in its space activities in an efficient manner in harmony with the country's long-term support capabilities.

2. ROK Space Development

a. Aspirations for Space and ROK Motivations

Many scholars have examined on national motivations for space development. However, it is not easy to discriminate such motivations because the analysis requires extensive and comprehensive understanding across the political, economic, and social background of a nation. Fortunately, scholars sort the motivations into three or four categories to make it easier to approach. John Logsdon distinguishes the motivations for space activities briefly. In 1983, Logsdon pointed out the list of motivations as “scientific discovery, national security, national image, and beneficial applications.”¹⁰ Yet presenting the four motivations, the author simplified the factors later into “science, security, and society” as the dominant motivations for human space activities.¹¹

Moltz also sheds lights on these motivations. The author argues that the nation's orbital motivations have three distinct goals focused on “scientific-technological progress, national security, and international prestige,” and these goals are related to each other.¹² Furthermore, the author claims the ROK's motivations are: (1) economic development aims and state-led industrial development as with other industrial sectors in the past, (2) security concerns created by threats of North Korea's nuclear and missile developments, and (3) the desire for national pride and to become a technologically advanced society.¹³

Hyoung Joon An asserts that the ROK's motivations have changed over time. According to the author's argument, the ROK's goals for space development are “modernity” through progress in scientific-technology (1958-69), “self-defense” concerns

¹⁰ John Logsdon, “The Motivations for Space Activities,” in *The First 25 Years in Space*. A Symposium, ed. Allan A. Needell (Smithsonian Institution Press, Washington, DC, 1983), 4.

¹¹ Ibid.

¹² Moltz, *Asia's Space Race*, 25.

¹³ Ibid., 137–8.

about national security (1970-84), “economic security” (1985-97), and “national prestige” (1998-2013).¹⁴

A nation’s official purposes and goals for space activities are expressed at its national acts and plans regarding space development. The ROK’s historic space policies consist of two acts and five plans: the Aerospace Industry Development Promotion Act of 1987; the Space Development Promotion Act of 2005; the Mid- to Long-Term Basic Plan for Space Development of 1996; the Space Development Promotion Act of 2005; the First Basic Plan to Promote Space Development of 2007; the Second Basic Plan to Promote Space Development of 2001; and the Mid- to Long- Term Space Development Plan of 2013.

According to these documents, the Acts’ priorities shifted their focus from the airplane industry to the space industry. The Aerospace Industry Development Promotion Act of 1987 states its purpose to contribute to national economic development by promoting the aerospace industry, science, and technology.¹⁵ On the other hand, the Space Development Promotion Act of 2005 was established to

facilitate the peaceful use and scientific exploration of outer space and to contribute to national security, the sound growth of the national economy, and the betterment of life of citizens through the systematic promotion of the development of outer space and the efficient use and management of space objects.¹⁶

Meanwhile, the ROK’s space plans’ objectives have evolved from general to specific, maintaining their purposes to acquire independent technological capabilities for space activities. One of the plans’ ultimate goals was “to join the top 10 countries in the space industry by competing in the global market.”¹⁷ Afterward, the goals concerned the

¹⁴ Hyoungh Joon An, “National Aspirations, Imaged Futures, and Space Exploration: the Origin and Development of Korean Space Program 1958–2013,” Dissertation, Georgia Institute of Technology (December 2015), 208.

¹⁵ Korea National Law Information Center, “Aerospace Industry Development Promotion Act,” last modified January 28, 2015, <http://www.law.go.kr/법령/항공우주산업개발촉진법>.

¹⁶ Korea National Law Information Center, “Space Development Promotion Act,” last modified January 20, 2015, <http://www.law.go.kr/법령/우주개발%20진흥법>.

¹⁷ KARI, “Planning of Mid- and Long-term National Space Development Plan,” Korea Ministry of Science, ICT and Future Planning, last modified December 10, 2013, 186.

expansion of infrastructure, financing and investment plans, research and development, international cooperation, management of space objects, extension of civil participation, and high-quality human resources.¹⁸

Based on these motivations and policies, the ROK has extended its space capabilities thus far; there is no difference in the views among scholars about the fact that the ROK has achieved remarkable progress in space development despite its short history of space activity compared to neighboring space-faring nations. Certainly, the ROK has taken latecomer's incentives and succeeded in its catch-up strategy throughout its space industries, but a debate has emerged about the advantages and disadvantages of the ROK's space activities as a latecomer.

b. *Economic Latecomer*

The concept of latecomers was elaborated by an economic historian, Alexander Gerschenkron, in 1962. The author had studied Europe on countries like Germany in 19th-century as a case of late industrializing country that wanted to catch up the other industrialized countries such as England. Gerschenkron claims that "borrowed technology...was one of the primary factors assuring a high speed of development in a backward country entering the stage of industrialization."¹⁹ Furthermore, the author stressed the important role of the state's institutions to ensure its development with those borrowed technologies.²⁰

Based on this idea of economic latecomer, John A. Mathews elaborates these thoughts by analysis of latecomer firm behavior and strategy to catch-up with leading firms. While Mathews focused on technological aspects of latecomer development in his early work, the author enlarged latecomer's features in his article, "Catch-up Strategies and the Latecomer Effect in Industrial Development," by discussing international

¹⁸ Korea Ministry of Science, ICT and Future Planning, "Mid to Long Term Space Development Plan." accessed March 9, 2016, 11; Korea Ministry of Science, ICT and Future Planning, "Second Basic Plan to Promote Space Development." accessed March 5, 2016, 12.

¹⁹ Alexander Gerschenkron, *Economic Backwardness in Historical Perspective: A Book of Essays* (Cambridge: Belknap Press of Harvard University Press, 1962), 8.

²⁰ Ibid., 354.

position, changes on industrial structure, involvement of value chains, institutional and economic learning, firm and industrial creation, and so on.²¹

Linsu Kim also claims that the technical development trajectories in latecomer country are different from those of developed countries.²² The author uses an institutional environment framework to analyze a complex learning process for technological capacity acquisition in latecomer countries. Kim asserts that technological capability acquisition is through “interactions with the international community, interactions with domestic community, and in-house efforts.”²³ Furthermore, Kim shed lights on the fact that this process is affected by five factors: (1) the market environment, such as export-oriented and protected import systems, (2) policies by the government that affect the adoption of foreign technology, support institutions, and the quality of education, (3) the educational system for the future, (4) the sociocultural environment, and (5) organization and management.²⁴

Regarding path of the ROK’s space technology development, Chin Young Hwang stresses that the ROK’s historical path is similar to that in other industries.²⁵ The author sheds light on the path as three stages: (1) contracting with foreign companies to develop a space system, (2) developing the system under the ROK’s responsibility with supporting of foreign companies, and (3) developing the system independently.²⁶ Moreover, introducing recent space development activities of the ROK, such as satellites and launcher development, Won-hwa Park claims that the ROK adopted a “two-track

²¹ John A. Mathews, “Competitive Advantage of the Latecomer Firm: A Resource-Based Account of Industrial Catch-Up Strategies,” *Asia Pacific Journal of Management* 19, no. 4 (December, 2002): 472; John A. Mathews, “Catch-up Strategies and the Latecomer Effect in Industrial Development,” *New Political Economy* 11 no.3 (2006): 325–27.

²² Linsu Kim, *Imitation to Innovation: The Dynamics of Korea’s Korea Technological Learning* (Boston, MA: Harvard Business School Press, 1997), 91.

²³ Ibid., 91–94.

²⁴ Ibid., 94.

²⁵ Chin Young Hwang, “Space Activities in Korea-History, Current Programs and Future Plans,” *Space Policy* 22 (2006): 194.

²⁶ Ibid., 199.

approach” to gain its space technology in the early 1990s.²⁷ The two-track approach included:

One relying on foreign technology to manufacture and place in orbit communications satellites, another to foster indigenous technology, starting with small satellites and launching them into low-Earth orbit(LEO), through technology cooperation programs with the other space-faring nations.²⁸

c. Government-Led Development

The ROK government has played a key role in space industrial development. Initially, infrastructure, institutions, and facilities related to space activities were established by the ROK government. KARI (formerly affiliated with the Korea Institute of Machinery and Materials), which leads the ROK space activities, was founded in 1989. The SatReC Initiative (SatReC-I) which is the ROK’s leading commercial provider was founded as a subsidiary institution of Korea Advanced Institute of Science and Technology (KAIST, affiliated to MSIP) in 1999.

Subsequently, the ROK government made efforts to adopt foreign technology. The ROK’s first satellite, the KITSAT-1 (*Uribyul-1*), which is for scientific experimentation, education of students, and testing next generation technology, was developed through collaboration program between KAIST and the University of Surrey, UK, in 1992.²⁹ The first Korea Multi-purpose Satellite (KOMPSAT, *Arirang-1*) was developed by KARI in association with the U.S. company, TRW.³⁰ In addition to these efforts to adopt foreign satellite technologies, the ROK government stimulated its space launch vehicles and a launch facility development by the conclusion of two bilateral agreements with the Russian Federation in 2006 and 2007. The agreements states as their purpose goals “to promote mutually beneficial scientific, technological, industrial, economic and other cooperation related to the exploration and use of outer space for

²⁷ Won-hwa Park, “Recent Space Developments in South Korea,” *Space Policy* 26 (2010), 117.

²⁸ Ibid.

²⁹ Hwang, “Space Activities in Korea,” 197; Moltz, *Asia’s Space Race*, 141–42.

³⁰ KARI, “Korea Multi-Purpose Satellite (*Arirang*),” accessed March 8, 2016, http://www.kari.re.kr/eng/sub03_02_01.do; Moltz, *Asia’s Space Race*, 144.

peaceful purposes” and “to establish cooperative relations with regard to technology safeguards in connection with the implementation of joint programs and projects in the field of the exploration and use of outer space for peaceful purposes.”³¹

Ultimately, the ROK’s satellites series, such as KITSAT, KOMPSAT, and Geostationary Earth Orbit Satellite, Korea Space Launch Vehicle (KSLV-I), and the NARO Space Center were developed and have been operated by ROK government-led programs.

Within this infrastructure, SatRec-I has played an important role to develop the ROK’s space capabilities. SI was separated from KAIST and commercialized in 2009 when KAIST was incorporated with SatReC. SatReC has participated in foreign satellite programs, such as the Malaysian *RazakSat* in 2009, the UAE *DubaiSat-1* and -2 in 2009, 2013, and the Spanish *Deimos-2* in 2014.³² Moreover, the company offers three core technologies for small Earth observation satellites, including satellite platforms, mission payloads, and ground component technologies.

d. Problems Facing the ROK’s Space Development

Some scholars point out problems facing the ROK’s space development. One of the schools claims that late- developing countries like the ROK face obstacles in trying to establish sustainable space industries. U. M. Leloglu and E. Kocaoglan assert the problem that the only initially available market for late-developing spacefaring countries is their own domestic one, but it is hard to meet its national needs and compete successfully with foreign companies which already have high-level space technologies and protection and

³¹ Ministry of Foreign Affairs of the ROK, “Agreement Between the Government of the Republic of Korea and the Government of the Russian Federation on Cooperation in the Field of the Exploration and Use of Outer Space for Peaceful Purposes,” entered into force September 5, 2006; “Agreement Between the Government of the Republic of Korea and the Government of the Russian Federation on Technology Safeguards Associated with Cooperation in the Field of the Exploration and Use of Outer Space for Peaceful Purposes,” entered into force Jul 17, 2007. <http://www.mofa.go.kr/search/search.jsp?searchData=우주>.

³² SatReC Initiative, “Mission List,” accessed May 20, 2016, https://www.satreci.com/eng/ds1_1.html?tno=8.

support by their governments to apply political pressure.³³ The authors give an example by quoting the Green Paper on European Space Policy,

The United States in particular protect their industry from external commercial pressures thanks to support from a large national security and defense market which is closed to foreign suppliers. Application to commercial civil satellites of export control law—notably the application of clauses related to dual-use technologies—reinforces this support.³⁴

Another school cites problems from internal circumstances. Joosung J. Lee and Seungmi Chung argue in their article, “Space policy for late comer countries: A case study of South Korea,” that the problem of the ROK’s space development is in its institutional policy. Their argument is that KARI has to change its role.³⁵ The ROK’s space policy was focused on “technology catch-up” initially without deeper consideration of a space industrial development plan and strategy for later on.³⁶ Accordingly, the market size of the ROK’s commercial space industry is heavily focused on satellite application up to 72%, which has created a weak foundation for the space industry.³⁷ This problem leads to another concern, which is that most companies’ needs are concentrated on satellite applications, while research institutes and universities are focused on manufacturing satellites, launch vehicles, and ground-based systems.³⁸ Moreover, the ROK’s space industry environment is difficult for private enterprise due to high costs and limited accessibility to experimental facilities.³⁹ Thus, Lee and Chung argue that the main problem facing the ROK’s space program is the absence of an institute like the U.S. NASA and JAXA of Japan, which have the role of encouraging

³³ U. M. Leloglu and E. Kocaoglan, “Establishing Space Industry in Developing Countries: Opportunities and Difficulties,” *Advances in Space Research* 42, no. 11 (December 01, 2008), 1882.

³⁴ Ibid.

³⁵ Joosung J. Lee and Seungmi Chung, “Space Policy for Late Comer Countries: a Case Study of South Korea,” *Space Policy* 27, no.4 (2011): 227.

³⁶ Ibid.

³⁷ Lee and Chung, “Space Policy for Late Comer Countries,” 230.

³⁸ Ibid.

³⁹ Ibid.

technology transfer and equipment sharing and acting as a moderator for communication between companies.⁴⁰

On the other hand, Chin Young Hwang and Jeongwon Lee, et al. argue the problem is that the ROK government gives immoderate value to hardware products. The authors assert that the ROK has developed mainly hardware-oriented space technologies, such as the satellites and rockets developed by the space technologies on which the ROK government policy concentrated.⁴¹ The Mid- to Long-term National Space Development Plan, which is the most recently announced, supports this assertion. The Plan pronounces its objectives as guaranteed independent space access and continuous development of satellites through the private sector's participation. Even though the Plan mentions a guarantee of competitiveness for space development, such as scientific-technology and manned missions, the ROK has been closed to reopening its astronaut program after its only one female space flight participant visited the International Space Station for 11 days in 2008; there are no more planned astronauts.

In addition, some scholars point out the ROK's meagerness in military space capability and applications. Moltz emphasizes that the trend of space programs in Asia usually has begun with civilian applications first then turned to military use, in contrast to the space superpowers' case.⁴² On this point, Wade Huntley also asserts that smaller powers countries typically pursue opportunities in the realm of civil space collaboration first, and then shift their focus to military space applications.⁴³ Futron, which is a U.S. consulting firm that publishes a Space Competitiveness Index for space-faring nations annually, also indicates "limited military space assets and organization" as one of the

⁴⁰ Ibid.

⁴¹ Hwang, "Space Activities in Korea, 199; Jeongwon Lee, Hyun-jung Jo, and Jae Dong Choi, "The Organizations for Space Education and Outreach Programs in the Republic of Korea," *Acta Astronautica* 69 (2011): 730.

⁴² Moltz, *Asia's Space Race*, 27.

⁴³ Wade L. Huntley, "Smaller State Perspectives on the Future of Space Governance," *Astropolitics* 5, no. 3 (2007), 257.

weaknesses facing the ROK's space program.⁴⁴ But the ROK is on its way to try to acquire independent military capabilities. A plan for five military-purpose surveillance satellites by the early 2020s is ongoing, although realization of the plan is blurred by budgetary problems. Furthermore, Tae-Hyung Kim argues that the ROK's military space plan, led by the ROK Air Force (ROKAF), has not progressed as expected. The author points out the obstacles as

lack of coordination with the civilian authority, bureaucratic wrangling within the military in prioritizing each other's project, budgetary limitations, lack of public awareness and support, and shortage of sound plans due to lack of productive debate.⁴⁵

Daniel A. Pinkston asserts that the ROK has been reluctant to launch its own military satellites despite the fact that the ROK has a major interest in satellite technology for military purpose.⁴⁶ The author quotes an interview with Dr. Park Jin, a member of the ROK National Assembly's National Defense Committee, stating that the reason the ROK is reluctant to move into military applications is that launching independent military reconnaissance satellites is expensive and could harm the ROK-US alliance.⁴⁷

3. SUCCESS IN THE PAST

The ROK's drive toward space industrial power is in many respects comparable to past cases of the ROK government's targeting of specific manufacturing industries. A number of studies deal with the ROK's successful economic development through a

⁴⁴ Futron, *Developing Japanese Space Competitiveness: Perspectives from Futron's 2009 Space Competitiveness Index(SCI)*, Keynote address to Japan's Institute for Unmanned Space Experiment Free Flyer (USEF) Seventh Space Industry Symposium (December 2009), 30.

⁴⁵ Tae-Hyung Kim, "South Korea's Space Policy and Its National Security Implications," *The Korean Journal of Defense Analysis* 22, no. 4 (December 2010): 524.

⁴⁶ Daniel A. Pinkston, "North and South Korean Space Development: Prospects for Cooperation and Conflict," *Astropolitics* 4, no. 2 (2006): 216.

⁴⁷ Ibid.

catch-up strategy and adopting latecomer's incentives in such manufacturing industries as automobiles, semiconductors, and shipbuilding.⁴⁸

First of all, the *Competitive Industrial Performance Report 2014* published by the United Nation Industrial Development Organization (UNIDO) ranks the ROK's competitive industrial performance fourth worldwide, following Germany, Japan, and the United States since 2010.⁴⁹ Its rank has risen gradually from seventeenth in 1990 to sixth in 2005.⁵⁰ The report uses the Competitive Industrial Performance (CIP) index to assess and benchmark the industrial competitiveness of individual countries. Industrial competitiveness is defined as "the capacity of countries to increase their presence in international and domestic markets whilst simultaneously developing industrial sectors and activities with higher value added and technological content"⁵¹ The report insists, given the country's significant number of medium- and high-tech industries, that the ROK's manufacturing sector is competitive.⁵²

The Development Centre Studies of (OECD) analyze the ROK's technological catch-up and skills development in the report, *Industrial Policy and Territorial Development: Lessons from Korea*. According to these studies, the ROK's catch-up strategy has four major elements:

- (1) Multi-annual planning with clear targeted and associated budget, (2) targeted measures to support national industries, including support to domestic firms, development of skills, infrastructure building and import

⁴⁸ Eunhee Sohn, et al., "Technological Catching-up and Latecomer Strategy: A Case Study of the Asian Shipbuilding Industry," *Seoul Journal of Business* 15, no. 2 (Dec 2009); Dong-Sung Cho, et al., "Latecomer Strategies: Evidence from the Semiconductor Industry in Japan and Korea," *Organization Science* 9, no.4(1998); Dong-Ok Lee, et al., "The Korean Automobile Industry - Challenges and Strategies in the Global Market," *Journal of International Marketing* 4, no. 4 (1996), 85; Annalisa Primi et al., *Industrial Policy and Territorial Development: Lessons From Korea* (Paris: OECD Pub., 2012), 35–36.

⁴⁹ UNIDO (2015), *Competitive Industrial Performance Report 2014*, Research, Statistics and Industrial Policy Branch Working Paper of United Nation Industrial Development Organization, Vienna, 12.

⁵⁰ Ibid., 12.

⁵¹ UNIDO, *Competitive Industrial Performance Report 2014*, 2.

⁵² Ibid., 11.

controls, (3) export promotion measures, and (4) management of capital markets.⁵³

Among those elements, the report emphasizes the Five-Year Economic Development Plan which was established by the ROK government consecutive seven times from 1962 to 1992 as a major policy instrument of the ROK's catch-up strategy because the Plans set clear goals and promoted harmonized actions across several domestic capabilities.⁵⁴

Moreover, on the technological catch-up and skills development, the success of the ROK's catch-up strategy has been possible through factors "linking technology policies with industrial policy, rising private investment in R&D, and continuous upgrading of human capital and skills," the authors claim.⁵⁵ First, the ROK made several steps toward technology-intensive activities: learning from foreign practices, creating government research institutes, and investing R&D funds into the private sector, especially the chaebols.⁵⁶ Next, the ROK increased its investment in R&D for the private sector by more than 70% of total R&D expenditures in 2009, while 60% of it was for the government in 1970s.⁵⁷ Finally, the ROK has fostered human capital and skills by programs such as the Brain Korea 21 and efforts to increase the number of researchers and engineers.⁵⁸ To be specific, the OECD Development Centre notes the ROK's automobile and semiconductor industries as successful cases. Its automobile industry started with promotion acts, and then followed typical latecomer's development steps adopting foreign technologies first and producing cars independently later.⁵⁹ Moreover, several institutional efforts, such as import restrictions, an automobile industry promotion

⁵³ Annalisa Primi et al., *Industrial Policy and Territorial Development: Lessons From Korea* (Paris: OECD Pub., 2012), 29.

⁵⁴ Ibid., 30.

⁵⁵ Ibid., 41–53.

⁵⁶ Ibid., 41–42.

⁵⁷ Ibid., 47.

⁵⁸ Ibid., 49–50.

⁵⁹ Ibid., 35.

plan, and private R&D support were made by government.⁶⁰ Meanwhile, its semiconductor industry has had similar support, such as R&D resources, establishment of the Law of the Promotion of the Electronic Industry, and formulation of the Plan of Fostering the Electronics Company.⁶¹ Moreover, the ROK has invested in the semiconductor industry indirectly through establishment of the Semiconductor Design Training Center for the purpose of developing highly skilled human resources.⁶²

D. PROBLEMS AND HYPOTHESES

According to the literature review, the following facts are clear: (1) the ROK has made successful progress in its economic growth through its manufacturing industries, (2) the ROK has a strong will to develop its civil, commercial, and military space programs with a catch-up strategy, (3) even though the ROK is motivated in part by security concerns, its space development has been focused on civil and commercial activities, and (4) the ROK faces a difficult situation caused by internal and external factors.

However, the literature on the ROK's space policies and programs fails to answer the following questions:

- (1) Does the ROK's space industry have the same features or follow the same trajectory as other industries in terms of a catch-up strategy?
- (2) If so, where does the ROK's space development stand?
- (3) If not, what factors make it different?
- (4) How has the ROK invested in military space capability? and
- (5) What strategy should the ROK choose to build a sustainable military space capability?

These questions are important for examining the sustainability of the ROK's space development in an efficient manner in harmony with the country's long-term support capabilities.

⁶⁰ Ibid.

⁶¹ Ibid., 35–36.

⁶² Ibid., 36.

On the other hand, a space industry itself is difficult to compare with other domestic industrial developments directly because of complicated considerations in terms of politics or military. Thus, in order to diagnose military space sustainability of the ROK, it is necessary to use a comparison with cases of other countries' space activities.

The hypotheses about these questions are that

- The ROK's space development has had a trajectory similar to other successful industries, but insufficient efforts have been made in some areas, such as policy direction and R&D investment, especially by the private sector.
- The ROK has promising opportunities in space development due to the strength of its technological competitiveness in niche markets.
- While the ROK has invested in certain, independent military space capabilities, it will be best served – in terms of sustainability – by maintaining a certain level of cooperation and engagement with its major ally, the United States.

E. RESEARCH DESIGN

Two comparative case studies, internal and external cases, will be examined. The internal case studies will consist of the automobile and semiconductor industries, and the external case studies will be of Israel's and Australia's space programs.

As stated before, the ROK's automobile and semiconductor industries are considered as successful cases, through a combination of government policies, R&D support, and promotion of human resources. To compare them with the ROK's space industry, the internal case studies will use following elements (see Table 1).

Table 1. Comparable Elements and Sub-elements for Internal Cases.

Elements	Sub-Elements
Policy	Promotion Act
	Promotion Plan
R&D Investment	Total R&D Budget
	R&D Budget in Private Sector
Human Resources	R&D Performing Institutions and Researchers
	Foundation of Research Institutions

Sources to be used will be information from the Korea Nation Law Information Center, Structural Analysis (STAN) Database from OECD, R&D information from the Korea Institute of Science and Technology Evaluation and Planning (KISTEP), the Ministry of Strategy and Finance, and the Korea Institute for Industrial Economics & Trade.

Israel's and Australia's space programs are significant to analyze the orientation of technology development by comparison with the ROK's case. First, Israel is a smaller country than the ROK in terms of GDP, but it is rated ahead of the ROK in space development. John J. Klein characterizes Israel as a medium space power on the level of Japan and India in a recent article.⁶³ Also, unlike the ROK, Israel's space program was motivated initially by security concerns about the threats posed by neighboring countries. Its space program started in the early 1980s, and focused on military space technologies such as reconnaissance, observation, and communication.⁶⁴ *The Space Report 2013* also emphasizes that military applications have been the main driver of its space activities.⁶⁵ Recently, Israel has increased its civil space funding, published new policies, and tried to

⁶³ John J. Klein, "Space Strategy Considerations for Medium Space Powers," *Astropolitics* 10, no. 2 (2012): 111.

⁶⁴ Deganit Paikowsky, et al., "Israel's Space Strategy," in *Space Strategy in the 21st Century: Theory and Policy*, ed. Eligar Sadah (New York, NY: Routledge, 2013), 322.

⁶⁵ Space Foundation, *The Space Report 2013*, Space Foundation (2013), 52.

invest in the commercial market by producing civilian devices to promote the sustainability of its space program, but its “lack of industry scale continues to limit its commercial space presence, despite a vibrant startup sector,” according to analysis by the Futron Corporation.⁶⁶

On the other hand, Australia has a similar level of national power to the ROK in terms of GDP. However, Australia is in the only three OECD countries that does not have a national space agency. Moreover, Australia has promoted efficient satellite utilization policy through using foreign satellite and sharing data with the owners of these satellites, especially the United States. But this policy is beginning to change to due to the perceived risk of excessive dependence of foreign capabilities. According to *Australia’s Satellite Utilisation Policy* published by Department of Industry, Innovation, Science, Research and Tertiary Education of Australia (DIISRTE), Australia has typically accessed “international space systems in a fragmented fashion, depending on geographic advantages or the goodwill of other nations.”⁶⁷ The policy emphasizes that Australia has recognized its space dependencies recently and has begun to pursue independent operation of satellites for the national interests.

To compare each case, this thesis will use the framework from Danielle Wood and Annalisa Weigel’s work. Table 2, generated by Wood and Weigel and published in one of the leading journal in space sector, *Space Policy*, introduces a framework of the Space Technology Ladder (STL).⁶⁸ The authors analyze the strategic policy choices of developing space countries from Africa, Asia, and Latin America. The study defines national space activity as “investment in areas of satellites and launch vehicles,” and uses the STL, which consists of four categories: launch capability, a satellite in Geostationary

⁶⁶ SatMagazine, “Futron’s 2014 Space Competitiveness Index – An Executive Summary,” (June 2014), 72; “Israel: Israel Uses Military Expertise to Join Commercial Space Race.” *Asia News Monitor*, March 09, 2015.

⁶⁷ Commonwealth of Australia (2013), *Australia’s Satellite Utilisation Policy*, Department of Industry, Innovation, Science, Research and Tertiary Education of Australia, 3.

⁶⁸ Danielle Wood and Annalisa Weigel, “Charting the Evolution of Satellite Programs in Developing Countries – The Space Technology Ladder,” *Space Policy* 28 (2012), 16–17.

Orbit (GEO), a satellite in Low Earth Orbit (LEO), and establishment of a national space agency.⁶⁹

To collect meaningful data, the authors analyze each country's milestones and when they achieved each level of the ladder for the first time. Furthermore, based on the STL achievement by countries, Wood and Weigel discuss their policy decisions, which they divide into three categories: space program capabilities, national context, and international context. In addition, they summarize the policy decision points: their method of acquiring satellites—purchase or manufacture; satellite manufacturing—building payloads or only the bus; the primary purpose of satellite projects; the timing of building local satellite processing facilities; and the decision of investment in local launch capability.⁷⁰ Thus, it is useful to analyze the comparative orientation of the ROK's space technology by using the STL framework.

⁶⁹ Ibid.

⁷⁰ Ibid., 21.

Table 2. The Space Technology Ladder.

The Space Technology Ladder	
13	Launch Capability : Satellite to GEO
12	Launch Capability : Satellite to LEO
11	GEO Satellite : Build Locally
10	GEO Satellite : Build through Mutual International Collaboration
9	GEO Satellite : Build Locally with Outside Assistance
8	GEO Satellite : Procure
7	LEO Satellite : Build Locally
6	LEO Satellite : Build through Mutual International Collaboration
5	LEO Satellite : Build Locally with Outside Assistance
4	LEO Satellite : Build with Support in Partner's Facility
3	LEO Satellite : Procure
2	Space Agency : Establish Current Agency
1	Space Agency : Establish First Nation Space Office

Adapted from Danielle Wood and Annalisa Weigel, "Charting the Evolution of Satellite Programs in Developing Countries – The Space Technology Ladder," *Space Policy* 28 (2012), 16–17.

F. THESIS OVERVIEW

The current chapter will be Chapter I. Chapter II will examine the internal cases, divided into two parts: the automobile and semiconductor industries. Chapter III will describe the ROK's space policies, R&D investment, efforts to foster human resources, international cooperation, and development path. Chapter IV will scrutinize the external cases, also divided into two parts, Israel and Australia. Finally, Chapter V will offer analysis of the ROK's prospects for developing a sustainable space program and make some policy recommendations.

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II. THE INTERNAL CASES

This chapter will examine the ROK's automobile and semiconductor industries in terms of policies, R&D investment, and human resources of each industry in order to compare with and against those of the ROK space industry. To be specific, policies will be studied to figure out their objectives and formulas which were set up under the governmental acts and official plans in order to achieve growth of automobile and semiconductor industries. Next, R&D investment will be examined by budgetary expenditure in R&D fields by the government and private sector. Finally, this chapter will look into human resources of automobile and semiconductor industries by the growth of the number of R&D performing institutions, increasing researchers engaged the institutions, and examination of milestones of research institutions' foundation.

For its internal cases, the thesis analyzes two manufacturing industries, the automobile industry and the semiconductor industry. The industries are representative examples of the ROK's successful economic development through a catch-up strategy and adopting latecomer's incentives, and the OECD Development Centre notes that both of these industries benefited from promotion acts, private R&D support, and the government-leading development of skilled human resources.⁷¹ Moreover, the two industries' positions have high world ranking. According to the Korea Automobile Manufacturers Association (KAMA), the ROK was ranked fifth in an automobile industry among the other nation.⁷² In particular, the growth of exports by ROK's automobile industry from 1998 to 2014 is remarkable. The amount of exports in terms of money has been sextupled during the period; it was \$12.8 billion in 1998 and became \$75.6 billion in 2014.⁷³ Moreover, the ROK produced 4.5 million cars which account for 5.4% of the world market share, exported 3.2 million cars a year as the third largest

⁷¹ Annalisa Primi et al., *Industrial Policy and Territorial Development: Lessons From Korea* (Paris: OECD Pub., 2012), 35.

⁷² Korean Automobile Manufacturers Association, "2013 sutjalo bon jadongcha sanub" 2013 숫자로 본 자동차 산업, [Examination of The Automobile Industry Through Numbers in 2013], 24.

⁷³ ROK National Statistical Office, "Jipyo sangsae: Jadongcha saneub" 지표상세: 자동차 산업 [Detailed Index: Automobile Industry] accessed October 14, 2016. http://www.index.go.kr/potal/stts/idxMain/selectPoSttsIdxSearch.do?idx_cd=1150&clas_div=&idx_sys_cd=518&idx_clas_cd=1

number of exportation in the world, and put five companies, which are Hyundai, Kia, GM Korea, Renault-Samsung, and SSangyong Motors, into the list of a hundred-world-ranking manufacturers in 2013.⁷⁴ On the other hand, Korea Trade-Investment Promotion Agency (KOTRA) analyzes that ROK semiconductor industry is leading the world market in a field of memory manufacture.⁷⁵ The growth of exports by ROK's semiconductor industry from 1998 to 2014 is also outstanding. The amount of export in terms of money has been increased three and half times during the period; it was \$17 billion in 1998 and became \$62.6 billion in 2014.⁷⁶ In addition, the manufacture of D-RAM's share of the world market was 56%, NAND-type flash memory makes up 52.6% in 2009, and international competitiveness of the industry, especially, is the world best class in fields of process capability and yield per unit process.⁷⁷ Moreover, Hyeondai and Lucky-Gumsung Electronics had lead the industry during the early period, and current leading companies in the semiconductor industry are Samsung Electronics and SK Hynix.

For analyses, this thesis uses information from the governmental institutions, such as ROK National Law Information Center and ROK National Archives, and Korea Institute of S&T Evaluation and Planning. A period of analyses for policies and foundation of agency is from the earliest milestone to present; it for R&D investment and the number of researchers and institutions is from 1998 to 2014. Although the early stage's information of R&D investment and the number of researchers would be significant index due to the fact that they reflect efforts by the government and private sector to promote the industry, the information has been impossible to locate the data, , because the R&D information for ROK industries, like automobile, semiconductor, and

⁷⁴ Ibid.

⁷⁵ Korea Trade-Investment Promotion Agency, "Bandochae" 반도체 [Semiconductors], http://www.contactkorea.go.kr/jsp/ko/info/info2_1_2.jsp.

⁷⁶ ROK National Statistical Office, "Jipyo sangsae: Bandochae saneub" 지표상세: 반도체 산업 [Detailed Index: Semiconductor Industry] accessed October 14, 2016. http://www.index.go.kr/potal/stts/idxMain/selectPoSttsIdxSearch.do?idx_cd=1155&clas_div=&idx_sys_cd=518&idx_clas_cd=1.

⁷⁷ Ibid.

air and space, has not been totalized before 1997.⁷⁸ But still, analysis of patterns of variation in the same period of time among the industries is also sufficient to find differences.

A. AUTOMOBILE INDUSTRY

1. Policy

Policy is divided into two parts, promotion act and promotion plan. In order to promote the automobile industry, ROK established the Automobile Industry Protection Act and adopted several Five-year Automobile Industry Plan, such as the first Five-Year Automobile Industry Plan, the Five-year Plan for Localization of Automobile Products. Moreover, the Automobile Industry Basic Promotion Plan, the Automobile Industry Unification Plan, and the Long-term Plan for Promotion of the Automobile Industry were adopted in accordance with the Presidential Orders for Promotion of Automobile Industry.

a. Promotion Act

The first ROK law related with promotion of the automobile industry was legislated and enforced with the title of the Automobile industry Protection Act on May 31, 1962.⁷⁹ It only had ten articles consisting of only 12 sentences, but the provisions were exceedingly commanding. Its objective was to protect and raise ROK automobile industry through ways in which of adjustment of the production cost, import control of cars and its components, and a preferential tariff.⁸⁰ Then Minister of Trade and Industry (currently the Minister of Trade, Industry, and Energy (MOTIE)) had the authority to adjust of the production cost, limit the amount of imported cars and its parts, and lighten

⁷⁸ Korea Institute of S&T Evaluation and Planning, “Report on the Survey of Research and Development in Science and Technology,” ROK Ministry of Science and Technology (1998); Korea Institute for Industrial Economy and Trade, “Chong yungugaebalbee byunhwa” 총연구개발비변화 [Transition of R&D Budget], <http://www.istans.or.kr/su/TimeSeries1.jsp?scode=262&ucode=77&ccode=2#>; OECD ilibrary, “R-D Expenditure by Sector of Performance and Type of R-D(1963-1980),” OECD, http://www.oecd-ilibrary.org/science-and-technology/data/research-and-development-statistics/r-d-expenditure-by-sector-of-performance-and-type-of-r-d-1963-1980_2448a8a8-en; The KISTEP report comprises basis information to make OECD data, and ROK has been a member of OECD since 1996, accordingly, no report was drawn up before 1997.

⁷⁹ Korea National Law Information Center, “Jadongcha gongub bohobeob” 자동차공업보호법 [Automobile Industry Protection Act], <http://www.law.go.kr/lsEfInfoP.do?lsiSeq=627#>

⁸⁰ Ibid.

taxes which assigned to automobile enterprises.⁸¹ The Act, however, had been applied temporarily because its prescribed duration in force was by the end of 1967.⁸²

b. Promotion Plan

(1) The First Five-Year Automobile Industry Plan

The First Five-Year Automobile Industry Plan, which was a concrete plan of the First Five-Year Economic Development Plan created by former President Park Jung-hee, was established on April 17, 1962.⁸³ The contents of the Plan were to support the Automobile Industry Protect Act.

(2) Automobile Industry Unification Plan

The Automobile Industry Unification Plan was promoted in 1963. It sought to reduce expenses of the automobile industry through a guideline of production standards which offer monotonous production of vehicles.⁸⁴ According to the plan, the guideline states three standards. First, a passenger car must be produced as a small-size car which consumes less fuel, regardless of a purpose of the car whether for private use or business use, in order to save foreign currency which is paid for gas.⁸⁵ Next, a middle- to large-size car must be equipped a diesel engine for the saving of fuel, the number of models is restricted in order to standardize the industrial manufacturing process.⁸⁶ Finally, each manufacturing plant is allowed to produce specific components in order to protect and nurture the automobile industry until it become mature.⁸⁷

⁸¹ Ibid.

⁸² Ibid.

⁸³ Korean Presidential Archives, “Jaeilcha kyungjaekaebal ogaenien gaehuik(1962-1966)” 제 1 차 경제개발 5 개년 계획(1962-1966) [The First Five-Year Economic Development Plan(1962-1966)], <http://www.pa.go.kr/research/contents/policy/index020202.jsp>

⁸⁴ ROK National Archives, “Jadongcha sanub yuksung” 자동차산업육성 [Promotion of Automobile Industry], <http://www.archives.go.kr/next/search/listSubjectDescription.do?id=001632>

⁸⁵ Ibid.

⁸⁶ Ibid.

⁸⁷ Ibid.

(3) Five-year Plan for Localization of Automobile Products

The Five-year Plan for Localization of Automobile Products, also known as the Automobile Industry Comprehensive Promotion Plan, was adopted in 1964.⁸⁸ ROK government designated 75 private enterprises to achieve localization of automobile components through interrelationship among each other and carried out economic support policy toward the business.⁸⁹

(4) Automobile Industry Basic Promotion Plan

After the Five-year Plan for Localization of Automobile Products had run out in 1969, the ROK government established the Automobile Industry Basic Promotion Plan to fill up the gap of a plan for localization. On December 1969, the Automobile Industry Basic Promotion Plan was adopted to promote localization for the automobile industry, which is as a link of extended the Five-year Plan for Localization of Automobile Products, because its objectives for localization was hindered due to sluggish results.⁹⁰

(5) Presidential Orders for Promotion of Automobile Industry and Long-term Plan for the Promotion of Automobile Industry

President Park emphasized the significance of an automobile industry because President believed that the automobile industry could lead other industries toward the rapid growth, so he made the orders to foster the industry in 1973. His actual plan can be summarized by four steps; first, achieve localization of automobile manufactures by 1975; second, simplify the types and models of cars; third, separate manufacturing process and assembling process while use existing plants to manufacture and assemble parts; and fourth, prepare the step for exportation of components through making a manufacturing process to meet the world standards.⁹¹ In accordance with the orders, then Ministry of Commerce (now known as MOTIE) implemented the Long-term Plan for the Promotion of Automobile Industry on January 1973 in order to execute the orders by concrete

⁸⁸ Ibid.

⁸⁹ Ibid.

⁹⁰ Ibid.

⁹¹ Ibid.

plan.⁹² One of the most significant objectives of the plan was to accomplish localization-rate as up to 72% by the end of 1973 and 95% by 1975.⁹³

2. R&D Investment

a. Total R&D Budget

The total R&D budgetary expenditure for the automobile industry has been increased steadily over a period of analysis. The increasing trend of the amount of the R&D budget is obvious with reference to the linear line (see a solid line at Figure 1). According to KISTEP, the R&D budget amount for the automobile industry was 1.47 trillion KRW in 1998. The budget was gradually increased, and the amount of the total R&D budget became 5.88 trillion KRW in 2014.⁹⁴ During the past 17 years, the R&D budget is increased by 300%. The rise is notable because GDP of the ROK was increased by 204% from 487 trillion KRW to 1,484 trillion KRW during the same period.⁹⁵

b. R&D Budget in Private Sector

The R&D budget in private sector also has been increased constantly. Moreover, it shares considerably high percentage of the total expenditure. According to KISTEP, the automobile industry's R&D budget by private sector was 1.43 trillion KRW in 1998, and it shared 98% of the total R&D budget at that time.⁹⁶ At the same time, the private sector's R&D budget has been increased untiringly and maintained its share in the total R&D budget (see a dash line at Figure 1). Consequently, the industry's R&D Budget by private sector was 5.7 trillion KRW, and it was 97% of total R&D budget in 2014.⁹⁷

⁹² Ibid.

⁹³ Ibid.

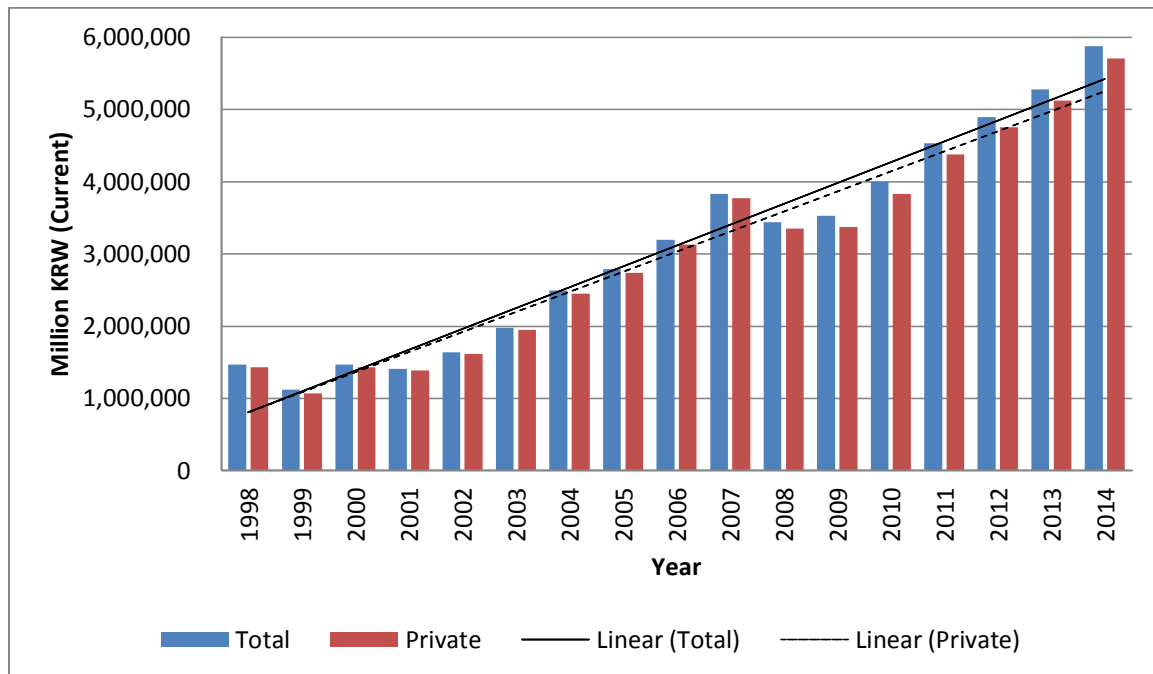
⁹⁴ Korea Institute for Industrial Economy and Trade, "Chong yungugaebalbee byunhwa" 총연구개발비변화 [Transition of R&D Budget], <http://www.istans.or.kr/su/TimeSeries1.jsp?scode=262&ucode=77&cocode=2#>

⁹⁵ Economic Statistics System, "100 Korean Stat." http://ecos.bok.or.kr/jsp/vis/keystat/index_e.html#/detail

⁹⁶ KISTEP, "Report on the Survey of R&D in S&T."

⁹⁷ Ibid.

Figure 1. R&D Budget of Automobile Industry.



Source: Korea Institute of S&T Evaluation and Planning, "Report on the Survey of Research and Development in Science and Technology," ROK Ministry of Science and Technology; synthesis of information from 1998 to 2014.

3. Human Resources

a. R&D Performing Institutions and Researchers

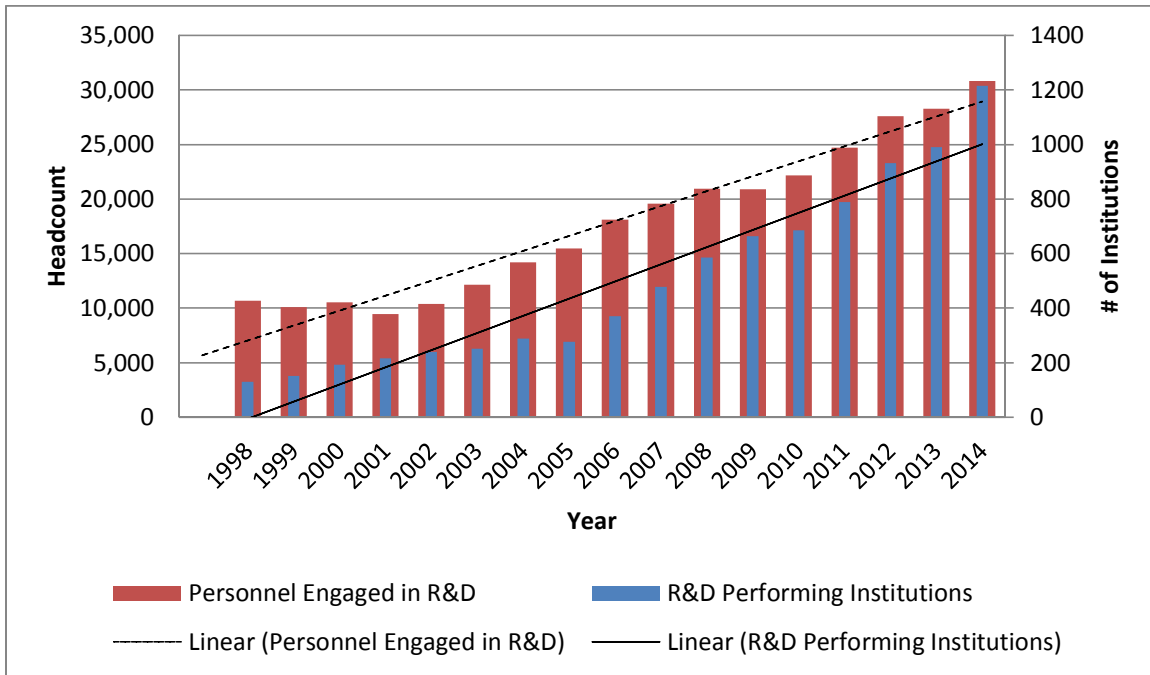
The number of the R&D performing institutions and researchers in the institutions has been raised up increasingly (see a solid line and a dash line at Figure 2). The number of institutions which perform R&D for the automobile industry was 130 in 1998.⁹⁸ Moreover, the headcount of personnel engaged in R&D is 14,693 persons, and researchers were 10,669 persons at that time.⁹⁹ Among those researchers, 221 persons have doctor's degree, 2,264 persons have master's degree, and 6,485 persons have bachelor's degree and were graduated from a university.¹⁰⁰

⁹⁸ Ibid.

⁹⁹ Ibid.

¹⁰⁰ Ibid.

Figure 2. Human Resources of Automobile Industry.



Source: KISTEP, “Report on the Survey of Research and Development in Science and Technology”; synthesis of information from 1998 to 2014.

On the other hand, the number of R&D performing institutions for the industry was increased to 1,215 in 2014, and the number of personnel engaged in R&D was 39,341 persons, and researchers were 30,842 persons.¹⁰¹ Among those researchers, 847 persons have doctor’s degree, 6,626 persons have master’s degree, and 22,233 persons have bachelor’s degree among those researchers.¹⁰²

The increment of the number of R&D performing institutions has been accompanied the increased number of researchers who work at the institutions (see a solid line and a dash line at Figure 2). Two line’s gradients look similar to each other; however, it does not necessarily mean that increasing number of institutions carries augmentation of researchers in terms of quantity. The number of researchers per institution was 82 persons in 1998, but the number of researchers per an institution was decreased to no small extent, 25 persons per institution.

¹⁰¹ Ibid.

¹⁰² Ibid.

b. Foundation of Research Institution

There is no institution established by ROK government for the automobile industry. Instead, several nonprofit corporations, such as the Korea Automotive Technology Institute, which was founded in 1990, and the Korea Automotive Research Institute, are being funded by the government to enhance a level of R&D.¹⁰³

B. SEMICONDUCTOR INDUSTRY

1. Policy

The policies to promote the semiconductor industry are divided into an act and two plans: the Electronics Industry Promotion Act of 1969, the Eight-year Plan for Promotion of Electronics Industry, and the Plan of Fostering the Electronics Company.

a. Promotion Act

The Electronics Industry Promotion Act was established on Jan 28, 1969 for the first time, revised in 1981, ceased and replaced with the Industry Promotion Act in 1986. In 1969, electronics industry was designated as one of the six-basic industries, which were selected by the government to develop technologies and promote economy, so main purposes of the act were to modernize industrial technologies and to contribute economic growth of a nation.¹⁰⁴

The Act stated that the Minister of Trade and Industry (currently MOTIE) publicly announces the Plan of Advance Electronics Industry, which is focused on sub-industries required to develop manufacturing technologies, increase the output of the process, and improve efficiency of the process. Next, the Act announced to raise the Electronics Industry Promotion Fund to promote the industry, and prescribed a government subsidy, like a loan with long-term low interest, to move forward with the Plan.

¹⁰³ Ibid.

¹⁰⁴ Korea National Law Information Center, “Jeonjagongupjinghuengbeob” 전자공업진흥법 [Electronics Industry Promotion Act], <http://www.law.go.kr/lsInfoP.do?lsiSeq=644#0000>

b. Promotion Plan

(1) Eight-year Plan for Promotion of Electronics Industry

The Eight-year Plan for Promotion of Electronics Industry was adopted in 1969 along with the Electronics Industry Promotion Act. Originally, the plan was designed to cover a period of 5 years from 1969 to 1973; however, it had changed its term of matter to 8 years in order to match with a cycle of a national-level plan, the Third Five-year Plan for Economic Fostering, which was planned to be ended in 1976.¹⁰⁵

The three major objectives of the plan were development of prioritized fostering components, achievement of a goal of exports, and localization of manufacturing for components.¹⁰⁶ According to the plan, several institutions were selected to achieve the goal. Among those institutions, the Fine Instruments Center (currently the Korea Testing Laboratory), National Industrial Institute (currently the Korean Agency for Technology and Standards), and Korea Institute of Science and Technology (KIST) were the main spindles to move forward with the plan.¹⁰⁷

(2) Detailed Plan for Fostering Semiconductor Industry

MOTIE established the Detailed Plan for Fostering Semiconductor Industry in 1982. The semiconductor industry was able to be supported by the government in accordance with this plan. In particular, this plan is unique due to the fact that it was the ROK's first plan which targets specific industry to promote its productivity individually.¹⁰⁸ The plan pointed out one of the problems facing ROK semiconductor industry was that enormous investment is needed in the beginning of the industry, so

¹⁰⁵ ROK National Archive, “Jeonja Gongeup Jinghueng Gyehuik” 전자공업진흥계획 [Plan for Promotion of Electronics Industry], <http://www.archives.go.kr/next/search/listSubjectDescription.do?id=001657>

¹⁰⁶ Ibid.

¹⁰⁷ Ibid.

¹⁰⁸ KISTEP, “Kuknae bandochae jangbisanub yuksungul wehan jeongbuui R&D jiwonjeongchek banghyang” 국내반도체 장비산업 육성을 위한 정부의 R&D 지원정책 방향 [Direction of R&D Support Policy by Government for Promotion of Domestic Semiconductor Industry], *KISTEP R&D Focus* 2009–12, no.23 (2009), 15.

private sector shirked investment in the industry due to risk bearing.¹⁰⁹ Accordingly, the plan stated detailed schemes like a fundraising up to 1.4 billion KRW for technical development and cutting down an inland tax and tariffs in order to solve the problem and activate investment by private sector.¹¹⁰

2. R&D Investment

a. Total R&D Budget

The rise of the total R&D budget for the semiconductor industry is outstanding. The total budget expenditure was 0.97 trillion KRW in 1998; it was increased to 16.8 trillion KRW in 2014.¹¹¹ The increased rate is 1,631%. Given the fact that the GDP growth of the ROK during the same period was 204%, the R&D budget for the semiconductor industry was increased more steeply than the one for the automobile industry. In fact, the actual gap of the budget between 1998 and 2014 becomes larger than the numerical value shown at the figure, because KISTEP analyzed the R&D budget with expenditure not only of the semiconductor industry alone but also of the whole Electronics industry including the semiconductor industry until 2007. Moreover, a trend of the growth has been increased regularly throughout the period. (see a solid line at Figure 3). To short, the ROK semiconductor industry's R&D expenditure in 2014 surpassed 16 times than the electronics industry's R&D budget in 1998.

b. R&D Budget in Private Sector

The private sector's R&D budget for the semiconductor industry also has been raised remarkably like the one of the automobile industry, and likewise, its share in the total R&D budget has been vast. According to KISTEP, the R&D budget by private sector was 926 billion KRW in 1998, and it was 95% of total R&D budget at that time.¹¹² In 2014, 16.7 trillion KRW is semiconductor industry's budget for R&D by private sector,

¹⁰⁹ ROK Presidential Archives, "Bandochae gongub yuksung kehuik" 반도체공업 육성계획 [Plan for Fostering Semiconductor Industry], http://www.pa.go.kr/research/contents/policy/index.jsp?sate=PS1_02&tcate=PS1_02_04#wrap

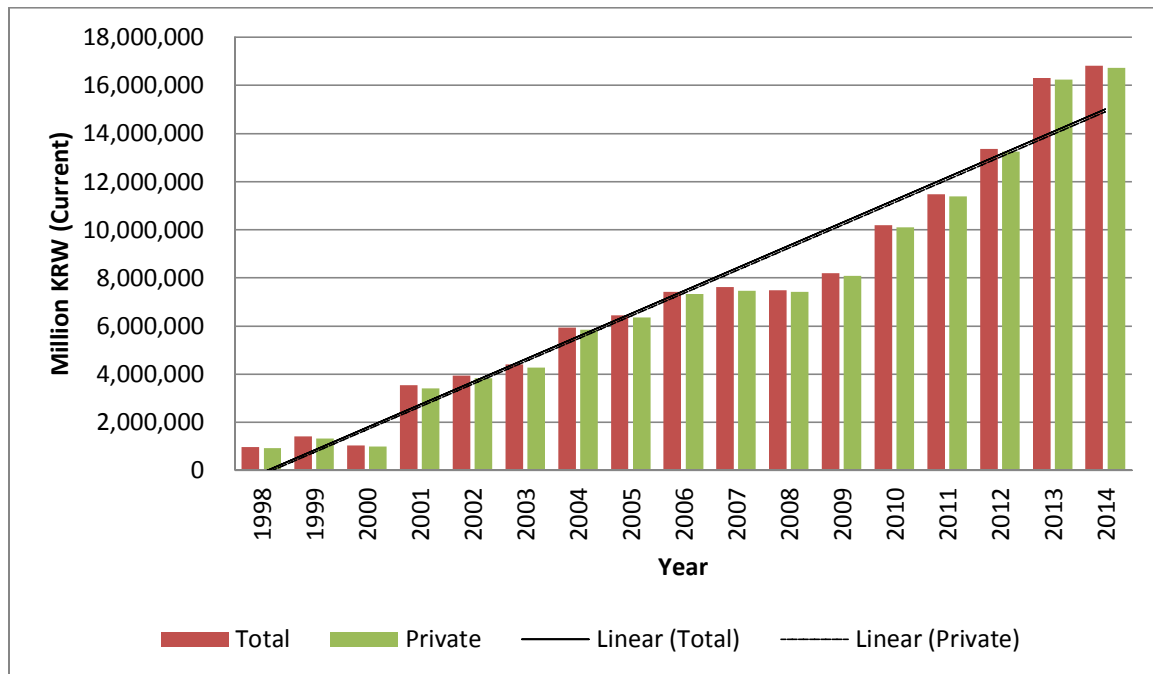
¹¹⁰ Ibid.

¹¹¹ KISTEP, "Report on the Survey of R&D in S&T."

¹¹² Ibid.

and it shared 99% of total R&D budget. Moreover, increasing trend is nearly identical with the trend line of total R&D budget growth (see a dash line at Figure 3). The amount of R&D budget by private sector was 16.7 trillion KRW in 2014 which is almost analogous to the total R&D budget in that year.

Figure 3. R&D Budget of Semiconductor Industry.



Source: KISTEP, “Report on the Survey of Research and Development in Science and Technology”; synthesis of information from 1998 to 2014.

3. Human Resources

a. R&D Performing Institutions and Researchers

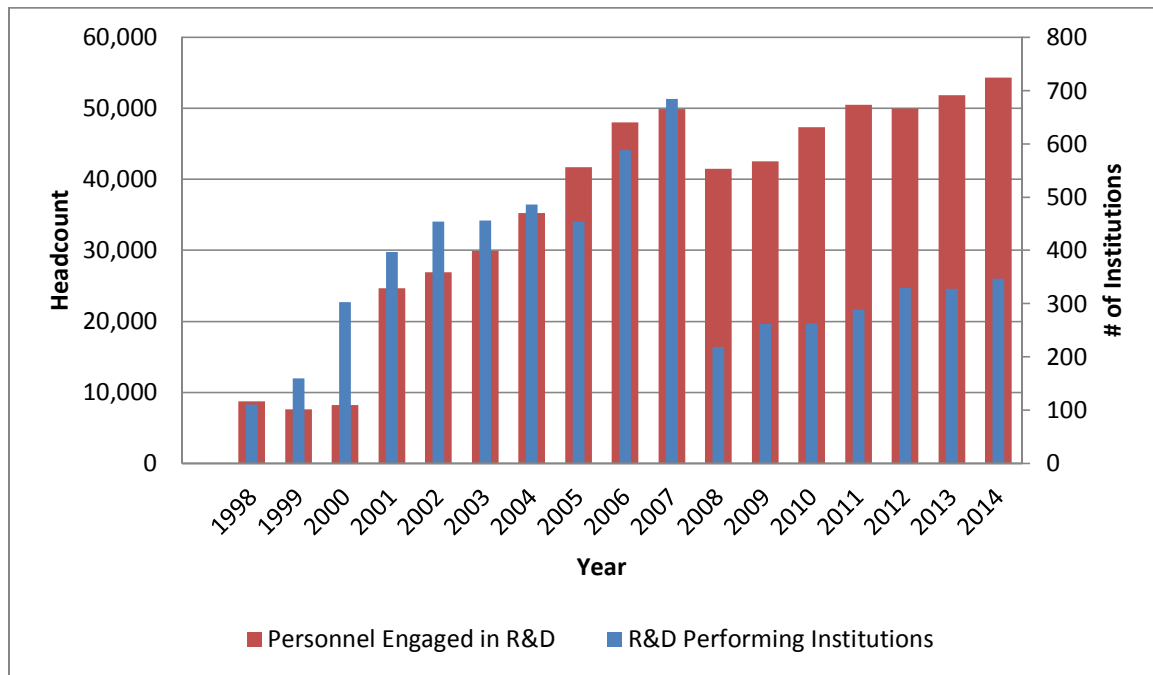
The number of R&D performing institutions for semiconductor industry in 1998 was 111.¹¹³ The headcount of researchers in the institutions were 8,755 persons.¹¹⁴ Among those researchers, 602 persons have doctor’s degree, 2,867 persons have master’s degree, and 4,995 persons have bachelor’s degree and were graduated from a

¹¹³ Ibid.

¹¹⁴ Ibid.

university.¹¹⁵ The number of researchers per one institution was 79 persons. The number of institutions to researchers is charted in Figure 4.

Figure 4. Human Resources in the Semiconductor Industry.



Source: KISTEP, “Report on the Survey of Research and Development in Science and Technology”; synthesis of information from 1998 to 2014; KISTEP had put together information about the electronic components industry and the semiconductors before 2007, and has examined the semiconductor industry only since 2008. Thus, a linear line that shows a trend of variation is pointless in this figure.

In addition, the number of R&D performing institutions in 2014 was 347, and the number of researchers was 54,335 persons.¹¹⁶ Among those researchers, 5,504 persons have doctor’s degree, 14,059 persons have master’s degree, and 30,642 persons have bachelor’s degree and were graduated from a university.¹¹⁷ The number of researchers per one institution was 156 persons. A linear is pointless in this analysis due to a rapid decrease between 2007 and 2008, because KISTEP put data about the electronics

¹¹⁵ Ibid.

¹¹⁶ Ibid.

¹¹⁷ Ibid.

components companies and the semiconductor companies together before 2007 and split them into distinct subjects of analysis from 2008.

b. *Foundation of Research Institution*

The National Industrial Institute (currently the Korean Agency for Technology and Standards) and Korea Institute of Science and Technology (KIST) were the major institutions to achieve the objectives of several plans for promotion.¹¹⁸ Moreover, the Korea Electronics Industry Cooperative, Association of Exportation of Electronics Products, and the Fine Instruments Center (currently the Korea Testing Laboratory) were founded in the late 1960s; however, no institution was established just for the sake of development of semiconductor's technologies.¹¹⁹

C. CONCLUSION

The ROK's two successful industries, the automobile and the semiconductor, have followed typical latecomer's development steps to develop skills and achieve technological catch-up. First, each industry's policy, which consists of promotion acts and plans for promotion, set clear goals and targeted measure to support the industries. The major points of the objectives were to protect the industries until they become mature and to promote the industries through ways of localization, standardization, enhancement of efficiency of manufacturing process. In particular, these efforts for promotion were encouraged by presenting exact number of targeted level and date. Moreover, ROK government has stimulated investment by private sector through a plan for domestic firm supporting like fundraising, import control, encouragement of exports, and preferential tariffs.

Next, the industries have three features in R&D investment. First, R&D budgetary expenditure for the industries has been increased steadily throughout a period of analysis.

¹¹⁸ ROK National Archive, "Jeonja Gongeup Jinghueng Gyeuik' 전자공업진흥계획 [Plan for Promotion of Electronics Industry], <http://www.archives.go.kr/next/search/listSubjectDescription.do?id=001657>

¹¹⁹ Suengryong Kim, "Jeonja jinheung bokoseo" 전자진흥 보고서 [A Report for Promotion of Electronics], *Digital Times*, October 10, 2010. http://www.dt.co.kr/contents.html?article_no=2010111102010532614001

Both of the industries have increased R&D budgets more than increases of GDP, and the growth rates are also regular. In addition, shares of private sector's investment in R&D budgetary have been steady and heavy. Showing at the figures, linear trend lines express that the growth of the total budget has increased along with private sector's R&D budget. Moreover, rate of shares has been over 90% for the most of the period and some case shows even 99%.

Finally, human resources of each industry also have been increased persistently in terms of the number of R&D performing institutions and researchers who engage R&D. Even though headcount of researchers per an institution was decreased, total number of researchers was considerably increased due to increment of the number of institutions performing R&D.

Yet, unlike analysis by the Development Centre Studies of the OECD, establishment of a government-led institution is not featured in the ROK's automobile industry and the semiconductor industries. Some R&D activity has been performed through some institutions; however, those institutions were not founded for the sake of developing specific industries' technologies and skills.

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III. ROK SPACE PROGRAM

This chapter will examine the path of development followed by the ROK space industry by looking into its policies, R&D investment, and human resources. Prior to analyzing these factors, the chapter summarizes the historical development of the ROK space program in order to create a ROK Space Technology Ladder (STL). The ROK's STL will be then compared with the external cases in Chapter IV. Although Wood and Weigel analyzed the ROK STL along with the other countries in their article, "Charting the Evolution of Satellite Programs in Developing Countries—The Space Technology Ladder," this chapter will elaborate some points of Wood's and Weigel's study and focus on the ROK case only. Moreover, ROK investment in military space capability, which was not dealt with in the article by Wood and Weigel, will be examined for the sake of drawing implications for the ROK's space program.

Next, to compare with the internal cases, the automobile and semiconductor industries, the chapter will employ the same methods by which the internal cases of the automobile and semiconductor industries were examined. First, policies which were adopted for the space industry will be discussed in terms of the objectives and structures that were set up under the governmental acts and official plans in order to achieve growth of the air and space industry. Next, R&D investment will be studied by budgetary expenditures in R&D fields by the government and private sector. Finally, human resources will be analyzed through examination of milestones related to the foundation of research institutions and changes in the number of R&D performing institutions and researchers engaged in these institutions.

Finally, the current status of the ROK's space industry will be deduced by contrast and comparison with that of the automobile industry and the semiconductor industry. Questions pursued include whether the space industry has enjoyed the same features and follows the same trajectory, and what factors create differences.

A. HISTORICAL SPACE ACTIVITIES

1. Space Agency

Korea Aerospace Research Institute (KARI) takes full charge for national space research of the ROK. Guangrae Cho, the president of KARI, explains the purpose of KARI is “contributing to solid development of the national economy and enhancement of national life through a new exploration and technological advancements, development, and dissemination in the field of aerospace science and technology.”¹²⁰ Moreover, he clarifies that KARI was founded in 1989.¹²¹ Even though KARI established as an independent institution in 1996, it recognizes an Aerospace Center, which was founded in 1989, as a predecessor. The Aerospace Center was established on October 10, 1989, as an affiliate of the Korea Institute of Machinery and Materials (KIMM). The ROK government had had an interest in advanced technology industries, such as nanotechnology and biotechnology, since the 1980s, and aerospace technology was also one of the industries which the ROK had watched with keen interest.¹²² ROK’s genuine efforts toward fostering an aerospace industry were codified in legislation called the Aerospace Industry Act of 1987, and the Aerospace Center under the KIMM was established as the first and the only one aerospace-specialized research institute at Daedeok Research Complex in Daejeon city.¹²³ Furthermore, the Aerospace Center became a member of International Aeronautical Federation in 1992.

On November 22, 1996, KARI became independent from KIMM and established as an incorporated foundation, which is owned by the government. KARI’s research activities are divided into aeronautics including fixed-wing aircraft and rotorcraft, satellites, space launch vehicles, utilization of satellite images, and satellite navigation.¹²⁴ Accordingly, the organization consists of an Aeronautics R&D Office, a Satellite R&D

¹²⁰ “Greeting Address,” KARI. http://www.kari.re.kr/eng/sub01_01.do.

¹²¹ Ibid.

¹²² ROK National Archives, “Hankook hanggong wooju yeonguso” 한국항공우주연구소 [Korea Aerospace Research Institute]

¹²³ Ibid.

¹²⁴ KARI, “R&D.” http://www.kari.re.kr/eng/sub03_01.do.

Office, the NARO Space Center in charge of space launch vehicles, a Convergence Technology Research Office, and a Satellite Information Center.

2. Satellite

The ROK's satellite programs are divided into four categories: the Science and Technology Satellite (STSAT), the KOREASAT, the Korea Multi-purpose Satellite (KOMPSAT), and the GEO KOMPSAT. In each category, the first satellites produced, some of the second satellites, and all *KOREASATs*, were developed in cooperation with foreign institutes or enterprises, while the others were developed independently. Furthermore, the development of satellites assumes an aspect of increased commercial participation in the satellite program recently.

a. *KITSAT and Science and Technology Satellite (STSAT)*

The satellite development in the ROK was initiated by KAIST.¹²⁵ KAIST manufactured *KITSAT-1* (ROK name *Uribyul-1*) in collaboration program with the University of Surrey, UK.¹²⁶ *KITSAT-1* was launched on 11 August 1992, by the Ariane rocket from Kourou, French Guiana.¹²⁷ After that, *KITSAT-2* (*Uribyul-2*) and -3 were developed independently by the SatReC Initiative.¹²⁸ The ROK launched *KITSAT-2* in 1993 and *KITSAT-3* in 1999.

The STSAT is for scientific experimentation, education of students, and testing next generation technology. In October 1998, the STSAT development was started based on technology acquired through the *KITSAT* series.¹²⁹ Its development took place through cooperation among KARI, the University of California at Berkeley, and the

¹²⁵ Moltz, *Asia's Space Race*, 141; "About SI," Satrec Initiative. <https://www.satreci.com/aboutsi/?anchor=a01&/>; on this, Hwang states in his article that *KITSAT-1* development was initiated by the Satrec Initiative; however, the Satrec Initiative was founded by former KAIST engineers as a private manufacturer in 1999. It seems he mentioned the Satrec Initiative as a sub-organization that was already founded under KAIST since the satellite program was started; Hwang, "Space Activities in Korea," 196.

¹²⁶ Moltz, *Asia's Space Race*, 141–2.

¹²⁷ KARI, "Planning of Mid- and Long-term National Space Development Plan," 27.

¹²⁸ Hwang, "Space Activities in Korea," 197; Hwang also considers the Satrec Initiative the same entity as KAIST here.

¹²⁹ KARI, "Planning of Mid- and Long-term National Space Development Plan," 29.

University of South Australia.¹³⁰ *STSAT-1* was launched in Russia by Cosmos-3M rocket in 2003.¹³¹ *STSAT-2* development started by SatRec Initiative in 2002, and it was launched successfully by the KSLV-I, the first Korean space launch vehicle, in 2013.¹³² Yet it was the third attempt to launch *STSAT-2* by the KSLV-I. The first attempt was in 2009, and the second one was in 2010, but both of those efforts failed to put the satellite into orbit.¹³³ The original mission of *STSAT-2* was monitoring the Earth and its atmosphere with its dual-channel radiometers.¹³⁴

STSAT-3 was developed by KARI and SatRec Initiative for observation of space and the Earth with its primary payload: a near-infrared camera and a secondary payload, a micro image-spectrometer.¹³⁵

b. KOREASAT (*Mugunghwa*)

KOREASAT, also known as *Mugunghwa* is the ROK's communications satellites. *Mugunghwa* is a name of flower that is a national symbol of the ROK. Since *KOREASAT-1* was launched in August 5, 1995, five *KOREASATs*, -1, -2, -3, -5, and -6, have been boosted in GEO. In addition, *KOREASAT-5A* is being planned to take a back-up role for *KOREASAT-5*. All of the satellites were produced by foreign companies, such as U.S. Lockheed Martin, French Alcatel-Lucent or Thales Alenia Space, launched by U.S. Delta II rocket from Cape Canaveral Air Force Base, the U.S., Ariane launcher from Guiana Space Center, or Russian Zenit rocket. The satellites are operated by KT Corporation only for a purpose of public communications except *KOREASAT-5* which

¹³⁰ Ibid.

¹³¹ Ibid.

¹³² Ibid.

¹³³ Ibid.

¹³⁴ Hwang, "Space Activities in Korea," 197.

¹³⁵ KARI, "Planning of Mid- and Long-term National Space Development Plan," 30.

equipped Ka-band for military communications.¹³⁶ *KOREASAT-5* was launched in August 22, 2006.

c. Korea Multi-Purpose Satellite (KOMPSAT)

The Korea Multi-Purpose Satellite (KOMPSAT) orbits in LEO and observes the Earth, oceans, and scientific phenomena. The *Arirang-1*'s development began in 1994, and KARI announced that *Arirang-1* was jointly developed with a U.S. company, TRW, as the ROK had no experience in developing multi-purpose satellites at that time.¹³⁷ *Arirang-1* was launched in 1999. The experience of developing of *Arirang-1* was a stepping stone for the ROK to develop satellites of the future. Based on this experience, *Arirang-2* was produced by “a rate of self-sufficiency of 91.5% in satellite design and 65.2% in the fabrication of the satellite parts,” which was completed in cooperation with a German Astrium and an Israeli Elbit.¹³⁸

Since then, the ROK has been able to develop satellites almost independently, except for some parts. *Arirang-3*, capable of 70-cm-resolution optical observations, *Arirang-5*, equipped all-weather Synthetic Aperture Radar (SAR), and *Arirang-3A*, capable of 55-cm-resolution optical and IR observations were developed and launched successfully.¹³⁹ Especially, *Arirang-3A* was produced by the Korea Aerospace Industry (KAI) and Korean Air, so it contributed to localization of satellite manufacturing.¹⁴⁰ *Arirang-6* will be equipped with SAR for all-weather earth observations and is scheduled for launch in 2019.¹⁴¹

¹³⁶ KARI, “Mugunghwa 5ho Sunggongrie Balsa” 무궁화 5 호 성공리에 발사 [Mugunghwa-5 Launched Successfully], accessed November 13, 2016. http://www.kari.re.kr/cop/bbs/BBSMSTR_000000000065/selectBoardArticle.do;jsessionid=7854F7980FBFFBC2EBB97BA21319892B?nttId=2693&kind=&mno=sitemap_02&pageIndex=35&searchCnd=&searchWrd=.

¹³⁷ KARI, “Korea Multi-Purpose Satellite (*Arirang*),” accessed March 8, 2016, http://www.kari.re.kr/eng/sub03_02_01.do; Moltz, *Asia's Space Race*, 144.

¹³⁸ KARI, “Korea Multi-Purpose Satellite (*Arirang*)”; Moltz, *Asia's Space Race*, 144.

¹³⁹ KARI, “Korea Multi-Purpose Satellite (*Arirang*)”

¹⁴⁰ KARI, “Planning of Mid- and Long-term National Space Development Plan,” 35.

¹⁴¹ KARI, “Korea Multi-Purpose Satellite (*Arirang*).”

d. GEO KOMPSAT

The ROK has also developed Geostationary Orbit Satellite, the *GEO KOMPSAT-1*, also known as *Cheollian-1*, for the purpose of carrying out communications, ocean monitoring, and weather observation.¹⁴² This multifunctional satellite is the world's first ocean observing GEO satellite in real time, and the ROK became the seventh country to have its own weather satellite; it was developed by domestic institutes in cooperation with EADS Astrium and launched successfully by an Ariane 5 rocket in 2010.¹⁴³

In addition to *Cheollian-1*, two more GEO KOMPSATs are being developed. The *GEO KOMPSAT-2A* is for weather observations and is going to replace the role of the *GEO KOMPSAT-1*, and *GEO KOMPSAT-2B*'s purpose is ocean and environmental observations.¹⁴⁴ These satellites are scheduled for launch in 2018 and 2019, respectively.¹⁴⁵

3. Space Launch Vehicle

The ROK's rocket development program was started first as a research program for a weapons system rather than for space capability. The first modern rockets were developed by National Institute for Defense Science Technology in 1958.¹⁴⁶ The institute was, however, dissolved in 1961, so the ROK's rocket program was interrupted.¹⁴⁷ Moreover, the ROK attempted to possess its own surface to surface missiles in the late 1970s. The ROK tried to switch a purpose of Nike-Hercules air-defense missiles, which were provided by the United States to surface to surface missiles; however, this attempt made the United States to be concerned about security destabilization in the Korean peninsula.¹⁴⁸ Accordingly, missile development of the ROK has been restricted within

¹⁴² KARI, "Geostationary Earth Orbit (GEO) Satellite," accessed March 8, 2016, http://www.kari.re.kr/eng/sub03_02_02.do.

¹⁴³ Ibid.; KARI, "Planning of Mid- and Long-term National Space Development Plan," 36–7.

¹⁴⁴ KARI, "Geostationary Earth Orbit (GEO) Satellite."

¹⁴⁵ Ibid.

¹⁴⁶ KARI, "Planning of Mid- and Long-term National Space Development Plan," 16.

¹⁴⁷ Ibid.

¹⁴⁸ Moltz, *Asia's Space Race*, 140.

the range of 180km.¹⁴⁹ Afterwards, some universities tried to continue to develop rockets, but only KARI began full-scale launcher development in the late 1980s.¹⁵⁰ KARI's rocket programs are divided into three categories: the Korea Sounding Rocket, the First Korean Space Launch Vehicle (KSLV-I), which is also known as Narocho, and Korea Space Launch Vehicle (KSLV-II).

a. *Korea Sounding Rocket (KSR)*

KARI has developed three KSRs since 1990. The KSR-I was launched in 1993 with a solid fuel engine and a payload of less than 200 kg.¹⁵¹ After five years of development from 1993, two KSR-II's were launched consecutively in 1997 and 1998. It also had a solid fuel engine and its payload was 150 kg.¹⁵² The KSR-III was the first liquid propellant rocket, developed from 1997 to 2002.¹⁵³ Solid fuel engines for the KSR-I and KSR-II had advantages of short launching preparation time and preservation of fuel, but the ROK promoted liquid propellant rocket development due to such regulations as the Missile Technology Control Regime (MTCR) spell out, which banned development of solid fuel engines.¹⁵⁴ The KSR-III was launched in 2002, and its technology contributed to the KSLV-I.

b. *First Korean Space Launch Vehicle, Narocho (KSLV-I)*

The KSLV-I was developed through international cooperation; Russia was selected as a partner because of a lack of other international willingness to cooperate with the ROK's in space launch vehicle program. KARI said that "Russia was the only advanced country in the field of space launch vehicles that was willing to cooperate, and had the intention to commercialize Korea's launch vehicle technology."¹⁵⁵ According to

¹⁴⁹ Ibid.

¹⁵⁰ KARI, "Planning of Mid- and Long-term National Space Development Plan," 16.

¹⁵¹ KARI, "Scientific Rocket," accessed March 10, 2016, http://www.kari.re.kr/eng/sub03_03_03.do.

¹⁵² Ibid.

¹⁵³ Ibid.

¹⁵⁴ KARI, "Planning of Mid- and Long-term National Space Development Plan," 20.

¹⁵⁵ KARI, "First Korean Space Launch Vehicle Narocho (KSLV-I)," accessed March 10, 2016, http://www.kari.re.kr/eng/sub03_03_02.do.

the contract with Russia, the first stage of KSLV-I, which had a liquid propellant rocket, was developed by Khrunichev State Research and Production Space Center, and the second stage, which had a solid fuel rocket, was carried out by KARI.¹⁵⁶ Launching of the KSLV-I succeeded on its third attempt in 2013.

c. *Korea Space Launch Vehicle (KSLV-II)*

The KSLV-II's development program consists of three phases that will take 10 years; the program aims to launch the KSLV-II, which will be built locally, twice in 2020.¹⁵⁷ Its goal is to put a 1500 kg satellite into LEO at 600–800 km, and the program will use a three-stage liquid propellant rocket (four clustered liquid rocket engines, a 75-ton liquid rocket engine, and a 7-ton liquid rocket engine).¹⁵⁸

d. *Naro Space Center*

The Naro Space Center is the first and the only satellite launch site in the ROK. According to the KARI, its construction was started in 2000 in accordance with the Mid-to Long-Term Basic Plan for Space Development of 1996.¹⁵⁹

The Center consists of “a launch complex, a satellite integration and test center, a launch vehicle assembly building, a solid rocket motor building, a launch control building, an optical equipment building, and the Space Education/PR Center,” and a propulsion test facility was constructed in the Center for a purpose of development of KSLV-II in 2013.¹⁶⁰

4. *Military Capability*

Despite continued threats by its main enemy, North Korea, since the Korean War, the ROK has had little space capability. One of the most influential factors for the present

¹⁵⁶ Ibid.; KARI, “Planning of Mid- and Long-term National Space Development Plan,” 22.

¹⁵⁷ KARI, “Korean Space Launch Vehicle KSLV-II.”

¹⁵⁸ Ibid.

¹⁵⁹ KARI, “Naro Space Center,” accessed November 14, 2016, http://www.kari.re.kr/eng/sub03_03_04.do.

¹⁶⁰ Ibid.

status is the ROK's dependence on the U.S. defense alliance. The ROK military has used communicational, meteorological, and geographical information provided by the U.S. military, and the worth of the information is hard to measure in money. Launching *KOMPSAT-3* in 2012 was useful to some extent in getting rid of a gap in ROK intelligence capabilities; however, North Korea's threats through its missiles and nuclear weapons are still above the ROK's ability to respond to and defend against, so the ROK still relies on U.S. intelligence assets.¹⁶¹

On the other hand, the ROK's efforts to develop independent intelligence capability through infrastructure and assets are ongoing. The ROKAF opened a Space Intelligence Center in order to receive real-time information of satellite maneuvers from the U.S. and share it with domestic institutes.¹⁶² In addition, this is the first national-level center based on an MOU signed between the Ministry of National Defense and the Pentagon on September 2014.¹⁶³ On the other hand, the introduction of space assets is in progress under the name of the 425 Project. The 425 Project is a plan to launch one SAR-equipped satellite into GEO and four EO/IR surveillance satellites which have 0.3 to 0.5 m resolution capability into LEO with a 1 trillion KRW budget by 2022. These satellites will be developed independently and manufactured locally. The SAR satellite will be developed by the Agency for Defense Development (ADD), the EO/IR satellites are under KARI's responsibility, and KAI and SatReC Initiative are expected to serve as production companies, while the ROK will purchase a foreign launch service for these satellites.¹⁶⁴ Furthermore, ROK military seeks to have autonomous intelligence assets based on space capability, which allow the ROK to keep surveillance and reconnaissance of Korean peninsula 24/7. The ROK military claims that space assets are essential to minimize Kill-Chain cycle for detection and preemptive strikes and build the Korean Air

¹⁶¹ "South Korea to Deploy Military Spy Satellites Amid 'Threats' from North," *BBC Monitoring Asia Pacific* (February 6, 2013).

¹⁶² "Air Force Opens Space Intelligence Center," *The Korea Times*, July 8, 2015.

¹⁶³ "DOD Agrees to Share Space Data with South Korea," *U.S. DOD News*, September 4, 2014, <http://www.defense.gov/News/Article/Article/603194>

¹⁶⁴ "Gun jeongchal wuisung dat olryutda" 군 정찰위성 닷 올렸다 [Weigh Anchor for Military Surveillance Satellites], *Yonhapnews*, August 8, 2016; "SatReCI, KAI suju kyoungjaeng" 썬트렉아이, KAI 수주경쟁 [Competition Between SatReCI and KAI], *Edailynews*, August 8, 2016.

and Missile Defense (KAMD) and the Korea Massive Punishment and Retaliation (KMPR) against nuclear and missile threats by North Korea.¹⁶⁵

B. BACKGROUND ON THE ROK SPACE INDUSTRY

1. Policy

The ROK's space policies have consisted of two acts and five plans: the Aerospace Industry Development Promotion Act of 1987; the Space Development Promotion Act of 2005; the Mid- to Long-Term Basic Plan for Space Development of 1996; the Space Development Promotion Act of 2005; the First Basic Plan to Promote Space Development of 2007; the Second Basic Plan to Promote Space Development of 2011; and the Mid- to Long-Term Space Development Plan of 2013.

a. Promotion Acts

Over time, the ROK's priorities for promotion of an aerospace industry have shifted their focus from the airplane industry to the space industry. The Aerospace Industry Development Promotion Act of 1987 aimed to contribute to national economic development by promoting the aerospace industry and aerospace science and technology.¹⁶⁶ But, the ROK could not afford space science and industry at that time. Although the Mid- to Long-Term Basic Plan for Space Development was established in 1996, there was no laws related space development only. The Space Development Promotion Act of 2005, however, was established "to facilitate the peaceful use and scientific exploration of outer space and to contribute to national security, the sound growth of the national economy, and the betterment of life of citizens through the systematic promotion of the development of outer space and the efficient use and management of space objects."¹⁶⁷

¹⁶⁵ Ji-Hye Jun, "3 Military Systems to Counter N. Korea: Kill Chain, KAMD, KMPR," *Korea Times*, November 1, 2016.

¹⁶⁶ Korea National Law Information Center, "Aerospace Industry Development Promotion Act," last modified January 28, 2015, <http://www.law.go.kr/법령/항공우주산업개발촉진법>.

¹⁶⁷ Korea National Law Information Center, "Space Development Promotion Act," last modified January 20, 2015, <http://www.law.go.kr/법령/우주개발%20진흥법>.

(1) Aerospace Industry Development Promotion Act

The ROK's first act legislated in the air and space field was the Aerospace Industry Development Promotion Act (hereafter referred to as Aerospace Industry Act) in December 1987, although it focuses on the aircraft industry only.¹⁶⁸ The purpose of this Act was "to contribute to the sound development of the national economy and the improvement of people's lives by supporting and promoting rationally the aerospace industry, and researching and developing efficiently aerospace science and technology."¹⁶⁹ Given the purpose of this act, the ROK aimed to develop science, and technology for the aerospace industry, including "producing aircraft, spacecraft, related accessory apparatus, or related materials."¹⁷⁰

The starting point of this act was necessarily the government. Yet the government is not necessarily the only customer of the aerospace industry. Article 3 of this act, establishment of a plan for an aerospace industry development fund, includes the following requirements: demand by year and category for aircraft, spacecraft, other vehicles, and materials to be purchased by the Government; specialization and systematization of the aerospace industry; establishment of a comprehensive research system and budget for research and the development in aerospace science and technology; and a plan for participation in international joint development projects and technology introduction.¹⁷¹

In 2007, the article was amended with clauses on matters concerning

goals and direction for the development of the aerospace industry; implementation structures and strategies for the development of the aerospace industry; plans for the development of the aerospace industry; a comprehensive research system for research and development of aerospace science and technologies and research and development budgets; fund raising necessary for the development of the aerospace industry and investment plans; fostering of professional human resources

¹⁶⁸ Korea National Law Information Center, "Aerospace Industry Development Promotion Act," last modified January 28, 2015, <http://www.law.go.kr/법령/항공우주산업개발촉진법>.

¹⁶⁹ *Ibid.*, enforcement date January 21, 2014.

¹⁷⁰ *Ibid.*

¹⁷¹ *Ibid.*

necessary for the development of the aerospace industry; international cooperation to revitalize the development of the aerospace industry; and creation of a specialized complex for the aerospace industry.¹⁷²

The article reflected solely the demand of government-centered industry at the initial time of the legislation; however, it latter shifted to and reflected to a greater degree of civil- and commercial-centered demand.

According to Article 3, the ROK government was to establish a basic plan for the aerospace industry development. The basic plan for the aerospace industry, however, was almost solely focused on the aircraft industry, as opposed to the space industry. The Aerospace Industry Development Policy Council was established under the jurisdiction of the Ministry of Trade, Industry, and Energy (MOTIE) “to deliberate on matters concerning the establishment of the basic plan and the coordination of accompanying important policies of the Government and main affairs among Ministries,”¹⁷³ according to Article 14 of the act. The first council was held in 3 July 1997 to establish the basic plan. The main agenda items were a mid-size aircraft development plan laid by the MOTIE and the Korean Advanced Training Jet development plan laid out by the Ministry of National Defense.¹⁷⁴

(2) Space Development Promotion Act

The Space Development Promotion Act (hereafter referred to as the Space Development Act) legislated in 2005 was a basic plan for space, more so than the Aerospace Industry Act. The purpose of this act was “to facilitate the peaceful use and scientific exploration of outer space and to contribute to national security, the sound growth of the national economy, and the betterment of citizen’s lives by systematically

¹⁷² Ibid.

¹⁷³ Ibid.

¹⁷⁴ Korea Development Institute, “Hanggongwoojusanub jeongcheksimuihui gaechoi” 항공우주산업 정책심의회 개최 [Opening of a Council for the Air and Space Industry’s Policy], last modified July 4, 1997, http://www.kdi.re.kr/policy/ep_view.jsp?idx=9104.

promoting the development of outer space and by efficiently using and managing space objects.”¹⁷⁵ It contained the following articles:

- a. Formulation of a Basic Plan for the Promotion of Space Development
- b. Designation of an Institution Specializing in Space Development
- c. Domestic Registration of Space Objects
- d. International Registration of Space Objects
- e. Liability for Damages Caused by Space Accidents
- f. Formulation of a Basic Plan for Preparing against Dangers in Space
- g. Designation of a Space Environment Surveillance Agency
- h. Composition of a Space Accident Investigation Committee
- i. Dissemination and Use of Satellite Information

b. *Promotion Plans*

The objective of the ROK’s space plan have evolved from generalized to specific, maintaining their purpose to acquire independent technological capabilities for space development. One of the goals has been “to join the top 10 countries in the space industry by competing in the global market.”¹⁷⁶ Subsequently, its goals have concerned the expansion of infrastructure, financing and investment plans, research and development, international cooperation, management of space objects, extension of civil participation, and high-quality human resources.¹⁷⁷

¹⁷⁵ Korea National Law Information Center, “Space Development Promotion Act,” last modified January 20, 2015, <http://www.law.go.kr/법령/우주개발%20진흥법>.

¹⁷⁶ KARI, “Planning of Mid- and Long-term National Space Development Plan,” Korea Ministry of Science, ICT and Future Planning, last modified December 10, 2013, 186.

¹⁷⁷ Korea Ministry of Science, ICT and Future Planning, “Second Basic Plan to Promote Space Development,” accessed March 5, 2016, 12; Korea Ministry of Science, ICT and Future Planning, “Mid to Long Term Space Development Plan,” accessed March 9, 2016, 11.

(1) Mid- to Long-Term Basic Plan for Space Development

The first genuine national space development plan was the Mid- to Long-Term Basic Plan for Space Development of 1996. The Mid- to Long-Term Basic Plan for Space Development was deliberated by the National Science & Technology Commission, which was founded under the Ministry of Science and Technology (MOST, the current Ministry of Science, ICT, and Future Planning). The plan incorporated a space development plan for 1996 to 2015, including the development of 19 satellites, a scientific rocket, and a space launch vehicle by 2015.¹⁷⁸ This Basic Plan was amended three times in 1998, 2000, and 2005. In the 2005 version, the plan divided the period into the Mid-Term (2006-2010) and the Long-Term (2011-2015).

The Long-Term plan's goals were "to acquire the independent technological capabilities for space development and to join the top 10 countries in the space industry by competing in the global market."¹⁷⁹ In addition to the Long-Term plan, the Mid-Term plan's goals were more specific: acquiring micro-satellite launch capability by 2007 and independent development of a LEO multipurpose satellite.¹⁸⁰

(2) First Basic Plan to Promote Space Development

According to Article 5 of the Space Development Act, the ROK government is supposed to write a basic plan for space development promotion every five years, and the basic plan should include matters concerning:

... objectives and direction-setting for space development policies; ... systems and strategies to pursue space development; ... plans to pursue space development; ... expansion of infrastructure necessary for space development; ... financing and investment plans for space development; ... research and development for space development; ... nurturing of professionals necessary for space development; ... international cooperation for the invigoration of space development; ... promotion of

¹⁷⁸ KARI, "Planning of Mid- and Long-term National Space Development Plan," Korea Ministry of Science, ICT and Future Planning, last modified December 10, 2013, x.

¹⁷⁹ Hwang, "Space Activities in Korea," 195.

¹⁸⁰ Ibid.

space development projects; ... use and management of space objects;
[and] ... utilization of the results of space development.¹⁸¹

The basic plan is to be deliberated by the National Space Committee, according to Article 6 of the Space Development Act. The National Space Committee appoints the Minister of MISP as a chairman, and vice-Minister of Strategy and Finance, Foreign Affairs, and MOTIE as essential members of the committee according to the Article 6.¹⁸²

In 2007, the First Basic Plan to Promote Space Development (hereafter referred to as the First Basic Plan) was established. The priorities of the First Basic Plan were establishment of independent space technological capability, presentation of a future vision, fostering infrastructure, and establishment of institutions.¹⁸³

(3) Second Basic Plan to Promote Space Development

The priorities of the Second Basic Plan in 2011 were early possession of independent space technology, setting up of infrastructure for using satellite information, extension of civil participation, training of high-quality human resources, and establishment of international cooperation.¹⁸⁴

(4) Mid- to Long-Term Space Development Plan

In 2013, the Mid- to Long-Term Space Development Plan was adopted as a revision of the Second Basic Plan to Promote Space Development. The plan defined the ROK's vision as the "enhancement of the Nation's reputation and distribution to national economy development by strengthening independent space development capability."¹⁸⁵ The plan aimed to achieve this vision through five objectives: increasing the proportion of the space budget in the Government R&D budget; establishing an independent launch

¹⁸¹ Korea National Law Information Center, "Space Development Promotion Act," last modified January 20, 2015, <http://www.law.go.kr/법령/우주개발%20진흥법>.

¹⁸² Ibid.

¹⁸³ Korea Ministry of Science, ICT and Future Planning, "First Basic Plan to Promote Space Development," last modified June 20, 2007, 15.

¹⁸⁴ Korea Ministry of Science, ICT and Future Planning, "Second Basic Plan to Promote Space Development," accessed March 5, 2016, 12.

¹⁸⁵ Korea Ministry of Science, ICT and Future Planning, "Mid to Long Term Space Development Plan," accessed March 9, 2016, 11.

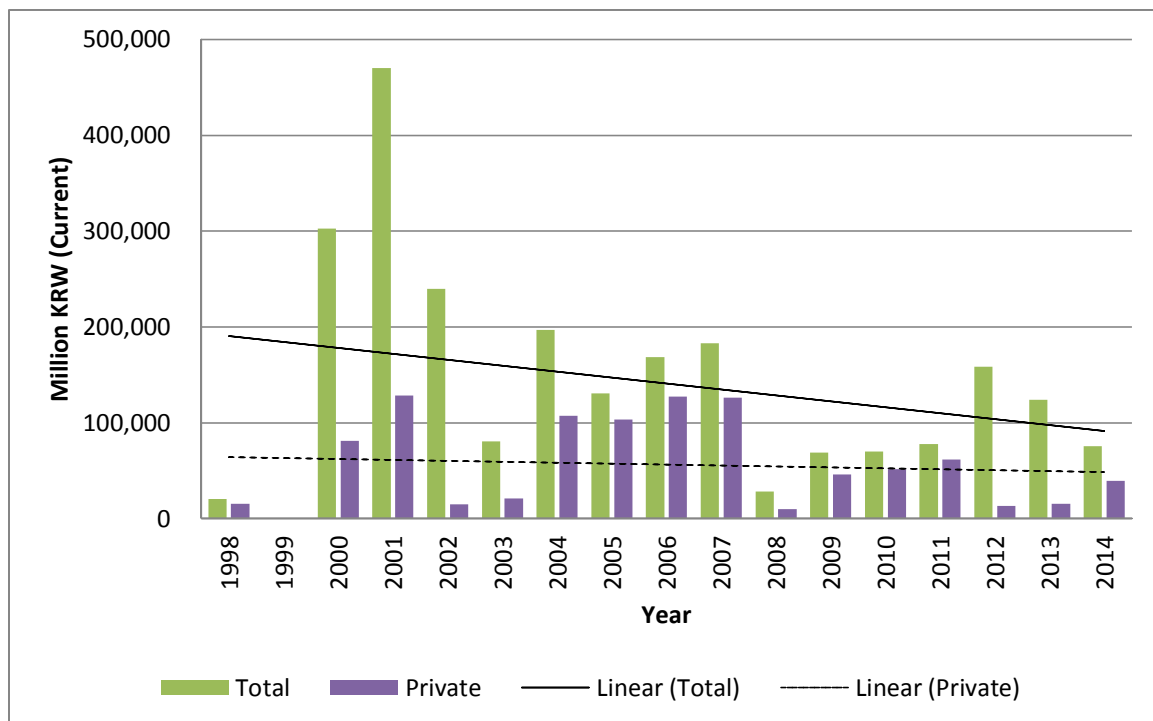
capability by development of the KSLV-II; sustaining development of satellites by extended civilian participation; and establishing space competitiveness.¹⁸⁶

2. R&D Investment

a. Total R&D Budget

A linear line, which shows the trend for total expenditures, indicates that – despite the plan – budgets have been decreasing (see a solid line at Figure 5). However, the more important feature of the total R&D budget for the ROK air and space industry is its inconsistency, and the variations of the budget are fundamentally distinct from those of the automobile and semiconductor industries in terms of the amount and the rate of increase.

Figure 5. R&D Budget of Air and Space Industry.



Source: KISTEP, “Report on the Survey of Research and Development in Science and Technology”; synthesis of information from 1998 to 2014; KISTEP had examined about the aerospace industry before 2007, and has researched on the aircraft, spacecraft, and its parts industry since 2008.

¹⁸⁶ Ibid.

The ROK air and space industry's total R&D budget was 20.6 billion KRW in 1998. Moreover, the amount of expenditure was not only for the aerospace industry but also the air industry, including an aircraft industry, so the actual budget for the space industry was much less than 20.6 billion KRW. To make matters worse, R&D investment shrank to 182 million KRW in 1999. Luckily, it recovered and exceeded 302 billion KRW in 2000 and 470 billion KRW in 2001; however, fluctuations of R&D investment have been repeated throughout the period of analysis.

b. R&D Budget in the Private Sector

R&D budgetary expenditures by the private sector also have fluctuated repeatedly, and the amounts and share in total R&D budget was dismally low. 128 billion KRW in 2001 is the largest investment by the private sector; this was only 27% of total R&D budget. On the other hand, the private sector bore 100% of the total R&D budget in 1999; it was only 182 million KRW. Overall, the average share rate of the private sector in ROK air and space industry during the past 17 years was 51%.

Although the trend line shows that R&D budget in private sector maintained its level during the period, it lacks consistency due to fluctuations from 182 million to 128 billion KRW (see a dashed line at Figure 5).

3. Human Resources

a. R&D Performing Institutions and Researchers

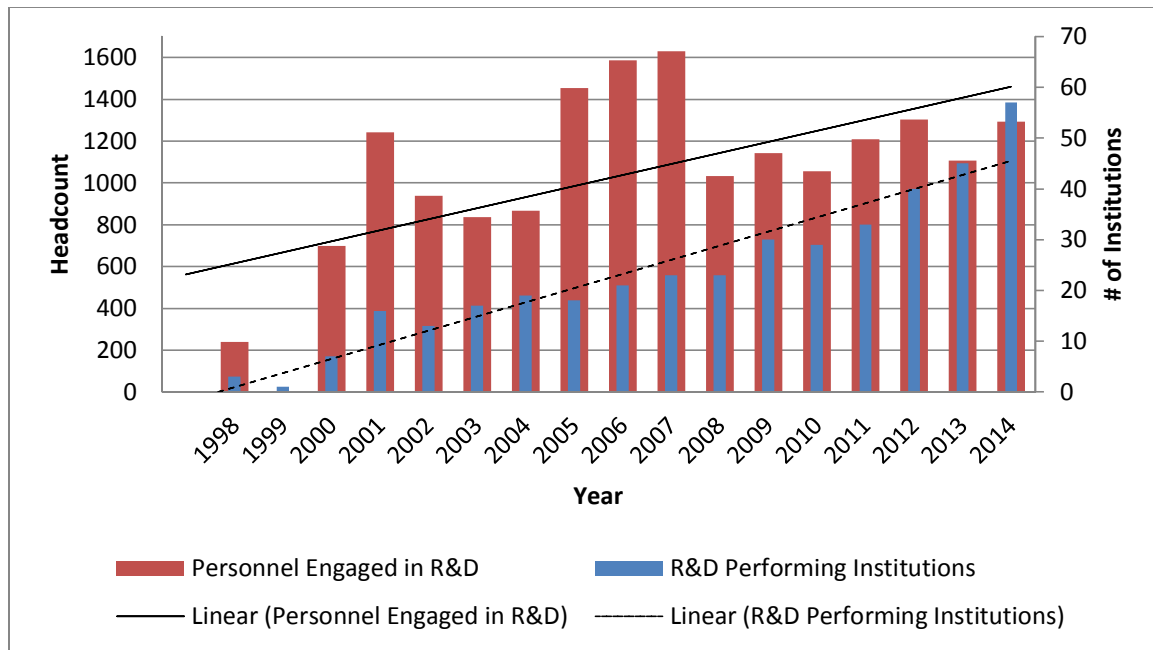
The number of researchers who were engaged in R&D for the air and space industry has been increasing except for the unique value in 1999 (see Figure 6). Moreover, the number of institutions that perform aerospace R&D has been regularly increasing more than the rate of increase of researchers.

Only three institutions were counted among aerospace R&D institutions in 1998, but there were 57 institutions by 2014. The headcount for researchers also grew from 239 in 1998 to 1,294 in 2014. But still, the actual number is arguably estimated to be less than that because of the fact that the number of institutions and researchers is includes statistical data for the aircraft industry and its subsidiaries.

b. Foundation of Research Institution

On October 10, 1989, the Aerospace Center was founded as an affiliate to KIMM, and KARI was established independently on November 22, 1996, as discussed earlier.

Figure 6. Human Resources of Air and Space Industry.



Source: KISTEP, “Report on the Survey of Research and Development in Science and Technology”; synthesis of information from 1998 to 2014; KISTEP had examined about the aerospace industry before 2007, and has researched on the aircraft, spacecraft, and its parts industry since 2008.

C. DIFFERENCES FROM THE INTERNAL CASES

Given the argument presented in the literature review, ROK’s space industry has sought to achieve mature development through a catch-up strategy as a latecomer following the past lessons learned from the trajectories of the ROK’s successful automobile and semiconductor industries. Undoubtedly, the latter two industries have included the critical elements and factors that foster the success of catch-up industries according to the research carried out in Chapter II. In this regards, how has the ROK’s space industry differed from the other two industries? In short, most of elements are

different. The space industry shows features at variance with the other industries across in the fields of policy, R&D investment, and human resources.

1. The Problem of Policy Vagueness

First of all, the policies for the space industry are less explicit than these of the other industries in terms of setting goals and targets. A typical example for this assertion is that one of the goals stated in the Mid- to Long-Term Basic Plan for Space Development was “to join the top 10 countries in the space industry by competing in the global market.”¹⁸⁷ It is hard to confirm whether the ROK has joined the top 10 countries’ club in the space industry or not, and entering the club is not important to the country’s space development. That is because rankings can be measured differently from case to case, and a nation’s space capability should not be gauged by relative evaluation. Moreover, considering the fact that succeeding plans tend to follow in the former’s footsteps, the setting up of goals in the first plan failed to provide proper guidelines for the following plans in comparison with the plans for the automobile and semiconductor industries.

In addition, the policies are insufficient to encourage the private sector to participate in business and R&D investment. Even though the acts and plans repeatedly call for the expansion of commercial participation, a specific plan or formula for its implementation or promotion is almost nonexistent. On the other hand, the Automobile Industry Protection Act of 1962 stated several formulas, such as adjustment of production costs, import control of cars and components, and a preferential tariff for automobile enterprises.¹⁸⁸ The ROK government also had offered similar subsidies for the semiconductor-manufacturing enterprises to promote development of that industry. In particular, the government provided capital for firms in the semiconductor industry in order to reduce possible risks in investment, while plans ordered commercial firms to follow guidelines for production standards in order to achieve localization,

¹⁸⁷ KARI, “Planning of Mid- and Long-term National Space Development Plan,” Korea Ministry of Science, ICT and Future Planning, last modified December 10, 2013, 186.

¹⁸⁸ Ibid.

standardization, and improved efficiency in the manufacturing process. In consequence, the government succeeded in encouraging private sector participation in the industry in spite of investor reluctance.

An additional difference is that the ROK's aerospace promotion act did not target the space industry specifically. For instance, the only act for promotion of the space industry, the Aerospace Industry Act of 1987, failed to differentiate between the aircraft industry and the space industry. Although the two industries have similarities to each other in terms of technology and skills compared with other industries, they also have significant differences that present a problem of focus for the industry. This means that the center of the industry tends to lean toward the aircraft industry rather than a space industry in the ROK due to the former industry's maturity and market sizes. While the ROK space industry is at the stage of toddling, the aircraft industry has developed and accumulated its technologies through several national scale military projects, such as Korean Trainer Experimental, Korean Attack Helicopter, and Korean Fighter Program, starting with ROK manufacturing of licensed 500MD helicopters since 1976.¹⁸⁹ Also, the ROK government established a Detailed Plan for Fostering the Semiconductor Industry, which targeted the semiconductor industry specifically within the electronics industry.¹⁹⁰ Unlike the plans for these industries, there has been no such detailed plan for space industry.

2. Slump in R&D Investment by the Private Sector

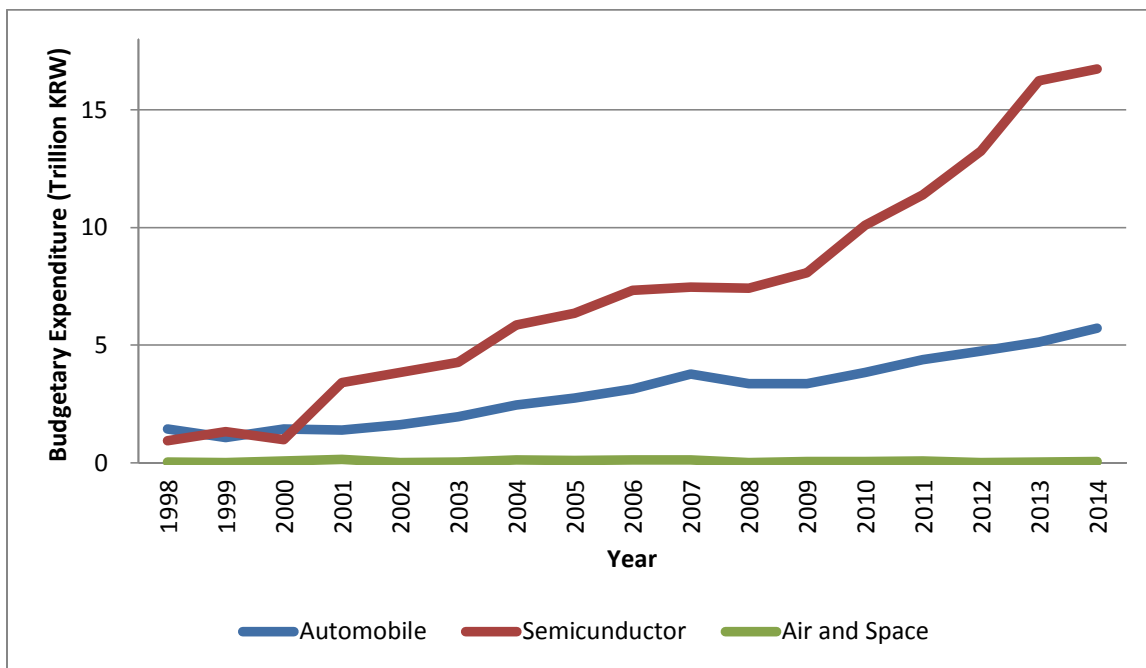
The most significant difference between the space industry and the others is feeble R&D investment by the private sector. As noticed in Chapter II, most of the R&D investment for the automobile industry and the semiconductor industry came from the private sector; its share was over 95% during the period. Thus, the gap in the total R&D budget between the space industry and the others originates in the lack of R&D investment by the private

¹⁸⁹ Woo-young Choi, "The History and Current State of Korean Aircraft Industry," *Journal of Current Industrial and Technological Trends in Aerospace* 9, no.1 (2011), 20.

¹⁹⁰ KISTEP, "Kuknae bandochae jangbisanub yuksungul wehan jeongbuui R&D jiwonjeongchek banghyang" 국내반도체 장비산업 육성을 위한 정부의 R&D 지원정책 방향 [Direction of R&D Support Policy by Government for Promotion of Domestic Semiconductor Industry], *KISTEP R&D Focus* 2009-12, no.23 (2009), 15.

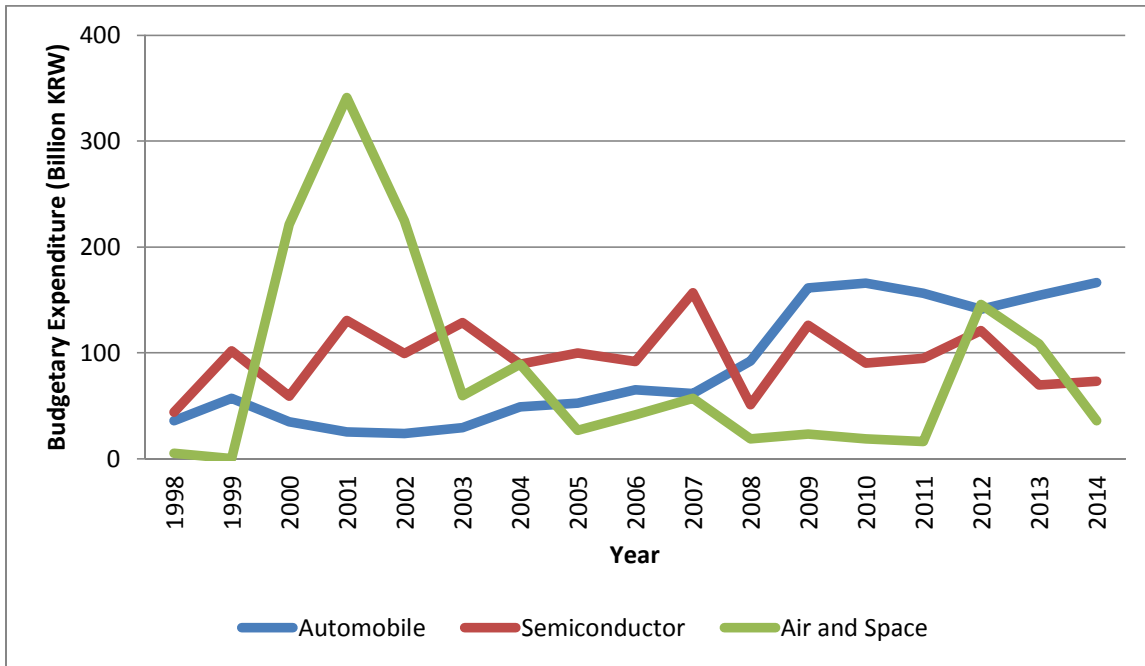
sector. A minimum gap of R&D budget by the private sector between the space industry and the semiconductor industry was 911 billion KRW in 1998, and the gap differed a great deal over the past 17 years. Consequently, the maximum gap between the two industries reached a massive 16,692 billion KRW in 2014. Moreover, the gap with the automobile industry is not small (see Figure 7). Besides, the gap in the private sector's share of the R&D budget is conspicuous when one compares the combined government and public sector investment figures (see Figure 8). So, it is reasonable to conclude that the overall size of R&D investment by the government and public sector does not matter as much as what the relative share of the private is within these numbers. Put simply, private investment is more successful to sustainability than government investment.

Figure 7. R&D Budgets by Private Sector.



Source: KISTEP, “Report on the Survey of Research and Development in Science and Technology”; synthesis of information from 1998 to 2014.

Figure 8. R&D Budget by Government and Public Sector



Source: KISTEP, “Report on the Survey of Research and Development in Science and Technology”; synthesis of information from 1998 to 2014.

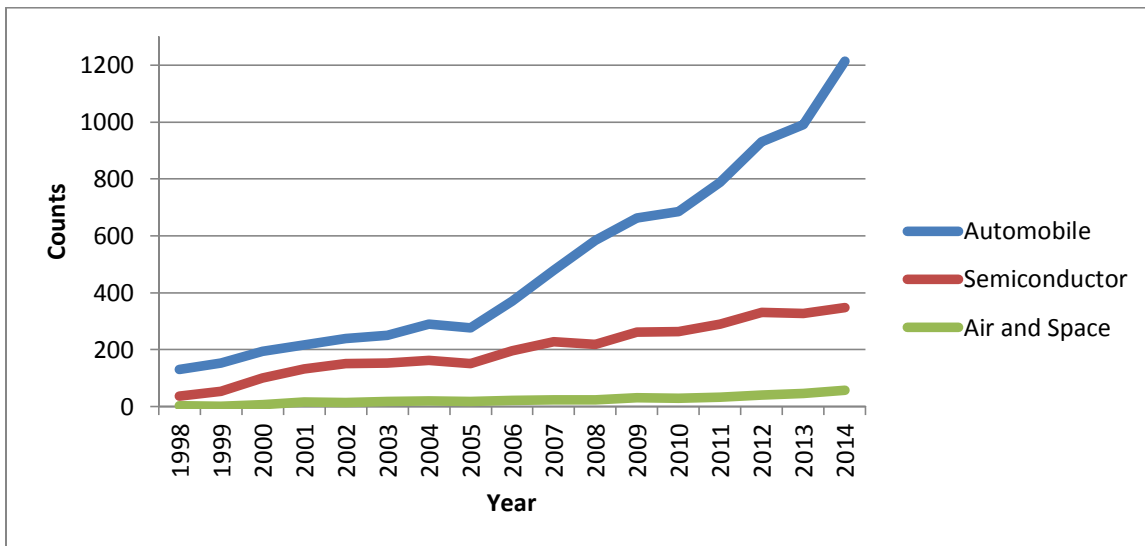
Moreover, unpredictable changes of R&D investment in the space industry by the government and public sector have weakened private investment (see Figure 8). Private enterprises invest in a certain business when they predict stable profitability; however, capricious R&D investment in national projects worries the private sector. In particular, the fact is that chaebols, such as Samsung, LG, SK, and Hyundai, which are conglomerates and major businesses in the ROK, have invested in the automobile and semiconductor industry for two possible reasons: the policies were favorable to these chaebols so that they invested in the automobile and semiconductor industries willingly, or the chaebols invested in the automobile and semiconductor industries because they found favorable market in these industries. In any case, private sector made clear-cut investment in R&D unlike the space industry.

3. Inadequate Human Resources

In contrast to the data of the automobile industry and the semiconductor industry, the human resources of the space industry have lagged in terms of their absolute quantity

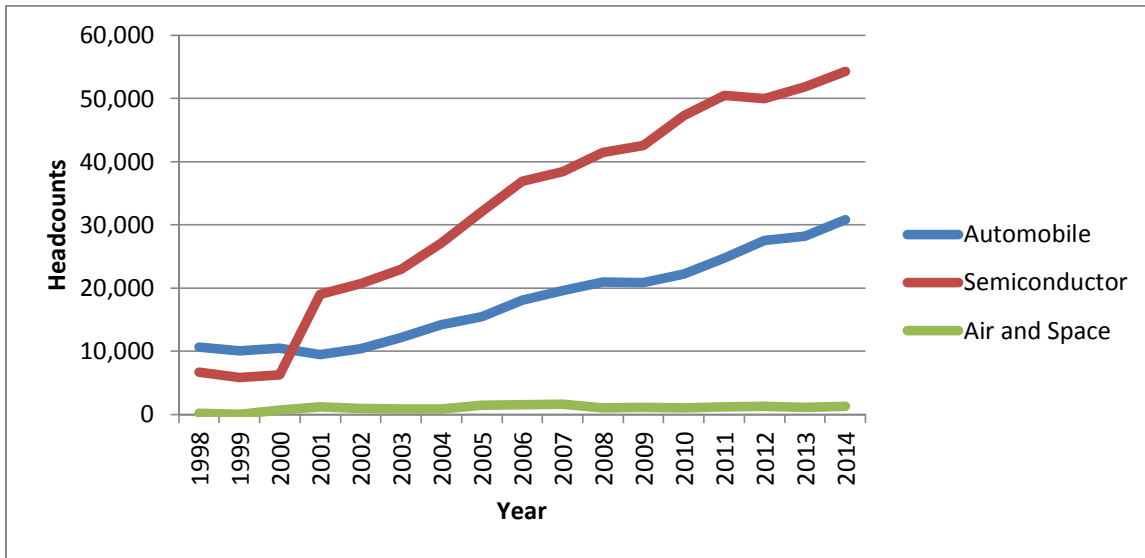
and a growth rate as well. A curve for growth of the number of R&D institutions and researchers in the space industry is much lower-pitched at a glance than those of the automobile industry or the semiconductor industry (see Figure 9 and Figure 10). While the number of R&D institutions in the automobile industry was 1,215 in 2014, it was only 57 in the space industry. Moreover, the growth rate of analytic variables is also inconspicuous compared to striking growth rate of the others. The headcount of researchers in the semiconductor industry increased by eight times and nearly fifty thousand personnel, while the number of researchers in the space industry increased by only five times to just 1,055 people.

Figure 9. Comparison of Institutions by Industry



Source: KISTEP, “Report on the Survey of Research and Development in Science and Technology”; synthesis of information from 1998 to 2014.

Figure 10. Comparison of Researchers by Industry



Adapted from KISTEP, “Report on the Survey of Research and Development in Science and Technology”; synthesis of information from 1998 to 2014; the data shown at this figure for the semiconductor industry before 2007 are adjusted to balance the rate of increment between data before 2007 and after 2008. The numerical values on the figure are one third of the actual number of institutions examined by KISTEP.

D. CONCLUSION

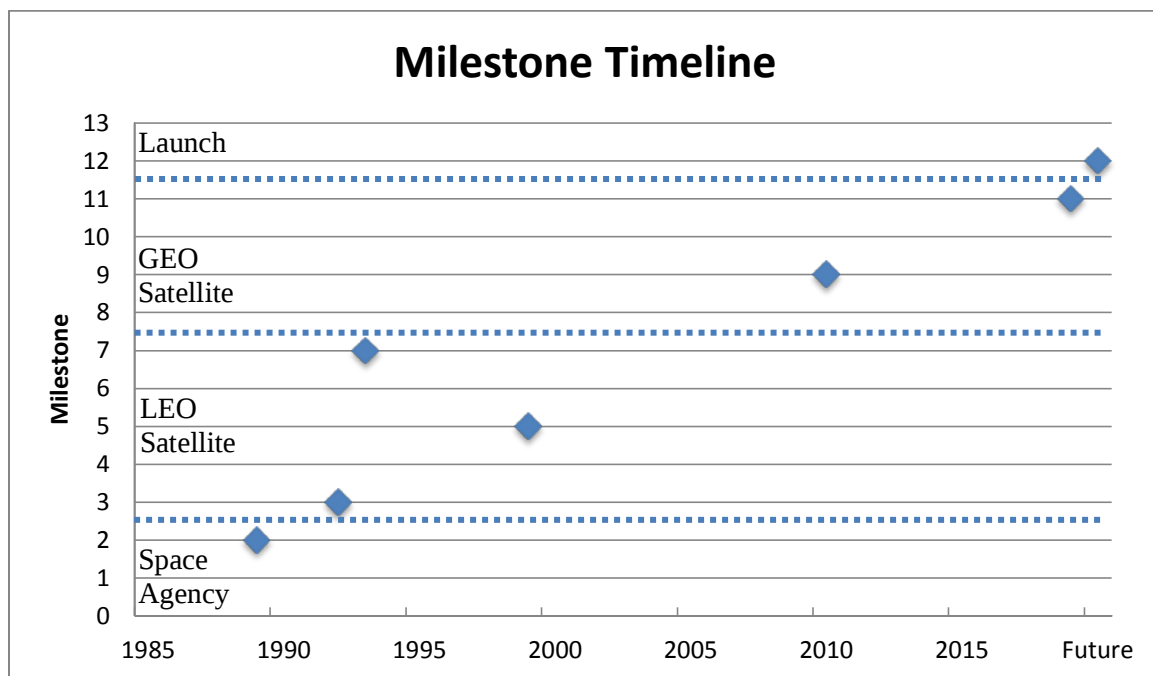
An ROK space program, for satellites in particular, has developed significantly in a short time. In 1989, KARI was founded as the first milestone of the STL; after four years, the ROK launched a LEO satellite on a foreign rocket built locally without foreign assistance; after seventeen years afterward, it built a GEO satellite locally with help from outside; and it has plans to launch a GEO satellite that will be produced domestically in 2019 (see Figure 11).

To achieve these results, the ROK space program has followed regular steps in manufacturing satellites. First of all, the ROK utilized international cooperation for the procurement of satellites. This foreign assistance was essential to develop satellites in a short period of time due to the fact that the ROK’s capability in the space field was virtually nonexistent. Based on the technologies that were gained from the process, the ROK has sought to build satellites locally, even though some payloads and buses of the satellites still required foreign assistance. Finally, it succeeded in building a LEO satellite locally and is now planning to produce a GEO satellite independently.

The ROK also shows similar steps in the field of launch capability. Despite the early efforts to make its own rockets through the KSR, the ROK had to be assisted by foreign technology for launch vehicles due to the regulations of MTCR. With foundational technologies for the KSLV-I acquired from Russia, the KSLV-II program, which will be built locally, is in progress even though the launch vehicle still depends on some foreign aid.

On the other hand, the ROK is attempting to develop an independent space military capability in surveillance satellites in LEO and GEO, while it currently relies on U.S. space assets. But still, the ROK will continue to support and to maintain cooperation with its allies and partners in terms of space information sharing.

Figure 11. ROK Space Programs' Milestone Timeline



Adapted from Danielle Wood and Annalisa Weigel, "Charting the Evolution of Satellite Programs in Developing Countries – The Space Technology Ladder," *Space Policy* 28 (2012), 16–17.

This growth, however, does not offer an optimistic view for sustainable space programs for ROK in the long term when compared with features of such successful industries as the automobiles and semiconductors. Vague policies, a slump in R&D

investment especially by the private sector, and inadequate human resources are the main reasons for anxiety regarding the sustainability of the ROK's space program. Moreover, the future of the ROK's independent military space capability is puzzling. The ROK, which does not have an ability to produce an autonomous GEO satellite yet, is planning to launch independent military-purpose GEO satellites by its own agencies and enterprises. Accordingly, several obstacles are inevitable. Despite an initial requested budget for the surveillance satellites of 64 billion KRW, the National Assembly approved only 2 billion KRW for FY 2016.¹⁹¹ Moreover, the first launch of one of the satellites, which was planned in 2020 initially, has been postponed.¹⁹²

These concerns show that the research structure and investment profile of the ROK's space programs are important. A nation's needs and aspiration for space should be solid if it seeks to set policy objectives, capital investment, and development of human resources clearly in order to prevent wasting resources and efforts.

The ROK could accomplish its objectives through one-time performance if its main aspiration is "national prestige," as asserted by H. J. An.¹⁹³ In fact, the ROK's first astronaut program could be one of the evidences that the ROK's priority in the space is national prestige. The program, which had been invested \$25.4 million by the government, was terminated due to resignation of the first and only astronaut in 2014, and the ROK plans no more astronaut program at present.¹⁹⁴

Such an aspiration is, however, unlikely to foster the private sector's investment in the space industry. Consequently, the phenomenon, which has appeared in R&D investment and the human resources, has been foreseen due to lack of the interest in a space field by private business. Furthermore, military-purpose satellites, which will play

¹⁹¹ "Daebuk jeongchal wuisung yesan daepok sakgam" 대북 정찰위성 예산 대폭 삭감 [Huge Cut of Budget for Surveillance Satellites Against North Korea], *Yonhapnews*, December 3, 2015.

¹⁹² "Gun jeongchalwuisungsaeub ilnyun jiyoun" 군정찰위성사업 1년 지연 [Military Surveillance Satellites Project Postponed] *Korea Herald Business*, October 5, 2016.

¹⁹³ Hyoung Joon An, "National Aspirations, Imaged Futures, and Space Exploration: the Origin and Development of Korean Space Program 1958–2013," Dissertation, Georgia Institute of Technology (December 2015), 208.

¹⁹⁴ "South Korea's First Astronaut Officially Quits," *Korea Times*, August 12, 2014. <http://www.koreatimesus.com/16153/>.

a major role in national security, should not be a case for national prestige. Otherwise, the sustainability of the space program will not be attained due to a waste of resources, excessive investments, and disorientation of technological development.

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IV. THE EXTERNAL CASES

This chapter examines Israel's and Australia's space programs as external comparative cases. To be specific, the historical space activities, such as the foundation of a space agency, satellite development, and launch vehicle construction, of each country will be dealt with first. Based on the major milestones of Israel's and Australia's space programs, this chapter will build an STL, which was provided by Wood's and Weigel's study, in order to find out the implications for the ROK. Next, the space policy, R&D investment, and human resources of each country will be studied. Through the study of space policy, R&D investment, and human resources, which are the same categories that were employed for the internal case study, the status of the ROK's space programs will be substantiated in a comparative context. Finally, the chapter will analyze and compare the three countries in terms of the future direction of policy and investment.

Israel's and Australia's space programs are useful cases for the ROK's sustainable space development. Israel has ranked higher in the field of space even though its economic power is weaker than the ROK's. On the other hand, Australia has less space power although its total GDP is similar to the ROK's. These reciprocal trajectories of Israel and Australia should provide meaningful comparative reference points to inform the ROK's space program and to decide which directions of policy and investment are sustainable. The existing literature mostly has viewed the ROK's space program by contrasting it with those of the major space powers, such as the United States, Russia, or Japan. Accordingly, the ROK's space ability has been analyzed as just an immature one which needs to expand quantitatively and qualitatively throughout all of its aspects. Yet it is hard to achieve growth of capability and capacity simultaneously due to the intricate considerations of available expenses and time. Moreover, a space industry has distinct features that are more sensitive than those present in the automobile industry or a semiconductor industry in terms of the size of the market, potential customers, level of maturity of its technologies, and political considerations.

A. ISRAEL'S SPACE PROGRAM

1. History of Space Activities

a. Space Agency

The first space agency of Israel was the National Committee for Space Research (NCSR) founded in 1960. While the only distinguished space activity under the NCSR was launching of a solid fuel sounding rocket, *Shavit-2*, on July 1961, the NCSR has an important meaning as a space agency because it paved the way for the Israeli space program through space research and education.¹⁹⁵

Israel launched its space agency, the Israel Space Agency (ISA), which was established under the Ministry of Science and Development, in July 1983. ISA's responsibilities included supervision and coordination of the national space efforts including space policy, collaboration with foreign countries, and scientific activities that involved Israeli academic institutions and industry.¹⁹⁶ Although it had only four full-time employees and a \$500,000 annual budget at the time of its foundation, ISA's annual budget has since grown to \$50 million.¹⁹⁷ Its budget is relatively small when compared to other space faring nations' budgets; however, the Israeli Ministry of Defense covers many satellite programs, the development of launch vehicles, and the operation of the Palmachim launch site.¹⁹⁸

b. Satellites

Israel has developed its satellites autonomously since the beginning of its satellite program. Historically, the major satellites of Israel have been the Ofeq spy sateliites,

¹⁹⁵ Daphne Burleson, "Israel," *Space Programs Outside the United States* (Jefferson, NC: McFarland & Company, Inc., 2005), 153.

¹⁹⁶ Deganit Paikowsky, et al., "Israel's Space Strategy," in *Space Strategy in the 21st Century: Theory ad Policy*, ed. Eligar Sadah (New York, NY: Routledge, 2013), 323.

¹⁹⁷ "Israel Space Agency," *Global Security*, accessed October 31, 2016. <http://www.globalsecurity.org/space/world/israel/agency.htm>; Burleson, "Israel," 153; Dan Fisher, "Israel Space Program Sets Lofty Goals: Security, Industrial Development Are Prime Concerns," *Los Angeles Times*, June 10, 1985.

¹⁹⁸ "Israel Space Agency," *Global Security*, accessed Oct 31, 2016. <http://www.globalsecurity.org/space/world/israel/agency.htm>.

TechSAR, the Earth Resources Observation Satellite (EROS), and the Afro-Mediterranean Orbital System (AMOS), according to ISA.¹⁹⁹

The first Israeli satellite was *Ofeq-1*, which was launched into orbit by Shavit launcher from the Palamchim launch site in Israel on September 19, 1988. Israel built and launched it without any foreign assistance.²⁰⁰ Along with Israel's space aspiration, its purpose was to develop reconnaissance satellites, even though *Ofeq-1* did not carry a camera. Afterwards, *Ofeq-2* and *-3* were launched and entered LEO successfully on April 3, 1990, and April 15, 1995, respectively. At that time, *Ofeq-3* was announced as a test satellite like the other satellites, as a matter of fact, it was a prototype for the *Earth Resources Observation Satellite (EROS)*.²⁰¹ On January 1998, *Ofeq-4*'s launching failed due to a malfunction of the Shavit-1 launch vehicle. However, overcoming the failure of *Ofeq-4*, *Ofeq-5* was launched successfully on May 2002. *Ofeq-5* had the capability of sending color imagery with less than 1 m resolution through a telescopic camera developed by Israeli enterprise, Elbit Systems.²⁰² Afterward, the series of Ofeq continued to *Ofeq-11*, which was launched on September 2016. In addition, *TechSAR*, which is capable of delivering synthetic aperture radar image, was launched from India in 2008 and 2010.

On the other hand, the accumulated technologies and skills acquired during development of those spy satellites contributed to Israel's commercial space capability. *EROS-A* was produced with *Ofeq-3*'s bus and launched by a Russian launch vehicle in 2000, and it has an improved CCD electro-optic capability with a resolution of 5 ft.²⁰³ *EROS-B* was launched in 2006 on a Russian Soyuz-Fregat launcher as well. Moreover, the communication satellites in the Afro-Mediterranean Orbital System (AMOS) were

¹⁹⁹ ISA(2013), *Israel Celebrates Space*, Israel Ministry of Science and Technology, 8.

²⁰⁰ Bruce A. By and Hurwitz. "Space Race Or Missile Gap?," *Jerusalem Post*, December 14, 1989.

²⁰¹ Burleson, "Israel," 154.

²⁰² Brian Harvey, et al., "Israel," in *Emerging Space Powers: The New Space Programs of Asia, the Middle East and South-America*, ed. Brian Harvey (Berlin: Chichester, UK: Springer, 2010), 395.

²⁰³ Burleson, "Israel," 154; "Israel's Palmachim Spaceport," *Space Today Online*, accessed October 27, 2016; the boundary between military and commercial purpose is ambiguous, because EROS satellite transmitted its data to Israel intelligence agencies.

manufactured by the Israel Aircraft Industry (IAI).²⁰⁴ *AMOS-1* was launched by Ariane 44L from Kourou on May 15, 1996, and *AMOS-2* entered orbit from Kazakhstan in 2003.

c. Launch Capability

Israel has independent launch capability through its Shavit vehicle, which means a comet in Hebrew. Shavit was developed by domestic corporations entirely. The overall management was under the IAI, and components of the Shavit are also produced locally. Shavit consists of a three-stage solid propellant booster; the first and second stages, called Jericho-2, were created by TAAS, which is former Israel Military Industries, in the 1980s, and the third one was produced by Rafael, the Israeli Arms Development Research Authority.²⁰⁵ The Shavit blasted off in September 1988 for the first time.²⁰⁶ After that, several Israeli satellites, such as Ofeq, AMOS, EROS, and TechSAR, have been launched successfully by the Shavit.²⁰⁷

Even though almost all Israel satellites have entered orbit via the Shavit, some satellites have relied on foreign launch vehicles due to the limited launch capacity of the Shavit and Israel's unique geographical location. Shavit's payload capacity to LEO is only 300 kg.²⁰⁸ Thus, heavy satellites like AMOS, which weighs nearly 1 ton, are not able to be launched by the Shavit. In addition, Israel has had to launch its rocket toward the northwest over the Mediterranean Sea from the launch site, the Palmachim Air Force Base, in order to prevent potential trouble with its neighboring countries to the east. This reverse course against the earth's rotation requires more fuel consumption for entering satellite orbit and forces a specific operational orbital track.²⁰⁹ While it is trying to develop an enhanced launch vehicle with a more powerful upper stage motor so that is

²⁰⁴ Burleson, "Israel," 154.

²⁰⁵ "Shavit," *Global Security*, accessed November 11, 2016. <http://www.globalsecurity.org/space/world/israel/launch.htm>.

²⁰⁶ Ibid.

²⁰⁷ Ibid.; ISA(2013), *Israel Celebrates Space*, 8.

²⁰⁸ ISA(2013), *Israel Celebrates Space*, 8.

²⁰⁹ Burleson, "Israel," 157.

able to load heavier payloads and place them in GEO, Israel has not yet tested such a system.²¹⁰

2. Policy

Israel's aspiration toward space activity was started by national security concerns due to threats from neighboring countries. According to Paikowsky, Israel's space policy has mainly focused on capability for "early warning intelligence, deterrence, and self-reliance in cutting-edge technologies."²¹¹ The author argues that the starting point of Israel's desire for independent space capability was the Yom Kippur War in 1973; during the war against Egypt and Syria, Israel wanted to get satellite intelligence from the U.S., but was denied.²¹² Even though the reason why the United States could not offer the information was a technical problem, Israel assessed that it was intentional.²¹³

Given this ambition, Israel has invested in independent space technologies for observation, reconnaissance, and communications. Based on such autonomous technologies – sovereign development of satellites and launching capability – Israel has raised its level of self-reliance.

Recently, Israel has sought to expand its international cooperation. The main reason to engage in international cooperation is "to reduce the economic burden a space program entails," Paikowsky argues.²¹⁴ Israel's ongoing international cooperation projects are Vegetation and Environment New Micro Spacecraft (VENuS) with France, Mapping Using Synthetic Aperture Radar Mission (MUSAR) and Mediterranean Israel Dust Experiment (MEIDEX) with NASA, and hyperspectral scientific satellites project (SHALOM) with Italy.²¹⁵ Furthermore, Israel seeks to strengthen ties with foreign countries not only in the civil and commercial space fields but also on military side

²¹⁰ Ibid.

²¹¹ Paikowsky, "Israel's Space Strategy," 322.

²¹² Selection from Deganit Paikowsky, *The Power of the Space Club* (draft manuscript), to be published by Oxford University Press, forthcoming 2017.

²¹³ Ibid.

²¹⁴ Paikowsky, "Israel's Space Strategy," 325

²¹⁵ Ibid., 324–6; ISA (2013), *Israel Celebrates Space*, 10.

regarding security. Israel signed a plan for “joint research grants and increased cooperation in space, cyber and information security” with Japan on January 4, 2015, even though the Israeli government announced that the plan is for the Israeli economy through market expansion.²¹⁶

3. Investment in R&D

Israel has invested its budget into the space field intensively. In 2013, Israel’s space budget as a share of GDP was 0.034%, while the ROK invested 0.023%.²¹⁷ However, exact statistics for Israel’s R&D budget expenditure for space programs are not available because they have not been announced publicly.²¹⁸ It is likely that a considerable part of the space program’s expenditures come from the defense budget; this amount is also confidential. According to Harvey, ISA’s annual space budget was approximately \$70 million in the late 2000, and 90% of it was related to the Ministry of Defense’s technological program.²¹⁹ In 2010, the newly enacted space plan’s annual budget was some \$80 million.²²⁰ Moreover, a newspaper, which interviewed a director of the Israel Space Agency, says that “[Israel’s] aerospace industry continues to receive a substantial cash infusion from [its] \$9 billion military budget,” even though it was in an economically hard time.²²¹

Yet the investment in space programs that can be estimated through other data sources seems substantial. According to the OECD, Israel’s Revealed Technological

²¹⁶ “Israel Seeks To Strengthen Space Ties with Japan,” *Spacenews*, January 5, 2015; Barbara Opall-Rome, “Israel Seeks Space, Cyber Cooperation with Japan,” *DefenseNews*, January 4, 2015.

²¹⁷ OECD (2014), *The Space Economy at a Glance 2014*, OECD Publishing, 43. <http://dx.doi.org/10.1787/9789264217294-en>.

²¹⁸ OECD, “Main Science and Technology Indicators (Edition 2016/1),” OECD Science, Technology and R&D Statistics (database). DOI: <http://dx.doi.org/10.1787/db23df7c-en>; it does not provide statistics of Israel’s R&D space program budget separately because that data is “included elsewhere.”

²¹⁹ Harvey, “Israel,” 388.

²²⁰ Selection from Deganit Paikowsky, *The Power of the Space Club* (draft manuscript), to be published by Oxford University Press, forthcoming 2017; OECD (2011), *The Space Economy at a Glance 2011*, OECD Publishing, 24. <http://dx.doi.org/10.1787/9789264111790-en>.

²²¹ Michael Cabbage, “Israel Overcoming Political, Financial Obstacles To Build A World-class Space Program,” *Knight Ridder Tribune News Service* (Jan 15, 2003); interviewed Aby Har-Even, who is current director-general of the Israel Space Program.

Advantage (RTA) index in space-related technologies, which is defined as “a country’s share in patents in a particular field of technology, divided by the country’s share in all patents,” is 2.11 and ranked third in the world following 5.13 of Russia and 3.72 of France, while the ROK’s index is 0.77.²²² Moreover, OECD also observed that “aerospace is part of several high-tech activities which play a leading role in Israeli economic growth.”²²³

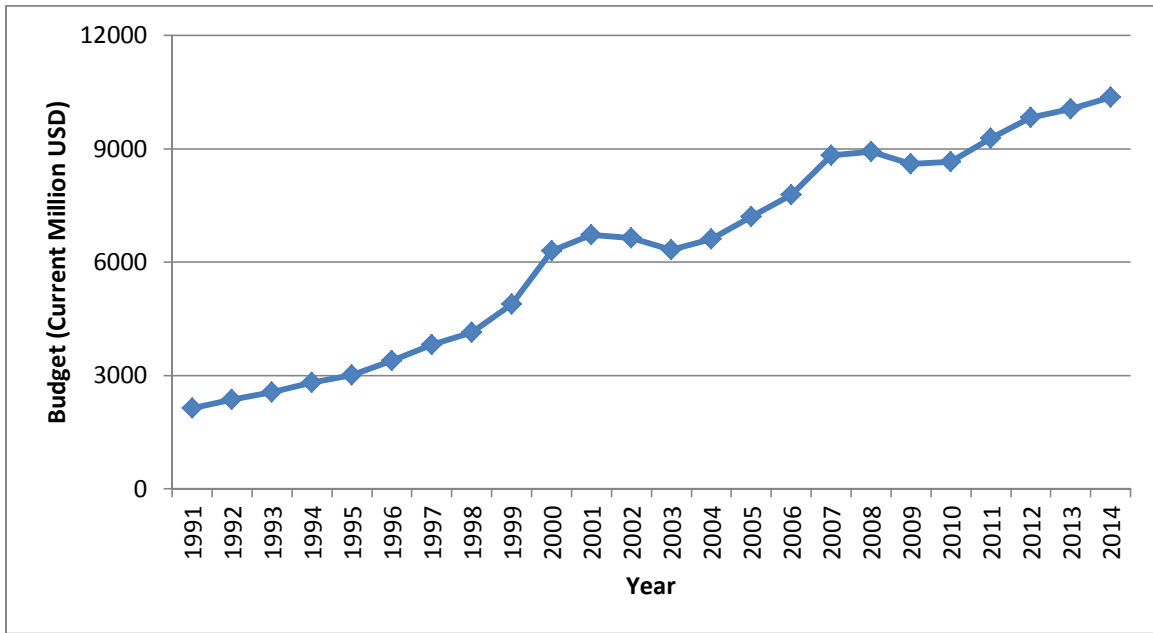
Another index, that allows one to judge efforts of Israel’s R&D, is Gross Domestic Spending (GDS) on R&D. Total expenditure on R&D in terms of GDS has been reported to the OECD since 1991. According to the report, Israel spent \$2.1 billion in 1991, and later on, it grew continuously to end with \$10.4 billion in 2014; this figure is 4% of Israel’s GDP total (see Figure 12).²²⁴

²²² OECD (2014), *The Space Economy at a Glance 2014*, OECD Publishing, 70. <http://dx.doi.org/10.1787/9789264217294-en>

²²³ OECD (2011), *The Space Economy at a Glance 2011*, OECD Publishing, 24. <http://dx.doi.org/10.1787/9789264111790-en>

²²⁴ OECD, Gross Domestic Spending on R&D (indicator), accessed on October 21, 2016, doi: [10.1787/d8b068b4-en](http://dx.doi.org/10.1787/d8b068b4-en).

Figure 12. Israel's Gross Domestic Spending on R&D



Source: OECD (2016), Gross domestic spending on R&D (indicator), accessed on October 21, 2016, doi: 10.1787/d8b068b4-en.

4. Human Resources

Israel has reported its statistics on researchers to the OECD only twice, and the statistics were just their number per 1,000 people employed. According to the data, 15.7 persons per 1,000 employed were researchers in 2011 and 17.4 persons in 2012. As is widely known, Israel claims its society is knowledge-based. While the quantity of available data is scanty, a headcount of researchers can be deduced reasonably as more than some 2 % of the employed Israeli population at present.

B. AUSTRALIA'S SPACE PROGRAM

1. History of space program

a. Space Agency

Australia does not have a national space agency.²²⁵ Historically, the Australian Space Office (ASO) was founded in 1987 under the Department of Industry, Technology and Commerce to support Australian Space Board (ASB) that directs the National Space Program of 1986.²²⁶ The Australian Space Council (ASC) was established and replaced the ASB in 1994 according to the Australian Space Council Act of 1994; however, the ASO and ASC were ceased in 1996 due to budget cuts.²²⁷ But still, the ASO's role was limited to a secretariat.

After that, some organizations have existed for research on space engineering in Australia. The Cooperative Research Centre for Satellite Systems (CRCSS) was founded in 1998. It is a multi-site joint venture of 6 universities, 4 private companies, and 2 government agencies.²²⁸ CRCSS was responsible for the FedSat project that is for scientific experiment.²²⁹ CRCSS's role in Australian space activity was unique. Jeff Kingweall argues that "there is no major Australian facility devoted to the process of providing an in-space platform to support scientific and engineering," except the CRCSS; however, the CRCSS was closed in 2005.²³⁰ In addition, The Australian Space Research Institute (ASRI) was established in May 17, 1993; it is a non-profit organization, which

²²⁵ Trent Dalton, "Astronaut Andy Thomas Is on a Mission to Launch Australia into the Space Age," *Australian*, March 5, 2016.

²²⁶ Standing Committee on Economics of the Australian Senate, *Lost in Space? Setting a New Direction for Australia's Space Science and Industry Sector* (Canberra, Australia: Senate Printing Unit, 2008), 49.

²²⁷ *Ibid.*, 51–2.

²²⁸ "CRC for Satellite Systems. (1998-)," National Library of Australia, accessed November 13, 2016, <http://nla.gov.au/nla.party-1471320>.

²²⁹ Jeff Kingwell, "Punching Below Its Weight: Still The Future of Space in Australia?," *Space Policy* 21 (2005): 161.

²³⁰ *Ibid.*

was founded through a merger between the Australian Space Engineering Research Association (ASERA) and the AUSROC Launch Vehicle Development Group.²³¹

Since the late 2000s, the necessity of establishing a national space agency has been raised again in Australia; but still, a space agency that takes charge of comprehensive supervision for a national space program does not exist. The Standing Committee on Economics of the Australian Senate in November 2008 argued that “Australia [would regain] an important place in global space science and industry by gradually developing a dedicated space agency.”²³² The report recommends an establishment of a space agency and Space Industry Advisory Council following other OECD countries’ cases.²³³ Based on these efforts, the Space Coordination Committee (SCC) was established for the purpose of enhancement of the Australian economy and social infrastructure through cooperation and coordination of the Australian agencies concerned to “the application of space technologies, particularly through the use of satellite information.”²³⁴ The members of the committee include the Department of Industry, Department of Defense, Bureau of Meteorology, Commonwealth Scientific and Industrial Research Office (CSIRO), and etc.²³⁵ The competent authority of the committee is the Department of Industry, Innovation and Science, and it is focused on civil and commercial space. In 2013, a Space Coordination Office was established under the Department of Industry, Innovation and Science to serve the purpose of administration.²³⁶

²³¹ “About ASRI,” Australian Space Research Institute, accessed November 13, 2016. <http://www.asri.org.au/About>.

²³² Standing Committee on Economics of the Australian Senate, *Lost in Space? Setting a New Direction for Australia’s Space Science and Industry Sector* (Canberra, Australia: Senate Printing Unit, 2008), 2.

²³³ *Ibid.*, 66.

²³⁴ Australian Department of Industry, Innovation and Science, “Civil Space Coordination,” Australian Government, accessed November 13, 2016. <http://www.industry.gov.au/industry/IndustrySectors/space/Civil-space-coordination/Pages/default.aspx>.

²³⁵ *Ibid.*

²³⁶ “Australia Launches First Space Coordination Office,” *NEWS.COM.AU*, April 10, 2013, <http://www.news.com.au/technology/science/australia-launches-first-national-space-coordination-office/story-fn5fsgyc-1226616179039>.

b. Satellite

Australia was the seventh country to launch and possess its own satellite from its territory. Despite this early achievement, Australia failed to maintain a sustainable path for the development of satellites. Jeff Kingwell argues that the “Australian public space endeavor has been characterized by a disconnected series of short-term projects and procurement contracts.”²³⁷ Kingwell cites the *Weapons Research Establishment Satellite (WRESAT)* and *FedSat* as examples of “disconnected series of short-term projects,” and *Aussat* series is a case of “procurement contracts.”

The *WRESAT* was the first satellite launched in Australia. It was launched on a U.S. Sparta rocket from the Woomera launching range in Australia on November 29, 1967. Even though its name contains weapons research, *WRESAT* was equipped only with scientific instruments for measurement of temperature, radiation, and ozone concentrations.²³⁸ Subsequently, Australia orbited its second satellite, *Oscar-5*, which was boosted on January 1970 and maintained the orbit for 43 days.²³⁹ *Oscar-5* was launched by a U.S. Thor-Delta rocket from Vandenberg Air Force Base in California.

Aussat-1, also known as *Optus A*, which was launched in 1985, was the first GEO satellite of Australia. It was also the first nationally owned satellite for the purpose of communication. *Aussat-1* and -2 were built by the Hughes company, and launched from the U.S. space shuttle. Moreover, *Optus B*, *C*, and *D*, which were also *Aussat* series, were built by Loral and Orbital Sciences, and launched by commercial launch providers. After that, ten *Optus* series satellites has been launched and owned by the Australian corporation, Optus. The most recent-launched satellite, *Optus-10*, was also developed by the U.S. Loral.

²³⁷ Kingwell, “Punching Below Its Weight,” 161.

²³⁸ Moltz, *Asia’s Space Race*, 161.

²³⁹ Ibid.

Fedsat-1 was developed locally for the purpose of scientific experiments. It was developed by the CRCSS and launched on December 2002.²⁴⁰ But, as noted earlier, the end of the project, the CRCSS was abolished in 2005.

c. *Launch Capability*

Australia has various types of sounding rockets, but does not have autonomous space launch capability. Since 1949, almost 40 types of rockets have been developed and launched at the Woomera range in Australia, which was constructed by the UK as a firing range for missiles in the 1940s; however, no Australian satellite has been launched by an Australian launch vehicle. Moreover, Australia has not mapped a plan to build its own launch capability. Instead, Australia has boosted its satellites by European Ariane, Chinese Long March rockets, or the U.S. space shuttles and rockets.

Australia has had favorable conditions to develop its own launch capability. Even though Australia successfully launched its own satellite, *WRESAT*, by the U.S. Redstone-based Sparta launch vehicle in 1967, it did not link it with further projects. In particular, Australia rejected an offer to join the European Space Agency in 1972, when it was the only non-European member of the European Launcher Development Organization.²⁴¹ Consequently, Australia lost a chance to utilize European-built facilities at the Woomera launch site and skilled personnel for two decades until the commencement of the FedSat project.²⁴²

Moreover, Australia has tried to develop commercial launch capacity; but it failed each time for various reasons. International facilities were planned to be constructed in Cape York, Christmas Island, and Woomera during the early 1990s to 2000s; but the plans were canceled because of problems of financing, aboriginal community's protests, and technical failures of the spacecraft.²⁴³

²⁴⁰ Institute for Telecommunications Research, "Fedsat – Historical Highlights," University of South Australia, accessed on October 31, 2016. <https://www.itr.unisa.edu.au/projects/fedsat>

²⁴¹ Kingwell, "Punching Below Its Weight," 162.

²⁴² Ibid.

²⁴³ Moltz, *Asia's Space Race*, 162.

2. Policy

Australia has sought efficiencies in space policy through the utilization of foreign satellites and data. Australia's geographical location has significantly affected its space policy. According to Australia's Satellite Utilisation Policy, Australia relies on "international space systems to support critical civilian and national security functions" and accesses "international space systems in a fragmented fashion, depending on geographic advantages or the goodwill of other nations."²⁴⁴ Australia's unique location far from potential adversaries makes the country have fewer concerns about national security. Thus, Australia has had less interest in a spy satellite and has paid more attention to communication and meteorological satellites, which are relatively easy to purchase from a foreign country. Moreover, the space superpowers' interest in the location of Australia also has affected Australia's space policy. Located in the southern hemisphere, Australia is able to provide hosting services to other Western countries in terms of satellite observation systems through radar sites and other ground stations. Its spacious territory has also allowed other space powers to conduct experiments with missiles and launch vehicles at the Woomera range.

However, Australia's space policy is being shifted toward increased space capability. Recognizing the importance of space, Australia now emphasizes the significance of a space industry by stating principles to "focus on space applications of national significance, assure access to space capability, strengthen and increase international cooperation," etc.²⁴⁵

Moreover, Australia has increased military cooperation with the United States through the Wideband Global Satellite (WGS) communications system and the Space Situation Awareness (SSA) partnership. The WGS system consists of six satellites and improves "the communications support" to Australian "deployed forces in a cost

²⁴⁴ Commonwealth of Australia (2013), *Australia's Satellite Utilisation Policy*, Department of Industry, Innovation, Science, Research and Tertiary Education of Australia, 3.

²⁴⁵ *Ibid.*, 2.

effective manner.”²⁴⁶ Australia entered a partnership with the United States in 2007 to access the system. On the other hand, the SSA is for “the monitoring and tracking of orbiting space-based objects such as satellites and debris using ground-based radar and optical stations.”²⁴⁷ Australia signed this bilateral treaty with the United States in 2013.²⁴⁸ This international cooperation in the military space sector is able to be arranged due to Australia’s “favorable geographical location and abundant landmass.”²⁴⁹

Yet still, Australian international engagement is toward programs related to infrastructure, such as space vehicle tracking and geospatial information, and its space policy does not contain space activities, such as satellite manufacturing, manned space flight, independent launch capability, and exploration to other planets.²⁵⁰

3. Investment in R&D

The space budget information of Australia is transparent; it has been reported near-biennially to international organizations like the OECD and World Bank. According to the data, Australian private sector’s investment in R&D for the aerospace industry has been limited. In 2001, only \$2.9 million was invested in R&D by the Australian private sector, while the ROK’s expenditure was \$621 million in the same year.²⁵¹ The Australian private sector’s R&D expenditure on the aerospace industry had increased to \$81.8 million in 2006 as its peak, but it shrunk to \$23.6 million in 2011 (see Figure 13). Moreover, the private sector’s R&D investment for the space industry was irregular when

²⁴⁶ Australian Department of Defense, “Wideband Global Satellite,” *Defence Annual Report 2007–08*. http://www.defence.gov.au/AnnualReports/07-08/vol2/ch3_02_wgs.htm.

²⁴⁷ Australia-United States Ministerial Consultations, “Australia-United States Space Situational Awareness Partnership,” Department of Foreign Affairs and Trade of Australia. <http://dfat.gov.au/geo/united-states-of-america/ausmin/Pages/australia-united-states-space-situational-awareness-partnership.aspx>.

²⁴⁸ Deganit Paikowsky, Gil Baram, and Isaac Ben Israel, “Trends in Government Space Activity and Policy in 2013,” *Astropolitics*, 12, no.2-3. 109. DOI:10.1080/14777622.2014.961889.

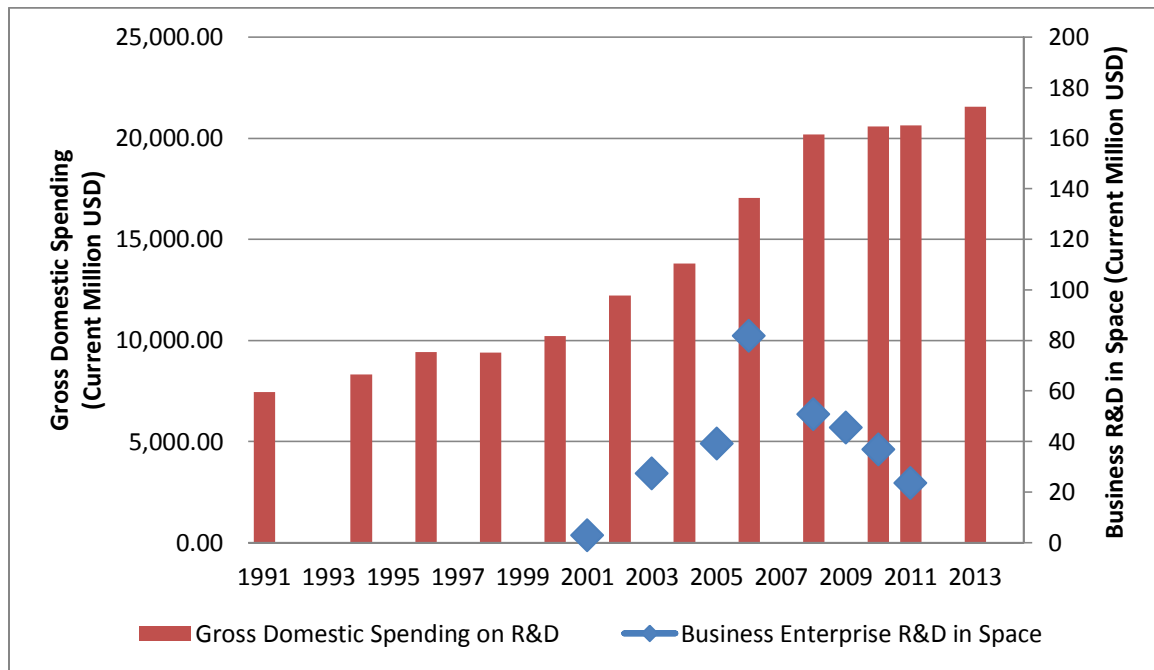
²⁴⁹ Moltz, *Asia’s Space Race*, 160.

²⁵⁰ Department of Industry, Innovation, Science, Research and Tertiary Education of Australia, “International Engagement,” Australian Government, accessed on November 1, 2016. <http://www.industry.gov.au/industry/IndustrySectors/space/Civil-space-coordination/Pages/International-Engagement.aspx>.

²⁵¹ OECD.Stat, “Business Enterprise R-D Expenditure by Industry,” accessed October 28, 2016, <http://stats.oecd.org>.

compared with the total R&D budget of Australia. Australia's GDS on R&D has also been reported biennially; contrary to the R&D expenditures by the private sector, it has been increased gradually (see Figure 13). The fact that aerospace R&D by the private sector is decreasing while domestic R&D spending is increasing shows that Australia's space field is immature.

Figure 13. Australia's R&D Spending



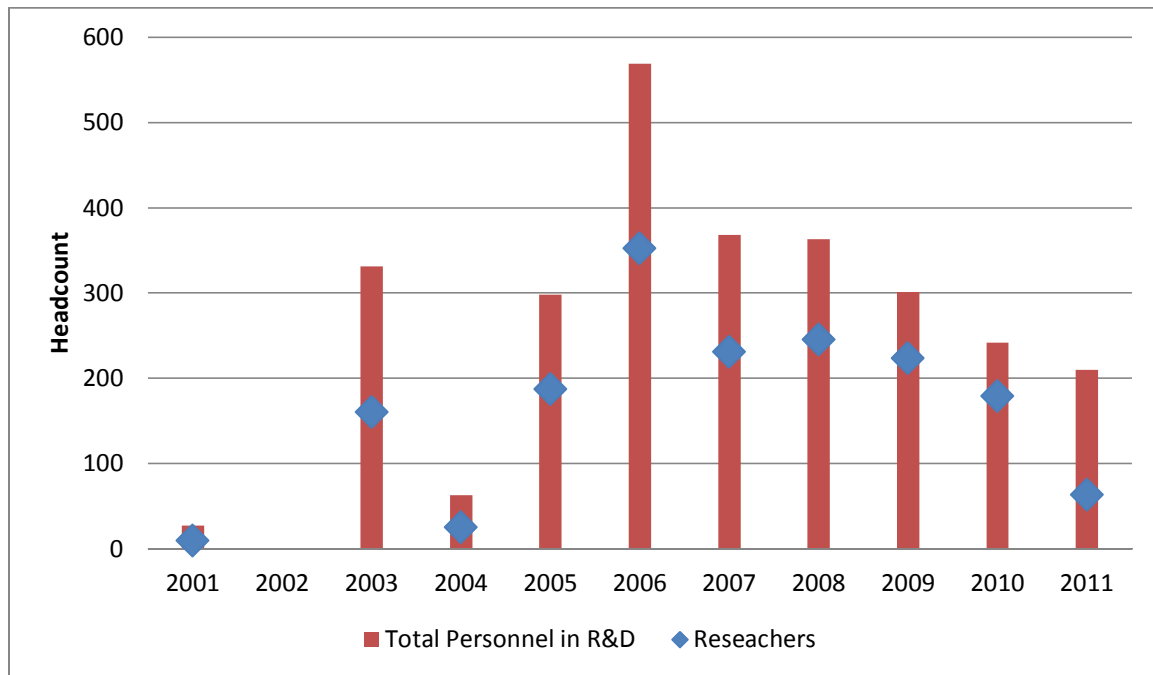
Source: OECD (2016), Gross domestic spending on R&D (indicator), accessed on October 21, 2016, doi: 10.1787/d8b068b4-en; OECD.Stat, "Business Enterprise R-D Expenditure by Industry," accessed October 28, 2016. <http://stats.oecd.org>.

4. Human Resources

Australia has scanty human resources in the R&D sector for a space industry. Data about air and space enterprises' R&D personnel, which are reported to the OECD, shows that the average number of Australian space researchers from 2001 to 2011 was 167 personnel, and 277 is the numerical mean of total personnel in the R&D sector (see

Figure 14). On the other hand, the headcount of space researchers per 1,000 employed personnel was below nine until early in the 2010s.²⁵²

Figure 14. Australia's R&D Human Resources in Aerospace industry



Source: OECD.Stat, "Business Enterprise R-D Personnel by Industry," accessed October 28, 2016. <http://stats.oecd.org>; data for 2002 is confidential.

C. DIFFERENCES WITH THE ROK SPACE PROGRAM

1. Early Aspirations for Space Capability Regarding Dependency

The most significant difference among the three countries' space programs derives from the early perspectives on space capability and the value or risks of dependency. In fact, the ROK's starting point was in the middle of Israel's and Australia's case. The ROK selected two tracks: it sought to acquire international assistance in civil and commercial space in order to achieve its goals through a catch-up strategy as a latecomer, while it relied on foreign space capability, especially U.S. assets, for military purposes.

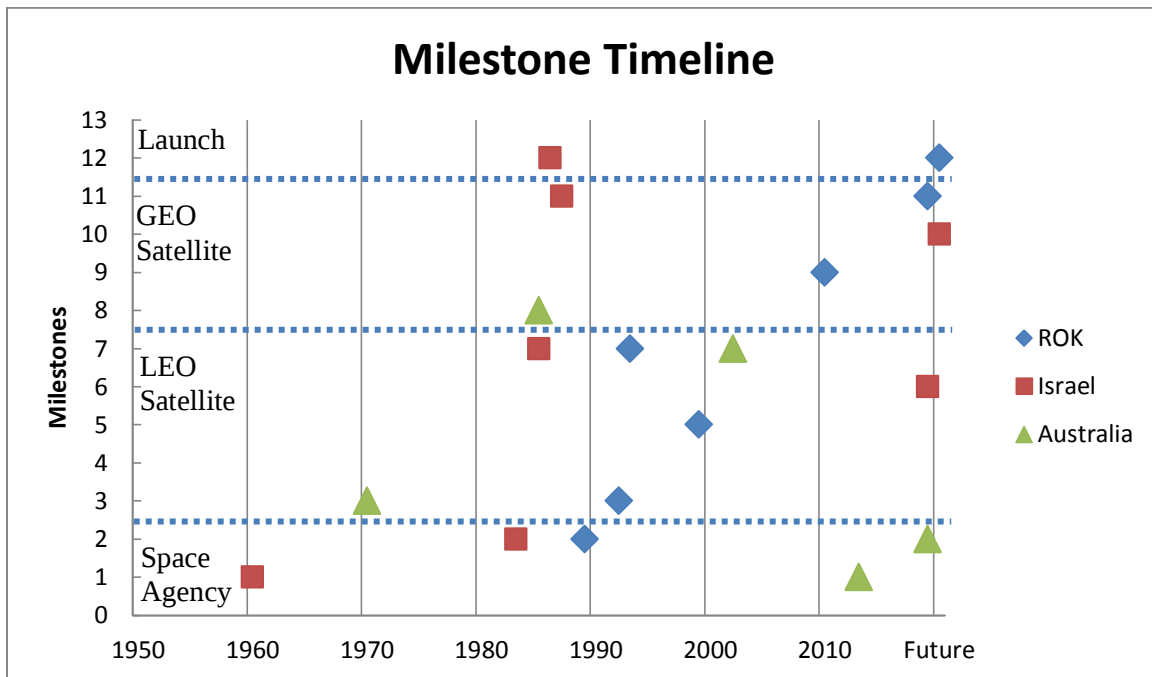
²⁵² OECD (2016), Researchers (indicator), accessed on October 21, 2016, doi: 10.1787/20ddfb0f-en.

Israel's main objective in its space programs was to achieve independent space capability in order to diminish national security concerns. To reach this goal, Israel focused on autonomous development of reconnaissance and communication satellites for military purposes. Moreover, Israel developed a self-reliant launch capability through its Shavit rocket and launch site on its territory, even though it has limitations on payload weight and selection of orbital direction due to Israel's unique geographic location.

By contrast, Australia has preferred a less costly client status for its space capability. Australia did not put an emphasis on independent space capability. The development of Australian satellites was not seen as a national security priority. Rather, Australia purchased satellites from foreign enterprises and profited by foreign satellite data in the fields of communication, broadcasting, and the environments of the atmosphere and the ocean. Instead, Australia offered Western space powers authorization to use its territory to build space observation and radar sites, as well as missile test ranges. This was the most affordable course that Australia could follow, because the interests of Australia and the interests of leading Western space-faring nations were quite compatible.

The Milestone Timeline shows the results of the aspirations of the three countries well (see Figure 15). Following the foundation of a national space office and agency, Israel produced LEO and GEO satellites locally and launched a LEO satellite on its own launch vehicle. Except launch capability to GEO, which is hard to achieve for Israel due to its difficult location, Israel accomplished all of the top milestones. By contrast, Australia procured almost all of LEO and GEO satellites via purchase except some LEO satellites, *WRESAT*, *Oscar-5* and *Fedsat-1*, and uses satellite data from foreign countries. Moreover, Australia has not established its own national space agency, but only has a Space Coordination Office for the purpose of administration in 2013.

Figure 15. Space Programs' Milestone Timeline



Adapted from Danielle Wood and Annalisa Weigel, "Charting the Evolution of Satellite Programs in Developing Countries – The Space Technology Ladder," *Space Policy* 28 (2012), 16–17; added Israel and Australia's data.

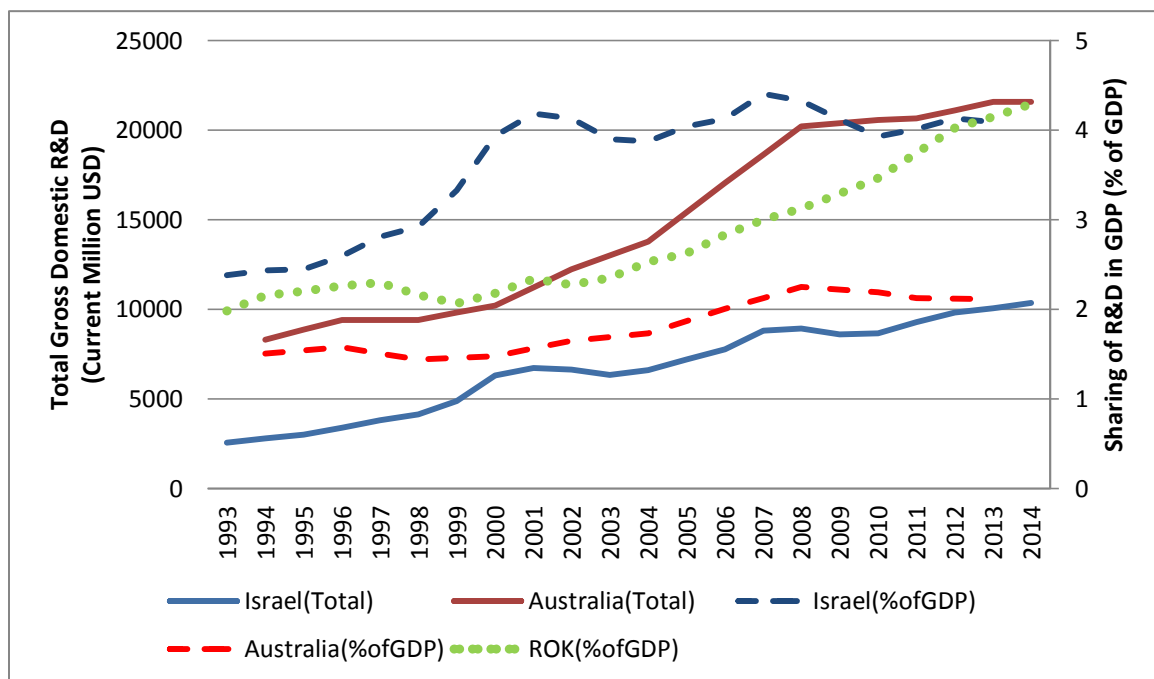
2. Investment in Space

The three countries also have different features in R&D investment in terms of budget and human resources. First of all, the ROK has invested in the space R&D sector irregularly according to the examination in Chapter III. On the other hand, Israel has invested reliably high expenditures to space based on its defense budget.

Israel invested \$2.8 billion in its total domestic R&D budget in 1994, and the amount of investment was increased \$10.3 billion in 2014. When we look into the data of total Australian expenditures on R&D, it has put more money into R&D generally throughout the period of analysis; Australia's total budget for R&D exceeds Israel's at \$8.3 billion in 1994 and \$21.6 billion in 2014 (see solid lines in Figure 16). Israel has invested less than a half of the expenditures compared to Australia; however, Israel's share of the R&D budget in GDP far exceeds Australia's R&D share. While Australia's share of the R&D budget in GDP was 1.56% in 2001, Israel invested 4.2%. The most

recent data shows that Israel maintains twice the investment in R&D in terms of its share of the R&D expenditures (see dash lines in Figure 16). It is hard to confirm that Israel has also a commensurate effort in space with data that fails to specify the space field itself. Nevertheless, we can estimate that Israel's R&D efforts have been higher due to the facts of the Israeli space program's characteristics, which are led by the government's ample defense budget, relatively high level of space technology, and major role of the space industry in the Israeli economy.

Figure 16. Comparison of Expenditures on R&D by Country

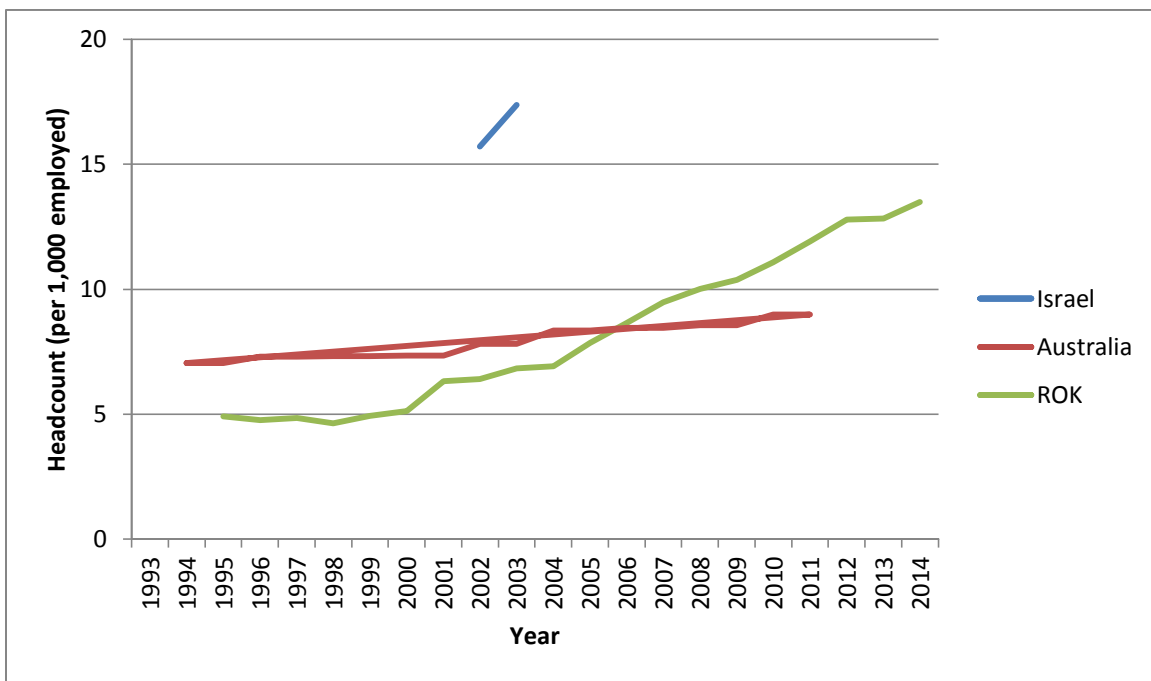


Source: OECD (2016), Gross domestic spending on R&D (indicator), accessed on October 21, 2016,. doi: 10.1787/d8b068b4-en.

In this regard, the ROK's effort in R&D in terms of the share of the budget in GDP was also in the middle of the other two countries' paths (see dotted line in Figure 16). Moreover, it caught up to Israel in 2013 with more than 4% of GDP. But still, this does not necessarily mean that the ROK is putting more effort into R&D for space since 2013, because the share of the space budget in the ROK is scanty within total R&D expenditures.

Moreover, the development of researchers in terms of total researchers per capita is also more mature in Israel than in the ROK or Australia, even though the number of ROK researchers has grown. Israel reported data of the number of researchers per 1,000 employed personnel only two times in 2002 and 2003; however, the number of 17 researchers per capita is considerably higher than the ROK's six and Australia's eight researchers per capita (see Figure 17). Here, the ROK shows rapid growth since the mid-2000; however, the increase in the actual number of researchers in the ROK's space sector is insignificant. According to the statistics for researchers of the ROK space industry from 2008 to 2014, when the KISTEP examined an aerospace industry divided into the aircraft, spacecraft, and its parts industry, the numbers are substantially the same (see Figure 6 in Chapter III).

Figure 17. Comparison of Researchers Per Capita by Country

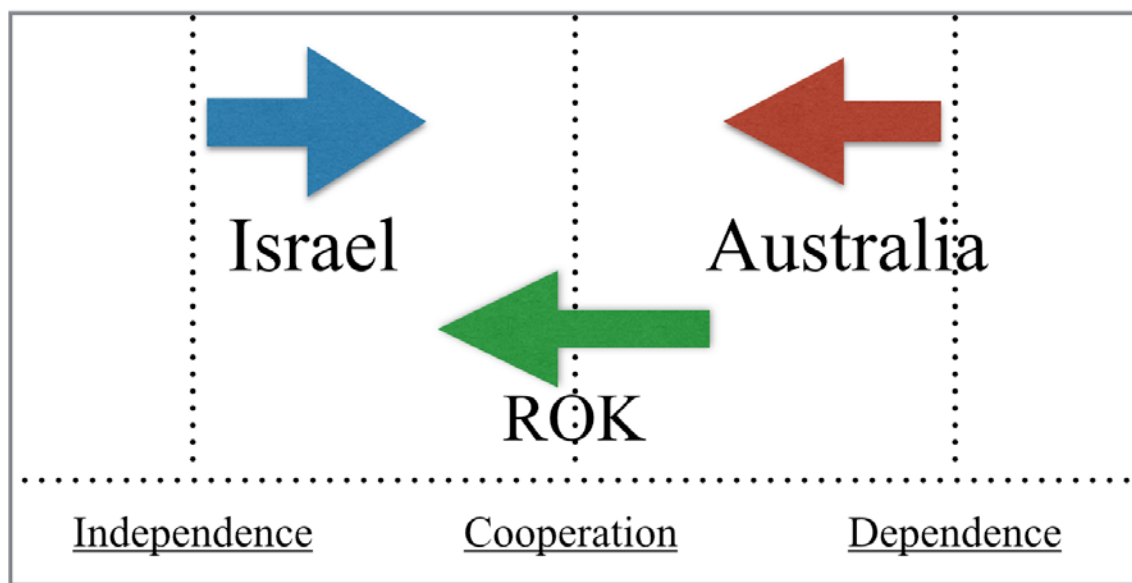


Source: OECD (2016), Researchers (indicator), accessed on October 21, 2016, doi: 10.1787/20ddfb0f-en.

3. Transition among Dependency, Independence, and Cooperation

All of the three countries are now in the process of transitions that are changing their initial space strategies. Even though each of the countries had a different starting point, particular direction, and incentive for change, they are moving within a framework of dependence, independence, and cooperation in trying to find their own sustainability in space activity (see Figure 18).

Figure 18. Transitions among Dependence, Independence, and Cooperation



Israel has explicitly announced that it is expanding international cooperation. The area of cooperation, which Israel seeks to strengthen, is spread over the civil, commercial, and military areas. This transition is obviously breaking away from Israel's initial space aspirations, which were to pursue independence, but is because of the economic burden of the space program and small domestic market. Moreover, Israel has favorable conditions for expanding cooperation. Advanced space technologies and skills, which were obtained through sufficient R&D investment, allow Israel to establish an advantageous position in international cooperation. Consequently, Israel is expected to succeed in its transition toward cooperation in civil and commercial space activities.

Australia also seeks to shift its objectives in space activity toward international cooperation, as it has announced in its national satellite utilization policy. However, the direction of Australia's transition is the exact opposite to Israel's course. Australia is pursuing international cooperation in order to escape from its long-lasting dependency in the space activity, because it realizes the importance of space capability. But Australia is mainly looking for space applications through international cooperation, not the acquisition of its own assets, such as satellites and launch vehicles. Even in military space, Australia is pursuing international cooperation through the WGS communications system and the SSA partnership with the United States.

In contrast, the ROK's movement started from a mid-point of dependence and cooperation to another intermediate point, between independence and cooperation. It plans to capture both economic and security interests. The direction is the same as Australia's transition; however, its goal is closer to Israel's final stage. In particular, launch capability and satellite manufacturing are the main fields that the ROK seeks for autonomy. Unlike Israel, however, the ROK is anticipating that it can achieve its goals based on space technology and know-how gained from foreign countries during past development projects related to satellites and launch vehicles. Still, low investment in R&D and human resources and lack of infrastructure are obstacles for these two lines of independence and cooperation when compared to Israel's and Australia's cases.

D. CONCLUSION

This chapter examined the space activities of Israel and Australia as external case studies to draw implications for the ROK's space program. The thesis selected the two countries because of their space capabilities in contrast to their own economy: Israel, which has more space capabilities when compared to the size of its GDP, and Australia, which has less space capabilities considering the size of its GDP. This arrangement creates an expectation about the status of the ROK's space program that lies midway between the two countries. Indeed, the ROK is in the middle of the two countries in terms of the path of its STL milestones, R&D investment, and development of human resources.

The most significant implication is that these phenomena are affected by a nation's needs for space. The two countries began their space activities with different initial ambitions: Israel pursued its own development due to security concerns; Australia implemented a dependent space policy for economic benefits. Israel invested in space initially in order to acquire independent space capabilities; Australia did not invest as much as Israel did because it was able to access space through international assistance. Even in military space, Israel still can enjoy independence through its self-reliable satellites while it expands international cooperation in civil and commercial space; Australia seeks to assure access to military space capability through international cooperation.

In this regard, the ROK should set a clear goal that it seeks to achieve through its space activities. The lesson learned in this chapter is not to copy the model of either Israel or Australia, but to draw a path toward a sustainable ROK space program in the future. The ROK has sought a stepping stone to prepare a transition toward autonomous space capabilities. According to the analysis in the Chapter III, however, it is still ambiguous whether the purpose to achieve space independence is for national security or national prestige. If the former is the real goal of the ROK, its path toward a sustainable space program should approach Israel's model. Currently, the ROK's destination of the policy transition is quasi-independence like Israel's; however, the direction of the transition is noteworthy because it is the opposite direction to Israel's changes today. Without abundant R&D investment and a mature level of space technologies through rich research in space like Israel has put in space activities, the ROK cannot reach its targeted point. Moreover, these efforts cannot achieve a favorable result in the short-term.

At the same time, the ROK should pay attention to the international cooperation that Australia is benefiting from. It is more judicious for the ROK not to pursue all-out independent space capabilities in order to prevent the waste of its limited resources. Although the ROK is lacking in advantages of geolocation and size of territory like Australia has, it can use its strength in human resources based on a knowledge-based society and a solid alliance with its allies, especially the United States.

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V. CONCLUSION

A. SUMMARY

This thesis examined two internal cases, the automobile industry and the semiconductor industry, which are considered as successful industries of the ROK, and two external cases, Israel's and Australia's space activities, which are useful to compare with the ROK's. The purpose of these comparative studies was to answer the following research question: what are the challenges and opportunities facing the ROK in policy-making and investment for establishing a sustainable space program? The findings here indicate that the ROK's space development has had a similar trajectory to other successful industries but that insufficient efforts have been made in some areas, such as R&D investment in the private sector and human capital promotion. But the ROK still has opportunities in space development due to the strength of its technological competitiveness in niche markets; and it will be best served by maintaining a certain level of cooperation and engagement with its major ally, the United States.

For the conceptualization of sustainability of space development, this thesis provided a definition of sustainability as a process of setting policy objectives, capital investment, and development of human resources to meet the need of a nation in space activities in an efficient manner in harmony with the country's long-term support capabilities. Under this definition, three important factors for a sustainable space program were defined: policy, R&D investment, and human resources. Accordingly, both internal cases and external cases were analyzed in terms of these factors.

The results of these comparisons are shown in the following table (see Table 3). In addition to the comparative results, this table has added analyses of the factor of sustainability, which is the most significant influencing element, in the ROK's automobile industry and the semiconductor industry and Israel's and Australia's space activities. The main sustainability factor of the ROK's space program, which left with a question mark, will be discussed in the final implications section.

Table 3. Comparison Results of ROK Space Programs with Case Studies

Elements	Sub Element	Comparative Case		ROK Space Program
		Automobile	Semiconductor	
Internal Cases	Policy	Goal-oriented	Goal-oriented	Ambiguous
	R&D Investment	Fairly high	High	Low
	Human Resources	Institutions Intensive	Researchers Intensive	Weak
	<i>Main Sustainability Factor</i>	<i>Private investment</i>	<i>Private investment</i>	?
		Israel	Australia	
External Cases	Policy Transition	Independence to Quasi-Independence with Cooperation	Dependence to Quasi-Dependence with Cooperation	Quasi-Dependence to Quasi-Independence
	Investment in R&D and Human Resources	High	Low	Med
	<i>Main Sustainability Factor</i>	<i>Advanced Technology</i>	<i>Infrastructure</i>	?

1. Comparative Study of Internal Cases

Through a comparative study with the automobile industry and the semiconductor industry of the ROK, this thesis revealed three facts regarding the ROK's space industry. First, the ROK's space policy is not clear about its goal setting and investment direction compared with other industries. Next, R&D investment for the space industry and investment by private sector in particular have been insufficient in terms of steadiness and scale. Finally, the space industry has fewer researchers and R&D institutions, and the growth in their number is slower than in the other industries.

On the other hand, these experiences are affected by the fact that suspected ROK's needs and aspirations toward space are national prestige rather than national security or the development of science and technology. The setting of policy objectives, capital investment, and development of human resources are influenced by a nation's needs and aspirations. The ROK's space policy emphasizes world ranking, but is characterized by poor investment by the private sector and few human resources, despite advanced technology. First, the amount of investment depends on specific space projects in order to achieve the targeted ranking, and the fact that the space industry is perceived as a government-led activity affects the investment climate. Next, the policy setting has raised uncertainties in decisions by private business on whether to invest or not. Accordingly, failure to attract investment by the private sector, unlike in the automobile industry and the semiconductor industry, also leads to a failure in human resource development. Consequently, this immaturity of private sector participation leads to a vicious circle that makes it hard to break the recognition that space is a government-led industry. Above all, this problem is well represented in the fact that there is no chaebol, which plays an important role in the Korean economy, in the space industry.

This result will be an obstacle to a sustainable ROK space program in the future. Due to the fact that a space industry is related to not only the civil and commercial sectors but also military space, the space industry cannot be evaluated in the same way as other manufacturing industries; however, it also needs to have proper policy and investment, especially from private sector, in order to ensure future sustainability.

2. Comparative Study of External Cases

The three countries, Israel, Australia, and the ROK, have different starting points compared each other in their space policies in regard to dependency. Israel started its space program in order to solve concerns about national security and focused on military space capability at first. Australia relied on foreign assistance in order to fulfill its needs in civil, commercial, and military space activities from the beginning. The ROK commenced its space programs with international assistance as a stepping stone toward independent space capability in civil, commercial, and military space.

These origins of space aspirations affected each country's performance in space programs. The three countries' space programs in the STL show that each country's goal for space activities was reflected in the outcomes. Israel has been steadfast in its ability to build and launch its own satellite by its own launch capability, beginning with the establishment of a national space agency. Australia, however, purchased most commercial satellites from foreign companies while it has had some intermittent satellite programs by its own. The absence of a national space agency and the lack of a plan for independent launch capability also come from the same reason. In contrast, the ROK has built its satellites locally based on technologies and skills acquired from international partners through initial programs for satellite development.

Next, the level of R&D investment and development of human resources by each country has also been affected by the objectives of the three countries. Even though this thesis did not compare data of the space sector only (due to lack of data), it is clear that Israel has made a major investment in space in terms of funding and human resources based on other information. Israel maintains a high level of total R&D investment and number of total domestic personnel involved in research; Australia is the opposite of Israel; and the ROK's beginning was similar to Australia's, but it is now emulating and seeking to become more like Israel. However, this does not necessarily mean that the ROK's efforts in the space sector have become sustainable due to the factors examined in Chapter III.

Moreover, Israel and Australia are pursuing the expansion of international cooperation, although each country's purpose of pursuing is different. The ROK is changing its policy direction; however, it seems to emphasize independent space capability, especially in military space and the launcher program. But, it is unclear how insufficient domestic R&D investment and human resources will affect the sustainability of the ROK's space program.

B. IMPLICATIONS

Four implications can be derived from these findings for the sustainability of the ROK's space program. In order to take a path toward a sustainable space program, the ROK should:

- Redefine national needs and aspirations for its space activities;
- Plan to expand private investment, especially in space R&D;
- Invest in the space sector with a long-term vision; and
- Continue to strengthen ties with international partners.

First of all, the most significant implication, which is derived from this thesis, is that sustainable space development should be based on clear goal setting. The selected elements for comparative analysis, R&D investment and human resources, are strongly influenced by the selection of national policy objectives. The two domestic industries that are selected as the internal cases were stimulated by private investment and developed human resources along with this investment. Even in the external cases, the performance of investment and human resource development in each country varied according to their policy direction.

In this regard, the ROK should clarify the objectives of its space activity. As many studies have stated, national prestige could be one of the objectives that a country seeks to achieve; however, it is unlikely to achieve long-term sustainability when a government makes a space policy that orients performance only based on the objective of national prestige. National prestige could be a primary objective for the ROK due to its unique security environment, if the strategy provides relative security advantages through demonstrating advanced space capability ahead of its competitor. But, the ROK in fact interrupted its main astronaut program despite a large initial investment. The ROK should not aim to join the world's top ten space powers, but instead should adopt a strategy that states clearly the specific purpose of space utilization to the country.

Adoption of this objective also affects the private sector's investment climate because investment stability has deteriorated. Moreover, the space industry is a hard area

to secure the profitability of private businesses. Few businesses are willing to invest in a space industry that lacks profitability as well as stability. Not surprisingly, the investment in the space industry by private sector in the ROK is considerably low. Thus, the space industry as a whole is affected easily by the government's and public sector's investment. In other words, inconsistent government R&D investment leads to instability of the whole market. Therefore, the expansion of private R & D investment is derived from the stability of the market based on the government's consistent investment.

In addition, the ROK should now find an alternative to its catch-up strategy, which drives the ROK to achieve space milestones in a relatively short period of time, and focus instead on long-term investment. In fact, the ROK is in an unfavorable situation to resist the temptation to adopt a catch-up strategy, because it is in a situation in Northeast Asia where security concerns are accelerated, it is confronting a major enemy (North Korea), and it is surrounded by advanced space powers. In this context, it is easy to feel impatience. However, as can be seen in the case of the ROK's domestic industries and Israel's space program, stable space capability is not achieved in a short period of time.

Finally, the ROK must seek ways to expand international cooperation rather than pursue independent space capability. As shown in the case of Israel and Australia, each country changed the center of its policy direction toward international cooperation even though their key drivers are different. However, the ROK, which does not have the high technologies and skills of Israel or the advantageous geographical advantages of Australia, has few sustainability factors to pursue independence in its space activities. In this respect, the recent United States-Republic of Korea Framework Agreement for Cooperation in Aeronautics and the Exploration and Use of Airspace and Outer Space for Civil and Peaceful Purposes, which signed in April 27, 2016, and became effective in November 4, 2016, would be an appropriate opportunity to expand civil and commercial cooperation with the United States.²⁵³ This agreement calls for civil space cooperation

²⁵³ Diplomacy in Action, "United States-Republic of Korea Framework Agreement for Cooperation in Aeronautics and the Exploration and Use of Airspace and Outer Space for Civil and Peaceful Purposes," accessed in November 16, 2012, U.S. Department of States. <http://www.state.gov/r/pa/prs/ps/2016/04/256625.htm>.

between the two countries by “exchanges of scientific data and exchanges of scientists, engineers, or other experts” among implementing agencies, such as NASA, the National Oceanic and Atmospheric Administration (NOAA), KARI, KASIAT, and the Korea Meteorological Administration (KMA).²⁵⁴ In addition to this, the ROK should look for more engaged cooperation in the field of military space, as in the case of Australia’s SSA partnership or WGS communication systems. An attempt toward autonomous military space capability without ripe space technologies, unlike Israel’s case, can undermine the sustainability of space development because a lot of resources and efforts are consumed. In particular, it is expected that an astronomical budget will be put in place for the independent construction of the Korean Air and Missile Defense (KAMD) and the Korea Massive Punishment and Retaliation (KMPR), which the ROK military is currently pursuing against North Korea’s threats.

C. CONCLUSION

The future of space activities of the ROK is not as pessimistic as some of the conclusions of this thesis may seem to indicate. The criticisms about the prospects for sustainable growth in the ROK’s space program aim to provide the basis for hopeful suggestions for successful development and increased sustainability. While there may be many concerns, it is clear that the ROK has grown remarkably in the space sector in a short time and still has the potential for growth. But it is time for a new phase. To enter that phase, the only thing that the ROK needs to clarify is what it wants to derive from its space activities.

The conclusions of this thesis thus also highlight the next major question: what exactly is the niche market on which the ROK’s space program should concentrate to establish its sustainability? To find this niche, the needs of the international space market and the capabilities of the domestic space industry should be judged appropriately. Considering the domestic market alone, manufacturing satellites and launch vehicles is hardly profitable. Except in the broadcasting communication sector, the small size of the ROK’s domestic space market makes it difficult for private enterprises to expect a profit.

²⁵⁴ Ibid.

In addition, the ROK's launch vehicle business has a limitation due to the fact that leading countries' experience, price, and current market share are hard to compete with. Instead, the sale of imagery from low-cost small satellites might be a niche market for the ROK space industry because the large international companies have little activity in the field thus far.²⁵⁵

In summary, as Moltz argues, the ROK faces a difficult challenge to “catch up and maintain a competitive position in all space-related areas” due to “its economy and resource base.”²⁵⁶ Therefore, finding its own niche market is important for a sustainable ROK space program that avoids wasting resources and other efforts.

²⁵⁵ Korea Ministry of Science, ICT and Future Planning, “Segyesijang Bunseokae Gichohan Ujubunya Sanubhwa Jeonryak maryun” 세계시장분석에 기초한 우주분야 산업화 전략 마련 [Industrialization Strategy for a Space Industry Based on Global Market Analysis], accessed on November 24, 2016. http://www.prism.go.kr/homepage/entire/retrieveEntireDetail.do;jsessionid=89CAE980AF41C2AA8A5A0F1634D2F63F.node02?cond_research_name=&cond_research_start_date=&cond_research_end_date=&research_id=1341000-201000197&pageIndex=1208&leftMenuLevel=160.

²⁵⁶ Moltz, *Asia's Space Race*, 156.

APPENDIX A. COMPARISON OF R&D BUDGETS

KRW (Million, Current Currency)

Year	Automobile		Semiconductor [†]		Air and Space ^{††}	
	Total	Private	Total	Private	Total	Private
1998	1,468,998	1,432,891	970,770	926,964	20,672	15,601
1999	1,124,193	1,067,360	1,425,252	1,323,595	182	182
2000	1,465,764	1,430,729	1,045,313	986,362	302,503	81,179
2001	1,411,568	1,386,235	3,537,426	3,406,582	470,316	128,778
2002	1,641,989	1,618,439	3,933,496	3,834,160	239,827	14,961
2003	1,981,118	1,951,900	4,407,388	4,278,857	80,705	21,378
2004	2,498,065	2,448,972	5,946,556	5,857,141	196,897	107,388
2005	2,790,318	2,737,711	6,452,180	6,352,535	130,531	103,711
2006	3,198,703	3,133,570	7,430,724	7,338,991	168,826	127,646
2007	3,831,826	3,770,214	7,623,679	7,466,651	183,083	126,072
2008	3,442,680	3,350,393	7,478,411	7,427,296	28,527	10,041
2009	3,532,498	3,370,950	8,203,148	8,076,885	69,020	45,897
2010	3,999,724	3,833,602	10,186,323	10,096,163	70,269	51,439
2011	4,537,290	4,381,186	11,482,440	11,387,494	77,949	61,595
2012	4,893,457	4,752,010	13,368,737	13,247,596	158,721	13,186
2013	5,276,408	5,121,877	16,315,293	16,245,667	123,903	15,588
2014	5,876,278	5,709,687	16,805,069	16,731,974	75,492	39,508

[†]Electronic components industry including the semiconductors (before 2007), Semiconductor industry only (after 2008). ^{††}Aerospace industry (before 2007), Aircraft, Spacecraft, and its parts industry (after 2008). Source: Korea Institute of S&T Evaluation and Planning, "Report on the Survey of Research and Development in Science and Technology," ROK Ministry of Science and Technology.

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APPENDIX B. HUMAN RESOURCE IN AUTOMOBILE INDUSTRY

Year	R&D Performing Institutions	Personnel Engaged in R&D	Researchers Degree (Person)		
			Doctor	Master	Bachelor
1998	130	10,669	221	2,264	6,485
1999	152	10,080	192	2,353	7,057
2000	193	10,520	171	2,607	7,136
2001	217	9,483	242	2,426	6,274
2002	239	10,381	345	2,362	6,799
2003	251	12,154	360	3,010	8,142
2004	289	14,193	362	3,584	9,597
2005	277	15,486	463	3,949	10,584
2006	370	18,125	573	4,296	12,449
2007	479	19,597	506	4,494	13,946
2008	585	20,930	704	4,822	14,646
2009	663	20,890	726	4,848	14,522
2010	686	22,191	626	5,118	15,178
2011	789	24,724	730	5,427	17,704
2012	932	27,582	797	5,800	19,479
2013	991	28,261	815	6,129	20,309
2014	1,215	30,842	847	6,626	22,233

Source: Korea Institute of S&T Evaluation and Planning, "Report on the Survey of Research and Development in Science and Technology," ROK Ministry of Science and Technology.

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APPENDIX C. HUMAN RESOURCES IN SEMICONDUCTOR INDUSTRY

Year	R&D Performing Institutions	Personnel Engaged in R&D	Researchers Degree (Person)		
			Doctor	Master	Bachelor
1998	111	8,755	602	2,867	4,995
1999	160	7,617	568	2,685	3,898
2000	303	8,190	643	2,737	4,359
2001	397	24,687	1,911	7,129	13,280
2002	454	26,897	1,961	8,052	14,449
2003	456	29,922	2,455	9,351	15,708
2004	486	35,271	2,951	11,097	19,824
2005	454	41,740	3,687	12,828	21,729
2006	588	48,015	4,153	14,196	25,967
2007 [†]	684	49,937	4,322	14,611	27,270
2008 ^{††}	219	41,465	3,682	11,963	22,698
2009	262	42,547	3,828	12,207	23,322
2010	263	47,334	4,364	13,375	26,196
2011	289	50,488	4,782	14,083	28,016
2012	330	49,974	4,907	13,965	27,647
2013	328	51,855	5,218	13,911	28,919
2014	347	54,335	5,504	14,059	30,642

[†]Electronic components industry including the semiconductors (before 2007). ^{††}Semiconductor industry only (after 2008). Source: Korea Institute of S&T Evaluation and Planning, “Report on the Survey of Research and Development in Science and Technology,” ROK Ministry of Science and Technology

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APPENDIX D. HUMAN RESOURCES IN AIR AND SPACE INDUSTRY

Year	R&D Performing Institutions	Personnel Engaged in R&D	Researchers Degree (Person)		
			Doctor	Master	Bachelor
1998	3	239	25	103	108
1999	1	3	0	0	3
2000	7	699	29	228	438
2001	16	1,243	77	443	679
2002	13	938	46	340	546
2003	17	836	46	340	445
2004	19	867	49	314	470
2005	18	1,455	64	523	796
2006	21	1,587	63	580	858
2007 [†]	23	1,631	85	622	884
2008 ^{††}	23	1,033	31	370	582
2009	30	1,142	14	386	678
2010	29	1,057	38	411	571
2011	33	1,210	43	459	652
2012	40	1,304	49	511	680
2013	45	1,107	35	435	597
2014	57	1,294	48	490	696

[†]Aerospace industry (before 2007). ^{††}Aircraft, Spacecraft, and its parts industry (after 2008). Source: Korea Institute of S&T Evaluation and Planning, "Report on the Survey of Research and Development in Science and Technology," ROK Ministry of Science and Technology

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APPENDIX E. R&D INVESTMENT, ISRAEL AND AUSTRALIA

Year	Israel		Australia		
	Gross Domestic Spending on R&D (Million USD)	Sharing of GDP on R&D (% of GDP)	Gross Domestic Spending on R&D (Million USD)	Sharing of GDP on R&D (% of GDP)	Business Enterprise R&D in Space (Million USD)
1991	2,134	†	7,451	†	†
1992	2,358	†	†	†	†
1993	2,562	2.384	†	†	†
1994	2,812	2.436	8,309	1.507	†
1995	3,007	2.444	†	†	†
1996	3,391	2,596	9,413	1.580	†
1997	3,822	2.811	†	†	†
1998	4,414	2.921	9,396	1.437	†
1999	4,893	3.327	†	†	†
2000	6,299	3.932	10,219	1.477	†
2001	6,721	4.185	†	†	2.9
2002	6,631	4.132	12,219	1.649	†
2003	6,332	3.9	†	†	27.3
2004	6,614	3.875	13,788	1.732	†
2005	7,197	4.039	†	†	39.2
2006	7,782	4.128	17,048	2.004	81.8
2007	8,818	4.407	†	†	†
2008	8,926	4.329	20,198	2.248	50.7
2009	8,605	4.121	†	†	45.5
2010	8,659	3.930	20,572	2.192	36.8
2011	9,282	4.011	20,646	2.123	23.6
2012	9,829	4.129	†	†	†
2013	10,049	4.088	21,563	2.112	†
2014	10,358	†	†	†	†

†: No data for various reasons. . All data are shown as current currency. Source: OECD (2016), Gross domestic spending on R&D (indicator), accessed on October 21, 2016, doi: 10.1787/d8b068b4-en (Accessed on 21 October 2016).

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APPENDIX F. HUMAN RESOURCES

Year	Researcher Per Capita (per 1,000 employed)			Total Personnel in R&D	Researcher in R&D
	Israel	ROK	Austria	Australia's Space Industry	
1994	†	†	7.05	†	†
1995	†	4.925	†	†	†
1996	†	4.772	7.311	†	†
1997	†	4.842	†	†	†
1998	†	4.646	7.316	†	†
1999	†	4.943	†	†	†
2000	†	5.127	7.342	†	†
2001	†	6.324	†	27	9
2002	15.705	6.407	7.826	†	†
2003	17.378	6.839	†	331	160
2004	†	6.926	8.341	63	25
2005	†	7.867	†	298	187
2006	†	8.639	8.459	569	352
2007	†	9.471	†	368	231
2008	†	10.015	8.562	363	245
2009	†	10.384	†	301	223
2010	†	11.084	8.982	242	179
2011	†	11.916	†	210	63
2012	†	12.787	†	†	†
2013	†	12.840	†	†	†
2014	†	13.495	†	†	†

†: No data for various reasons. Source: OECD (2016), Researchers (indicator), accessed on October 21, 2016, doi: 10.1787/20ddfb0f-en.

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