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Spin-offs from space technology to cultural life

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Abstract

In this paper, we examine the points of similarity and difference between Korea, Japan, and the USA in terms of the spin-off effects of space technology on cultural life. In Japan and the USA, spin-off effects of space development research by government funded research centers are diffusive while in Korea they are interruptive. Spin-offs of research results impact cultural life via technology transfer and commercialization in businesses. This is because the Korean aerospace industry has progressed largely based on an overall system, but the promotion of internal parts and sub-systems, which can trigger technological development and spin-off effects in manufacturing, has been neglected. In the case of the KARI, the government funded research center, we argue that it is necessary for KARI to devote more resources to transfer (or promote spin-offs of) space technology to small and medium-sized businesses and other industries.

Keywords: *Space Development, Sectoral Innovation System, Satellite, Space Launch Vehicle, Resource, Diffusion, Complex Product System, Technology Gap*

1. Introduction

The purpose of this study is to deduce the policy implications of Korean aerospace development via analysis of the spin-off effects of space technology on cultural life by comparing the cases of Korea, Japan, and the USA. We will analyze the points of similarity and difference between Korea, Japan, and the USA in terms of the spin-off effects of space development research on cultural life(spread of technology, technology transfer, and commercialization of technology) as developed by government funded research centers and promoted by businesses[1].

Compared to technology on earth, technology in space is characterized by the special conditions of usage such as zero gravity, vacuum state, high-strength radiation, high-temperature difference, demands for light weight and high reliability. In addition, minimal change in the design of systems, extremely frequent inspections and testing are needed. Since technology to be used in space is different, conventional technology already in use on the earth suffers from limitations when used in space. Comprehensive inspection of space devices and technology is required to secure high reliability in use. Due to these inherent high-quality characteristics, proven space technology is widely sought after and applied to other industrial areas[2].

The first types of direct spin-off in which proven technology has spread to nongovernment sectors are cases such as gyro technology, structural analysis, heat resistant materials, and GPS car navigation. The next type of spin-off is R&D driven, where the metaphysics was originally established in other areas, but subsequently intensive R&D was done for the purpose of space development, with consequential spread to nongovernmental sectors. Examples include solar cells, fuel cells, and the reverse osmosis system.

Most research centers in space development throughout the world strive for technology transfers, improvements in public services, and knowledge diffusion or positive spillovers from research. In order to

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promote the use of R&D results from space development research centers, awareness should be raised about how nongovernment (or private) enterprise can use the research results, and an environment conducive to enterprise use should be maintained [3].

In this study, we explore the characteristics of spin-off and diffusion of space technology in three countries: Korea, Japan, and USA.

Table 1. Definition of Characteristics in Spin-off and Diffusion of Space Technology [4]

Countries	Contents	Characteristics
Korea; Japan, USA	Transfer, Diffusion of Space technology	disconnected ↔Diffusive

2. Spin-offs of Korean Space Development

2.1 Spin-offs of Korean Technology in the Aerospace Industries

Since the aerospace industry is a knowledge intensive industry where the effect of technical spin-off is very big, it is an essential industry for Korea. Although Korea is poor in natural resources, it can potentially achieve a high level of development through technology. The industry is a strategic industry playing an important role in industrial structure. Due to its leading-edge nature, accuracy in systems, high-tech management skills base, a broad range of related industries, and intellectually labor-intensive characteristics, the aerospace technology has a huge spin-off effect on other areas.

According to an actual survey of the current state of the aerospace industry by the Korean government, Korea Aerospace Industries, a mid-sized firm, is now making use of its technology of "on board computers(OBC)" obtained from the development of Arirang-2/KOMPSAT-2 by adopting it to the aircraft industry through on board computer data processing technology. The company Satrec Initiative is making use of satellite technology (such as low noise power units) by applying it to nuclear safety (such as environmental radiation detectors) through its nuclear use commercial program. The company KoSPACE is making use of satellite communication technology(such as M/W component design for satellite payloads) by applying to

satellite terminals (such as Ku-band LNB and BUC).

In the field of launch vehicles Doowon Heavy Industrial Co. is applying its "technology of pressure vessel welding for launch vehicles" and "technology of spinning" , obtained from the R&D of KSR-3 and KSLV-1 to the manufacturing of internal pressure vessels and the missile Raydome. Top Engineering Co.is applying its "technology of launch control" and "simulator technology", obtained from the R&D of KSLV-1 to the ship building industry, ship automation, and ship simulators.

Table 2. Spin-off Examples of Aerospace Technology Industries in Korea [5]

Implementing company	Spin-off	Field of application	Original technology	Technical field	Results	Related national projects
Korea Aerospace Industries)	data analysis technology	aircraft development	satellite on-board computer	satellite	locally develop aircraft on-booard computer	KOMPSAT-2
Doowon Heavy Industrial Co.	polarity variable welding device	pressure vessel manufacturing)	launch vehicle pressure vessel welding	space launch vehicle	reduce operating costs	KSLV-1

Doowon Heavy Industrial Co.	SPINNING	Raydome	SPINNING	space launch vehicle)	technology deveopment	KSR-3
Top Engineering	ship automation technology	Ship industry	KSLV-1 launch control technology)	ground system for space launch vehicle)	product diversification	space center construction project)
Top Engineering	ship simulation technology	marine transportation industry	KSLV-1 simulator technology	space launch vehicle	Product Diversification	KSLV-1
Rings Wave	manual investigation through dielectric resonator	telecommunications industry	filtering technology for satellite communications	satellite	Product miniaturization	satellitedevelopment

2.2 The spread of Research results via Industry-University-Institute Cooperation in Korea

In the innovation program for space development in Korea, the characteristics of technology diffusion is to be studied by reviewing knowledge transfer, public service performance, and knowledge spread by the Korea Aerospace Research Institute, a research organization specialized in exploring space. Korea Aerospace Research Institute has built up an information system based on the Web for web users to access and search the data of research results, classified according to the data category, and produced by the Aerospace Knowledge Information System Korea Aerospace Research Institute is highly regarded as a provider of user friendly services to external web users, because it has built up a service system for sending requested data to users via e-mail according to the key words registered by external web users. It also plays an important role as a source of knowledge to diffuse research results.

In spite of the continuous effort to expand the transfer of technology by increasing successful distribution of research results and by increasing licensing fees, compared to other areas of technology in Korea and the same area of technology in foreign countries, the diffusion of research results has been weak in recent years.

The Korea Aerospace Research Institute is trying to transfer and diffuse aerospace knowledge to the youth and general public by internally installing a new Exhibition Center, and is operating a diverse and fruitful program of study field trips. Externally, it organizes nationwide events on aerospace technology, and provides special lectures and exhibitions for the diffusion of technology and culture[6].

3. Spin-offs of Space Development in Japan

3.1 Examples of Technological Spin-off Effects

In Japan, the kinds of spin-off in aerospace industries can be classified into two types, based on the specific usage environment factors and conditions of aerospace devices, such as zero gravity, vacuum state, high strength radiation, high temperature difference, lightweight requirements, peak electric power and high reliability requirements.

A direct type of spin-off is one where R&D results in aerospace are directly transferred to private sectors. Examples are gyro technology, structural analysis, heat resistant materials, food safety management, and car navigation.

The R&D driven type of spin-off is one where the principles and system structures were initially pioneered in other areas, but R&D was intensively performed in the aerospace area, and then the R&D results were transferred to private sectors, in areas such as solar cells, fuel cells, and reverse osmosis systems.

In October, 2003, the Japan Aerospace Exploration Agency (JAXA) was established in order to take over the national aerospace program previously performed by ISAS, NAL, and NASDA. JAXA, as an independent government R&D organization, is focusing on industrial cooperation as a fundamental goal.

Table 3. Spin-Off Cases of Space technology in JAPAN[7]

Category	Spin-Off Case(Contribution to Living)	Enterprise Implementing Spin-Off
Spin-off cases that are transferred from JAXA's technology and based on license agreement	Water Renewal Technology for Space → Water Purification System	New Medican Tech Corporation
Spin-off cases that are transferred from JAXA's technology but not based on license agreement (paper publication, etc.)	Structural Design Technology for Space Engineering → Diamond Cut Can(Chunai "Hyouketsu")	Kirin Brewery Co., Ltd., Toyo seikan Kaisha, Ltd.
Spin-off cases that are transferred from JAXA's technology but not based on license agreement (paper publication, etc.)	Material Technology for Space Plane → Functionally-Graded Material(Spiked-Shoes for Baseball, Wristwatch, Shaver)	Mizuno Corporation, Citizen Holdings Co., Ltd., Matsushita Electric Works Co., Ltd.
Spin-off cases that are transferred from JAXA's technology but not based on license agreement(paper publication, etc.)	Deployment Technology of Solar Array Paddle in Space → Miura-Fold(Map)	Orupa Co., Ltd
Spin-off cases that are transferred from space technology owned by Japanese enterprises	Image Analysis Technology Association with Optical Sensor for Earth Observation Satellites → Sugar Content sensor for Fruits	Mitsui Mining & Smelting Co., Ltd.
Spin-off cases that are transferred from space technology owned by Japanese enterprises	Rose onboard Space Shuttle "Discovery" → Perfume of Smell of Rose blossomed in Space	Shiseido Co., Ltd.

3.2 The spread of Research results via Industry-University-Institute Cooperation in JAXA

In October, 2003, the Japan Aerospace Exploration Agency (JAXA) was established in order to take over the national aerospace program previously performed by ISAS, NAL, and NASDA. JAXA, as an independent government R&D organization focusing on industrial cooperation as a fundamental goal.

As a recent marketing activity, JAXA is aggressively promoting Private-Governmental cooperation projects by utilizing the equipment and technology of JAXA. These are done through cooperation in the following projects.

ⅰ) WINDS((InterNetworking engineering test and Demonstration Satellite,
ⅱ) Engineering Test Satellite (ETS)-VIII,
ⅲ) Japan Experiment Module (JEM or KIBO),
ⅳ) SOHLA

JAXA has various experimental devices, including devices for space environment testing, engine combustion testing, and wind tunnel testing. These devices are applied to satellites, launch vehicles , and aircrafts. JAXA provides these devices to private companies when they are not being utilized, so that private enterprise can make full use of them.

JAXA is also planning a "Space Open Lab" through which other research organizations can easily participate in aerospace development. The "Space Open Lab" is a unique system of Industry-University-Institute Collaboration. The "Space Open Lab" is a virtual laboratory for creating an aerospace-related business through Internet webpages.

JAXA is fostering aerospace-related business through this “Space Open Lab,” and provides opportunities for people with different backgrounds from various industries, universities, and research institutes to participate in their research. JAXA encourages cooperation through accelerated exchange of information, spin-offs, and spin-ins in order to realize a new type of business.

JAXA provides a support structure incorporating technical advice and introduction of business partners, in order to induce people to attend their “Space Open Lab.”

① Application Improvement of Intellectual Properties via IP Program

The JAXA is transferring intellectual property rights (such as patent rights, copyrights including software programs, remote-sensing data technologies, and technological methods) to aerospace enterprises and others
through its“IP Program".

JAXA technology is utilized practically in many areas. An example of an area other than aerospace where JAXA technology is applied is register-related technology, originally developed for satellites. Its use has expanded to submarine cables. The technology has aided the development of international telephone lines. The filter used to feed fish in the space shuttle is now commercially utilized as a depurant in aquariums for tropical fishes. Another piece of JAXA technology applicable to various industrial areas is the technology of thermal cutouts for the projectile H-II.

This technology is being applied to residential buildings. The shock-absorbing material of docking devices between satellites is being applied to the assistance devices in medical treatment. The intellectual properties and the various application ideas of the intellectual properties of JAXA are provided to the general public through their public website. The JAXA is trying to return its research results to the wider society via a continuous stream of technological spin-offs.

② Promotion of Businesses Utilizing the Intellectual Property Rights of JAXA through its “Technology Transfer Program”

The development of products in the private sector, utilizing the intellectual properties of JAXA, is a current picture of spin-offs. This can be attributed to the technical risk and issue of expense.

③ The JAXA program to support venture enterprise

A plan to promote the commercial application of intellectual properties of JAXA is to help JAXA personnel start venture enterprises by utilizing intellectual properties of JAXA. "The JAXA program to support venture enterprise" is a new program to encourage JAXA personnel to start venture enterprises. It supports JAXA personnel in obtaining the rights to intellectual properties of JAXA, and to start venture enterprises.

4. Spin-offs of Space Development in the USA

4.1 Examples of Effects of Technology Spin-offs

NASA has endeavored to expedite the spin-off of aerospace technology since 1976. It publishes an annual report of data on technology spin-offs based on its separate research centers, and gives awards to excellent research centers. Each research center profits through technology licensing, while the related industries obtain new technology from NASA and apply the technology to their industries manufacture of products.

Table 4. NASA Spinoff Technology in the US (2017 edition) [8]

Industry	NASA Technology	Spin-off
Health and Medicine	Efficient image sensor based on CMOS	CMOS dental image sesor
	Heat pipes	Heat control in brain surgery
	UV light based diagnostic test reader for astronauts	UV light based diagnostic test reader
	Liquid cooling garments for wear under spacesuits	Cooling technology used for medical, atheltic, and industrial uses
	Bone densitometer used on ISS	Results provide medical studies performed in microgravity
	Phase-change materials (PCMs)	Temperature-regulating fabrics in wraps and blankets for babies
Transportation	Reconfigurable radio through software updates	Flight tracking with receivers placed in orbit (scheduled for 2018)
	Simplified and automated CFD processes	Increased user-friendliness for commercial and governmental use
	Orion parachute recovery system	Commercial use by spacecraft companies
	Sensor that measures atmospheric carbon dioxide from space	Remote-sensing of car and truck carbon dioxide emissions
	Rot3DC — air flow modeling program	RotCFD — simplified Rot3DC
	Aircraft hydraulic testing facilities	User-friendly hydraulic carts
Public Safety	Orion video system	High-speed, compact cameras
	Dampers for rockets	Dampers for buildings
	Sensors for monitoring helicopter conditions	Sensors for monitoring train rails and predicting failure
	Vibrating wire sensor to monitor supercooled liquid water in skies	Sensor used to monitor dangerous conditions in clouds
	Nanofiber water filter	Portable water filtration system
	Vacuum chamber for Curiosity mass spectrometer	Miniaturized vacuum pump
Consumer Goods	CMOS image sensors	Phone cameras, HD video
	Spiralock threading	Low center of gravity on golf clubs
	Blue-light-cancelling lens	Clearer ski goggles
	Rechargeable silver-zinc batteries	Longer lasting hearing aid batteries
	NASA research for increased manufacturing power	Large-scale 3D printer
	NASA DEVELOP Program	Detailed imagery of vineyards
	Carbon nanotube resin	Integration into sporting goods and ships

Table 5. NASA Spinoff Technology in the US (2017 edition) (continued)[8]

Industry	NASA Technology	Spin-off
Energy and Environment	GPS correction technology	Self-driving tractors
	Controlled-release fertilizer	Used in fields and groves worldwide
	Satellite imagery	EEFlux
	Sensors that monitor power usage	Use in hotels, hospitals, offices, etc.
	Earth observation	Rainforest wildfire monitoring
	X-ray diffraction mineral analyzer	Used at mining and drug companies
	Balanced flow meter	Increased efficiency and reliability of nuclear plants
	Computer Learning Imagery Platform	Predict annual yields of farms
Information Technology	Laser imaging	Archaeology application
	Configuration-Based Aerodynamics	Commercial and governmental use
	Space Launch System data acquisition system	Commercialized and sold to aerospace companies and car companies
	Light ray-tracing software	Use across multiple industries
	Data connectors on Orion	Aviation, oil and gas exploration application
	Space operation scheduling program	Public space mission scheduling
	Solid-state power amplifier	Develop rada, communicatiotns, and defense systems
Industrial Productivity	3D-woven quartz composite, a versatile heat-shielding material	Commercialized and used in aerospace companies and race cars
	Vibration-testing equipment	Commercialized for nuclear warhead and car tests
	Former NASA astronauts	Crash course in spaceflight based on Johnson Space Center training
	Polymid aerogels	Pipe insulation in extreme environments
	Materials International Space Station Experiment (MISSE)	Space exposure testing for companies, universities, and government agencies
	Optical filters for imagers	Improved products and new devices for Materion Corporation
	Zinc-Silicate, an anti-corrosion coating	Block corrosion in certain infrastructure
	Outgassing test facility	Space industry inventions from lab
	Current and voltage sensors for Space Shuttle and Hubble Telescope	Stronger custom current sensors
	High-heat cement made with fly ash	Converts waste ash into concrete

4.2 NASA's Effort to Transfer Technology

Aerospace institutions justify space development as a “matter of principle” in pushing scientific frontiers. As human beings continue to explore beyond the boundaries of the earth into the solar system, it is argued that the human race gains inspiration through research, discovery, and understanding. The USA and advanced European nations cite space exploration and space travel as examples of human development. NASA has been supporting the utilization and commercialization of the technology they have developed, as part of their goals. The Technology Transfer Offices in the 10 research centers organized under NASA play a central role in disseminating research results and supporting services.

Each of the offices, connected by organizational networks, supports technology transfer. The spin-off project office is separately operated to support general services.

① Biz Tech

The Biz Tech service is one of programs run by NASA field centers. With this program, a small business incubator organization located at Huntsville, Alabama, is supporting the technological utilization and distribution by supplying information on technologies with developing prototypes or technologies which test the feasibility of prototypes.

② ETC(Emerging Technology Center)

The ETC (Emerging Technology Center), located at Baltimore, Maryland, as the most recent incubator of startup technologies. It has become a new member of the organization. It is a research center performing research in collaboration with Goddard Space Flight Center and universities in the USA.

③ NASA NCC

The NASA NCC, run by California State Polytechnic University, is an organization playing the role of business incubator. It supports the commercialization of space technology from the JPL (Jet Propulsion Laboratory) at NASA and the DFRC (Dryden Flight Research Center) at NASA

④ Missippi Enterprise for Technology

Mississippi Enterprise for Technology is an institution organized in the form of a consortium comprised of private enterprise, groups and organizations in local development, economic development departments in government, Mississippi University, and NASA. The institution performs the role of supporting commercialization of space technology in collaboration with technical experts at Stennis Space Center.

Specifically it plays an important role in commercializing the image data of remote exploration obtained from Stennis Space Center

⑤ SBIR (Small Business Innovation Research) program

This program provides solutions to technological problems encountered in the course of performing NASA's duties. In collaboration with private enterprise it puts commercialized technology into the market place. Every year, NASA accepts project proposals on the technology subjects from small and medium-sized enterprises

It selects some proposals and supports a series of processes needed in commercializing the technology. The SBIR, as a program for transferring space technology, operates in the management office located in Goddard Space Flight Center.

⑥ STTR(Small Business Technology transfer) program

This program, originating in SBIR, is the program that supports the start of venture businesses at universities and aids in transferring space technology to universities.

6. Comparison of Examples in Three Countries

Space industry is a knowledge intensive industry which impacts society through technological spin-offs. It creates a great ripple effect due to its intrinsic characteristics, such as the nature of leading edge enterprises, high level of systematic structures, high degrees of management technology, a high value product, and a wide range of related industries[9].

Korea, Japan, and the USA are trying to increase the application of aerospace technology to other industrial areas through the expanding efforts of spin-off space technology.

They are reinforcing the logical reasons for exploring space by creating applicable areas of space technology. Since space development is performed by the government and public organizations, the agencies for space development in each country are required to transfer and spread the research results of aerospace technology.

Table 6. Definition of Diffusion Characteristics of Aerospace Research Results in Korea, Japan, and the USA

Countries	Definition of Characteristics
Korea	Disconnected Neutral Diffusive
	① Aerospace companies such as "Korea Aerospace Industry" and "Satrac-i" apply the space technology obtained from Arirang Project, small size satellite projectile Project, and the Project of space center construction to areas such as aircraft development , nuclear power safety, shipbuilding industry, the telecommunications industry. However, spin-off examples to other areas are still insignificant. ② KARI, a specialized Korean research organization for space development endeavors to expand the information system and transfer the space technology to private enterprises, but commercialization and industrialization of the national projects are still insignificant.
Japan	Disconnected Neutral Diffusive
	① The spin-off is composed of two types; the direct type of spin-off is one where the R&D results on aerospace are directly transferred to the private sector, and the R&D drive type of spin-off is one where the principles and system structures were initially established in other areas, but the R&D was intensively performed in the aerospace area, and then the R&D results transferred to the private sector, ② JAXA, a specialized Japanese Research Organization for space development, is improving the diffusion of space technology with the collaboration of industry, universities, and research institutes through the expanded application of intellectual property right s, a program for transferring space technology, a program for supporting venture enterprises.
USA	Disconnected Neutral Diffusive
	① NASA plays a central role in applying aerospace original technology to industrial areas such as textile , electricity, medical treatment, machinery, broadcasting, construction, sports, and food production. ② NASA, a specialized American Research Organization for space development is supporting the diffusion of space technology to its incubator programs, educational programs, and external consignation, by constructing a network for technology spin-offs.
Common features	Endeavors to transfer and diffuse space development technology via increased spin-offs to other areas of industry and programs of Industry-University-Institute Collaboration.

6. Political Implications in Korean Aerospace Development

Korea, Japan, and the USA all apply space technology to other areas through expanding the spin-offs of space technology and disseminating the technology developed by public research centers. However, Korea shows symptoms of discontinuity. It can be said that this result has become apparent in the process of Korea adopting advanced technologies from foreign countries and as Korea has been absorbing general technologies such as those found in cell-phones, semi-conductors, TFT-LCD, and cars.

There exists a mismatch between the technical knowledge need by private enterprises and the technical knowledge which the "government funded research centers" and universities can provide. The innovation agents have been operating the space technology based on their own plans with an insignificant link mechanism.

Universities with professors, "government funded research centers" with researchers, and private enterprises with human resources have been constructing exclusive, closed, and isolated groups. Because of this, there has been no connecting mechanism where "government funded research centers" and universities can effectively apply the technical knowledge adopted and generated in various areas.

The effect of technical spin-offs on the other industrial areas and on production inducement is one of the important factors in fostering aerospace industries.

While in other countries such as Japan and the USA, these spin-offs of space technology appears empirically, the spin-off effect of research results in Korea is shown to be insignificant. This is because the level of technology in the area of Korean aerospace is behind developed countries, and the industry of Korean aerospace technology has progressed within the unit of a system, but there has been neglect in terms of fostering a program of internal parts and subsystems that can induce the effects of technology and production. In concrete terms, it will be necessary for KARI, as a "government funded research center," to plan more actively to transfer technology to small and medium-sized businesses, and to spread and expand aerospace technology to other industries.

In order to achieve this goal, it is imperative that Korea develop an organization exclusively responsible for the successful utilization of aerospace technology, similar to those in Japan and the USA. The beneficial effect of technology on production inducement is dependent on public policy for supporting the growth of the aerospace industry. In order to achieve this goal, technology spin-offs should be sought continuously, and a positive effort to expedite profitable activities is required.

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