ASAN REPORT

Space Technology Development:
Effects on National Security and International Stability

EDITED BY PARK JIYOUNG
JULY 2014

THE ASAN INSTITUTE for POLICY STUDIES

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About

Asan Institute for Policy Studies is an independent, non-partisan think tank that undertakes policy-relevant research to foster domestic, regional, and international environments that promote peace and prosperity on the Korean Peninsula, East Asia, and the world-at-large.

The Science & Technology Policy Program aims to provide a comprehensive public understanding of science, technology, and innovation, while assisting organizations and governments in science and technology (S&T) policy decision-making. The center provides policy recommendations and alternatives through independent and interdisciplinary assessments of socio-economic contributions of science and technology programs to the nation.

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Surnames are written first for the people from Asia.

Contents

Executive Summary 06

Chapter 1 10
Space Technology Cooperation and Its Effect on National Security and International Stability
Victoria Samson, *Secure World Foundation*

Chapter 2 33
Use of Geospatial Information for Crisis Management: the Case of the European Union Satellite Centre
Tomaz Lovrencic, *European Union Satellite Centre*

Chapter 3 52
Policy Review on Space Technology Development
Park Jiyoung, *The Asan Institute for Policy Studies*

Chapter 4 67
Perspective on Korean Space Technology Development Programs
Choi Joon-Min, *Korea Aerospace Research Institute*

Executive Summary

The use of space has become a crucial part of national security and international stability. Today the existence of a national space program is symbolic of a nation's standing in the regional security setting and also an integral part of military calculations in international security. The use of space is not only a crucial part of national security but also for a country's economic security. Developed correctly, space technology can lead to positive domestic externalities. With this in mind, it is important to understand the changing landscape of the use of space—how it is being used and developed, and who the stakeholders are. In addition, space security and stability face numerous threats, which may be manmade or natural, and for a variety of reasons. One example of a manmade threat is the widespread testing of anti-satellite weapons (ASAT), which may undermine international security and stability if intentions are not clear. With space technology becoming more widespread, security concerns over dual-use and intent have increased. To mitigate such concerns international cooperation on an agreed legal framework should be developed. While a draft treaty has been presented by China and Russia, there currently is no formal international treaty banning the placement of weapons in space. There are also no international organizations made specifically to negotiate use of space issues.

Space technology cooperation has beneficial effects on national security and international stability. However there are some roadblocks to international cooperation on space technologies, even though it can help with national security priorities. There are different values placed on various space programs, as well as different budget levels. Also, there is still a sense that technologies related to national security have to be maintained control over, so there is some unease about sharing information or collaborating internationally on national security types of programs.

Transnational security threats require transnational answers. The multiplication of non-state actors and non-state threats on the international scene demands new measures from national and transnational decision makers. In today's globalized world, it is mostly not useful to tackle security challenges from a national point of view, since many of these go far beyond national influence and require effective multilateralism in order to be handled appropriately. International cooperation has therefore become crucial in order to respond to today's global challenges.

Space-based intelligence is an important tool to affront this new reality. As an effective example of international space cooperation, the European Union Satellite Center and its use of geospatial information for crisis management is introduced. The EU Satellite Centre takes an important role as an operational entity that provides security-related analysis to support the decision making process. The EU Satellite Center, in particular, has become a very vital part of EU military strategy and national defense due to their high performance and guaranteed operational autonomy. The SatCenter engages in educational training to empower analysts with skills and knowledge and also participates in space and security programs. The existence of the SatCenter, the EU's only multinational operational entity in the area of space and security, has considerably strengthened the EU's multilateral approach to conflict management.

The increasing relevance of space technology development to states, which carry significant strategic, economic, and commercial implications, is a central issue in the national security of states. Space power will be instrumental

in 21st century Southeast and Northeast Asian diplomacy, strategy, and geopolitics. National security and economic policy makers in the region must begin to treat space power issues as core strategic interests. While space contestation is increasing, given its importance, the world is simultaneously evolving into a multipolar order, where a greater number of forces, ideas, and technologies threaten stability in space cooperation. In this regard, the areas of space development are not exceptional in reducing potential threats and sustaining stability. International society has the most pivotal responsibility to take part in this ongoing progress. Under these circumstances, the importance of strong policymaking, statesmanship, and cooperation both at the national, international, and industrial level should be stressed. This endeavor is a decades-long process in which all the related entities and actors must contribute with practical solutions.

With the escalation of space competition among four nations of Northeast Asia, Korea has launched a rigorous space technology development program since the 1980s under the strong lead of the national government. In order to create an environment for sustainable space technology development, strong governmental leadership, national economic capability, consensus and a support from the general public, and voluntary investment from the private sector are crucial. Space development in Korea is controlled by the national space development plan that goes up to 2025 with the vision of promoting the peaceful use and scientific exploration of outer space, ensuring national security, and contributing to the growth of the national economy. Korea has been successful with satellite development and finally was able to take full responsibility in KOMPSAT-3 development. With the completion of a test facility in the Naro Space Center, Korea will proceed to obtain the technical capability to become a superpower in space launchers.

At a national level, technology policymaking is complicated on account of the relationship with national security. Prioritization and trade-offs that are needed for resource constraints are impediments to successful implementation and sustainable space development.

Chapter 1.
Space Technology Cooperation and Its Effect on National Security and International Stability

Victoria Samson
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The space domain is changing and, along with it, is the use of space. Perhaps it would be more accurate to state that access to and use of space is being broadened, which in general is a positive trend, but it does have consequences which could affect the stability of the space environment. It used to be that space was the domain of a handful of countries, with the focus being on nation-states as the primary stakeholders of space assets. Now, there are over 60 countries with assets on orbit, and even more that depend upon space-gathered information and/or communication. And non-state actors like commercial entities are becoming necessary partners in discussions on how to make space a stable and reliable environment.

Part of this change in the use of space is that it is becoming an important part of national security and international stability. This comes from not only typical national security missions like communications, remote sensing, and observation, but also from the fact that space is a crucial part of how the international economy and banking system functions and hence is a necessary part of ensuring economic security and stability. The development of space capabilities often leads to positive externalities domestically, such as the research and development of offshoot technologies and an educated populace of scientists and engineers. And the prestige of national space programs can help enhance countries' standing in regional security dynamics and affect international security calculations.

Because of this change, the stability of the space environment is even more important than it was ever for international security, and as such, factors that weaken the former can also harm the latter. Things like space weather, space debris, radio frequency interference (RFI), and particularly anti-satellite weapons (ASATs) can create doubt about the reliability of space assets and thus destabilize relations on the ground.

What can also create doubt about space assets is their intent. Because space assets' capabilities can be dual-use—used innocuously or deliberately wielded as part of a military took kit, sometimes even simultaneously—one cannot examine their capabilities to get a sense of what their users intend to do with them. Instead, intent is often extremely subjective, and is therefore much harder to determine. Perception of intent relies very heavily on pre-existing relationships and can be shaped by actions. This is where international cooperation and an approach to space that recognizes its very international nature comes in handy and can have a very strong effect on stabilizing and strengthening international relations. As well, responsible space behavior can be a signal for good intent; alternatively, reckless behavior in space can sometimes be a signal for malevolent intent, or at least, lend itself to misinterpretation about the nature of a particular space asset.

Space technology and cooperation can be effectively used as a type of soft power outreach, if used properly. As it will be discussed later in this paper, China has been quite effective at using space technology programs as part of an overall effort of reaching out to potential partners. Finally, while space technology cooperation has very beneficial effects on national security and international stability, there are roadblocks that can limit how much cooperation can be reasonably accomplished. Some of this is specific to how existing space powers like the United States approach international cooperation.

Because the space domain has changed, how we handle space technologies and national security must evolve with it. The challenges are not insurmountable but still require a shift in thinking and how we view space capabilities.

Changing Nature of Space Domain

During the early part of the Space Age, space was the domain of just a handful of countries. Work in space used to be done primarily through civil national space agencies (i.e., NASA and its international counterparts). Commercial entities played a very small role.

That has all changed. At present, 11 countries have indigenous space launch capability, with South Korea being the newest one to demonstrate that capability. Over 60 entities (national governments, civil space agencies, scientific and educational groups, and commercial companies) operate nearly 1,000 active satellites. Additionally, the amount of human-created objects in Earth orbit greater than 10 centimeters in diameter that are being tracked has rocketed to 22,000 objects, which includes pieces of debris big enough to track. In Low Earth Orbit (LEO, up to 2,000 kilometers altitude), there are an esti mated 10,000 pieces of debris, with 523 satellites currently in operation.[1] Medium Earth Orbit (MEO) has currently 75 operational satellites, with around 500 pieces of trackable debris. Geosynchronous Orbit (GEO, about 36,000 kilometers altitude) has 435 satellites currently operating, along with roughly

1,000 pieces of trackable debris. Furthermore, there are an estimated half million pieces of debris that are between one and ten centimeters in diameter that are not tracked but could seriously damage satellites if they were to crash into them; the average velocity of satellites and debris is seven kilometers per second in LEO and 3.1 kilometers per second in GEO.[2] The picture just keeps getting more complicated as additional countries realize the benefits from space and put more satellites into Earth orbit, which lends itself to an increasingly cluttered picture and a higher possibility for more debris being created.

There is currently not a lot of situational awareness of why space assets malfunction—often, it is an educated guess at best. This can be disconcerting if there are pre-existing political tensions, since a malfunctioning satellite can lead countries to assume the worst and ratchet up hostilities accordingly.

By countries with the capability, space has long been used for military applications, as in intelligence-gathering, position, navigation, and timing (PNT) capacities, communications, and surveillance. Weapons have never been positioned in space and for a very long time, satellites were considered outside of the reach of enemies. In fact, many of the early arms control treaties between the United States and then-Soviet Union had special sections resolving not to interfere with “national technical means,” or spy satellites, since the concern was that if those satellites were lost, the other country would have

1. For this and other information about the satellites operating at various orbits, please go to the Union of Concerned Scientists’ Satellite Database, dated June 1, 2013: http://www.ucsusa.org/nuclear_weapons_and_global_security/space_weapons/technical_issues/ucs-satellite-database.html.
2. “The Persistent Problem of Orbital Debris,” Secure World Foundation, last updated June 27, 2013, http://swfound.org/space-sustainability-101/the-persistent-problem-of-orbital-debris/.

to assume that a nuclear attack was imminent and respond accordingly. But with more countries increasing their dependence on space and incorporating space capabilities into their national security strategies, it is increasingly possible that space assets could be interfered with as a tool of conflict.

Space is becoming an important part of national security and international stability. This comes from not only typical national security missions, but also from the fact that space is a crucial part of how the international economy and banking system functions and hence is a necessary part of ensuring economic security. The development of space capabilities often leads to positive externalities domestically, such as the research and development of offshoot technologies and an educated populace of scientists and engineers. One of the biggest issues always brought up in the United States when discussing the future of space is the role of STEM (science, technology, engineering, and math) for students. There is a real worry that most of the current space industry workforce is within a decade or so of retirement. When that generation retires, what will disappear along with it is a wealth of institutional memory about high-tech programs like space technology programs. And the prestige of national space programs can help enhance countries' standing in regional security dynamics and affect international security calculations. We saw this during the Cold War where the United States and Soviet Union competed to achieve various "first places" in space (first satellite, first man on orbit, first man on the moon), and we are seeing it now to a lesser extent in Asia between various space powers who are using space as a proxy for regional rivalry.

More broadly speaking, the relationship between science and technology policy and national security is a complicated one. Many different and often contradictory objectives must be balanced. These include determining where

to fall on the spectrum between scientific openness and military secrecy; figuring out how to make promising technologies turn into actual and usable capabilities; and prioritizing technical and military goals, without giving up one in pursuit of the other.

Major stakeholders in space are no longer just nation-states: commercial entities play a very prominent role. There is no longer a strict divide between assets that have strictly government users versus those who have solely commercial users, as the two types of users (and assets) are blurred. This can be seen in US military communications, where most of them are carried across satellites operated by commercial entities. There is also less of a divide between national assets, due to the internationalization of satellite companies. For example, a satellite could be built by a Ukrainian company in the United States and launched by a French rocket. How its state would be determined via international law is unclear, since a satellite is considered to be the property of the launching state, which could be the state which launched it or the state where it was launched. Finally, space has become internationalized in that many satellites service many different countries, so an interruption in one country's satellite may have unintended consequences elsewhere.

Threats to Space Security and Stability

Due to the national security implications of space technology and capabilities, a reliable and predictable space environment is a crucial part to ensure stability. Threats to space assets and security can have effects on the ground by weakening overall stability. These threats can be manmade or natural, deliberate or unintended, or some combination thereof.

One such possible threat is space weather, or changes in the space environment and how they affect Earth, usually through the sun's radiation affecting the Earth's magnetic fields and upper atmosphere. Solar radiation, if intense, has the potential to interfere with satellite electronics to the extent of making them stop working entirely. Additionally, the Earth's upper atmosphere can be heated from this solar activity and expand accordingly, which in turn can raise the amount of drag on satellites. Either way, if a satellite stops working during a tense situation, no matter what the cause, it can destabilize the space environment.

A couple of major space debris events over the past several years have really highlighted this issue's importance, changing earlier conceptions of what has been termed the "big sky" attitude: because space is so big, we did not really need to worry about collisions on orbit. In February 2009, an active US Iridium satellite and an inactive Russian Cosmos satellite impacted each other at an altitude of 790 kilometers. This major collision event created nearly 2000 pieces of trackable debris. Orbital debris, as mentioned earlier, travels at such high speeds that it can threaten a satellite.

Radio frequency (RF) communications are essential to satellites, which use radio waves to receive information from ground controllers and send information back. Satellites can also use radio waves for their general operations. When there is interference with the RF communications, interrupting the satellites' work, this can be unintentional or intentional.[3] Unintentional RF interference (RFI) can be traced to several causes. Sometimes it is the result of space weather and solar radiation interacting with the Earth's atmosphere; sometimes it can be caused by weather closer to the ground like rain or clouds. Manmade unintentional RFI happens when a satellite is on the same frequency as another satellite and transmits too closely to it, or when there is a communication system on the ground using the same or a similar frequency as a satellite network.

3. For a backgrounder on RFI and how it affects space sustainability, please see SWF's "Radio Frequency Spectrum, Interference and Satellites Fact Sheet," dated June 25, 2013, http://swfound.org/media/108538/SWF_RFIFactSheet.pdf.

Intentional RFI is when the satellite's communications are deliberately interfered with, often in an attempt to temporarily or reversibly do so without destroying the satellite and creating a very clear red line of a destructive attack on another country's asset. It also minimizes the possibility of orbital debris being created. It is a relatively low-tech form of attack and can be done with as simple an arsenal as a transmitter and an antenna. Intentional RFI, often referred to as "jamming," can be used in a variety of measures in limiting the adversary's ability to utilize their space assets.

While RFI can be traced back to a specific geographic location, governments can—and have—argued that they either had nothing to do with it or did not know it was happening, making it unclear at times whether the RFI was a deliberate act of war, completely innocent by-product of satellite communications, or somewhere in-between. If countries believe that another country is deliberately targeting their satellites, they do not have a lot of international recourse. The International Telecommunications Union (ITU) is responsible for making sure that GEO satellites do not interfere with other satellites at that altitude, whether it is RFI or actual physical interference. But there is no international organization charged with doing that for satellites at other altitudes. RFI is something that the satellite companies are very much concerned with but is an issue that is often glossed over for other, sexier space stability issues like ASATs.

The widespread testing of ASAT capabilities would likely undermine political and strategic stability, especially without clarity of intent. Further, testing or using debris-generating weapons could contaminate the orbital environment for decades to centuries, significantly affecting all space actors and severely undermining the long-term sustainability of space.

The United States and the then-Soviet Union both tested ASATs during the Cold War for a total of 53 times, but ultimately decided against actively using them as a tool of war, as they were considered far too dangerous and destabilizing.[4] (As an interesting point of comparison, during the Cold War, the United States held 1,054 nuclear tests, while the then-Soviet Union held 715 nuclear tests.[5]) The last Cold War-era ASAT test was in 1985, when a US F-15 targeted an aged Air Force scientific satellite; its impact created over 250 pieces of trackable debris, with the last piece finally decaying out of LEO in 2002.[6]

The first deliberate and known ASAT test in the post-Cold War period was held by the Chinese in July 2005, when they launched a modified DF-21 ballistic missile (also known as the SC-19); nothing was thought to be a target. In February 2006, the SC-19 was launched at a satellite but seems to have deliberately missed it. In January 2007, the Chinese intentionally shot down their inoperable Fengyun-1C weather satellite the SC-19 at an altitude of 860

4. Michael Krepon and Michael Heller, "A Model Code of Conduct for Space Assurance," *Disarmament Diplomacy*, no. 77 (May/June 2004), http://www.acronym.org.uk/dd/dd77/77mkmh.htm.
5. Keith Rogers, "Soviet Nuclear Legacy Surfaces at Atomic Museum," *Las Vegas Review-Journal*, September 3, 2011, http://www.reviewjournal.com/news/las-vegas/soviet-nuclear-legacy-surfaces-atomic-museum.
6. Laura Grego, "A History of Anti-Satellite Programs," Union of Concerned Scientists, January 2012, http://www.ucsusa.org/assets/documents/nwgs/a-history-of-ASAT-programs_lo-res.pdf.

kilometers. This test created over 3000 pieces of trackable debris, with an additional estimated 150,000 pieces of debris that is too small to be tracked, and could stay in LEO for decades, if not the better part of a century.

The United States held a response of sorts in February 2008, when it shot down its uncontrolled de-orbiting satellite USA-193 with a retrofitted missile defense interceptor.[7] It was done at a low enough altitude that the debris created from it de-orbited fairly quickly. As well, the United States made an effort to be very transparent ahead of time with what it was planning, how it intended to shoot down the satellite, when, and so forth.

In January 2010, the Chinese held what they termed a "missile defense" test, where an interceptor shot down a ballistic missile at a low enough altitude so that debris created fairly quickly de-orbited. While it was officially a missile defense test, it used the same interceptor as the one used during the 2007 ASAT test and so it was suspected to be testing ASAT capabilities under the guise of something else.[8] Furthermore, China held another "missile defense" test in January 2013. The interceptor used during this test is unknown. Finally, in May 2013, China launched something that they said was a high-altitude research mission, but which others believed to have been related to their ASAT program.

7. For a longer discussion of this, please see, Victoria Samson, *American Missile Defense: A Guide to the Issues* (Contemporary Military, Strategic, and Security Issues), Praeger Security International, (Santa Barbara, CA: ABC/CLIO, 2010), 88-91.
8. Tim Ross, Holly Watt, and Christopher Hope, "WikiLeaks: US and China in Military Standoff over Space Missiles," *The Telegraph (UK)*, February 2, 2011, http://www.telegraph.co.uk/news/worldnews/wikileaks/8299495/WikiLeaks-US-and-China-in-military-standoff-over-space-missiles.html.

Dual-Use Space Technologies and Responsible Space Behavior

The problem with the proliferation of space technologies is that those sorts of capabilities can be dual-use. As such, intent—not hardware—is going to be the primary way to signal that they are non-threatening, which raises a host of questions about what is needed to demonstrate responsible and non-hostile behavior on orbit. This becomes even more important when dealing with issues like active debris removal or rendezvous and proximity operations, where how one views these programs' intent is intimately tied to how one views the country possessing those technologies. At times, it is easy to get so caught up in the technical possibilities that the more vexing legal, policy, and political challenges that these programs pose are overlooked, but which must be dealt with if space powers are to move on to the next stage in utilizing space.

International cooperation or at least an international approach to these shared complicated issues can help clarify intent. Misperceptions or mistrust should not fill in the gaps, as perceptions of space capabilities and behavior is strongly influenced by the political realities on the ground. So norms of behavior or a generalized agreement about what constitutes responsible use of space can help with this. This can be done via formal legal treaties, as well as more informal, soft law approaches.

There are four main space treaties currently in force. They are the 1967 Outer Space Treaty, which bans placing weapons of mass destruction in space; the 1968 Rescue Agreement, which calls for cooperation in rescuing astro nauts who are in distress; the 1972 Liability Convention, which requires compensation for damage a state's space objects may do to another state's assets in space, on earth, or in flight; and the 1974 Registration Convention, which compels signatories to undertake international notification of space launches. While these treaties are foundational elements of international space law, they do not cover grey areas which have emerged in the subsequent decades as more actors join the space domain and change how they approach it.

There is no international treaty formally banning putting weapons in space. In February 2008, China and Russia submitted to the United Nations' Conference on Disarmament the draft Treaty on the Prevention of the Placement of Weapons in Outer Space, the Threat or Use of Force against Outer Space Objects (PPWT). This treaty is viewed as a way in which to ban space-based missile defense—a capability that no country is actively seeking, but of which the United States is apparently suspected of considering—yet allows for work on and deployment of ground-based ASATs. The United States has said that due to the lack of verification measures within the PPWT, it will not be able to support it. Meanwhile, the PPWT carries on in a state of limbo where it is unlikely to be supported by the broader international community but also is not appearing to be dropped by China or Russia.

While space is inherently international and its stability affects global security, there is no usable international forum for negotiating space security issues. The Conference on Disarmament (CD) is the United Nations' primary disarmament forum and would normally be a likely candidate for these types of discussions. However, the CD is a consensus-driven organization and thus must agree on what issues it should discuss. For over a decade, the CD has been completely stopped up and not moved forward on any of its key issue areas.

The other key UN organization that deals with space issues, the Committee on Peaceful Uses of Outer Space (COPUOS), has a strictly civil space mandate and thus shies away from any discussions that veer toward security issues.

It recently has taken up the general issue of space sustainability via its Long-term Sustainability of Space Activities (LTSSA) Working Group.[9] Four expert groups were formed to discuss the following issues which were deemed crucial to long-term space sustainability. Expert Group A is tasked with examining sustainable space utilization supporting sustainable development on Earth and is co-chaired by representatives from Portugal and Mexico. Expert Group B looks at space debris, space operations, and tools to support space situational awareness sharing, and is co-chaired by representatives from Italy and the United States. Expert Group C discusses space weather and is co-chaired by representatives from Japan and Canada. Finally, Expert Group D looks at regulatory regimes and guidance for new actors in the space arena; it is co-chaired by representatives from Australia and Italy. These expert groups are working on creating a draft outline of best practice guidelines, with the goal of submitting it to the COPUOS Science and Technology Subcommittee in 2014, which then will review the report and present it to the full COPUOS in 2015.

One of the big concerns about the effectiveness of the LTSSA Working Group has been how well it would mesh its efforts with other international initiatives intended to make the space environment a stable and predictable one. One of them is an effort which was initiated through the United Nations called the Group of Governmental Experts (GGE).[10] This was proposed by Russia in 2010 that a group be appointed by the UN Secretary-General to

9. Tiffany Chow, "UNCOPUOS Long-Term Sustainability of Space Activities Working Group Fact Sheet," Secure World Foundation, last updated June 2013, http://swfound.org/media/109514/SWF_UNCOPUOS_LTSSA_Fact_Sheet_June_2013.pdf.

10. Tiffany Chow, "Group of Governmental Experts on TCBMs in Outer Space Activities Fact Sheet," Secure World Foundation, last updated June 2013, http://swfound.org/media/109311/SWF%20-%20GGE%20Fact%20Sheet%20-%20June%202013.pdf.

examine transparency and confidence-building measures (TCBMs) in outer space, with the goal of ultimately producing a report that would give recommendations for TCBMs that would help ensure stability in space. A GGE is a fairly common UN mechanism and can provide very good recommendations; however, since it is a consensus-driven process, it can provide very mediocre recommendations, very bad recommendations, or none at all. For this particular group, the experts have had two out of three meetings (the third is scheduled for July 2013 in New York City) and are scheduled to give their report to the Secretary General by the end of this calendar year. The membership, like most things related to the United Nations, is highly political. A GGE usually consists of representatives from 15 countries, typically the five permanent members of the Security Council—the United States, Russia, the United Kingdom, China, and France—with the remaining ten spots selected based on State applications and attempting to have a fair geographic representation. They are, in alphabetical order: Brazil, Chile, Italy, Kazakhstan, Nigeria, Romania, South Africa, South Korea, Sri Lanka, and Ukraine.

Another international approach to space stability is the proposed draft International Code of Conduct for outer space activities (CoC).[11] In 2010, the European Union released a draft version of it for discussion by the international community. This CoC is an effort to put in one place the best practices or established and agreed upon norms of behavior for operating safely in outer space. A new draft was released in June 2012 after discussions on it began. The European Union has been trying to shepherd this document through regional discussions around the world starting in 2012, and held

11. Tiffany Chow, "Draft International Code of Conduct for Outer Space Activities Fact Sheet," Secure World Foundation, last updated May 2013, http://swfound.org/media/83247/icoc_factsheet_may2013.pdf.

the first negotiating meeting in Kiev, Ukraine, in May 2013. The United States has said that it officially likes the idea of "a" Code of Conduct and thus is open to discussing one in general, without promising to sign this particular Code of Conduct. Many space-faring nations are working with the EU on developing appropriate wording that allows for what constitutes responsible space behavior without unduly limiting countries' access to space. Some of the BRIC countries—Brazil, Russia, India, and China—have been worried about this non-legally binding document, either because they are concerned that it is not indeed a legal treaty, or because they think that it may be used to institutionalize disparity in space capabilities.

These international approaches to space stability are not mutually exclusive. In fact, they as a group demonstrate a strong commitment to ensuring that space is usable over the long-term and thus can be used for national security and international stability goals. By participating in these efforts, countries can express their good intentions for their space programs and limit concerns others may have about what their space capacity may say about their national goals. These international efforts are part of a general proliferation of responsible behavior that is not legally-binding and yet more or less considered common practice and necessary for all responsible space-faring nations to carry out.

Other Signals for Space Technology Intent

States need not depend upon the success of international discussions to demonstrate their good intentions. For example, having a written and publicly accessible national space policy/strategy/white paper can be helpful to signal how a country is approaching space, as it can be pointed to when asked

about priorities for its space program. Many countries do not do this, whether it is because they cannot put one together (Australia released its national space policy in April 2013 after years of review) or because they choose not to in order to have more maneuvering room in how they approach space.

Finally, improving space situational awareness can help by verifying actions in orbit and by establishing pathways for technical cooperation and data exchange, which lays the groundwork for possible future collaboration and allows for regular communication between space actors. SSA can be defined in many different ways, but for the purposes of this paper, can be described as characterizing the space environment and its impact on activities in space. Improving space situational awareness can help by verifying actions in orbit and establishing pathways for technical cooperation and data exchange, which lays the groundwork for possible future collaboration and allows for regular communication between space actors. Right now, most owner/operators know where their objects are but are dependent on information from the outside for whether there are any close approaches or conjunctions impending for their spacecraft. This typically comes from the US military, which maintains one of the biggest databases in the world on objects in orbit around Earth. The United States has been reluctant to allow owner/operators to tap directly into the information, due to concerns about possible national security implications, but it does share some SSA information and warnings about potential conjunctions globally. For safety and sustainability efforts to be effective, some specified amount of orbital data will need to be available to all who have assets on orbit.

Concerned about satellite operational safety and reliability, satellite communication companies Inmarsat, Intelsat, and SES in 2009 formed a non-profit entity called the Space Data Association (SDA) to provide services to participating operators for collision warning and mitigating radio frequency interference. Each member shares information on the positions and other relevant aspects of its satellites to the SDA, which in turn provides operators with data intended to allow for safe and efficient satellite operations. This is another example of the increasingly important role of the commercial sector in establishing cooperative efforts and norms of behavior in space; also, if the commercial sector is amenable to cooperating for the greater good, governments should be able to follow suit.

Space as Soft Power Outreach

Working cooperatively on space capabilities can both shore up national security capacity and be a way to establish or strengthen relationships that can also prove beneficial to international security and stability. US-USSR space diplomacy during the Cold War is a good example of this. Even during times of serious political mistrust, there was some joint scientific experimentation and cooperation on-going in space. Efforts like the 1975 Apollo-Soyuz Test Project docking mission created a back-door for dialogue and allowed for informal communication to take place, and when relations got better, meant that foundations had already been laid for other cooperative efforts. Certainly, the competition that was on-going at the time should not be downplayed, but there was sufficient cooperation that the doors of communication remained more or less open. The International Space Station was begun after the Cold War ended and undoubtedly it helped for the United States and Russia to have prior experience in cooperating on scientific space projects.

China is a case study in using space programs as a type of soft power outreach. It is launching many other countries' satellites, and much like its efforts to track down rare earth materials, is using space to create relations with countries it may want something from later on down the line. For example, China is seen to be Venezuela's most important strategic ally in space.[12] China has taken steps to share space technologies with emerging space states, which now have options other than the United States and the Western world in finding partners who can mentor their space programs. This approach helps China win friends in strategic places while simultaneously strengthening its space sector.[13]

Roadblocks to Space Technology Cooperation

There are some roadblocks to international cooperation on space technologies, even though it can help with national security priorities. The first is that there are different values placed on various space programs, as well as different budget levels. What is a top priority for one country may be unimportant or unaffordable for another. Also, there is still a sense that technologies related to national security have to be maintained control over, so amongst some national security professionals, there is some unease (whether or not it is truly merited) about sharing information or collaborating internationally on national security types of programs.

12. A good examination of this issue can be found by Megan Ansdell, Laura Delgado, and Dan Hendrickson, "Analyzing the Development Paths of Emerging Spacefaring Nations: Opportunities or Challenges for Space Sustainability?" April 2011, http://www.gwu.edu/~spi/assets/docs/Ansdell%20Delgado%20Hendrickson_Final.pdf.
13. For an interesting discussion of this from an Indian perspective, please see Ajey Lele, "Space Technology and Soft-Power: A Chinese Lesson for India," Institute for Defence Studies and Analyses, October 5, 2009, http://www.idsa.in/node/3154/5261.

Another possible difficulty in cooperating on space technology is data-sharing issues, specifically, space situational awareness (SSA) sharing. The US military tracks space objects and sends information about potential conjunctions to all space operators as warranted, including countries like Russia and China. This is a great opportunity for doing international outreach, yet problems in doing so limit what can come out of it. These problems can be as prosaic as making sure that our data is in the same format as their data, or knowing who to contact when a possible conjunction may occur (and to fix this last one, a directory of contacts has been proposed). They can also be affected because the data is not actually shared, just the analysis that a conjunction may occur—a "take our word on it" sort of mentality, which involves a lot of trust in data provided by the US military, particularly because moving a satellite on orbit means using up valuable fuel that then affects its total workable lifespan. Other data-sharing issues include things like classification issues, which are residual concerns about security consequences of sharing information. Currently, if a launch contains one classified payload, all items are classified, even if the rest of the payload would otherwise be considered unclassified. As well, often, there are bureaucratic impediments to sending and receiving information. Many countries have civil space agencies in charge of space programs and sharing space information, but all international relations go through departments like a Ministry of External Affairs, which lends itself to confusion and miscommunication. Finally, there is the optics of working with the US military. Most countries do not have the luxury of splitting their space efforts into civil and security space like the United States does, so in order to cooperate with the United States on SSA data sharing, they have to have the ability and/or the willingness to partner with the US military, which may have negative connotations domestically.

Another speed bump that could slow down cooperating on space technology is political issues. For example, the United States' NASA and White House are explicitly forbidden by Congressional legislation from working with their equivalents in China on space issues. This traces back to the antipathy of a single Congressperson, Rep. Frank Wolf (R-Virg.), who is highly critical of China due to their persecution of religious minorities in general and Christians in particular. The result is that two of the most preeminent space powers cannot consider any cooperative efforts in space, at least for programs that involve NASA or outreach from the White House. This effectively prevents any type of relationship-building that might prove useful for either country's national security concerns; furthermore, it sends a message of suspicion and distrust to China which could negatively affect how the two countries interact on other issues of national security.

Many in the United States warn ominously about an Asian space race. While much of that is fear-mongering intended to goad increased investment in the US space industry, it does have some basis in fact. There may not be a specifically Asian space race being undertaken at present, but the major space stakeholders in Asia are certainly cognizant of what the others are doing and there do appear to be efforts to keep current or at least keep up with others' plans.

Focusing more on the United States as a possible partner for space technology cooperation, there are a few other issues which may affect its ability to commit fully to such a venture. The first is a lack of reciprocity. Often, the United States has a different definition of what cooperation is than other countries do. We see cooperation often as a single directional type of program, with us giving them data/systems/technologies/etc., while other countries want cooperation to be a two-way street where they have something of value to be included. Space programs are prestige programs for all and should be treated accordingly.

There is starting to be recognition of this, as seen by a paper released by the federally-funded National Research Council (NRC) released in a 2012 report called "NASA's Strategic Direction and the Need for a National Consensus."[14] In it, the NRC found that "If the United States is to continue to maintain international leadership in space, it must have a steady, bold, scientifically justifiable space program in which other countries want to participate, and, moreover, it must behave as a reliable partner."[15] It points out that "All of the countries of the world, including potential strategic rivals on other fronts, are potential partners in the space arena."[16] And it notes,

> "There is in fact an inherent tension between the desire of countries—including the United States—to develop and demonstrate their technological and political strength with their space programs and the desire for and opportunities provided by international cooperation. At times developing space powers may wish to "go it alone" in order to advance and demonstrate their capabilities, but later seek to join in cooperative efforts with longstanding space powers as a means of demonstrating that they are now on a near-equal status."[17]

Finally, a message that the US governmental space stakeholders should re-

14. *NASA's Strategic Direction and the Need for a National Consensus*, Committee on NASA's Strategic Direction, Division on Engineering and Physical Sciences, National Research Council of the National Academies, 2012, http://www.nap.edu/download.php?record_id=18248.
15. Ibid., 2.
16. Ibid., 42.
17. Ibid., 43.

ally listen to is the admonition that "To lead is not necessarily to command [emphasis in the original] and it is possible to establish international partnerships where all the members take part in major decisions and their interests are clearly aired and considered."[18] As to whether this lesson has been learned, it is too soon to tell, but old attitudes take a while to evolve, even if drastically different circumstances have arisen.

Export control regulations could also hamper attempts by the United States to work with other countries on space technologies. The International Traffic in Arms Regulations (ITAR) is a set of regulations which control the import and export of items on the US Munitions List (USML). Satellites and their related components were placed on the USML in the late 1990s, effectively severely limiting how much the US satellite industry could work with non-US entities. This much extra red tape adds an increased level of complexity to cooperative efforts, as well as concerns about whether sharing specific technologies would adversely affect national security. There now exists a category of products marketed internationally as being ITAR-free so as to save users the hassle of dealing with US bureaucracy on this. In late 2012, the US Congress passed a law that removed the regulation putting satellites on the USML, but they did not get officially put on the US Department of Commerce's Commerce Control List (CCL), which would have fully reformed the export controls on satellites and their components. It is up to the Obama administration as to what technology will be on what list; in May 2013, a draft list was released for public discussion, which would officially move commercial satellites onto the CCL list, but leave things like satellite servicing technologies, suborbital spacecraft, and Department of Defense payloads off of it.[19] Loosening up US export control restrictions still is very much a work

18. Ibid., 44.

in progress; should they succeed, there could be increased cooperation with select partners that could enhance relations while leading the way for eventual cooperative efforts on issues that affect international security and stability.

Access to and the use of space has changed drastically; as such, countries think differently about space technology and national security. Often, new space actors get very excited about their technical achievements, and understandably so, but they do this to the point to where they overlook the real-world consequences of their space programs. Existing space actors, for their part, fail to recognize fully the extent that the international system and access to space have changed and do not evolve accordingly. Nations of all types should be ready to examine the ripple effects of their space technology programs in order to ensure that they find the consequences acceptable and to recognize the responsibilities inherent in their national security implications.

19. Jeff Foust, "Export Control Reform Enters the Home Stretch," *TheSpaceReview.com*, June 17, 2013, http://thespacereview.com/article/2314/1.

Chapter 2. Use of Geospatial Information for Crisis Management: The Case of the European Union Satellite Centre

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Introduction

New EU operation or mission—new tasks for the EU Satellite Centre. This has been the rule rather than the exception since the Centre's support to EUFOR DR Congo in 2006. The European Union's Common Security and Defense Policy (CSDP) is growing steadily and the EU Satellite Centre is growing with it. EUFOR Tchad/RCA, EUMM Georgia, EUBAM Rafah, EULEX Kosovo, EU NAVFOR—Atalanta, EU SSR Guinea Bissau, EUFOR Althea BiH, and EUBAM Rafah—the Satellite Centre has supported or is supporting them all.

The European Union Satellite Centre (EU SatCen), established in 2002 to support the CFSP, particularly the EU's Common Security and Defense Policy (CSDP), by producing geospatial information products based on the analysis of satellite imagery and collateral data, has experienced a remarkable evolution during the last years, mainly due to the huge increase in task requests for CSDP operations and missions. In fact, the SatCen has had to shift its workforce completely in order to attend the large amount of tasks for these operations and missions—all first priority.

But why is the work of the SatCen so important to the crisis management conducted in the framework of EU External Actions as well as the crisis management of international organizations such as the UN?

EU Satellite Centre—analysis for decision making

The SatCen is the only operational entity in space and security matters in support of the European External Action Service. It is becoming the leading provider of security-related geospatial information products and services in the EU, fully connected to the EU CFSP/CSDP structures as well as all relevant development and cooperation actions in the space and security domain.

Art. 2 of the Council Joint Action states that the mission of the EU Satellite Centre is to "support the decision making of the European Union in the field of the Common Foreign and Security Policy (CFSP), in particular of the European Security and Defense Policy (ESDP), including European Union crisis management operations, by providing, as appropriate, products resulting from the analysis of satellite imagery and collateral data, including aerial imagery, and related services to the EU Council and its bodies; EU Member States or the Commission; Third states that have agreed to specific provisions; international organizations such as the UN, the OSCE and NATO if the request is relevant to the CFSP, in particular to the ESDP."

As a unique operational asset, the EU SatCen serves a variety of institutional users ranging from the EU's high-level decision makers, such as the High Representative of the Union for Foreign Affairs and Security Policy (HR), Ministries of Foreign Affairs and Ministries of Defense of EU Member States and the crisis management and situational awareness structures of the European External Action Service (EEAS), to the personnel on the ground involved in missions and operations. Within the EEAS, main users of SatCen products are the Crisis Management and Planning Department (CMPD), the EU Military Staff (EUMS), the Civilian Planning and Conduct Capability (CPCC) and the Intelligence Analysis Centre (IntCen). Furthermore, the Commission, Third States and International Organizations like the United Nations can request the support of the Centre.

This singular position requires tailoring the Centre's Geospatial Intelligence (GEOINT) and Imagery Intelligence (IMINT) products and services to support and enable SatCen users in their specific undertakings. These comprise a variety of activities from diplomatic, economic and humanitarian measures to mission planning or intervention.

The Lisbon Treaty has increased the operational engagement of European actors and made it more complex. This is reflected in the demand for SatCen products and services and, consequently, capability development both in qualitative and quantitative terms has become a central concern for the SatCen, as mandated by its stakeholders.

Operational Chain

The Centre operates under the political supervision of the Political and Security Committee (PSC) and the operational direction of the High Representative of the Union for Foreign Affairs and Security Policy.

The EU SatCen primary sources of satellite data are commercial providers. The EU SatCen also benefits from agreements with Member States allowing access and exploitation of high quality governmental satellite imagery. Collateral data, i.e. essential additional information underpinning and complementing the imagery analysis, are acquired from open sources and from users.

EU SatCen products, handled at various levels of confidentiality, are delivered both to central operational entities (e.g. EU Military Staff) and to the Operational Headquarters (OHQs). Every single product is systematically distributed to all Member States, facilitating cooperative decision making in the field of Common Foreign and Security Policy (CFSP) and Common Security and Defense Policy (CSDP).

The EU SatCen in the User's Decision Making Cycle

The SatCen has to execute its mission in close cooperation with the crisis management structures of the European External Action Service under the operational direction of the HR. The strengthening of the link with these bodies to collect operational needs as well as to support and refine the tasking was a primary concern in 2012. This implied nurturing user awareness through exchange of expertise and collection of requirements.

Member States and other concerned entities were engaged through Technical Working Groups (TWG), Expert Users Fora (EUF), the Governmental Imagery Forum, bilateral meetings and other events.

Data Sources

The EU SatCen does not have direct control over satellite sensors. Although its sources of primary data are commercial and governmental providers activated on a case-by-case basis, the EU SatCen continues directing its efforts toward the development of an autonomous European capability in the field of IMINT/GEOINT, giving preference to European space assets when quality, reactiveness and cost offer are even.

The development in Europe of Earth observation systems for intelligence is clearly related to the need for an autonomous European capability. The new dimension of EU external action and the growing need for out-of-area civilian missions and military operations often require effective intelligence support in remote areas during extended periods of time and for a great number of different tasks.

Recent developments on the commercial market have allowed private companies to create high-resolution satellite sensors that are adequate for almost all needs of the military community. Even if governmental satellites are in most cases still able to provide a better resolution, the technological gap has dramatically decreased, and commercial satellites are producing almost the same at a much lower cost.

Another advantage of commercial imagery is its unclassified nature, allowing a wider distribution of the imagery and derived products, and the fact that they do not face the same legal restrictions as governmental systems. The dissemination of derived products can be done using the Internet and consequently end users have fast and easy access to the information.

The increase in tasking has not only had a remarkable effect on the production process, but has also led to a substantial improvement of the capability to make urgent programming of commercial imagery over crisis areas.

Continuous negotiations with the most relevant providers have allowed the Centre to get better contractual conditions with a significant optimization of the financial impact. At the same time, the SatCen has made use of emergency services from commercial providers, giving the Centre 24/7 access to imagery.

Governmental satellites, however, have in recent decades become unquestionably vital to defense and security as also to the EU SatCen due to their high performance and guaranteed operational autonomy.

In order to answer the requirements of its users, including EU entities, EU Member States, Third States and international organizations such as the United Nations, the EU Satellite Centre has further consolidated its access to high resolution commercial and governmental satellite imagery.

In 2008, the Centre signed an agreement on the access to Hélios II govern mental imagery (owned by France, Italy, Spain, Belgium and Greece). In the same year, the EU signed an arrangement for access to governmental COSMO-SkyMed imagery, COSMO-SkyMed being an Italian dual-use system which comprises both commercial and governmental satellite imagery. The set-up procedures of the secure network for the delivery of COSMO Sky-Med are ongoing.

Finally, a similar agreement for access to the German SAR-Lupe governmental imagery system was signed and implemented. A SAR-Lupe connection between the SatCen and the German Ministry of Defense has been put in place, awaiting final technical and security tests to be declared fully operational. This connection will allow an immediate exchange of data.

Nevertheless, until the launch of Pleiades-1 (France) in December 2011, most of the intelligence support produced by the EU SatCen still relied on non-European commercial satellite sensors.

During Operation EUFOR Chad/CAR, from February 2008 to March 2009, the EU Satellite Centre experienced a dramatic improvement in the way it provided support to troops on the ground. A specific arrangement signed with the Hélios partners for the purposes of the Operation enabled the Secretary General/High Representative to request that Hélios governmental satellites be programmed to collect extremely valuable imagery on the area of operations. A similar arrangement was established with Hélios countries during the recent SatCen support to the EU anti-piracy operation Atalanta (EU NAVFOR Atalanta).

Since the early 1960s, several countries have increasingly developed governmental satellites as part of their military strategy and national defense. These systems were able to provide very high resolution imagery not available on the commercial market. Now, commercial systems have almost the same capabilities as governmental systems at a much lower cost. In fact, it is estimated that around 90 percent of military needs can be solved with commercial data.

However, governmental satellites remain invaluable to the EU and its Member States, the two main reasons being guaranteed confidentiality and potential vulnerabilities of commercial satellites (e.g. jamming, cyberattacks, encryption and even physical destruction by anti-satellite weapons).

Core Business: Geospatial Intelligence

The geospatial analysis reports produced by the Centre range from brief descriptions for rapid response requirements to detailed studies on complex areas and installations. Furthermore, the Centre offers both specialized training to image analysts of the SatCen and from Member States and courses to non-specialists.

The production of GEOINT is the core business of the Centre. However it also cooperates with national and international institutions in the field of space. It participates in the Copernicus (former GMES) and SSA programs and works closely with the European Defense Agency, the European Commission and the European Space Agency, as well as other institutions and international organizations in the field of space and geospatial intelligence.

Tasking of the SatCen has increased substantially in the last years as a consequence of the growing number of EU operations and missions and of the increasing need of GEOINT support for the EEAS decision making process in general. Furthermore, the ongoing crises in North Africa and the Middle East have contributed significantly to the workload of the SatCen.

During the past year, the main customers of the SatCen were the EEAS in general, UNSMIS, EUFOR BiH, EUMM Georgia and EUBAM Rafah.

Operational Highlights

During the past year, the main customers of the SatCen were the European External Action Service in general (EUMS, IntCen and CPCC), the United Nations Supervisory Mission in Syria (UNSMIS), Operation EU NAVFOR Atalanta and the EU missions EUFOR Bosnia and Herzegovina, EUBAM Rafah and the EU Monitoring Mission in Georgia. The Centre also received an increasing number of requests from Member States.

The monitoring of the crisis in Syria for the needs of the United Nations Supervision Mission in Syria (UNSMIS) constituted a great workload for the Centre, whereby the SatCen worked for considerable time in crisis mode. This implied extended working hours, shift work and opening of the SatCen during weekends, in order to cope with the high demand for products and the need for timely and immediate reporting.

The support to the Operational Headquarters in Northwood (UK), in the framework of EU NAVFOR Atalanta continued. A geo-database of Somalia was generated which constitutes the base map for the operation.

EUMM Georgia also continued to be a main user of SatCen products. Tasks carried out by the SatCen included analysis of imagery to report on important infrastructures and activities in the region.

Furthermore, the SatCen monitors possible proliferation of weapons of mass destruction and the development of nuclear technology in several countries. In this context, it analyzes several suspected facilities in various countries where ballistic missiles and test and launch facilities are possibly being developed.

Equally, uranium mines, uranium conversion facilities, heavy water reactors, nuclear power plants and yellow cake production facilities are monitored to analyze the development of nuclear facilities.

The SatCen has supported EUFOR Althea in Bosnia-Herzegovina with over 100 products over the area of responsibility of the EU mission.

Exercises constitute a highly valued tool for improving the integration of GEOINT in the global information planning and decision process. The SatCen participated actively in the Multi-Layer Exercise 2012 (ML12) by providing background information, additional analytical products and developing a geo-portal for providing the training audience with a common and updated picture of the exercise scenario. This tool is now also used for the operational activity of the Centre. The main objective of the exercise was the testing of the EU comprehensive approach to Crisis Management (CM) and new operational EU CM procedures; therefore it was crucial to demonstrate the SatCen present and future capabilities.

Training

Another of the EU SatCen's services is to empower analysts with skills and knowledge, first for EU SatCen needs, then for Member States and institutions. Training also enables the SatCen to exchange experience and knowledge as well as to create cohesion in the very sensitive GEOINT domain with different stakeholders. In-situ courses are also favored when possible, resulting in savings for Member States because they do not have to send the trainees to the SatCen.

The courses delivered yearly the EU SatCen premises are:

- Synthetic Aperture Radar course
- Military Training Studies course—with the support of a guest speaker from the Belgian Satellite Centre
- Industries l and II training modules
- Geospatial Intelligence Course
- SatCen Induction Course

Training activities also included a Nuclear Course delivered in October, containing for the first time information on nuclear weapons and their development and testing.

Concerning external activities, following the request of the CMPD, the SatCen gave a presentation to the League of Arab States in Cairo, Egypt, focusing on the role and uses of commercial imagery in support of situational awareness and humanitarian operations. Attendees were mostly staff of the Situation Room, recently set up within the Crisis Department of the Arab League.

Staff from the Training Unit and Operations Division delivered training to the Managing Director for Crisis Response and Operational Coordination (MD-CROC) at the EEAS. This training comprised presentations on the geospatial products and services provided by the SatCen and their value for situational awareness during a crisis.

SatCen staff attended a training course in advanced Synthetic Aperture Radar processing techniques in Switzerland. Information from this course will be used to build a second module for the SatCen Radar Course, which is planned to be delivered for the first time in 2013. The Centre also delivered a two-week Imagery Intelligence course to staff of the Finnish Ministry of Defense and an imagery analysis training course to FRONTEX.

Space and Security Programs

The Centre participates in space and security programs in compliance with the framework provided by the CJA and following the decisions and the recommendations of the Board and the Council. The involvement in such programs has provided valuable tools and services in support to the EU SatCen core business. It also constitutes an important source of additional means for the benefit of the EU SatCen and its stakeholders.

The Centre is active in developing the security dimension Copernicus program (formerly GMES—Global Monitoring for Environment and Security) and has now finalized the project "Support to Precursor SSA Services" (SPA). Both are part of the European Commission's Seventh Framework Programme in support of the European Space Policy, with SPA co-financed and directly controlled by the Member States.

Global Monitoring for Environment and Security (GMES)/ Copernicus project

The GMES program was officially renamed on 11 December 2012. From that date on, the European Commission's Earth Observation Programme has gone under the name of "Copernicus", and is therefore mentioned by this name hereafter.

The Centre continues cooperating with the Copernicus Programme in its security dimension to support the development of services addressing Maritime Surveillance, Border Control and in particular Support to EU External Actions.

The Centre participates in Copernicus meetings organized by the European Commission's DG ENTR such as the Copernicus Committee, Partner Board and User Forum and supports the work of the Copernicus/GMES Bureau related to Border Control and Support to External Actions.

The Centre works with FRONTEX and the Commission on the future implementation of the EUROSUR CONOPS (concept of operations) including an EMSA/EU SatCen/FRONTEX cooperation framework and the use of future Copernicus Services to be available under Border Control.

The Copernicus program comprises several projects aiming at developing an operational capacity by 2014. In 2012, the SatCen participated in the following: GMOSAIC, SAFER, BRIDGES, DOLPHIN and NEREIDS.

The SAFER and G-MOSAIC projects ended in March 2012 after three years of existence. SAFER (Services and Applications for Emergency Response) intended to reinforce the European capacity to respond to emergency situations, its main objective being to prepare the initial operations of the Emergency Response Service. G-MOSAIC (GMES services for Management of Operations, Situation Awareness and Intelligence for regional Crises) aimed at supporting EU operations in the prevention and management of external regional crises. Its main objective was to support the definition and implementation of security-related core services.

The EU SatCen chairs the Validation Board and is part of the Steering Committee of the DOLPHIN project which addresses three main policy areas: border surveillance, traffic safety and fisheries control and capabilities. The project is aimed at identifying and developing new capabilities which cannot be fulfilled by currently available technology and space-based assets. In particular it addresses the detection of very small and/or fast boats such as those used for drug smuggling, the reconstruction and the monitoring of ship routes, the detections of boat rendezvous and the detection and classification of objects other than ships, such as icebergs.

The Centre's role in the NEREIDS project is mainly related to general user engagement, definition of user requirements, facilitation of interoperability with military standards, validation of data processing and demonstration activities. The project provides improvements in different domains including innovative Earth Observation (EO) data processing techniques, intelligent data fusion techniques, use of microsatellite constellations in equatorial orbits with real-time video data and application of innovative techniques such as geographical data mining and feature-based track classification. It also addresses traffic monitoring, illegal fishing and illegal immigration.

The BRIDGES project started in January 2012. It aims at providing scenarios for the future governance and data policy of the security dimension of Copernicus and the role of the SatCen in this context. The first BRIDGES Institutional Advisory Board and the first BRIDGES Workshop were organized by the Copernicus Unit at the Spanish Office for Science and Technology in Brussels on December 11-12 2012. More than fifty stakeholders from Member States and EU Institutions were involved, including the European Commission, EEAS (CMPD, INTCEN, Civilian Crisis Management and the EU Situation Room) as well as the European Defence Agency (EDA) and the European Space Agency (ESA).

The workshop provided a very good forum to pave the way for the future governance of the Copernicus Services in Security, in particular Support to EU External Actions. Not surprisingly EU SatCen missions and the potential role(s) in Copernicus were also raised, in particular during the Institutional Advisory Board, by the participants.

Space Situational Awareness (SSA)

The EU SatCen cooperates with EU Member States, the European Defense Agency (EDA), and the European Space Agency (ESA) on their respective activities for Space Situational Awareness (SSA).

In October 2012, the SPA support action project ended. SPA supported the development of a governance and data policy for Space Situational Awareness from a technical perspective.

Through the implementation of SPA, the EU SatCen supported a technical dialogue on SSA matters and spread the gained knowledge to EU Member States and relevant stakeholders.

The project helped the core activity of the EU SatCen by contributing to protect space assets and by optimizing the acquisition of satellite imagery.

Following the mandate from the SatCen Board, in November 2012, the EU SatCen SSA Team initiated work on Support to the development of a European SSA capability (STEP). STEP is an FP7 support action that, capitalizing on the achievements of SPA, strives to provide a technical perspective for the development of SSA data policy by facilitating the dialogue between key SSA stakeholders contributing infrastructure elements in Europe, by catalyzing a common understanding of organizational and governance issues.

The Importance of International Cooperation

Transnational security threats require transnational answers. The multiplication of non-state actors and non-state threats on the international scene demands new measures from national and transnational decision makers. In today's globalized world, it is mostly not useful to tackle security challenges from a national point of view, since many of these go far beyond national influence and require effective multilateralism in order to be handled appropriately. International cooperation has therefore become crucial in order to respond to today's global challenges.

Space-based intelligence is an important tool to affront this new reality. The SatCen contributes both as an early warning tool, giving information for the early detection and possible prevention of armed conflicts and humanitarian crises, and as a reactive tool for crises that have already broken out by providing products in a short time frame.

The European Security Strategy (ESS) also emphasizes the importance of space for European security. With the foundation of the SatCen in 2002, EU Member States took a decision that indicated the way to go and represents the implementation of an important objective of the European Security Strategy. The existence of a multinational operational satellite centre considerably strengthens the EU's multilateral approach to crisis management. The challenges expressed in the ESS include the monitoring of regional conflicts, cases of state failure, threats posed by organized crime, terrorism and the proliferation of weapons of mass destruction. Satellite reconnaissance is very suitable to answer a great part of these challenges because it is global, not intrusive, in line with international law, doesn't affect a crisis and is fast if the circumstances allow it, i.e. an ideal tool for the detection and analysis of today's global security concerns.

Conclusion

In the report on the functioning of the EU SatCen of September 14, 2012, the High Representative of the Union for Foreign Affairs and Security Policy defined the Centre as "the only EU operational entity in the area of space and security." Conscious of the responsibility conferred by this singular position, the SatCen continues its constant effort maximizing the exploitation of the resources allocated to the fulfillment of its mission.

Space-based information is one of the key fundamentals for sound European Union decision making. Thanks to advances in satellite technology and optimal governance solutions for a multinational operational satellite centre, such support can substantially improve multinational decision making, thus considerably strengthening the EU's multilateral and comprehensive approach to crisis management.

Most of the geospatial information (GEOINF) support provided today to the newly established European External Action Service is produced by the EU Satellite Centre (SatCen). Whether for the High Representative of the EU for Foreign Affairs and Security Policy, the European Union Military Staff, the EU

Joint Intelligence Centre, the EU Civilian Planning and Conduct Capability or for one of the many EU missions and operations abroad, the SatCen analyzes satellite imagery and collateral data to give the appropriate answer—in terms of quality and timeliness—to the task requests received from its users.

The development of the capability continues to be pursued through the improvement and implementation of tools in support of imagery analysis and production chain. The exploitation of the cooperation projects like Copernicus and Space Situational Awareness provide a major contribution to reinforce the SatCen core business.

The growth of information requirements in the field of EU's Common Foreign and Security Policy and developments in satellite technology both in the commercial and governmental sector, have led to a constant increase in operational engagement of the EU SatCen over the last few years. During the past year, some of the SatCen's main customers were for example not only the EEAS, EUFOR Bosnia and Herzegovina and EU Monitoring Mission in Georgia, but also international actors in the field of international security, such as the United Nations Supervisory Mission in Syria.

In addition, the monitoring of possible proliferation of weapons of mass destruction and the development of nuclear technology in several countries added to the strengthening of collective security and treaty verification in this domain.

The EU SatCen is presently able to provide user-requested and validated information support to a great variety of actors, exchanging geospatial products and collateral data with the EU, its 27 Member States, and international security actors, through dedicated networks and respecting the time-critical demands of crisis management operations. Operational GeoInf support to a United Nations mission, like the one in 2012, opens yet another avenue for the European Union to contribute and support this Organization through the EU SatCen, thus strengthening its commitment to the EU's foreign policy goal of effective multilateralism.

The Centre's future capabilities will depend on relevant economic, political and technological developments at EU and Member State level. The current trend in Europe is to use more and more dual systems, but in a time when defense budgets and suffering significant cuts, the demand for cheaper solutions is growing. The future trend will most probably be to develop more responsive, more cost-effective and more custom- oriented satellite systems.

International cooperation, even in such a sensitive area of geospatial information, is possible thanks to technological innovation and better governance solutions and has follows the principle of "common information for common action."

Chapter 3. Policy Review on Space Technology Development[1]

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The key component of space technology development is the nation's desire for developing space, which is reflected in the policy making process. The interest in space among nations is increasing by the day for several reasons. One of the main reasons is the emerging competition between new state actors and developed countries for space development in a multipolar system. The space development capability of new state actors, particularly, in the Asia-Pacific region, has risen dramatically. Another reason is the increasing importance of space technology to a nation's national security, providing nations with: the capability to legally monitor other states, increased presence in the national and global arena, enhanced strategic depth, and early warnings of security threats. The third reason is to establish global norms to effectively regulate space development, which includes bilateral and multilateral efforts as well as aspects that are conventional and institutional. Currently, there is no legal or institutional instrument to define or regulate the purpose of space development. In fact, its dual-use is tacitly accommodated. Aside from national security and global norms, the economic aspect is another driving force behind space development: private sectors are attracted to commercial space development for economic benefit and satellites are extremely beneficial to states for their technical versatility and global presence. At the same time, space development often provides highly qualified human resources and enhances a nation's national prestige in the international arena. In these respects, given its strategic importance and increasing relevance to a nation's capacity building, space technology development is imperative.

1. Part of this chapter is based on the April 23, 2013 workshop discussions on *Space and International Security* held by the Asan Institute for Policy Studies.

Emerging Powers in Space Development

It is important to recognize that geopolitical and strategic contexts influence space policies, not only technical and scientific issues. Space is technically and politically different and risky, yet geopolitical risk is rarely explicitly considered in space policy matters. However, sustainable policies, prudence, understanding of space operations, and political support can mitigate geopolitical risks. After all, the state of space security is invariably a reflection of security on Earth.

Today, at least sixty countries are operating satellites in space, demonstrating that interest among states in developing space programs has increased. In comparison to the past twenty years, when only a handful of countries were taking interest in satellites and operating them in space, today we can find entities such as the Maldives, the African Union, and Afghanistan increasingly looking into space development. Such interests are emerging from radical geopolitical changes in the international order over the last 25 years. With the rise of a multipolar order, a new set of actors are emerging, including the BRICS and especially China. G20 countries have either already developed space programs or expressed interest in developing space technology. The Asia-Pacific region shows a massive rise in the dissemination of space systems. Parts of the Asia-Pacific are crisis hotspots, including Northeast Asia (China, Korea, and Japan) and the South China Sea, and tensions between Southeast Asian states also exist. Countries such as China, Japan, Vietnam, and South Korea are developing either military satellites, or at the very least, dual-use capabilities for military purposes. Along with dual-use capabilities, space technology transfer can be utilized as an effective diplomatic instrument by controlling related export items. In regard to new actors and interests, power and wealth creation and productivity are increasingly moving eastwards and away from Europe and Russia. Specifically, the most remarkable progress in space development is found in China, Japan, South Korea, and among the Southeast Asian countries. Such changes are important to space development because they indicate the rise of different contending world views that are becoming relevant to discussions on space power and policy.

China, as one of the emerging powers in space development, has proceeded with the Shenzhou program. China has tried to operate the new international space station, Tiangong 1, as a part of the Tiangong program. It is still a small space module, but China is seeking to develop its own full-sized space module by the 2020s. Chinese spacecraft Shenzhou 10 was successful in test docking with the Tiangon 1 on June 13, 2013. This indicates the possibility of substituting the old International Space Station (ISS) with Chinese technology in the mid- to long-term.

Space power is the ability to exert prompt implementation to, in, and from space during peace and war time. Space power is important since it is a critical feature of power in today's multipolar world. While changes always happen, this is a truly tumultuous time and is certainly an era of disruption, uncertainty, but also opportunity. Unlike unipolar or bipolar systems, a multipolar system historically is not stable. Dual-use disruptive technologies, including satellites and cyberspace, are continuously disseminated through space programs in a multipolar world. Compared with the 19th century, when sea power symbolized the status of a state as a world power, space power is currently emerging as a new symbol of national prestige. Even with a global wealth pivot to the East and the anticipated US relative decline, the US will sustain its superior economic and military power around the globe and lead space development for a while. To attain this symbolic status, countries are economically, diplomatically, and militarily motivated to mimic the space program of the US. Based upon the global hegemonic power struggle, which has become increasingly congested, competitive, and complex with many potential contentions, a country's decision to develop its space program is also heavily influenced by observing what other countries do in this area.

Besides its symbolic significance in providing honor and prestige, domestic political priorities and regional geopolitics across the world create demand for a space program, including a satellite system. In essence, security and civil uses of space are interrelated, just as commercial and political uses are interrelated. Such interconnections elaborate the strong relationship between space technology development and national security. While nations do not often realize the increasing reliance on space development for national security, the reality is a space program is deeply involved in national security. For instance, naval forces heavily use satellite communication through a global positioning system (GPS). Furthermore, considering the symbolism of space development, China and the EU[2] put effort in developing independent global positioning systems on their own rather than utilizing the US technology based system. In particular, as a middle power in space development, Germany has actively participated in the European project based on the newly activated legal framework. In addition, space is a commercially and economically competitive asset. With greater technological sophistication and advancement, satellites are becoming economically competitive. As some parts of satellites—micro-processing parts in particular—are becoming even smaller and cheaper, establishing space programs is also becoming more affordable and possible for other nations. An increasing number of services, products, and jobs are produced from space development programs, which is evidence of the strong correlation between space development programs and the economic competitiveness of nations.

Space Development and National Security

Space development influences national security strategy as well as international security. National security strategy is set to protect its own people, infrastructure, economy and society.

Space-based capabilities support protecting these elements through military or economic operations. In earlier days there were a limited number of space nations. But nowadays, there are around sixty nations or actors who own or operate in-orbit platforms. Space technologies such as launch vehicles, satellites, and remote sensing are dual-use technologies, with their broad applications, play important roles in national security. For the nature

2. The European Union (EU) and European Space Agency (ESA) have pursued development their independent high-precision positioning system, which is the global navigation satellite system (GNSS), under the "Galileo Project." With the expected Chinese GPS, the GNSS will be one of the pillars to change the existing structure of US-centered space development.

of dual-use technology, space technology and technological assets in the US are regulated by the International Traffic in Arms Regulations (ITAR).[3] Conflicts over space technologies are considered with their implications for foreign policy.

Space-based technology underpins many aspects of national security. Among the underpinning technologies to national security, satellite communication and national security are most strongly tied. While their strong ties are due to satellites' ability to provide information, they are also part of states' strategic rationale for geostrategic decision making. The first benefit of operating satellites is the capability to provide states with perspective. Satellites provide states with the capability to see other states from greater vantage points and distance from their own borders. They can also capture scenes across a wider surface and larger dimensions. The second benefit is the provision of access. Satellites are the only legal means to be able to monitor and observe the space of other states, even for areas with limited accessibility such as North Korea. This benefit is especially imperative to countries, such as South Korea, where national security threats are more acute than other states.

By providing perspective and access, satellites give strategic depth and early warnings of threats to national security forces, as was the case for Israel in the 1970s. With its geostrategic disadvantage of being located between the border of the West Bank and the Mediterranean Sea across the distance of 10 miles, Israel was in the middle of a constant threat of conventional invasion since its founding. Hence, Israel started its space program in the 1970s and

3. Directorate of Defense Trade Controls, US Department of State, International Traffic in Arms Regulations updated October 8, 2013, http://pmddtc.state.gov/regulations_laws/itar_official.html.

currently has a number of impressive optical communications and imaging satellites that can detect any signs of conventional threats. Such geostrategic perspective is also important to a state that is disadvantaged by its geography to monitor regions distanced from its capital. Examples of such states include Russia and Australia. Central states can observe other regions through satellites, which give them long views of shores and thus provide political cohesiveness. Each country facing geostrategic restrictions has utilized the advantage of satellite systems to be able to facilitate the capability of providing perspective and access, as previously mentioned. However, it is inevitable to cause controversy over the strategic purpose of satellites between the rights of self-defense and militarization.

Major policy interests of space developing countries are to ensure access to reliable space capabilities for military and security operations. While international cooperation is an inevitable solution for space development, each nation aims to maintain space capabilities by itself out of the necessity of domestic responsibilities or specific sovereign interests. It is needed for space developing countries to set a balance between advantages from international cooperation and sovereign control of space operations. Strategic choices facing space developing nations in space activities include continued dependence on US, European, and Russian space capabilities, developing indigenous space programs, and reliance on commercial space activities.

For the developed nations, maintaining leadership roles in space is the essential component of national security since their technological superiority is being challenged by emerging space nations. In the Cold War era where there was a "bipolar architecture," conventional arms control measures had always been elusive for space security. Moreover, this inclination has escalated in the post-Cold War period. However, based on the benefits and the important security role that space programs provide, sustainable policies, strong statesmanship, and international cooperation are essential to the contemporary multipolar world, which is especially vulnerable to instability and breakdowns in the long run. Norms will only spread when emerging space powers build legal and policy foundations. The space security debate dominated by the US, Russia, and China is stale and broken, which is why norms for safe space operations are imperative. Norms in space are possible, but will only be successful if they are operator-led. Cooperation is imperative also because space is contested, and satellites are prone to jamming each other due to environmental reasons, which can thus interfere with other satellites. Given the increasing relevance of the greater number of states and policymaking in space technology, states need to cooperate to have stability in space. That is to say, "peace on earth also creates peace in space." Increased policy expertise means better ability to protect national interests in space, and understand issues. This leads to political support for practical norm-building based on realities in space. Many initiatives to build technical capacity are already underway.

Space development programs and activities are increasing with a tacit agreement on their importance to national security. Taking account of emerging systems and technologies which are counter-space in some cases, sustaining international cooperation and monitoring system in space technology development is important to strengthen safety, stability, and security in space. Current challenges for space development include increasing congestion, conflicts, and competition in space. Also, almost all the space-faring or space-developing nations face budget restrictions for their space programs and need to maintain the sustainability of space capabilities by inspiring and mobilizing an aerospace workforce.

Issues in Space Technology Development

Policy considerations in developing space capabilities and technologies include satellite utilization, launching capability, space exploration, industry engagement, international collaboration and global security.

Satellites

Information from satellites covers broad ranges of applications for weather forecasting, disaster surveillance, environment monitoring, and communications as well as for research purposes. Many systems rely on satellites in a modern society and utilization of satellite is evolving. A satellite is made up of a number of different components and needs ground stations and equipment to control and communicate with. Types of satellites vary depending on their purpose of operation and orbit. It is known that over 60 entities are operating nearly 1,000 satellites and a lot more are planned. Quality of information received may depend on the types of satellites along with remote sensing capability. Space-developing nations should first define their critical need for satellites and develop a space plan accordingly.

Launching capabilities

The largest budget allocation for space developing countries goes to developing launch vehicles, and not every nation develops this capability. If a nation decides to have its own launching capability, strong government support is critical at the initial stage of development. The government should make several steps to ensure the space development program is aimed in the right direction. Firstly, the government should gain consent from tax payers to invest in space technology development. In addition to the general public, it also needs to encourage voluntary investment from industries. Given that the government is increasingly attaching greater importance to space development, sustainable space technology development is essential to maintain this support. At the same time, because governments operate with a limited budget and economic capability, the voluntary investment of industries into space business is important to continue growth as a space power. The collective support from both the government and industries can be economically strategic successfully by generating high-quality employment opportunities. The leadership of space programs is also important because the key to sustainable space development is organizing a framework that would last long enough for the space program, with qualified heavy industries and greater human resources.

Space exploration

Space development plans include space exploration through international cooperation, and enhancing research capability on space science and space surveillance systems for disastrous events. However, the major concern on this agenda is the financial burden. Space is not only a place where national security is achieved or to merely compete with other states, but a place of sustainable economic development. Each space-faring nation has space development plans for peaceful use of space and, through it, for economic benefit. In this regard, space should be predictable and sustainable for all who are interested in developing space. For this, activities with regard to space have to be transparent and information should be shared among nations.

Industry participation

For cost–reducing technological development, industry participation is essential and will promise to a nation a sustainable space capability. There should be strong support for the commercial space industry since industries are reluctant to invest in space because it does not involve mass production. In addition to states, multinational corporations (MNCs) are increasingly facing new challenges, which make it important for MNCs to also cooperate in space policies. Besides the new multipolar order, the rise of GRIN technologies, meaning those in genetics, robotics, information, and Nano Processes, add to the challenges that MNCs face by creating a "new era of destruction," where it is easy to cause local devastation. Space technology is particularly vulnerable to this, which underscores the difficulty that MNCs in space programs will face. Given these conditions, the importance of cooperation between MNCs is imperative as well. To give examples of MNC cooperation, Satellite Communication, a conglomeration of corporations, has been established to create norms in space technology. In particular, including MNCs, the conglomeration of corporations as a consortium for space development program are expected to be able to settle the persistent budget constraints of governments in each country brought about by the global financial crisis and the recession in the meantime. After the financial crisis, governmental sectors have paid more attention to lowering all costs related to space development and considered the civil sector as a new alternative. In the case of civil sector entities such as MNCs, they usually develop space programs on the basis of technology transfer from governmental sectors. Moreover, while recognizing the specific context of its operation, in order to establish a secure cooperative system in the industrial level, the EU showed affirmative action. The EU Space Committee has been suggested as a replicable model, in which codes of conduct for space operations can be established. Moreover, given such challenges, engagement from senior policymakers outside of space agencies, such as ministers of foreign affairs, is important in the area of commercial space because commercially, the civil space development has

a structure, which cannot help but rely on its own self-regulation. Due to this reason, through an enforcement mechanism, diverse specific organizational and institutional entities are required to control and/or manage their activities in the civil space development areas. The civil sector has been the new area of competition for leadership in pursuing space development.

International collaboration

Even though they are systemically dependent, in technological development dimensions, the characteristics of space development are likely to be originally independent, but in order to express the strategic dimension, as one of a global public good, it should be interdependent in practice, particularly, as cooperative. However, due to the flexibility and openness of space resources, each state has no choice but to be very susceptible to external infringement. Regarding space development, the cooperative initiative in national, international, and industrial levels should be considered.[4] In this context, while recognizing the importance of cooperation, it would be difficult to reach agreements on space policy, given that states have conventionally experienced difficulty in their experience in many critical areas, such as climate change and the global economic recession from 2008. In addition, the greater number of powers in the contemporary multipolar world creates contending ideas, and a greater number of individual national interests tend to override collective interests. Under such circumstances, states need to take a more nuanced approach in policymaking by dealing with specifics rather than creating a grand bargain. Possible areas of cooperation among allies might include: ballistic missile early warning data exchange, cooper-

4. Eligar Sadeh, ed., *Space Strategy in the 21st Century: Theory and Policy* (New York: Routledge, 2013), 5-8.

ation in geolocation of purposive satellite jamming by hostile entities and actors, including state and non-state, particularly, toward GPS, space situational awareness (SSA), intelligence sharing, maritime domain awareness (MDA), and by conducting regular strategic dialogues.

A role model of integration of national, international, and industrial levels is the European Union (EU) because they have the European Space Policy (ESP), in which diverse entities and actors at the national, intergovernmental, and supranational levels are involved. Through the ESP, the EU, one of the newcomers in space development, has been successfully implemented to conceptualize the EU's strategic and coherent space development policy in the long term. Furthermore, the ESP has expanded into collaboration with the North Atlantic Treaty Organization (NATO). NATO has attempted to establish its own space policy in terms of security. Eventually, through the ESP, the EU is identifying its own role in the global space arena to be able to respond to evolving regulatory and institutional arrangements.[5] In the long-term, the ESP and other EU space policies are expected to contribute to cooperative initiatives in national, international, and industrial levels beyond the region.

Conclusion

The importance of space technology development is increasing, with a view that it is closely related to a nation's capacity building as well as strategic

5. Christophe Venet and Kai-Uwe Schrogl, "European Experiences with Space Policies and Strategies," in *Space Strategy in the 21st Century: Theory and Policy*, ed. Eligar Sadeh (New York: Routledge, 2013), 263-277.

advantages to national security. At the same time, international or industrial cooperation is essential to meet the high expense of developing technology. Space development is a complex process that requires strong policymaking, statesmanship, and close cooperation mechanisms in line with national, international, and industrial level interests. In order to examine the complexity of space development and offer the right direction for its use, as a cooperative initiative, triangular collaboration among these levels should be considered.

In general, space is likely to be more of public good than any other resource. Simultaneously, its indirect and supranational nature appears to infringe on the sovereignty of each state due to the possibility of unlimited surveillance from outer space. Thus, the triangle among national, international, and industrial levels is even more crucial to examine space development.

The increasing relevance of space technology development to states, which carries significant strategic, economic, and commercial implications, is a central issue in national security. Space power will be instrumental in 21st century Southeast and Northeast Asian diplomacy, strategy, and geopolitics. National security and economic policy makers in the region must begin to treat space power issues as core strategic interests. While space contestation is increasing given its importance, the world is simultaneously evolving into a multipolar order, where a greater number of forces, ideas, and technologies threaten stability in space cooperation. In this regard, the areas of space development are not exceptional in reducing potential threats and sustaining stability. International society has the most pivotal responsibility in taking part in this ongoing process. Under these circumstances, the importance of strong policymaking, statesmanship, and cooperation at the national, international, and industrial levels should be stressed. This endeavor is a decades-long process in which all related entities and actors must contribute practical solutions.

At the national level, technology policymaking is complicated on account of its relationship with national security. Prioritization and trade-offs that are needed for resource constraints are impediments to successful implementation and sustainable space development.

Chapter 4.
Perspective on Korean Space Technology Development Programs

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Abstract

Korea started a space program in the late 1980s, which means that the space development history of Korea is 30 to 40 years behind that of other space advanced countries. Nevertheless, Korea is recognized as one of the few countries in the world which have successfully developed space technologies within a short period of time. In addition, the recent success of NARO (KSLV-1, Korea Space Launch Vehicle-1) will brighten the perspectives on Korea space technology development programs and be helpful to the formation of the renaissance era in space development. To achieve this favorable environment for space development, consistent investment by the government is vital. More importantly, we have to have a strategy to sustain this newly achieved environment for a long period of time. The desirable case is that strong government leadership and voluntary investment from the private side create a virtuous cycle of sustainable space technology development. This paper is about this kind of sustainability and argues that it should be reflected in incoming and future Korean space technology development programs. For illustration, the Korean space launch vehicle program is selected as an example of proposed sustainable space technology development after analyzing several statistics related to space development.

Introduction

Space competition

Recently, Northeast Asia has been receiving much attention from the international space community due to four geographically close nations that have been producing noticeable, and sometimes worrisome, developments. The four nations are China, Japan, the DPRK (Democratic People's Republic of Korea, North Korea) and Korea. Most of all, China is getting closer to manned exploration of the Moon after a series of successes with manned spacecraft (Shenzhou program), Moon exploration (Chang'e program), and the Chinese space station (Tiangong program). This series of successes will make China the second country to send humans to the Moon. Meanwhile, Japan was inspired by the return of MUSES-C (Hayabusa, a 6 billion km journey from 2003 to 2010), and has been developing cost effective space launch vehicles to be survived in the commercial launch service market. In policy, Japan established a basic space law in 2008 and achieved a legal basis to use space technologies in various aspects under less conservative interpretations of "peaceful use." Depending on its own interpretation, space technologies can be used for military purposes in the name of national security. In addition, Japan consolidated the government structure for space development in 2012. For the DPRK, they are developing space technologies in order to enhance and show off their missile technology capability even though there exist UN Security Council sanctions against the DPRK (e.g. Resolutions 1718, 1874, and 2087), which ultimately ban any kind of technology development which is related to ballistic missiles. On the contrary, Korea is developing space technologies observing international agreements such as MTCR (Missile Technology Control Regime), missile guidelines between Korea and the USA, and others. Specifically, Korea has had great success in low earth orbit observation satellite development rather than space launch vehicle development. Considering the aforementioned facts, it could be said that two competitive landscapes exist in Northeast Asia. The first one is between China and Japan while the other is between the DPRK and Korea.

Brief view of space development in Korea

It is said that Korea started its space development at least 30-40 years later than space developed countries, since KARI (Korea Aerospace Research Institute) was established in 1989, and the first satellite was launched in 1992. Nevertheless, Korea has made remarkable achievements in space development within a relatively short period of time so that space emerging countries take Korea as a role model for benchmarking. In particular, Korea has been ranked as number five or six in the area of low earth orbit observation satellites after the success of KOMPSAT-3 (Korea Multi-Purpose Satellite-3, a.k.a. Arirang-3) since it can provide 0.7m optical resolution images. Most importantly, Korea has an almost perfect success rate in satellite development as shown by KITSAT-1, 2, 3 (Korea Institute of Technology Satellite); KOMPSAT-1, 2, 3; and COMS (Communication, Ocean, and Meteorology Satellite, a.k.a. Chullian), which is the first geostationary orbit satellite developed in Korea. Others include STSAT-1 (Science and Technology Satellite), and Naro Science Satellite while STSAT-2 did not survive due to launcher failure. With this series of successes, Korea has become a key member in the space community. Korea has also purchased geostationary orbit telecommunication satellites such as KoreaSat-1, 2, 3, 5 and 6 and has co-ownership with Japan of Han-Byul (MBSat). In addition, Korea's first radar image satellite "KOMPSAT-5" is to be launched in August, 2013. Soon thereafter, the science and technology experimental satellite, STSAT-3, follows it. KOMPSAT-3A, which has an IR (Infra-Red) channel as well as visual channels, is to be launched in 2014.

The recent success of NARO (KSLV-1) re-ignited the national enthusiasm to develop space technologies after the previous two failures and many delays might have negatively influenced other national space programs. With this success, Korea became a space-faring country. The world now counts Korea as the 11th member of the unofficial Space Club. There may be criticism due to the fact that the 1st stage of NARO was developed by Russia. Nevertheless, since the total program was conducted by Korea, there is no controversy in global opinion about the fact that Korea has become a space-faring nation. Taking KSLV-1 as a stepping stone, Korea launched the KSLV-II program in 2010, which is developing the next version of the Korea space launch vehicle in an indigenous way.

Space development programs in Korea have been planned and conducted by the government. The first Korean national space policy was established under the name of "Mid to Long Term Plan for National Space Development" in 1996. Later on, it was amended three times and replaced by the "Space Development Promotion Basic Plan" in 2007. The current 2nd Space Development Promotion Basic Plan was established at the end of 2011. In addition, to support the national space policy, the Space Development Promotion Act was established in 2005. According to the 2nd Space Development Promotion Basic Plan, space development programs will be set up by 2025. However, considering that the development period of a space launch vehicle is about 10 years and for a satellite it is about 5 years, a longer national plan may be necessary for industries to prepare and decide upon investment in the space program. Considering this fact and in order to give people a visible idea of upcoming space technology development, the Korean government is preparing its vision by 2035 reflecting opinions from inter-governmental bodies, and KARI has also prepared its own vision for space technology development by 2040 in parallel. These visions will be concretized and they could complement each other. At last, a new national long-term space plan will be established through consensus from space experts and taxpayers—people.

New economy boosting engine

Space technology development can act as an economy boosting engine and generate high quality employment. Historically, the Apollo project generated thousands of high technologies, and quite a number of those technologies were spun off. It is also known that 400,000 people were involved in the Apollo project. Under WTO (World Trade Organization) system, there are not many areas that can be led by a government. Atomic energy and space development are two areas where a government takes leadership. However, space development can be the better candidate considering that there is much opposition to atomic energy development. Nevertheless, to keep this advantage, space technology development should be sustainable for a very long period of time. To achieve sustainable space technology development, there are three major factors beside government leadership. The first one is a national economic capability. The second is a consensus from the people. The third is voluntary involvement from industries. The initial ecological system for space technology development can be founded by a government and the consensus of the people. However, to maintain and expand the above eco-system, the voluntary involvement of industries is vital. In order for industries to invest, the establishment of a long-term vision and national road map could be the most effective way. With full understanding, the government and KARI are preparing these in order to make space technology development play a key role enlarging the national economy and creating new quality jobs which are the key objectives in the new Korean government's creative economy.

Space Development in Korea

Old history of Korean launcher

Some Korean historians say that Korea was a leading country in rocket development ever since the multiple rocket launcher "Shin-Gi Jeon," whose literal meaning is "ghost technology arrow," was developed under the leadership of King Sejong in 1448. It was an improvement of "Joo-Hwa" which was developed by Choi Moo Seon at the end of the Koryo dynasty and its literal meaning is "running fire." To manufacture "Shin-Gi Jeon," the design tolerance was 0.3mm. The larger size launcher was called "Grand Shin-Gi Jeon." One noticeable thing is that "Shan-Wha Shin-Gi Jeon," which is a variation of "Grand Shin-Gi Jeon," is recorded as the first two-stage rocket in the world. These rockets could scare and distract enemies, but could not damage

Figure 1: Shin-Gi Jeon

Source: Doopedia

Figure 2: Grand Shin-Gi Jeon

Source: HelloDD

the enemies as much as conventional cannons in terms of gunpowder consumption. For example, "Grand Shin-Gi Jeon" is known to use more than three times as much gunpowder as "General Hwa Tong," which was the biggest artillery at that time. Due to this reason and others, the first Korean historical rocket did not appear to have a long lifespan and this technology did not turn out to be sustainable.

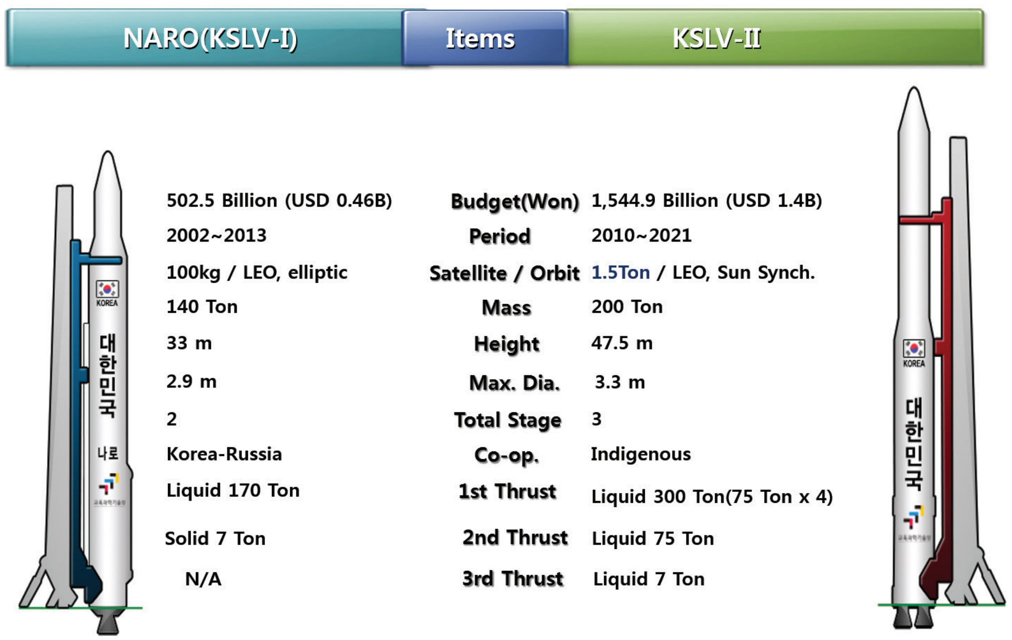
Korea space launch vehicle

Korea started space activities in the late 1980s and has made rapid growth in the space sector due to strong government leadership and a high success rate. In particular, the success rate of satellite development is perfect except for the case of launcher failure. However, Korea encountered difficulties in space launch vehicle development. The success rate of the KSLV is 33.3 percent since it was successful after two failures while the global average success rate of first space launch vehicle is known as 27.2 percent. Based on these accomplishments, KARI is preparing itself to take the next step in indigenous space launch vehicles (KSLV-II), and lunar exploration missions in space by 2020.

Figure 3 shows the differences between NARO (KSLV-I) and the KSLV-II. The mass of satellite which KSVL-II can carry is 1.5 tons while it is 100kg for NARO. Another big difference is that the KSLV-II is a 3-stage launcher which uses all liquid engines while NARO is a 2-stage launcher with a solid 2nd stage.

The KSLV-II program started in 2010 and it is in progress now. In this program, the 75 ton liquid engine development is the most important. The core components of the 75 ton engine, such as combustor, turbo pumps, gas generators, etc., were manufactured and are awaiting actual level tests. After the

Figure 3: Comparison between NARO and KSLV-II

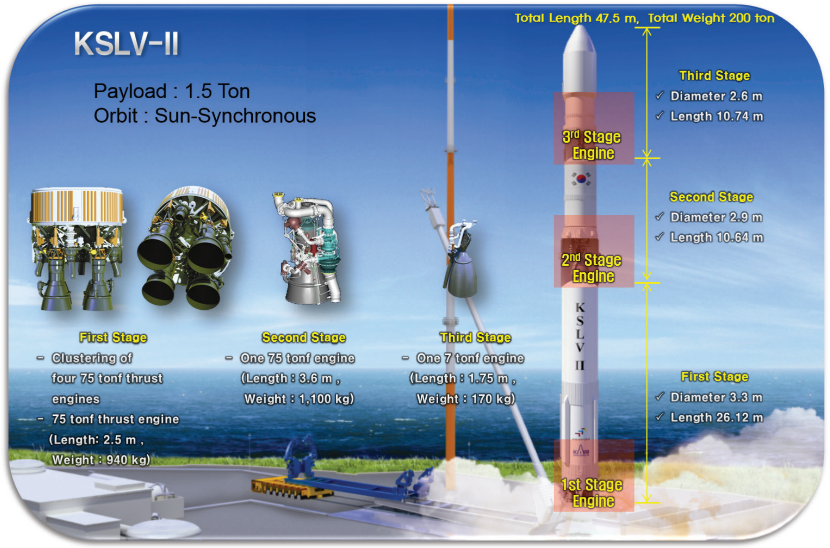


NARO(KSLV-I)	Items	KSLV-II
502.5 Billion (USD 0.46B)	Budget(Won)	1,544.9 Billion (USD 1.4B)
2002~2013	Period	2010~2021
100kg / LEO, elliptic	Satellite / Orbit	1.5Ton / LEO, Sun Synch.
140 Ton	Mass	200 Ton
33 m	Height	47.5 m
2.9 m	Max. Dia.	3.3 m
2	Total Stage	3
Korea-Russia	Co-op.	Indigenous
Liquid 170 Ton	1st Thrust	Liquid 300 Ton(75 Ton x 4)
Solid 7 Ton	2nd Thrust	Liquid 75 Ton
N/A	3rd Thrust	Liquid 7 Ton

Source: KARI (Korea Aerospace Research Institute)

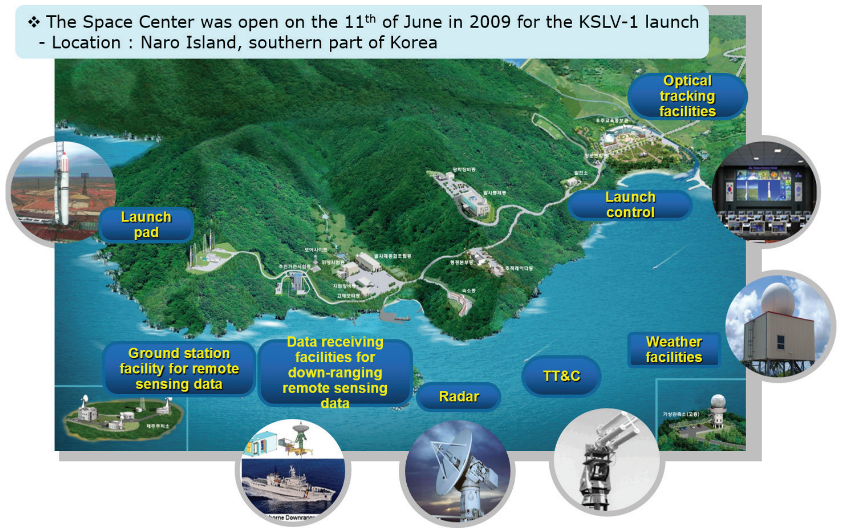
ground tests, the 75 ton liquid rocket engine will be fight-tested in 2017. After this success, four 75 ton engines will be grouped (clustered) to be the 1st stage rocket and one 75 ton engine will be used for the 2nd stage rocket. For the 3rd stage rocket, a 7 ton liquid engine is to be developed. The illustration of this mechanism is shown in Figure 4. The complete system of the KSLV-II is planned to be launched in 2019, which will insert a 1.5 ton satellite in a low earth orbit. In parallel, the Naro Space Center will be equipped with test facilities and be expanded to accommodate the KSLV-II launch. Figures 5 and 6 show the current and the 2nd phase of the Naro Space Center, respectively.

Figure 4: Configurations of KSLV-II



Source: KARI (Korea Aerospace Research Institute)

Figure 5: Current NARO Space Center



Source: KARI (Korea Aerospace Research Institute)

Figure 6: The 2nd Phase of NARO Space Center

Source: KARI (Korea Aerospace Research Institute)

Four infrastructures for space launch vehicle development

To be a technology superpower in space launchers, four infrastructures should be established. They are man power, space center, test facilities, and space industries. We can say that the 1st and 2nd infrastructures (man power and space center) were achieved during the NARO program and the 3rd infrastructure (test facilities) should be completed during the KSLV-II program. The 4th one (space industries) should be continuously established not only during the KSLV-II program but also following programs since the space industries in Korea are still in the early stages and are to be expanded.

Satellite development

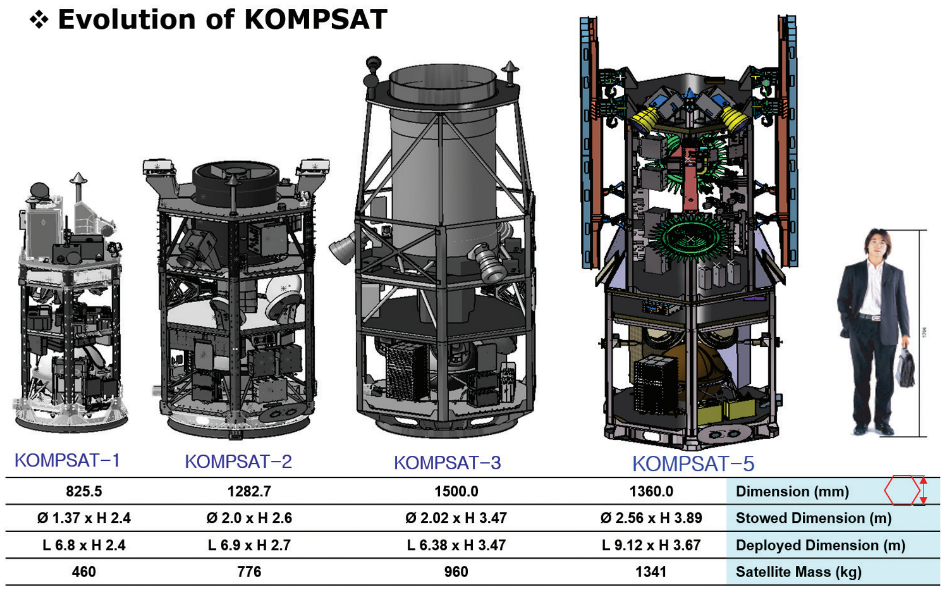
At present, KARI is preparing for GEO-KOMPSAT-2A and 2B, 2nd generation geostationary orbit satellites of COMS, planned for launch in 2017 and 2018, respectively, and the CAS500(Compact Advanced Satellite) program, which was initiated this year to implement a system of twelve 500kg class satellites in orbit by 2025. Table 1 shows all the major satellites which were and are to be developed by KARI.

Table 1: Major Satellites of KARI

Satellite	Specifications
KOMPSAT-1	Sun Synchronous Orbit: 685km Resolution: PAN 6.6m Mass: 460kg Launch: December 21, 1999 Mission Completion: January 31, 2008
KOMPSAT-2	Sun Synchronous Orbit: 685km Resolution: PAN 1m/MS 4m Mass: 800kg Launch: July 28, 2006
KOMPSAT-3	Sun Synchronous Orbit: 685km, Resolution: PAN 0.7m/MS 2.8m Mass: 1,000kg Launch: May 18, 2012
KOMPSAT-5	Sun Synchronous Orbit: 550km SAR(Synthetic Aperture Radar) Payload Resolution: 1m/3m/20m Swath width: 5km/30km/100km Mass: 1,400kg Launch: Planned for August 2013
KOMPSAT-3A	Sun Synchronous Orbit: 528km Resolution: PAN 0.55m/MS 2.2m/IR 5.5m Mass: 1,000kg Launch: Planned for 2014

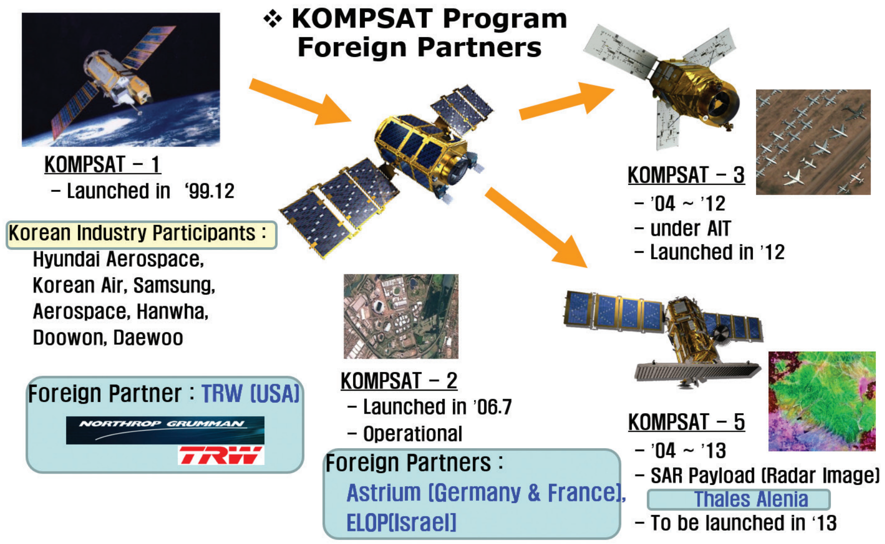
Satellite	Specifications
COMS	Geostationary Orbit: 128.2E Resolution: Meteo. 1 & 4km/Ocean 500m Mass: 2,460kg Launch: June 27, 2010
GEO-KOMPSAT 2A	Geostationary Orbit Resolution: Meteo. 1km & 2km Launch: Planned for 2017
GEO-KOMPSAT 2B	Geostationary Orbit Resolution: Ocean 250m/Environ. 2.5km Launch: Planned for 2018

Figure 7: Evolution of KOMPSAT



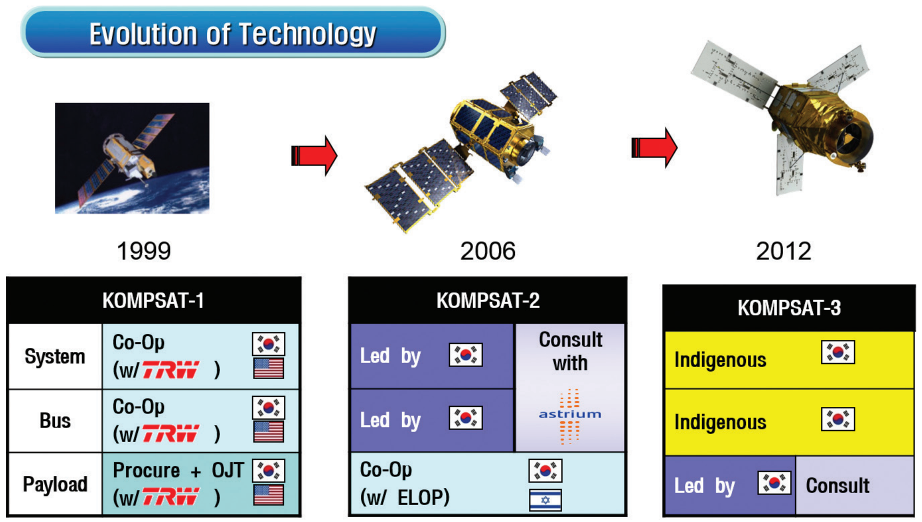
Source: KARI (Korea Aerospace Research Institute)

Figure 8: Foreign Partners of KOMPSAT Programs



Source: KARI (Korea Aerospace Research Institute)

Figure 9: Technology Accumulation of KOMPSAT Programs



Source: KARI (Korea Aerospace Research Institute)

Figure 7 shows how KOMPSAT satellites evolve in size as time passes. As seen in Figure 8, KARI has collaborated with many foreign partners, such as TRW (currently, merged to Northrop Grumman) for KOMPSAT-1, Astrium and ELOP for KOMPSAT-2 and Thales Alenia for KOMPSAT-5, while KARI has taken full responsibilities in KOMPSAT-3 development. Figure 9 shows how KARI has accumulated satellite technologies from KOMPSAT-1 to KOMPAT-3. For KOMPSAT-1 development, the system and bus were developed in cooperation with TRW while the camera was procured from TRW. For KOMPSAT-2, the development of the system and the bus were led by KARI with some consultation, while the camera was co-developed with ELOP. Finally, the development of KOMPSAT-3 was led by KARI.

National Space Development Plan

Space development promotion plan

Space development in Korea is controlled by the national space development plan. The "National Space Development Plan" was established in 1996. After that, the "Basic Space Development Promotion Act (2005)" and the "Space Development Promotion Basic Plan (2007)" were established. The "Space Development Promotion Basic Plan" is updated every five years so that it was updated at the end of 2011 (for the second time). The plan has the following two sentences as its vision and has been amended as seen in Table 2.

Vision:

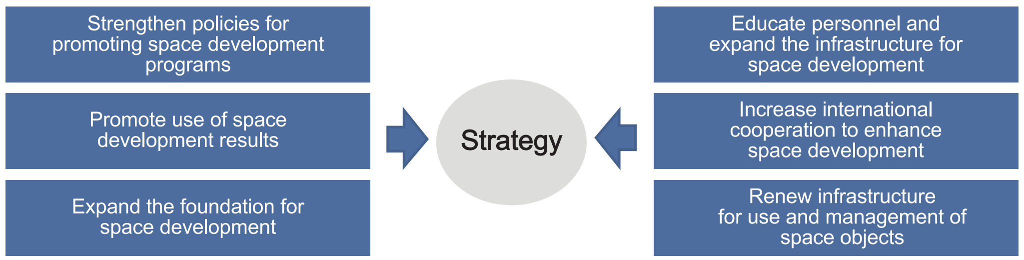
- Promote the peaceful use and scientific exploration of outer space
- Ensure national security and contribute to the growth of the national economy

Table 2: Chronicle of National Space Development Plan

'96. 4	Established the Mid to Long Term Plan for National Space Development: First National Space Policy
'98. 11	1st Amendment of the Mid to Long Term Plan for National Space Development ('96~'15)
'00. 12	2nd Amendment of the Mid to Long Term Plan for National Space Development ('96~'15)
'05. 5	3rd Amendment of the Mid to Long Term Plan for National Space Development ('96~'15)
'05. 5	Enactment of the Space Development Promotion Act
'07. 6	Establishment of the 1st Space Development Promotion Basic Plan ('07~'11)
'07. 11	Establishment of the Space Development Roadmap
'10. 8	Discussions on the Space Development Action Plan with the Ministries related
'11. 12	Establishment of the 2nd Space Development Promotion Basic Plan ('12~'16)

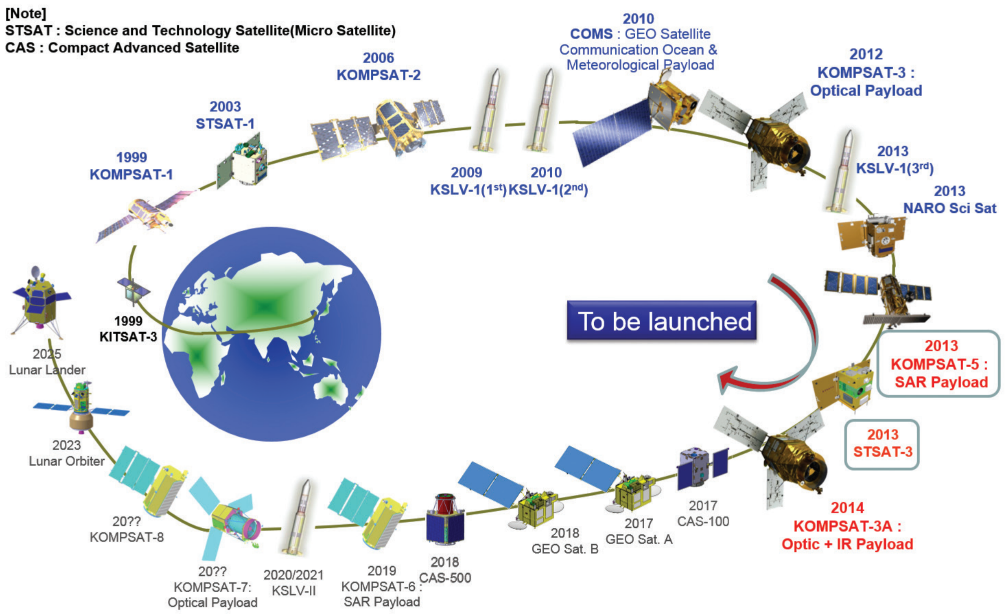
Figure 10 shows the strategy for space development in Korea and Figure 11 shows the overview of satellites and launchers which were developed or are to be developed by the space development plan. The schedule for lunar ex-

Figure 10: Strategy of Space Development in Korea



Source: KARI (Korea Aerospace Research Institute) ploration is based on the 2nd Space Development Promotion Basic Plan and is to be updated.

Figure 11: Overview of Space Development Plan in Korea



Source: KARI (Korea Aerospace Research Institute)

Public sector space stakeholders

The Korean government established a new cabinet in 2013. According to this change, the following five ministries are the space stakeholders in the public sector. Among them, the Ministry of Science, ICT and Future Planning (MSIP) is the leading government body for space development:

1) Ministry of Science, ICT and Future Planning
2) Ministry of Trade, Industry and Energy
3) Ministry of Environment (Korea Meteorological Administration)
4) Ministry of Maritime Affairs and Fisheries
5) Korea Communications Commission (Direct Presidential Body)

The key roles of MSIP in space development are as follows:

- Chairing the National Space Steering Committee
- Defining the National Space Plan
- Ensuring availability of funds for Space Development

Sustainable Space Technology Development

Affordable budget

On January 30, 2013, when NARO was successfully launched, Yonhap News conducted a survey of 1,000 people on the acceptable space development budget in Korea. The result showed that 63.4 percent of respondents said that space development budget in Korea should be increased and 50.1 percent of respondents said that the appropriate annual tax payment per capita for space development is KRW 10,000. Moreover, 18.1 percent and 11.3 percent of respondents answered KRW 20,000 and KRW 30,000, respectively. In other words, about 80 percent of Korean people are willing to pay more than KRW 10,000 for space development. This survey result is very encouraging since each Korean paid about KRW 4,000 for space development in 2011.

Table 3 shows statistics for major countries' budgets in 2011, which include government budget, government R&D budget and space R&D budget. It shows that the United Sates spent USD 42.4 billion for space R&D and

Japan spent USD 3.5 billion while Korea spent USD 0.2 billion. This means that the United States and Japan had space R&D budgets 212 times and 17.5 times as much as Korea did, respectively. Even though the absolute values in the table may have their own meanings, they might be misinterpreted in determining an affordable budget for space development in Korea since most countries in the table are economically developed or have much larger populations than Korea. For this reason, the ratio of interested value to a country's own size is adopted for the purpose of acquiring a more meaningful or fair interpretation. As shown in Table 3, the ratio of Korean government R&D budget to its GDP is 1.358 percent while all the values of other major countries are below 1 percent, and the ratio of Korean government R&D budget to its overall budget is 6.53 percent (by calculation). This value is considerably higher than any other countries. The facts show that the Korean government invested in R&D at a relatively higher rate than any other major country. However, as shown in the last column of Table 3, the ratio of Korea's space R&D budget to its GDP is 0.017 percent, while the value for America is 0.272 percent, for Russia it is 0.326 percent, and all the values of other major countries, except Brazil, are much higher than Korea's. Also, the ratio of Korea's space R&D budget to its government R&D budget is 1.27 percent (by calculation) while the value for America is 29.4 percent, for Russia it is 38.2 percent, and all the values of other major countries are much higher than Korea's. These facts suggested that the Korean government should invest much more in space R&D than as it does. Adversely, it can be said that the Korean government has the capability to invest much more in space R&D than now.

It is suggested that, since Japan spent 0.059 percent of GDP on space R&D while Korea spent 0.017 percent, three times as much the current amount should be invested in space R&D in Korea to catch up to Japan's level of attention to space R&D. Furthermore, since the ratio of Japanese space R&D budget to its government R&D budget is 10.3 percent (by calculation) while Korea's is 1.27 percent, it is not surprising to say that eight times the current amount should be invested in space R&D in Korea.

Table 3: Statistics of Major Countries' Budget in 2011

Rank	Country	GDP (USD Billion)	Government Budget		Government R&D		Space R&D Budget	
			Budget (USD Billion)	Ratio to GDP (%)	Budget (USD Billion)	Ratio to GDP (%)	Budget (USD Billion)	Ratio to GDP (%)
1	USA	15,609.6	3,599.0	23.056	144.3	0.924	42.4	0.272
2	China	7,991.7	1,729.0	21.635	40.7	0.509	3.0	0.038
3	Japan	5,980.9	2,495.0	41.716	34.1	0.570	3.5	0.059
4	Germany	3,478.7	1,588.0	45.649	29.2	0.839	2.0	0.057
5	France	2,712.0	1,535.0	56.600	19.4	0.715	3.1	0.114
6	UK	2,452.6	1,188.0	48.438	13.2	0.538	0.7	0.029
7	Brazil	2,449.7	901.0	36.780			2.1	0.009
8	Italy	2,066.9	1,112.0	53.800	11.1	0.739	1.1	0.053
9	Russia	2,021.8	376.2	18.607	17.3	0.856	6.6	0.326
10	Canada	1,804.5	747.8	41.441	8.4	0.466	0.6	0.033
11	India	1,779.2	333.0	18.716			1.4	0.079
12	Australia	1,585.9	521.8	32.902				
13	Spain	1,397.7	672.1	48.086				
14	Mexico	1,207.8						
15	Korea	1,163.5	242.0	20.799	15.8	1.358	0.2	0.017

Role of Government

Space industry in Korea is still in its nascent stage so that the government's support is needed for a while. According to an industry survey conducted by KARI last year,[1] just 61 companies claimed they have relationships to the space industry in 2011. Among them, 44.2 percent recorded less than one billion won in gross annual sales and 50.8 percent of them had less than 100 employees. The Korea's space industry is estimated at USD 990 million, which corresponds to merely 0.3 percent of the global space market.

In the past 10 years (2004-2013), one space launch vehicle project was completed and six satellites (COMS, KOMPSAT-2 & 3, two STSAT-2, Naro Science Satellite) were launched. This means that about 0.6 satellites were launched every year. However, since STSAT-2 and Naro Science Satellite did not need much involvement from industry, the practical involvement from industry was much lower than the literal meaning of 0.6 satellites per year. It is suggested that, in order to induce industries to continuously participate and invest in space development, delay or discontinuation of projects should be avoided. If these things happen, maintaining human resources and production lines will be jeopardized, not to speak of profitability. This is what the government should do to establish an initial sustainable environment for space development.

1. Fact-finding Survey on Korean Space Industry, Ministry of Education, Science and Technology, 2012.

Strategy for Sustainable Space Launch Vehicle Development

Statistics

The KSLV-II project was launched in 2010 by national demand. However, it is necessary to eventually penetrate the commercial launch service market in order to make space launch vehicle technology sustainable. For this reason, the Korean space launch vehicle program is selected as an example of sustainable space technology development and then a realistic strategy is proposed for this goal. In the long run, the perspectives of the Korean space launch vehicle development programs might be a reflection of what this paper proposes as a strategy. To obtain the right strategy, it is necessary to analyze and predict the commercial launch service market first.

During the year of 2011, a total of 84 launches were conducted as shown in Table 4. Specifically, 18 commercial launches were conducted while 66 non-commercial launches were done. Russia recorded the largest number of commercial launches at 10 (56%). Meanwhile, Europe recorded four launches (22%), China two (11%), and multination two (11%). Multination stands for the Sea Launch company. In 2011, no commercial launches were made by the United States. In order to be classified as a commercial launch, one of the following conditions should be met:

- The contract is made through an international tender
- The consumer is civilian
- The launch was conducted with FAA approval

During the year of 2011, a total of 133 payloads were carried in space as shown in Table 5. Specifically, 35 payloads were carried by commercial launches while

98 payloads were done by non-commercial launches. Russia recorded the largest number of commercial payloads at 21 (60%).

Table 4: Statistics of Space Launch in 2011[2]

Country	Commercial Launches	Non-Commercial Launches	Total
USA	0	18	18
Russia	10	21	31
EU	4	3	7
China	2	17	19
Japan	0	3	3
India	0	3	3
Iran	0	1	1
Multi-National	2	0	2
Total	**18**	**66**	**84**

Table 5: Statistics of Payload in 2011[3]

Country	Commercial Payload	Non-Commercial Payload	Total
USA	0	28	28
Russia	21	32	53
EU	8	9	17
China	4	17	21
Japan	0	3	3
India	0	8	8
Iran	0	1	1
Multi-National	2	0	2
Total	**35**	**98**	**133**

2. Commercial Space Transportation: 2011 Year in Review, FAA, 2012.

3. Ibid.

Table 6 shows statistics of launches in 2012. During the year of 2012, a total of 78 launches were conducted. Specifically, 13 were made by the United States, 24 by Russia, 10 by Europe, 19 by China, two by Japan, two by India, three by Iran, two by North Korea, and three by multinational. Among them, 20 were commercial launches. The total number of launches and the number of commercial launches in 2012 are comparable with five-year averages of the total number (77) and the commercial launches (23). The United States recorded two commercial launches in 2012 while it made none in 2011. The two commercial launches were conducted by the Space-X company. Their Falcon-9 launch vehicles delivered supply goods to the International Space Station.

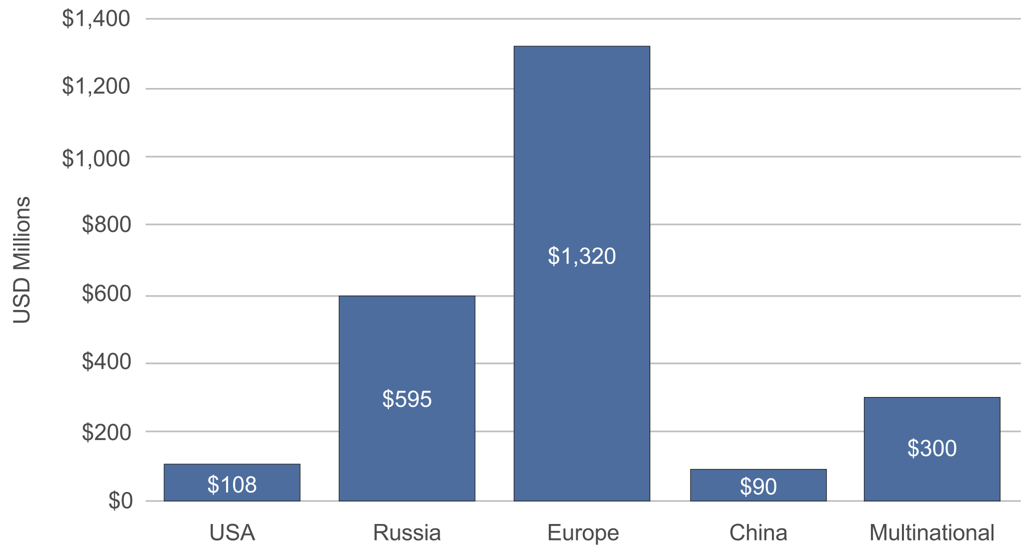
Table 6: Statistics of Space Launch in 2012[4]

Country	Commercial Launches	Non-Commercial Launches	Total
USA	2	11	13
Russia	7	17	24
EU	6	4	10
China	2	17	19
Japan	0	2	2
India	0	2	2
Iran	0	3	3
North Korea	0	2	2
Multinational	3	0	3
Total	**20**	**58**	**78**

The revenue of commercial launch services in 2012 is forecasted to be approximately USD 2.4 billion. This value is similar to those in 2009 and 2010. However, it is approximately USD 500 million higher than that in 2011. Figure 12 shows the sales of individual countries.

4. Commercial Space Transportation: 2012 Year in Review, FAA, 2013.

Figure 12: Sales of Commercial Launch Service in 2012[5]



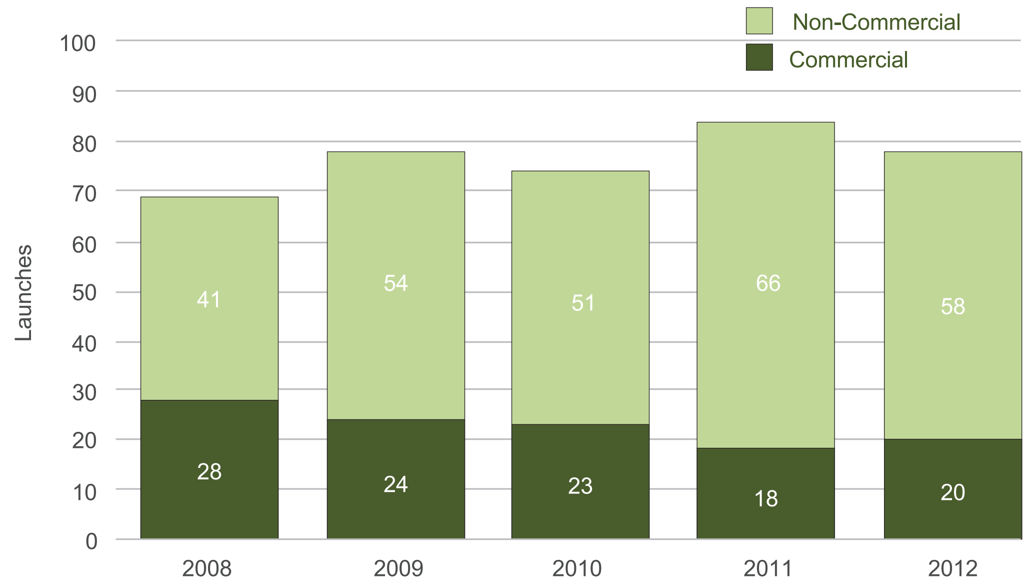
Source: FAA (Federal Aviation Administration)

As shown in Figure 13, during the last five years (2008-2012), the total number of launch was 383 and the annual average is about 77. During this period, Russia recorded the highest number of launches at 141 (37%). The United States recorded the second highest at 85 (22%), China was third with 70 (18%) and Europe was fourth with 36 (9%). The aforementioned four countries (including Europe) conducted 86 percent of the all launches. One hundred and thirteen (113) commercial launch services were performed during the five years, which means that approximately 23 commercial launches were conducted annually.

In the last five years, an annual average of commercial geostationary transfer orbit launch services was 17 out of 23, which is the annual average of total

5. Ibid.

Figure 13: Statistics of Launch for 5 Years[6]



Source: FAA (Federal Aviation Administration)

commercial launch services. This means that 74 percent of the commercial launches were for geostationary transfer orbit launch. Consequently, it is necessary to upgrade the KSLV-II for commercialization so that it can carry payloads to a geostationary transfer orbit.

Strategy for space launcher development

President Park Geun Hye declared in December 2012 during her presidential election campaign that Korea would launch its first lunar lander by 2020 by reducing the development period of KSLV-II, which will be the first indigenous space launch vehicle of Korea. To meet this goal, the most critical

6. Ibid.

event is to launch its own space launch vehicle for a 1.5 ton commercial satellite in or before 2019 so as to prove indigenous technologies. To achieve this objective, a 75 ton liquid rocket engine should be tested first in 2017. With this verified liquid engine, a three staged launch vehicle is integrated in such a way that four 75 ton liquid engine units are clustered for the 1st stage, one 75 ton liquid engine is used for the 2nd stage, and one 7 ton engine is used for the 3rd stage. It could be quite a challenging schedule since the development schedule is much reduced. However, most of the key components of the 75 ton engine, including the combustor, turbo pump and gas generator, have already been produced and are awaiting integrated tests. As long as test facilities required for the development of liquid engine and propulsion systems are prepared according to schedule, it is achievable.

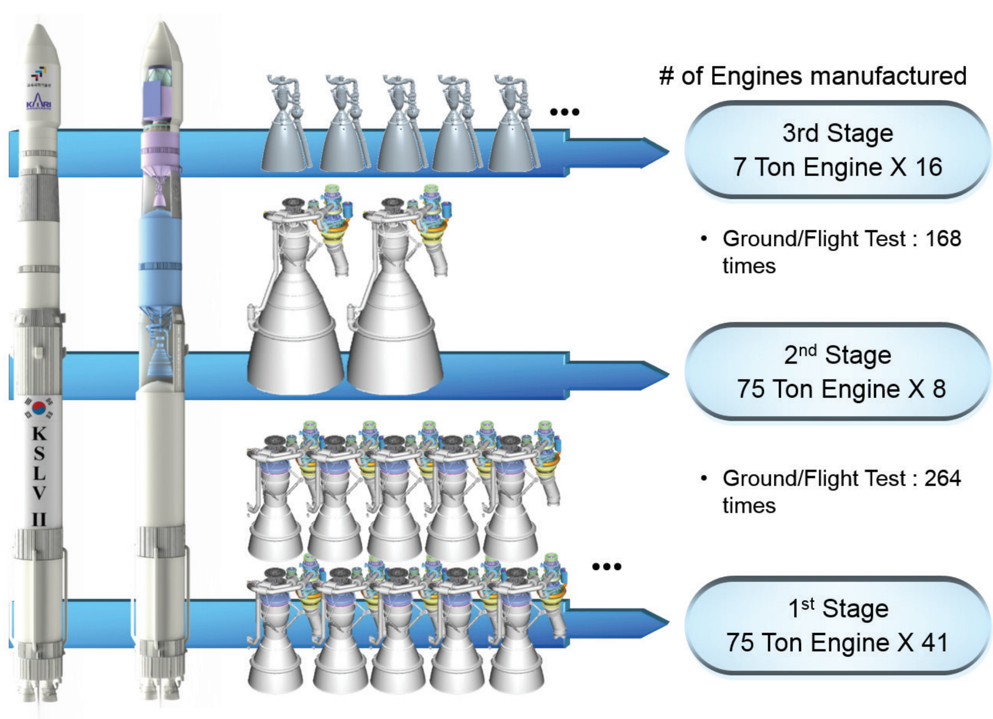
In the 1960s and 1970s, the Korean government used to persuade and drive industries to invest in specific areas which did not seem to be profitable at first but very important for future industrialization and establishment of infrastructure in the name of patriotism and compensation through other manners. However, in the 21st century, this kind of policy will not work in Korea anymore. Unless the Korean government shows a long-term plan and a long-term vision, industries will hardly invest. The government can make an initial ecological system for space technology development and industrialization. However, investment from industries is necessary to sustain the system and expand it. Voluntary investment from industries is possible when they see a future vision and the government shows a strong will with a long-term national development plan.

For the voluntary investment from industries in KSLV-II, it should be acknowledged by industries that a total of 65 liquid engines need to be manufactured for the KSLV-II project to complete ground/flight tests and launches (Fig. 14), and 95 liquid engines will be needed when the lunar exploration is added (Fig. 15). The strategy which is taken in the KSLV-II project is that the same proven engines are clustered to get more power rather than to develop a new more powerful engine. Due to this strategy, mass production becomes possible, and consequently, design and manufacturing costs are reduced.

Once technological independence is obtained through the development of the KSLV-II, it will be much easier to launch a three ton satellite into geostationary transfer orbit or a 10 ton satellite into low earth orbit (KSLV-III, not planned yet). Furthermore, the larger size space launch vehicle (KSLV-IV, not planned yet) can handle at least 20 tons of large cargo. With these space transportation capabilities, space hotels, space factories, space solar power plants, and other huge space architecture can be constructed. According to this futuristic vision, commercial investment by industrial entities is naturally expected. The strategy which is to be taken for KSLV-III and -IV development is similar to the one for KSVL-II development in that a larger number of identical proven engines are clustered for more power (KSLV-III). Ultimately, the 1st stage rocket has two identical boosters (total three identical units), side by side, to achieve maximum power (KSLV-IV). Due to this strategy, the mass production of the liquid engines becomes possible and a cost reduction is foreseen.

At the same time, the facilities of the Naro Space Center are being expanded for KSLV-II. For KSLV-III, the launch site should be located near the equator to take full advantage of the Earth's rotation speed since KSLV-III will be used for geostationary transfer orbit launch. If a terrestrial launch site is not available near the equator, a sea-launch is an alternative as currently provided by Sea Launch company. KSLV-IV can be launched from the same launch site as KSLV-III with some upgrades. Beyond this conventional space launch vehicle, as an ultimate space transportation vehicle, a reusable space plane which can take off and land from a space airport should be developed. If this is possible, the cost of space transportation will be less than USD 1,000 per Kg while it is currently around USD 20,000 per Kg.

Figure 14: Total Required Number of Engines for KSLV-II

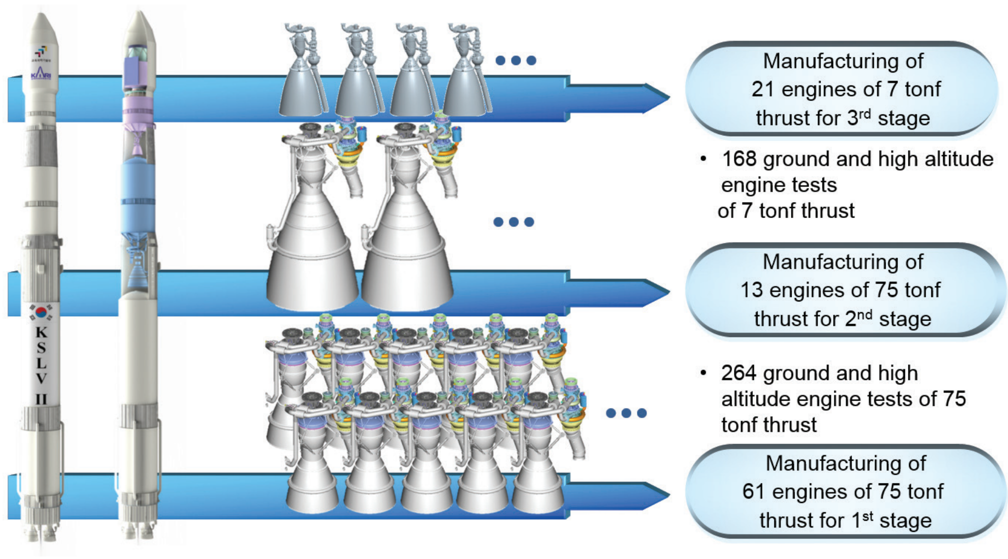


49 engines of 75 tonf thrust + 16 engines of 7 tonf thrust = 65 Units

Source: KARI (Korea Aerospace Research Institute)

Now, some changes in space development are observed. Space technology development is now being recognized as a Blue Ocean in space developed countries so that the space technology development race is accelerating. One noticeable thing is that a private company started a commercial launch

Figure 15: Total Required Number of Engines for KSLV-II and Lunar Exploration



74 engines of 75 tonf thrust + 21 engines of 7 tonf thrust = 95 Units

Source: KARI (Korea Aerospace Research Institute)

service business. The Space-X company in the United States developed the space launch vehicle "Falcon-9" and the space transport ship "Dragon" in order to deliver supply goods to the International Space Station. The company turned to a profit 10 years after establishment. The space launch vehicle development strategy of Space-X is very close to what is mentioned in this paper and is subject to benchmarking. The Merlin-1C engine which has approximately 43 tons of thrust was developed and it was clustered to achieve the high power needed. This clustering technique was the most important factor to reduce the development cost and time for Space-X. In parallel, many ventures gathered and established Space Valley in the Mojave Desert in the United States. Space Valley seems to follow Silicon Valley and the phenomena is reminiscent of the aviation venture establishment period in the early 20th century.

Conclusion

This paper puts Korean space technology development programs into perspective. Some programs are under the national development plan while some programs are not, but this is necessary to make the space technology development sustainable. The government's leadership is very important in space development. In addition, support and consent of the people are more important since we are living in an open society. However, to achieve and maintain sustainable space technology development, the importance of investment from the private sector cannot be overly emphasized since we are living in a market economy society. Government strong leadership being well balanced with its own economy size, support from people and investment from the private sector are the requirements for sustainable space technology development.

As suggested in this paper, the Korean government should invest three-to-eight times the budget of 2011 in space R&D to catch up with Japan's level of attention to space R&D. Also, to maintain human resources and production lines in space industries, delay or discontinuation of projects should be avoided. This is what the government should do to establish an initial sustainable environment for space development.

Mass production of liquid engines can reduce development cost and time and should be recognized by industries for voluntary investment in space launch vehicle development. The goal of space launch vehicle development is beyond technology independence and lunar exploration. To be sustainable, it must be commercialized. This commercialization concept should be set up in the early development phase of KSLV-II and borne in mind during the entire development period. At present, the space launch service market

is dominated by a small number of countries. Before the competition becomes fiercer, Korea has to enter the commercial market. Since Korea is at the top level of precision machining, electronics and information technology, commercialization of space launch vehicles will not be as hard as people expect.

Acknowledgement

The strategy for space launch vehicle development is based on "Space Vision 2040," which was established at the Korea Aerospace Research Institute from the last half of 2012 to the first half of 2013.

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