한국항행학회논문지
Journal of Advanced Navigation Technology

항행 및 항법

J. Adv. Navig. Technol. 21(3): 203-209, Jun. 2017

소형위성의 개발현황 및 군사적 활용 방안

Development Trends of Small Satellites and Military Applications

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[요 약]

대형 위성들은 수십억 달러가 넘는 개발 비용이 사용되고, 우주환경에서 운영하기까지 수십 년이 걸릴 수도 있다. 이에 비해 소형 위성은 상용 소프트웨어, 센서 등을 활용해서 비용을 절감할 수 있으며 개발 기간을 2년 이내로 단축시킬 수 있다. 본 논문에서는 이렇게 많은 이점을 가지고 있는 소형위성의 국내외 개발현황을 살펴보고, 소형위성을 군에서 활용하기 위한 몇 가지 방안을 제안한다. 먼저, 해외 개발현황으로 미국, 일본의 소형위성 개발현황을 소개하고, 국내 소형위성 개발현황을 소개한다. 군사적 활용방안은 크게 교육, 연구, 작전 분야로 분류하여 제안한다. 최근 소형위성은 상업 분야에서 빠르게 발전하고 있으며 향후 군에서도 중요한 역할을 할 것이다. 따라서 향후 스타워즈를 준비하고 있는 군에게 소형위성은 반드시 필요한 자산이며, 연구개발을 통해 지속적으로 발전시켜 나가야 한다.

[Abstract]

Large satellite development programs might take decades to build, launch and operate in space environments at costs in excess of a billion dollars. However, small satellites can reduce the costs not only by using commercial software and sensors, but also by shortening the development period to two years or less. In this paper, we discuss the development status of small satellites, and propose some military applications of small satellites. First, we describe the industrial trends of small satellites in advanced countries such as the United States and Japan. Also, we describe the development status of small satellites in Korea. Military applications are largely classified into education, research, and operational purposes. Small satellites are developing rapidly in commercial markets and they will play an important role in military sector. Therefore, the military should consider small satellites as important strategic assets in future conflicts and provide means to develop them.

Key word : Small satellites, Cubesat, Nano satellites, Micro satellites, Military applications of small satellites.

https://doi.org/10.12673/jant.2017.21.3.544

Received 28 April 2016; **Revised** 1 June 2017
Accepted (Publication) 5 June 2017 (30 June 2017)

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Ⅰ. Introduction

The development of small satellites represents a change to the conventional space industry model. Compared to traditional large satellites, small satellites are manufactured within a shorter time and are much cheaper [1]. Small satellites have less launch risk and their turnover rate is much faster than large satellites. Also, new technologies can be tested with them.

With the development of electronic, electrical and optical technologies, miniaturization of highly integrated modules has become possible. Therefore, the development of small satellites is accelerating. As a result, small satellites have carried out earth observation, space data collection, and asteroid exploration, which had previously been performed by medium satellites. In addition, small satellites can perform missions that cannot be performed by large satellites. They can form satellite fleets to collect information from various parts of space and are helpful to carrying out related research [2-3]. Because the cost of medium and large satellites is very high, projects which were carried out by governments are now carried out by private companies using small satellites. 28 small satellites were launched in 2008, 141 in 2014, and 3000 are predicted to be launched between 2017 and 2021 with a market size of over $ 7.5 billion [4]. No longer is space the domain of governments and large space agencies.

Satellites can be easily classified by mass. Depending on the mass, a satellite can be classified as a small satellite up to 500kg, a medium satellite less than 1,000kg, and more than 1,000kg are considered to be large satellites [5]. Small satellites are further classified into minisatellites, microsatellites, nanosatellites, picosatellites, and femtosatellites according to their mass [6]. Generally, because larger satellites need more budget, there are strong incentives to miniaturize the the satellite as much as possible.

The rest of this paper is organized as follows: Section 2 discusses the background of small satellites, development trends of small satellites, and the current status of domestic and international developments of small satellites. Section 3 introduces military applications of small satellites. Finally, Section 4 discusses the results of this research and presents questions for further research.

Ⅱ. Backgrond

2-1 Small satellites

Small satellites are usually launched into Low Earth Orbit (LEO). As a result, orbits of small satellites decay quickly and this short lifetime favors rapid development and replacement. Therefore, demands for cheaper satellites and launch vehicles are continually increasing.

There are a lot of different ways to classify small satellites – by function, orbit type, size, mass, and so on [7]. Among these factors, Classification by mass is widely used. Table 1 shows a scheme for classifying satellites by mass. Within this scheme small satellites are defined as all satellites with a mass of less than 500 kg. Small satellites are further classified into minisatellites with a mass of less than 500 kg, microsatellites with a mass of less than 100 kg, nanosatellites with a mass of less than 10 kg, picosatellites with a mass of less than 1 kg, and femtosatellites with a mass of less than 100 g.

The small satellite industry has experienced unprecedented investment, with launch, development, and operation of small satellites increasing each year. Commercial space is dedicated to transforming industry and the growing small satellites market allows reductions in costs while also improving small satellite technologies. Fig. 1 shows number of satellites currently in orbit and predicted to be in orbit by 2019 [8]. Rapid growth has been taking place since 2012.

표 **1.** 소형 위성의 분류
Table 1. Classification of small satellites

100 ~ 500 kg	Minisatellites
10 ~ 100 kg	Microsatellites
1 ~ 10 kg	Nanosatellites
100g ~ 1 kg	Picosatellites
10 ~ 100 g	Femtosatellites

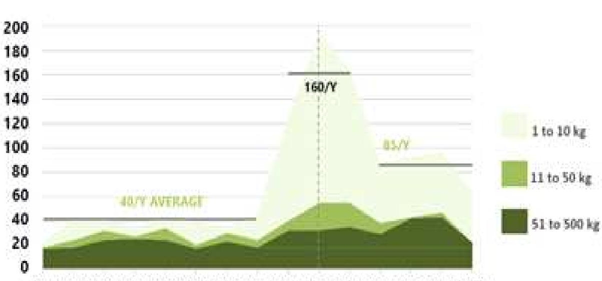

그림 **1.** 2019년까지의 위성 수
Fig. 1. Number of satellites in orbit by 2019.

2-2 Development status of small satellites in the U.S.

NASA is carrying out a lot of development projects for 1U ~ 6U class small satellites through Small Spacecraft Technology Program (SSTP). 1U class means one cubesat unit which is defined as a satellite in a 4 inches cube or about the size of a tissue box and weighs approximately three pounds. The purpose of the SSTP is to develop new technologies for small satellites as subsystems of large satellites and to reduce costs, risks and time for large satellites [9]. The program's current focus is on systems for communications, propulsion, power and pointing. Beginning in 2015 and running through 2016, six small satellites funded by the SSTP will launch. These satellites will demonstrate a variety of technologies such as high-speed optical communications to increase downlink rates from small satellites [10].

With the development of new technologies, NASA is conducting a major space flight mission for small satellites. NASA Ames Research Center has played a key role and led NASA in conducting a number of research and development in aerospace technology. In 2013, they launched PhoneSat 1.0 to validate the Nexus One smart phone technology in space. It was a very important issue that NASA demonstrated low-cost, modern electronics can fly in space. In 2014, they were experimenting with verification of communication information sharing between eight cubesats in space [11]. In 2016, TechEdSat-5 will launch from the International Space Station (ISS) and deploy an aero-brake. This is an exo-atmospheric drag chute that can be used for controlled de-orbit of a small payload canister from Earth orbit [12].

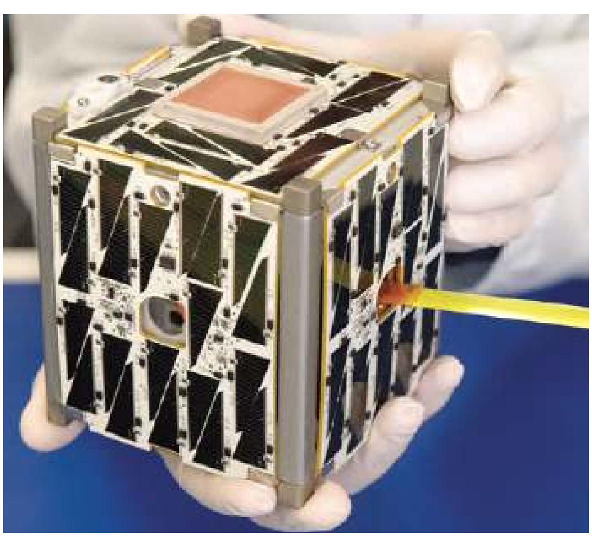

그림 2. NASA의 Phonesat
Fig. 2. Phonesat of NASA.

Small satellite technologies are used by many organizations outside of NASA to explore low-Earth orbit and the effects of microgravity. Together with NASA, companies like NanoRacks, SpaceX, and Orbital ATK give commercial companies the opportunity to fly their small satellites as auxiliary payloads on cargo resupply missions to the International Space Station. Small satellites may be deployed directly from the rocket or a spacecraft depending on the mission. NanoRacks signed a teaming agreement with Blue Origin to offer integration services on their New Shepard space vehicle in 2015 [13]. NanoRacks, along with partners at United Launch Alliance (ULA) and Space Systems Loral was selected by NASA to participate in the NextSTEPs Phase II program to develop commercial habitation systems in low-Earth orbit and beyond in 2016.

In academic fields, there foundations of U.S. small satellite technology were established at the Small Satellite Conference, which has been hosted by the American Institute of Aeronautical and Space Sciences (AIAA) and Utah State University since 1987. Each year, the conference publishes a large number of papers related to small satellites and holds exhibitions. The conference attracts contributions from universities and professional research institutes in Japan, Russia, and Europe.

2-3 Development status of small satellites in Japan

The Japan Aerospace Exploration Agency (JAXA) was designated as the core agency to support the Japanese government's overall aerospace development and utilization. Therefore, they can conduct integrated operations from basic research and development, to utilization. In particularly, JAXA plays an important role on the International Space Station (ISS).

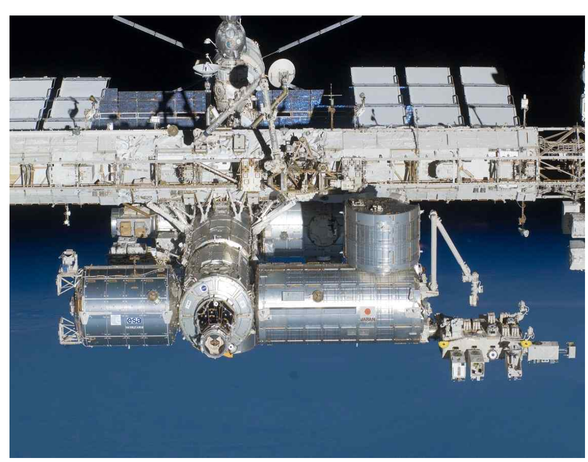

그림 3. 우주정거장과 일본 실험 모듈 “Kibo”
Fig. 3. ISS and Japanese Experiment Module "Kibo."

In 2015, the Kounotori 5 cargo spacecraft arrived at the International Space Station with astronaut Kimiya Yui, who was on a long-duration mission on the ISS [14]. On the ground, astronaut Koichi Wakata assisted the docking as lead capcom (capsule communicator). It was the first time that the two roles were handled by Japanese at the same time. In the meantime, the Japanese Experiment Module Kibo has been operating securely since its completion in 2009, and its utilization is expanding with new space-based experiments and private-sector use. In 2012, they succeeded in launching small satellites directly into space orbit in Kibo module [15]. As a result, small satellites can be placed into orbit with less vibration than launch from a ground station. Over than 60 small satellite launches from Kibo were successful from 2012 to 2015. However, they still have to survive launch from Earth.

2-4 Development status of small satellites in Korea

The first small satellite in Korea was the KITSAT- 1 launched in 1992. Next, KITSAT-2, 3 were launched in a row. Kyunghee University in Korea developed two Triocinema satellites in cooperation with UC Berkeley and Imperial College in order to study space environment changes. There satellites were successfully launched in 2013.

The Korea Aerospace Research Institute held a Cube Satellite Contest in 2012 to expand and promote space technology [16]. Through this contest, acquired technologies for small satellites and designs for various small space vehicles. The level of technology in Korea is relatively low compared to foreign spacefaring countries like the United States.

Ⅲ. Military applications of small satellites

In the wide range of services delivered by military space systems, the military has many ongoing requirements that depend on quite large satellites. Surveillance satellites and telecommunications satellites, for instance, can be the size of a small house. Thus, military satellites can be very large, large, medium, or small, depending on the specific need. However, small satellites for military applications can actually cover a number of those needs.

For example, small satellites could be part of a space-based radar system as distributed bi-static elements and synthetic aperture radar of small satellites might facilitate resolution for battlefield operations. Also, small satellites could provide to communicate a lot of data in battle fields and enhance combat effectiveness with useful information such as weather, target, and bomb damage.

3-1 Education

Recently, there are more opportunities for educators to use the technologies of small satellites. Small satellites are being used by the Korean military for Air Force Academy cadets and Air Force officers whose jobs are related to space. The Korean Air Force Academy is leading the development of small satellites in the Korea. Also, the Korean Air Force Academy has opened a ground station for launching small satellite launches in 2014 and is currently conducting research for launching small satellites in 2018. These developments are led by professors of Air Force Academy, and cadets are participating. These programs have helped contributed to the strength of Air Force space at low cost. Through these experiences, the Air Force can develop space technologies and the ability to perform space operations. In addition, these small satellites can provide voice communications between the ground station and PeaceEye, one of the assets of the Air Force Moving Platform for air surveillance, and Intelligence, Surveillance and Reconnaissance (ISR) capability with satellite constellations. It is possible to provide seamless communication and ISR capability with a 24-satellite constellation. Although geostationary satellites can provide seamless communication, it is effective to use a 24-satellite constellation. Because small satellites can be operated quickly with low cost.

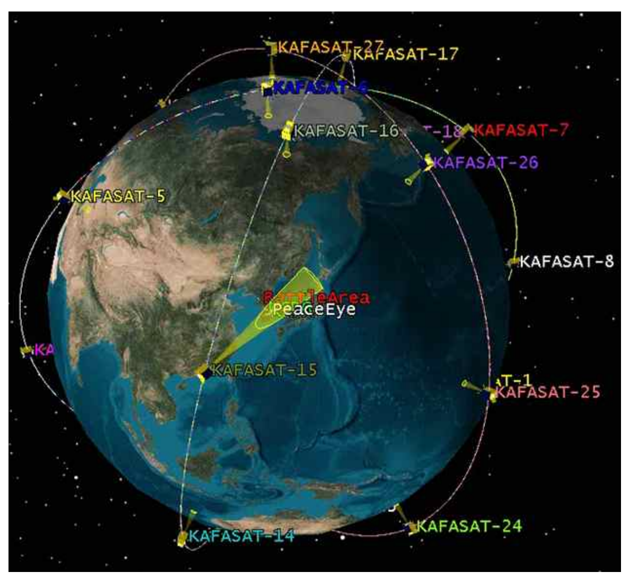

그림 4. 24개의 위성군을 통한 24시간 통신 및 ISR 개념도
Fig. 4. Concept of seamless communication and ISR capability with 24 satellite constellations.

3-2 Research

As interest in the space environments increases, the Korean Air Force has been working with the U.S. Air Force since 2015 on research regarding ionosphere effects that cause satellite and military communication disturbances. Research is currently being conducted with ground-based measurements, but space-based measurements can provide superior results. Small satellites can be very useful for this research and may provide valuable measurements from space. Space-based measurements from these small satellites would have better quality than those from ground facilities. Because the accuracy of ground-based measurements depends on the atmospheric conditions. Also, Space-based measurements from small satellites help us to understand space environments.

There is an example that satellite observations can help answer. There were some questions in carbon cycle science about anthropogenic CO_2 emissions. The questions are how this uptake is partitioned to different area across the earth. Initially, experts used ground-based facilities and most techniques depend on observing infrared reflected off Earth's surface. However, Clouds interfered with accurate measurements and the measurements had some errors. To handle this problem, space-based measurements were used with ground-based observations. Since then, additional space-based measurements have begun in many different fields.

Also, A constellation of small satellites can help weather officers better model the weather. For example, NASA's newest small satellite constellation helps scientists track storms, as well as predict their intensity. This is also expected to improve storm surge forecasts.The eight micro-satellites use new GPS technology and analysis techniques to better predict what exactly is going on beneath the rain.

One of reasons to use of small satellites in research is to take advantage of the rapid sequence possible with small satellites, from development through launch, operations, and management. Typical small satellite projects move from idea to implementation within 18-24 months. In terms of price, advances in sensor technologies will make small satellites more cost-effective [17].

3-3 Operation

In the case of commercial services, the functions of telecommunications, remote sensing, and navigation services are well established, In the case of military systems, the outbreak of emergency situations prompted by an enemy attack can occur with little or no warning. The military can adapt to these situations by using small satellites that can be assembled, launched, and operated quickly.

First, small satellites can enable communications by voice, data, and even images in battle fields. Some Korean military operations might depend on commercial satellites in wartime. Military small satellite constellations can also support remote mobile communications. Currently, the Korean military uses HF radio for long distance ground communications, but small satellite constellations can provide high quality communications between ground stations.

Also, small satellites are useful for data collection. Many types of military services require broadband service and large commercial satellites. However, there are other services that require only the collection of small amounts of data to detect and monitor battle fields. One example is the Close Air Support (CAS) mission. In the past, the Joint Terminal Attack Controller (JTAC) would identify the enemy ground target directly and delivered its position to the friendly fighter. Recently, Unmanned Aerial Vehicles (UAV) have been widely used for ground target identification. However, it is very difficult for a UAV to carry out missions with fighter aircraft, because the UAV is easily affected by weather conditions such as wind, rain, and snow. Small satellites can be an alternative to using a UAV. Small satellites with visible and IR sensors could enhance surveillance and target identification capabilities to support operations. Also, small satellites can transmit target data and bomb damage to fighters. Small satellites could support friendly forces for battlefield operations in all weather, day, and night conditions.

Ⅳ. Conclusion

Large satellites development programs might take decades to build, launch and operate in space environments at a cost in excess of a billion dollars. However, small satellites can have benefits such as lower costs to develop, lower costs to operate, and a higher refresh cycle that supports rapid technology evolution. In this paper, we described the major trends of small satellites in advanced countries such as the United States and Japan. We also described the development status of small satellites in Korea. Small satellites are rapidly developing in the commercial market and they will play an important role in the military sector. Therefore, the military should consider small satellites as important strategic assets and provide a way to develop them. These are our recommendations for the Korean military and some of the concepts from this paper should be refined by future work.

In education, the Korean Air Force Academy should lead the development of small satellites and provide the means for the development of supporting technologies. In research, the Korean Air Force should work with the U.S. Air Force on joint projects involving the development and use of small satellites. In operations, small satellites should be used for communication and surveillance. Because small satellites can be assembled, launched, and operated quickly with low cost, they could be very useful for military applications.

Until now, there have been no satellites in military operations for the Korean Air Force. However, the Korean Air Force Academy will launch a small satellite in 2018 and small satellites will be the key in future conflicts. Because small satellites are manufactured within a shorter time and are much cheaper than traditional large satellites despite same or better performance.

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