論文 (*Article*)

日本の新宇宙開発パラダイム

A New Paradigm for Japan's Space Development

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This paper examines the salient features of the past space development in Japan. In spite of Japan's non-military oriented space development efforts, they have been biased toward technology-push pattern rather than application-pull pattern. In order to make policy changes toward more desirable space development, a need for a new paradigm will be proposed. This new paradigm includes formulation of a sound policy agenda, promotion of more application-oriented projects, decentralization, and mass participation. As a tool to analyze each nation's space development pattern, a Space Development Index is also proposed. Based on the new paradigm, a number of policy proposals at the national, regional and international level will be presented. Reflecting the geopolitical change surrounding Japan, the need for establishing a regional space security forum will be proposed.

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Introduction

Space is the latest new frontier for human activity and it is one which is not yet fully tapped. Space is the place where our potential capabilities will be tested and fully realized. Historically humans have been faced with numerous barriers to their development and have overcome these barriers through ingenuity and determination. Humans have expanded their living space, and have succeeded in adjusting themselves to this new environment. To expand our activities to outer-space is a natural course in human development. With our increasing understanding of space and ability to stay for longer periods and live there like on earth, we could survive as human beings. We could recognize ourselves and the earth better through exploring space. With an unlimited chain of space activities, we could understand more about our existence and we could find more freedom.

In spite of its importance, space development has not been placed as a national priority area in Japan. Unfortunately in the advanced space faring-nations like US and USSR, military use and the political motive of national prestige has been the main driving force for space development. Japan's space development, which had been based on adherence to the unique philosophy of non-military space activities up to the end of the 20th century, has lead to the overly general and obscure space development programs today. Thus it is necessary to examine the past space development pattern and identify the inherent problems. In order to recognize the space development pattern of each nation, a new index, namely a Space Development Index, will be presented. Then I will point out a necessary paradigm shift in space development for Japan. Keeping in mind Japan's factor endowments, its comparative advantage, and its budgetary constraints, I will make policy proposals at national, regional and international level.

Japan' space development pattern

Japan's past space development has been characterized by several salient features. Firstly, it was a cyclical mixture of endogenous and exogenous technology. Prof. Hideo Itokawa initiated his space development in the middle of 1950's realizing a big handicap in Japan's aero-industry due to the post-war ban of aero-industry development by the occupation policy. Switching from air to space, Itokawa had to develop a launch vehicle by fully exploiting his domestic resources. Owing to his strenuous efforts by the mid-1960's. Japan even exported solid fuel launch vehicle. Japan's rapid progress and proliferation in launch vehicle capabilities became a vital concern to the US global security conception. Itokawa did not initiate a liquid fuel launch vehicle project which could have made it possible launch satellites into orbit.

With the establishment of the National Space Development Agency (NASDA) in 1969 and the US-Japan agreement on technology transfer from US to Japan in the field of launch vehicle and satellite, Japan could build a liquid launch vehicle with imported technology and curtailed its endogenous solid launcher project. Through technology imported from the US, Japan could learn about US space technology on the one hand, but on the other hand lost its autonomy as a result of various regulations on the production and utilization of the US launch vehicle. Thus Japan had to develop its own liquid launch vehicle which resulted in the development of the domestically made H-2 launch vehicle. However, facing international competition, NASDA had to utilize imported components for the expanded version of the H-2 launch vehicle. The Super 301 imposed by the US in 1990, forced Japanese satellite industry into the free trade scheme except for R&D satellites. Since Japan's satellite industry was still at the infancy level, it received a fatal blow by Super 301. Even in the field of R&D satellites in order to chase cutting-edge space technology, JAXA has to rely on imported technology for key components. This situation applied to information gathering satellites as well.

Secondly, space commercialization has been advocated by NASDA since the start of its H-2 project. At present JAXA has four types of H-2 launch vehicle. In view of the fact that the total world demand for satellite launches has been very limited, and a substantial proportion of satellites are related to military or reconnaissance usage, the market for a commercial launch service is extremely limited. Furthermore a number of failures of the H-2 rockets and its high cost have proven to be a bottleneck for raising Japan's competitive power. Without cost-down effects of the economy of scale, it is almost impossible to make space industries economically viable. We should be free from the illusion of space commercialization.

Thirdly, political meaning in space development has changed drastically in Japan in recent years. In response to North Korea's missile flight over Japanese territory in 1998, the government decided to start the Information Gathering Satellite (IGS) project in the same year. The development of various missiles, coupled with nuclear tests, and threats of abductions, are undeniably supporting IGS activities. The rapid economic expansion and political offensive by China, recent nationalistic and pro-North Korean political shift in the Republic of Korea, and anti-Japanese sentiment demonstrated in the case of textbooks and the Yasukuni Shrine issues, tended to arouse Japanese nationalism. With Japan's neighboring nations being either politically non-democratic and/or directly or indirectly supporting North Korea, Japan faces the prospect of isolation in East Asia. This geopolitical change could lead to a strengthening of the IGS and other activities related to space security in Japan.

Paradigm shift

Japan' space development has a tendency toward pursuing cutting-edge technology. Major projects pursued by JAXA and NASA are listed in the Table 1. As easily seen from the table, Japan's space activity is concentrated on few big projects with huge cost and technology -push type R&D projects.

For example, the development cost of the Advanced Land Observing Satellite (ALOS) and ETS-Ⅷ amounts about fifty billion yen each, and took more than five years to build. Besides the projects listed in this table, Japan has participated in the International Space Station and spent over six hundred billion yen so far with very limited tangible results expected.

The Japanese space agency tends to install many new functions in one satellite, which results in a costly satellite and possibility of big losses in case of malfunction of the launch vehicle and /or satellite.

Small satellites in general can not perform the same function as big satellites. However their capability has rapidly improved over the last decade. It is said that small or micro-satellite's capability is around 60 to70 percent of big satellite, while the development cost is only around one tenth of that of a large satellite.

In recent years, many small satellites projects have appeared in Japan. In 1998, University Space Systems Symposium (USSS) started under the Japan US Science Technology and Space Application Program (JASTSAP) which has been held annually in Hawaii. Through discussion between US and Japanese students, USSS agreed to launch small satellites project jointly. In 2003, the University Space Engineering Consortium (UNISEC), an NPO, was established by Japanese universities, which aimed at implementing small satellite and rocket projects. At present, UNISEC has 42 group members; most of

Table 1. Launch Records List of JAXA

Launch Date	Flight Name	Mission
12/18/2006	H—IIA・F11	ETS-VIII (Engineering Test Satellite-VIII)
10/14/2006	*Areane5	LDREX-2 (Piggy Back)
09/23/2006	M-V-7	SOLAR-B: The 22nd scientific satellite
09/11/2006	H—IIA・F10	Next Generation IGS(Information Gathering Satellites)#1
02/22/2006	M-V-8	ASTRO-F: The 21st scientific satellite
02/1/2006	H—IIA・F9	MTSAT-2(Multi-functional Transport Satellite 2)
01/24/2006	H—IIA・F8	ALOS(Advanced Land Observing Satellite)
08/24/2005	*Dnepr	Optical Inter-orbit Communications Engineering Test Satellite(OICETS) Innovative Technology Demonstration Experiment Satellite(INDEX)
07/10/2005	M-V-6	ASTRO-EII: The 23rd scientific satellite
02/26/2005	H—IIA・F7	MTSAT-1R(Multi-Functional Transport Satellite-1 Replacement) Third Ignition Experiment of H-IIA Upper Stage Engine
11/29/2003	H—IIA・F6	Information-gathering Satellite
05/09/2003	M-V-5	MUSES-C: The 20th scientific satellite
03/28/2003	H—IIA・F5	Information-gathering Satellite
12/14/2002	H—IIA・F4	ADEOS-II(Advanced Earth Observing Satellite II) Piggy-back payloads(Micro-Lab Sat, WEOSS, Fed Sat
09/11/2002	H—IIA・F3	DRTS(Data Relay Test Satellite) USERS(Unmanned Space Experiment Recovery System)
02/04/2002	H—IIA・F2	MDS-1(Mission Demonstration test Satellite-1) VEP-3(H-IIA Vehicle Evaluation Payload#3) DASH(Demonstrator of Atmospheric Reentry System with Hyper Velocity)
08/29/2001	H—IIA・F1	Flight Demonstration Test VEP-2(H-IIA Vehicle Evaluation Payload#2)
02/10/2000	M-V-4	ASTRO-E: The 19th scientific satellite

* JAXA satellites launched by other countries
(出所：http://www.jaxa.jp/missions/result/rocket-result_e.html)

them are universities located in various prefectures throughout Japan and its members are very active in developing small satellites and rocket projects. These projects are very cost-effective and have the possibility of business application in future. At this point, it should be noted that a cooperative called SOHLA was established in Higashi-Osaka-city in 2002, which aimed at launching small satellites through the initiative of the local and medium firm manufacturers. Although the funds for the SOHLA projects came from a government source, this kind of venture spirit is highly appreciated.

The success of small satellite projects by the Surrey Satellite Technology Ltd.(SSTL) and Scaled Composite's Space Ship One, which won the Ansari X- prize in 2004, proved the effectiveness of induced technological innovation theory developed by Prof. Yujiro Hayami. This theory insists that even under the limited factor endowments, technological innovation could happen to overcome critical production factors. Innovative ideas like the X-prize initiated by Dr. Peter Diamandis will pave the way for commercial sub-orbital tourism and possibly to commercial orbital tourism. An appropriate incentive will bring about buoyant innovative space activities.

As stated above, it is clear that a paradigm shift in space development from inflexible traditional bureaucratic space development to flexible, innovative, and cost-effective space development is required. Table 2 encompasses the important elements in this paradigm shift.

Space Development Index (SDI)

Space development in a few leading space-faring nations so far has been biased toward military use and space exploration for the past half the century. In order to examine the development level of space development and application in each nation objectively, we need a sort of quantitatively measurable standard for space development and application in each nation. Thus, we would like to propose a Space Development Index (SDI), which is derived from the same method as the Human Development Index (HDI) in the annual Human Development Report by UNDP.

SDI is composed of five indexes; namely a space infrastructure index, a space exploration index, a satellite broadcasting and communication index, a space application index, and a national security index. The space infrastructure index relates to the capability of satellites, launch vehicles, and international space stations. The space exploration index encompasses various space exploration activities, including the lunar and mars missions and deep space missions. The satellite broadcasting and communication index relates to satellite broadcasting and communication activities commonly seen today. The space application index involves remote sensing and GIS activities, and other earth observation

Table 2. Paradigm shift in Space Development

Item	Traditional paradigm	New paradigm
Policy agenda	Too general and inconsistent	Specific and consistent
Space program	Technology-push type	Utilization-pull type
Project size	A few big projects	More small and medium projects
Feasibility study	Insufficient cost-benefit analysis and cost-effect analysis	Well-prepared cost-benefit analysis and cost-effect analysis
Technology	Chasing knife-edge technology, Reliance on outsourcing	Enhance endogenous capability
Project criteria	Not clear	Cost-effective
Project aim	Output-oriented	Result-oriented
Project time span	Long-term	Short- and medium-term
Development system	Centralization	Decentralization
Earth observation	Short-term data	Data continuity
Satellite mission	Multi-purpose	Single or limited purpose
Participation in policy agenda	Limited	More participation
International cooperation	Not specific	More focus to Asia-Pacific region, more joint projects with Europe
IGS	Confidential	Open as much as possible

activities such as provided by meteorological satellites. Finally the national security index encompasses the range of reconnaissance satellites and the development of other space military devices. Each index takes a value between zero and one. The SDI is the average of the total sum of the above five indexes. The SDI also takes a value between zero and one. Each index includes numerous factors and thus weighting of each factor is required. Unfortunately this SDI does not include a number of important space activities, including micro-gravity experiments and space tourism. We can include these activities in the SDI index by adding new indexes.

How to calculate the SDI is another issue. One way to calculate the SDI is through space experts' replies to questionnaires in rating various activities. This method is not necessarily objective since every expert has, more or less, a biased view. However it will be a good start to judge patterns of space development in each nation.

US space development has been comprehensive, yet security factors occupy one of the most crucial portions of US space activities. Needless to say, major space projects, including the Apollo project and the space shuttle project had military implications. With ample budget and people's domestic support to be the leader of the world, US type of space development is one choice. Japan, with a relatively small budget and less domestic concern about space development, it would be well advised to pursue a more balanced space development. In other words, Japan's space development should take almost a regular pentagon shape in the space index diagram.

Policy proposals

In view of the Japan's sluggish economic and social development since the collapse of the bubble and the lack of Japanese leadership in the world development, along with the stagnant space development in Japan, it is necessary to alter the traditional space development policy to give stimulus to Japanese society. Several proposals for space development will be made at the national, regional, and global level.

At the national level, Japan should promote space tourism, especially at the sub-orbital space tourism. This implies that Japan should develop its own space rocket plane for sub-orbital flight. The X-prize proved that it is not expensive to develop a space vehicle. To develop a safe space vehicle capable of transporting 20-50 passengers, the design for the vehicle should the subject of a prize system. Furthermore it will be necessary to raise funds for this sub-orbital vehicle. The ministry concerned with space travel should prepare for the construction of a new space port or the reform of an existing airport. An independent body beside JAXA should be established to promote this new space venture business. At the same time the government has to prepare the legal and institutional arrangements for routine space tourism.

In order to revitalize Japan's society and give inspirations to an ailing Japanese people, it would be wise for Japan to initiate a manned orbital flight. This would involve two projects; namely one to develop an inexpensive launch vehicle to carry a few astronauts, and the other one to develop a space vehicle for tourism for orbital flights. The former might be possible by developing a Soyuz type launch vehicle. The basic concept for a manned launch vehicle should be based on full safety standards, be a simple structure, and be low cost. The importation for foreign technology for manned space flight is one choice, which may bring about good relations with a new partner. Similarly in the case of a sub-orbital space vehicle, the development of such a vehicle would require raising funds for an orbital flight prize. In addition, it may require an absolutely novel approach to develop an inexpensive fuel and, if possible, an unconventional energy source. for the launch vehicle for economical space tourism and to realize Space Solar Power Systems (SSPS).

To reduce the launch cost by the order of two to three times, which is a necessary condition for expanded future space activities, a prize for a new energy source for practical use should be provided for the real innovator.

A further necessary step is for Japan to develop its own earth observation space systems. First of all, Japan should have at least one or two more weather satellites to be used as back-up to the existing one and for further enhancing our capabilities in gathering and disseminating weather information Asian developing countries. Japan could also build its own earth observation constellation by launching around ten satellites. In manufacturing satellites for such constellation, Japan should import technology from SSTL. This system should not cost much if Surrey technology is used. Middle- sized satellites costing around two billion to three billion yen each would be sufficient for ordinary earth observation activities. This total system would cost only about half of the ALOS.

Space exploration has been a vital part of space development in Japan. Historically, most ISAS projects have been appreciated for their high academic standards in spite of a limited budget. The series of X-ray astronomy satellites is a good example of a cost effective science mission with continuity. JAXA should maintain this good tradition. A truly unique new exploration plan for Japan should be proposed by professionals from around the world. A Moon and Mars space race is taking place in the space-faring nations today. Japan could play an important role in this race with novel ideas.

As for the International Space Station, Japan should retreat from this expensive project immediately. If Japan still wants to continue this project, various business activities or novel utilization of KIBO space should be considered. International cooperation in space is important, but spendthrift and outdated projects should not be pursued in the post cold- war era.

As a balanced space development Japan has to intensify its reconnaissance capabilities through satellites. With the experimental flight of a missile by North Korea in 1998, which flew over Japan's territory, Japan changed swiftly its past space development principle of non-military purpose and launched an Information Gathering Satellite (IGS) in 2003. Up to today, the government has spent over three hundred billion yen for the IGS project, which squeezed the small space budget further. Satellite reconnaissance activities are under the control of the Cabinet Intelligence and Research Office. At the start of the IGS project, it was the common understanding that information obtained by IGS would be used by various ministries. Yet so far no information obtained by the IGS has been released to the public by the Cabinet Office. The existence of a Sushi-curtain is unacceptable. If the Cabinet Office adhere to this policy, it would be a big waste of resources. With the enactment of legislation for a forthcoming Basic Space Law of Japan, the newly born Ministry of Defense should be in charge of reconnaissance satellites.

The Ministry of Defense should enhance its intelligence capabilities at the global level. It should be reminded that information gathered by satellites is a part of intelligence activities. Japan tends to satisfy itself by joining resolutions or high-technology sensor races. With the establishment of a reconnaissance satellite system, Japan could be in a better position in preparation for various threats from neighboring countries and also to enhance its peace keeping operations.

At the regional level, Japan has to strengthen its disaster prevention activities. Asia has been suffering from various natural disasters. In order to reduce loss or damage by disasters, satellite information could play a crucial role. Japan started the Sentinel-Asia project, a regional disaster management system, in 2006, which is a long -waited meaningful project. With the utilization of ODA funds, Japan should expand these activities among Asian countries.

In Asia, the Space Application Section of UNESCAP has been implementing various projects endorsed by the Asian Ministerial Conference. These activities have focused on space applications, and therefore benefits for the poor people in developing countries. Remote sensing and GIS information have been utilized extensively in a number of Asian countries, particularly in China and India. The successful telemedicine project in India could be a good example whereby other countries projects could learn about it. The Satellite Distance Learning Program in Thailand has been active for more than a decade, and could have more possibilities for providing educational opportunities to Thailand and its neighboring countries. Various experiences in space application projects in each country could be disseminated to the member countries and positive cooperation in novel space application projects should be explored.

Under the strong leadership of China, the secretariat of the Asia-Pacific Multilateral Cooperation in Space Technology and Applications (AP-MCSTA) was established in Beijing in 2002 to implement regional cooperation projects for space development and applications. In 2005, eight countries signed a space cooperation convention for Asia-Pacific Space Cooperation Organization (APSCO). Japan has been holding Asia Pacific Regional Space Agency Forum (APRSAF) meetings since 1993 without any concrete policy. In view of the success of manned space flight, numerous ambitious space projects, a historically close relationship with many Asian countries, and its solid space policy, China would be the leader in regional space cooperation. Therefore Japan had better support selected APSCO's projects as long as they are compatible with Japan's comparative advantage, and beneficial to poor or handicapped people in developing Asian countries.

A contemporary serious issue for Asia is related to the growing political instability in this region. There exist many conflicts between countries in Asia and also domestic conflicts. Besides, a number of countries are increasing their military budgets. The total sum of military related imports of China and India accounts for about a quarter of world arms imports. China and India will be giant nations politically and economically within two decades. China and India are already very advanced countries in the space development field. While the power of China and India is on the rapid upward trend, Japan's power is on the decline. In addition, China conducted a successful anti satellite (ASAT) weapons test in January 2007, which is a big threat for the US's military dominance in space. While the cooperation between the US and China would be stagnant in the near future, China will pursue its goal in space exploration to show its power and technological supremacy. In spite of swelling China's power, the US has been shifting its military strategy for Asia as a reflection of its global military realignment which might bring about a political cavity in East Asia. Under such a geopolitical shift, political instability could exist, or even be reinforced. In order to prevent from or mitigate possible conflict and increase mutual understanding, it is necessary to discuss space security issues among the nations concerned through establishing an Asian Space Security Forum (ASSF), which could deal with political stability, safety, and security in the field of space. Members of ASSF may be any nations in Asia, including China, India, Japan, and Republic of Korea. Non-regional countries could participate in ASSF as observers, but it is up to the opinion of ASSF members. This Forum is intended to enhance mutual misunderstanding for each space development, to prevent any conflict in space -related matters and to maintain peace in Asia. Escalation of a space weaponization race coupled with information shutdown though various curtains, including a Bamboo-curtain, a Curry-curtain, a Kimchi-curtain, and a Sushi-curtain should be avoided.

At the global level, Japan should take leadership in global disaster management activities. Japan is a member of the International Charter"Space and Major Disasters". However only one satellite, ALOS, is not enough for performing these vital activities.

As mentioned earlier Japan should build its own disaster management constellation to carry out frequent and global observation. Secondly, Japan should have more ties with ESA and European countries in the field of space. Unfortunately Japan did not participate in the Galileo project even though ESA was willing to accept Japan's participation. To rely on GPS only, is not a wise decision and ultimately will reduce Japan's security level in the long-run. In order to enhance Japan's security level, it should have an alternative navigation system. Besides, European countries tried to develop their own space capabilities by maintaining independence from the US. Airbus, Ariane launcher, and Galileo are just a few good examples of Europe's endogenous aerospace development. Besides, Japan could learn a diversified and unique approach to space development. Another partner is Canada, which has developed robotics technology like the Shuttle Robotic Arm and RADARSAT. Canada's political stance and its cooperation with the US is another lesson for Japan. At the academic level, Japan should have more joint projects with leading space - related universities and institutions including Space Policy Institute of George Washington University, International Space University, European Space Policy Institute, Asian Institute of Technology and International Institute for Aerospace Survey and Earth Sciences (ITC). Lastly Japan had better assist space-related UN global projects in UNOOSA, especially in the field of space law.

International cooperation is only meaningful if Japan has its own policy and professional competence. Just becoming a member of the project or hosting meetings as seen in the past pattern for Japan's space cooperation project is a waste of resources.

Conclusion

As discussed there exist many prospects for Japan's space development. The most important issue is to have Japan's solid space policy agenda with people's support. The problem is not money, but strong passion, knowledge and leadership. Lastly we would like to close this paper with the following motto: "Think astronomically, act locally."