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*The Current State and Significance of Small Hydropower and Institutional Issues Concerning its Popularization*

*Space Situational Awareness to Mitigate Disastrous Risks from Space*

*Japanese Researchers' Awareness Concerning the Use of Advanced Measurement and Analysis Instruments in the Life Sciences*

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# Executive Summary

## 1 The Current State and Significance of Small Hydropower and Institutional Issues Concerning its Popularization

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Since the accident at the Fukushima No. 1 nuclear power plant operated by Tokyo Electric Power Co. caused by the Great East Japan Earthquake, the spread and promotion of power generation via renewable energies and distributed energy resources have become more important policy issues than ever for Japan. Solar and wind power get most of the attention in discussions of generating power with renewable energies, but small hydropower certainly has an important role to play. Small hydropower has less potential for development (i.e. scale of facility capacity) compared to solar and wind power, but compared to other means of power generation with renewable energy it enjoys many advantages such as an extremely high equipment utilization ratio, small load variation and fairly sound technology. We could say that the development of this is type of renewable energy generation is one that Japan should also prioritize. The first step should be to build distributed energy resource (DER) systems, particularly in mountainous areas, to generate power for consumption in nearby areas. Furthermore, local communities depend on the water resources in their area, so it is essential to take another look at local resources in the development process and contribute to stimulating local economies. While a variety of initiatives are underway across Japan, we may not have an adequate understanding of sites with the potential to generate small amounts of power through small hydropower. Thus, this warrants more detailed research.

But generally speaking, popularizing and promoting renewable energy, which has higher generating costs than existing power sources, needs policy means to support it. In August 2011, the Japanese government passed into law the Act on Special Measures Concerning Renewable Energy and the fixed-tariff system for renewable energy will come into effect in July 2012. This will impose a long-term obligation on electric utilities to buy power generated by renewable energy at a certain price for the purpose of spreading and encouraging the adoption of these power generation methods. The tariffs and other matters will be decided by the Minister of Economy, Trade and Industry, who will do so based on the deliberations of the Procurement Cost Estimation Committee. On April 27, 2012, the committee released its proposals concerning tariffs for each type of renewable energy generation, including small hydropower.

Traditionally, one reason why coordinating among “water rights” and other such matters has been a hindrance to the spread of small hydropower is the extremely complex administrative procedures. In recent years, Japan has seen a gradual relaxation of regulations and simplification of procedures while the direction the technology is heading in has become clearer since the Great East Japan Earthquake, but the government still has a number of matters under consideration. Although small hydropower still has room for technological development and cost reduction, it is a power-generating technology that could grow significantly with the relaxation of various systemic/institutional constraints, even without any technological breakthroughs. Considering the power situation in Japan today, the country needs further regulatory relaxation and procedural simplification.

(Original Japanese version: published in May/June 2012)

## 2 Space Situational Awareness to Mitigate Disastrous Risks from Space

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There are three types of disastrous risks from outer space that could cause harm on the Earth's surface: space debris, space weather and Near-Earth Objects (NEOs). Due to recent incidents including a number of large satellites re-entering the atmosphere, large solar flares and near-misses between Near-Earth Asteroids (NEAs) and our planet, our current space monitoring infrastructure cannot entirely rule out the risk of a disaster originating from space. Thus, we must verify any serious threat posed to humanity's existence and society's infrastructure.

Space Situational Awareness (SSA) has been the subject of great attention by experts in various fields in their efforts to raise a general awareness of the risks posed by the space environment and measures to counteract them. This goes beyond merely monitoring the space environment. Europe, the United States, China and others are hammering out policies that take SSA into account. However, the SSA concept itself has yet to take root in Japan. Although different organizations and research groups deal with the three types of space environment risk independently, their efforts are not yet integrated. Japan should gain a comprehensive understanding of space environment risk and establish measures to deal with it, such as by revising the Basic Plan for Space Policy.

With regards to space debris in particular, Japan should coordinate with other countries to encourage the formulation of the Code of Conduct, an international framework for space activities. Furthermore, researchers across the globe are starting to develop technologies to guide large, uncontrollable space debris back down to Earth at a safe location. Japan should use its rendezvous technology and robotics to take the lead in researching and developing a viable space object capture system.

It is imperative to continue monitoring daily space weather as well as watching out for gigantic NEOs that may appear in the future.

In order to execute the above policies, there is an urgent need for Japan to recognize the importance of SSA and define the direction of the country's SSA efforts in a policy paper. Meanwhile, Japan also needs to consider making efforts to train personnel to carry out activities that mitigate space environment risk.

(Original Japanese version: published in May/June 2012)

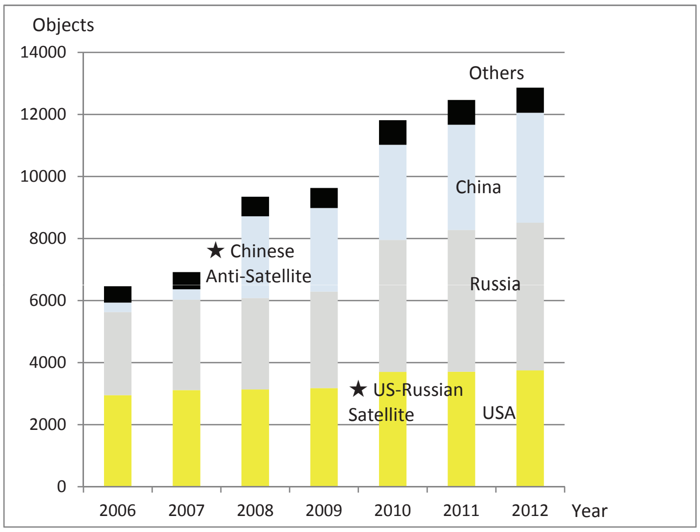


**Figure :** Rapid Increase in Debris Due to Satellite Destruction and Collisions

Source: Compiled by the Science and Technology Foresight Center from data published every January in the Satellite Situation Report from 2006 through 2012.

# 3 Japanese Researchers' Awareness Concerning the Use of Advanced Measurement and Analysis Instruments in the Life Sciences

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There is a need to make effective use of new, advanced measurement and analysis instruments to exploit innovations in life sciences. The Science and Technology Foresight Center conducted a written survey and held a workshop for experts to study Japanese researchers' awareness of the use of advanced measurement and analysis instruments.

The survey found that in life sciences, the degree of dependence to foreign countries, especially to the United States, for advanced measurement and analysis instruments in Japan is much higher than in other research fields. The state-of-the-art instruments supplied by foreign companies are standardizing over the domestic products. Japanese researchers tend to actively utilize the foreign-made instruments to collect high-quality data for international publications. Approximately 40% of the survey respondents feel the price gap between the instruments provided by Japanese and foreign manufacturers, especially the U.S., companies.

The main subject of discussion at the workshop was the domestic-overseas price gap. Total costs of producing the foreign-made instruments are composed of diverse fixed and variable costs. Among them, costs for the import procedures, the maintenance and inspection and so on, help Japanese researchers purchase and use these instruments efficiently. The first thing Japanese researchers need to do in order to narrow the domestic-overseas price gap is for many of them to recognize that there is indeed a price gap between the instruments made in Japan and foreign countries. Furthermore, we need to create a market to compete with foreign-made instruments, such as by stimulating the used instruments market and accelerating the development of Japanese-made instruments.

(Original Japanese version: published in July/August 2012)

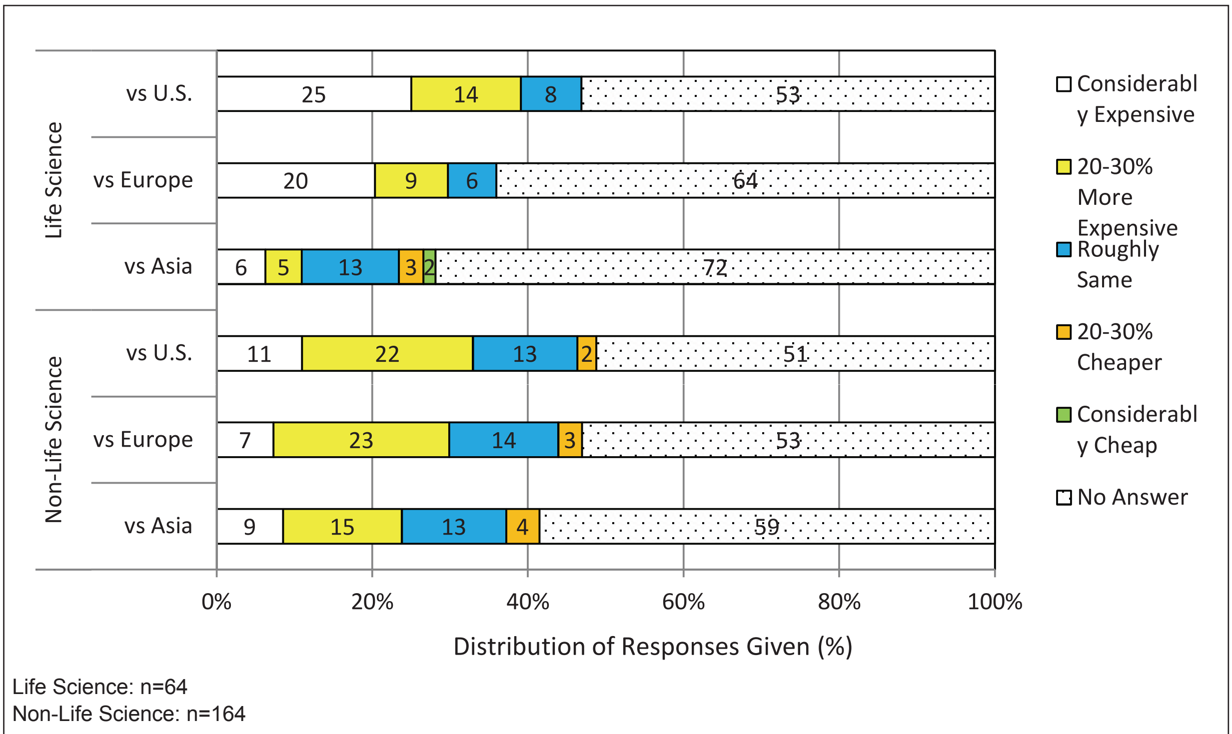


**Figure :** How do instrument prices in Japan compare to other countries?

Compiled by the Science and Technology Foresight Center

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# The Need to Change the Concept of Water-related Disaster Prevention

Yasushi Ito
*Visiting Fellow*

## 1 Introduction

Since the 1990s, we have known of the grave necessity, in terms of combating global warming, for power generation by renewable energies that do not directly produce $CO_2$ emissions. However, the spread of such technologies has been slow due to the high cost of using renewable energies; the fact that many of them have difficulty providing a stable energy supply because of how they generate it and fluctuations caused by the natural environment; as well as—particularly in Japan—the weak support these technologies receive from government. On the other hand, it is well known that the disaster at the Fukushima No. 1 nuclear power plant operated by Tokyo Electric Power Co. (TEPCO), which was caused by the tsunami spawned by the Great East Japan Earthquake, has made the rapid spread of renewable energy an extremely important policy issue in Japan.

One reason why we need to spread and expand our use of renewable energies is their small environmental impact. However, that is not all. Another big reason garnering attention is their compatibility with "distributed" energy resource (DER) systems. Until now, Japan's power supply systems have mainly focused on setting up large power stations in remote locations and transmitting the power to where it is consumed. This is the "large-scale, concentrated model." But the Great East Japan Earthquake showed that with this approach, an accident at a large power station has a huge effect over a widespread area. A system that depends on a certain amount of distributed energy resources to generate power with relatively small facilities located near where it is consumed can mitigate these kinds of supply risks. In March 2012, the National Policy Unit's Energy and Environmental Council released the Energy Regulation and Reform Action Plan: Implementation of 28 Important Points for Green Growth (Draft), which also cites "the use and expansion of distributed energy resources" as a part of power system reforms.[1] Of course, distributed energy resources also come with supply risks, so a balance between "concentrated" and "distributed" is needed.

Now when one mentions generating power with renewable energy, one often imagines doing so by conventional means such as solar, wind and biomass. Meanwhile, small hydropower has received relatively little attention. This is because hydropower is a fully developed, mature technology that is not seen as so much of a new frontier like solar power and the like. It may also be due to the impact of criticism directed at hydropower for causing environmental destruction with large dams, which is accompanied by criticism of public works projects. However, small hydropower generates more electricity in Japan today than any other method defined as "renewable energy generation," and it has yet to live up to its full potential to develop and expand. Furthermore, while solar and wind power planning is done on a large scale, by definition small hydropower is not so large, thus making it compatible with future DER systems. Among all renewable energies, small hydropower fits the requirements for low environmental impact and compatibility with distributed systems extremely well.

This report will outline the state of small hydropower (primarily in Japan) and the significance of its expansion, followed by an examination focusing on the systemic/institutional issues related to further spreading and developing this technology. For information about the technical aspects of hydropower, please refer to the March 2010 issue of Science & Technology Trends Quarterly Review, which took up this topic.[2]

## 2 The Current State of Small Hydropower and its Growth Potential

### 2-1 Definition of Small Hydropower

As is evident from its name, small hydropower is a form of hydroelectric power that generates small amounts of electricity output, but there is no precise definition regarding the exact scale. For example, the European Small Hydropower Association (ESHA) defines it as hydropower with an output of 10,000 kW or less.[3] In Japan, the New Energy and Industrial Technology Development Organization (NEDO) classifies hydropower according to output in the following manner : 1,000 to 10,000 kW is small hydropower, 100 to 1,000 kW is mini hydropower, and output below 100 kW is micro hydropower.[4] However, these definitions are not necessarily in general use. As addressed later in this report, the Act on Special Measures Concerning New Energy Use by Operators of Electric Utilities that went into effect in 2003 to promote "new energy" supports hydropower with an output of less than 1,000 kW, while the Act on Special Measures Concerning Renewable Energy enacted in August 2011 aims to promote hydropower with an output of less than 30,000 kW, which it terms "small-to medium-sized hydropower." This report examines small hydropower by defining it with the standard of 10,000 kW of output or less—which is often adopted internationally.

While hydropower generally makes use of hydraulic head, there are four forms in which the water is used: flowing water, reservoirs, storage tanks and pumping. As for ensuring hydraulic head used to generate power, there are three methods: conduits, dams, and a dam/conduit combination.[5] Since in many cases small hydropower uses relatively small flows and hydraulic head, it generally generates power by either using flowing water as is (instead of damming a river or employing storage tanks) or by placing a weir over a river upstream to collect water and direct it into a channel to create hydraulic head.[6] However, an extremely small-scale project may employ a dam.

### 2-2 Where Small Hydropower is Used

Until now, small hydropower has mainly been used on rivers and channels such as agricultural waterways, catering to power demand by local communities (rural villages, etc.), with the surplus being sold off in many cases. In principle, small hydropower is possible anywhere there is hydraulic head, so it has also been used inside water utility facilities as well as buildings and other structures. We are gradually seeing more and more small hydropower inside water utility facilities and general buildings, where setup mostly requires no complicated procedures.

### 2-3 The State of Small Hydropower Thus Far and Future Growth Potential

According to estimates of "areas with long-lasting energy" by Chiba University's Research Center on Public Affairs for a Sustainable Welfare Society and the Institute for Sustainable Energy Policies (ISEP), an NPO, hydropower with an output of 10,000 kW or less accounted for 61.05% of power generated by renewable energies in 2008, while hydropower with output of less than 1,000 kW accounted for 5.04%, more than the 4.17% share generated by biomass.[7] However, this is not the result of a recent proactive push to develop small hydropower. Rather, the rate of growth for small hydropower has long been slower than that for solar and wind power. This shows that small-scale hydropower plants built in the past are still operating today.

There are a number of estimates concerning small hydropower's future growth potential. Table 1 shows the potential scope for development that hydropower has according to the Water Power Resource Survey (March 2004) conducted by the Agency for Natural Resources and Energy. According to this, there is still room to develop a total of 6 million kW or more from hydropower with an output of 10,000 kW or less per power generation facility.[8] On the other hand, there is little room for development of power generation facilities with an output of 1,000 kW or less. Generally, the smaller the output category, the more undeveloped sites, but only the output category of less than 1,000 kW has an extremely low estimated number of undeveloped sites. Normally, the smaller the output level, the easier it is to install equipment and the more sites are available. From its outset, the above-mentioned Water Power Resource Survey has not considered mountain streams and small rivers thought not to be very economical in its estimates,[9] so the author believes it highly likely that the potential for small-scale sites has been underestimated.

The Survey on the Potential for Adding Renewable

**Table 1 :** Water Power Resource Estimates by the Agency for Natural Resources and Energy

| Power (kW) | Developed | | | Under Construction | | | Undeveloped | | |
|---|---|---|---|---|---|---|---|---|---|
| | Sites | Output (kW) | Generation (MWh) | Sites | Output (kW) | Generation (MWh) | Sites | Output (kW) | Generation (MWh) |
| Under 1,000 | 474 | 203,462 | 1,268,665 | 8 | 1,297 | 29,578 | 371 | 242,190 | 1,218,611 |
| 1,000 – 3,000 | 417 | 744,930 | 4,181,420 | 9 | 17,570 | 95,715 | 1,232 | 2,262,500 | 9,193,048 |
| 3,000 – 5,000 | 166 | 625,415 | 3,312,857 | 2 | 6,700 | 30,846 | 523 | 1,961,900 | 7,887,463 |
| 5,000 – 10,000 | 287 | 1,941,550 | 10,028,377 | 4 | 29,500 | 147,897 | 340 | 2,287,800 | 9,174,150 |
| 10,000 – 30,000 | 363 | 6,036,800 | 27,939,264 | 6 | 90,500 | 367,799 | 209 | 3,313,000 | 12,331,126 |
| 30,000 – 50,000 | 91 | 3,466,800 | 15,238,149 | | | | 21 | 801,900 | 2,610,500 |
| 50,000 – 100,000 | 64 | 4,189,990 | 16,398,316 | | 61,800 | 521,726 | 14 | 879,100 | 2,353,400 |
| 100,000+ | 26 | 4,643,300 | 13,628,309 | 2 | 543,000 | 850,077 | 3 | 378,000 | 1,109,000 |
| Total | 1,888 | 21,852,247 | 91,995,357 | | 750,367 | 2,043,638 | 2,713 | 12,128,390 | 45,877,298 |
| Average | | 11,574 | 48,726 | | 23,449 | 63,864 | | 4,470 | 16,910 |

Source: Compiled by the Science & Technology Foresight Center based on materials from the Agency for Natural Resources and Energy website (http://www.enecho.meti.go.jp/hydraulic/index.html).

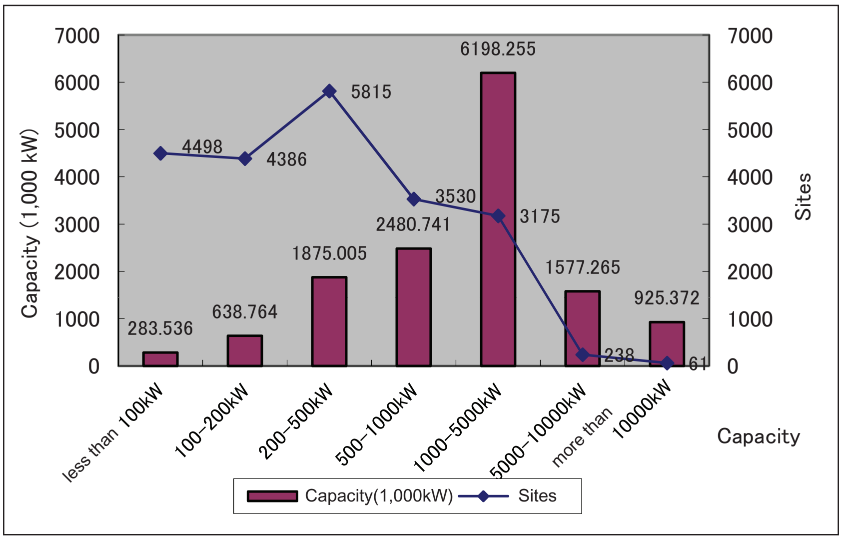


**Figure 1 :** Small Hydropower Potential (MOE Survey)
Source: Compiled by the Science & Technology Foresight Center based on materials from Reference #10.

Energy published by the Ministry of the Environment (MOE) in March 2011 contains estimates for small hydropower's potential. Figure 1 compiles these estimates. Here, the potential for adding hydropower with an output of 10,000 kW or less per power generation facility (on rivers) is approximately 13 million kW.[10] Because the potential here is a theoretically estimated amount that does not consider the stricter constraints that would accompany it, the actual potential is that which subtracts unusable sites due to natural or social constraints. However, this figure does not subtract the portion that is already in use. According to the Water Power Resource Survey in Table 1, approximately 3.5 million kW of hydropower with an output of 10,000 kW or less per power generation facility has already been developed, so some simple math (13 mil kW - 3.5 mil kW) would put the unused potential at around 9.5 million kW. This amount produced by this simple subtraction is not precise since each survey employed different calculation methods, but it does allow us to understand the general situation.

The MOE estimates that there are 18,229 sites that could produce less than 1,000 kW each and that they have the potential to generate around 5.3 million kW of power hydropower. This is larger than the amount estimated by the Water Power Resource Survey in Table 1, but some experts have indicated that this is still an underestimate.[11] The ministry estimates that there are 593 locations conducive to small hydropower

**Table 2 :** Characteristics of Major Renewable Energy Generation

| Type | Small Hydro | Solar | Wind |
|---|---|---|---|
| Utilization | approx. 70% | approx. 12% | approx. 20% |
| Cost | 8–25 yen/kWh | 37–46 yen/kWh (Residential) | 10–14 yen/kWh (Land, 4.5+ MW) |
| Notes | Little temporal variation in generation. | Only generates during the day. Generation fluctuates according to amount of sunlight. | Generation fluctuates according to wind strength. |

Source: Compiled by the Science & Technology Foresight Center based on materials from the MOE website (http://www.env.go.jp/earth/ondanka/shg/page02.html).

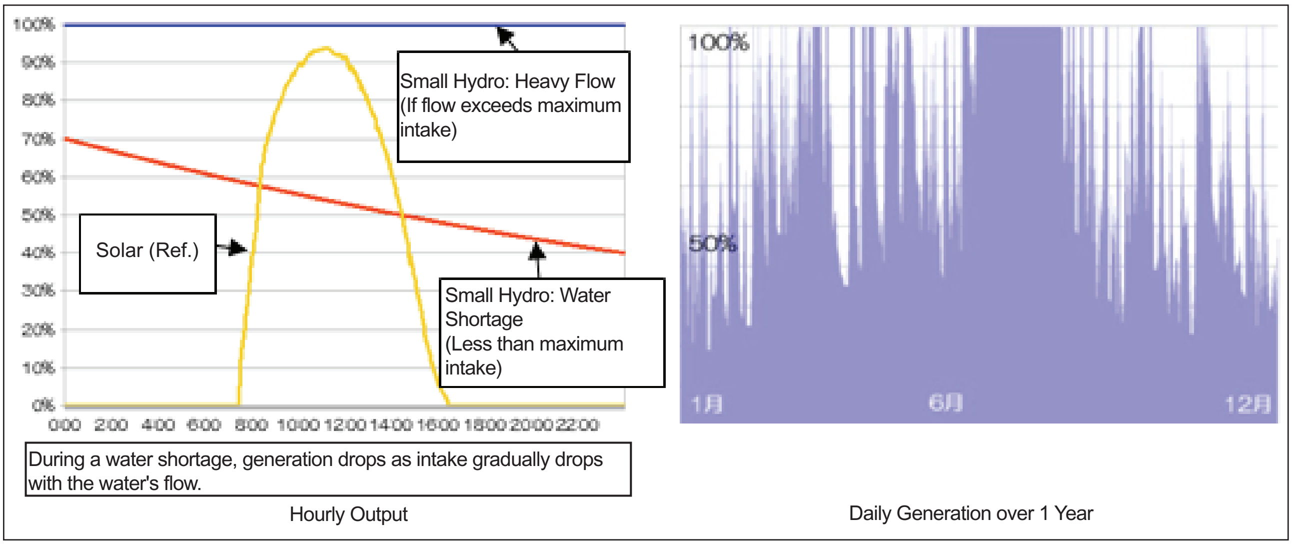


**Figure 2 :** Small Hydropower Max Output and Output Ratio Change (Visualization)

Source: Cited from the MOE website (http://www.env.go.jp/earth/ondanka/shg/page02.html).

on agricultural waterways, with a potential output of roughly 258,000 kW. Kobayashi (2011) studied agricultural waterways on alluvial soil where small hydropower facilities have already been installed. He calculated an estimate of the scope for potential development on a main waterway (approximately 18 km in length) and a lateral canal (12 km in length). Considering that small hydropower is feasible where this is a certain amount of hydraulic head, he found 100 suitable locations along a total of roughly 30 km of agricultural waterways. Japan is said to have 40,000 km of lateral canals for agricultural water. Even if there are few agricultural waterways to be found that are suitable because their water flows over flat ground, Kobayashi argues that the MOE's estimate of only 593 locations along 40,000 km is too low a figure. More detailed research is warranted, especially on the potential to produce output of less than 1,000 kW per generating facility.

## 3 The Significance of Promoting Small Hydropower and Problems

### *3-1 Small Hydropower's Advantages*[12]

Small hydropower's advantages when compared to other forms of renewable energy are:

1. Equipment utilization is around 60% to 70%, much higher than generating power with other renewable energies.
2. Relatively small output fluctuation makes it unlikely to destabilize the power grid.
3. Preliminary surveys and construction are relatively simple.
4. The basic technology for hydropower has already matured, so the technology itself is fairly sound.

On the other hand, small hydropower experiences the following problems:

1. Other parties have interests in using water resources, and legal procedures to start up a new power station are complex.
2. In general, producing many of the same pieces

of equipment is best to keep down power generation costs, but because each site has its own characteristics (hydraulic head and discharge) that vary greatly, equipment specifications must accommodate, thus making mass production of equipment relatively ineffective compared to other power generation equipment.

### *3-2 What is the Significance of Promoting Small Hydropower?*

When compared to solar, wind and other such forms of generating power with renewable energy, the potential to add small hydropower is small. This may be why some people question the significance of promoting the growth of this technology.

First, a look at small hydropower's potential shows us that it cannot become Japan's primary source of power. However, Japan has been forced to reduce its reliance on nuclear energy since the accident at the Fukushima No. 1 nuclear power plant caused by the Great East Japan Earthquake, but at the same time we need to cut down on carbon dioxide emissions in order to stop global warming. Under such circumstances, increasing power output by renewable energies even a little bit would be significant so long as the costs are not too great. For example, if the MOE's estimate that there is a potential to add approximately 10.5 million kW of small hydropower generating capacity with facilities producing 10,000 kW of electricity or less is correct, then developing all of these sites would be equivalent to around 4% of the 237.15 million kW generated by all general electric utilities in 2009.[13] This is no small amount in a time when we are asked to maximize our energy conservation efforts. While some have said that the potential to add small hydropower is comparatively small, one could counter that its potential can be projected to a certain extent—more accurately than what we can project for solar and wind power. In other words, small hydropower is a renewable energy we could develop that has relatively low technical and economic risks and it is a renewable energy source that we should prioritize for development.

Additionally, the significance of promoting the growth of small hydropower is not only limited to increasing the overall amount of power supplied from renewable energy. The above-mentioned estimates for renewable energy power output in the Areas with Long-lasting Energy includes estimates for "natural energy power self-sufficiency," which shows to what extent renewable energy meets an area's residential and farming/fisheries sector power demand. As of 2008, more than 30 municipalities had 100% "power self-sufficiency" and the number with 50% or better reached 67.

Most of these municipalities are small communities located in mountainous areas suitable for small hydropower. Even at present, small hydropower meets a hefty share of power demand in these municipalities (and nearby areas). If untapped small hydropower potential were developed, it would be a significant boost for communities with high amounts of latent "energy (i.e. power) self-sufficiency."

Providing power, which the Great East Japan Earthquake turned into a pressing issue, reconfirmed the importance of adopting systems based to a certain extent on distributed energy resources. However, transitioning a power supply system to a distributed model requires sufficient preparation and time. Spreading the use of small hydropower, which has high equipment utilization and a relatively low load variation compared to other renewable energies, would be the first step to demonstrating the feasibility of a system based on distributed energy resources that generates power close to where it is consumed, especially in mountainous areas suitable for small hydropower and their surrounding areas.

## 4 Growing Small Hydropower as a Community Development Model

Small hydropower's generating capacity is constrained by a site's unique natural features (discharge, hydraulic head, etc.) as well as social constraints (water rights, etc.; discussed in further detail below). In order to generate small hydropower, one must look at the area's water resources, coordinate with the local interests and engage in sufficient discussion, but this is also an essential process for stimulating local economies. In fact, there are places throughout Japan that are adopting and using small hydropower to try and create sustainable communities. One could say that these small hydropower projects are "community development models" for rural areas.[14] Let us look at some examples below.

A local NPO in Omachi, Nagano Prefecture (population about 30,000) used small hydropower on some of the agricultural waterways running through

**Table 3 :** Municipalities with 50%+ Small Hydro Self-Sufficiency (2008)

| Prefecture | Municipality | Self-Sufficiency (%) | Prefecture | Municipality | Self-Sufficiency (%) | Prefecture | Municipality | Self-Sufficiency (%) |
|---|---|---|---|---|---|---|---|---|
| Hokkaido | Sobetsu | 181.68 | Niigata | Itoigawa | 72.95 | Kyoto | Minamiyamashiro | 97.01 |
| | Niseko | 177.27 | | Tsunami | 65.26 | | Kasagi | 62.88 |
| | Rankoshi | 141.31 | | Myoko | 58.03 | Nara | Kamikitayama | 249.93 |
| | Aibetsu | 119.46 | | Aga | 57.28 | | Yoshino | 60.17 |
| Aomori | Fukaura | 99.61 | Toyama | Asahi | 95.76 | Tottori | Wakasa | 98.1 |
| Iwate | Kawai | 96.89 | | Tateyama | 77.54 | | Haku | 82.03 |
| | Iwaizumi | 74.28 | | Uozu | 53.5 | | Kofu | 51.88 |
| Miyagi | Shichikashuku | 131.22 | | Kamiichi | 52.13 | | Yazu | 50.08 |
| Akita | Kazuno | 55.77 | Yamanashi | Hayakawa | 347.18 | Shimane | Tsuwano | 53.45 |
| | Higashinaruse | 50.25 | Nagano | Oshika | 788.81 | Okuyama | Kagamino | 103.02 |
| Yamagata | Nishikawa | 174.13 | | Hiraya | 542.93 | Tokushima | Miyoshi | 68.54 |
| | Okura | 68.65 | | Sakae | 604.87 | Ehime | Kumakogen | 126.06 |
| | Asahi | 66.25 | | Komi | 191.91 | Kochi | Niyodogawa | 157.18 |
| Fukushima | Shimogo | 169.29 | | Yasuoka | 138.16 | | Otoyo | 137.83 |
| | Furudono | 152.19 | | Anan | 137.28 | Kumamoto | Itsuki | 1594.61 |
| | Kawauchi | 75.43 | | Nagiso | 130.79 | | Mizukami | 844.32 |
| Gunma | Kuni | 608.88 | | Achi | 129.18 | | Sagara | 142.21 |
| | Katashina | 298.21 | | Otari | 109.71 | | Oguni | 114.34 |
| | Tsumagoi | 87.03 | | Agematsu | 97.64 | | Yamato | 107.42 |
| | Naganohara | 58.64 | Shizuoka | Shibakawa | 106.72 | Miyazaki | Nishimera | 528.08 |
| Kanagawa | Yamakita | 199.55 | | Oyama | 83.2 | | Hinokage | 99.78 |
| | | | Mie | Odai | 77.36 | | Gokase | 74.67 |
| | | | | | | Kagoshima | Minamiosumi | 64.18 |

Source: Compiled by the Science & Technology Foresight Center based on "Areas with Long-Lasting Energy (2008)" from the Institute for Sustainable Energy Policies, Chiba University.

the city to produce energy for local use. The NPO also used the sites to reduce the environmental impact of tourist facilities and for producing local specialties, as well as to teach visitors about the environment, in an attempt to revitalize the community.[15] After the small hydropower facility took shape, the NPO encountered the systemic/institutional barrier posed by water rights (discussed in further detail below) and the technical issue of whether it was actually possible to generate power on agricultural waterways. The NPO secured three test sites, appended a consent form from each land improvement district (LID) and submitted water usage applications in accordance with the River Act. Then, they started small hydropower performance testing while at the same time organizing events such as a symposium on natural energy and local history and a study group on mini hydropower. Later, after the small hydroelectric power stations began operating, the NPO has conducted eco tours of them (three locations with maximum output of 800 W, 300 W and 700 W) and used the sites for studying the environment.

In the Itoshiro district of Kujo, Gifu Prefecture, home to around 300 residents, another local NPO is working on a small hydropower project.[16] The NPO hoped to revitalize the local community as its population has failed to halt its decline. The district had had a small hydroelectric power station until 1955, so the NPO began working on small hydropower as a way to “discover new things by studying the past.” The project got underway in 2007. The local economy was stimulated in line with the small hydropower project’s progress and efforts were started up to encourage people from outside the district to settle there. There were some new residents who decided to move to Itoshiro after coming there to tour the small hydropower facilities. Recently, in June 2011, a 2.2 kW small hydropower facility began operating on an agricultural waterway, and there are plans to transmit the power generated to an adjacent agricultural produce processing facility.

Of course, in the future small hydropower will need to transform from a symbol of community development into a means of meeting a certain amount of local power demand.

## 5 Policy Means to Further Promote Small Hydropower

Because generating power with renewable energies is typically expensive at present—with some exceptions—it will be difficult to spread these technologies without some sort of supportive government policies, whether in Japan or other countries. Below is an outline of policy means to promote the spread of small hydropower in Japan.

### *5-1 Act on Special Measures Concerning New Energy Use by Operators of Electric Utilities (the Renewable Portfolio Standard [RPS] Law)*

Japan's RPS law enacted in April 2003 obliges electric utilities to use new energies and such to generate at least a certain percentage of their power. As for hydropower,the law initially only applies to hydroelectric stations on waterways, with output of less than 1,000 kw, but an amendment to the law in April 2007 expands the scope to include waterways with small dams. The amount of renewable energy that each electric utility is required to use is determined according to the "Use Target for Electricity from New Energy, etc. by Electric Utilities" that are formulated every four years by the Minister of Economy, Trade and Industry (METI) for the forthcoming eight years. The total use target for FY 2010 was set at 12.2 billion kWh (1.35% of electricity sold in Japan).

The most important feature of the RPS law is that it allows the trading of "New Energy Certificates." Thus, when a party produces electricity with renewable energy, the new energy certificates are issued. Utilities can also purchase certificates to fulfill their obligations. For example, an electric utility operating in an area with no sites suitable for small hydropower can fulfill its obligations relatively cheaply by purchasing New Energy Certificates from another party that has set up small hydroelectric power stations, instead of having to build its own such power stations at great cost.

### *5-2 Act on Special Measures Concerning Renewable Energy (the Feed-In Tariff Law)*

While the RPS law is a policy means that should soundly achieve the targets in the obligations it imposes on electric utilities, they will not generate more power with renewable energy than obliged to unless given an incentive to do so. This thus risks setting a veritable "ceiling" on the spread of renewable energies if the obligated amounts are low. Furthermore, the term "renewable energy" encompasses a range of technologies at significantly varying stages of development, so of course the cost of generating power with them varies as well. If electric utilities are only required to use a certain amount of renewable energy of any sort, then they will focus on the relatively cheaper power generation methods and the policy will not end up encouraging the spread of diverse types of power generation. In fact, according to research that used national panel data to quantitatively analyze the effect of policy means and such on patent applications concerning renewable energy-related technology, RPSs increase the number of patent applications for wind power technology, which at present is relatively lucrative cost-wise compared to other forms of renewable energy, but they do not result in more patent applications for solar power and other forms of renewable energy that are not as cost-efficient.[17]

Europe, where renewable energy is spreading, is encouraging this by introducing "feed-in tariffs" that oblige electric utilities to buy electricity generated by renewable energy at a high enough price to allow the producers to recover their costs over the long term. More people are calling for the introduction of this system in Japan. By guaranteeing renewable energy producers long-term electricity sales at a price sufficient to recover the cost of their investment, feed-in tariffs provide renewable energy companies with a high level of predictability to create a system that promotes generation with renewable energy. Japan first introduced a feed-in tariff system in November 2009 that was limited to surplus energy generated with solar power. The initial purchase price was set at 48 yen/kWh for residences and 24 yen/kWh for non-residences over a period of 10 years. Thereafter, the system was expanded to include all renewable energies via the Act on Special Measures Concerning Renewable Energy that passed the Diet on August 26, 2011, but it only comes into effect on July 1, 2012. Specifically, the law requires electric utilities to purchase all power generated with solar, wind, hydro (small- to medium-sized hydropower with output of less than 30,000 kW), geothermal and biomass (though only surplus power in the case of residential solar power), the cost of which utilities incur will be transferred to entire customers as a "Surcharge for renewable energy" added to customers' electricity bills that is proportionate to the power they consume. In other words, power consumers will bear the burden in the form of higher electricity bills. The higher the tariffs, the greater the cost borne by power consumers.

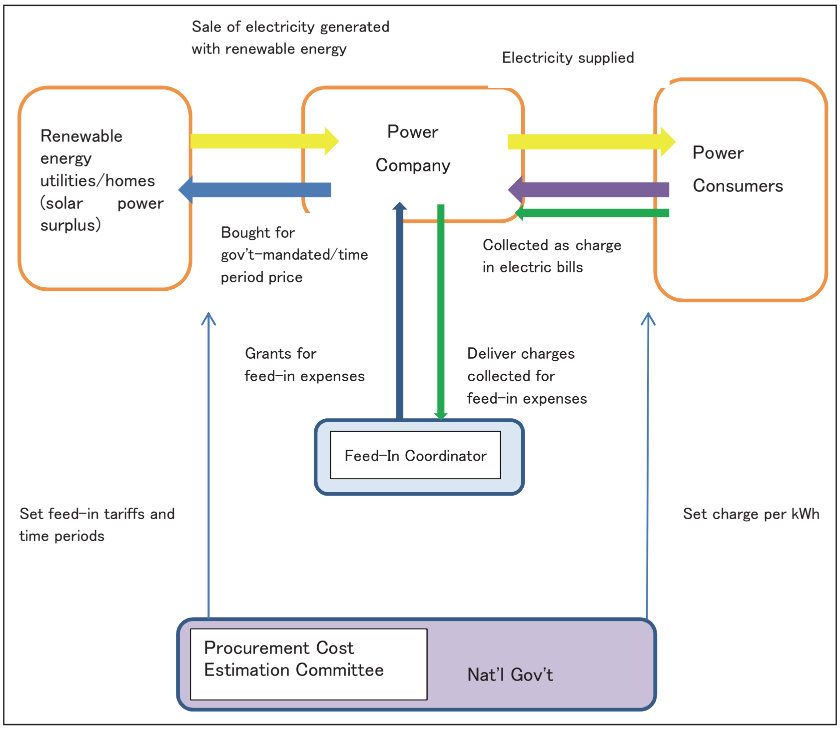


**Figure 3 :** Feed-in Tariff Syustem Structure
Source : Compiled by the Science and Technology Foresight Center, based on materials from the Agency for Natural Resources and Energy

**Table 4 :** Procurement Cost Estimation Committee Proposal (as of April 27, 2012)

| Source | Output | | Price (Yen) | | Purchase Period |
|---|---|---|---|---|---|
| | | | incl. tax | base | |
| Solar | 10+ kW | | 42.00 | 40 | 25 |
| | Under 10 kW (purchase of surplus) | | 42.00 | 42 | 10 |
| Wind | 20+ kW | | 23.10 | 22 | 20 |
| | Under 20 kW | | 53.75 | 55 | 20 |
| Geothermal | 15,000+ kW | | 27.30 | 26 | 15 |
| | Under 15,000 kW | | 42.00 | 40 | 15 |
| Small/ Medium Hydropowe | 1,000 kW – 29,999 kW | | 25.20 | 24 | 20 |
| | 200 kW – 999 kW | | 30.45 | 29 | 20 |
| | Under 200 kW | | 35.70 | 34 | 20 |
| Biomass | Gasification | | 40.95 | 39 | 20 |
| | Direct Fuel Combustion | Unused Wood | 33.60 | 32 | 20 |
| | | Regular Wood | 25.20 | 24 | 20 |
| | | General Waste/Sewage | 17.85 | 17 | 20 |
| | | Recycled Wood | 13.65 | 13 | 20 |

Source: Compiled by the Science & Technology Foresight Center based on materials from the Procurement Cost Estimation Committee.

However, enterprises whose expenses from purchasing power exceed a certain proportion of their sales will be granted reduced surcharges. In addition, due to the possibility that the speed at which renewable energies spread may vary by area, the law will set up a body to coordinate the size of the cost burden for power consumers. This cost burden coordinator will temporarily collect the surcharges levied by electric utilities and then give each power company the money in the form of a grant according to the actual cost of tariffs (see Figure 3). It should be noted that the RPS law will be nullified when the feed-in tariff system goes into effect.

The degree to which renewable energy will spread is determined by tariff rates, their expiration dates and the like. The METI, while respecting the opinion of the Procurement Cost Estimation Committee (an impartial third-party committee of five members formed by the upper and lower houses of the Diet), decides these matters for each type of renewable energy, installation, size and so forth. After the committee's first meeting on March 6, 2012, it continued debate while hearing comments from many renewable energy-related enterprises, then announced its proposal on tariffs and expiration dates on April 27 (see Table 4). As for small hydropower, it was divided into three categories of generation facilities according to installed capacity: less than 200 kW; 200 to 999 kW; and 1,000 to 29,999 kW. Tariffs were set at 35.70, 30.45 and 25.20 yen, respectively, while expiration dates were set at 20 years following commencement for all three categories.

For three years after the law takes effect, tariffs will be set with particular consideration given to the profits of parties that generate power with renewable energy, in order to expand the concentrated use of renewable energy, thus reflecting the committee's proposal on this point. Tariffs and expiration dates will be revised every fiscal year, taking into consideration the cost of generating each kind of energy and other relevant matters.

### *5-3 Subsidies for Capital Investment*

Subsidies for capital investments in renewable energy are a subsidization policy that has been carried out since a relatively early period. The METI, the Ministry of Agriculture, Forestry and Fisheries (MAFF) and other government agencies have set up subsidies for construction and other costs associated with hydroelectric power stations.

At present, the METI offers various subsidies for small- and medium-sized hydroelectric power stations: a subsidy for the construction costs other than the introduction of new technology (20% for power stations with an output of 1,000 to 4,999 kW, 10% for an output of 5,000 to 29,999 kW) and a subsidy for the cost of introducing new technology (50% for an output of 1,000 to 29,999 kW). In FY 2011, the ministry granted subsidies to 14 small- and medium-sized hydroelectric power stations. Together with geothermal power utility subsidies, they amounted to approximately 2 billion yen.

MAFF subsidies are managed as part of land improvement projects (irrigation drainage, etc.), rural development projects and the like. It used to be that one-off maintenance confined only to power generation facilities was not covered by MAFF subsidies, but new installations and renovations to single pieces of generating equipment have been allowed for some projects since FY 2009. Many of the MAFF's subsidies cover 50% of expenses, relatively high compared to the METI's.

## 6 The Water Rights Problem

Water rights are an especially high hurdle to surmount when operating small hydropower. When using river water for hydropower, one must obtain a "water usage permit." Even if one were to use water for hydropower that is already permitted for agricultural, industrial or other use, a new permit is required because the purpose is different. Furthermore, getting a permit even for small-scale hydropower generally requires going through the same procedures as those for large-scale hydropower produced by a dam. In the cases of the municipalities discussed earlier in this report, for its application to use the water, the organization generating the power (in this case a local NPO) had to obtain consent from the LID as well as from the organization permitted to use the water for agriculture. A water usage application takes a year-and-a-half from the prior consultations to obtaining the official permit. It has also been reported that when a single small hydroelectric power facility exceeded the scale of the initial plan that was originally discussed during the application process, it incurred a backlash from the local LID and the water wheel eventually had to be removed.[18] This is how operating even a small-scale generation project of less than 1,000 kW of output requires negotiating among various water rights.

However, the RPS law relaxed the procedural requirements for permits and water rights as they concern small hydropower by targeting the technology for promotion.[19] In 2005, the amount of paperwork for using water that is subordinate to other water usage was reduced. That has, for example, simplified the permit procedures if one were to take water already permitted for agricultural use and draw it from a field to generate small hydroelectric power (subordinate power generation). In the following year, 2006, it was made known that if one were to use water for small hydropower after it has already been completely used for its permitted purpose, then no new permit is required. As an example, no new permit is needed if one were to generate small hydroelectric power on a channel that is currently used only as a drainage ditch.

This is how government can simplify some of the many procedures required when water rights for agricultural and other use have already been assigned, but problems still remain. Regarding the use of water for agriculture, water can be drawn from waters for agricultural use during paddy cultivation, but only a limited amount can be drawn during winter, when no farming occurs. Thus, power generation that depends on agricultural water becomes impossible in winter.[20]

If one wants to secure access to an amount of water in winter as well in order to generate power, then the purpose of the water right becomes power generation, thus requiring the power producer to obtain another new permit.

A power producer that takes water directly from a river has to obtain a new water right for power generation. Furthermore, the procedures become incredibly complex because the consent of any persons or entities affected by taking the water is also required.

Even after obtaining a permit to use water for power generation, operation is still made difficult. The maximum amount of water that the power producer can take per second is prescribed by the water usage permit, so the electric utility must never take more than this amount of water. However, from the time the Great East Japan Earthquake struck until April 30, 2011, when power supplies had difficulty meeting demand, power producers were temporarily allowed to exceed the volume-per-second rule so long as their 24-hour average of water taken did not surpass the amount permitted. This measure allowed power producers to take less water from rivers at night while taking more during the day to help cope with peak daytime electricity demand by generating more power at that time.[21] Since it is extremely difficult for a power producer required to comply with a volume-per-second rule to manage operations while responding every second to a natural flow of water that is constantly changing, power producers typically take only around 95% of the permitted volume so that they do not exceed it due to some sort of disturbance. However, a requirement to comply with a one-day average allows a power producer to adjust even if it takes a somewhat larger amount of water earlier in the day, thus reaching nearly 100% of the permitted amount and generating around 5% more power.[22] Although there have been urgent calls to make this measure more than temporary, the government did not do so. Instead, it relaxed the regulation only somewhat, requiring power producers not to take more than the permitted amount of water each hour.[23]

The labyrinthine procedures associated with obtaining water rights and other regulations that hinder the spread of small hydropower are gradually being relaxed and improved. For example, the Great East Japan Earthquake Special Reconstruction Zone Act and the General Special Zone Act that came into effect in 2011 have simplified subordinate power generation-related procedures and shortened the standard amount of time for processing paperwork.[24] Furthermore, in March 2012 the government announced that environmental impact assessments for rivers and other requirements had been waived for certain small hydropower projects. The government also established a consultation desk for procedures relating to water rights for power generation. However, many matters concerning procedural simplification are still in the review phase.[25]

## 7 Conclusions: The Significance of Small Hydropower and Related Issues

Compared to solar and wind power, small hydropower does not have great growth potential in terms of quantitative power output. However, it does compare favorably to other means of generating power with renewable energies because of its high equipment utilization, low load fluctuation and the mature technologies it employs. Another advantage of small hydropower is its compatibility with a power supply system employing a "distributed model" that generates power for consumption in nearby areas. In addition, it is essential to examine the local area's resources and environment during the process of developing small hydropower because it depends on local water resources. Thus, it can contribute to stimulating the local economy. This is in fact happening in many places in Japan. While small hydropower receives less attention than other means of generating power with renewable energies, such as solar and wind power, it is very significant for us to encourage the growth of this technology.

With regards to quantitative estimates of the potential to add new small hydropower, especially for small-scale projects generating less than 1,000 kW, we may not have an adequate understanding. More detailed research is needed. While small hydropower still has room to develop cost-cutting techniques, it is a power generation technology that could expand greatly if various infrastructure restraints were relaxed, even without any technical breakthroughs. Although the complex procedures for water rights and other impediments to the technology's spread are gradually being relaxed, we are not yet encouraging small hydropower enough. While it goes without saying that there are historical reasons for the difficult water rights procedures and that we will need to thoroughly examine the effects of further regulatory relaxation, when we consider the state of the power supply in Japan today, we see that we need to urgently examine problems such as specific benefits as well as the costs and other problems associated with the spread of small hydropower, and also take another look at the various regulations, including an examination of the effect of relaxing regulations such as water usage procedures that the government has required thus far.

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Toshihiro Matsuo of the National Small Hydropower Promotion Association provided helpful information for this report, for which the author expresses his deepest gratitude.

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## Profiles

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Ito's specialties are environmental economics and regional economics. His research began with digging up Japan's pollution and environmental policies during its period of high-speed growth, and has now come to focus on the effects of environmental and energy policy on technological development and popularization. Ito has recently been devoting effort to studying the post-earthquake reconstruction and recovery as well.

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2

# Space Situational Awareness to Mitigate Disastrous Risks from Space

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## 1 Introduction

In recent years, there has been rising interest in the risk of a disaster produced by the environment in outer space.

Rather than experts in various fields monitoring the space environment independently, the global focus has turned toward broadly educating people across fields about the likelihood of disasters originating in space and ways to counteract them. These efforts are termed Space Situational Awareness. Unlike space surveillance , SSA includes activities to publicize the results of monitoring the space environment.

There are three types of disaster risks posed by the dangers of space on the Earth's surface (hereinafter referred to as "space environment risk"): 1) "space debris" (danger posed to operational satellites and the Earth's surface by a collision/descent of satellites orbiting the Earth at high speed or their fragments), 2) space weather (danger posed to orbiting satellites and ground-based infrastructure by geomagnetic storms, solar wind and other phenomena produced by solar activity) and 3) near-Earth objects (NEOs; the risk of asteroids, comets and other objects in an elliptical orbit around the Sun which intersect with the Earth's orbit).

This paper will address trends concerning research on the hypothetical risks associated with space debris, space weather and NEOs—the main subjects of concern for SSA—and corresponding countermeasures.

## 2 What is Space Environment Risk?

The October 2004 edition of this journal published a report on the space environment and monitoring its changes. This report provided an overview of measures to monitor, defend against and mitigate the risk posed by space debris, satellite damage due to severe near-Earth space weather produced by the Sun, as well as the likelihood of a near-Earth asteroid collision.[1] Below, this paper will primarily discuss, based on how the situation has changed since then, the state of and danger posed by each type of space environment risk that could lead to a disaster on the Earth's surface.

### *2-1 Risks of Space Debris*

**(1) The Situation of Space Debris**

According to the Satellite Situation Report[2] issued on January 9, 2012, 38,044 objects have been registered as orbiting the Earth thus far (as of the end of 2011), of which 21,723 have already burned up in the atmosphere. Figure 1 shows the number of objects placed into orbit by Russia, the United States, the European Space Agency (ESA), France, Japan, China and India. Objects flying through space with a diameter of 10 cm or wider are cataloged for the report. There are thought to be hundreds of thousands of smaller pieces of space debris. Because they orbit the Earth at very high speed, nearly 8 km per second, even those with a diameter of 1 cm pose a significant risk in the event of a collision.

According to a study conducted by NASA in 2010, only 10 of the 4,700 space missions conducted since the dawn of space development account for one-third of all cataloged space debris produced. The mission which produced the most debris was an anti-satellite missile test conducted by China against its Fengyun-1C weather satellite (FY-1C, international registration number 1995-025A) on January 11, 2007. By June 2011 it had produced 3,217 pieces of debris, of which 3,078 are still in orbit as of January 2012. This accounts for approximately 24% of flying objects other than orbiting payloads. While it is natural that Russia and the U.S., who have launched far more satellites in the past, account for more space debris than China, the amount of debris added by China's destruction of only one satellite presents an unusual case.

If R represents the number of rocket bodies, D the number of debris produced by satellites (excluding non-operational payloads, although in some cases they are counted as space debris), and S the total objects in orbit, then (R+D)/S shows the proportion of orbiting objects other than payloads. Because China's anti-satellite missile test produced an extremely large amount of debris, the country accounts for an incredibly high percentage of non-payload orbiting objects: about 97%. In contrast, the ESA and Japan account for a fairly low amount of debris when compared to the global average. The U.S., Russia, France and India, among others, are around the global average. It should be noted that at the present moment, we cannot help but increase the amount of orbiting debris produced by payloads because rocket bodies inevitably add to the debris during launch. An issue that countries will need to cooperate on in the future will be controlling the production of space debris—including rocket bodies—and disposing of it safely.

**(2) Cases of Highly Dangerous Space Debris**

**a) Large amount of space debris from an anti-satellite missile test**

On January 11, 2007, China tested a missile that destroyed the retired Fengyun-1C (FY-1C) weather satellite. It is thought that the People’s Liberation Army (PLA), which launched the missile, believed that there would be no trace of the satellite and that its components would burn up in the atmosphere. However, the satellite’s destruction actually vastly increased the number of flying objects in orbit, and most fragments have not disappeared. The space agencies of other countries heaped criticism on China for increasing the danger of space debris collisions. This is because the destroyed satellite’s remnants are in a polar orbit at an altitude of nearly 800 km, where many countries’ Earth observation satellites revolve around the Earth.

**b) Nuclear-powered satellite re-entries and current operations**

On January 24, 1978, Cosmos 954, a Soviet maritime reconnaissance satellite, fell on the snowy plains of northwestern Canada. While no people were hurt, Cosmos 954 scattered numerous components contaminated with radiation from the nuclear reactor that powered it. The Canadian government demanded roughly 14 million dollars to pay for the recovery and decontamination. The Soviet Union paid Canada around 3 million dollars as compensation for the damage. By 1988, before the Soviet Union broke up, it had launched 37 satellites with onboard nuclear reactors of the same model, of which five have re-entered the atmosphere and 32 are still in orbit. The U.S. has also launched many satellites equipped with nuclear batteries fueled by plutonium. Some are planetary probes that have traveled far from Earth, but many still orbit our planet. Although none are said to have fallen back to Earth yet, we must continue to monitor them.

**Table 1 :** Registered Orbiting Objects at End of 2011

| Country/ Organization | Orbiting Objects | | | | | Objects No Longer Orbiting | | | | Total |
|---|---|---|---|---|---|---|---|---|---|---|
| | Payloads | Rocket Bodies (R) | Satellite Debris (D) | Subtotal (S) | (R+D)/S*1 | Payloads | Rocket Bodies | Satellite Debris | Subtotal | |
| USA | 1112 | 653 | 3111 | 4876 | 77.2% | 794 | 612 | 4052 | 5458 | 10334 |
| Russia | 1457 | 985 | 3674 | 6116 | 76.2% | 2468 | 2729 | 8958 | 14155 | 20271 |
| ESA*2 | 48 | 6 | 38 | 92 | 47.8% | 9 | 7 | 15 | 31 | 123 |
| France*2 | 55 | 129 | 308 | 492 | 88.8% | 8 | 62 | 607 | 677 | 1169 |
| Japan | 128 | 43 | 35 | 206 | 37.9% | 28 | 57 | 140 | 225 | 431 |
| China | 120 | 66 | 3430 | 3616 | 96.7% | 57 | 90 | 556 | 703 | 4319 |
| India | 50 | 15 | 114 | 179 | 72.0% | 9 | 10 | 267 | 286 | 465 |
| Others | 630 | 31 | 83 | 744 | 16.0% | 61 | 11 | 116 | 188 | 932 |
| Total | 3600 | 1928 | 10793 | 16321 | 78.0% | 3434 | 3578 | 14711 | 21723 | 38044 |

Source: Compiled by the Science and Technology Forecast center based on Reference #2.

*1 (R+D)/S represents the proportion of non-payload objects in orbit.

*2 Because European rockets are developed by the ESA and launched by a French company, Rocket Bodies are attributed to the ESA only in the case of ESA satellite launches and are attributed to France when satellites are unrelated to the ESA.

**c) Terminated large satellite re-entries**

Outside of satellites equipped with nuclear reactors, there is also a great risk of a major disaster caused by the re-entry of a large inoperable satellite. As shown in Figure 2, there has been a series of incidents since September 2011 in which large satellites that have lasted beyond their useful life have re-entered the atmosphere and sent large components flying down from space and towards the Earth at high speed.[3] There is a particularly high risk posed by satellites launched up until the 1990s, when space debris countermeasures were inadequate. The Rossi X-ray Timing Explorer (RXTE) is an American x-ray telescope that is expected to descend in 2014 or later. Figure 2 shows examples of recent and predicted large satellite re-entries.

The risk of disaster posed by these sorts of objects falling from space is one aspect of the burden we bear from increased activity in space. The international community is demanding that space-faring countries take it upon themselves to take sincere safety measures. We especially must not forget that a country which causes a disaster in another one due to a falling satellite is liable for damage under the Outer Space Treaty.

**d) Satellite collisions in space**

As the number of satellites and space debris increases, so, too, does the likelihood of collisions between flying objects in space. If two satellites collide, then it can cause a major disturbance, even on the Earth's surface. Although there have not yet been any collisions between operational satellites, an operational satellite did hit a non-operational satellite on February 10, 2009, when Iridium 33, a communications satellite operated by U.S. company Iridium Satellite LLC (now Iridium Communications Inc.), was involved in a lateral collision over Siberia with Cosmos 2251, a retired Russian military satellite.

It is very difficult to make advance predictions of satellite collisions. Furthermore, calculating collision predictions enough to prevent all such accidents would require enormous time and expenditures. In Iridium'

**Table 2 :** Recent Large Satellite Re-entries and Possible Future Re-entries

| Owner | Name | Launch Year | Re-entry Date | Landing Site |
|---|---|---|---|---|
| USA | UARS | 1991 | Sep 24, 2011 | South Pacific |
| Germany | ROSAT | 1990 | Oct 23, 2011 | Bay of Bengal |
| Russia | Fobos-Grunt | 2011 | Jan 15, 2012 | Chile Pacific Coast |
| USA | RXTE | 1995 | 2014 - 2023 | - |

Source: Compiled by the Science and Technology Foresight Center from various materials.

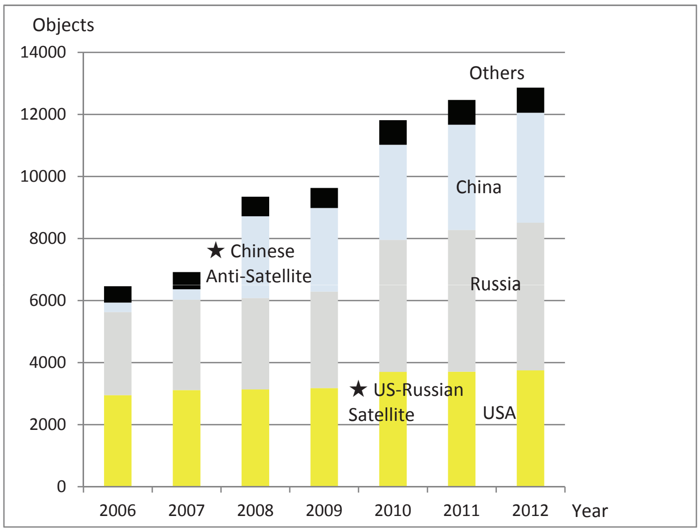


**Figure 1 :** Rapid Increase in Debris Due to Satellite Destruction and Collisions

Source: Compiled by the Science and Technology Foresight Center from data published every January in the Satellite Situation Report from 2006 through 2012.

s case, it was cheaper to launch a replacement satellite than to predict collisions. Furthermore, because the company operates more than 66 satellites, they can surmise that even if one is lost, they can use a backup, so a collision will not affect communications services.

**(3) The Risks of a Continuous Increase in Space Debris**

Figure 3 shows the increase in space debris over the past few years. This graph was compiled from space debris figures for the U.S., Russia, China and other countries as posted in the Satellite Situation Report from 2006 through 2012. The amount of Chinese space debris rose sharply in 2007 due to the anti-satellite missile test, while American and Russian space debris jumped up in 2009 after the collision between their satellites. If the amount of space debris continues to increase at the pace set thus far, then we may enter a phase in which space debris collisions create more debris, and thus more collisions, and so on.

In September 2011, the National Academy of Sciences (NAS) and the National Research Council (NRC) released a report recommending that NASA draw up a strategy to deal with space debris and formulate policies to remove debris and lessen the danger. The NRC suggested specific steps for NASA to take: record, analyze, report and share information on spacecraft defects; hold a public debate on space debris; and take initiatives in consideration of the long-term problems for the public.

## *2-2 The Risks of Space Weather*

**(1) Space Weather and Space Weather Forecasting**

The environment surrounding the Earth is far from quiet: particles and radiation fly about and induce electromagnetic activity to create a highly unstable, variable area. While the Earth's surface is protected because the atmosphere significantly mitigates these dangers, humanity is not entirely unaffected by them. This is why the variable environment around the Earth is called "space weather."

The main indicators for space weather are the speed of solar wind and the amount of plasma. The electrical charge of the plasma in solar wind reacts with the Earth's magnetosphere to produce aurorae over the poles and electrical potential difference (i.e. voltage). While the focus has been on monitoring what can be observed of the situation of the ionosphere and terrestrial magnetism,[1] in recent years, space telescopes have made it possible to observe the Sun and predict solar activity even hours or days in advance.

Space weather forecasting is observing this sort of solar activity and changes in the space environment, predicting space weather and reporting this information to the public via researchers.

**(2) Harmful Effects of Space Weather Variability on the Earth's Surface**

While a solar maximum that would have a great effect on space weather is predicted for 2013, in early 2012 we are already entering a time when we need to be cautious: for example, large solar flare warnings. Solar weather is worst when it poses a high risk of damaging solar panels on satellites operating in space or harming their internal circuitry. It can also have an electromagnetic effect on power lines and other ground-based equipment.

One example of how a solar flare (an explosive phenomenon on the Sun's surface) can affect satellites occurred in 2006 when a number of ESA satellites had their observation equipment power supplies knocked out. When satellites for practical uses such as communications/broadcasting satellites, Earth observation satellites and navigation/positioning satellites stop functioning, it can have a direct impact on society's infrastructure.

March 6, 2012 witnessed the largest solar flare in the preceding five years, and the National Oceanic and Atmospheric Administration (NOAA) in the U.S. issued a warning that it could affect satellites, radio communications and more.

## *2-3 The Risks of Near-Earth Objects*

**(1) The Situation of Near-Earth Objects**

Near-Earth object (NEO) is a term mostly applied to near-Earth asteroids (NEAs), comets and meteoroids from other planets that fly in an elliptical orbit intersecting with the Earth's. There are tens of thousands of NEAs among the numerous asteroids between Mars and Jupiter that approach Earth's orbit. Countries are working to understand asteroids that, while they will not strike our planet, may possibly pass within a distance equivalent to that between Earth and the Moon.

In November 2011, an NEA with a diameter of 400 meters passed the Earth at a range equal to four-fifths the distance between us and the Moon. Another asteroid of this size passed nearby 30 years before, and NASA predicts the next to occur in around 2028.

There are a great many smaller NEAs that burn up after entering the Earth's atmosphere. Recently, an example of a near-miss was when the asteroid 2012 BX34 passed the Earth at a distance of approximately 59,000 km on January 27, 2012.

Even smaller meteoroids frequently hit the Earth. They can fetch a high price, as in the case of a meteoroid from Mars that landed in Morocco in January 2012 and was purchased by the University of Arizona.

**(2) The Danger of an NEO Strike**

If a relatively large NEO happened to strike the Earth, it would cause major changes to the Earth's environment. A large NEA hitting the Earth is the generally accepted explanation for the extinction of the dinosaurs. While these sorts of collisions are incredibly rare, when they do occur, they cause enormous harm to the Earth's living creatures. NEOs must be monitored and data on their trajectories collected in order to quickly determine the risk of an impact. If there was a risk of an NEO hitting the Earth, then we would consider ways of changing the object's trajectory.

## 3 Space Situational Awareness (SSA) Policy of Space-faring Countries

Major space-faring countries have begun issuing policies on Space Situational Awareness (SSA) in order to reduce space environment risk. Western space related persons became more interested in SSA because of the Chinese missile test in 2007 that destroyed a Chinese own satellite.

The International Code of Conduct (CoC) for Outer Space Activities put forward by Europe is a cooperative international framework to reduce manmade space environment risk. Under this framework, countries with advanced space programs such as the U.S., Europe, Russia, Japan, China and India would coordinate their SSA activities and promote relevant policies to improve on the status quo. This would enhance their ability to deal with naturally occurring space environment risk posed by space weather, NEOs and the like by conducting joint monitoring and sharing information.

The U.S. and Japan delegate the tasks of monitoring and investigating the aforementioned three types of risk between different organizations, and at present the subject of SSA in government policy is confined only to space debris. Europe has created an SSA program budget that deals with both space debris and space weather, but it still does not have integrated SSA policies for NEOs. China first referred to the three types of space environment risk in a 2011 white paper on space.[4] All the major space-faring nations should formulate comprehensive policies to deal with the three types of risk in the future and engage in international cooperation. The state of SSA efforts in each country/region is given below.

### *3-1 SSA Policy in Europe*

**(1) The European Space Agency SSA Program**

In 2009 the European Space Agency (ESA), a group of 19 European member countries (the most recent being Romania, which joined in 2012) and Canada, its lone associate member, established a budget for SSA to implement space debris countermeasures and space weather forecasting to complement the agency's main programs for launch vehicle/satellite development and manned spaceflight. The size of the budget for the three-year preparatory period started at 9 million euros in 2009, growing to around 10 million euros in 2010 and around 16 million euros in 2011. However, the budget dropped to 15.4 million euros in 2012,[5] a modest amount for the first year of full-scale implementation following the preparatory program.

Up to now, the ESA has set up a telescope in Spain to monitor space debris in geostationary orbit and built a European space weather observation network that should prove useful for SSA activities on into the future.

Right now the ESA treats NEOs as a separate issue from SSA, but there is a proposal to link ground-based facilities, data distribution and the like with SSA.[6]

**(2) EU Initiatives**

The European Union (EU) and ESA hold a regular meeting of administrators (the ESA Council at Ministerial Level). At the seventh meeting held in November 2011, the participants displayed their awareness of the need to establish SSA response capabilities to protect Europe's space assets.

In March 2011, the European Council (EC) conducted a survey on awareness of the EU's overall space program. Eighteen of the questions were about SSA. There were 608 respondents from 27 countries. First off, the survey found that around 97% of people are aware of the damage that solar flares and space debris cause to satellites. The respondents rated business sectors for how much they are affected by such phenomena on a five-level scale, with a rating of 5 being most highly affected. Those sectors that received many ratings of 4 or higher included aircraft and automobile navigation/positioning systems (73%) and weather forecasting and Earth observation satellites (69%). Furthermore, 57% of respondents said that the EU should make sure it can deal with SSA-related problems.

Meanwhile, the EU has also proposed the CoC, a multilateral cooperative framework to maintain order among the space programs of the world's countries. The CoC is an attempt to win the support of major space-faring countries outside of Europe such as the U.S., Russia and Japan in dealing with the many problems associated with safety in outer space, and to foster a globally shared view of the CoC's guidelines. The U.S. and Australia have already declared that they will be involved in these efforts, while Japanese Foreign Minister Koichiro Genba announced on January 25, 2012 that Japan will participate in the EU-led formulation of the CoC. It is thought that formulating international rules on the development and use of space and implementing them through multilateral cooperation will contribute to mitigating manmade space environment risks.

**(3) Initiatives by Individual European Countries**

While one distinguishing characteristic of European space activities is that the ESA executes large projects that no one country can undertake alone and that are funded by multiple member states, these activities have a multilayered structure in that the space agencies of individual member states also execute their own domestic space programs. Although member states have conducted SSA-related initiatives on their own, they have not done so jointly.

Examples of these go-it-alone efforts include ROSACE (an optical telescope to monitor geostationary orbits) and TAROT (a telescope to track high-speed objects), managed by France's space agency, the National Centre for Space Studies (CNES); Germany's TIRA (the Tracking and Imaging Radar at FGAN); Norway's Globus (a space monitoring radar); and Sweden's EISCAT (a network of space monitoring radars). All of these facilities have been set up to monitor space debris. The French Air Force also operates a radar network, developed by The French Aerospace Lab (ONERA) to monitor space debris.

In the future, rather than using this two-tiered structure to support each country's equipment and fund the ESA, member states will likely head in the direction of funding the ESA so that it can manage SSA facilities for all of Europe in a balanced, continent-wide manner. Expectations are that each country's equipment will continue operating under a primary center that will allocate roles through a network. Meanwhile, costs will also be cut by closing certain facilities. These and other measures will streamline the continent's SSA efforts.

### *3-2 SSA as a Component of the New U.S. Space Policy*

In the United States, the Department of Defense (DOD) monitors space debris, the National Oceanic and Atmospheric Administration (NOAA), an agency administered by the Department of Commerce (DOC), observes space weather, while the National Aeronautics and Space Administration (NASA), certain universities and other organizations monitor NEOs.

The New National Space Policy announced by the Obama administration in 2010[7] states that the direction of U.S space activities will be to display American leadership in space in order to make it a place that the countries of the world can use peacefully, and to sustain a stable space environment for humanity to obtain the many benefits of outer space. Furthermore, the policy warns that irresponsible behavior in space affects all the people of the world and asks all countries to act responsibly so that posterity will inherit the opportunity to use and explore outer space. Moreover, it promises that the United States will also act responsibly in space. Regarding SSA, the announcement states that the U.S. will focus on space debris caused by human activity, enhance the country's capabilities, and bolster a common view of the issue by working together with other countries and industry.

On January 17, 2012, the U.S. government released a statement declaring that it will work with the EU to formulate an International Code of Conduct for Outer Space Activities in order to build a multilateral framework for the safe development and use of space, with a focus on dealing with space debris.

### *3-3 Space Debris Measures in Japan's Basic Plan for Space Policy*

In Japan, the idea of SSA has not yet taken root in the Basic Plan for Space Policy.[8] The Japan Aerospace Exploration Agency (JAXA) handles space debris monitoring, mitigation measures and the like, the National Institute of Information and Communications Technology (NICT) monitors and forecasts space weather, while the National Astronomical Observatory of Japan (NAO) and incorporated NPOs study NEOs. Japan has not integrated efforts to deal with space debris. The Basic Plan for Space Policy should be revised with an integrated approach to SSA and deal with space environment risk.

The Basic Plan for Space Policy formulated in 2009 names the following three space debris-related issues as subjects that concern the "preservation of the space environment."

**(a) Knowing the Distribution of Debris**

While JAXA and other organizations currently monitor debris with their space observation capabilities, they can only distinguish orbiting debris down to a meter in diameter. They do not have a detailed or accurate understanding of sub-meter debris that could destroy a satellite in a collision. In the future, JAXA wants to work with observational data from other countries with the goal of understanding exact orbital positions and other characteristics of sub-meter debris.

**(b) Minimizing the Creation of Space Debris**

Effective ways to minimize the creation of space debris are to keep components from flying off of operational satellites and to prevent retired satellites from exploding. In Japan, JAXA drafts its own guidelines to reduce debris, with which it strictly complies. Japan is promoting the preservation of the space environment by making sure to address the matter internationally, such as by actively participating in the creation of an international framework to reduce the amount of debris created. Japan is also pushing ahead with research on measures to protect satellites from debris, and on satellites that would limit ground damage after re-entering the atmosphere upon retirement.

**(c) Steps to Remove Debris**

The Inter-Agency Space Debris Coordination Committee (IADC) and others point out the possibility that an increase in the amount of debris could lead to collisions between these objects, thus leading to a natural increase in the number of objects making up the debris. In Japan, the technology to capture debris or remove it from orbit (e.g. robots to capture debris and other technology) is still in the research phase. In the future, Japan will continue working with international partners, while promoting research with the goal of using small satellites and such to demonstrate technology to capture debris or remove it from orbit.

### *3-4 SSA Policy in the Chinese Space White Paper*

In the year 2011, China surpassed the U.S. by launching 19 rockets, second in the world only to Russia. The U.S. and Europe have warned China about SSA as the country has quickly ramped up its space program. In December 2011, around the start of China's twelfth Five-Year Plan (2011-2015), the country published "China's Space Activities in 2011," that year's edition of its space white paper. It made mention of initiatives related to space debris, space weather and NEOs alongside major projects such as manned spaceflight and lunar exploration. The paper describes specific plans for countermeasures against space debris in particular. When we remember that the reason for the West's heightened interest in SSA is the missile test China conducted to destroy one of its own satellites, we can interpret China's positive space debris-related efforts as a response to the West's reaction. If the white paper is a statement that China will not repeat the action that produced the massive amount of space debris from its anti-satellite missile test, we should welcome China taking a step towards coordinating with the international community.

## 4 Space Environment Risk Countermeasures

Nowadays, many more countries recognize the existence of space environment risk. They should deal with this risk based on sound government policy.

What the three types of risk have in common is that we need to first set up arrangements for monitoring targets and then develop the technical capabilities to deal with each type.

### 4-1 Space Debris Countermeasures

At present, many countries are monitoring or taking steps to protect against and minimize space debris. As yet, very few measures have been taken to remove particularly dangerous large debris.

**(1) Space Debris Monitoring**

The U.S. constantly monitors space debris of at least a certain size. U.S. Strategic Command (Stratcom) tracks 800 satellites and over 20,000 pieces of space debris in regular operation, and releases tracking informations to other countries as possible as it can. Even so, there is a great deal of untracked space debris because Stratcom is significantly lacking in personnel to track all objects flying around the Earth that could affect a satellite. Additionally, there is no country tracking satellites more than the U.S. does.

Japan has also been relatively quick to set up and operate its own monitoring facilities. JAXA uses the space debris monitoring facility in Okayama Prefecture owned by the Japan Space Forum (JSF) to keep a daily visual watch on space debris in geostationary orbit, determine the trajectories of satellites in low-Earth orbit and conduct other monitoring. However, six to eight years have passed since the JSF facility was completed and its performance is inadequate. An issue warranting examination is how to beef up JAXA's monitoring capabilities through international collaboration in order to add more monitoring facilities or improve performance.

However, Europe, Russia, China and others monitor objects flying through space visually and with radar, allowing each to collect its own data that takes advantage of each country's geographical traits. More international cooperation in monitoring should take place to supplement the limits of U.S. monitoring capabilities.

**(2) Measures to Protect the Space Station and Satellites from Space Debris**

NASA runs a program that examines measures to protect the Space Station and satellites for practical use from space debris. The program's central office is at the Johnson Space Center (JSC) in Houston, Texas.[9] NASA's greatest concern regarding space debris protection is the threat to the safe operation of the International Space Station (ISS), where three to six astronauts are onboard at any time. The structure of the ISS protects it from particle-sized debris collisions with bumpers, but it has to regularly raise or lower its trajectory to avoid medium-sized and large space debris. The thrust generated by Russian and European supply ships docked at the ISS is used to change the station's trajectory.

**(3) Measures to Reduce Space Debris**

In February 2007, the General Assembly of the United Nations adopted the Space Debris Mitigation Guidelines, recommended by the IADC, as a measure to reduce the amount of space debris. Countries that launch satellites are taking the necessary steps to reduce space debris in accordance with these guidelines. Of course, Japan is developing satellites based on the guidelines and taking measures to deal with space debris.

China, which is becoming a major space-faring nation alongside the U.S. and Russia, is involved with the IADC, where it cited its steps to reduce the amount of space debris produced by satellites and launch vehicles in its 2011 Chinese space white paper. An example of China taking proactive steps to reduce space debris is its operating plan for the Tiangong-1 space station launched in September 2011. After three Shenzhou spacecraft dock with Tiangong-1 and it completes its two-year mission, the plan calls for the space station to re-enter the atmosphere over a safe location.

**(4) Development of Space Debris Removal Technologies to Avoid Satellite Re-entries**

The safest way to deal with the risks associated with a satellite re-entering the Earth's atmosphere is to remove it before it descends on its own. There are many ideas about how to do this, including the use of a suction device to capture it or employing lasers to alter its trajectory. A satellite can be forced to re-enter the atmosphere in a planned manner that lands it in a safe place. This can be done by launching a chaser satellite controllable from the ground that will capture the target satellite. After docking, the chaser satellite is directed by its ground-based operator to use its thrust to maneuver it and the target satellite into a new re-entry trajectory.

In February 2012, a Swiss university published an idea of developing a 1-kilogram capture satellite to conduct an experiment to seize a miniature satellite (also 1 kg) already in orbit and burn it up in the atmosphere. Although the size of the satellites is small, the idea received intense media coverage as a concrete example of how we might deal with space debris. The Innovative Technology Research Center, part of JAXA's Aerospace Research and Development Directorate in Japan, is conducting R&D on technology for a system that would capture space debris and dispose of it from orbit. This idea has been around since the 1990s, when an entry to the annual Satellite Design Contest in Japan proposed using a chaser satellite to capture a target satellite with a suction cup-equipped arm, similar to the mechanism employed by an octopus' tentacle. Japan would likely make a major contribution to the world's development of space if it can safely remove space debris by employing its expertise in rendezvous technology and robotics.

### *4-2 Monitoring and Responding to Space Weather Fluctuations*

For a long time now, we have been learning about space weather through indirect means such as monitoring geomagnetism over our planet or observing the situation of the ionosphere. This mainly used to focus on dealing with noise in radio communications and the like, but now space weather has a significant effect on essential components of our infrastructure: satellites, aircraft, power lines, pipelines and more. Thus, we now have to take steps to protect satellite solar panels and electronics from harm posed by space environment risks.

**(1) Monitoring by Solar Observation Satellites**

Our capabilities to observe the Sun with satellites have improved to provide early warning of changes in the solar activity. In recent years, the standard practice has been to place solar observation satellites at Lagrangian points to directly monitor solar activity and predict changes in solar weather.

Figure 4 shows what is being observed by U.S, European and Japanese solar observation satellites. The observational data from U.S and European satellites placed at particularly gravitationally stable Lagrangian points (L1, L4 and L5) is used effectively for monitoring solar activity. The two STEREO satellites monitor the Sun from its sides at positions ahead and behind the Earth in its orbit, thus enabling NASA to predict, according to the Sun's rotation, when enhanced activity will affect the Earth. Data from Hinode, the Japanese solar observation satellite, has also contributed to global efforts to monitor space weather.

**(2) Space Weather Forecasting Sites of Various Countries**

At present, the 13 major space-faring nations have set up websites providing up-to-date space weather forecasts for the general public. All of them operate in a partnership with the International Space Environment Service, an organization within the United Nations Educational, Scientific and Cultural Organization (UNESCO).

**a) United States of America**

In the U.S., NOAA's Space Weather Prediction Center (SWPC) uses data from its GOES geostationary satellites to compile information for space weather forecasting. The SWPC website publishes daily information on observations and predictions.[10]

**Table 4 :** Main Solar Activity Observation Satellites

| Name | Owner/ Operator | Orbit | Mission | Launch Year | Subject of Observation |
|---|---|---|---|---|---|
| GOES | USA/NOAA | Geostationary | Weather Observation | 1994 onward | Solar X-ray images, X-rays, protons (hydrogen ions), electrons |
| SOHO | ESA/NASA | L1 | Solar Observation | 1995 | Coronal mass ejection (CME) |
| STEREO | USA/NOAA | L4 & L5 | Solar Observation | 2006 | Lateral solar activity |
| Hinode | Japan/JAXA | Polar Orbit | Solar Observation | 2006 | Coronal holes on Sun's surface |

Source: Compiled by the Science and Technology Foresight Center from various materials.

The top page shows the latest image of the Sun, along with the degree of geomagnetic storms, solar radiation storms and radio blackouts. Geomagnetic storm forecasts use a six-level scale indicating the disturbance they will create: None, Minor, Moderate, Strong, Severe and Extreme. Similarly, the site uses a six-level scale for particle/ion density in the event of solar storms of 10 MeV or greater and, if radio blackouts are forecast, the maximum luminosity of solar X-rays.

**b) Europe**

The ESA mainly forecasts space weather by releasing images of the Sun taken by the Solar & Heliospheric Observatory (SOHO), a joint ESA-NASA project, at the ESA Space Weather Web Server.[11] However, compared to other country's websites, this one's weather forecasts are tailored more for experts. It does not provide easily understandable indicators as NOAA does.

**c) Japan**

The NICT publishes daily observational information at the Space Weather Information Center (SWC) website, with sources including U.S. satellites and Hinode, the Japanese solar observation satellite.[12] The top page uses graphics to provide a summary of observational information.

Furthermore, the Space Weather News website provides more accessible information for the general public with daily space weather forecasts in a format closely resembling terrestrial weather forecasts.[13]

**d) China**

The National Space Weather Monitoring and Warning Center, which belongs to the National Satellite Meteorological Center, publishes information on its website that includes three-day space weather forecasts.[14]

**e) Russia**

The Space Research Institute (IKI) of the Russian Academy of Sciences (RAN) runs a space weather forecast service. Established in 1965, the IKI was involved in Mars and Venus space probe projects, but now it conducts observations of the Earth and scientific research on near-Earth space to study its effects on ecosystems and elsewhere. Part of this work is the research on and the distribution of information about space weather forecasts. The IKI website's content includes data on geomagnetic storms.[15]

**(3) Countermeasures by Satellite Operators Using Space Weather Forecasts**

Government organizations and companies that operate satellites (e.g. communications/broadcasting, weather, navigation/positioning satellites) providing us with important information every day reference the space weather forecasts provided by various countries and control their satellites to protect them from threats such as geomagnetic storms.

Based on this information, the countermeasures they take include changing a satellite's orientation so that the surface of its solar panels are not facing towards a geomagnetic storm, or putting the entire satellite into an energy-conserving safe mode to maintain minimal functionality.

In addition, the International Space Station is moved to a safer location when space weather poses a potential health hazard to the astronauts on board.

Space weather can affect the Earth's surface as well as outer space. For example, power utilities pay attention to space weather to avoid the danger of irregular currents in power lines caused by electromagnetic induction.

Other than the above, astronomers, amateur radio operators and others also pay attention to fluctuation in space weather.

**Table 5 :** Main NEA Monitoring Facilities

| Name | Operator | Country | Main Telescope Caliber | Number of Asteroids Monitored |
|---|---|---|---|---|
| NEAT | NASA | USA | 1 m | 11,000+ |
| Spacewatch | University of Arizona | USA | 1.8 m | 20,000+ |
| Bisei Spaceguard Center | Japan Space Forum | Japan | 1 m | ~ 5500 |

Number of asteroids monitored is current as of February 2012.

### *4-3 Near-Earth Object Monitoring and Safety Measures*

**(1) NEO Monitoring by Various Countries**

A number of countries monitor NEOs with observatories and satellites. The Near Earth Objects-Dynamic Site (NEODyS)[16] is a website that lists all of the world's observatories and telescopes that are now monitoring asteroids and comets or have done so in the past. It also allows visitors to view data on near-Earth asteroids (NEAs) observed the day before. However, there are not many satellites that can find NEAs efficiently. Figure 5 shows what kind of NEA monitoring takes place at major facilities in the U.S. and Japan.

NEODys lists 109 Japanese observatories and personal telescopes distributed across 30 of the country's prefectures. The Bisei Spaceguard Center in Okayama Prefecture is the most active NEO monitoring site. The center uses data from a telescope with a caliber of 1 meter and equipped with a CCD camera to observe space debris in geostationary orbit. It can also detect NEAs. However, most NEO monitoring in Japan is currently performed voluntarily by NPOs and civilians. To properly monitor NEOs, the country needs to set up an official monitoring infrastructure.

**(2) Measures to Deal with NEOs that May Strike the Earth**

Even if we could monitor the trajectories of all NEAs and comets and determine the existence of any NEOs that might strike the Earth and when, at present there are very few concrete measures we could take in response. However, there are investigations already underway on how to possibly avoid a collision.

In December 2009, a committee formed by the Russian Federal Space Agency (FSA) to investigate ways of avoiding a possible collision with the asteroid Apophis in 2036 published a plan to do so. There are worries that Apophis, with a diameter of 350 meters, could turn 500,000 square kilometers of land into desert were it to strike the Earth.[17] Some method of altering the asteroid's trajectory would be necessary to avoid a collision. Because this would require the development of equipment especially for this purpose, the committee suggested that this could become an international project.

While NASA, based on earlier data, announced that Apophis had a small 1 in 45,000 chance of an impact on Earth on April 13, 2036, a recalculation of Apophis' trajectory using the latest data has revised the likelihood of a collision down to 1 in 250,000.

The technology described earlier in this paper to safely capture space debris and make it re-enter the Earth's atmosphere may help us develop the technology needed to deal with a dangerous asteroid like Apophis in the future by altering its trajectory.

## 5 What Japan Should Do Next

Japan also needs to put more effort into mitigating space environment risk by having an active Space Situational Awareness (SSA). Given the monitoring that is conducted now, we cannot entirely rule out this risk. We must recognize that it could pose a grave threat to humanity's existence and to society's infrastructure.

However, while Europe, the U.S., China and others are working out policies formulated with an awareness of SSA, the concept itself has still not taken root in Japan. Different organizations and research groups deal with the three types of space environment risk, but they are not in fact exclusive of each other. For example, if Japan developed space environment observation satellites that can monitor space debris, solar weather and NEOs and had multiple groups collaborating by sharing observation data, then we could expect that to have a synergistic effect. To do this, Japan should gain a comprehensive understanding of space environment risk and establish measures to deal with it, such as by revising the Basic Plan for Space Policy. With regards to space debris in particular, Japan should coordinate with the U.S., Europe, Russia, China and others to encourage the formulation of the Code of Conduct, an international framework for space activities.

Japan needs to continue engaging in each of the following concrete activities to deal with the three types of space environment risk.

(1) There are limits to the capabilities of the U.S., the current leader in this field, to track the growing amount of space debris. Each country should contribute to the effort by taking advantage of its own geographical traits and technical capabilities. While of course Japan is developing satellites in compliance with its Space Debris

Mitigation Guidelines, the country should be proactive and take the global lead, such as by setting up monitoring facilities and developing debris mitigation technology. On the technical front, Japan should especially upgrade current performance in optical and radar observation.

(2) Japan also has new opportunities worldwide to research and develop technologies to capture large, uncontrollable space debris and bring it back to Earth in a safe location. Japan should employ its advanced rendezvous technology and robotics to research and develop a viable space object capture system.

(3) Space weather forecasts are now essential information to protect satellites for practical use that are integrated with society's infrastructure, as well as to protect ground-based facilities from adverse effects. These forecasts are needed to guarantee the continued operation of these public services.

(4) While the improved performance of observational equipment such as optical telescopes and CCD cameras has made the monitoring of NEOs more efficient, Japan needs to build a monitoring infrastructure (e.g. training relevant personnel) and operate it on a continual basis. In addition, measures to prevent a giant NEO from possibly striking the Earth in the future would likely be examined as an collaborative, international endeavor, so Japan should bring along its advanced technological prowess while actively participating in international partnerships.

In order to execute the above policies, there is an urgent need for Japan to first understand what the world is doing about SSA and know what the country needs to do, and then define the direction of Japan's SSA efforts in a policy paper. Meanwhile, Japan also needs to consider making efforts to train personnel to carry out activities that mitigate space environment risk.

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3

# Japanese Researchers' Awareness Concerning the Use of Advanced Measurement and Analysis Instruments in the Life Sciences

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## 1 Introduction

Measurement and analysis are an important key technology to produce world-leading, original findings. In the scientific community, the memory of a Nobel Prize awarded for the research and development of a mass spectrometer is still fresh in our minds.

In the field of the life sciences, dramatic performance advances in next-generation sequencers now allow us to map enormous amounts of genomic data and identify the genetic causes of diseases. The future will see a need to make effective use of new, advanced measurement and analysis instruments—in accordance with research goals—in order to expand research and development and spur innovation in the life sciences.

In 2003, the Science and Technology Foresight Center (STFC) conducted a survey on the use of life science instruments. The results indicate that a relevant issue is the reliance on foreign-made (i.e. non-Japanese) instruments.[1] Later on, in 2011, Professor Masashi Yanagisawa at university of Tsukuba raised a question on a newspaper in terms of the price gap between instruments provided in Japan and the United States, which conducted an another written survey on the use of foreign-made instruments in Japan. The STFC then held a workshop, to which it invited experts with a wide range of perspectives concerning the instruments. After the STFC presented with the results of the latest survey, the participants discussed the current state and issues of use of the instruments and the direction to take in the future.

The main purpose of this report is to present the content of this workshop. Chapter 2 compiles the content of the written survey report, while Chapter 3 summarizes the workshop discussions that revolved around its results. The reader should note that some of the discussions also touched on an interview survey conducted after the workshop.

## 2 Result of the written survey

First, the STFC utilized its network of experts to conduct a written survey on the use of foreign-made instruments and the prices in Japan.

### *2-1 Written Survey Overview*

The registrants in the network, as of March 2011, are 2,196 experts who work in science and technology for industry, government and academia, allowing the STFC to collect a broad range of opinions over the internet. The survey was conducted March 10-25, 2011. There were 228 respondents, making for a response rate of 10.4%.

Sixty-four respondents had main backgrounds in life sciences, accounting for 28% of all respondents. Following life sciences, the major research sectors included nanotechnology/nanomaterials (21%), the environment (10%) and information and communications (10%). The characteristics of the responses in life sciences, were basically highlighted by comparing it with those given from whole research sectors except for life sciences.

It should be noted that the term “instrument” in this report refers to advanced measurement and analysis equipments such as electron microscopes, mass spectrometers, X-ray analyzers, nuclear magnetic resonance spectrometers, DNA amplifiers, DNA sequencers and SNP analyzers. Instruments provided by companies based in the U.S. are called “American instruments.” Likewise, instruments supplied by companies based in Europe, Asia (excluding Japan) and Japan are called “European instruments,” “Asian instruments” and “Japanese instruments,” respectively.

### *2-2 Heavy Usage of Foreign-Made Instruments in Life Sciences*

In the 2003 survey,[1] the share of Japanese instruments used was lower in the life sciences compared to other fields of research such as nanotechnology/nanomaterials, indicating heavy usage of foreign-made instruments.

When respondents were asked whether the proportion of foreign-made instruments they use had changed in the past five years, 41% of those in life sciences answered it had "increased considerably" or "increased somewhat." By contrast, only 18% gave these responses in other fields, while 72% stated that their usage was unchanged (see Figure 2). These data shows that it tends to use foreign-made instruments in life sciences more frequently than other research sectors.

### *2-3 Particularly Heavy Use of American Instruments*

When asked which foreign-made instruments ("American," "European," "Asian" or "other countries'"), the results showed that "American" instruments were used the most by 73% of respondents who work in the life sciences, followed by "European" at 27%. No respondents acknowledged using "Asian" or "other countries'" instruments more than any others. Outside of the life sciences, on the other hand, "American" instruments were most likely to be used the most by respondents, at 54% (see Figure 3). These data suggests that life sciences make

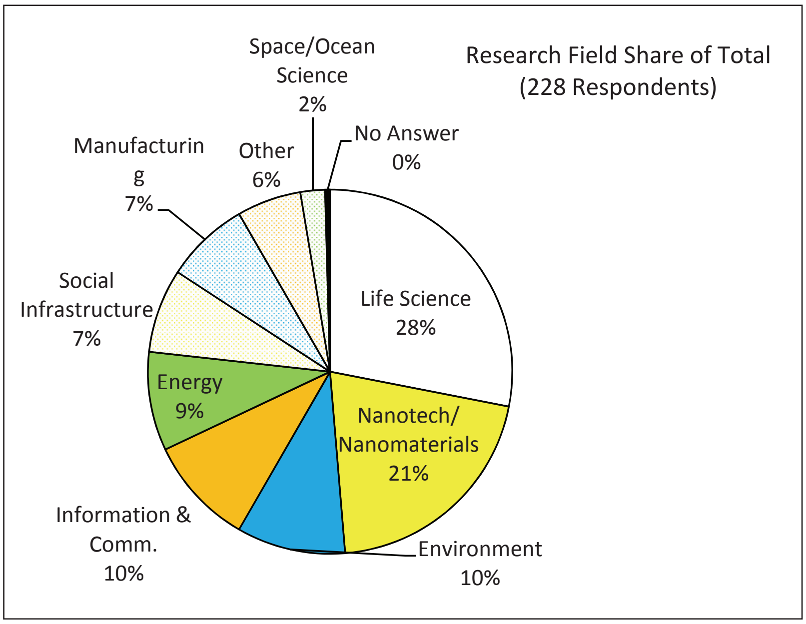


**Figure 1 :** Written Survey Respondent Field of Research Breakdown

Compiled by the Science and Technology Foresight Center

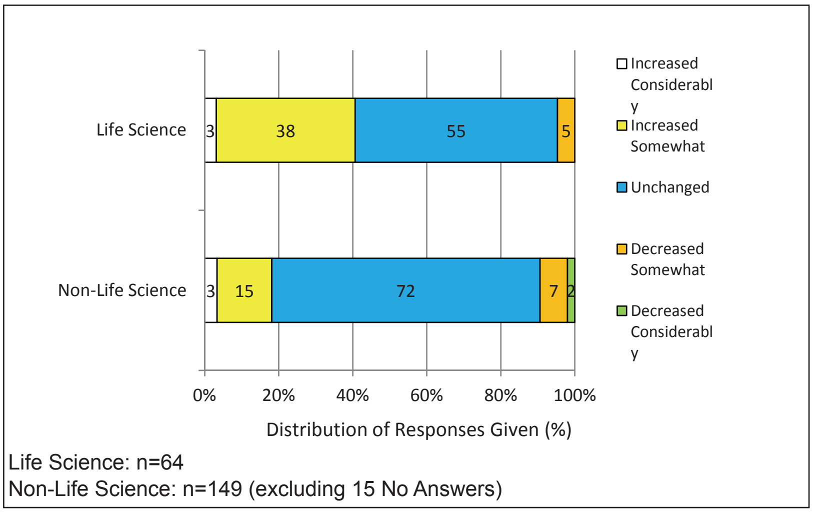


**Figure 2 :** How has the amount of foreign-made instruments you use changed in the past 5 years?

Compiled by the Science and Technology Foresight Center

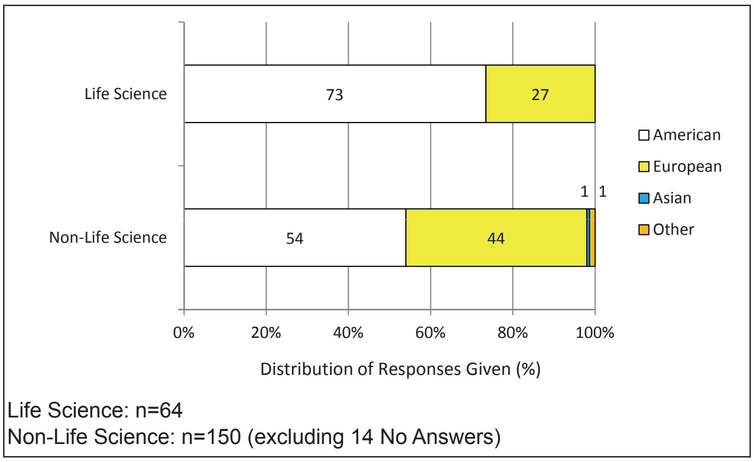


**Figure 3 :** What country produces most of the foreign-made instruments you use?
Compiled by the Science and Technology Foresight Center

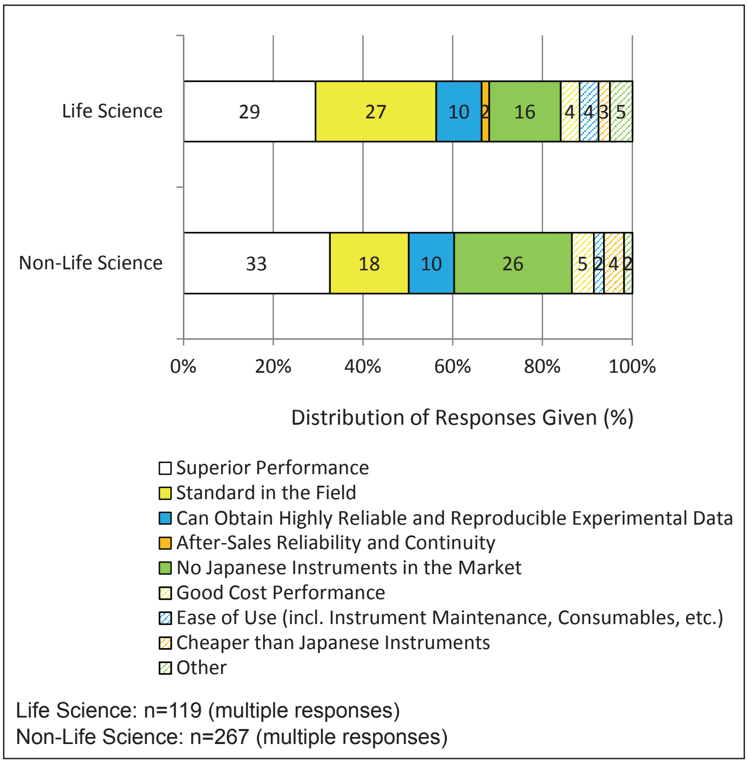


**Figure 4 :** Why did you select the foreign-made instruments you use? (Select top two choices.)
Compiled by the Science and Technology Foresight Center

heavier use of American instruments than other fields of research.

## *2-4 Foreign-Made Instruments Chosen for Both Performance and Prevalence*

Respondents were allowed to make multiple selections to answer why they choose to use foreign-made instruments. Together, "superior performance" and "the standard in the research field" made up over half the selections, at 29% and 27%, respectively. These were followed by "no Japanese instruments in the market" and "can obtain highly reliable and reproducible experimental data," showing that foreign-made instruments are selected both for their performance and prevalence (see Figure 4). Few respondents chose the other selections, reflecting researchers in life sciences rarely choose the equipment from points of views such as the maintenance service, the price, and the ease of use.

Compared to other fields of research, a high proportion of respondents in life sciences selected "the standard in the field," while few chose "no Japanese instruments in the market." These results show that in life sciences, the standardization of foreign-

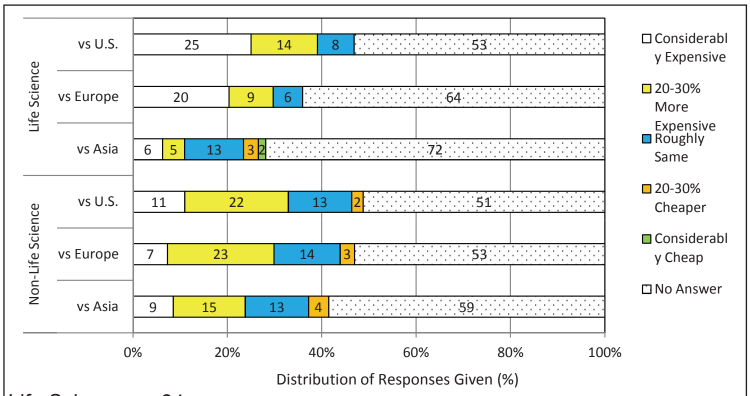


**Figure 5 :** How do instrument prices in Japan compare to other countries?
Compiled by the Science and Technology Foresight Center

made instruments has been proceeding over those made in Japan, and researchers prefer to collect data using foreign-made instruments for the international publications.

### *2-5 Roughly 40% Sees Especially Large Price Gap between Japan and the U.S.*

When asked about the cost of purchasing foreign-made instruments in Japan, 39% of respondents answered that it was either "considerably expensive" or "20-30% more expensive" than doing so in the U.S. In the same question, 29% of respondents gave these same answers regarding purchases in Europe and 11% regarding purchases in Asia outside of Japan. Compared to other fields of research, there was a more striking recognition in life sciences of a price gap, particularly between Japanese and American instruments (see Figure 5).

However, over half of respondents chose "no answer" to these questions. The authors believe that many researchers may be in a setting that makes it difficult for them to obtain information on instrument prices overseas.

### *2-6 Summary*

The results of the written survey show a tendency to make heavy use of foreign-made instruments in life sciences, particularly American instruments. Researchers mainly choose foreign-made instruments because of their good performance as well as because of their prevalence and their status as the international standard. These results conform with the results of the 2003 survey.[1] Furthermore, compared to researchers in other fields of research, a high proportion of those in the life sciences feel that there is a foreign-made instrument price gap between Japan and the U.S. In the 2003 survey as well,[1] a large proportion of respondents from the life sciences answered that instrument prices in Japan are even higher than in the U.S. These results indicate that there have not been any major changes since the latest survey in the reasons why researchers opt for foreign-made instruments or their perception of prices. Within the scope of examples in the STFC's preliminary survey, prices of American instruments in Japan are around twice as expensive as in the U.S., but this is roughly equal to other places outside the U.S., thus not contradicting the results of the abovementioned survey.

## 3 Instrument Price-Focused Discussions

Next, the STFC organized a workshop to which it invited experts with a range of perspectives concerning instruments (users, purchasing/management, development, etc.) in order to add some multifaceted considerations of current issues concerning the use of instruments and the direction to take in the future. There were 15 participants in all. In addition to the chair, Dr. Masashi Yanagisawa, there were two university professors, four from the research promotion and management departments of university and public research institutes, four from company R&D departments and four government officials.

First, after presenting the results of the written survey, they entered a discussion on the use of instruments and related issues. All participants had fairly similar recognition of the heavy use of foreign-made instruments, so their discussion on this topic merely confirmed the facts. Much of the time was spent discussing the price gaps between Japan and other countries. This chapter will summarize the participants' recognition of the current state of affairs and their awareness of problems related to the domestic-overseas price gap, as well as ideas for steps to resolve issues.

### *3-1 Lack of Opportunities for Many Researchers and Purchasing Managers to Learn of Instrument Prices Overseas*

Most of the respondents in Figure 5 gave no answer. It suggests that most researchers and purchasing managers are not in a position to know the prices of instruments overseas, and such a situation on the demand side is a reason why there is not an active discussion over the domestic-overseas instrument price gap.

< Key Discussion Points >

- Many researchers do not know the actual selling price of instruments in Japan or abroad. Even insiders in the U.S. have experienced refusal on the part of their affiliated institutes to disclose instrument prices.
- The job of the researcher is merely to select the needed instrument. Typically, the relevant department in charge handles price negotiations, in which the researcher does not have an opportunity to be involved.

### *3-2 Domestic Prices are Inevitably Higher*

Generally, the Japanese subsidiary of an overseas manufacturer is the importer of a foreign-made instrument, which is then sold to clients through a domestic dealer. Since import processes generate various costs, domestic prices are inevitably somewhat higher than overseas. The main costs that push up prices are purchasing, exchange rates, and legal compliance work and personnel expenses added on to sales and maintenance.

< Key Discussion Points >

- The Japanese subsidiaries that import instruments also play roles as import procedure agents, refer maintenance services, etc. Shifting these costs push up prices. It is rather uncommon for a purchaser to interact directly, for example by directly corresponding in English or paying airfare to bring over a technician when a directly imported instrument breaks.
- The exchange rate used for catalog prices are set to mitigate the risk of a rate fluctuation that could make the yen somewhat cheaper. Thus, the value of the yen is generally set lower than the actual exchange rate.
- The participants cited supplementary sales and maintenance work such as manual translation, advertising expenses, maintenance training seminars, demonstration instrument purchasing/ maintenance/relocation, service parts storage and preparing backup instruments.
- Regulations must be followed in any country, with laws in Japan such as the Electrical Appliance and Material Safety Act and the Poisonous Material Control Law. Datasheets on the safety of reagents and other documents must be translated into Japanese.
- Personnel expenses include paying for procedures to import an instrument and quality checks.
- In addition to the above, each company involved in the processes between import and sale take their cut, thus raising the end price.
- Instrument purchase prices can vary even if maintenance service costs are included. In Japan, instrument prices are often set under the assumption that there will be some small amount of maintenance. In the U.S., the price only includes the cost of the instrument itself and a separate contract must be concluded for maintenance services.

### *3-3 Scope to Narrow the Domestic-Overseas Price Gap*

While there are factors behind the domestic-overseas price gap other than those listed in Section 3-2, it is suggested there is scope to narrow the gap from its present size. When a Japanese researcher learns about market prices overseas, it can result in a lower price during negotiation. If the manufacturer feels that the market holds promise for the future, they may sell the instrument for a low price.

< Key Discussion Points >

- There have been cases in which dealers parallel import instruments that have been quoted at nearly double the price in the U.S., which they then sell for around half the quoted price.
- The laboratory of a Chinese researcher who returned

to China from the U.S. was able to purchase instruments at roughly 90% the price in the U.S. While the authors believe that one reason why the price was approximately the same is that in China, these transactions are handled in U.S. dollars, thus eliminating any foreign exchange issues. However, this does not fully explain the lower price than in the U.S. It is thought that it could be because U.S. manufacturers want to enter China's vast market.

### *3-4 Other Opinions*

There are many factors hindering the fall of instrument prices in the Japanese market. These include the market structure, the number of rival manufacturers, and the poor alternatives for bidding on the candidates for purchasing models.

< Key Discussion Points >

- Many of the top-selling companies in the domestic market in 2001 were from the U.S. or Europe. In life sciences, foreign firms account for a particularly high share.[2] The market mechanisms that rely on foreign-made instruments make it difficult to hold instrument prices down.
- Laser microscopes are one type of instruments for which there is no domestic-overseas price gap, but this is because there are no international competitors to domestic manufacturers. Meanwhile, the price of endomicroscopes in Japan is twice that in the U.S. because there are no Japanese manufacturers competing in this field.
- In the case of expensive instruments such as next-generation sequencers, there are few candidates to choose from and few venders handling them, leaving little room for multiple bids.

### *3-5 Workshop Summary and Future Direction*

The workshop allowed the participants to share information on the current state of affairs, which included instrument prices in overseas markets and purchasing by other research institutes. Nearly all participants said that first of all, researchers need to be made aware of the domestic-overseas price gaps for foreign-made instruments. For example, if a handy information source for checking overseas prices were made available, then researchers could negotiate prices after referencing going market rates.

There are numerous factors that go into setting the prices of foreign-made instruments. Many participants in this workshop are of the opinion that if users took the cost of import procedures, maintenance and inspection, then they would be able to utilize foreign-made instruments more efficiently. Meanwhile, workshop participants used their past experience to determine that it is possible to shrink the current domestic-overseas price gap. It was pointed out that vendees need to learn as much as they can about the instrument prices in overseas markets and make effective use of research funds.

Participants said that in the near-term, the first step towards making more effective use of foreign-made instruments would be to stimulate the used instrument market, which is an established market in the U.S. bioventures, for example, helps new companies procure low-cost instruments. Next, participants were of the opinion that special zones should be made and that companies, universities, research institutes and other organizations within an area should be allowed to easily share and relocate instruments. Furthermore, if multiple universities, for example, were to team up and increase their purchasing power to order large amount of products constantly, then participants thought that could bring prices down. In the long-term, they pointed out the importance of encouraging domestic instrument development and creating a market to compete with foreign-made instruments.

## 4 Conclusion

From the results of the written surveys and the opinions of workshop participants, it is suggested that perhaps half the people working in life sciences are in an environment that makes it difficult to obtain information on overseas instrument prices. The authors expect that this report will be used as a chance to share information with as many people in this field as possible.

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