EU-Japan Centre for Industrial Cooperation

Space Industry Business Opportunities in Japan:

Analysis on the Market Potential for EU SMEs Involved in the Earth-Observation Products & Services

Tokyo, October 2016

Ryuichi Dunphy

Disclaimer

The information contained in this publication reflects the views of the author and not necessarily the views of the EU-Japan Centre for Industrial Cooperation, the views of the EU Commission or Japan authorities. The author believes that this paper is reliable and reasonably clear. While utmost care was taken to check and translate all information used in this study, the author and the EU-Japan Centre may not be held responsible for any errors that might appear. This report does not constitute legal advice in terms of business development cases. The author can be reached at ryuichi.dunphy@gmail.com.

About the Author

Ryuichi Dunphy is an Aerospace Engineer with a Master Degree in Aerospace Engineering from Delft University of Technology in the Netherlands, and a Dual Bachelor Degree in Space Engineering and Physics from the University of Queensland in Australia.

During his academic tenure, he worked as a project manager for feasibility studies with NASA Langley Research Centre on manned exploration mission of Mars, and also with the Brazilian Institute of Space Studies (INPE) on the microsatellite-based internet and remote-sensing system for the Amazon region. Prior to his graduate studies at TU Delft, he worked as a mechanical engineer in Australia, and after graduating, he worked as a satellite data processing support engineer at Portuguese Institute of Ocean & Atmospheric Studies (IPMA) in Lisbon.

Ryuichi is part Japanese, and is fluent in Japanese language. He has worked in Japan and has a deep understanding of the Japanese business culture and practices, as well as understanding of Asia after studying and working in Singapore and China. The 6-month MINERVA research fellow enabled him to develop a profound understanding of the market landscape of the Japanese space industry, and build an extensive network with the key players in both private and public sector.

Acknowledgements

First and foremost, I would like to express my sincerest gratitude to the EU-Japan Centre for Industrial Cooperation and Mr. Silviu Jora for accepting me for the MINERVA Research Fellowship program. The research topic was truly fascinating, and it enabled me to not only build valuable network with the key players in the Japanese space industry, but also greatly deepen my understanding of the Japanese space program.

I would like to thank Mr. Fabrizio Mura for his continuous support throughout my placement. I truly appreciate how he was always available for consultation, and his insight and ideas greatlJPYhanced the content of my research. I would also like to thank Ms. Yoko Kadoya for her support and guidance with my project. Her ideas and advice were simply impeccable, and they greatly assisted me in networking with various stakeholders in the Japanese space industry. Working with Fabrizio and Yoko has been the highlight of my experience at the centre where I learnt immensely about EU-Japan relationship.

Last but not least, I would like to thank my fellow MINERVA researchers, Manuel, Guillaume and Ines, and also all the staff at the EU-Japan Centre for making my 6 months most memorable. I look forward to working with you again in the future.

Oct 2017

Ryuichi Dunphy

1 Table of Contents

Table of Figures

List of Abbreviations

ADB	Asia Development Bank
AIS	Automatic Identification System
APRSAF	Asia-Pacific Regional Space Agency Forum
APSCO	Asia-Pacific Space Cooperation Organisation
bil	Billions
DEM	Digital Elevation Model
DSM	Digital Surface Model
EARSC	European Association of Remote-Sensing Companies
EC	European Commission
EEZ	Exclusive Economic Zone
EIB	European Investment Bank
EO	Earth Observation
EORC	JAXA Earth Observation Research Centre
ESA	European Space Agency
EUR	Euros
GCOM	Global Change Observation Mission
GEO	Group of Earth Observations
GIS	Geospatial Information System
GPM	Global Precipotation Monitoring
ICT	Information & Communication Technology
IGS	Information Gathering Satellites
InSAR	SAR Interferometry
JA	Japan Agricultural Cooperatives
JAXA	Japan Aerospace Exploration Agency
JICA	Japan International Cooperation Agency
JSS	Japan Space Systems
LIDAR	Light Detection & Ranging
MAFF	Ministry of Agriculture, Forestry & Fishery
ME	Ministry of Environment
METI	Ministry of Economy, Trade and Industry
MEXT	Ministry of Education, Culture, Sports, Science and Technology
MIC	Ministry of Internal Affairs & Communication
mil	Millions
MLIT	Ministry of Land, Infrastructure, Transport & Tourism

MOFA	Ministry of Foreign Affairs
NEP	North East Passage
NICT	National Institute of Information and Communications Technology
NOAA	National Oceanic & Atmospheric Administration
ODA	Official Development Assistance
PSInSAR	Permanent Scatters Interferometry SAR
QZSS	Quasi-Zenith Satellite System
SAR	Synthetic Aperture Radar
SME	Small & Medium Enterprise
WB	World Bank

Introduction

This report consolidates 6 months of research work conducted under the *MINERVA Research Fellowship Program* at the EU-Japan Centre for Industrial Cooperation from April to September 2016. The research topic was on *"Space Industry business opportunities in Japan: Analysis on the market potential for EU SMEs involved in the earth observation products and services"*, with the aim to analyse the market potential for EU SMEs involved in Earth Observation products and services, and offer concrete support to European SMEs in Earth Observation (EO) applications in building relationship with the Japanese space industry.

The report is split into 5 chapters. Chapter 1 gives a brief overview of the Japanese space industry, describing the size of budget of the Japanese space program, key government bodies and agencies, and major private companies, and also a brief treatment of the history of the Japanese space program.

Chapter 2 goes into more details of the Japanese space policy, describing the key policy aspects and recent developments in the Japanese government with respect to space.

Chapter 3 explores the Earth-observation applications industry in Japan, identifying all the relevant companies as well as their main areas of competences and disciplinary areas. The chapter also includes a detailed investigation of the current state of the Japanese Earth-observation programs and their capabilities, followed by a SWOT analysis to characterize the Japanese EO industry.

Chapter 4 consists of a detailed needs analysis for 8 user communities in Japan – Agriculture, Forestry, Fishery, Urban Infrastructure Monitoring, Sea Ice Monitoring, Maritime Management & Surveillance, Disaster Management, and Renewable Energy. Over 40 public and private entities were interviewed to gather their needs and concerns with respect to satellite application. The information obtained from the interviews was compiled to form a detailed set of system requirements to present unfulfilled needs and opportunities in Japan.

Finally, Chapter 5 gives conclusions and recommendations for both the European Commission and the European industry in order to develop partnership with Japan.

Executive Summary

As of 2016, there are over 60 companies in Japan pertaining to Earth-observation (EO) products and services. Most prominent companies are the surveying and mapping companies that have taken up satellite remote-sensing data as one of their tools to conduct various analyses work. Despite the reasonably large number of companies involved, the actual market size is relatively small. The market is estimated to be 0.8 bil JPY (approx. 70 mil EUR in current exchange rate) in 2010, but it is said that the majority is government contracts related the military, and the sum of non-military projects in public and private sectors is as little as 0.2 bil JPY. This is less than 1/10 of the market size of the EU, estimated to be approx. 1 bil EUR in 2015. The Japanese companies are heavily dependent on government contracts, where over 80% of their revenue come from publicly funded projects and feasibility studies both in and outside Japan, and revenues from the private sector only accounts for a small portion.

Such a heavy dependence on the publicly funded projects by the Japanese EO applications industry is largely attributed to the Japanese government's struggle to promote commercialisation and industrialisation of space. Japan has been a late comer in the recent movement of *"New Space"*, and the domain of space was completely focused on scientific R&D until mid-2000s, with no consideration for commercial applications. Thus, the public sector has been the dominant customer for the EO application companies, and the needs in the private were only given light treatment, in the form of publicly funded pilot projects. In farming applications, some companies have managed to establish an on-going business case, but only with the subsidies from the regional governments. Overall, with no incentives for the companies to explore alternative revenue source in the private sectors, combined with the typical conservatism and risk-averse attitude of the Japanese corporate culture, commercial EO applications catered for the private sector have not developed in Japan so far.

Nevertheless, the situation is slowly changing. To stimulate the commercialisation of space in Japan, the Japanese government has announced the Basic Plan of Space Policy in 2008 to make clear of their objectives and priority areas, as well as laying out the satellite development roadmap up to 2020. The country aims to grow the space industry to a cumulative total of 500 bil JPY by 2027. Although still in its infancy, the Japanese space agency, JAXA has established the New Enterprise Promotion Department to engage more companies to participate in space-related business. This movement is gaining traction in the industry as well, and it could be said that 2016 is the year of change as the major EO application companies, such as PASCO, Kokusai Kogyo and Air Asia Survey, are realizing that they need to move away from government contracts, and explore new opportunities in the private sector inside Japan as well as overseas. The Japanese companies are interested in engaging with Europe, in terms of both information exchange as well as collaborative ventures. But the key requirement in any form of cooperation is that it must create a *'win-win'* situation for the both sides, instead of competing for the same, small *'pie'*.

The Japanese EO communities have a strong expertise in L-band SAR, and satellite applications in agriculture and disaster management, and they also have unique and valuable EO satellites and instrument, GOSAT and AMSR, for monitoring greenhouse gases, and ocean and sea ice monitoring respectively. It is said that the EO communities need to improve the observation frequency to open up new commercial applications, and the EU should look to explore possible complementary operation of EO satellites with Japan. The project also identified 2 key weaknesses of Japan with respect to EO – lack of domestic optical satellite data until at least 2019, and the possible gap in their EO capability beyond 2021 due to largely uncertain development of their satellites.

The project also interviewed over 40 private and public entities in 8 industries that use EO products and services to understand their needs and opportunities with respect to satellite data. They are agriculture, forestry, fishery, urban infrastructure management, sea ice monitoring, with brief treatment of maritime management & AIS, disaster management, and renewable energy. The promising areas in Japan for EO applications are:

- Agriculture
- Maritime Management & Surveillance
- Fishery
- Urban Infrastructure Management

Taking these matters into account, the recommendations for the European Commission are:

1) Start an EU-Japan dialogue focused on EO products and services
2) Promote the EU's Copernicus in Japan
3) Sign a formal agreement between the EU and Japan on the use of Sentinel data
4) Resolve the issue of reciprocity of EO data
5) Find the funding infrastructure to support the formation of joint-research projects for the EO-related calls in Horizon 2020, to promote EU-Japan partnerships
6) Agree on a common set of goals and roadmaps for increasing the use of EO downstream applications

7) Set up EU-Japan collaborative projects by consolidating the funds of JICA, ADB, WB and EIB, and form an alliance to solve global problems together

Similarly, for the European industry pertaining to EO products and services, the recommendations are:

1) Build up relationship with Japanese companies through exchange of information, workshops and seminars
2) Participate in trade shows to network with Japanese industries and promote European EO products and services
3) Use the findings from the industry needs analysis in Chapter 4, and partner with Japanese companies to jointly develop applications to address those needs
4) Explore possible cooperation with the Japanese ICT industry and *"New Space"* companies
5) Approach prefectural and municipal governments about smart agriculture, smart forestry and smart fishery initiatives, and also approach large food companies and super market franchise

1 Japanese Space Scene

1.1 Overview

Japan has a long, rich history in space, and it is one of the major space-faring nations along with USA, Russia, Europe and China (Lele, 2012). It is the 4th country in space after erstwhile USSR, USA and France, the 1st Asian country to send a satellite into orbit (1970). It is also the 3rd country after USA and USSR to send spacecraft to the Moon (1990) and Mars (1998). Japan has conducted numerous missions in Earth Observation, Space Science and Exploration using their own launcher family, and it is a major participant in the International Space Station.

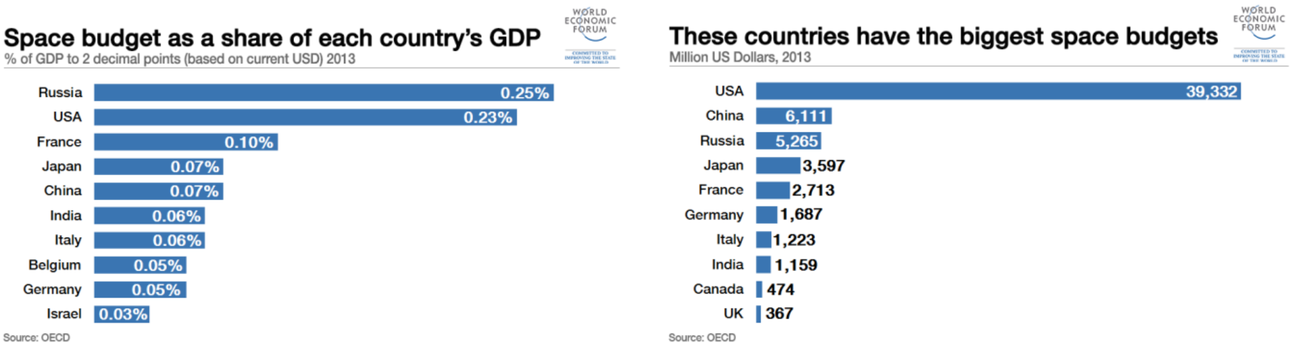


Figure 1-1 Comparison of countries' space budget (left) and as a % of their GDP (right) (Luxton, 2016)

In 2013, the Japanese space industry was composed of 8,181 workers (Hata, 2015), and generated a total sales volume of US$2.83 bil (Kawai, 2015a). The space services sector is estimated to be US$9 bil, but this is largely attributed to the communication & broadcasting sector.

Category	Sales Volume (Bil US$)
Space Industry (Launchers, Satellites, Grd. Facilities)	2.83
Space Services Industry (Communication, Broadcasting, GNSS, EO)	9.0
Space Service Equipment Industry (BS TV, BS Tuner, Car-Navigation, GPS device)	17.1
Space Service User Sector (utilisation of space services)	35.5
Total	**64.5**

Table 1-1 Breakdown of revenue of the Japanese space industry (Kawai, 2015a)

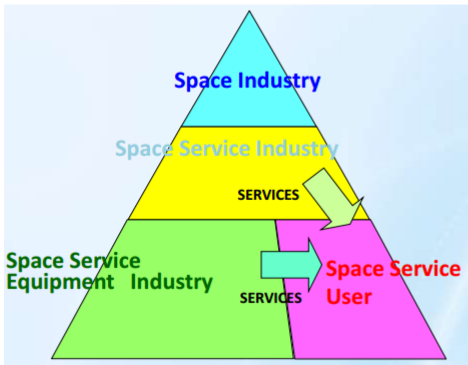


Figure 1-2 Representation of different sectors of the Japanese space industry (Kawai, 2015a)

Sales volume associated with Earth-observation products and services hasn't been thoroughly investigated in Japan, but some of the experts in the Japanese space industry has estimated it to be approx. 0.8 bil JPY (approx. 70 mil EUR in 2016 exchange rate) in 2010. However, some claim that the majority of 0.8 bil JPY is government defence contracts, and the actual revenue of non-defence, public and private contracts could be as small as 0.2 bil JPY. This figure is significantly smaller compared to that of Europe, which is estimated to be approx. 1 bil EUR in 2015 [EARSC, 2015].

1.2 Japanese Space Agency

The main government agency in charge of Japan's space development is the *Japan Aerospace Exploration Agency* (JAXA) (JAXA, 2016). It was established in 2003 after the merger of three governmental aerospace research and development bodies under the administrative control of the Japanese Ministry of Education, Culture, Sports, Science and Technology (MEXT). As of 2016, JAXA has executed 130 space missions in total, and the breakdown is shown on Figure 1-3.

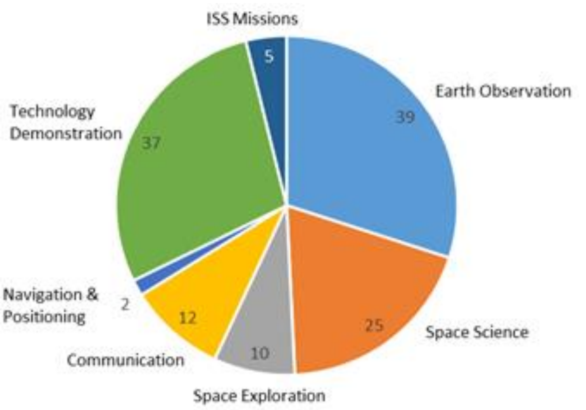


Figure 1-3 Breakdown of JAXA's space missions (JAXA, 2016d)

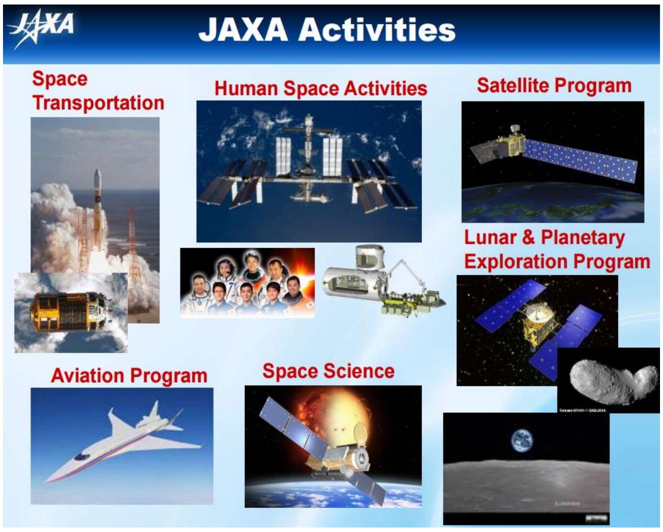
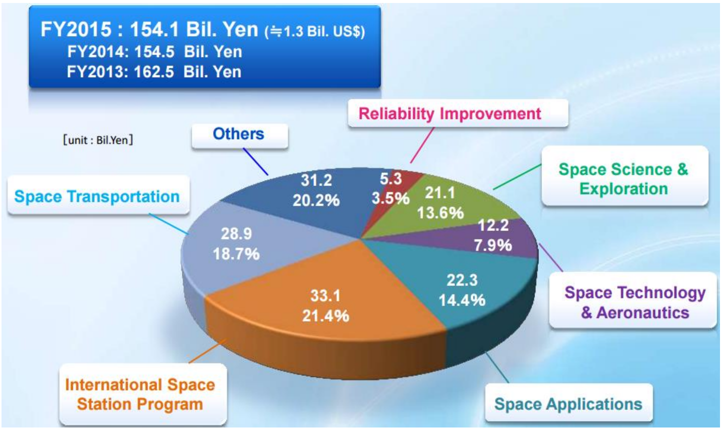


Figure 1-4 Examples of Japan's space program (Kawai, 2015b)

The annual budget for 2015 was 184.0 bil JPY, which is approx. 1.2 bil EUR in 2015 exchange rate.



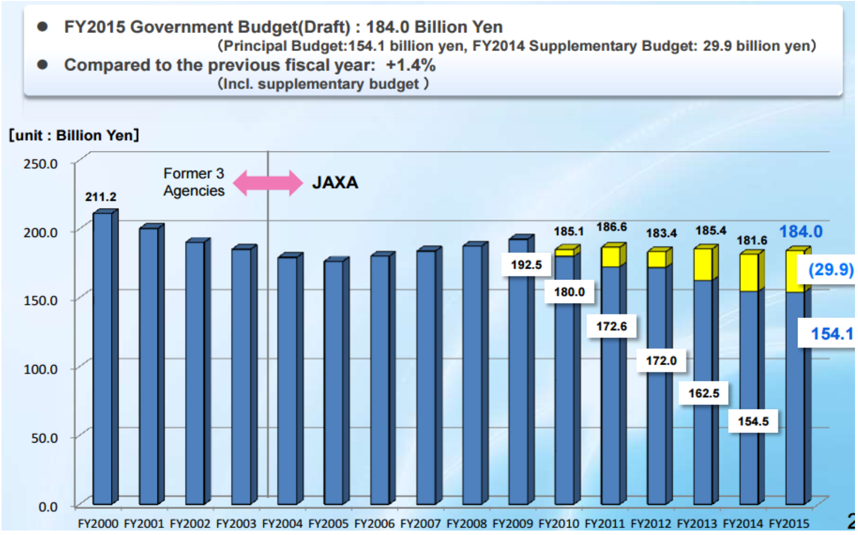


Figure 1-5 Change in JAXA's budget in the 2000s (Kawai, 2015a)

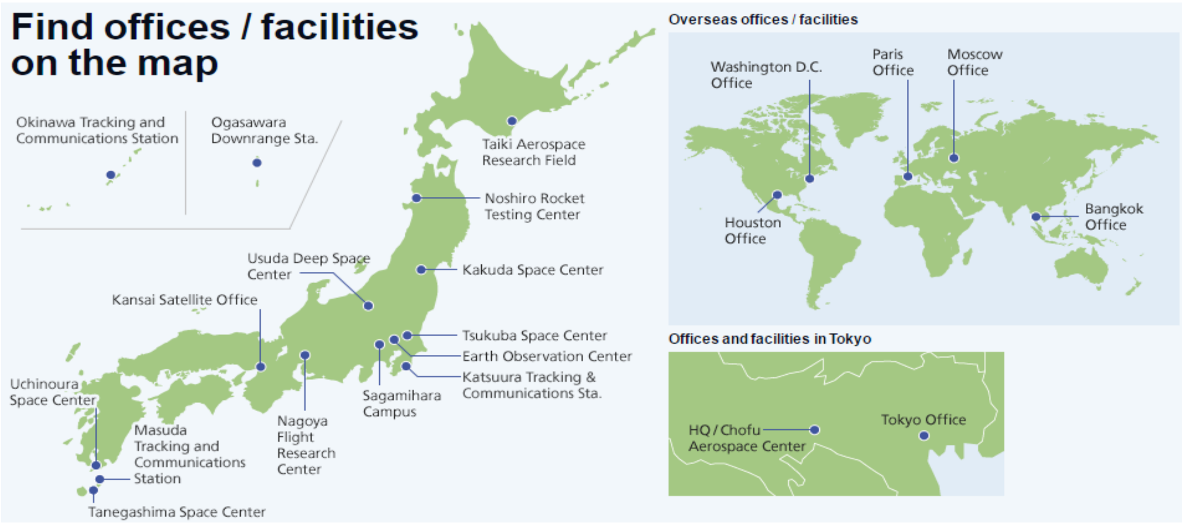


Figure 1-6 Locations of JAXA's offices and facilities (JAXA, 2016)

Japan is one of six national space agencies with full launch capabilities (Lele, 2012).

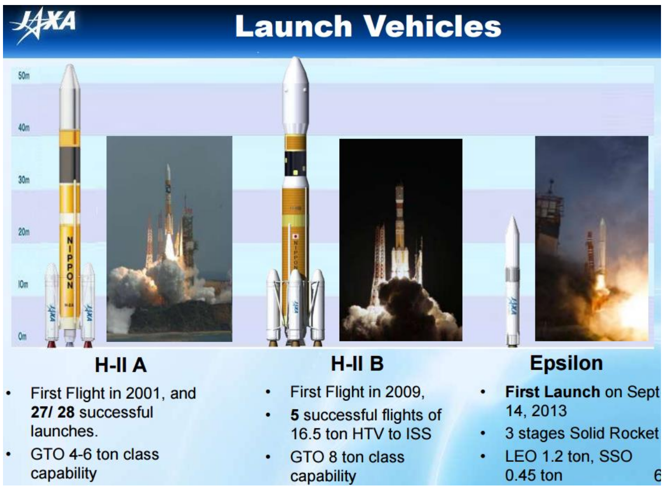


Figure 1-7 Japan's launch vehicles (Kawai, 2015b)

Completely separate to JAXA, another governmental body in Japan on space research and development is *Japan Space Systems* (JSS) (JSS, 2016). Being under the administrative control of the Japanese Ministry of Economy, Trade and Industry (METI), JSS has more industrial and commercial focus compared to JAXA. They are funded by METI and their member companies, which are predominantly from natural resource exploration and heavy machinery. Their key R&D projects are:

- **A**dvanced **S**atellite with **N**ew System **AR**chitecture for **O**bservation (ASNARO) (JSS, 2016)

ASNARO is a small, high-performance satellite bus development project where JSS was in charge of the top-level system design and the fabrication was contracted to NEC, a major Japanese IT and electronics company. The first satellite ASNARO-1 was launched in 2014.

Figure 1-8 An image of ASNARO-1 developed by NEC and JSS

- Hyperspectral imager development (JSS, 2016)

JSS developed the hyperspectral imager ASTER on-board NASA's *Terra* satellite, which has been particularly useful for natural resource exploration as well as many other areas. The successor, HISUI, is currently under development by JSS.

- Space Environment Reliability Verification Integrated System (SERVIS) (JSS, 2016)

The project aims to expand space-qualified components in Japan by adopting commercial parts and technology and verifying them in space environment.

- Air Launch System Enabling Technology (ALSET) (JSS, 2016)
- Space Solar Power System (SSPS) (JSS, 2016)

1.3 History

Japan's entry into the space arena came in the backdrop of several political restrictions that the country faced in the post-WWII era. As a result, right from the start, Japan's space development was shaped as a pure scientific pursuit, with very little military and industrial implications (Harvey, Smid, & Pirard, 2010).

The inclusion of Article 9 in 1946 into the Japanese Constitution, which was brought about by the US, made Japan to renounce its right to build and deploy armed forces (Although, they have subsequently overcome this by maintaining the Japan Self-Defense Forces under the United Nations). The development of aircraft was banned under the US occupation until the signing of the San Francisco Peace Treaty in 1951 (Shiroyama, 2014), which allowed re-commencement of the development of aviation technology under the sovereignty of Japan (Wikipedia, 2016a). In 1954, the *National Aerospace Laboratory of Japan* (NAL) was established to conduct research on aircraft, rockets and other aeronautical transportation systems.

Japan's space development started in the mid-1950s as a research group led by Prof. Hideo Itokawa at the University of Tokyo in order to re-establish Japan's technical ability in the aeronautics. With the aim of launching a man-made satellite, he and his team of researchers started the launcher development in Japan with a small, experimental rocket called the *Pencil Rocket* in 1955 (Wikipedia, 2016a).

By 1960, motivation to go ahead for a satellite program was gaining momentum, but due to the aforementioned political factors, the focus was largely space science. In 1964, the University of Tokyo established the *Institute of Space & Astronautical Science* (ISAS) as a lead agency to oversee Japan's space science programs. This was then followed by the formation of *National Space Development Agency* (NASDA) in 1969, to develop programs in the areas of remote-sensing, communications, meteorology, as well as launching and tracking of satellites (Lele, 2012). This led to Japan having two parallel space programs with two main organisations, ISAS and NASDA, each with own fleet of rockets and support facilities.

For nearly three decades, the above organisations and several others involved in the space development were reporting to different ministries in the Japanese government. Naturally, such diverse reporting channels and different budgeting allocations were counterproductive for overall growth of the program. Therefore, in 2003, a decision was made by the Japanese government to merge the three organisations into one, independent, administrative body, and JAXA was established.

In a similar manner, JSS was established in 2012 after the merger of three research organisations pertaining to space and remote-sensing under METI as shown in Figure 1-10.

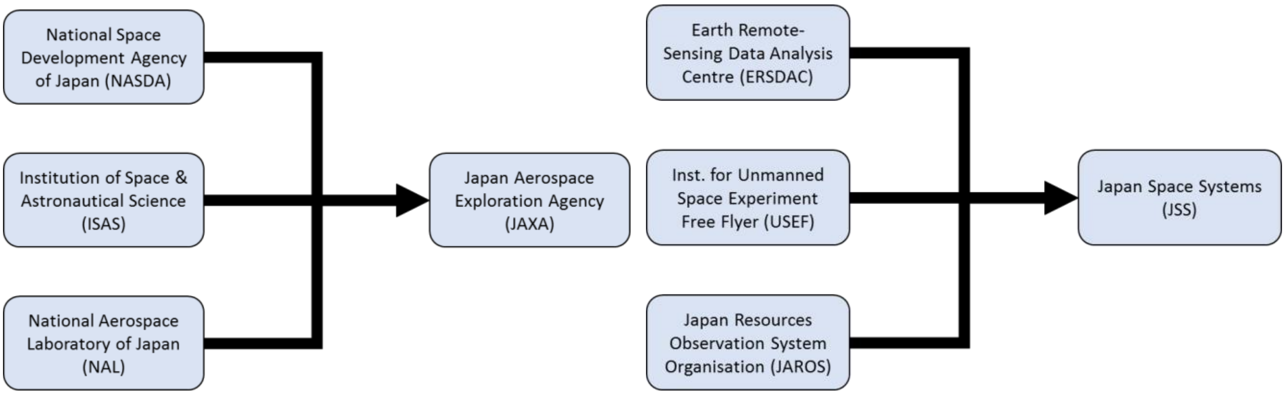


Figure 1-9 Formation of JAXA (left) and JSS (right)

1.4 Key Government Bodies

In Japan, space policy matters and development strategy are determined by the Prime Minister and the Cabinet, and the decision is passed down to the key ministries. The top-level structure of the decision-making process for space development in Japan is shown in Figure 1-11.

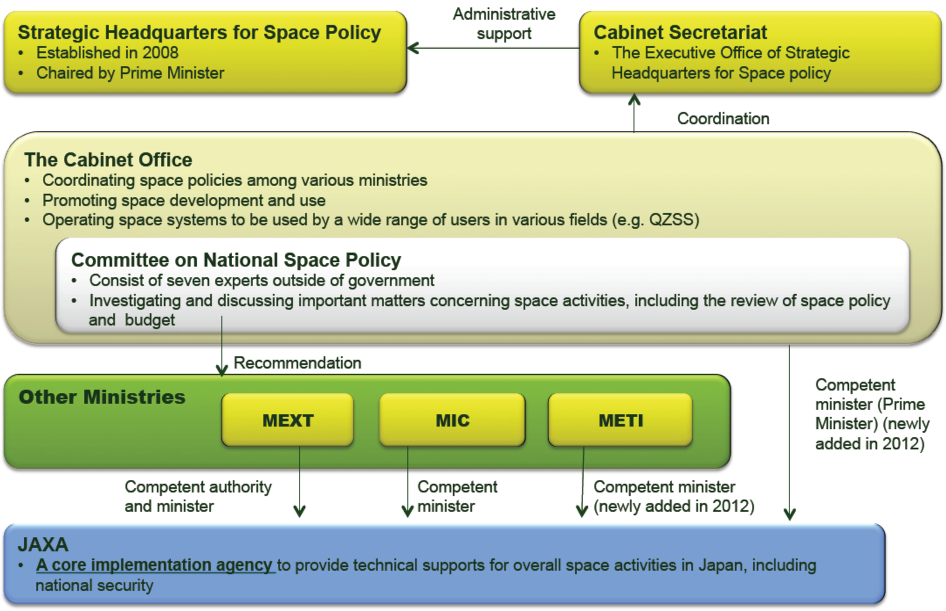


Figure 1-10 Japan's decision-making bodies for space (Shiroyama, 2014)

The Strategic Headquarters for Space Policy is the main decision-making body. It is chaired by the Prime Minister of Japan, and it consists of the ministers in the Cabinet, including the Chief Cabinet Secretary and the Minister of State for Space Policy as the vice chair (Shiroyama, 2014). The Strategic Headquarters coordinates the inputs from different ministries under the leadership of the Prime Minister, and develops and executes Japan's *Basic Law of Space Policy*, which was established in 2008. It is also in charge of approving the final legislation of space-related activities.

The Strategic HQ also coordinates the Space Systems Overseas Expansion Working Group, which is responsible of investigating the needs and project opportunities of countries overseas (Shiroyama, 2014). The WG consists of representatives and experts from the government, industry and academia, and liaises closely with the embassies and consulates of target countries.

The National Space Policy Secretariat is situated in the Cabinet Office, and it is the main support body for the Strategic Headquarters for Space Policy. The secretariat consists of 12 staff members and they are responsible for (Komizo, 2009):

- Drafting and update of the Basic Plan for Space Policy
- Development of new space policy initiatives, long-term strategies and lobbying to the Cabinet and other relevant government bodies
- Formulation of strategic budget allocation guidelines and follow up on each ministry's budget request to evaluate them against the guidelines
- Development and operation of satellite systems for inter-ministerial use

The Key Government Ministries liaise with the Strategic Headquarters for Space Policy and the Office of National Space Policy, and request projects that align with the national space policy to JAXA. The relationship is similar to that between the European Commission (EC) and the European Space Agency (ESA), where ESA is the technical prime contractor of EC. All the government ministries of Japan have some level of stake in the country's space development, but the four key ministries have stronger involvement than others with greater budget allocation, particularly MEXT, as JAXA was previously under their direct administration. In fact, the four ministries have their own, internal office for space development to promote space-related matters of their priority, which may or may not fully align with the direction set by the Cabinet Office. For more information on the bureaucracy of the Japanese political system, readers are encouraged to seek other sources.

1.5 Main Aerospace Companies

The Japanese space program has been supported by major heavy industries and electronics companies of Japan. The main manufacturers for launchers and spacecraft are briefly described below.

Launcher

For launcher development, the two prime manufacturers are:

1) *Mitsubishi Heavy Industries* (MHI)
    - A multinational engineering, electrical equipment and electronics company, and one of the core companies of the Mitsubishi Group.
    - Prime contractor for the liquid-fuel rockets, H-IIA and H-IIB, as well as for the future H-III rocket.
    - The H-II series has been used to launch spacecraft into geostationary orbit (GEO), lunar orbit as well as interplanetary orbits.
    - Focusing on expanding its overseas operations/business – recently won the launch contract for the UAE's Mars exploration mission (Foust, 2016)
2) *IHI Aerospace Co., Ltd.*
    - A subsidiary of *IHI Corporation*, another major heavy industries company in Japan.
    - Prime contractor for the solid-fuel rockets *Epsilon* and M-V (retired in 2006), developed together with JAXA.
    - *Epsilon* is designed for launching small satellites into LEO, similar to ESA's *Vega* launcher.

Spacecraft

The two main prime satellite manufacturers are:

1) *Mitsubishi Electric Corporation* (MELCO)
    - Multinational electronics and electrical equipment manufacturing company, and one of the core companies of Mitsubishi.
    - Build the majority of Japan's spacecraft, and also the prime contractor for HTV (*H-II Transfer Vehicle*), the cargo vehicle for the ISS.

- Pushing hard to expand its business overseas with their satellite bus DS-2000 for telecommunication satellites. Have won contracts from South Korea, Singapore, Turkey and Qatar (Cabinet Office, 2015).

2) *NEC Space Technologies, Ltd.*

- Previously a joint-venture between the aerospace divisions of NEC and Toshiba, but NEC bought all of Toshiba’s share in 2015 to become a fully-owned subsidiary of NEC.
- The two companies have built 50 spacecraft in total (Wikipedia, 2016b).
- Looking to expand their business overseas, particularly in developing countries with their expertise in small to medium-size spacecraft bus, NEXTAR (Cabinet Office, 2015).

Overview of the Japanese Space Scene

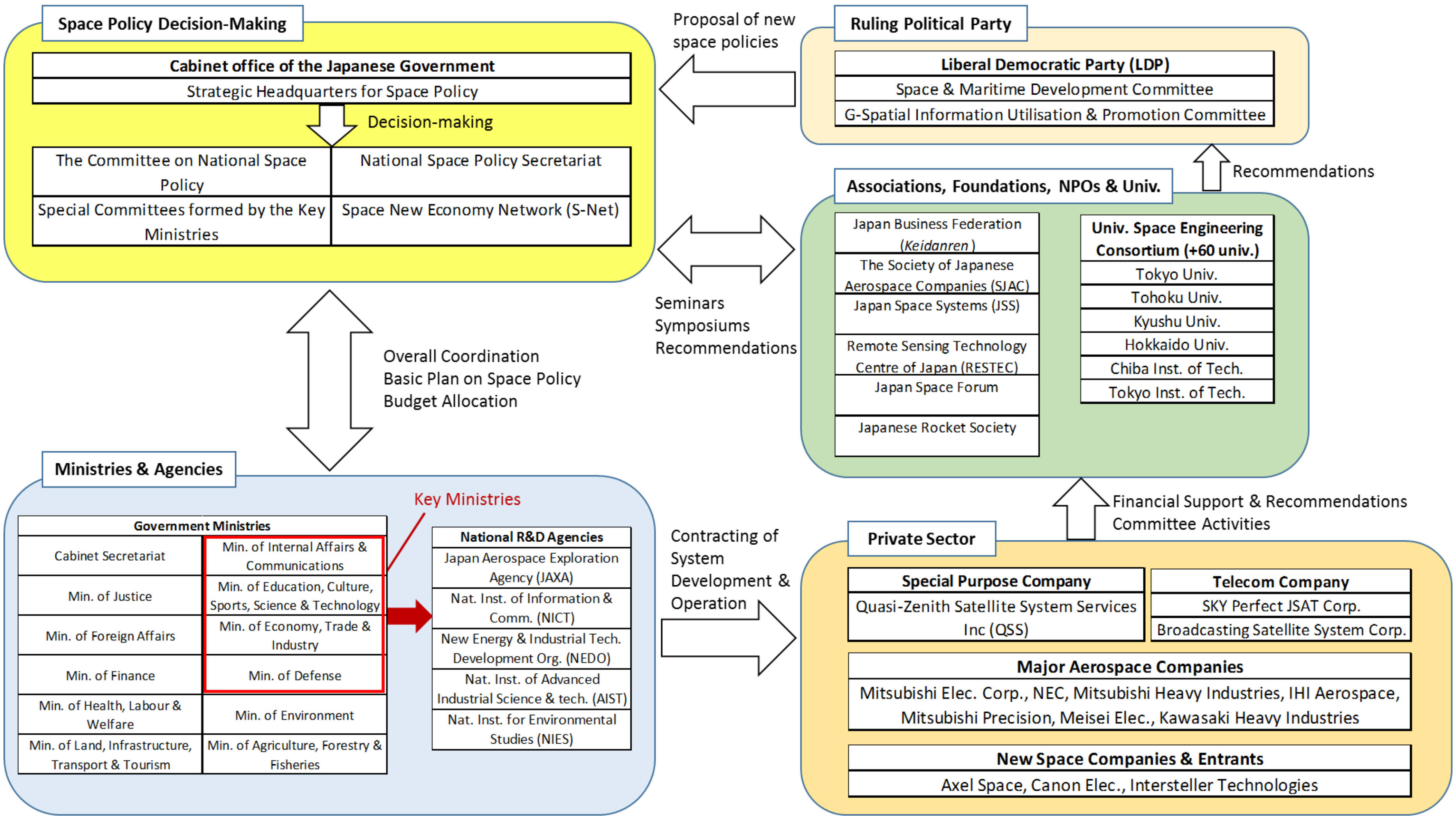


Figure 1-11 Overview of the Japan space scene (modified from JSS' internal material. Copy right JSS)

2 Japanese Space Policy

2.1 Background

The self-imposed ban on the use of space technology for military purposes during the post-WWII era somewhat restricted Japan to direct its space program for purely scientific purposes. Typically, in many countries across the world, governments and military act as drivers for the development of their space industries, collaborating with civilian companies to accelerate technological development, which in turn leads to the creation of new products and services. In Japan, however, there has been no demand from the military, and consequently, this ecosystem didn't develop (Lele, 2012).

Despite these limiting factors, the government agencies and the private space companies in Japan continued to build up its technical expertise through space science missions. However, the US saw the threat of Japan's growing capabilities in space, and activated the Super 301 of their 1974 Trade Act during the US-Japan Trade Conflict over semiconductors in the 1980s (Zeng, 2004). Super 301 is a section of the Trade Act that enables the Trade Representative to single out a country as an unfair trader, begin trade negotiations with that country and, if the negotiations do not conclude to America's satisfaction, impose sanctions. Japan was named an unfair trading nation in 1989, and negotiations began on forest products, supercomputers, and telecommunications satellites. The Japanese government, which didn't see space as a politically important area at the time, ceded to the US's claims and agreed to sign the Japan Satellite Procurement Agreement in 1990 (Zeng, 2004).

The agreement stipulated that Japan make the procurement of all satellites open international tendering, particularly communication satellites and any other satellite development activities intended for commercial applications (ITA, 2016). The only exclusion to this was R&D satellites, defined as satellites designed and used entirely, or almost entirely, for the purpose of in-space development and/or validation of technologies new to either country, and/or non-commercial scientific research. The Japanese satellites at the time were marked by high cost due to small government orders, and the Japanese space companies had not matured enough to compete against the US satellite manufacturers, which already had experience in commercial satellites to offer lower cost. As a result, 19 of 20 communication satellites owned by Japanese telecommunication companies are US-made (Hata, 2015).

The agreement discouraged the Japanese space companies, and limited to Japan to focus on R&D for space science missions and technology demonstrations. This caused the three significant problems for the Japanese space industry (METI, 2009):

1) The industry became overly-dependent on a small number of government space projects, which prevented companies to leverage scale to reduce costs and make their investments pay out.
2) Focus on science mission caused the spacecraft design to be somewhat too specific and to lack versatile commercial applications, limiting the companies from exploring opportunities in the private sector.
3) The important factors for generating sales in the space industry is reliability and substantial experience or track-record in developing space-qualified systems. The opportunities for the Japanese companies to design and operate space systems became rather limited, and this prevented them to building up their portfolio and thus, they couldn't build up their share in the global market. Outside of the Japanese public sector, the main Japanese aerospace companies have struggled to win bids on the international market with only 3 launch contracts and 4 telecommunication satellite contracts.

Year	Contract
2008	Telecom satellite contract for a joint-purchase by Singapore Telecommunications Ltd., and Chunghwa Telecom Company of Taiwan for MELCO
2009	Launch contract for KOMPSAT-3 of South Korea for MHI
2011	2 telecom satellites contract for Turksat of Turkey for MELCO
2013	Launch contract for Telesat of Canada for their Telstar 12V satellite for MHI
2014	Telecom satellite contract for Eshail Sat of Qatar for MELCO
2015	Launch contract for the UAE's EO satellite, Khalifa Sat for MHI

Table 2-1 List of recent bids won by Japanese space companies (METI, 2009)

Furthermore, Japanese government budgets have tended to run on a one-year basis, making it difficult for companies to plan ahead and make long-term investments (Export to Japan, 2015). These factors caused space to be unprofitable business with small outlet, and many companies in Japan have withdrawn from the industry over the years as shown in Figure 2-2. Figure 2-1 shows the difference in the revenue sources for the space industry between Japan and the EU in 2013, which clearly demonstrates the significant dependence of the Japanese aerospace companies on government contracts (METI, 2009).

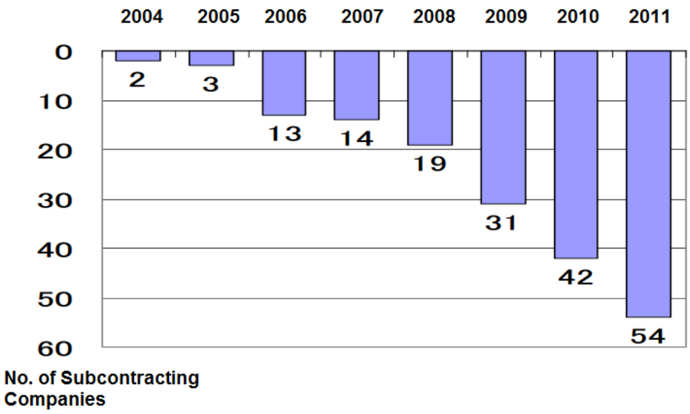


Figure 2-1 Cumulative total of Japanese companies that withdrew from space. Modified from (Hata, 2015)

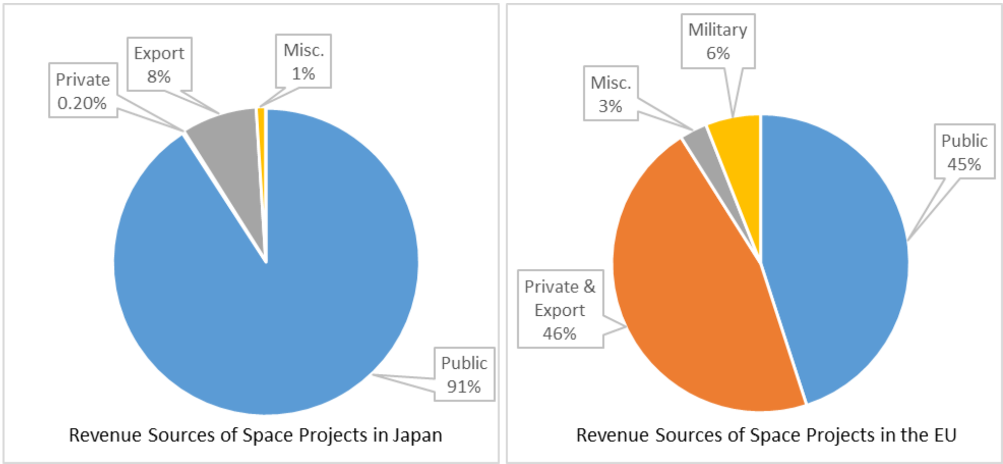


Figure 2-2 Revenue sources for space projects in Japan (left) and in the EU (right) for 2013. Modified from (Cabinet Office, 2015)

To address the situation of the weakening Japanese space industry, and to respond to the change in the international circumstances of space development marked by the US and Europe's shift towards the private sector, the Japanese government started discussions on devising the national space policy in the early 2000s.

2.2 Basic Space Law

To meet the aforementioned socioeconomic and political concerns, the Japanese government enacted the Basic Space Law in 2008. The Basic Space Law consists of 4 chapters and 35 articles that defines Japan's objectives and approach for its future space development. (Cabinet Office, 2016). The Basic Space Law is currently available only in Japanese, but the main points can be summarised as follows (Komizo, 2009):

1) Basic Concepts & Measures of Space Development
   - Peaceful use of space
   - Improvement of citizen's lives

- Promotion of space-related industries
- Advancement of values for humankind
- Promotion of international cooperation
- Consideration of environmental preservation

2) Establishment of Headquarters for Space Policy
   - The Headquarters to be established under the Cabinet, with the Prime Minister as the Director-General and the Chief Cabinet Secretary and the Minister of State for Space Policy as the Vice Director-General
3) Establishment of the Basic Plan of Space Policy
4) Review of Space-related Organisations
   - Review of the function of JAXA and other organisations involved in space-related activities
   - Re-evaluation of the functions of related executive government bodies

The main component of the Basic Space Law is the establishment of the Headquarters for Space Policy within the Cabinet office, and the Basic Plan of Space Policy to define mid to long-term plans on Japan's space development initiatives and programs.

What is significant about the Basic Space Law is that it defines a radical, new direction for Japan's space program, especially around the use of satellites for defence and security and the commercialisation of space technology (Aoki, 2011). Articles 2 and 3 subtly hint at the possibility of using space for military activities, and the author's unofficial translation are presented below:

Article 2 – Peaceful Use of Space

"Space Development and Use shall be carried out in accordance with treaties and other international agreements with regard to Space Development and Use including the Treaty on Principles Governing the Activities of States in the Exploration and Use of Outer Space, including the Moon and other Celestial Bodies, in accordance with the pacifism of the Constitution of Japan."

Article 3 – Improvement of Citizen's Lives

"Space development and utilisation must be conducted in such a manner that it contributes to the improvement of the lives of Japanese citizens, formation of safe and secure society, mitigation of disaster,

poverty and other threats against the human livelihood, and ***securing peace and safety in the international community as well as our country's national security****".*

Some of the legal experts in Japan, such as (Aoki, 2011), argue that the new law marks the end of the non-military policy of Japan, as the interpretation of the above articles can be expanded to allow military use of space. Such use may include the development of passive or defensive military satellites by the Japan Self-Defense Force, and the participation of organisations such as JAXA, to support these efforts.

2.3 Basic Plan of Space Policy

Article 24 of the Basic Space Law called for the establishment of the Basic Plan of Space Policy to define Japan's plans on the development and utilisation of space at the fundamental level, as well as the technological roadmap for Japan's future space development (Cabinet Office, 2013). The Basic Plan of Space Policy was first established in 2009 with the aim of increasing the budget for space to 2.5 trillion JPY in 5 years from both the government and the private sector. However, this was deemed difficult due to the ongoing financial stringency of the Japanese government, and the private sector unable to find sufficient private or foreign demand. Therefore, the Basic Plan for Space Policy was modified in 2013 and again in 2015 (Komiya, 2015), to define more effective ways to promote space utilisation and strengthen Japan's industry base. The latest version covers a five-year period starting from 2013, and oversees the development for the next 20 years.

The three priority areas of the plan are (Cabinet Office, 2009):

1) **National Security & Disaster Management**

   The main feature of the plan is Japan's greater emphasis on the use of space technology for national security purposes. To secure safe and stable access to space, and to strengthen Japan's security capabilities through the use of space, the plan lists a host of new capabilities that Japan plans to develop:

   - Quasi-Zenith Satellite System (QZSS) is a satellite-based augmentation system for the Global Positioning System. The proposed system consists of 3 satellites and it is aimed to boost Japan's own positioning capabilities.
   - Three X-band defence communication satellites
   - Operationally responsive mini-satellites and missile early warning satellites

- Advanced optical and radar satellites, and data relay satellites
- Capabilities for Maritime Domain Awareness and Space Situational Awareness

2) Industrial Development

As was discussed earlier, the uncertain return on investment and low demand have made it difficult for Japanese space companies to sustain their business. In response to these issues, the plan lays out a detailed development, launch and operation schedule running to 2027, to enable companies to make their investment forecasts. The goal is to launch at least 40 satellites in the span of 10 years, and grow the upstream industry size by 65% above its current level to a cumulative total of 500 billion JPY by 2027.

3) Progress in Frontier Areas including Space Science

Japan's contribution to science through the use of space has been highly regarded on the international stage, and it is vital to continue this to strengthen Japan's position.

The overview of the Basic Plan of Space Policy is presented in Figure 2-3. Readers wishing to gain further details about the plan are encouraged to refer to the English version of the plan, which is available online [Cabinet Office, 2013].

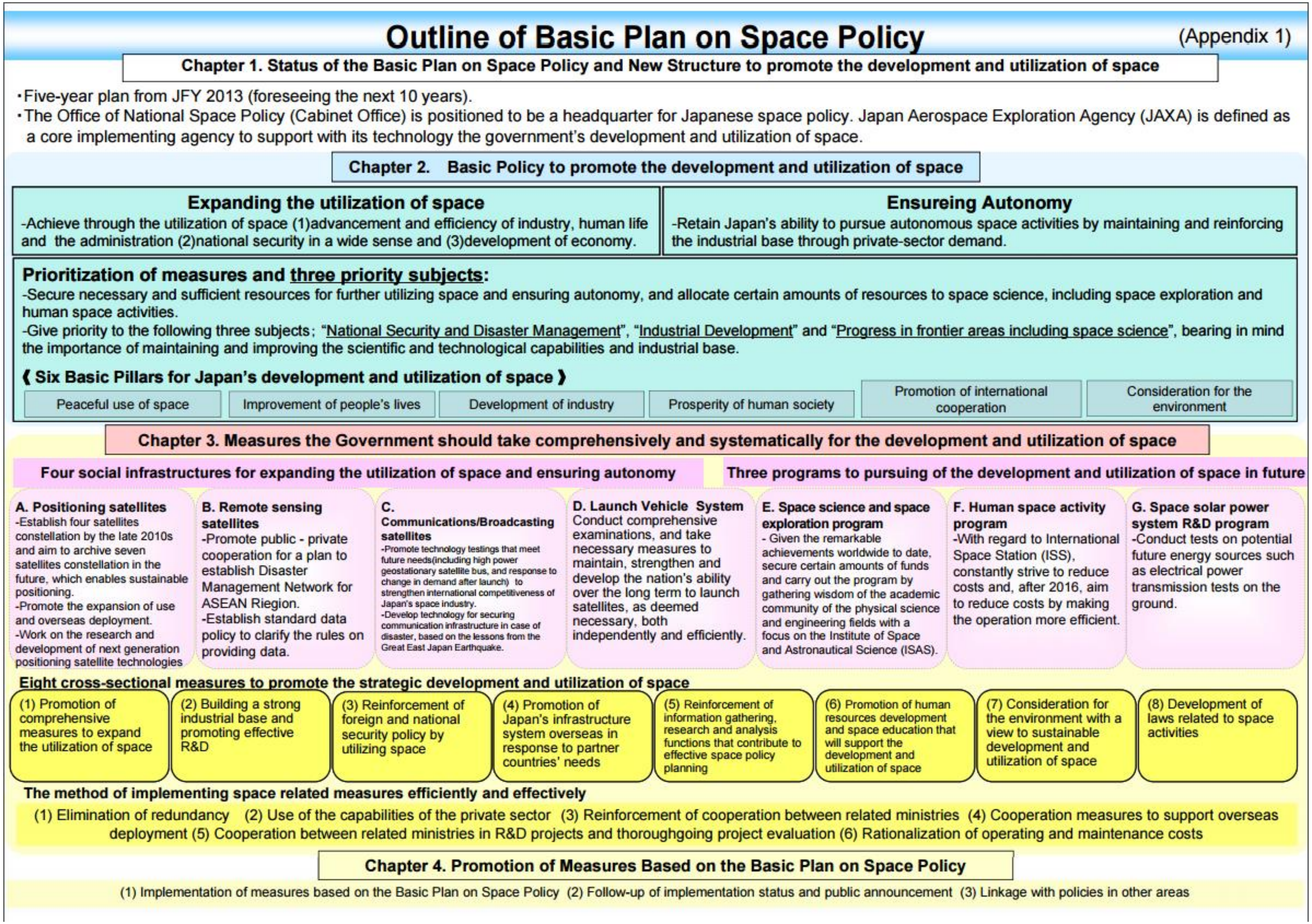


Figure 2-3 Overview of Japan's Basic Plan on Space Policy (Cabinet Office, 2009)

2.4 Government Budget

The total government budget in 2016 for the space-related activities across all the ministries was 342.1 bil JPY, which is an increase of 22.8 % to the 2015 budget (Cabinet Office, 2015). The budget for 2017 is currently under discussion and information is expected to be available during Sept to Oct 2016. Note that the supplementary budget is an additional budget that the government can request in case where the initial amount was deemed insufficient.

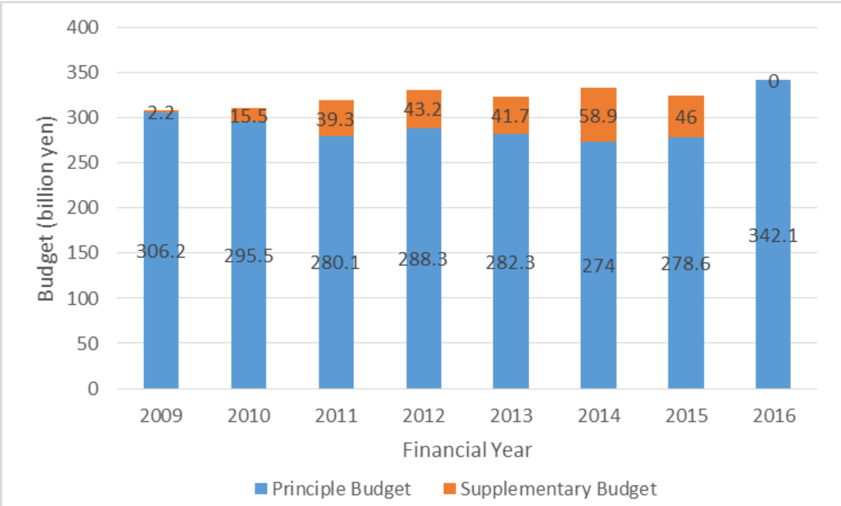


Figure 2-4 Change in Japan's space budget. Modified from (Cabinet Office, 2015)

Just over half (55.3%) of the 2016 budget was allocated to the Ministry of Education, Culture, Sports, Science and Technology, followed by the Cabinet Secretariat (20.5%) and the Ministry of Defense (10.7%).

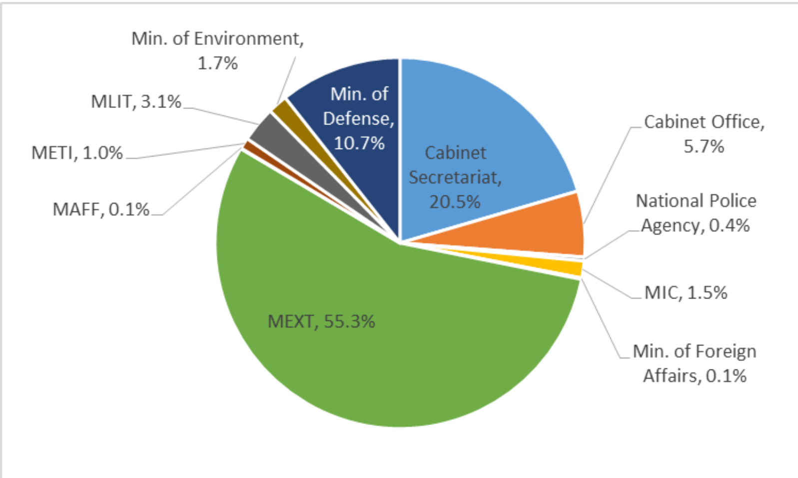


Figure 2-5 Budget allocation for the ministries of Japan for 2016. Modified from (Cabinet Office, 2015)

A detailed breakdown of the 2016 budget is presented in Table 2-2 (Cabinet Office, 2015).

Table 2-2 Key space projects of each government ministry of Japan (Cabinet Office, 2015)

Ministry/Agency	Project(s)	2016 Budget (bil JPY)
Cabinet Secretariat	Operation of Information-Gathering Satellites (IGS)	70.1
Cabinet Office	▪ Development, deployment and operation of Quasi-Zenith Satellite System (QZSS) ▪ Deployment and maintenance of the Central Mobile Network for Disaster Management ▪ Research on ways to expand the use of space ▪ Strategic Innovation Promotion Program (SIP)	19.6
National Police Agency	▪ Operation of high-resolution image analysis system ▪ Use of communication satellites	1.2
Min. of Internal Affairs & Communication (MIC)	▪ R&D for the future communication satellite technology for marine resource exploration ▪ R&D pertaining to space-based communication system technology	5.0
Min. of Foreign Affairs (MOFA)	▪ Support for the satellite imagery recognition and analysis system ▪ Costs pertaining to promoting *'Space diplomacy'*	0.4
Min. of Education, Culture, Sports, Science & Technology (MEXT)	▪ Advanced Radar Satellite ▪ Next-generation experimental satellites ▪ Small-scale, lunar-landing demonstrator ▪ New ISS transfer vehicle ▪ New launch vehicle development (H-3 rocket) ▪ Space Situational Awareness (SSA) System ▪ Revolutionary satellite technology demonstration program ▪ Satellite for Exploration of energization and Radiation in Geospace (ERG) ▪ Successor to the Greenhouse gas observation satellite (GOSAT-2) ▪ Climate change monitoring satellite (GCOM-C)	189.4
Min. of Agriculture, Forestry & Fisheries (MAFF)	▪ Revival progress of crops in disaster-impacted areas ▪ Operation of Vessel Monitoring System (VMS) for management and patrol of fishing activities	0.2
Min. of Economy, Trade & Industry (METI)	▪ R&D for the miniaturisation of ultra high-resolution SAR ▪ Further development of *Space Environment Reliability Verification Integrated System* (SERVIS)	3.3

	▪ R&D of hyperspectral sensor system ▪ R&D on improving the wireless transmission of power for Space-based solar system	
Min. of Land, Infrastructure, Transport & Tourism (MLIT)	▪ Development of navigation augmentation service using SBAS for aviation, based on QZSS ▪ Promotion of the G-spatial information system ▪ Activities for the geostationary meteorological satellite ▪ Utilisation of satellite for surveying purposes	10.6
Min. of Environment	▪ Preparatory activities for developing the successor of GOSAT ▪ Costs pertaining to Earth-observation using satellites	5.9
Min. of Defense	▪ Cost of using satellite communication and commercial satellite images ▪ Research pertaining to using space to strengthen the functionalities of C4ISR ▪ Activities pertaining to space monitoring	36.5

2.5 Key Space Projects

The Basic Plan of Space Policy defines several key projects vital for Japan's future space developments, and they are briefly described below (Komiya, 2015).

- **New Earth-observation Satellites** (MEXT, Min. of Environment)

Japan intends to bolster its Earth-observation capabilities with the establishment of the *Global Change Observation Mission*, or GCOM. The program aims to launch a series of successor satellites of the *Advanced Land Observing Satellite*, ALOS-1 & 2, and the *Greenhouse Gases Observing Satellite*, GOSAT. Details of the GCOM program will be discussed in Ch.3.

- **Advanced Small Satellite Development & Space Diplomacy** (METI, MOFA)

The main problems faced by the Japanese aerospace industry are 1) companies' heavy dependence on government contracts, and 2) insufficient demand from the private sector, leading to limited project experience, track record and reliability. To strengthen the industrial base and boost the competitiveness in the international market, Japan has decided to cultivate a new client base in the overseas market.

METI has been working with the *Japan Space Systems* (JSS) and NEC to develop an advanced small satellite bus for Earth-observation, called ASNARO (*Advanced Satellite with New system Architecture for*

Observation). The main features of the bus are its low cost and flexible, modularized design capable of installing different payloads depending on the mission objective. The first demonstration mission, ASNARO-1 was launched in 2014.

METI and NEC hope to boost Japan’s export in the space market and increase its presence by selling the small satellite as an affordable, fully-packaged solution for developing economies around the world. The package will not only include the satellite system, but also ground support infrastructure, training of staff, and loans from the Ministry of Foreign Affairs (MOFA) in the form of ODA. A Japanese delegation consisting of METI, MOFA, NEC and several ICT companies have already started approaching countries in South East Asia, Africa and the Middle East. NEC has recently won its first order from Vietnam to build 2 SAR satellites based on the ASNARO technology [VN Express, 2016].

- **Quasi-Zenith Satellite System** (Cabinet Office, MLIT) (Cabinet Office, 2016)

Japan is a heavy user of the GPS, and in order to establish its autonomy in space, the country has started developing its own GNSS infrastructure called the Quasi-Zenith Satellite System (QZSS). The QZSS is a satellite-based augmentation system for the GPS, and will consist of four satellites with inclined circular geostationary orbits. The constellation is designed such that there will always be a satellite visible almost directly above Japan to address the problems inherent in using GNSS in dense urban areas. Mitsubishi Electric has been contracted for the construction of the satellites and the first satellite *“Michibiki”* was launched in 2013. The remaining satellites are planned for launch before the end of 2017, and full operation by 2018.

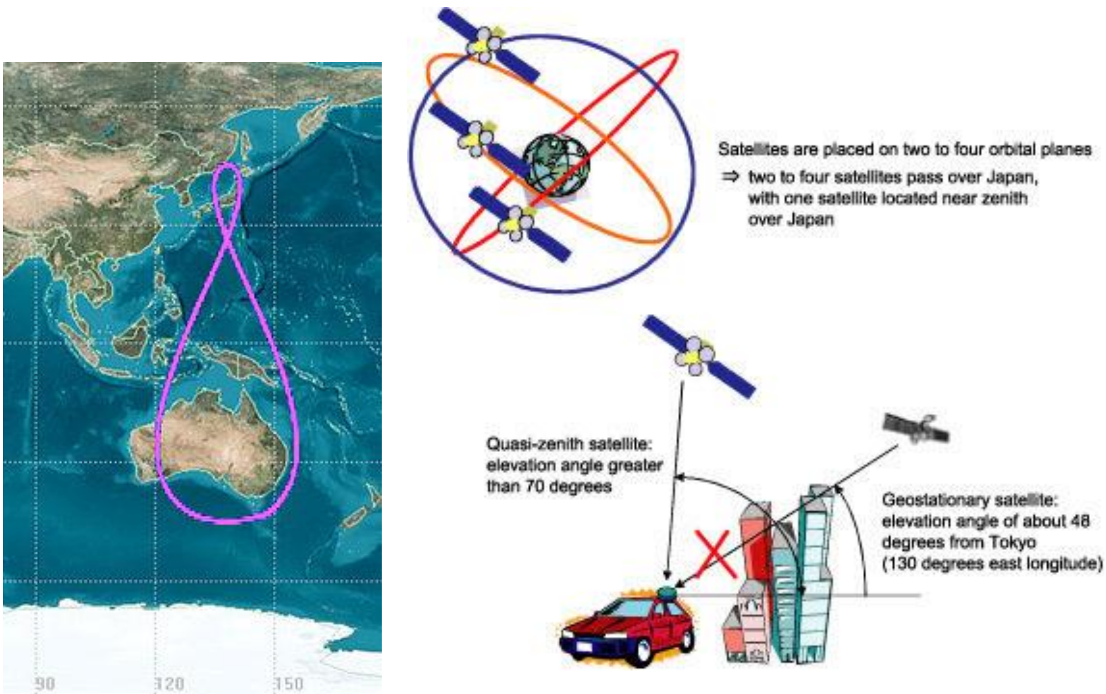


Figure 2-6 Ground track of QZSS (left) and the overall concept (right) (Cabinet Office, 2016)

- **G-Spatial Information System** (MIC, MLIT) (G-space, 2013)

The *G-Spatial Information System* is a next-generation information infrastructure led by the Cabinet Secretariat, MIC and MLIT. It aims to bring various geospatial information, positioning and Earth-observation data on to a single unified platform to promote new location-based products and services (LBS), and empower the private and public sector with new location and navigation information to realize the *"G-spatial society"*. QZSS will play an incremental role in this system, which will result in connecting various electronic devices and spreading geospatial information.

The system is still under development phase with numerous feasibility studies and demonstration projects conducted by companies and regional authorities throughout Japan. The most prominent figure leading these efforts is Prof. Ryosuke Shibazaki from the University of Tokyo, who is advising the Japanese government as a member of the G-Space Development and Promotion Committee. Under the leadership of Prof. Shibazaki, the University of Tokyo has formed a consortium with Keio University and the Tokyo University of Marine Technology & Science and have started a special inter-university program GESTISS (**GE**ospatial & **S**pace **T**echnology Consortium for **I**nnovative **S**ocial **S**ervices) to develop innovative systems to tackle global socioeconomic issues (GESTISS, 2016).

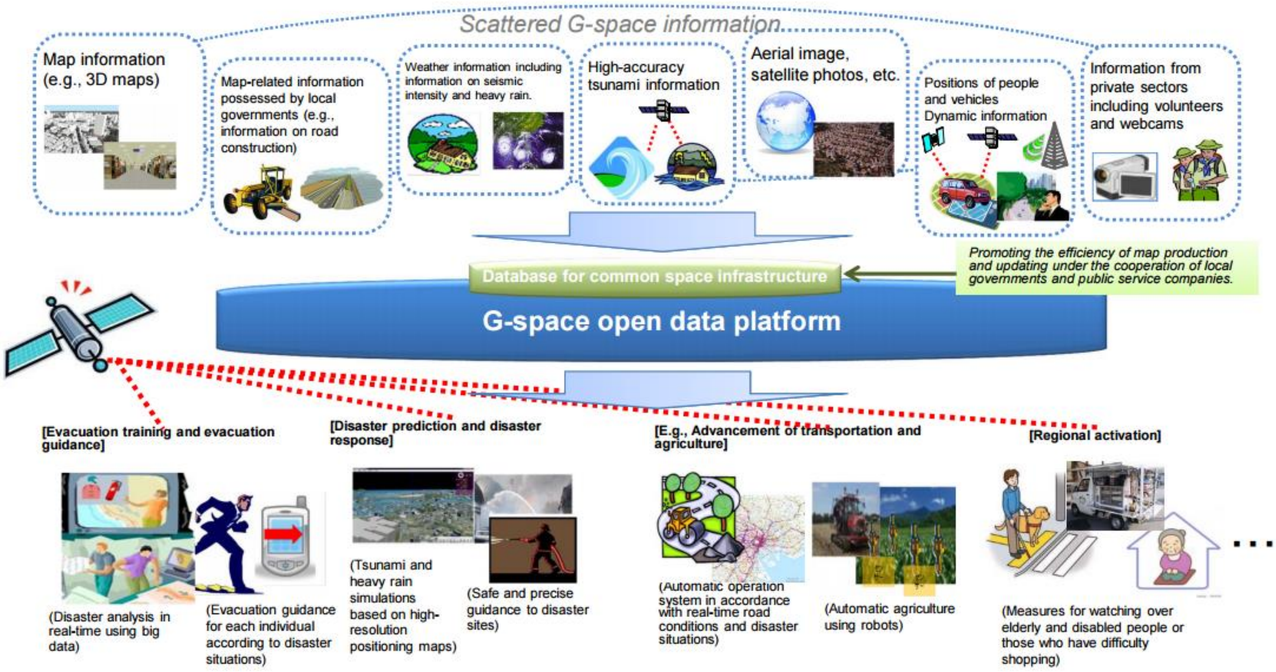


Figure 2-7 Overview of the G-Spatial Information System (G-space, 2013)

The University of Tokyo is in another consortium with Hitachi, a major IT and electronics company in Japan, and the National Institute of Information and Communications Technology (NICT), to jointly develop an interactive web platform to disseminate geospatial information to local communities (MIC, 2015). The platform is a map service with over 50 types of geospatial information, and demonstration experiments have already been conducted in several prefectures of Japan, including Akita, Shimane and Kochi (Teraoka, 2016). The Japanese government is determined to showcase these efforts during the Tokyo Olympics in 2020, and provide new, innovative services to tourists and spectators for the event (CAS, 2014).

- **Information Gathering Satellites** (The Cabinet, Min. of Defense) (Spaceflight101, 2016)

Information Gathering Satellites (IGS) form the Japanese spy satellite program, which was decided to be introduced in 1998 in response to North Korea's missile test in 1998. The main mission of the program is to provide early warning of impending hostile launches in Japan's neighbourhood and perform surveillance to collect information necessary for national security. The program currently consists of 7 operational satellites under direct control of the Cabinet, and the Basic Plan makes it clear that Japan will to continue to improve and reinforce its capabilities. The satellites are deployed in pairs, composed of an optical and a radar satellite, and are developed by Mitsubishi Electric Co., with inputs from the Secretariat of the Cabinet Office, MEXT, METI and MIC.

2.6 Recent Policy Developments

Article 35 of the Basic Space Law states *"The Government shall implement regulations pertaining to space activities and policies on utilisation and development of space, as well as develop legislation necessary to comply with relevant international agreements in an integrated, organised and timely manner"* (author's unofficial translation). In response to this, the current Japanese Cabinet has submitted two new bills to the parliament in March 2016 – 1) the Satellite Remote-Sensing Act, and 2) the Space Activities Act. The bills were scheduled to be discussed in the parliamentary session in June, but were postponed to August because the session ran out of time. The outcome is expected to be announced in the coming months and the bills to be enacted during 2017 – 2018 (JST, 2016).

2.6.1 Space Activities Act

The Space Activities Act is concerned with the launch and management of satellites, and it consists of 3 parts – 1) launch approval for satellites, 2) management approval for satellites, and most importantly, 3) third party liability in the case of a launch failure or a de-orbit of a satellite (Kataoka, 2010). One of the biggest obstacles in promoting commercial space activities is the launch liability issue, where the cost of a launch failure poses a great risk for any private entity to undertake. With the advent of new, commercial space enterprises such as SpaceX, the Japanese government hopes to alleviate the financial concerns and make it easier for companies to launch satellites and participate in various space activities.

2.6.2 Remote-Sensing Act

To foster the growth of the EO data industry in Japan, the Japanese government saw the need to follow the footsteps of Europe and the US to establish a clear legal framework on the sale and distribution of satellite images (Kozuka, 2016). The Satellite Remote-Sensing Act pertains to the commercial use of sub-meter satellite images, and the aim is to put regulations in place to prevent images being handed to countries or groups with malicious intent. The proposed act aims to clarify what satellite images are allowed for commercial use by having an approval process for the use of remote-sensing instruments and acquiring images. It also gives the government the right to restrict the distribution of the images to foreign entities.

2.7 Commercialisation & Promotion of Space

In line with the Basic Law on Space Policy on commercialisation of space, JAXA has launched numerous programs and initiatives in recent years to expand the Japanese space industry and promote greater use of space technologies. Currently, all of their programs are only open to Japanese companies and universities. Overseas entities are welcome to participate, but they must have a representative office in Japan.

2.7.1 Establishment of New Enterprise Promotion Department

Recently, JAXA established the New Enterprise Promotion Department with a specific focus on spin-off activities by promoting JAXA's technologies, patents and intellectual property for civilian use (JAXA, 2016c). The department has launched numerous initiatives to encourage involvement of SMEs to use JAXA's technologies for new product developments. Their activities are summarized in Figure 2-8.

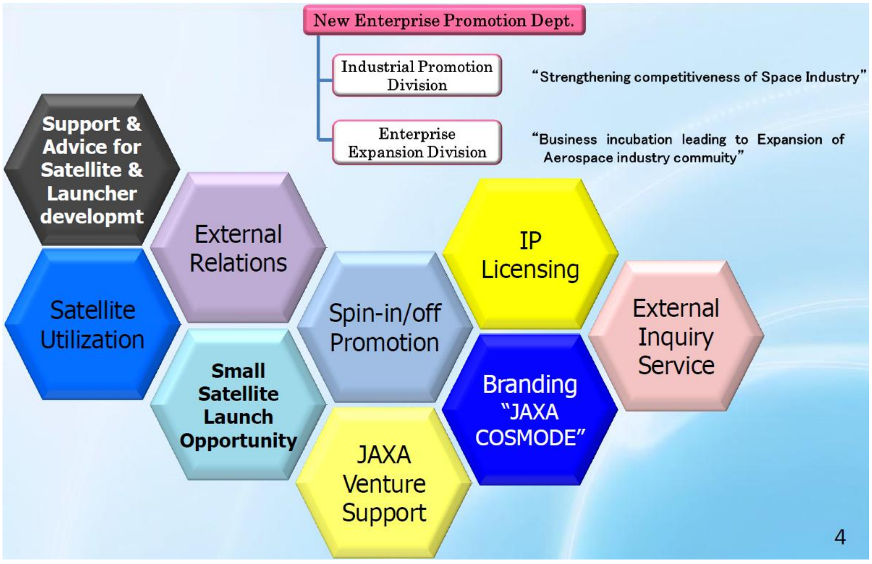


Figure 2-8 Overview of the activities by JAXA's New Enterprise Promotion Dept. (Kawai, 2015b)

- JAXA Open Lab Call for Proposals – A program for conducting joint R&D project between JAXA and private companies for developing new products using JAXA's technologies. Successful candidates are provided with up to 10 mil JPY annually over 3 – 5 years.
- Helpdesk for new business creation using JAXA's space technologies
- Database of JAXA's intellectual properties, research papers and satellite data
- Use of JAXA's testing facilities for private companies and universities
- Promotion of JAXA *Bizmode* logo on products using JAXA's technologies and patents

Spin-off Product	Company	Description
GAINA, thermal insulation paint	Nissin Sangyo Inc.	Special paint product based on the insulation material technology that is used for the fairings that protect a satellite during launch.
Application of UPS (Uninterruptible Power Supply) to AC output power storage devices	Japan Capacitor Industrial Co. Ltd.	JAXA's technology for highly efficient voltage balance control for extended-use capacitors.
MAXIFRESH PLUS	Goldwin Inc.	Space underwear deodorization, anti-bacterial properties, heat retention, antistatic properties, functional mobility and comfort using the highlJPYgineered material developed for the ISS and astronaut suit.

Table 2-3 Examples of spin-off products coordinated by JAXA's New Enterprise Promotion Dept. (JAXA, 2016c)

2.7.2 Development of New Business Solution using Satellite Data

Another important project launched by the New Enterprise Promotion Department is the business incubation for satellite application.

In 2014, the department issued a call for companies to take part in a collaborative R&D project with JAXA to develop new business solution using JAXA's satellite data. Similar to the Copernicus-related calls in the EU's *Horizon 2020*, the development period is 3 years, and the successful entities are expected to produce a marketable application, including a business model and expected users, to address one of the priority areas – resources & energy, disaster management, ocean, economy and education. Eight companies have been selected and they are expected to announce their product or service by 2017.

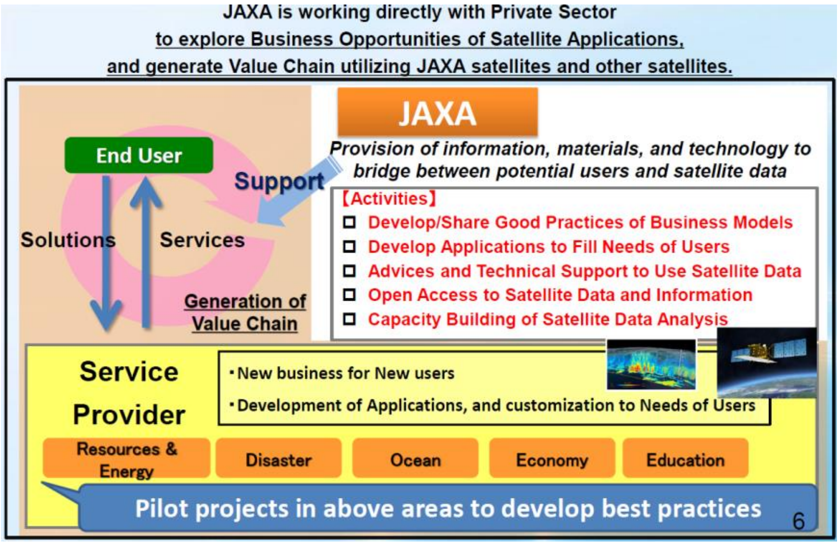


Figure 2-9 Overview of JAXA's business incubation program using satellite data (Kawai, 2015b)

2.7.3 Space Exploration Innovation Hub

The *Space Exploration Innovation Hub* coordinated by JAXA-ISAS is a separate initiative to the activities of the New Enterprise Promotion Department, and the aim is to encourage more collaborative projects via Public-Private Partnerships (PPP) for 1) technology development to support JAXA's future space exploration, and 2) technology development to benefit the industries (JAXA, 2016b).

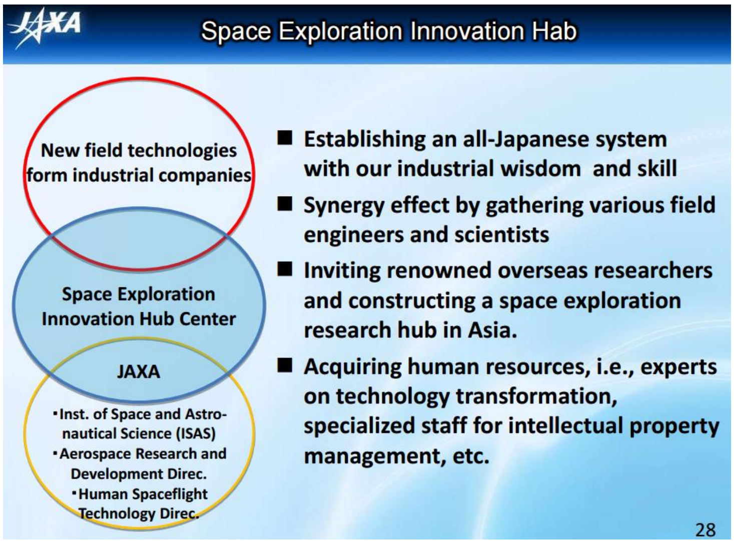


Figure 2-10 Overview of the Space Exploration Innovation Hub coordinated by JAXA-ISAS (Kawai, 2015b)

The program publishes a list of key research areas needed to further JAXA's space exploration efforts, and invites companies to participate on the collaborative project with JAXA. The idea is to establish a *win-win* scenario for both parties, where JAXA benefits from delegating key technology development activities, and companies and institutions benefit from using JAXA's expertise, intellectual property, and facilities to develop new products for terrestrial use as a *spin-off*.

3 Japanese Earth-Observation Industry

3.1 Japan's Earth-Observation Program

The overview of Japan's Earth-observation satellites, and the development plan defined by the Basic Plan of Space Policy are shown in Figure 3-1 and Figure 3-2.

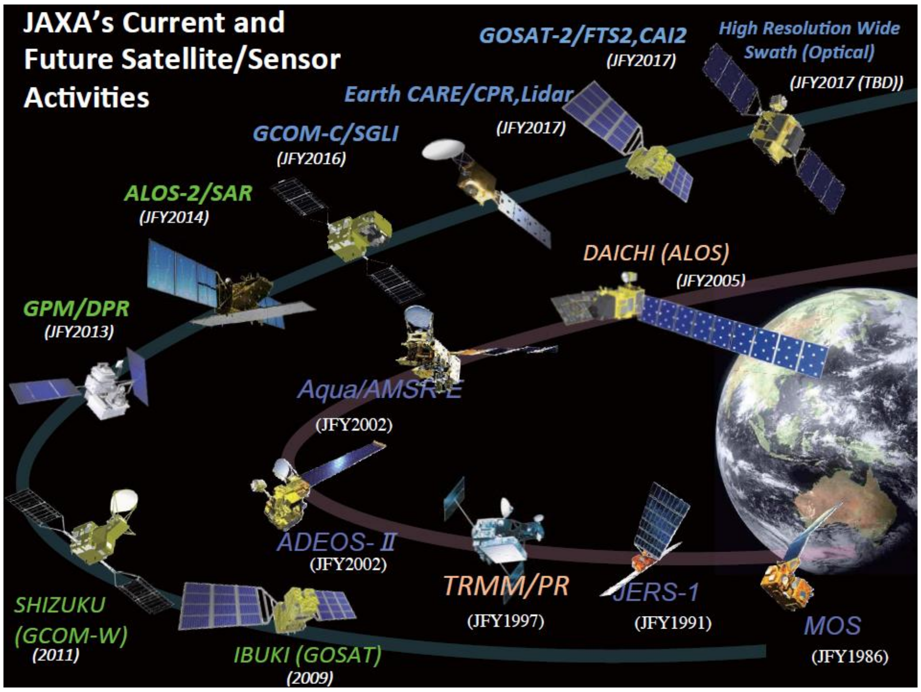


Figure 3-2 Overview of JAXA's current and future satellites (Kachi, JAXA Agency

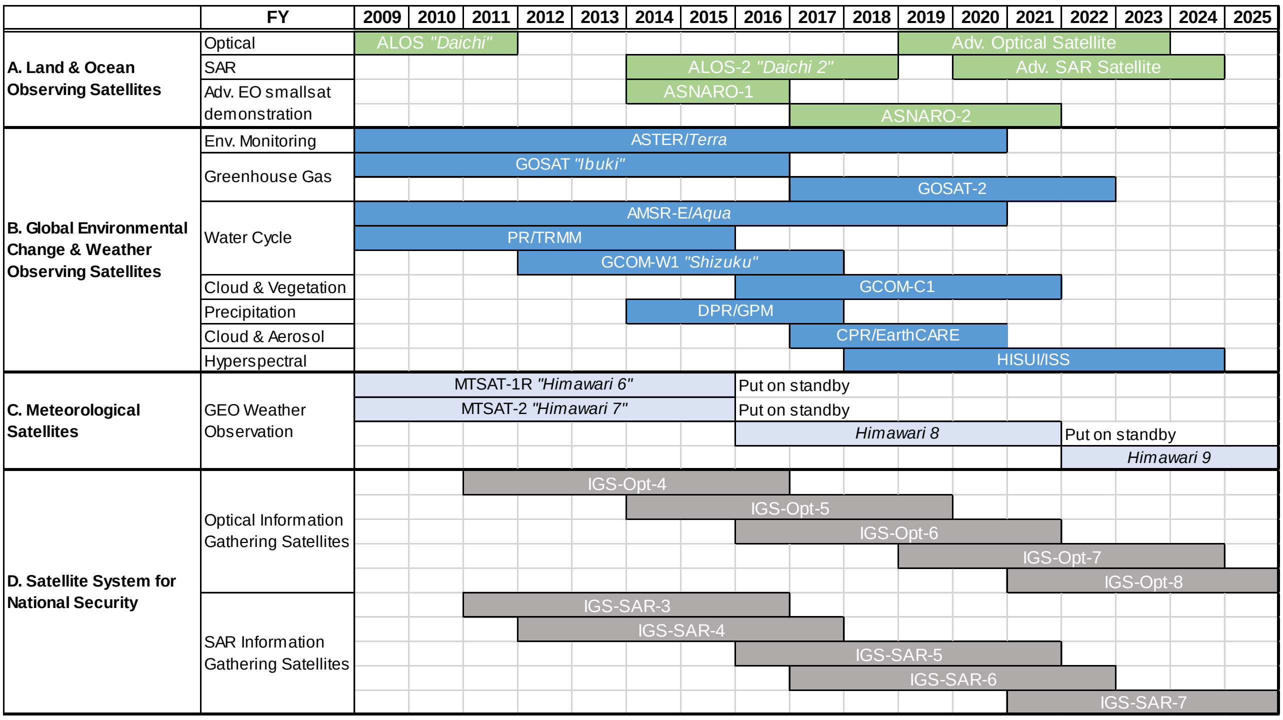


Figure 3-1 Development timeline of JAXA's EO satellites (modified from (Cabinet Office, 2009))

Japan's dedicated Earth-observation program is the *Global Change Observation Mission* (GCOM), which is coordinated and operated by JAXA, and the *Global Precipitation Monitoring* (GPM) in cooperation with NASA (Kachi, 2011). The main objectives of these programs are to provide long-term monitoring of the change in the Earth's environment by measuring parameters pertaining to the water cycle and the atmosphere, and utilise them to resolve global issues such as climate change and food and water security.

The two programs are Japan's contribution to the *Global Earth Observation System of Systems* (GEOSS) (Wikipedia, 2016d), which was decided by the participating countries and organisations of the *Group of Earth Observations* (GEO) during the 3rd GEO Summit in 2003 (JAXA, 2016). Japan's contributions to the program are disaster management, water cycle and climate monitoring (MEXT, 2011).

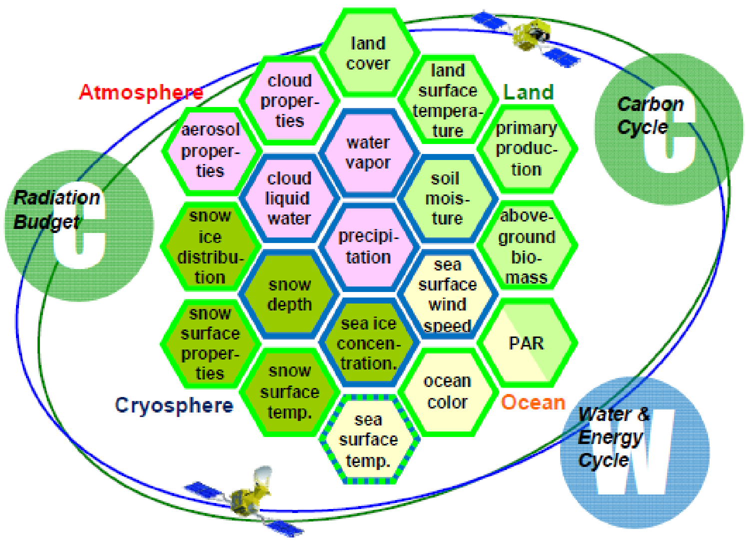


Figure 3-3 GCOM geophysical parameters in four categories (atmosphere, land, ocean and cryosphese), which can be observed by GCOM-W (blue border) and GCOM-C (green border) (Kachi, 2011)

GCOM consists of two medium-sized satellites, GCOM-W (water) and GCOM-C (climate). The initial plan was to have three generations of satellites with one year overlap to ensure 10-15 years stable data records to achieve global, comprehensive, and long-term Earth monitoring (Kachi, 2011). However, the program is currently under heavy debate and the fate of the satellites beyond the current generation remains uncertain.

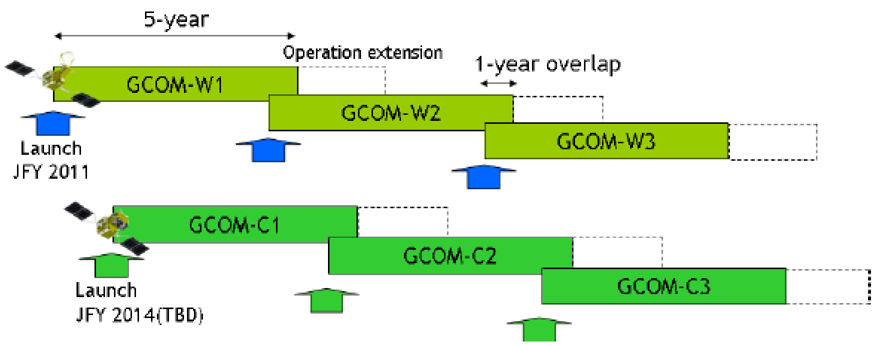


Figure 3-4 GCOM mission concept consisting of 2 satellite series (Kachi, 2011)

3.1.1 Main Issues

In response to the development plan announced by the Japanese government, the industry and academia have raised concerns on two critical weaknesses in the current Earth-observation capabilities of Japan.

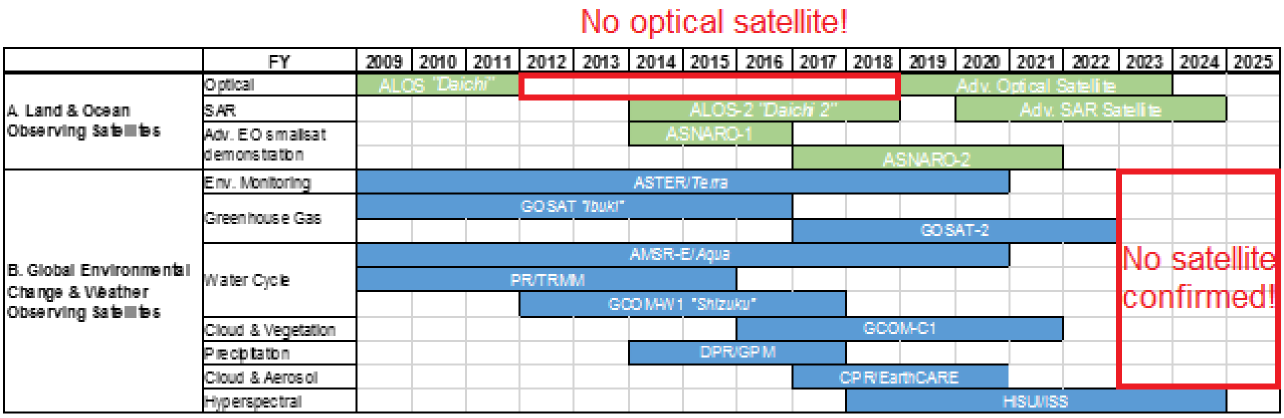


Figure 3-5 Two main issues with the Japanese Earth-observation program

Firstly, Japan currently doesn't have its own optical satellite after the retirement of Japan's highly successful Earth-observation satellite, ALOS in 2011. Therefore, until the launch of the Advanced Optical Satellite expected in 2019, the Earth-observation communities in Japan, particularly companies, will be heavily dependent on purchasing commercial optical data from overseas such as *Blackbridge RapidEye* and *SPOT Image*. Although most of the Japanese companies pertaining to EO products and services have formed exclusive distributorship agreements with commercial EO satellite operators overseas, the cost of these commercial data have contributed to preventing the growth of EO applications among private sectors in Japan.

Another issue raised by the academic community in Japan is the lack of certainty of the GCOM program, which, currently, is guaranteed only up to 2021 with the launch of GCOM-W1 and GCOM-C1. The idea is to launch follow-up missions as GCOM-W2 and C2, however, neither the Japanese government nor JAXA has made clear their long-term intentions and the future of the program is largely unclear beyond 2021 (Cabinet Office, 2012). Considering that the typical development time of a satellite mission is about 5 years, researchers are urging JAXA and the Japanese government to define long-term prospects in order to ensure data availability and continuity (Cabinet Office, 2012). Furthermore, the fact that GCOM-W1 and C1 have recently been renamed as simply GCOM-W and GCOM-C with the numbering omitted, imply that the GCOM program may not continue beyond its first generation of satellites, and it is highly likely that the Japanese space community is going to face a significant gap in their Earth-observation capability after 2021.

3.1.2 Current Missions

As of 2016, Japan operates 4 EO satellites plus 3 observation instruments on-board NASA's satellites. Their names and launch years are summarised below.

2002	AMSR-E on-board NASA's *Aqua* satellite
2002	ASTER on-board NASA's *Terra* satellite
2009	GOSAT *"Ibuki"*
2012	GCOM-W *"Shizuku"*
2014	DPR on-board NASA's GPM satellite
2014	ALOS-2 *"Daichi-2"*
2014	ASNARO-1

All of the satellites have been designed by JAXA and the Ministry of Education, Culture, Sports, Science and Technology (MEXT) with some input from the Ministry of Environment, except for ASTER and ASNARO-1, which were designed by Japan Space Systems (JSS) under the management of the Ministry of Economy, Trade and Industry (METI). A brief description of each satellite/instrument is presented in Table 3-1.

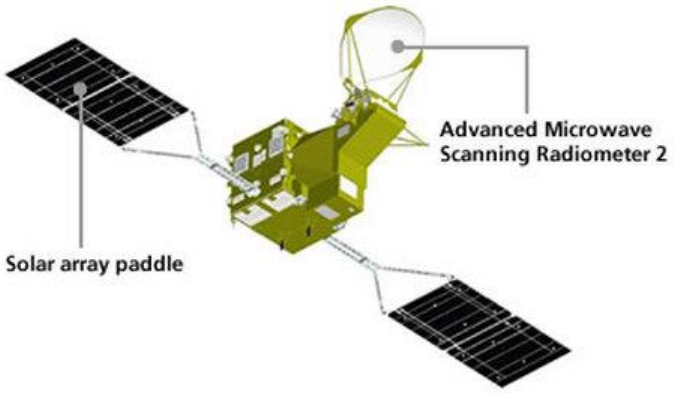


Figure 3-6 Overview of JAXA's GCOM-W (JAXA, 2016d)

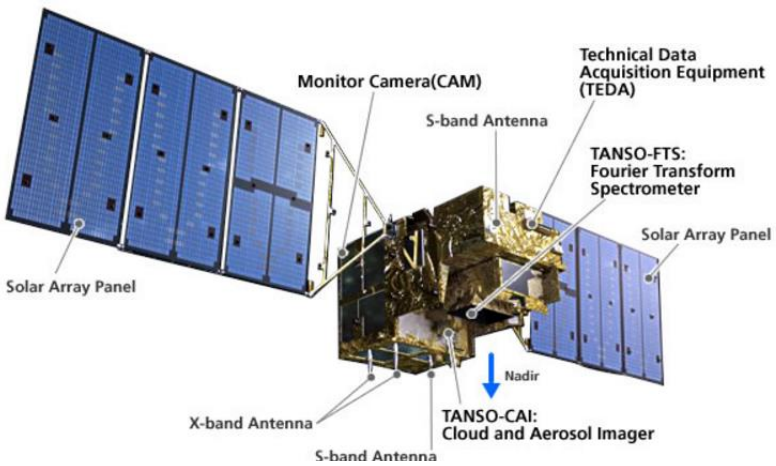


Figure 3-7 Overview of JAXA's GOSAT (JAXA, 2016d)

Table 3-1 Summary of Japan's current EO satellites

Name	Objective(s)	Sensor(s) & Main Features
AMSR-E (**A**dvanced **M**icrowave **S**canning **R**adiometer for **E**OS)	To study the precipitation, evaporation and water cycle as part of NASA's Aqua mission. (JAXA, 2016e)	AMSR-E is a microwave radiometer and a successor of AMSR that was on-board ADEOS-II. It measures cloud properties, soil moisture, sea surface temperature, near-surface wind speed, radiative energy flux, surface water, ice and snow (JAXA, 2016f). • Frequency bands of 6.925, 10.65, 18.7, 23.8, 36.5 and 89.0 GHz • Spatial resolution of 6 x 4 km (89.0 GHz) to 75 x 43 km (6.925 GHz)
ASTER (**A**dvanced **S**paceborne **T**hermal **E**mission & **R**eflection Radiometer)	To monitor the state of Earth's environment and ongoing changes in its climate system as part of NASA's *Terra* mission (JPL, 2016).	ASTER is a multispectral radiometer suite in visible to infrared spectrum, and it consists of 3 radiometers (JPL, 2016): • VNIR (Visible & Near-IR Radiometer) – 3 bandwidths with 15 m resolution • SWIR (Short Wave IR Radiometer) – 6 bandwidths with 30 m resolution • TIR (Thermal IR Radiometer) – 5 bandwidths with 90 m resolution
GOSAT (Greenhouse gases **O**bserving **SAT**ellite**)** ***"Ibuki"***	To monitor greenhouse gases globally, particularly to measure the atmospheric densities of carbon dioxide and methane.	2 Spectrometers in near-infrared to thermal infrared spectrum to measure different compounds in high resolution (JAXA, 2016d): • TANSO-FTS – a greenhouse gas sensor, with a spectral resolution of 0.27 – 0.5 cm^{-1} • TANSO-CAI – a cloud and aerosol sensor, with a spatial resolution of 500 m
GCOM-W "Shizuku"	Observe the water cycle by measuring precipitation, water vapour, wind velocity above the ocean, sea water temperature, water levels on land areas, soil moisture, sea ice and snow depths.	AMSR2 – a microwave radiometer, which is a successor to the AMSR-E carried by NASA's Aqua satellite (JAXA, 2016d): • 6 frequency bands 7 – 89 GHz • Cover 99% of the Earth in 2 days

Name	Objective(s)	Sensor(s) & Main Features
DPR (**D**ual-Frequency **P**recipitation **R**adar)	To make frequent (every 2-3 hrs), global observation of the Earth's precipitation as a part of NASA-JAXA joint mission, the Global Precipitation Measurement (GPM).	The DPR is radar on-board NASA's GPM core observatory satellite (JAXA, 2016d) • Provides 3D maps of storm structure across its swath, including the intensity of rainfall and snowfall at the surface • 2 frequencies to estimate the size of precipitation particles and detect a wide range of precipitation rates (Ku-band with 245 km swath, Ka-band with 120 km swath)
ALOS-2 (**A**dvanced **L**and **O**bserving **S**atellite 2) ***"Daichi-2"***	SAR EO mission for mapping, land monitoring, disaster management and natural resource surveying. A successor of the ALOS mission.	PALSAR-2 – A phased-array L-band SAR with the following operational modes (JAXA, 2016d): • Spotlight mode – 1 m spatial resolution • High-res mode – spatial resolutions of 3, 6 & 10 m, with swath width of 50, 50 & 70 km • Wide area mode – 100 m spatial resolution, 350 km swath width ALOS-2 also has an IR camera, CIRC, and an AIS receiver SPAISE2 for future applications pertaining to maritime domain awareness and governance
ASNARO-1	To develop and operate a next-generation high-performance small satellite bus system (< 500 kg) capable of high-res EO mission while drastically reducing the cost and the development period.	The fundamental concept of the ASNARO bus is to have a flexible payload arrangement, where the bus can be equipped with different sensors (optical, SAR etc) according to the mission without effecting the rest of the bus design (eoPortal, 2016). ASNARO-1 is equipped with a VNIR (visible near-IR) optical sensor using a Three Mirror Anastigat (TMA) telescope: • 1 panchromatic band and 6 multispectral bands with 0.5 and 2 m spatial resolutions respectively, swath width of 10 km ASNARO-2 will be same design but equipped with an X-band SAR, and will be launched in 2017.

3.1.3 Future Missions

JAXA plans to launch four satellites under the management of MEXT before 2020, with one sensor to be installed on ESA's *EarthCare* satellite. The hyperspectral imager, HISUI, is being developed by JSS and NEC under the administration of METI.

2017 GCOM-C
2017 GOSAT-2
2017 CPR – *Cloud Profiling Radar* to be on-board ESA's *EarthCARE* satellite
2018 HISUI – A hyperspectral imager to be on-board the International Space Station
2019 Advanced Optical Satellite
2020 Advanced Radar Satellite

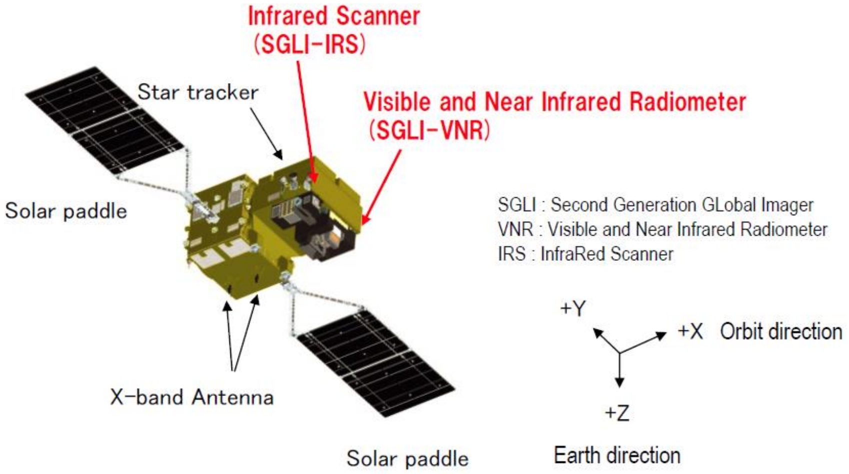


Figure 3-8 Overview of JAXA's GCOM-C [JAXA, 2016d]

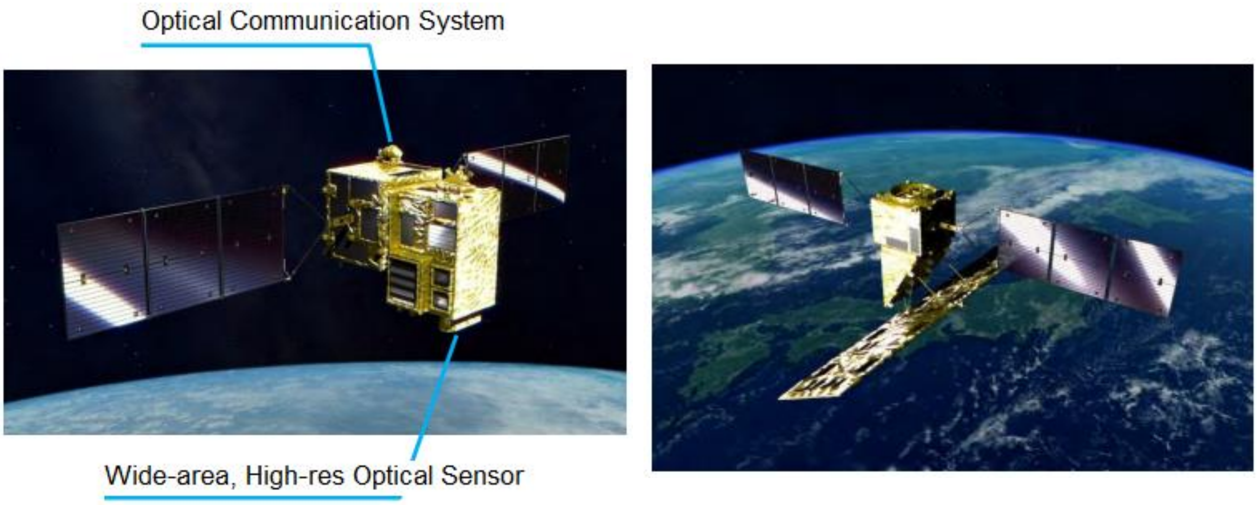


Figure 3-9 Conceptual drawings of the Adv. Optical Satellite (left) and the Adv. SAR Satellite (right) (Yamamoto, 2016)

Table 3-2 Summary of Japan's future EO missions

Name	Objective(s)	Sensor(s) & Main Features
GCOM-C	To monitor global climate change by observing the surface and atmosphere and collect data related to the carbon cycle and radiation budget.	SGLI – a multi-channel optical sensor consisting of SGLI-VNR for near-UV, and SGLI-IRS for thermal infrared wavelengths to monitor different physical phenomena (JAXA, 2016d): • SGLI-VNR – 11 channels, 250 m resolution • SGLI-IRS – 6 channels, 250 – 1 km resolution
GOSAT-2 *"Ibuki-2"*	A successor mission of GOSAT to monitor greenhouse gases, with new additional capability to observe black carbon and PM2.5 particles.	GOSAT-2 is expected to be very similar to GOSAT, with the same 2 spectrometers in near-infrared to thermal infrared spectrum, but with superior spatial and spectral resolution (JAXA, 2016d): • TANSO-FTS-2 – a greenhouse gas sensor • TANSO-CAI-2 – a cloud and aerosol sensor The improved sensors can now monitor CO2 at 0.5 ppm accuracy, and methane at 5 ppb accuracy per 500 km2 area.
CPR (**C**loud **P**rofiling **R**adar)	To conduct global monitoring of cloud and aerosols to improve the accuracy of climate forecasting as part of the ESA/JAXA joint mission, EarthCARE.	CPR is a Doppler radar with 36 dBZ sensitivity and a 500 m vertical resolution (JAXA, 2016d).
HISUI (**H**yperspectral **I**maging **SUI**te)	To provide the world's first operational hyperspectral imaging, and contribute to enabling superior monitoring for oil and mineral exploration as well as environmental monitoring as a successor to ASTER.	HISUI is a suite composed of 2 sensors (JSS, 2016): • Hyperspectral sensor – visible to short IR region in 180 bandwidths, with 10 nm spectral resolution, 30 m spatial resolution, and 30 km swath width • Multispectral sensor – visible to near IR region in 4 bandwidths, 5 m spatial resolution, 90 km swath width

Name	Objective(s)	Sensor(s) & Main Features
Advanced Optical Satellite	To provide high-resolution (< 1m) optical images with wide swath width to greatly increase Japan's EO capability in national security, disaster management, cartography and geospatial information.	The Adv. Optical Satellite will contain 2 sensor systems – a wide area/high-res optical sensor, and a dual wavelengths IR sensor to offer the following capabilities (Yamamoto, 2016): • Spatial resolution of 0.8 m for panchromatic, and 3.2 m for multispectral sensor, 70 km swath width
Advanced Radar Satellite	To high-resolution and highly responsive SAR images to assist with disaster management activities.	An improved version of PALSAR from ALOS-2 will be on-board with the following operational modes (Yamamoto, 2016): • Spot light mode: 1 – 3 m resolution, 25 km swath width • High resolution mode: 3 – 10 m resolution, 100 – 200 km swath width • Wide area mode: 10 – 25 m resolution, swath width of 700 km,

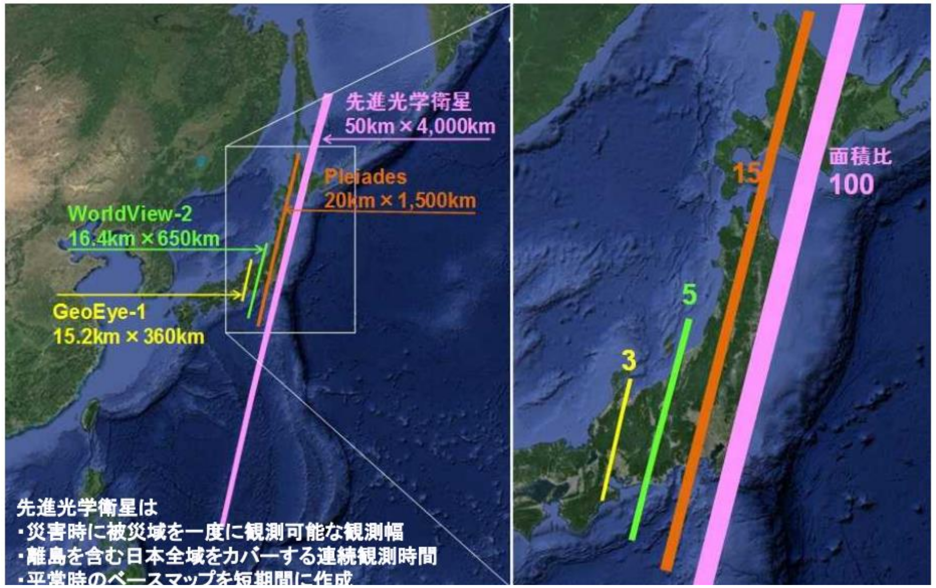


Figure 3-10 Comparison of swath width of different high-res EO satellites where the pink-coloured band represents the swath of the Adv. Optical Satellite (Yamamoto, 2016)

3.1.4 Past Missions

Japan's Earth-observation mission goes back to late 1980s with the launch of their first EO satellite, MOS-1 in 1987. Most of the satellites were developed by NASDA, before the formation of JAXA.

1987 – 1995	MOS-1 *"Momo-1"*
1992 – 1998	JERS-1 *"Fuyou"*
1996 – 1997	ADEOS *"Midori"*
1997 – 2015	PR – Precipitation Radar on-board NASA's TRMM satellite
2002 – 2003	ADEOS-II *"Midori-II"*
2006 – 2011	ALOS *"Daichi"*

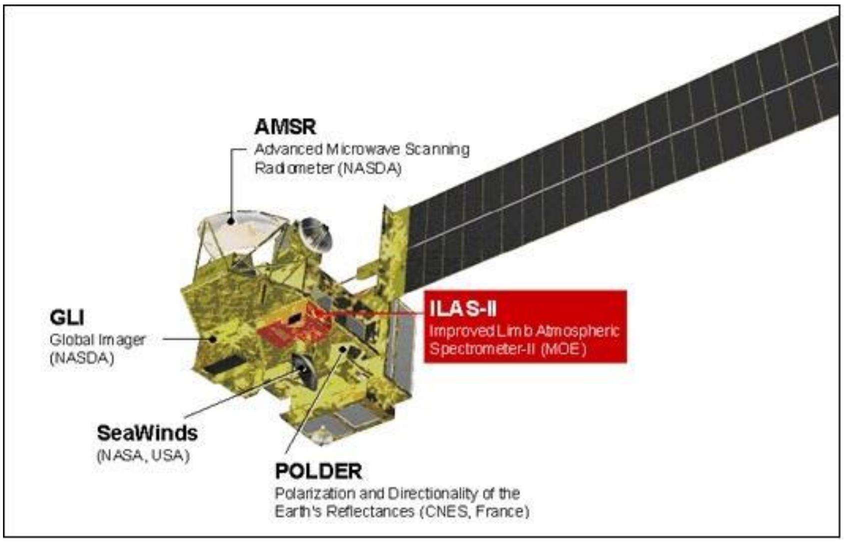


Figure 3-11 Overview of JAXA's ADEOS-II (eoPortal, 2016)

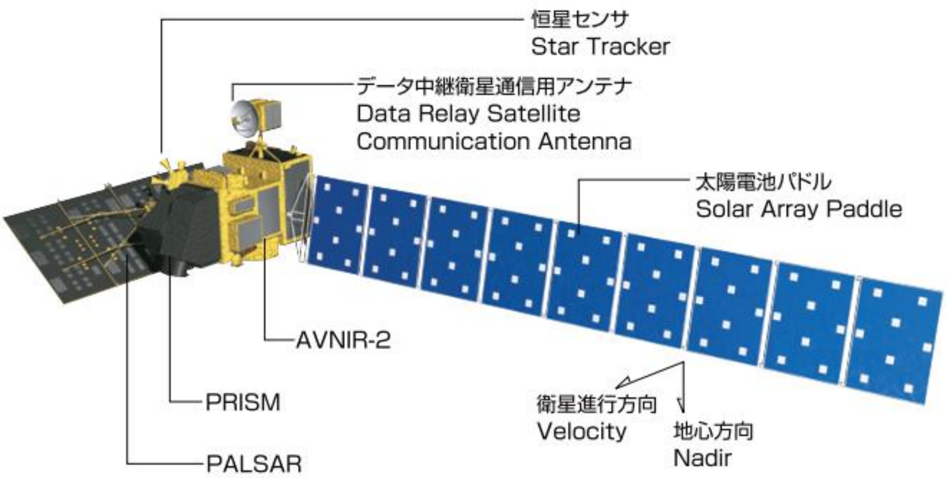


Figure 3-12 Overview of JAXA's ALOS (JAXA, 2016d)

Table 3-3 Summary of Japan's past EO missions

Name	Objective(s)	Sensor(s) & Main Features
MOS-1 (**M**arine **O**bservation **S**atellite-1) **"Momo-1"**	To provide ocean and land monitoring for contribute to agriculture, effective utilisation of Earth's resources and environmental protection.	MOS-1 was Japan's first Earth-observation satellite, and it contained 3 instruments (JAXA, 2016d): • MESSR (Multi-Spectral Electronic Self-Scanning Radiometer) – 2 visible and 2 IR bands with 50 m resolution and 100 km swath width • VTIR (Visible & Thermal IR Radiometer) – 1 visible and 3 IR bands, 1500 km swath width • MSR (Micro Scanning Radiometer) – measure microwave emission in the 23 GHz and 31 GHz bands.
JERS-1 (**J**apanese **E**arth **R**esources **S**atellite-1) ***"Fuyou-1"***	To conduct land observation to contribute to natural resources exploration, land management, agriculture, forestry and fisherJPYvironmental protection and disaster management.	JERS-1 contained 3 instruments (JAXA, 2016d): • L-band SAR with 18 m resolution, 75 km swath width • OPS – Visible and IR band optical sensor with 8 spectral bands to identify mineral deposits with 18 x 24 m resolution and 75 km swath width

Name	Objective(s)	Sensor(s) & Main Features
ADEOS (**AD**vanced **E**arth **O**bserving **S**atellite) ***"Midori"***	To observe Earth's environmental changes, focusing on global warming, depletion of the ozone layer, and deforestation.	The satellite contained 8 instruments developed by NASDA, NASA and CNES (JAXA, 2016d): • OCTS (Ocean Colour & Temperature Scanner) – 12 spectral bands to measure sea surface temperature and colour, chlorophyll concentration, water quality, atmospheric aerosol and cloud cover • AVNIR (Adv. Visible & Near IR Radiometer) – 4 multi-spectral and 1 panchromatic band with 16 and 8 m resolution respectively, to monitor chlorophyll concentration and vegetation growth • ILAS (Improved Limb Atmospheric Spectrometer) – 2 x 13 km resolution to measure aerosol and atmospheric trace gases • IMG (Interferometric Monitor for Greenhouse Gases) – 8 x 8 km swath width to measure greenhouse gases • RIS (Retroreflector in Space) – To measure atmospheric trace gases • NSCAT (NASA Scatterometer) – To measure sea surface wind direction and velocity with 25 and 50 km resolutions • TOMS (Total Ozone Mapping Spectrometer) – To measure ozone amount and the distribution of sulphur dioxide • POLDER (Polarization and Directionality of the Earth's Reflectances) – A passive optical radiometer and a polarimeter to observe solar radiation reflected by Earth's atmosphere
PR (**P**recipitation **R**adar)	To monitor and study tropical rainfall as part of a joint space mission between NASDA and NASA.	The PR instrument was on-board NASA's TRMM satellite to provide 3D maps of storm structure and rainfall distribution over land and ocean surfaces. It operated at 13.8 GHz with 4.3 km resolution and 220 km swath width (JAXA, 2016d).

Name	Objective(s)	Sensor(s) & Main Features
ADEOS-II *"Midori-2"*	To contribute to analysing global climate change, damage of the ozone layer and reduction of rainforests by monitoring the water and energy cycle system, and estimate the biomass and its fundamental productivity as a part of the carbon cycle.	The mission was a successor to ADEOS, and it contained instruments developed by JAXA, NASA and CNES (JAXA, 2016d): • AMSR (Advanced Microwave Scanning Radiometer) – 8 frequency bands from 6.9 to 52.8 GHz, 5 – 50 km resolution • GLI (Global Imager) – 36 spectral bands from 0.375 – 12.5 mm • ILAS-II (Improved Limb Atmospheric Spectrometer-II) – 4 spectral channels with 1 km resolution • SeaWinds – A successor of NASA's NSCAT on-board ADEOS that measured sea surface wind velocity and direction • POLDER – An optical radiometer developed by CNES
ALOS (**A**dvanced **L**and **O**bservation **S**atellite) ***"Daichi"***	To collect data to support cartography, disaster monitoring, land observation and natural resource exploration.	ALOS was a highly successful EO mission where it effectively captured scenes of several natural disasters, and the SAR data was actively used to monitor illegal logging in Brazil (JAXA, 2016d): • PRISM – A panchromatic sensor responsible for obtaining 3D land surface data by observing with 2.5 m resolution with 70 km swath width • AVNIR-2 – A visible & near IR multi-spectral radiometer, which was a successor to AVNIR on-board ADEOS. It had 4 channels with 10 m resolution and 70 km swath width • PALSAR – A phased-array L-band SAR with 3 modes operation with varying resolution and swath width. In high-res mode, it was capable of observing in 10 m resolution.

3.2 Value-Chain Analysis

JAXA has identified 60 companies and special corporations related to EO data products and services, split into different activities. The value-chain of the Japanese EO applications industry is presented in Figure 3-13.

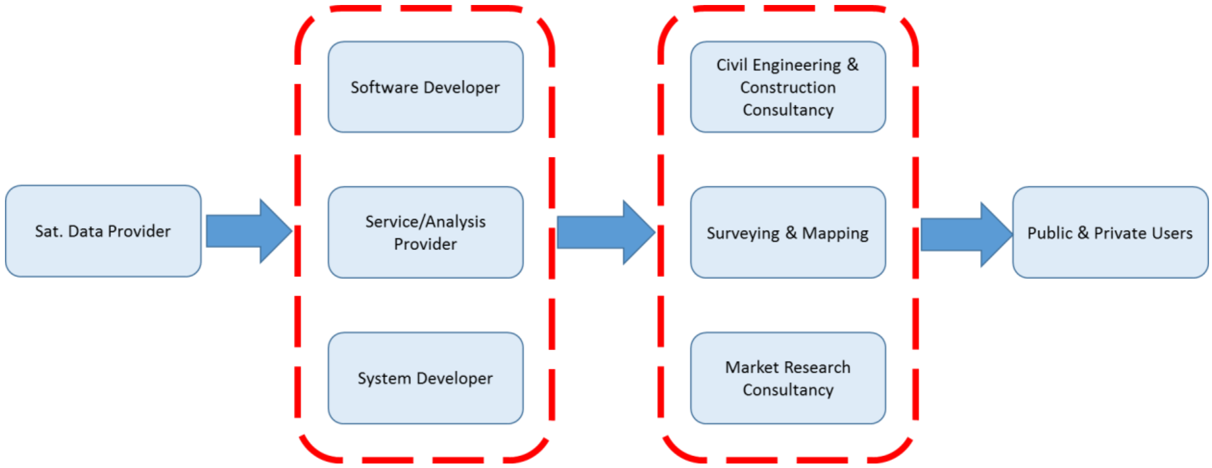


Figure 3-13 Value-chain for the EO applications industry of Japan

The Japanese companies don't undertake only one of the activities, but they typically handle multiple parts of the above value-chain. Figure 3-14 and Figure 3-15 show a capability matrix of each company's competence and main disciplinary areas.

Competence Areas

- **Data Provision** – re-selling or licensed distribution of satellite data
- **Software Provision** – provides in-house or distribution of existing software/application
- **Service Provision** – provides a service developed in-house, value-added, downstream applications
- **System Development** – provides a fully-developed system solution
- **Consultancy** – provides consultancy pertaining to construction projects using satellite imagery, and/or general business consultancy on the usage of EO data
- **Surveying & Mapping** – conducts surveying and mapping using satellite imagery

Disciplinary Areas

- **Agriculture –** services/products related to agriculture and farming
- **Forestry –** services/products related to forestry monitoring and management
- **Fishery** – services/products related to fishery

- **Oceanography & Marine Mgt.** – services/products related to ocean forecasting, ship routing, Automated Identification System (AIS), port management
- **Urban Infrastructure –** monitoring and analysis of buildings and public infrastructures using SAR interferometry and other techniques
- **Land Mgt. & Town Planning –** services such as analysis of land usage, urban development
- **GIS & LBS** – services/products related to GIS and Location-Based Services (LBS)
- **Disaster Mgt. –** Services/products related to disaster response and management, hazard maps and disaster impact maps
- **Environmental Monitoring –** Services related monitoring and analysis of environmental conditions such as water and soil quality
- **Mineral Exploration, Oil & Gas -** Services to identify deposits of minerals, oil and gas

The prominent companies in the Japanese EO data supply chain are 1) mapping and surveying companies that have shifted from conventional ground-based and aerial surveying to utilising satellite imaging to offer various consulting services, and 2) ICT companies that develop software services using satellite images.

Mapping & Surveying Companies

- Aero Asahi Corporation
- Air Asia Survey
- Kokusai Kogyo
- Naka-Nihon Air Survey
- PASCO

ICT Companies

- Fujitsu
- Hitachi Solutions
- NTT Data
- NEC
- Mitsubishi Space Software

Special Governmental Corporations

- Remote Sensing Technology Centre of Japan (RESTEC)
- Space Engineering Development

	Data Provision	SW Provision	Service Provision	System Development	Consultancy for Construction & Civil Projects	Surveying & Mapping	Market Research & Consultancy
Advanced Intelligence Research Laboratory		✓	✓	✓		✓	
Aero Asahi Cooperation	✓	✓	✓	✓	✓	✓	✓
Alpha Hydraulic Engineering Consultants Co. Ltd.	✓		✓	✓	✓	✓	✓
Asia Air Survey Co. Ltd.	✓	✓	✓	✓	✓	✓	✓
Bits Co. Ltd.		✓					
Buyodo Co. Ltd.	✓					✓	
CBMI Co. Ltd.	✓		✓	✓			✓
CBS Co. Ltd.	✓		✓			✓	
Cybernet System		✓	✓				
Environmental Simulation Laboratory Co. Ltd.		✓	✓				
ESRI Japan	✓	✓	✓	✓			✓
Exelis VIS				✓			
Forecast Ocean		✓	✓				
Fujitsu Systems		✓	✓	✓			
Geosphere Environmental Technology Corporation	✓	✓	✓	✓	✓		
Geosurf Co. Ltd.		✓	✓	✓	✓	✓	✓
Geotechnos Co. Ltd.					✓		✓
Giken Consultants	✓	✓	✓	✓	✓	✓	✓
Hazama Ando Corporation					✓	✓	✓
Hitachi	✓	✓	✓	✓			✓
Hitachi Solutions	✓	✓	✓	✓			
Image One	✓		✓				
Infomatix	✓	✓	✓	✓			
Intergraph - Hexagon Geospatial		✓	✓				
Itochu Techno-Solutions Corporation				✓			
Japan Association of Surveyors	✓				✓	✓	
Japan Fishery Service Information Centre			✓				
Japan Manned Space Systems Corporation	✓		✓				✓
Japan Space Imaging Co. Ltd.	✓						
JX Nippon Exploration & Development Co. Ltd.		✓			✓		✓
Kanai Metrology			✓		✓		✓
KCCS Mobile Engineering			✓	✓			
Kensetsu Kankyo Laboratory					✓		✓
Kokusai Kogyo Co. Ltd.	✓	✓	✓	✓	✓	✓	✓
Koyo Planning & Surveying		✓	✓		✓	✓	
Link Information Systems Co. Ltd.		✓					
LLC SCN		✓	✓				
Mitsubishi Space Software		✓	✓	✓			
Mitsui Bussan Secure Directions							✓
Nakanihon Air Service	✓		✓			✓	✓
Nittetsu Mining Consultants Co. Ltd.			✓		✓	✓	✓
NTT Data	✓	✓	✓	✓		✓	✓
NTT Data CCS	✓	✓	✓	✓			
NS Solutions Co. Ltd.			✓	✓			
Oriental Consultants Global			✓		✓		
Pasco	✓	✓	✓	✓	✓	✓	✓
Remote Sensing Technology Centre	✓	✓	✓	✓		✓	✓
Satellite Image Marketing	✓	✓	✓				
Satellite Positioning Research & Application Center	✓		✓				✓
Shashin-Kagaku Media Company	✓	✓	✓				
Shikoku Instrumentation Co. Ltd.			✓				
Shin Engineering Consultant Co. Ltd.	✓					✓	✓
Space Engineering Development Co. Ltd.	✓		✓				
Spacefish LLC		✓	✓		✓		
Sumiko Resources Exploration & Development Co. Ltd.		✓	✓	✓	✓	✓	✓
Tokyo Cartographic Co. Ltd.						✓	
VisionTech Co. Ltd.	✓	✓	✓	✓			✓
Weathercock	✓	✓	✓	✓			
Zenrin Co. Ltd.			✓			✓	
Zukosha Co. Ltd.							✓

Figure 3-14 Overview of the capabilities of the EO application companies in Japan (modified from (JAXA, 2016))

	Agriculture	Forestry	Fishery	Oceanography & Marine Mgt.	Urban Infrastructure Mgt.	Land Mgt. & Town Planning	GIS & LBS	Disaster Mgt.	Environmental Monitoring	Mineral Exploration, Oil & Gas
Advanced Intelligence Research Laboratory		✓								
Aero Asahi Cooperation	✓			✓	✓	✓	✓	✓		
Alpha Hydraulic Engineering Consultants Co. Ltd.				✓	✓		✓	✓	✓	
Asia Air Survey Co. Ltd.	✓	✓			✓	✓	✓	✓		
CBMI Co. Ltd.							✓			
CBS Co. Ltd.						✓	✓		✓	
Environmental Simulation Laboratory Co. Ltd.			✓						✓	
ESRI Japan						✓	✓		✓	
Exelis VIS	✓	✓				✓				
Forecast Ocean				✓						
Fujitsu Systems	✓									
Geosphere Environmental Technology Corporation									✓	
Geosurf Co. Ltd.	✓	✓								
Geotechnos Co. Ltd.									✓	✓
Giken Consultants						✓		✓		
Hazama Ando Corporation					✓			✓		
Hitachi							✓			
Hitachi Solutions	✓									
Infomatix	✓	✓				✓	✓	✓	✓	
Itochu Techno-Solutions Corporation						✓		✓	✓	✓
Japan Association of Surveyors					✓	✓				
Japan Fishery Service Information Centre			✓							
Japan Manned Space Systems Corporation	✓									
JX Nippon Exploration & Development Co. Ltd.										✓
Kanai Metrology	✓	✓								
Kensetsu Kankyo Laboratory				✓	✓	✓			✓	
Kokusai Kogyo Co. Ltd.	✓	✓			✓	✓	✓	✓		
Koyo Planning & Surveying		✓			✓	✓				
Mitsubishi Space Software								✓	✓	
Nakanihon Air Service	✓				✓	✓		✓	✓	
Nittetsu Mining Consultants Co. Ltd.										✓
NS Solutions Co. Ltd.						✓			✓	
NTT Data	✓	✓				✓	✓	✓		
NTT Data CCS						✓			✓	✓
Oriental Consultants Global	✓	✓			✓	✓		✓	✓	
Pasco	✓	✓			✓	✓	✓	✓		
Remote Sensing Technology Centre	✓	✓			✓	✓		✓		
Satellite Image Marketing	✓	✓		✓		✓		✓		✓
SCN							✓			
Shin Engineering Consultant Co. Ltd.					✓	✓	✓	✓	✓	
Space Engineering Development Co. Ltd.	✓	✓						✓		
Spacefish LLC			✓							
Sumiko Resources Exploration & Development Co. Ltd.										✓
Tokyo Cartographic Co. Ltd.							✓			
VisionTech Co. Ltd.	✓									
Zenrin Co. Ltd.						✓	✓	✓		
Zukosha Co. Ltd.	✓									

Figure 3-15 Overview of the disciplinary areas of the EO application companies in Japan (modified from (JAXA, 2016))

3.2.1 Industry Groups

The main industry groups for aerospace and EO data companies in Japan are Japan Space Systems (JSS) [JSS, 2016] and BizEarth [BizEarth, 2016].

Japan Space Systems

As described in Chapter 1, JSS is a special government corporation under METI, but it also functions as an industry representative group consisting of 42 member companies mainly from heavy manufacturing and natural resources industries in Japan (JSS, 2016). It is financed by both METI and the member companies, and has direct access to the Japanese government and ministries to give advice and recommendations in the interests of its members.

Table 3-4 List of JSS member companies (JSS, 2016)

Air Asia Survey Co. Ltd.	Mitsubishi Corporation
Dowa Holdings Co. Ltd.	Mitsubishi Corporation Exploration Co., Ltd.
Fuji Heavy Industries	Mitsubishi Electric Corporation
Fujikin Inc.	Mitsubishi Heavy Industries
Fujitsu Ltd.	Mitsubishi Materials Corporation
Furukawa Battery Co., Ltd.	Mitsubishi Materials Techno Corporation
Geosys Co. Ltd.	Mitsubishi Precision Co. Ltd.
Geotechnos Co. Ltd.	Mitsubishi Research Institute Inc.
High-ReliabilitJPYgineering & Components Corporation	Mitsubishi Space Software Co. Ltd.
Hitachi Ltd.	Mitsui Mining & Smelting Co. Ltd.
Hydro-soft Technology Institute Co.,Ltd.	Mitsui Oil Exploration Co.,Ltd.
IHI Aerospace	NEC Corp.
IHI Corporation	NEC Networks & System Integration Corp.
INPEX Corporation	Nittesu Mining Co. Ltd.
Itochu Techno-Solutions Corporation	Nittesu Mining Consultants. Co. Ltd.
Japan Petroleum Exploration Co. Ld.	PASCO Corp.
JGI Inc.	Remote Sensing Technology Centre of Japan
JX Nippon Exploration & Development Co. Ltd.	Sharp Corporation
Kawasaki Heavy Industries	Sumiko Resources Exploration & Development Co.
Keyware Solutions Inc.	Sumitomo Metal Mining Co. Ltd.
Kokusai Kogyo Co. Ltd.	

JSS has recently launched a new project called *Space Business Court* (JSS, 2016), which will act as an online platform to provide numerous services to stimulate creation of new EO downstream applications by the private sector. Space Business Court aims to be a *'one-stop shop'* for all matters related to developing EO-related businesses, and the platform will include (Takayama, 2016):

- Free, open distribution of pre-processed ASTER images to support new business creation
- Serve as a gateway for networking and partnering with EO application companies overseas
- Business incubation – provide business and technical support, as well as initial financing for new start-ups and SMEs

JSS has received full endorsement of the National Space Policy Secretariat of the Cabinet Office for their Space Business Court platform, and they hope to play a central role in the future of EO downstream applications in Japan.

BizEarth (BizEarth, 2016)

BizEarth is a business community for EO data and related companies. BizEarth differs from JSS is that it's not an official organisation approved by the government, but more of an industry association or club to share information and promote new practices. Their objective is to promote the use of EO data by (BizEarth, 2016):

- Proposing policy recommendations
- Elaborating and performing market surveys
- Supporting human resource development

BizEarth has consists of 21 full member companies plus 1 company with an observer status, most of which are key players in the Japanese EO data industry.

Table 3-5 List of BizEarth member companies

Air Asia Survey Co. Ltd.	JX Nippon Exploration & Development Co. Ltd.
CBMI Holdings	Kokusai Kogyo Co. Ltd.
ESRI Japan Corp.	Mitsubishi Space Software Co. Ltd.
Exelis VIS Co. Ltd.	Mitsui Bussan Secure Directions Inc.
Fujitsu Ltd.	NEC Corp.
Geosphere Environmental Technology Corp.	Orkney Upward Co. Ltd.
Geotechnos Co. Ltd.	PASCO Corp.
Hitachi Solutions Co. Ltd.	Remote Sensing technology Centre of Japan
Infoserve Inc.	Satellite Business Network
Japan Manned Space Systems Corporation	Space Engineering Development Co.
Japan Space Systems (Observer member)	VisionTech Inc.

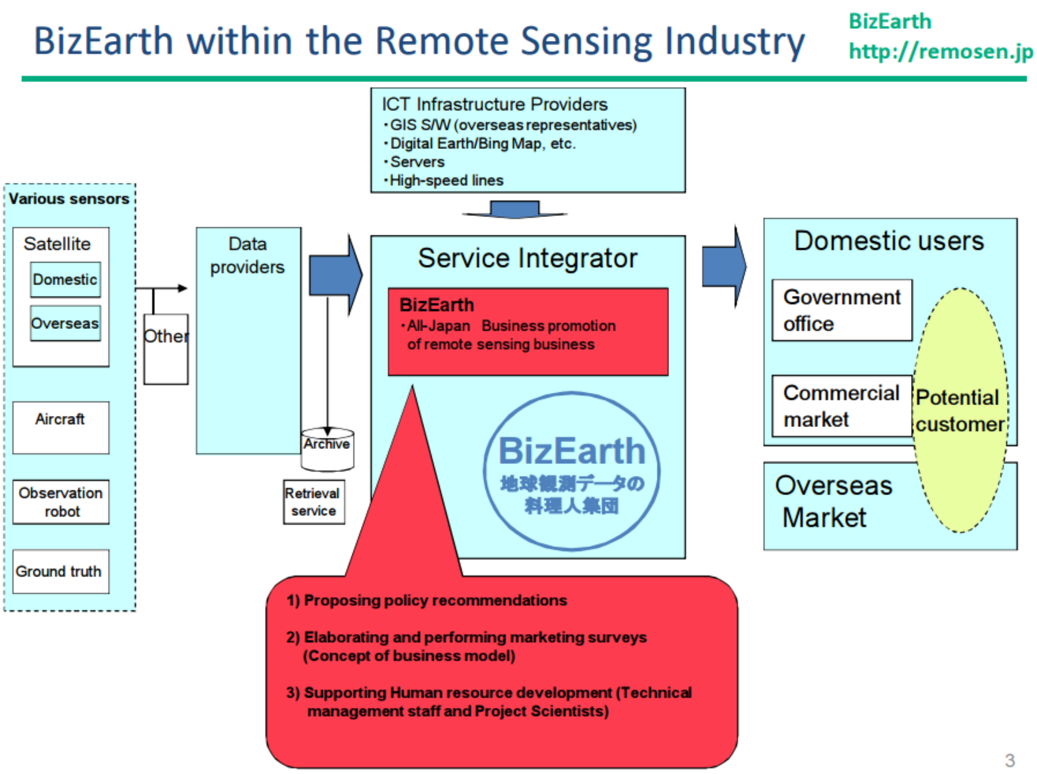


Figure 3-16 Overview of BizEarth's position in the EO applications industry in Japan (BizEarth, 2016)

Many companies are a member of both JSS and BizEarth, and they act as a gateway to Japan as they have strong ties with the Japanese industries and government ministries. JSS is intending to establish its position as the industry representative organisation to act as the intermediary between the industry and the government, similar to EARSC (*European Association of Remote Sensing Companies*) in Europe. They are currently having talks with BizEarth and JAXA about possible cooperation in the near future.

3.3 Recent Developments

3.3.1 New EO Satellite Developers

In response to the *"New Space"* developments in the US, marked by companies such as *Planet Labs* and *Planetary Resources*, the landscape of the Japanese space industry is going through changes in recent years, moving away from government R&D projects dominated by the major engineering companies. The focus is shifting to more commercial-oriented ventures and creating new business models to address the needs of the private sector. There is a growing interest in using smallsats for cheaper, near real-time Earth-observation services, and several companies have gone into cubesat and smallsat business.

1) *Axelspace Corporation* (Axel Space, 2016)
    - A small start-up company started in 2008 by the PhD students of the cubesat research group at the University of Tokyo.
    - In 2013, launched their first commercial Earth-observation satellite, WNISAT-1R for *WEATHERNEWS*, a company providing commercial, precise weather forecasting services.
    - In 2015, launched a technology demonstration satellite, *Hodoyoshi-1*, a 60 kg smallsat offering a ground resolution of 6.7 m.
    - Currently working on *GRUS* project – a large constellation consisting of 50 smallsats called *GRUS*, each weighing 95 kg and capable of observing with 2.5 m ground resolution. The users can access the data through an online platform, *AxelGlobe*.

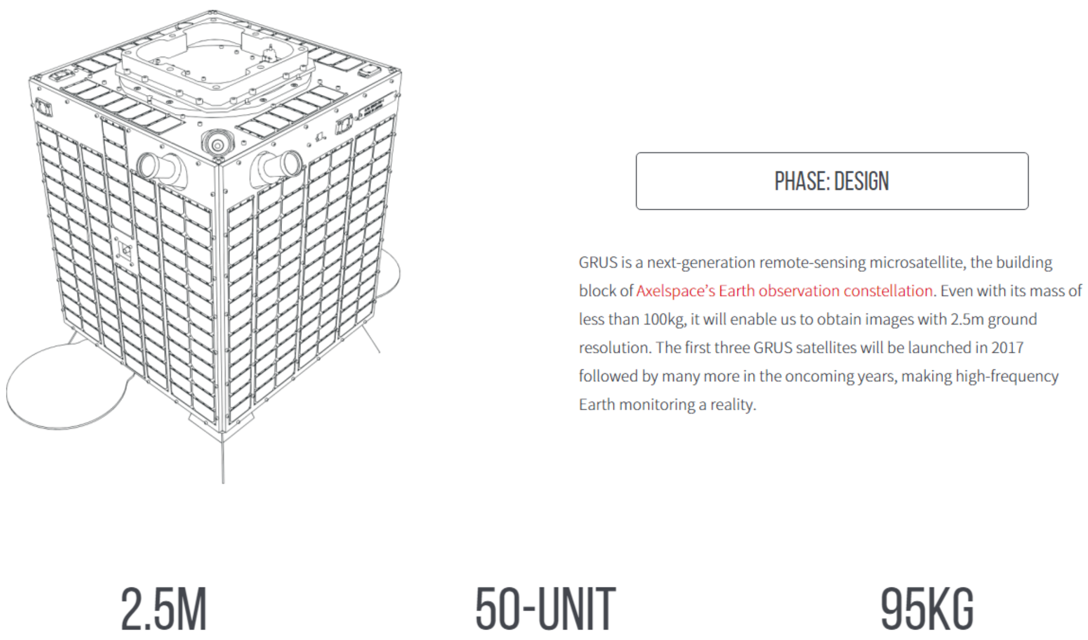


Figure 3-17 Overview of Axel Space's GRUS mission (Axel Space, 2016)

2) *Canon Electronics Inc.* (Hayakawa, 2014)

- Canon Electric is part of the Canon group companies, with a particular strength in camera and other optical devices and PC devices.
- In 2014, Canon announced that it will enter smallsat business using their expertise in camera technology to offer smallsats with lower cost, medium resolution and reliability, similar to the design concept of AxelSpace's *Hodoyoshi-1* satellite.
- They are currently developing their first satellite, CE-Sat-I, weighing 65 kg to provide 1 m ground resolution. The cost of one satellite is aimed at being under 1 bil JPY (approx. 9 mil EUR in 2016 Sept exchange rates)

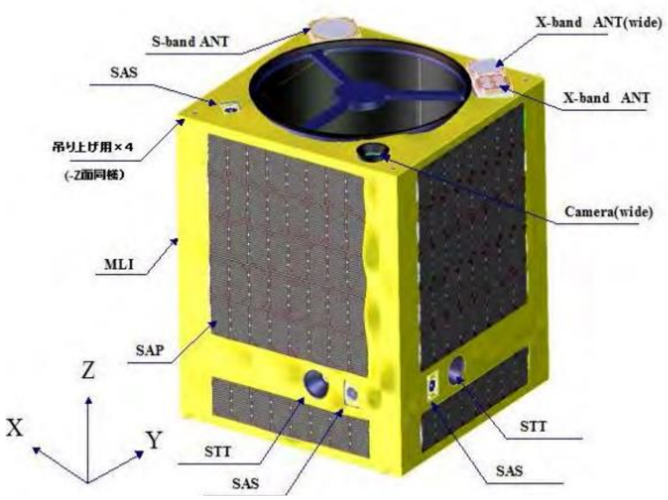


Figure 3-18 Canon Electric's CE-Sat-I (Hayakawa, 2014)

Ground Res.	1 m
Dimensions	50 x 50 x 85 cm
Mass	Under 65 kg
AOCS	3-axis stabilise
Orbit	600 km altitude, sun-synchronous orbit
Link	S-band 94 kbps (uplink), X-band 2Mbps (downlink)

Table 3-6 Key specifications of CE-Sat-I (Hayakawa, 2014)

3.3.2 Commercial EO Satellite Operation

JAXA and MEXT have taken steps to establishing the first commercial EO satellite operator in Japan by forming a Private-Public Partnership for the operation of the Advanced Optical Satellite with PASCO (Tsutsumi, 2016). The partnership is going to be similar to that between Airbus D&S and CNES when *SPOT Image* was established, and PASCO will be in charge of the operation of the satellite and the distribution and sales of the images.

It is important to note that PASCO has also signed a PPP agreement with METI for the operation of the ASNARO-1 satellite developed by NEC (eoPortal, 2016) (Kasai, 2016). So far, neither PASCO nor METI has given any information on their business model or how the images from ASNARO-1 will be distributed. The Remote-Sensing Act, which is currently under discussion by the Japanese Parliament, is expected to be the critical part of the equation, and it is said that PASCO is holding off any announcement until the bill is finalised during 2017.

This latest development with JAXA means that PASCO will be in charge of the sales of two high-resolution satellite data, and it is expected they will play a central role in the commercial EO data industry in Japan.

3.3.3 Growing Interests in Overseas Expansion & Collaboration

Since their inception, the EO application companies in Japan have been heavily dependent on publicly-funded, government projects. For most companies, about 80% of their whole revenues come from the public sector. Thus, companies have been rather complacent about exploring new opportunities outside of the public domain. However, it is said that the Japanese ministries are slowly undergoing a change in generation among their staff, and the new generation sees that it's not the government's role to act as a *"sponsor"* of an industry, and it's up to the industry to look for alternative revenues to ensure that their business is sustainable. This change in sentiment combined with the implementation of the Basic Plan of Space Policy and the push from the National Office for Space Policy to expand commercial activities in space are slowly creating a change in the Japanese EO application industry.

In the recent years, some of the major EO applications companies in Japan are paying greater attention to overseas markets, particularly Europe, to address potential needs in the private sector. For example, Kokusai Kogyo open their European office in Berlin in 2008 [KKC, 2016], and PASCO acquired a Finnish mapping company FM-International Oy Finnmap [PASCO, 2016] to strengthen their ties with the European market. They are interested in forming more partnerships with promising companies in Europe. Air Asia Survey is also forming new projects in the private sector in Japan, and looking to expand its presence in Europe. The two industry groups, JSS and BizEarth intend to be catalysts in further promoting these new developments.

Amidst all of this, the EU's *Horizon 2020* is gaining interest from the Japanese EO application companies as a potential tool to build relationships with European companies, but they also mentioned several obstacles preventing their full commitment. The current lack of funds and/or join-calls for space for non-EU entities is the biggest problem, and the companies are struggling to justify their participation over expected costs. Nevertheless, the interest is still strong. Both BizEarth and JSS are considering taking the matter up to the National Office of Space Policy to explore ways to set up a joint call between the EU and Japan for H2020 projects in space possibly for 2017/2018.

3.4 EO Data Provision

Over the last few years, Japan has been shifting to open-source data policy for the majority of their satellites, and now, nearly all of them are provided for free for both commercial and academic/research purposes. Exceptions are medium (2.5 – 20 m) to high (0.3 – 2 m) resolution images from ALOS and ALOS-2 satellites, which are provided for a cost through licensed data distributors and re-sellers. 2016 marked a significant change in Japan's stance on satellite data provision. METI decided to make the data from the ASTER instrument on-board NASA's *Aqua* available for free, including the value-added products ASTER-VA. Furthermore, RESTEC, which is the main distributor of ALOS and ALOS-2 data, also decided to provide the digital elevation model (DEM) created from ALOS data available for free. Thus, it could be said that Japan is undergoing a pivotal moment in their satellite data policy, and it is an opportune time for the EU to re-commence discussion with Japan on future collaboration and data reciprocity.

Table 3-7 Summary of data provision status of Japanese EO satellites

Name	Data Provision
Current Missions	
AMSR-E on-board NASA's *Aqua* satellite	Free [JAXA G-Portal, 2016]
ASTER on-board NASA's *Terra* satellite	Free [JAXA G-Portal, 2016]
GOSAT *"Ibuki"*	Free [NIES, 2016]
GCOM-W *"Shizuku"*	Free [JAXA, 2016]
DPR on-board NASA's GPM satellite	Free [JAXA G-Portal, 2016]
ALOS-2 *"Daichi-2"*	Not Free
ASNARO-1	Not Free
Past Missions	
MOS-1	Free [JAXA G-Portal, 2016]
JERS-1	Free [JAXA G-Portal, 2016]
ADEOS	Free [JAXA G-Portal, 2016]
PR on-board NASA's TRMM satellite	Free [JAXA G-Portal, 2016]
ADEOS-II	Free [JAXA G-Portal, 2016]
ALOS	Not Free

3.4.1 Open Free Data

All the data from JAXA's past missions are provided as open-source for free through several different web portals managed by different entities.

JAXA G-Portal

G-Portal (http://www.gportal.jaxa.jp) is a web portal managed by JAXA Earth Observation Research Centre (EORC), and provides all the data from JAXA's past missions completely free and open-source for both academic research and commercial purposes, including companies overseas. The portal doesn't require users to sign a contract with JAXA, but they need to register and also show JAXA's copyright on their final product/service. The name of the satellites and the sensor, and the parameters provided through G-Portal are listed below and in Figure 3-19.

- GPM satellite – DPR, GMI, KuPR, KaPR, DPR-GMI COMB, ENV
- GSMaP
- TRMM – PR, TMI
- JERS-1 – VNIR, SWIR, SAR
- ADEOS-II – AMSR, GLI
- ADEOS – OCTS, AVNIR
- MOS-1 & 1b – MESSR, VTIR, MSR
- ERS-1 – AMI
- Aqua – AMSR-E

as at April 2016

Group1	Group2	Products
Atmosphere	Precipitation	Amount of Precipitation
		Precipitation Qualitative
		Precipitation Particle Radius
	Cloud	Cloud Water/ Cloud Ice
		Cloud Flag
		Cloud partical effective radius and shape
		Elements of cloud top
		Classified cloud fraction
		Optical Thickness
		Water cloud optical thickness
		Ice cloud optical thickness
	Water Vapor	Water Vapor
	Aerosol	Optical Thickness
		Aerosol optical thickness over the ocean
		Aerosol optical thickness over the land
		Aerosol Particle Radius
		Aerosol Angstrom Exponent over the
		Aerosol Angstrom Exponent over the land
		Aerosol Extinction Coefficient
		Single-scattering albedo
	Radiation Balance	Latent Heating Profiles
Cryosphere	Sea Ice	Sea Ice Concentration
		Sea ice surface temperature
		Snow grain size
		Snow and ice covered area
		Okhotsk sea-ice distribution
	Snow pack	Snow Depth
		Snow and sea ice covered area
		Snow and ice surface temperature
		Snow grain size

Group1	Group2	Products
Terrestrial	Soil Moisture	Soil Moisture
	Snowpack	Snow Depth
		Snow covered area
		Snow grain size
	Ground Surface	Land-surface temperature
	Radiance/Reflectance	Atmospherically Corrected Land surface Reflectance
	Radiance	Precise Geometrically Corrected Image (Clear weather)
		Precise Geometrically Corrected Image
	Vegetation	Vegetation Parameters
		Normalized difference vegetation index
		Enhanced vegetation Index
		Shadow index
		Fraction of absorbed photosynthetically active radiation
		Leaf area index
		Above-Ground Biomass
		Vegetation roughness index
Ocean	Sea Surface Temperature	Sea surface temperature
	Sea Surface Wind	Sea Surface Wind Speed
	Ocean Color	Normalized water leaving radiance
		Chlorophyll-a concentration
		Suspended solid concentration
		Colored dissolved organic matter
		Atmospheric Correction Parameters
		Photosynthetically available radiation
Others	Radiance/Brightness temperature	Brightness Temperature
		Radiance
		Radiance/ Reflectance
	Radar	Calibrated Received Power
		Radar Reflectivity
		Backscattering cross section
		Backscattering cross section
	Geometric Information	Geometric Information
	Environment Auxiliary	Environment Auxiliary

Yellow color cells show products provided only for specific user.

Figure 3-19 Data products available on JAXA's G-Portal (JAXA G-Portal, 2016)

GCOM Data Providing Service

GCOM Data Providing Service (http://gcom-w1.jaxa.jp) is another web portal managed by JAXA, and it provides observation data of the AMSR instrument family for free and as open-source for academic and commercial purposes. The service doesn't involve royalty fees or signing a contract, but users need to register and show JAXA's copyright on their product/service. As for GCOM-C, which is expected to be launched in 2016/2017, the data policy is yet to be decided. The instruments and the physical parameters provided by the service are summarised in Table 3-8.

Instrument	Category	Physical Parameters
● AMSR-2 on GCOM-W ● AMSR-E on NASA's Aqua ● AMSR on ADEOS-II	Atmosphere	Total precipitable water. Cloud liquid water, Precipitation
	Ocean	Sea surface temperature, Sea surface wind speed
	Cryosphere	Sea ice concentration
	Land	Snow depth, Soil moisture content
	Brightness Temperature	Brightness temperature

Table 3-8 Data products available on GCOM Data Provision Service

GOSAT User Interface Gateway (GUIG)

GUIG (http://data.gosat.nies.go.jp) is a web portal which provides the observational data from the two sensors on-board GOSAT satellite, TANSO-FTS, the greenhouse gas sensor, and TANSO-CAI, the cloud and aerosol sensor. The portal is managed by the National Institute of Environmental Studies (NIES), which is administered by the Ministry of Environment. The data was initially not open-source and it incurred a fee, but the data policy was changed in 2015 to fully open-source, and the data is available for both academic and commercial use for free.

MADAS – ASTER data provision portal

The observational data of the ASTER instrument on-board NASA's *Aqua* satellite was managed by JSS, under the management of METI, but the task was transferred to the National Institute of Advanced Industrial Science & Technology (AIST), which is also a research body under METI. AIST distributes ASTER data as open-source for free for both academic and commercial purposes through its web portal, MADAS (https://gbank.gsj.jp). Note that users have to show the copy right of NASA/METI/AIST/JSS on their products.

3.4.2 Commercial Data

Currently, the only commercial satellite data in Japan is from ALOS, which has retired in 2011, and ALOS-2, which has been operating since 2014. Many of the major EO data companies in Japan, such as RESTEC and PASCO, have signed a prime distributorship agreement with JAXA to provide ALOS and ALOS-2 data at a cost. JAXA also provides up to 50 scenes per year for free for educational purposes.

Nevertheless, ALOS-2 only provides SAR data, and Japan doesn't have their own optical satellite data since the retirement of ALOS. Consequently, many Japanese EO data companies have been heavily dependent on the optical data from the commercial satellite operators in the US and Europe, as shown in Table 3-9. Some of them have also signed an exclusive distributorship or a general agency agreement with the operators.

Table 3-9 Main distributors of commercial EO data in Japan. European satellite data are printed in bold

Company	Satellite Data
Aero Asahi Corporation (Aero Asahi, 2016)	IKONOS (from Japan Space Imaging), ALOS
Asia Air Survey (Asia Air Survey, 2016)	ALOS, ALOS-2
Hitachi Solutions (Hitachi, 2016)	GeoEye-1, IKONOS, QuickBird, WorldView-1, 2 & 3, **RapidEye**, **COSMO-SkyMed** (through Japan Space Imaging)
Japan Space Imaging (JSI, 2016)	GeoEye-1, IKONOS, QuickBird, WorldView-1, 2 & 3, **RapidEye**, **COSMO-SkyMed**
Kokusai Kogyo (KKC, 2016)	GeoEye-1, IKONOS, QuickBird, WorldView-1, 2 & 3, SkySat, **Pleiades**, **RapidEye**, ALOS, ALOS-2, **SPOT-5, 6 & 7**, **COSMO-SkyMed**
Naka-Nihon Air Service	The company website states that they sell satellite data, but doesn't indicate which satellites
NTT Data (NTT Data, 2016)	GeoEye-1, IKONOS, QuickBird, WorldView-1, 2 & 3
PASCO (PASCO, 2016)	GeoEye-1, IKONOS, QuickBird, WorldView-1, 2 & 3, **SPOT-5, 6 & 7**, **RapidEye**, **TerraSAR-X**, **Pleiades**, EROS-B, ALOS, ALOS-2, RADARSAT-2
Satellite Image Marketing (SIM, 2016)	**SPOT-1 to 7**, FORMOSAT-2, **Deimos-1**
Shashin Kagaku Media Company (Shashin, 2016)	GeoEye-1, IKONOS, QuickBird, WorldView-1, 2 & 3, **Pleiades**, ALOS
Space Engineering Development (SED, 2016)	GeoEye-1, IKONOS, QuickBird, WorldView-1 & 2, ALOS, ALOS-2, **SPOT-5**
VisionTech (VT, 2016)	GeoEye-1, IKONOS, QuickBird, WorldView-1, 2 & 3, **SPOT-5, 6 & 7,** **RapidEye**, **Deimos-1**, **Pleiades**, SkySat-1, 2, ALOS, ALOS-2, **COSMO-Skymed**, RADARSAT-1 & 2

PASCO – RADARSAT and TerraSAR-X

PASCO has formed a partnership agreement with *MDA Geospatial Services* and *Infotera* to be their exclusive distributor in Japan for RADARSAT-1 and TerraSAR-X data respectively (PASCO, 2016).

Japan Space Imaging (JSI) – IKONOS, GeoEye-1

JSI was formed in 1994 when *Mitsubishi Corporation* gained shutter and distribution rights in East Asia for the IKONOS satellite in the East Asia region from *DigitalGlobe*. Mitsubishi sold its shares of JSI to Hitachi in 2013, and JSI has been operating as the exclusive distributor in Japan under *Hitachi* since then. JSI has also signed an exclusive distributorship agreement with *GeoEye* in 2008 for the sales of *GeoEye-1* data (JSI, 2016).

Image One – SPOT Satellites, FORMOSAT-2

Image One has formed an exclusive distributorship agreement with *SPOT Image* for the SPOT satellites and FORMOSAT-2 of Taiwan, and formed a joint venture company, *Tokyo SPOT Image* in 2002. However, in 2011, Image One sold off their shares in Tokyo Spot Image back to Airbus D&S, and changed their distributorship agreement to non-exclusive.

Satellite Image Marketing (SIM) – SPOT Satellites

In 2015, PASCO bought the 100% of shares of Tokyo Spot Image from Airbus D&S. The company was renamed to Satellite Image Marketing, and became one of PASCO's group companies (SIM, 2016). Currently, it is the exclusive distributor of SPOT Image in Japan.

3.4.3 Compatibility with the EU's Data Policy

Japan's free and open data policy for nearly all of their EO satellites aligns perfectly with the EU's policy for their Copernicus program. JAXA and JSS have a wide range of optical and SAR data that will complement the data service of Copernicus, and work toward expanding the data provision of the two regions. It is particularly important to note that the ASTER images come in resolution of 15, 30 and 90 m (Wikipedia, 2016c), which is comparable to those of Sentinel-2, which come in 10, 20 and 60 m resolutions.

Fully open data policy for satellite data and images is slowly gaining recognition in Japan. Between 2015 and 2016, METI and the Ministry of Environment have decided to provide their satellite data as free open-source, and furthermore, JSS and RESTEC also decided to provide ASTER images and the Digital Elevation Model of ALOS for free for all intents and purposes. Similarly, the meteorological data from the

Himawari satellites provided by the Japan Meteorology Agency is also considering of reviewing their data policy, which is currently not open-source.

As for the high-resolution images from ALOS and ALOS-2 and the upcoming Advanced Optical Satellite, JAXA and the Japanese government are determined on establishing Japan's first commercial EO satellite operator by partnering with PASCO to boost Japan's commercial space sector, and thus, it is quite unlikely that the images will be provided as open-source, at least in the near future.

3.5 International Cooperation

3.5.1 Government Funding Programs

The main channel where the EO application companies in Japan have worked on projects overseas is via the development projects funded by the Ministry of Foreign Affairs (MOFA) in the form of *Official Development Assistance* (ODA). In 2013, Japan was ranked as the 5th highest contributor of ODA behind Germany, UK, US and EU (Wikipedia, 2016e).

Projects funded under ODA are managed by the *Japan International Cooperation Agency* (JICA), which is a government agency under MOFA. JICA coordinates 3 types of aid programs – 1) loan assistance such as JPY loan, 2) grant aid, and 3) technical assistance (MOFA, 2016). For technical assistance, JICA puts out calls for proposals on projects to help developing nations with supplies, capacity-building & training, and construction of public infrastructure. R&D projects using EO data are also included under this scheme. JICA has conducted numerous development projects using EO data in South East Asia, Africa, and East Europe, and some examples are listed on the next page (Suzuki, 2012):

- Fundamental mapping project to develop national spatial database
  Moldova, Dec 2010 – Dec 2015, used ALOS/PALSAR data
- Research on ways to reduce damage caused by landslides and floods
  Malaysia, Jun 2011 – Jun 2016, used ALOS/PALSAR data
- Carbon Dynamics of Amazonian Forests
  Brazil, May 2010 – May 2014, used ALOS/PALSAR data

All of the major EO data companies in Japan, such as Kokusai Kogyo, Air Asia Survey, PASCO, and NTT Data have taken part on JICA-funded projects over the years. RESTEC has built a particularly strong relationship with Brazil for its contribution to combat illegal logging in the Amazon (RESTEC, 2016).

Currently, JICA projects are only open to Japanese companies, but talks are underway about the possibility of allowing consortiums with overseas partners.

Another public agency that conducts a lot of development projects overseas is the *Asian Development Bank* (ADB), headquartered in Manila, Philippines (Muraki, 2014). JAXA has had a significant involvement in projects funded by ADB as a technical advisor, and in July 2010, the two organisations signed an agreement to cooperate in the use of space technology for disaster management, climate change mitigation and adaptation, forest monitoring, and water resources management (JAXA, 2010). In 2012, the collaboration field was expanded to include agriculture and urban development, and the number of projects implemented has been increasing in recent years.

With JAXA as the prime technical advisor, many of the major EO data companies in Japan have formed consortiums to take part in ADB's projects as technical consultants. An example is shown in Figure 3-20 (Muraki, 2014).

Project Title	Applying Remote Sensing Technology in River Basin Management
Project Number	TA 8074-REG
Country	Regional (Bangladesh, Philippines, Viet Nam)
Department/Division	Regional and Sustainable Development Department/Sustainable Infrastructure Division
Executing Agency	Asian Development Bank
Sector/Subsector	Agriculture and natural resources/Water-based natural resources management
Amount Approved	$2,000,000 (ADB), $648,440 (JAXA in-kind)
Approval/Completion	27 April 2012/31 December 2014 (TBD)
Source	http://www.adb.org/projects/44164-012/main/
ST/GIS Application	Improvement of flood forecasting using satellite-based rainfall data and study to apply a Digital Terrain Model to local flood model; web-GIS for flood forecasting information sharing
ST Data	Global Satellite Mapping of Precipitation (GSMaP) provided by JAXA and digital surface model (DSM) derived from the Advanced Land Observing Satellite (ALOS)
ST/GIS Cost	International consultant for 9 person-months to develop methodology and system to calibrate GSMaP and capacity development International consultant for 4 person-months to correct the ALOS DSM $200,000 to procure ALOS DSM National consultant for 4 person-months national consultant to develop web-based GIS in Bangladesh and Viet Nam
ST/GIS Service Providers	JAXA, PASCO Corporation (ALOS DSM), Remote Sensing Technology Center of Japan (GSMaP calibration), national individual consultants (web-based GIS)
Users	Bangladesh Water Development Board (BWDB), Philippine Atmospheric, Geophysical and Astronomical Services Administration (PAGASA), National Hydro Meteorological Service (NHMS) under Ministry of Natural Resources and Environment (MONRE) of Viet Nam

Figure 3-20 Example of a project issued by ADB (Muraki, 2014)

3.5.2 Inter-Governmental Initiatives

Another channel that Japan goes through to build relationships with the international community is the *Asia-Pacific Regional Space Agency Forum* (APRSAF) (APRSAF, 2016). Japan plays a leading role in the forum, which is jointly organised every year by MEXT and JAXA. It's a separate initiative to APSCO, the *Asia-Pacific Space Cooperation Organisation*, which is coordinated by China.

Space agencies, governmental bodies, international organizations, private companies, universities, and research institutes from over 40 countries and regions take part in APRSAF, the largest space-related conference in the Asia-Pacific region. As of December 2015, it comprised 612 organizations from 45 countries and regions and 28 international organizations (APRSAF, 2016).

APRSAF currently organizes four working groups; Space Applications, Space Technology, Space Environment Utilization, and Space Education, to share information about the activities and future plans of each country and region in these respective areas.

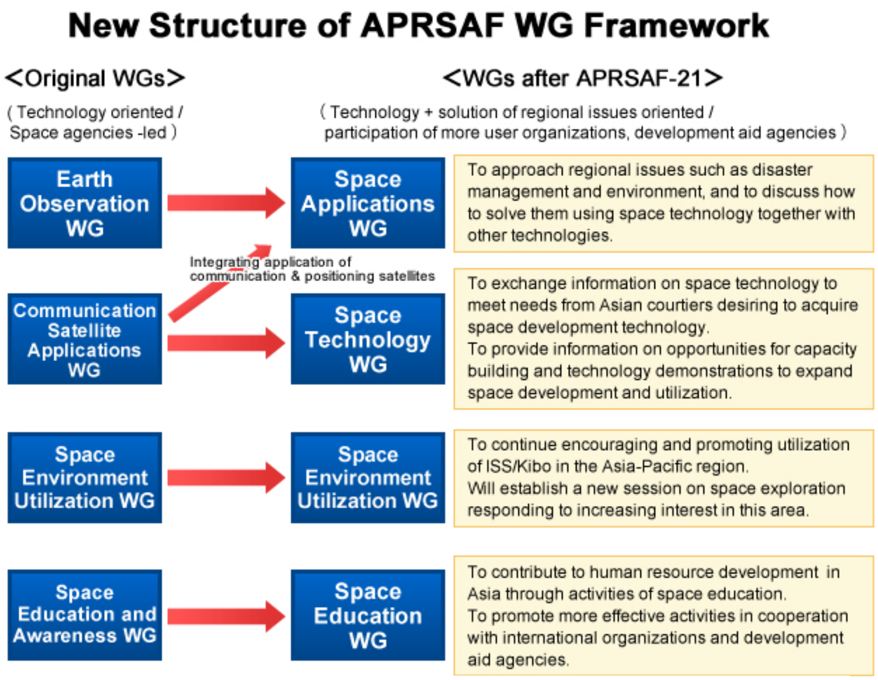


Figure 3-21 Working groups within APRSAF (APRSAF, 2016)

APRSAF coordinates four multi-national projects (APRSAF, 2016):

1) Sentinel-Asia

   The Sentinel Asia initiative is an international collaboration among space agencies, disaster management agencies, and international agencies for applying remote sensing and Web-GIS technologies to support disaster management in the Asia-Pacific region. In the case of a wild fire, flood, or an earthquake, member organization distributes their disaster-related data and products to the disaster-struck country, which includes satellite imagery, value-added images, and other observational data. Participating satellites include ALOS-2, IRS from the Indian Space Agency ISRO, THEOS from the Thai EO agency GISTDA, and KOMPSAT from the Korean space agency KARI, and others.

Japan has been playing a leading role for Sentinel-Asia making active use of their space assets and ICT infrastructures. For example, the network server infrastructure was developed by a major Japanese ICT company Fujitsu, and the data is transferred to the users' local mirrored server via Japan/JAXA's communication satellite, WINDS.

2) *Space Applications for Environment* (SAFE)

Space Applications for Environment (SAFE) is a voluntary initiative to encourage environmental monitoring in the long term to understand environmental changes, through demonstration activities and application development.

3) *Climate R^3*

Regional Readiness Review for Key Climate Missions (*Climate R^3*) seeks to determine the ability of APRSAF countries and institutions to benefit from data and information that will be provided by selected climate-related satellite missions in the coming years.

4) Kibo-ABC

Kibo-ABC is a collaborative program established by the Space Environment Utilization Working Group (SEUWG) of APRSAF, aiming to promote the utilisation of *Kibo* experimental module on ISS utilization in the Asia-Pacific region and to share and build on the outcomes.

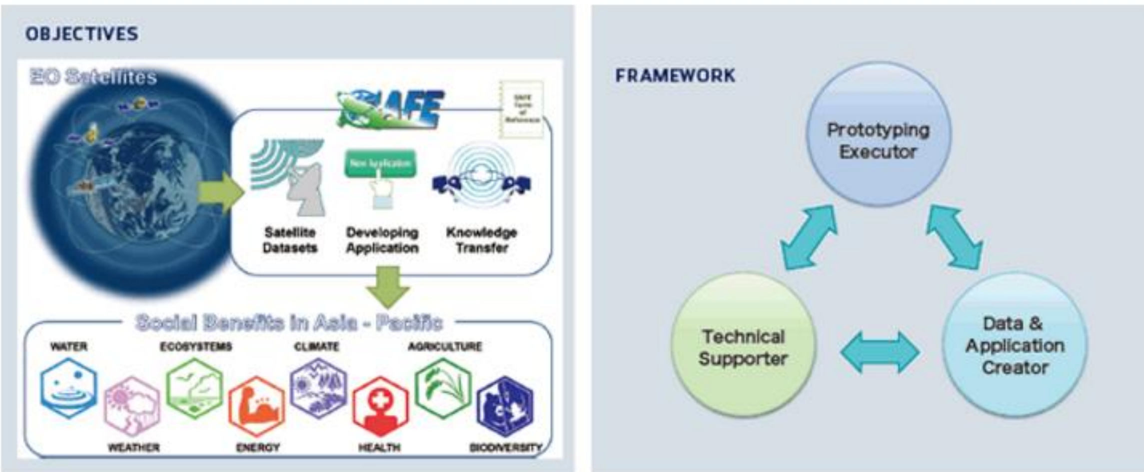


Figure 3-22 Overview of the SAFE project (APRSAF, 2016)

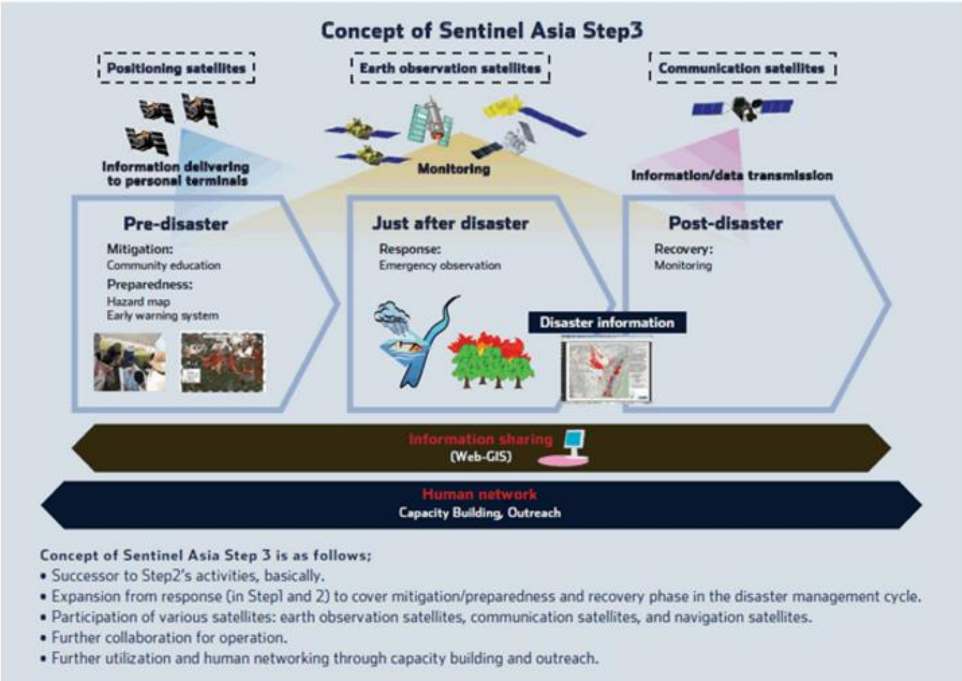


Figure 3-23 Concept of Sentinel-Asia (APRSAF, 2016)

Japan is also a member of *Group on Earth-Observations* (GEO). They are on the Executive Committee for 2016, and they have been contributing by developing a science and technology roadmap assessment (GEO, 2016).

In other areas, Japan has been taking part in various international frameworks to combat climate change. Japan's current EO program, the Global Change Observation Mission (GCOM) is Japan's contribution for the Global Earth Observation System of Systems (GEOSS). Furthermore, Japan is an active member of various climate change initiatives and conferences coordinated by the *World Meteorological Organisation* (WMO), UNESCO, the *United Nations Environment Programme* (UNEP), the *Committee on Earth Observation Satellites* (CEOS), and the *International Council for Science* (ICSU) (Nakajima, 2015).

3.5.3 Inter-Agency Agreements

Japan has formed numerous partnership agreements and MoUs, but this has only been at the space agency-level between JAXA and other space agencies, and a formal partnership hasn't been implemented at the EU level. Due to political and historical factors between Japan and the US, JAXA closely works with NASA, and has formed partnerships to share EO data from JAXA's GCOM program.

In the recent years, JAXA has also signed partnership agreements with ESA, DLR, CNES and ASI. Readers are encouraged to refer to the MINERVA report on EU-Japan cooperation in space for a full review of all the agreements between JAXA and various space administration bodies in Europe (Regina, 2014).

Discussions are already underway between JAXA and ESA, and JAXA and DLR about possible collaborative projects in the field of EO downstream applications.

3.6 SWOT Analysis

Interviews with over 10 prominent EO applications companies in Japan have given a clearer view of the current state of the industry, as well as issues and challenges that the companies face. To better characterise the EO application industry in Japan, a SWOT analysis was conducted, and the results are discussed in the proceeding sections.

3.6.1 Strengths

- **Expertise in L-band SAR**

  Compared to C and X-band SAR used in the US and Europe, Japanese SAR satellites have always used L-band SAR. L-band is found to be particularly effective in monitoring trees by penetrating the shrubs and branches to see the actual tree trunks. For this reason, the observational data from ALOS and ALOS-2 have been highly valued by Brazil to monitor the Amazon rainforests, and it's the main factor for the strong relationship between Japan and Brazil.

- **Significant scientific contributions of the sensors on-board the Japanese EO satellites**

  The sensors on-board many of the Japanese EO satellites have been highly regarded by the scientific communities around the world as indicated in Table 3-10. Apart from the L-Band SAR on-board ALOS and ALOS-2, the microwave radiometers, AMSR-E and AMSR-2 have been particularly valued in oceanography research.

	#articles	Citation except for self-citation	h-index	Articles in 2014	Citations in 2014
TRMM	2,224	27,974	85	232	262
AMSR	821	9,514	52	119	110
ALOS	787	5,033	34	169	174
GOSAT	191	1,262	25	42	50
GCOM	24	272	5	5	1
GPM	597	6,779	40	56	76
LANDSAT	9,828	139,670	147	1,021	993
MODIS	9,434	98,128	144	1,533	1,561

Table 3-10 Number of papers and citations pertaining to the Japanese EO satellites & sensors (Nakajima, 2015)

- **Vast experience in EO data application in agriculture**

Japan has traditionally been a country with very large emphasis on agriculture, with rice being a vital part of the country's diet. Consequently, Japanese EO application companies have a long history of utilising EO data for agriculture, both domestically and overseas, with a lot of expertise with using vegetation indices and growth modeling of crops, particularly rice.

- **Vast experience in disaster management**

Japan is very susceptible to various types of natural disasters, and as a result, the country has developed a wide array of disaster-resilient systems and infrastructures, as well as systems for rapid disaster response and damage mitigation. These include disaster-resilient structural designs, sensor network to monitor the conditions, communitJPYgagement and training, and also use of satellite images for disaster impact assessment.

Due to the relatively high frequency of natural disasters in Japan, EO application companies have a vast experience with conducting speed analysis of disaster-stricken areas and developing software tools for regular monitoring and disaster management.

- **Possession of GOSAT – currently, the world's only satellite dedicated to monitoring greenhouse gases**

As of 2016, Japan is the only country that possess a satellite dedicated to monitoring CO2 and greenhouse gases, aerosols. This gives Japan a unique dataset on the world stage, and to benefit both academic and business communities around the world.

- **Expertise in most areas of EO**

Aside from agriculture and disaster management, Japanese EO application companies have expertise in most disciplinary areas of Earth-observation, including forestry, fishery, SAR interferometry for ground and building monitoring, land type and usage analysis, and cartography.

3.6.2 Weaknesses

- **Heavy dependence on government-funded projects**

Although this is slowly changing, but at least for now, the EO application companies in Japan are heavily dependent on publicly-funded projects domestically and overseas through JICA and ADB. Due to the typical nature of government contracts being rather well-funded, the companies didn't have an urgent need to explore business opportunities in private sectors.

- **No optical satellite images until 2019**

As already discussed in previous sections, currently Japan doesn't have their own optical satellite images, and EO application companies have no choice other than to purchase expensive high-resolution optical images from overseas. The companies are aware of free, open data such as Landsat, but Japan is too small of a country make use of low to medium-resolution satellite images.

- **Possible Gap in the Japanese EO program**

Although the Japanese government has announced their EO program, the Global Change Observation Mission (GCOM), and the Advanced Optical and SAR satellites as successors of ALOS and ALOS-2, its long-term prospects are still largely uncertain beyond 2021. The primary reason for this is the nature of the budget of the Japanese government, which is only decided on a yearly basis. Depending on the political situation and priorities at the time, satellite projects can undergo significant changes from one year to the next. Such a volatile political situation with unstable government support and commitment makes it difficult for EO application companies to invest or make long-term business forecasts, and discourages them from taking any risks.

- **Not enough promotion of satellite data for commercial application**

Due to the EO application companies putting greater priority on the public sector, satellite applications are not really well-known among most private sectors. Lack of understanding of its potential benefits leads to lack of funding and enthusiasm to implement new practices, and this has been one of the main reasons that EO products and services have struggled to gain a foothold in the private sector.

- **Not understanding the needs of private sectors**

Leading from the first point, the EO application companies in Japan didn't put much focus on the private sector up until recently. Although some companies have contracted consultancy companies to conduct market and needs analysis of potential user communities, they were purely for internal purposes, and needs analysis by a neutral entity has never been conducted in Japan. This has left many of the EO application companies completely unaware of potential needs and opportunities in the private sectors.

- **Satellite imagery being too costly for general, private users**

Leading from the point above, commercial satellite images are typically too expensive for private users, and consequently, its use has been limited to serving the needs of public entities with sufficient amount of funds.

- **Lack of experience in marine and water-related areas**

The Japanese EO application companies haven't been very active in the field of maritime management and maritime domain awareness, and they are watching Europe closely to learn how to promote commercial activities in this area. Several companies expressed admiration for Europe's expertise in analysis dealing with water, such as flood modelling and sea altimetry to estimate internal ocean temperature, and their desire to establish information exchange with Europe to build up their capabilities.

Japan is also looking to strengthen its maritime capabilities, and JAXA's Earth Observation Research Centre (EORC) has conducted a detailed needs analysis for Japan.

3.6.3 Opportunities

- **Combining SAR images of different bandwidth**

In order to promote greater use of EO data in both public and private sector, satellite observation needs to be more frequently to capture time-dependent events such as illegal fishing and illegal logging, and maritime surveillance.

One approach is to establish a large-scale satellite constellation to provide near real-time observation, but another way is to combine the data from different satellites to fill-in each other's observation gaps. Some of the EO application companies in Japan have expressed strong interest in investigating how SAR images of different bandwidths can be used in conjunction to complement one another. For example, use C-band SAR data to fill in the deficiency in L-band SAR observation.

- **Need for more affordable, medium-resolution satellite images**

Japan currently doesn't have medium-resolution optical and SAR images as open-source. Therefore, the EU's Copernicus program has a huge potential in Japan, and the interviews showed that there's a high level of interest from the EO application companies on utilising the Sentinel data. Some companies weren't even aware of the Copernicus program, and thus, it could be a vital tool for them to identify and serve new needs that are currently unfulfilled in Japan.

- **Growing demand for alternative purchasing arrangements**

Some of the EO applications companies mentioned the need for alternative purchasing arrangements tailored to the situation of Japan for satellite images. For example, the requirement of minimum purchase area set on commercial satellite images adds unnecessary cost for the users because Japan is a small country with extremely fragmented land ownership. Other suggestions included rental of images, where a user can use the image for several days or even hours, and joint purchase of a license between two or more companies.

- **New entrants in the Japanese EO application industry with more commercial outlook**

Large, well-established companies in the Japanese EO application industry are still rather risk-averse and slow to move away from the public-funded projects that they have been so accustomed to. However, the newer companies are much more enthusiastic about the commercial EO downstream applications, and are potentially more open to discuss new business ventures.

- **No company offering value-added, downstream services in Japan**

No company in Japan so far has gone into developing value-added, downstream products and services possibly due to lack of understanding of the potential user needs and with more lucrative business opportunities in serving the public sector. Europe might be able to fill in this void. Instead of Japanese companies starting the development from zero, European SMEs that already have the knowledge of potential user needs and experience in developing downstream application can showcase their success to the Japanese companies, and set up distributorship agreements with interested Japanese companies.

- **Needs of the private sector have to be better identified**

Needs of the private sector in Japan haven't been readily investigated. European and Japanese companies can perhaps work together under a joint research initiative coordinated by industry groups from both sides, such as JSS, BizEarth and EARSC, to examine the user needs in greater details. An ideal output would be to identify new business opportunities where the companies from both sides can contribute using their key strengths and technical expertise.

- **EU-Japan collaboration in other parts of the world through jointly-funded programs**

The interviews with the Japanese EO application companies showed that they are technically well-equipped and they are probably at the same level with Europe. Hence, some Japanese companies advised that there may not be too much to be gained from partnering with Europe to try and address each other's market, other than exchange of expertise in some niche technical matters. Instead of trying to enter each other's *'playing fields'*, the two regions should cooperate and complement each other's key strengths, to conduct business in a third playing field, such as solving the needs of other, less-developed economies.

The Japanese government and the Japanese EO application companies have strong ties with countries in South East Asia, Africa and South America through projects with JICA and ADB. Likewise, the European companies have a strong presence in Africa through projects with the World Bank and the European Investment Bank. Therefore, it might be more beneficial and effective to conduct collaborative projects jointly funded by the public agencies of the two sides, and form international consortiums consisting of European and Japanese companies. For example, allow European companies to join the consortiums for projects in South East Asia and Brazil with JICA and ADB, and let them bring their technical expertise to the table. In return, Japanese companies also get to participate on projects in Africa with WB and EIB.

- **Complementary operation of European and Japanese EO satellites**

Ensuring sufficient temporal resolution is a critical factor for EO products and services, and satellites have to ensure that they can observe a particular phenomenon with short re-visit time. To achieve this, Japan is in a cooperation agreement with the US to set up their satellites in what is known as the *A-train* arrangement. It is a multinational satellite constellation where each satellite complements each other to shorten the re-visit time.

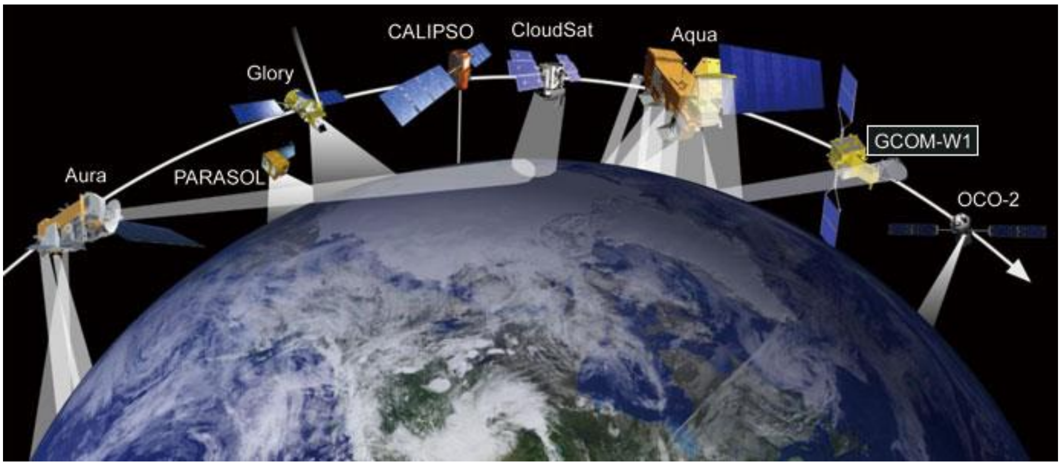


Figure 3-24 NASA and JAXA's *A-Train* satellite configuration (NASA, 2016)

The EU already have their *Sentinel* satellites, and Japan is slowly building up their constellation with the development of the Advanced Optical and Radar Satellites, and the *Global Change Observation Mission* (GCOM). It may be mutually beneficial for both sides to explore the possibility of cooperative operation, where the European and Japanese satellites can complement one another, and greatly increase the overall observational capabilities.

- **Need for a greater international cooperation to monitor growingly global, cross-boundary phenomena**

One of the Japanese EO application companies advised that the extent of the environmental phenomena that need to be observed is becoming more global, transcending over several national boundaries. Japan is subjected to such phenomena, including plant pollens, volcanic fumes and industrial smog, and they require multinational cooperation consisting of both governments and companies to work together and establish a joint monitoring system on a continual basis.

3.6.4 Threats

- **Medium-resolution, high-temporal resolution satellite images from other sources**

The *"New Space"* is rapidly growing in the US with the advent of numerous smallsat manufacturers such as *Planet*, *Planetary Resources*, and *Black Sky Global* just to name a few. These start-up companies are planning to develop a mega-constellation of cubesats to offer near real-time, global observation services. Superior temporal resolution may give these new players a greater competitive edge in application areas dependent on timely delivery of data, such as disaster identification and monitoring.

- **Growing significance of EO downstream applications**

Following on from the previous point, it is absolutely vital for Japan to keep up with the current trends in the international community, and activelJPYgage in discussions with various partner entities. It is said that the EO downstream application is the next key growth area along with GNSS, and it is important for Japan to be involved from early on to maintain its position in the future, or otherwise be left behind.

- **Proliferation of free, open-source satellite data**

Currently, Japan provides most of their satellite data on free, open-source basis for both academic and commercial purposes. The exceptions are ALOS, ALOS-2 and GOSAT, which are provided at a cost for commercial purposes, and for free with some restrictions, for educational purposes. With the world shifting more and more towards open data policy for publicly-funded satellite data, the pressure is on Japan to figure out a way to meet this movement whilst protecting its high-resolution satellite image business.

- **The Remote-Sensing Act of Japan**

The Remote-Sensing Act is aimed at assisting the Japanese EO application industry by placing a clear data policy on what is allowed and not allowed with respect to the handling of satellite images. Some industry members have warned that the new act has to be carefully considered as placing restrictions and approval process may have a negative effect on the companies.

- **High level of standards expected from private sectors**

One of the biggest difficulties about promoting the use of EO data in Japan is justifying the cost. For sectors such as agriculture and forestry, which have been suffering from low profitability over the years, it is absolutely vital to demonstrate clear, concrete benefits from using EO data that compensates for costs and efforts involved in implementing them. Currently, many of the user communities see EO application as having merely a *"potential"* to yield cost reduction and/or profit increase, and don't feel that there is a strong economic case that has direct benefits on their sales.

SWOT Analysis of the Japanese EO Application Industry

Strengths

- Expertise in L-band SAR
- Vast experience in EO data application in agriculture
- Vast experience in disaster management
- Possession of GOSAT – currently the world's only satellite dedicated to monitoring greenhouse gases
- Expertise in most areas of EO

Weaknesses

- Heavy dependence on government-funded projects
- No optical satellite images until 2019
- Possible gap in the Japanese EO program
- Not enough promotion of satellite data for commercial application
- Not understanding the needs of private sectors
- Satellite imagery being too costly for general, private users
- Lack of experience in marine and water-related areas

Opportunities

- Combining SAR images of different bandwidth
- Need for more affordable, medium-resolution satellite images
- Growing demand for alternative purchasing arrangements
- New entrants in the Japanese EO application industry with more commercial outlook
- No company offering value-added, downstream services in Japan
- Needs of the private sector have be better identified
- EU-Japan collaboration in other parts of the world through jointly-funded programs
- Complementary operation of European and Japanese EO satellites
- Need for greater international cooperation to monitor growingly global, cross-boundary phenomena

Threats

- Medium-resolution, high temporal resolution satellite images from other sources
- Growing significance of EO downstream applications
- Proliferation of free, open-source satellite data
- The Remote-Sensing Act
- High level of standards expected from private sectors

Figure 3-25 Results from the SWOT analysis of the Japanese EO applications industry

4 Industry Needs Analysis

As part of the research for the MINERVA project, different potential user communities from both private and public sectors were interviewed to understand their needs and concerns toward EO data. Over 40 interviews were conducted, consisting of company representatives, university researchers and public entities in 8 industries. These industries already are, or have the potential to become an important user of EO data products and services in Japan, and they are:

- Agriculture
- Forestry
- Fishery
- Sea Ice Monitoring
- Urban Infrastructure Monitoring
- Maritime Management
- Disaster Management
- Renewable Energy

For each industry, an overview is given to understand the current state as well as key issues and challenges faced by the industry. This is then followed by analysis of the existing systems and recent developments pertaining to EO application, and finally, discussion on the main needs identified from the interviews. The list of interviewees is given in Table 4-1.

Table 4-1 List of organisations interviewed

Subject Field	Organisation
EO Application Companies	RESTEC
	Satellite Business Network
	Satellite Positioning Research & Application Center
	NEC
	Air Asia Survey
	Kokusai Kogyo
	NTT Data
	Japan Space Systems
	PASCO
	Mitsui Bussan Secure Directions
Government Bodies	JAXA New Enterprise Promotion Dept.
	JAXA Mission Planning Dept.
	Ministry of Land, Infrastructure, Transport and Tourism
	Ministry of Economy, Trade & Industry - Space Industry Office
Forestry	Shinshu University
	Nagano Prefecture Forestry Department
	Hiroshima Prefecture Forestry Research Institute
	Forestry and Forest Products Research Institute
	Sumitomo Forestry
	Kita-Shinshu Forestry Owners' Cooperative
	Nagiso Timbers Ltd.
Fishery	Nagasaki Prefecture Fishery Research Laboratory
	Japan Fisheries Information Service Centre
	Environmental Simulation Laboratory
	Hokkaido University
Oceanography	Kyushu University
& Ship routing	Tokyo University of Marine Science & Technology
	Tokai University
	NYK Line
	Japan Agency for Marine-Earth Science & Technology
	Saga University Inst. of Ocean Energy
Agriculture	Japan Agriculture - Shihoro Branch Office
	Fujitsu Systems Hokkaido
	VisionTech
	Niigata City Council
Urban Mgt. & Infrastructure	Oyo Corporation
	Idea Consultants
	Gosei
	Toa Construction
Misc	Keio University Dept. Of Systems Design Mgt.
	Committee of Japan Space Activities for Safety & Security

4.1 Agriculture

4.1.1 Overview

Traditionally, Japan was a farming country with rice at the center of Japan's economy and culture where farmers paid taxes in the form of rice and other crops up until the late 1800's (MAFF, 2015). It was the dominant industry that employed 50% of the workforce up until the 1940's, but Japan's economic boom that began in the 1950s left farmers far behind in both income and agricultural technology (MAFF, 2015). Since then, Japan's agricultural sector has long been a model of inefficiency: tiny farms burdened by heavy regulation, propped up by government subsidies and protected by a vast array of tariffs and import controls (Spitzer, 2015). As a result, the sector has been steadily declining since the 1980's.

Key Economic Figures (2014/2015) (MAFF, 2015)

- Gross Domestic Output: 4.77 tril JPY
- Gross output: 8.4 tril JPY
- Total no. of farms: 1.377 mil
- Total no. of farm workers: 1.91 mil

Japan is a highly mountainous country with much of the country covered in steep terrain, leaving only about 20% of the land for cultivation, which was approximately 4.5 mil ha in 2015 (MAFF, 2015) as shown in Figure 4-1. The majority of the planted area in Japan is rice paddy fields and feed crops for livestock, but vegetables and livestock generates greater income despite the smaller planted area. Among product categories, vegetable output increased by 200 billion JPY from 1984 to 2014, while rice, livestock and fruit output declined (MAFF, 2015).

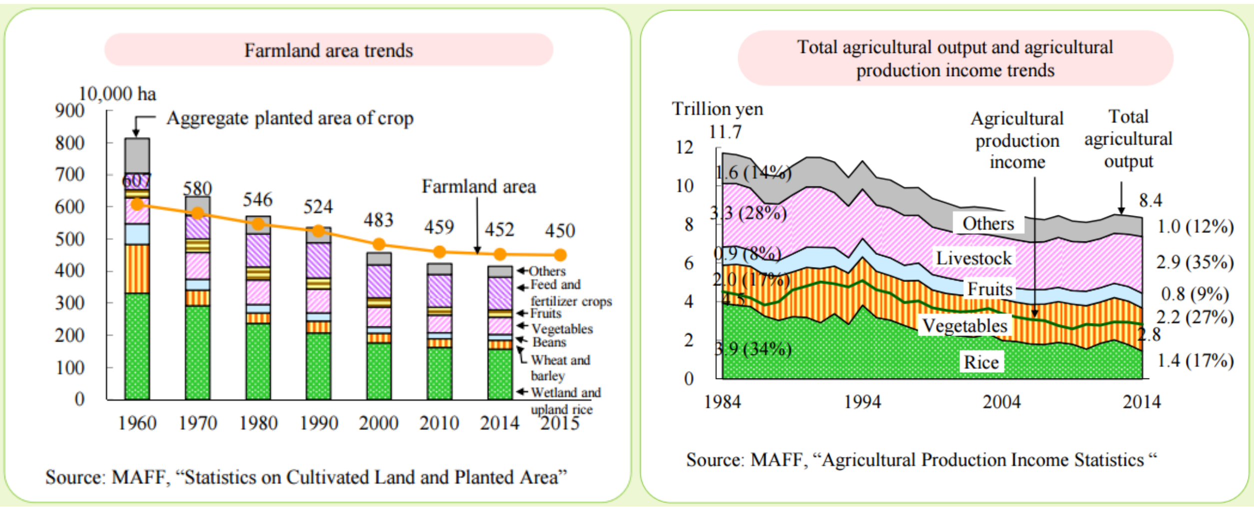


Figure 4-1 Agricultural output trends (left) and farmland area trends (right) (MAFF, 2015)

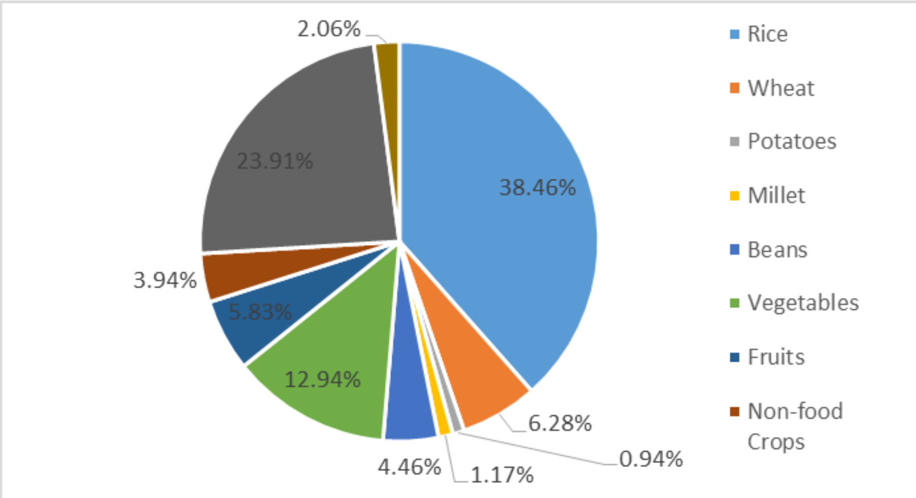


Figure 4-2 Breakdown of main farm goods in Japan (Modified from (MAFF, 2015))

Hokkaido prefecture has the largest area of farmlands and gross agricultural output, which is no surprise as it is the biggest prefecture in Japan and has many flat, open land suited for farming. This is followed by Ibaragi, Chiba, Kagoshima, Kumamoto, Miyazaki, Niigata and Aomori prefectures.

Table 4-2 Different regions of Japan and their agricultural output

Region	Total Farm Area (ha)	Gross Output (tril JPY)	Main Produce	No. of Farms (1000's)	No. of Farm Workers (1000's)
Japan Total	**5,379,000**	**8.65**	**Livestock, vegetables, rice**	**1699**	**1914**
Hokkaido	1,185,000	1.02	Livestock, vegetables, rice	45	98
Tokyo, Osaka & Kyoto	4,194,000	7.62	Vegetables, rice, poultry	1654	1816
Tohoku	990,000	1.36	Rice, vegetables, fruits	321	349
Hokuriku	376,000	0.44	Rice, vegetables, poultry	133	113
Kanto	926,600	1.94	Vegetables, rice, fruits	368	441
Chubu	340,100	0.78	Vegetables, rice, flowers	158	187
Kinki	285,800	0.46	Rice, vegetables, fruits	151	137
Chugoku	328,400	0.43	Rice, vegetables, poultry	155	131
Shikoku	200,300	0.42	vegetables, fruits, rice	98	115
Kyushu	701,200	1.66	Vegetables, Beef, rice	255	322
Okinawa	46,200	0.92	Sugar cane, beef, pork	15	21

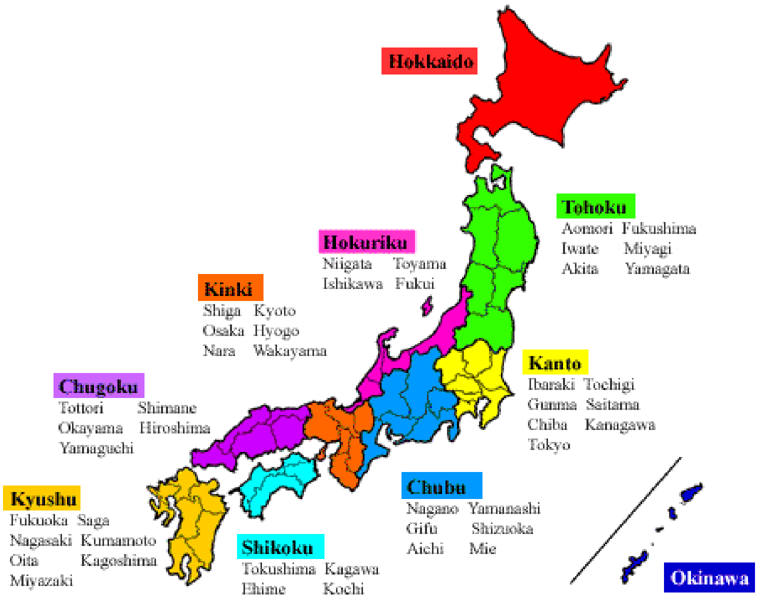


Figure 4-3 Different regions of Japan and the constituent prefectures (ELS, 2016)

The biggest problem with the agriculture industry in Japan is the high fragmentation of farmlands due to large population and shortage of arable land (Kobayashi, 2016). Compared to major European countries, Japanese farmers have significantly smaller amount of land for farming as shown in Table 4-3.

Table 4-3 Comparison of average farm area per farmer between Japan and other countries (Kobayashi, 2016)

Country	Average Area per Farmer (ha)	Ratio with Japan
Japan	2.3	1
UK	78.6	35
France	52.3	23
USA	169.6	75
Australia	2970.4	1309

Consequently, Japanese farmers can't use economies of scale to lower the price, and they have been struggling since the 1960's to maintain production to meet consumer demands, and compete against oversea imports. Except for large farms in Hokkaido and Tohoku regions, the situation has made it difficult for the Japanese farmers to maintain a profit, particularly rice farmers, and the Japanese government has been heavily subsidising their agriculture sector, mainly through tariffs placed on imported rice. The financial situation of different farming categories from the national consensus are shown in Table 4-4 (MAFF, 2015).

Farming Type	Revenue (mil JPY)	Cost (mil JPY)	Profit (mil JPY)	Change from 2013
Rice Farming	2.22	1.95	0.27	- 49.4 %
Dry-Field Farming	8.08	5.62	2.46	+ 8.4 %
Open-grown Vegetables	5.20	3.34	1.86	- 1.4 %
Indoor Vegetables	11.28	7.05	4.24	- 3.3 %
Fruits	5.46	3.59	1.88	- 4.3 %

Table 4-4 Average income per farmer for different farming types

With the aging and declining farmers' population, many of them have either 1) taken up other occupation, 2) reverted to part-time farming, or 3) shifted to growing high-value commodities such as fruits and indoor vegetables. 1) and 2) have resulted in an increase in abandoned or underutilised farm lands, and a decrease in the number of farms. 3) is reflected in the rise of indoor vegetable production described earlier in the section.

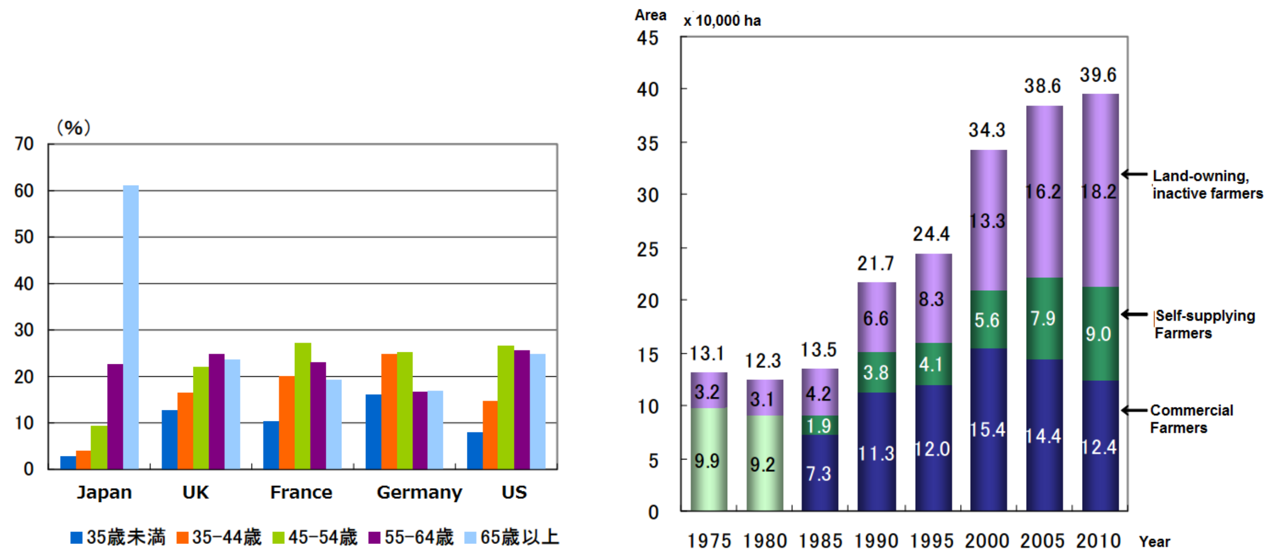
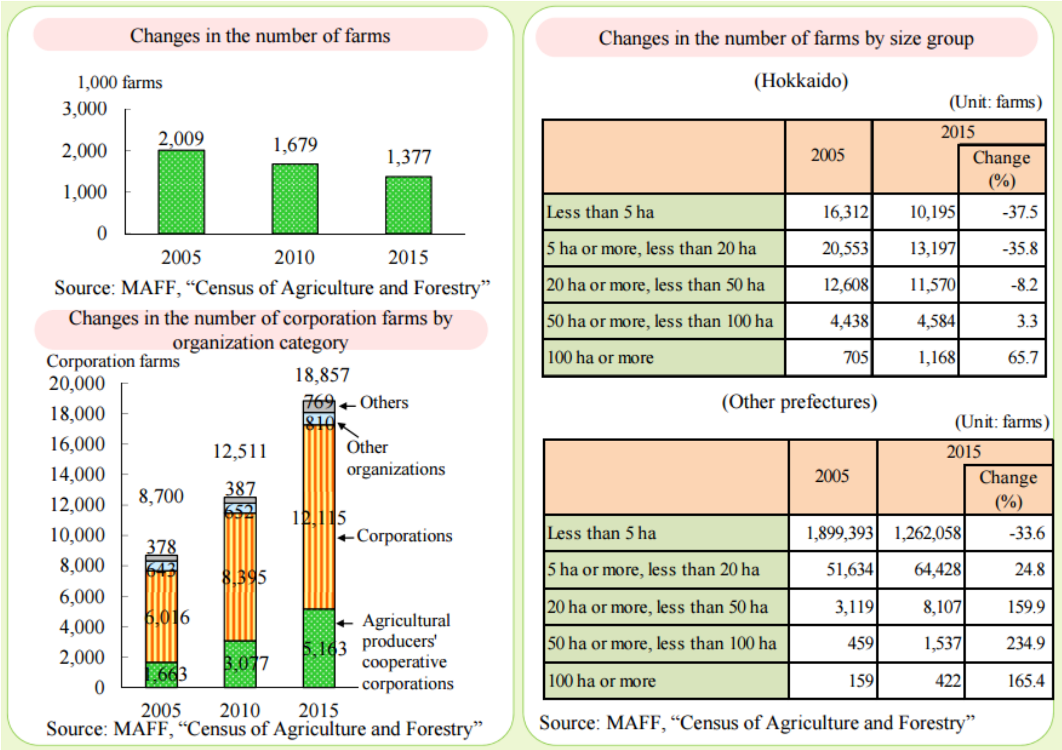


Figure 4-4 Workers' age distribution for selected countries (left) and total amount of land owned by different types of farmers (right) (MAFF, 2015)



(Hokkaido) (Unit: farms)

	2005	2015	Change (%)
Less than 5 ha	16,312	10,195	-37.5
5 ha or more, less than 20 ha	20,553	13,197	-35.8
20 ha or more, less than 50 ha	12,608	11,570	-8.2
50 ha or more, less than 100 ha	4,438	4,584	3.3
100 ha or more	705	1,168	65.7

(Other prefectures) (Unit: farms)

	2005	2015	Change (%)
Less than 5 ha	1,899,393	1,262,058	-33.6
5 ha or more, less than 20 ha	51,634	64,428	24.8
20 ha or more, less than 50 ha	3,119	8,107	159.9
50 ha or more, less than 100 ha	459	1,537	234.9
100 ha or more	159	422	165.4

Figure 4-5 Data on the no. of farms in Japan and the area owned (MAFF, 2015)

To combat the growing problem of abandoned farm lands, prefectural and municipal governments have started consolidating them between farmers, and also selling them to private companies to encourage new entrants into the agriculture business.

4.1.2 Stakeholder Analysis

The agriculture industry in Japan consists of various bodies from both public and private sector as shown in Figure 4-6.

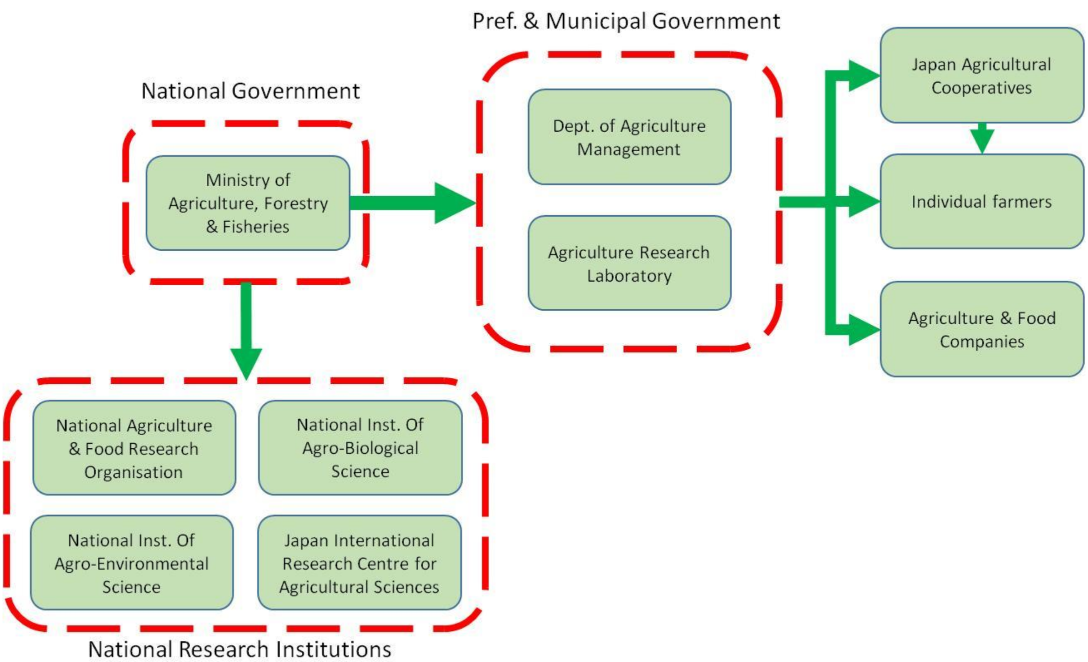


Figure 4-6 Stakeholders of the agriculture industry in Japan

The Ministry of Agriculture, Forestry & Fisheries (MAFF) decides the overall agricultural policies for Japan, and implements them through prefectural and municipal governments. These regional government bodies give guidance to their local agricultural communities to align with the national policies. The regional governments also organise and execute their own pilot projects and technology demonstrations in conjunction with the prefectural agricultural research laboratories to test new farming concepts, such as the use of EO data application. These initiatives often involve forming a consortium between companies, which offer the technical expertise and solutions, and individual farmers and farmers' cooperatives to offer the land to actually implement the technology.

Japan Agricultural Cooperatives, also known as JA or *Nokyo*, is the main administrative body that represents and coordinates 694 regional farmers' cooperatives in Japan. They provide their members support on production, packaging, transportation, and most importantly, technical guidance and coaching on new technologies such as EO data application. As of 2012, JA has approx. 4.6 million official members across Japan, and they have regional branch offices across the country to liaise and collaborate with the local farming communities. The JA branch offices often participate on pilot projects conducted by the prefectural and municipal governments, and often are the key organisation to distribute and promote new technologies among their members.

There are several agricultural research institutions that conduct research at national level. They operate several regional laboratories across Japan, and they also work together with prefectural research laboratories and the regional branches of JA by sharing their research findings and new agricultural techniques and technologies.

In recent years, a growing number of major food product companies and supermarket chains, as well as SMEs in ICT in Japan have decided to go into the farming business. Traditionally, only individual farmers were allowed to conduct farming businesses in Japan, but the change made to Agricultural Land Act in 2009 has made it easier for private companies to acquire farming land and register as a special agricultural corporation. In 2015, the number of special agricultural corporations was 15,106, and it is expected to increase further. This is contrary to the number of farmers and farm management bodies, which has decreased by 16.5% since 2010.

The major food production companies and supermarket chains have purchased abandoned farming land and implemented a very structured and systematic farming approach consisting of very strict logistics management and cost reduction measures in the hopes of making agriculture a profitable business again in Japan. They are mainly focused on high-value commodities such as tomatoes and cherries, which are easier to add commercial value through adjusting the features such as the level of sweetness, but *Aeon Agri*, a subsidiary of a major Japanese supermarket and department store chain *Aeon Co. Ltd.*, has started their own paddy-field rice production since 2014, and is achieving moderate success. The ICT SMEs are also following the trend by utilising their expertise to set up efficient sensor monitoring systems with big data analysis to better manage their production of high-value vegetables.

Some of the Japanese food product companies and supermarket chains that have gone into agriculture business are summarised in Table 4-5.

Table 4-5 Major food companies and companies that have recently gone into farming business

Company Name	Main Business	Total Farm Area (ha)	Main Commodity
Aeon Co. Ltd.	Supermarket chain	121 (18 farms)	Cabbage, rice, corn, leafy vegetables
Kagome Co. Ltd.	Tomato-related products	53 (11 farms)	Tomatoes
Calbee	Potato chips and snacks	7000 (indiv. farmers)	Potatoes
Lawson	Convenience store chain	170 (18 farms)	Leafy vegetables, root vegetables, potatoes
Ito-Yokado Co., Ltd.	Supermarket chain		
JR East	Railway	4 (2 farms)	Tomatoes, rice

Most of the companies operate farms that are inside Japan, but some of them own farms overseas as well, which are managed by their local subsidiaries. *Kagome Co. Ltd.* for example, has major production base s in Australia and Portugal, amongst several other regional offices around the world (Kagome, 2016).

Figure 4-7 Kagome's main farmlands in Japan. The company has 11 large-scale farms totaling to 53 ha to produce 14,000t of tomatoes per year (Kagome, 2016)

Figure 4-8 Kagome's production sites overseas (Kagome, 2016)

4.1.3 Existing Systems & Recent Developments

Smart Agriculture Initiatives

The concept of Smart Agriculture is rapidly gaining momentum in Japan, and more and more prefectural and municipal governments and JA regional offices are collaborating with EO applications companies, ICT start-ups and university research groups to conduct pilot projects in their region. A study has estimated the market size of the ICT smart agriculture will reach approximately 30 bil JPY by 2020. (Kawano, 2016).

The current and recent smart agriculture projects led by various Japanese regional authorities are focusing on the following 3 main areas:

1) Production management via sensor systems, data analysis and cloud operation
2) Precision farming with automated operations farming vehicles using GPS
3) Robots and robotic suits to assist farmers with their day-to-day work

Despite the high level of interest in Smart Agriculture, one must also note that many of the projects are still in feasibility study phase, and only a few of them have become ongoing commercial ventures. Nevertheless, the projects are conducted throughout Japan and some of them are briefly described in Table 4-6. Readers are encouraged to contact MAFF for the full list of all the recent pilot projects on smart agriculture (MAFF, 2016).

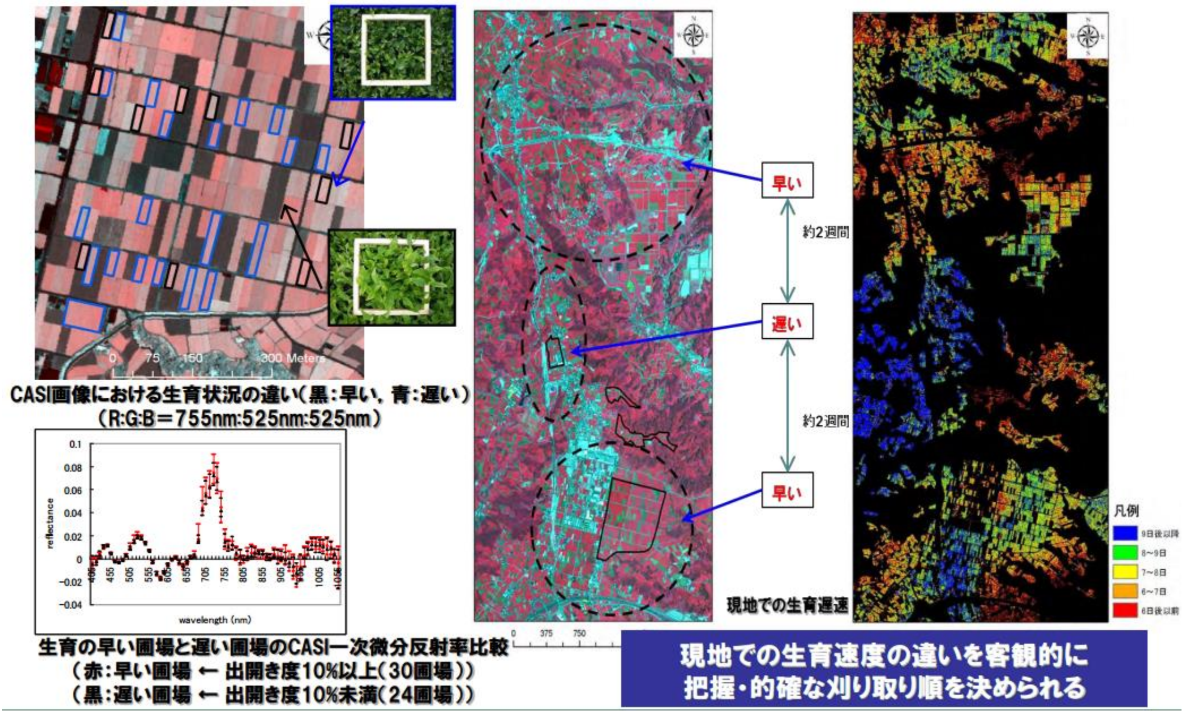


Figure 4-9 Analysis of the tea farm conducted in Saga, where dark green areas indicate tea leaves ready for harvesting (Arai, 2015)

Table 4-6 Examples of Smart Agriculture projects conducted in Japan (MAFF, 2016)

Project Title	Location	Parties Involved	Project Description
Use of Satellite Images to Identify High-quality Green Tea Leaves	Saga Prefecture	Saga University Dept. of Engineering and Science, Saga Prefectural Govt., Kokusai Kogyo	• Take photos of the tea leaves using satellite IR sensors • Identify high-quality tea leaves by determining the nitrogen content of the tea leaves from their reflectance • Separate these tea leaves to produce green tea with higher quality • Successfully achieved value-addition for the local tea industry
Development of Protein Level Map of Rice Paddy Fields	Hokkaido Prefecture	Japan Agriculture Naganuma Branch, Hokkaido Research organisation	• Rice tastes better when it contains lower amounts of protein • Use SPOT Satellite imagery to determine the protein level of rice paddy fields, and colour-code them according to the levels to create a colour map • Farmers can adjust the timing of harvest and the amount of fertiliser • The system has successfully added value to the local rice industry bJPYabling to sell the low-protein rice as a specially branded rice product in the market
Development of Paddy Field Management & Growth Monitoring System	Niigata Prefecture	Narumi Agriculture Co. Ltd., Souen Farm, Ishii Farm	• Register all the paddy fields on aerial photo maps • Visually select paddy fields of interest and input daily work operation via smartphones • Work records are automatically stored and organised to enable yearly comparison and analysis

Notable Domestic Products & Services

Several Japanese EO companies have developed agriculture support software using satellite images and achieved a reasonable level of success.

- *Geomation Farm* – Hitachi Solutions

Geomation Farm (Hitachi, 2016a) is an agricultural information management system developed by Hitachi Solutions. The software allows users to improve operational efficiency and reduce costs by determining the optimum harvest time of wheat and rice crops based on growth forecasting whilst ensuring appropriate application of fertiliser and other agricultural chemicals.

In Japan, the optimum harvesting time for wheat lasts only one to two weeks. If the wheat is harvested too early, additional energy and costs may be incurred in the drying process due to the excess water content. On the other hand, if harvesting is done too late, the risk of grains to germinate increases, resulting in lost commercial value of the crop. *Geomation Farm* uses images from *SPOT* satellites and *WorldView-1* & *2* to provide simple and visual guidance for the users on the best timing to harvest wheat, rice and other crops by colour coding each piece of crop area.

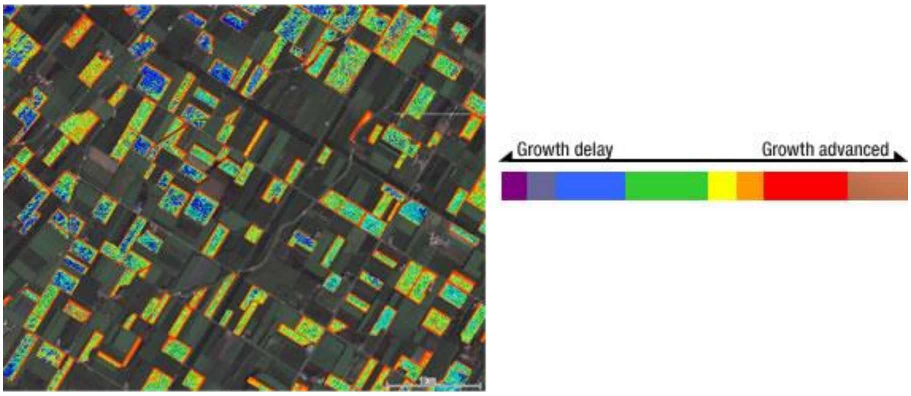


Figure 4-10 Screenshot of Hitachi Solution's Geomation Farm (Hitachi, 2016a)

By knowing the growth progress of each crop area, farmers and managers can adjust the order and the timing of when each piece of land will be harvested. This allows more efficient operation of combine harvestors, tractors and other machineries, resulting in savings in fuel costs and CO2 emissions.

Geomation Farm has already established a stable presence in Hokkaido prefecture, particularly in Tokachi region, where wheat is one of the main crops. The Shihoro branch office of Japan Agriculture has fully backed the software and they have been using it since early 2000. The staff at JA Shihoro conducts the analysis during the harvesting season each year and distributes the information to farmers in the region. Hitachi Solutions has integrated an algorithm to overcome cloud cover to ensure reliable and timely delivery of data.

- *AgriLook* – VisionTech

Agrilook (VT, 2016a) is an online platform which combines data from various EO and meteorological satellite with different spatial resolution and repeat cycle to regularly provide information and analysis to support rice paddy field farming.

Farmers and staff from the local farmers' cooperatives can access the platform as a general or a paid user with greater functionality to:

- View growth progress of the paddy field of interest
- View weather information
- Compare the growth progress against the data from previous years
- Develop a colour-coded, growth progress map to visualise the overall trend
- Manage application of fertilisers and pests
- Monitor the paddy fields via on-site live camera network

By building a one-stop platform that can process and combine several medium to low-resolution satellite data, VisionTech has effectively developed a service with an affordable price and high observation frequency. The company has integrated its own algorithm to overcome cloud cover and made the service available via smartphone and tablets.

Agrilook initially started as a pilot project funded by the Kita-Niigata branch of Japan Agriculture in 2009, and has gained support and trust of the farming communities since then. It is currently used regularly by the rice farmers in Niigata and Ibaragi prefectures.

International Projects

JAXA and the *Remote-Sensing Technology Centre of Japan* (RESTEC) have been active in South East Asia conducting several feasibility studies and capacity building in agriculture. The two organisations are also playing a central role in a multinational, multi-agency collaboration initiative, *Asian Rice Crop Estimation & Monitoring* (Asia-RiCE), which is a component of the *GEO Global Agricultural Monitoring* (GEOGLAM) initiative.

JAXA and RESTEC have developed two software tools, INAHOR (*INternational Asian Harvest mOnitoring system for Rice*; crop planted area estimation software) and JASMIN *(JAxa's Satellite-based MonItoring Network system for Food & Agriculture Organisation Agriculture Market Information System outlook*; agro-met information provision system for outlook). INAHOR estimates rice crop acreage and production using space-based SAR from the ALOS series, RADARSAT-2 and Sentinel-1. JASMIN provides satellite derived agrometeorological information including precipitation, drought index, soil moisture, solar radiation, land surface temperature, and vegetation index (RESTEC, 2016a). The software tools have been tested via several pilot projects and feasibility studies on rice fields throughout South East Asian countries.

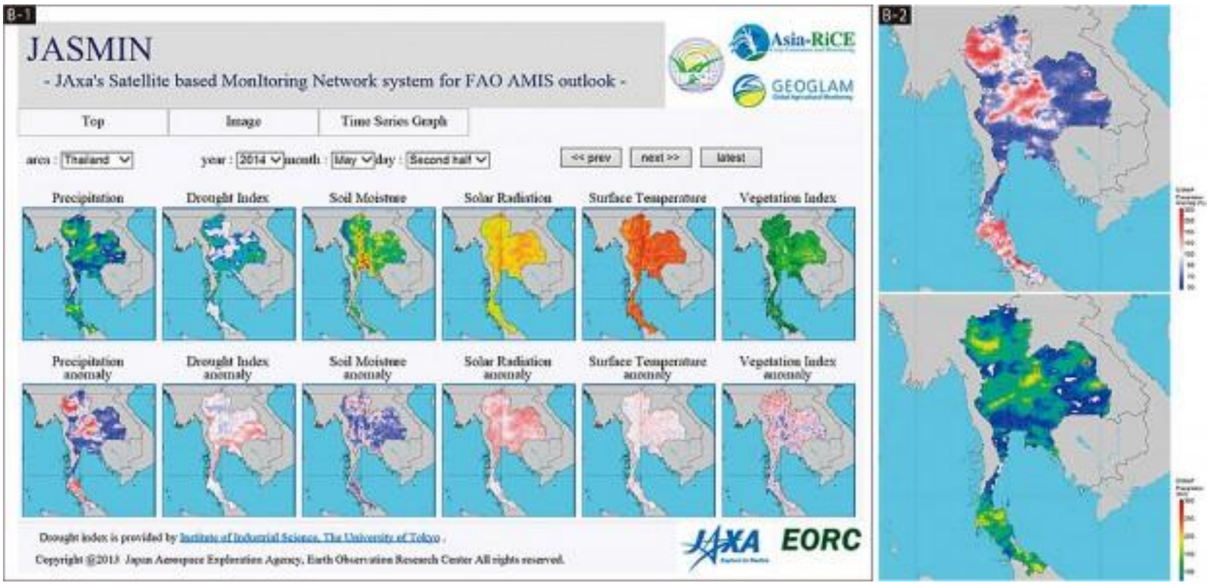


Figure 4-11 JAXA and RESTEC's JASMIN project in Thailand (RESTEC, 2016a)

In addition to the above efforts, the Asian Development Bank (ADB) and the Japan International Cooperation Agency (JICA) have been heavily funding various development projects and feasibility studies in South East Asia and Africa. The trend is expected to continue as ADB announced in 2012 to double their investment in agriculture-related projects and fund US$100-200 mil annually from 2013 and onwards (WSJ, 2016). Many major Japanese EO data application and consultancy companies such as Kokusai Kogyo, Pasco, NTT Data, and Aero Asahi all have long history of taking part in ADB and JICA's feasibility studies.

4.1.4 Needs & Opportunities

It is clear that the Japanese agricultural industry suffers from an aging and declining workforce population, and low profit levels due to inefficient operation. To address these issues, there is a strong need within the Japanese agriculture industry for improved production efficiency by implementing systems that can maximise the production and minimise the amount of human interventions. The findings from the interviews with various stakeholders in the industry identified the following needs and requirements for EO products and services shown in Table 4-7.

Table 4-7 Summary of key needs and requirement from Japan's agriculture industry

Requirement ID	Requirement Description
REQ-AGR-01	Timely acquisition of the satellite image on an area of interest after making a request (eg. 1 week)
REQ-AGR-02	Capability to overcome cloud cover when acquiring optical imagery
REQ-AGR-03	Free, open-source EO data with spatial resolution of ideally 5m, or at least 10m
REQ-AGR-04	Reduction of the minimum purchase area when purchasing satellite images
REQ-AGR-05	Less technically-intensive solution that do not require a high level of remote-sensing knowledge, IT literacy or an extensive IT infrastructure
REQ-AGR-06	A solution that consists of simple and visual agricultural forecasting and includes consultancy and guidance functionality to advise farmers on what they need to do next to maximise their production
REQ-AGR-07	Simple, easy-to-use applications that can be offered online or via smartphones and tablets
REQ-AGR-08	Capability to provide agricultural guidance when subjected to unusual weather
REQ-AGR-09	Functionalities to support various commercial activities – eg. account-keeping, revenue forecasting
REQ-AGR-10	An interface that connects automated driving system of farming vehicles with satellite observation data to automatically guide the vehicles according to crop growth, fertiliser distribution and other relevant data to create a fully-automated crop monitoring and harvesting system
REQ-AGR-11	Capability to monitor and predict growth of other crops & vegetables – eg. tomatoes, wine grapes

Satellite imagery has been long identified as a possible solution bJPYabling more efficient management of farm lands, water and fertilizer. In response to these needs, major agricultural prefectures such as Hokkaido and Aomori requested Japanese EO data companies to develop software using satellite imagery as part of government-funded pilot projects and feasibility studies. However, only a handful of them have succeeded in making it into an ongoing business venture. Interviews with the various stakeholders in the Japanese agricultural industry found the main factors preventing the spread of use of satellite imagery are 1) inadequate spatial resolution, 2) cost of satellite data, 3) unreliable data acquisition due to factors such as cloud cover, and 4) software design unsuited for the end users.

Currently, the most popular application for satellite image is determining the optimum harvesting time for rice, wheat and other cereal crops. The optimum timing is expected to be within days or few weeks, and thus, it is crucial that the image of a farm area is delivered in a timely and reliable manner (REQ-AGR-01), and that it can overcome cloud cover in some way (REQ-AGR-02).

As most of the farms in Japan are close together and only a few hectares each, satellite images must be at least 10 m or less in order to differentiate one farm from another, and to see trends within the farm area (REQ-AGR-03). Clearly, open, free data such as those of Landsat with 30 m spatial resolution is insufficient for Japan, and for this reason, the use of free satellite imagery has been limited to prefectures with large area such as Hokkaido, Niigata and some of the Northern prefectures. Therefore, there is a huge potential for Copernicus to gain a foothold in the Japanese agriculture industry.

The Japanese EO data companies responded to this situation by using commercial satellite data with a spatial resolution of 5 m or less. This certainly allowed more detailed analysis of large and small farms, however, it also significantly drove up the price. As these efforts were funded by the subsidies from the prefectural governments, JA branch offices and other farming communities stopped using the software when the subsidies ceased after annual budget review. The issue of minimum image area that needs to be purchased from satellite data providers also caused cost issues, as only a small portion of image is needed to analyse the small farm lands in Japan (REQ-AGR-04). High cost paired with cloud cover preventing a reliable acquisition of satellite images often discouraged farming communities from continuing the use of satellite data except for a few cases in Hokkaido and Aomori, where the Japanese EO companies managed to develop a cost-effective solutions by carefully balancing the spatial resolution needed and the cost of the commercial satellite data to fit the budget of the users.

Considering that the 1) majority of the workforce in the Japanese agricultural industry is over 60 years of age with rather low IT literacy, and 2) the staff at the prefectural governments and JA branch offices typically change every 2 to 3 years, any agriculture support software using EO data needs to be simple, visual, and easy to use and train (REQ-AGR-05). What the farmers and regional authorities in Japan urgently need is a fully-packaged solution that can provide not just the technical analysis, but also agricultural forecasting and consultancy in order to alleviate the work needed, and maximise their limited human resources

(REQ-AGR-06 & 07). Due to climate change in the recent decades, farmers are subjected to unusual weather more frequently, and they can no longer rely on their intuitions and experience to manage their farms (REQ-AGR-08), and they need to scientific advice on what they need to do next with their farms.

Leading from the above point, another need of the Japanese agricultural industry is a solution that can also support with various commercial activities, such as day-to-day management and accounting-keeping of farms (REQ-AGR-09). As more and more IT and food production companies enter the agriculture business, there is a potential need for IT solutions that can conduct revenue forecasting for acquisition of abandoned arable farm lands for example.

Another strong growth area in Japan is incorporating satellite images to assist automated driving of tractors and other farming vehicles. This is particularly the case in the *Tokachi* area in Hokkaido, where automated driving of farming vehicles is already widely implemented for harvesting wheat. A system which can guide the tractors automatically according to the analysis of the satellite images has a huge potential in Hokkaido and other Northern prefectures (REQ-AGR-10).

Lastly, the growing number of Smart Agriculture projects in Japan and the number of food and ICT companies entering the farming business imply that there is a whole new community of users that EO data companies can approach. Unlike traditional farmers with limited IT literacy or public bodies where their staff changes every 2 to 3 years, these private entities are better suited to utilising satellite-based solutions as they have adequate, dedicated human resource and technical abilities to use them. So far, no EO data company in Japan has expressed interests in this new user community, which suggests it may serve as a new avenue of possible collaboration between the EU and the Japanese companies to explore the needs. As most of the private food companies and ICT start-ups are currently focusing on high-value fruit and vegetables to maximise the profit from limited available land, such as tomatoes, cherries and wine grapes, there is also an opportunity to investigate whether satellite images can be utilised for commodities other than rice and cereal crops (REQ-AGR-11).

4.2 Forestry

4.2.1 Overview

Japan is one of the countries with the highest percentage of forest area in the world. Forests accounts for 67.4% of the total land area of Japan (37.79 mil ha), which makes it 18th in the world behind countries such as Finland and Sweden (Durst, 2010).

Key Economic Figures (2014/2015) (MAFF, 2015).

- Gross Domestic Product: 180 bil JPY
- Gross Output: 451 bil JPY
- Total forest area: 25.08 mil ha
- Total no. of forest workers: 51,200

Most of the forests in Japan are situated in the remote mountain areas spanning from the centre to north-eastern parts of Japan. The prefecture with the largest area of forest is Hokkaido with 5.5 mil ha, followed by Iwate, Nagano, Fukushima, Gifu, Niigata, and Akita, all of which holds more than 0.8 mil ha of forest. The main types of tree grown in Japan are Japanese cedar (44%), Cypress (25%) and Larch (10%) (MAFF, 2015).

53% of forests in Japan are natural forests, 41% are planted forest and remaining 5% consist of forest land without trees, such as logged over forests and alpine. Between natural and planted forests, 42% of forests are publicly owned, and 58% are privately owned, which consists of largely independent, small-scale forest owners and the rest being timber companies (MAFF, 2015). The ratios of natural/planted forests and different ownership types have been reasonably consistent over the years.

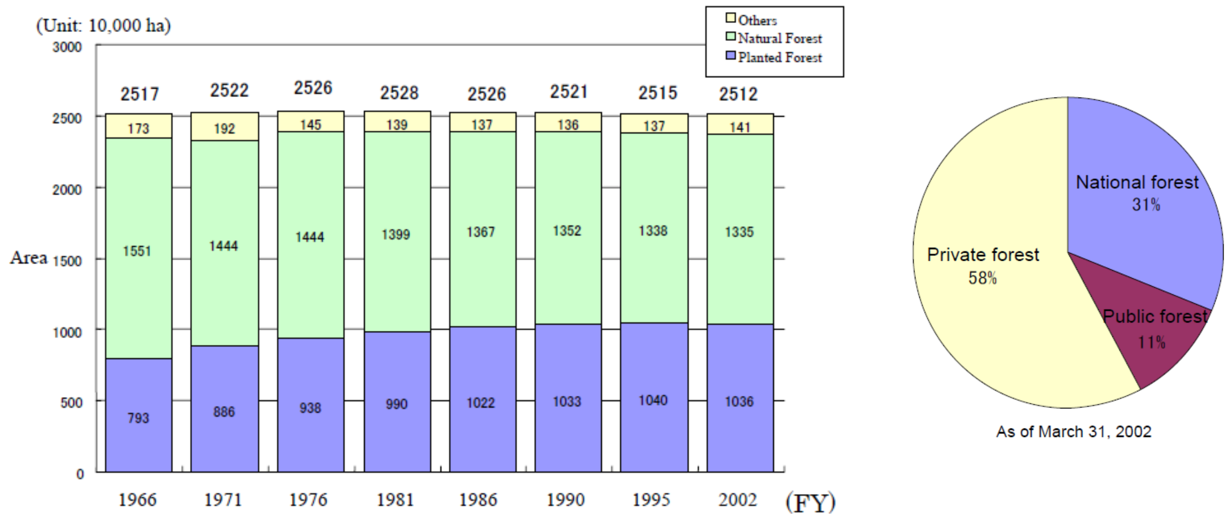


Figure 4-12 Ratio of Japan's natural and planted forests (left) and national, public & private forests (right) (MAFF, 2015)

Despite the large and abundant forest area, Japan's forest resources have not been well developed and the forestry industry makes only a small contribution to the Japanese economy. In 2014, the annual GDP of the forestry industry was 180 bil JPY, which represents a mere 0.04% of the country's total GDP, and it has been consistently low between 0.03 – 0.04% since 2000 (MAFF, 2015). Similarly, the gross output has been on a declining trend since the peak in 1980.

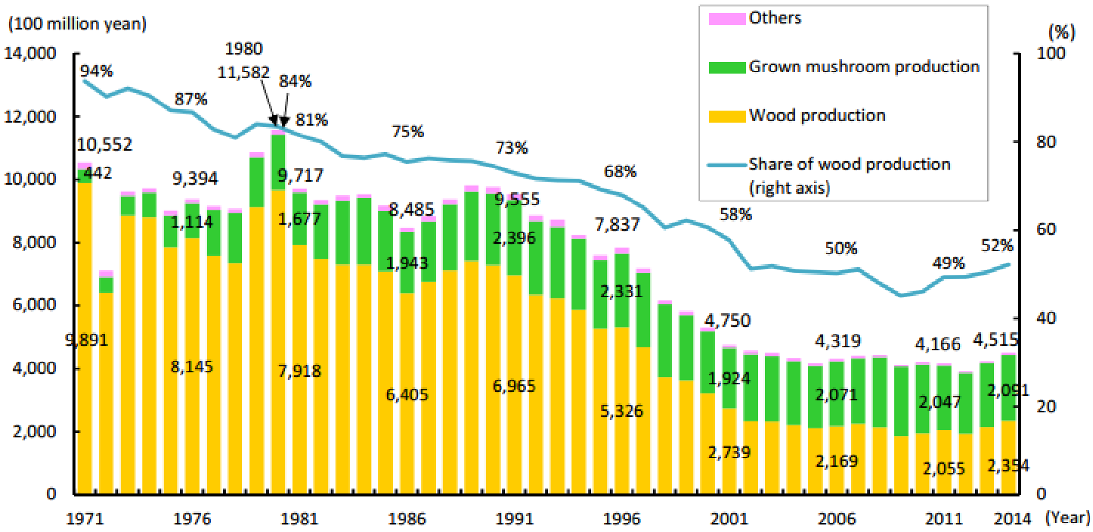


Figure 4-13 Japan's forest industry's gross output over the years (MAFF, 2015)

The main reason for this small economic performance is that although Japan currently has approx. 4,900 mil m^3 of growing stock as shown in Figure 4-14, but only 19 mil m^3, or 0.4% is actually utilised for commercial use as shown in Figure 4-15.

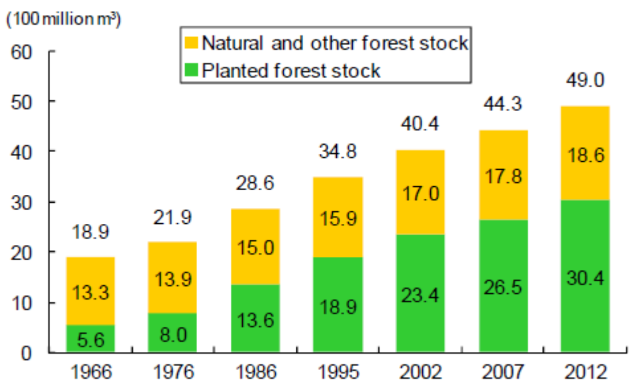


Figure 4-14 Japan's growing wood stock (MAFF, 2015)

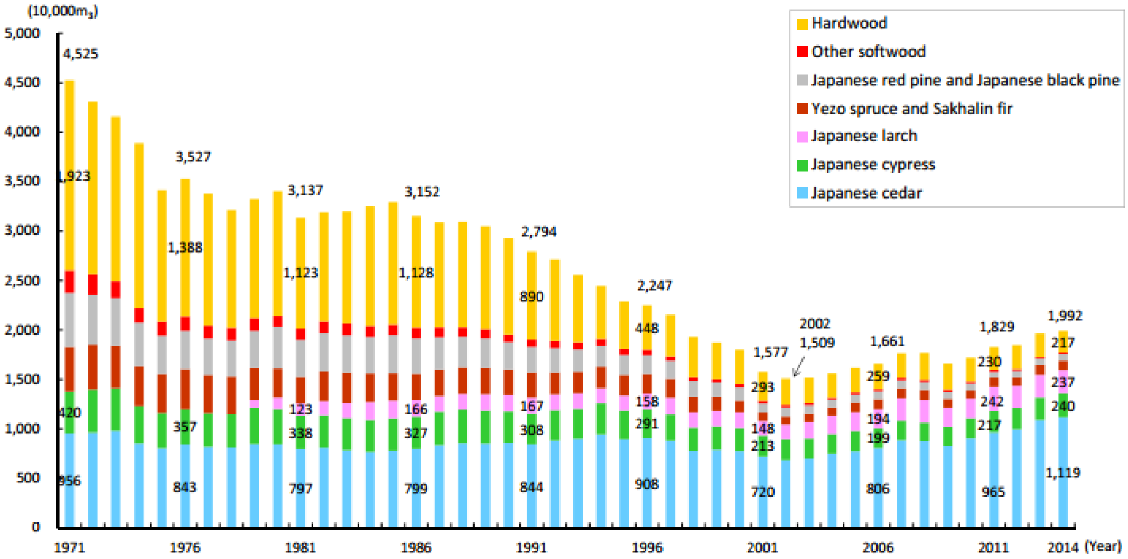


Figure 4-15 Japan's wood consumption over the years (MAFF, 2015)

In 2012, Japan's consumption of timber and wood products amounted to 70.6 mil m^3, but only 27.8% of this was produced in Japan and the rest was imported from overseas (MAFF, 2015).

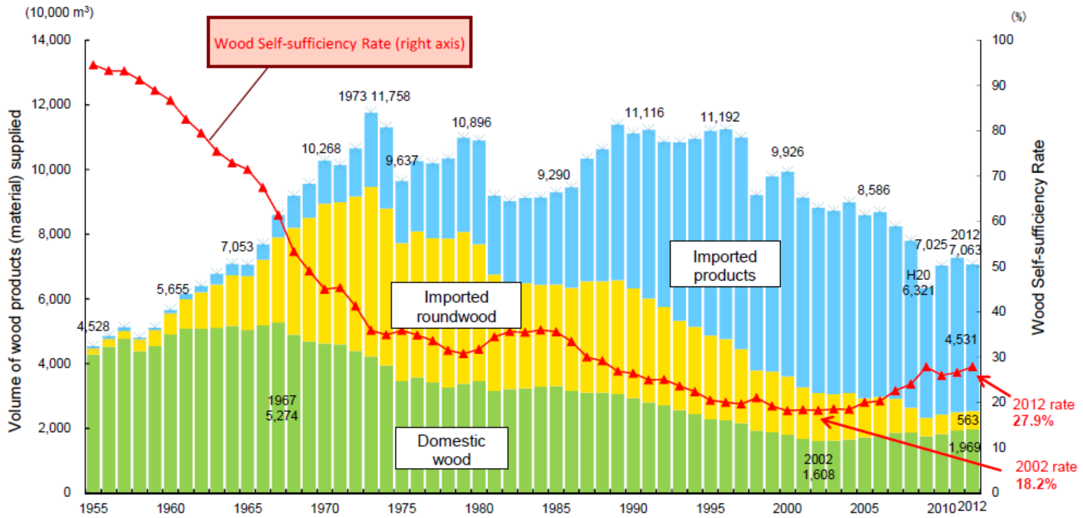


Figure 4-16 Japan's domestic wood consumption compared to that from overseas imports (MAFF, 2015)

The main factor for the decline of the Japanese forestry industry is the harsh working environment, and the lack of flat grounds. The steep terrains of Japan, where the majority of the forests are situated, have prevented the industry from installing access roads and work areas to assist the logging operation. This limited the use of larger, more efficient logging machinery, and forced the industry to resort to traditional methods using ropes and smaller machinery. This reduced the overall operational efficiency and drove up the production costs, leaving very little profit for the forest owners. The data published by the Forestry Agency shows that the average annual profit of the forestry owners was only 113,000 JPY in 2013, and even those with 20 – 50 ha of forest made about 670,000 JPY annually (MAFF, 2015).

The harsh environment also prevented forest owners from maintaining their forests regularly, which left the forests to be overcrowded with poor-growing, thin trees, and the resultant timber quality declined.

Another important factor is the small forest size and high fragmentation of private forests in Japan. In the 2010 Forestry Consensus, the total number forest owners with more than 1 ha of forest amounted to approximately 910,000. Only a small portion from this participates in commercial activities, and most of them are estimated to be inactive, or attend to their forests only part-time. The forest owners that take part in commercial activities are known as the Forestry Management Bodies, and in 2014, there were 140,186 forestry management bodies in total (MAFF, 2015). This high fragmentation and small land ownership have made it difficult for owners to put economies of scale into their business.

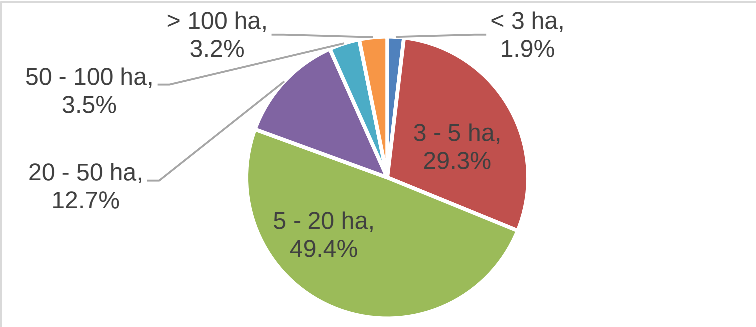


Figure 4-17 Breakdown of the area owned by farmers in Japan (Modified from (MAFF, 2015))

Due to the factors above, the Japanese forestry industry couldn't keep up with the domestic demand during the Japanese boom era in the 1960's and 70's, and got overtaken by cheaper imported timber. The low profitability and business prospects of the industry have discouraged new entrants into the industry. As a result, the industry is suffering from declining and aging workers population, which is shown in Figure 4-18. Most of the forest owners have either abandoned their forests or work only part-time, which further exacerbates the problem due lack of maintenance.

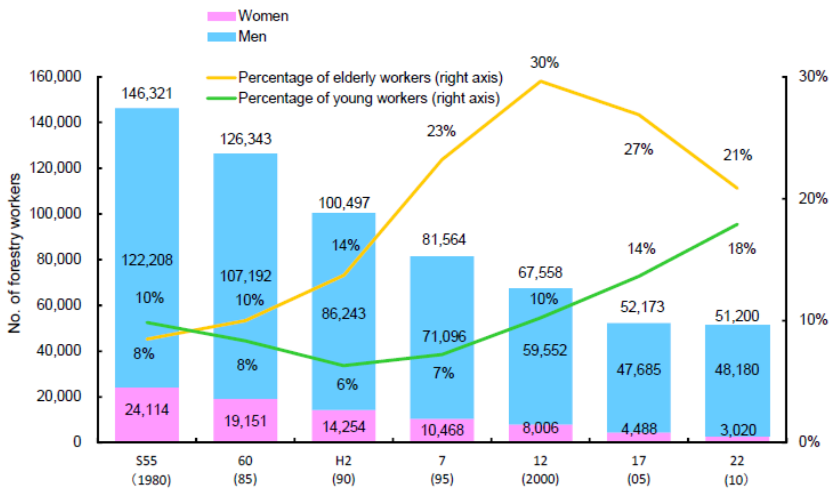


Figure 4-18 Workers' population in the Japanese agriculture industry (MAFF, 2015)

4.2.2 Stakeholder Analysis

Various bodies involved in the forestry industry can be split into national, prefectural and private level. The overall relationship is shown in Figure 4-19.

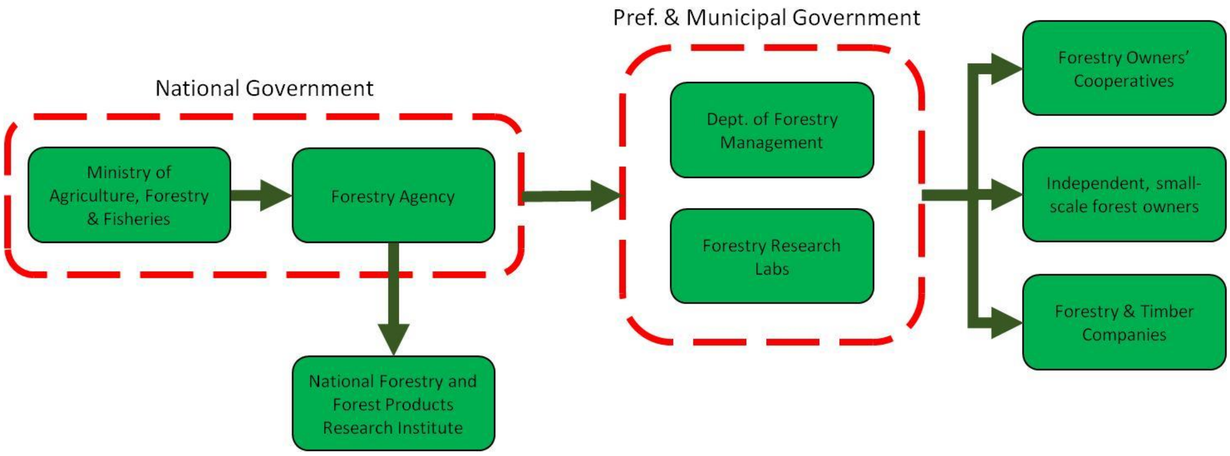


Figure 4-19 Stakeholders of the forestry industry in Japan

The Forestry Agency is an extra-ministerial bureau of the Ministry of Agriculture, Forestry and Fishery, and it is responsible for policy matters pertaining to sustainable growth of forests, stable supply of forest products, growth of the forestry industry, and promotion and support of national forests.

Most prefectural and municipal governments have a dedicated department for forestry policy and industry support. They liaise with the Forestry Agency to implement the policy to their local forestry communities, as well as executing and managing pilot projects on satellite application. Most prefectures have started using GIS for manage their forests.

The National Forestry & Forest Products Research Institute (FFPRI) and the prefectural forestry research laboratories are purely scientific entities and they conduct forestry research in topics relevant to Japan and their prefectures. FFPRI occasionally collaborate with entities overseas.

The prefectural governments and their research laboratories offer guidance for their local forestry industry and the forest owners' cooperatives. The forest owners' cooperatives are joint management bodies where individual forest owners can join. These bodies are typically responsible for most of forest maintenance activities including planting, weeding and thinning, and most of small-scale forest owners entrust the management of their forests to them.

The private company in Japan for forestry, timber production and other wood products is Sumitomo Forestry Co., Ltd. (*Sumitomo Ringyo*). The company is one of the largest land owners in Japan, and has a total of 42,247 ha of forests, consisting of natural and planted forests.

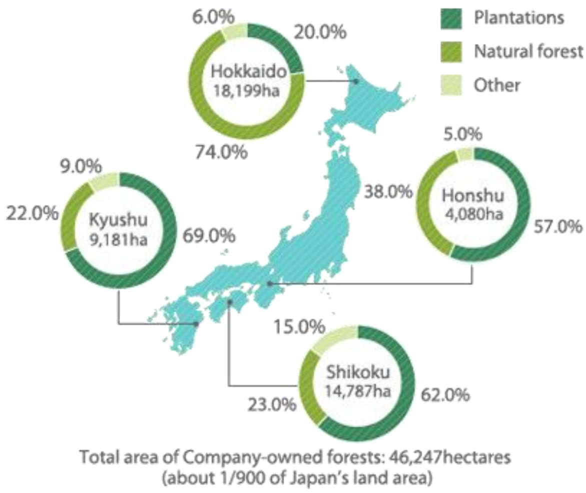


Figure 4-20 Amount of forest owned by Sumitomo Ringyo in different parts of Japan (Sumitomo, 2016)

4.2.3 Existing Systems & Recent Developments

New Forestry Policy

The main issues with the Japanese forestry industry are 1) the high fragmentation of small forests with unclear boundaries and ownership, 2) the mountainous environment preventing support infrastructures, such as forestry roads, to be installed, and the two leads to 3) inefficient maintenance and logging practices.

The Forestry Agency is aware of the state of its industry and to address the points 1 and 2, they announced the Forestry Industry Redevelopment Plan in 2010 to promote growth of the Japanese forestry industry and improve its supply of timber products. The plan aims to increase Japan's self-sufficiency rate for timber from 21% to 50% and production from 1.8 bil m^3 to 4 – 5 bil m^3 by 2020, by implementing 1) better forestry management practices and technology, 2) better utilisation of forest resources, and 3) review of relevant regulations and grants to support the forestry industry more effectively. Leading from this, the agency also revised the Forestry Act in 2012 to promote "coordination and consolidation of forestry practices" among small-scale forest owners. The agency is supporting field surveys and other activities to enable zoning and monitoring of individual forests, and also introducing "Cooperative Forest Management Area" between private forests and National Forests to consolidate forestry activities. The agency is also looking to develop forestry road network to support forestry activities. Thus, the government is working towards meeting the needs of the industry, and the industry is gradually changing.

Smart Forestry Initiatives

The above government policies has prompted several prefectural governments and city councils to get on board, and implement various *Smart Forestry* initiatives to re-energise and strengthen their local forestry industry. Some of the recent Smart Forestry initiatives related to remote-sensing, ICT and new technologies are listed in Table 4-8.

Table 4-8 Examples of Smart Forestry projects conducted by Japanese prefectures

Region	Initiative Description
Maniwa City, Okayama Pref.	Digital forestry management through utilisation of drones and ICT infrastructure
Yamaguchi Pref.	Utilisation of aerial laser observation to develop forestry cloud system
Shiojiri City, Nagano Pref.	Development of a biomass power generation plant
Tokushima Pref.	Introduction of heavy duty, mobile forestry machinery for increased cutting operation

The Smart Forestry initiatives among the Japanese regional governments indicate that the forestry industry is slowly embracing new technologies to shift to more modern, ICT-based operational practices. Maniwa city for example is fully embracing this new trend, and is hoping to achieve 2 bil JPY in revenue by 2017 after installing various ICT-based practices (Tokyo IT News, 2016).

Notable Domestic Products & Services

There have been some commercial activities with EO for the forestry industry in Japan. Companies such as Kokusai Kogyo, PASCO, and Asia Air Survey, have been using aircraft laser, LIDAR, and commercial, high-resolution satellite images such as IKONOS to develop GIS software for forest monitoring and management.

These GIS software are gaining recognition in Japan, and all of the 47 prefectural governments have implemented some level of GIS analysis into their forest management practices. However, the high cost of the data sources has made the software prohibitive for individual and small-scale forest owners, except for large forestry companies such as Sumitomo Forestry.

Asia Air Survey conducted a forestry analysis for the Saga prefectural government using aircraft laser observation. The Digital Elevation Model (DEM) and Digital Surface Model (DSM) from the observation were used to identify tree apexes, which then allowed tree height and tree trunk diameter to be determined. The data was then used to estimate the forest density, amount of yield and biomass, and incorporate these parameters into a forestry GIS and mapping data to enable zoning and management of individual forests. In 2014, Asia Air Survey started new business of ICT-based forest management service using aerial laser surveying in Japan , and the pricing is 3,000 – 4,000 JPY per hectare (Shinken, 2016a).

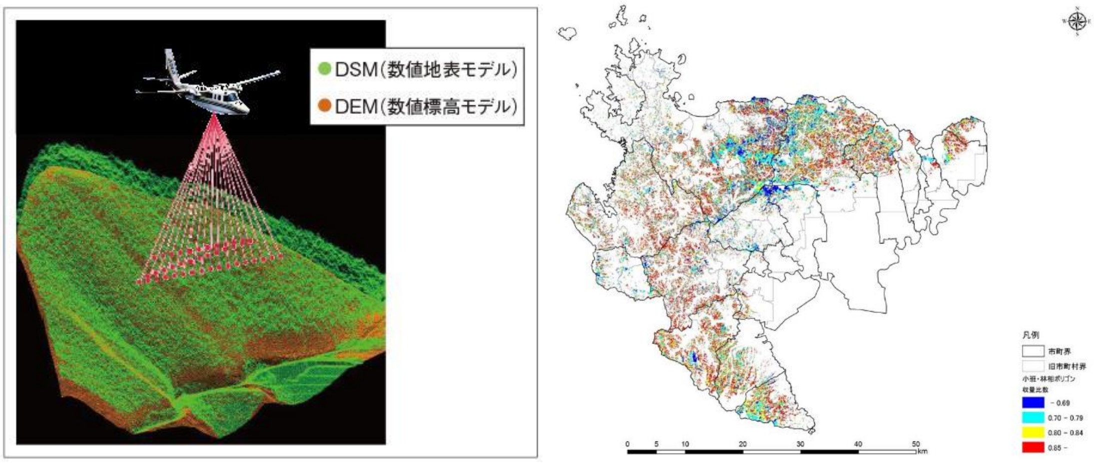


Figure 4-21 Air Asia Survey's forest survey using aerial laser (Shinken, 2016a)

Kokusai Kogyo has developed a software with very similar capabilities using aerial ortho images (visual and infrared) to zone the forest into different tree types and estimate the expected timber volume.

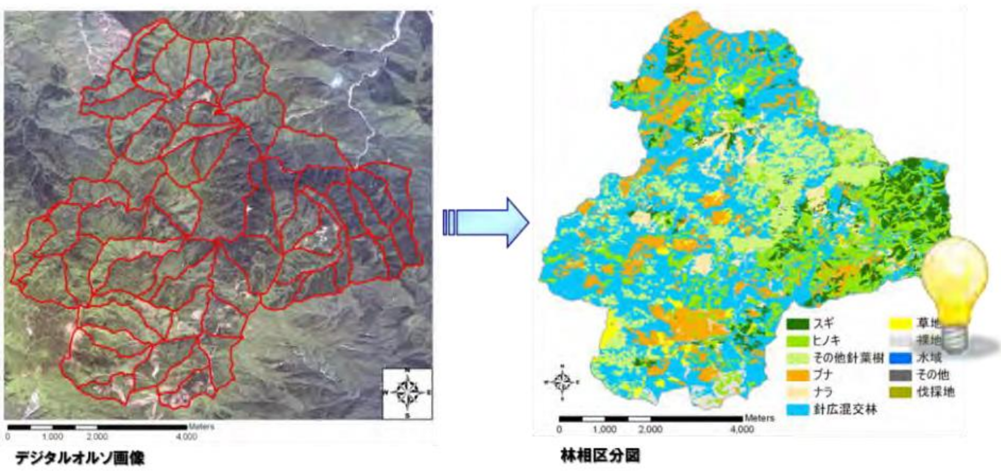


Figure 4-22 Kokusai Kogyo's forest characterisation project (Arai, 2015)

PASCO has developed a software called the *Forestry GIS Cloud Service*, which has similar functionalities but more tailored towards assisting various administrative tasks pertaining to forestry management such as forest log keeping, forest cutting and replanting record-keeping, and management of surrounding roads and other operational activities.

International Activities

As it is the case with agriculture, almost all of the Japanese EO-related companies involved in forestry are far more active overseas than in the domestic market. Free and open-source satellite images such as Landsat with low to medium resolution is better suited for serving the needs of developing economies that do not have the funds nor the necessary infrastructure to monitor and manage their forests.

Through the funding provided by the Japanese government's ODA or JICA, Japanese companies such as Kokusai Kogyo, Air Asia Survey, NTT Data, and PASCO have actively been conducting several feasibility studies and capacity-building projects in forestry monitoring and management for South East Asian countries and others, to assist with their participation in REDD.

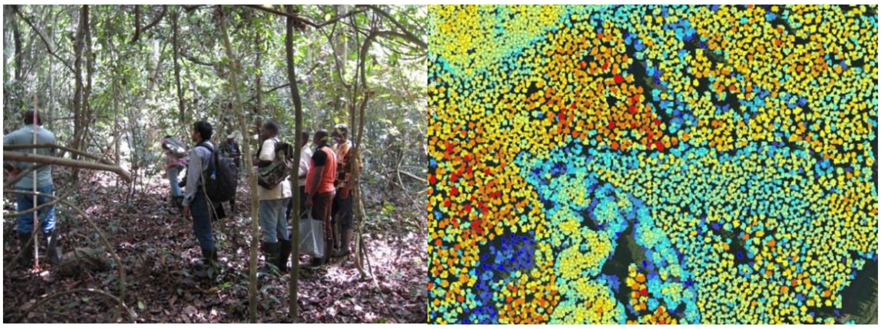


Figure 4-23 Forest surveying work done as part of REDD project in Sri Lanka (Arai, 2015)

As a reference, some of Kousai Kogyo's overseas projects related to forestry are summarised below. For the full details of the projects, readers are encouraged to refer to the company's website.

Project Title	Program for Forest Information Management
Country	Laos
Period	Sept 2009 – Present
Aim	To assist Department of Forestry of Ministry of Agriculture and Forestry to appropriately manage forest resource information necessary to promote REDD.
Action	Kokusai Kogyo carried out the basic design study, and is providing consulting services and technical assistance with: • Construction of the Forest Resource Information Centre • Provision of IT equipment for satellite image analysis • Development of technical skills for forest surveys

Project Title	Forest Conservation Program / Capacity Development on Forest Resource Monitoring for Addressing Climate Change
Country	Papua New Guinea
Period	Jun 2011 – Mar 2014
Aim	To develop the capacity of senior personnel of the Forest Authority with the utilisation of satellite imagery and GIS/database to monitor forest resources.
Action	Kokusai Kogyo executed various capacity-building activities including: • Setting up the national forest cover map using remote-sensing technologies, and forest resource database • Provision of satellite imagery and aerial survey data, SW, and surveying equipment

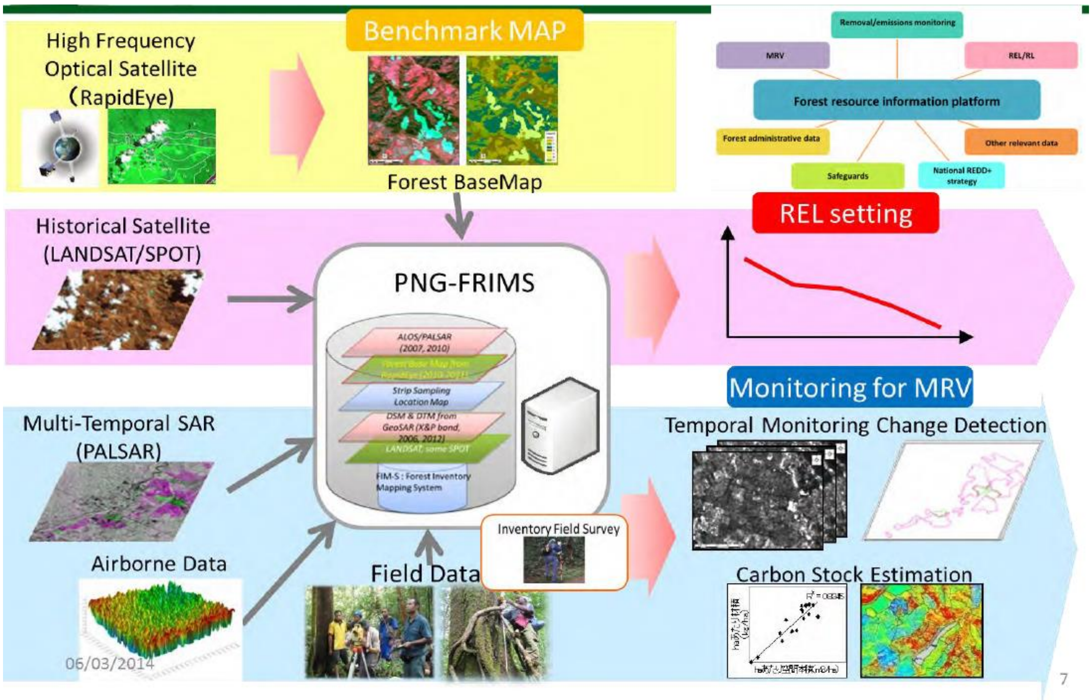


Figure 4-24 Summary of Kokusai Kogyo's REDD project in PNG (Arai, 2015)

RESTEC has also established a strong working relationship with Brazil, and have been actively providing deforestation analysis to combat illegal logging in Brazil's Amazon rainforest since 2009. The project was funded by JICA in cooperation with the *Brasilian Institute of Environment and Renewable Natural Resources* (IBAMA) and the *Science and Technology Unit of the Federal Police* (DPF).

The data from the PALSAR instrument on-board ALOS was used for the analysis. PALSAR is an L-band SAR instrument, and its long wavelength makes it particularly effective in penetrating not only cloud cover but also forest leaf cover to identify tree trunks. The project was hugely successful in identifying illegal logging activities, and RESTEC continues to work closely with the Brazilian entities now using the L-band SAR data from ALOS-2 after ALOS retired in 2011.

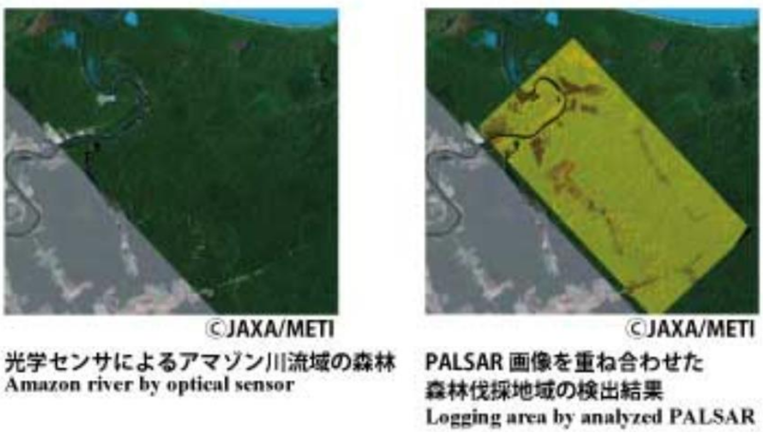


Figure 4-25 RESTEC forestry project in Brazil Amazon forest (RESTEC, 2016)

4.2.4 Needs & Opportunities

Similar to agriculture, the biggest challenge that the Japanese forestry industry is facing is the lack of manpower to maintain the forests efficiently. To address this issue, they need to optimise their limited human resources to monitor and maintain the forests more efficiently. Because Japan has extremely large amount of forests and so far, Japanese EO companies haven't actively addressed the industry's needs, the forestry industry has huge potential for further development. The key needs and requirements from the interviews are summarized in Table 4-9.

Table 4-9 Summary of the key needs and requirements from the Japanese forestry industry

Requirement ID	Requirement Description
REQ-FOR-01	Capability to identify individual tree as well as tree type
REQ-FOR-02	Affordable, or free satellite data with spatial resolution of at least 5 m, ideally sub-meter resolution
REQ-FOR-03	Capability to determine tree height, trunk thickness, and amount of biomass
REQ-FOR-04	Better method to identify and characterise broad-leaf trees
REQ-FOR-05	Overcome cloud cover to ensure timely delivery of images
REQ-FOR-06	Temporal resolution not so important; 1-2 observations per year
REQ-FOR-07	Capability to take images covering an area in the order of 100 – 1000 km^2
REQ-FOR-08	Functionality to determine optimum logging approach and transportation route to assist operations.
REQ-FOR-09	Capability to identify trees damaged by pests and diseases, or predict their outbreak
REQ-FOR-10	Affordable pricing that caters to the typical annual revenue of most independent, small-scale forest owners (110 – 700K JPY)

There is a strong need from the Japanese forestry industry for software tools that can assist with 1) zoning individual forests, and 2) identify individual trees as well as their physical characteristics, to enable forestry organisations to conduct forest planning, monitoring and yield prediction with smaller manpower (REQ-FOR-01). To support these activities, satellite image with a resolution of 1 m would be ideal (REQ-FOR-02). Several regional authorities and forestry research bodies have used commercial satellite images such as those from IKONOS, but these remained as one-off cases due to the high cost.

Currently, all prefectural governments conduct aerial surveys to collect forest information once every 5 years using LIDAR and other laser profiling methods with a spatial resolution of 0.4 m, and distribute the information to forestry owners' cooperatives at a cost. The cost of aerial survey is in the order of 100,000 to over 1 mil JPY, which does place some limitation on the frequency at which they can conduct the survey.

Therefore, there is a strong need for an affordable data for forest monitoring and surveying, and satellite remote-sensing is attracting interests in the recent years as a possible cheaper alternative. There may be an opportunity for European entities to collaborate with the Japanese counterparts to explore the use of medium-resolution data from Sentinel-1 and 2, whilst maintaining the spatial resolution required and affordability.

Interviewees expressed strong enthusiasm for information on the number of trees, tree types, as well as height, trunk diameter and the amount of useful biomass (REQ-FOR-03). They advised that such information would greatly assist in creation of tree type distribution map. They also mentioned the need was for an improved algorithm to better identify broad-leaf trees (REQ-FOR-04). The algorithm to identify tall, thin coniferous trees is fairly well-established, whilst broad-leaf trees are harder, as the branches spread more widely, making it difficult to differentiate individual trees.

Like agriculture, products and services using EO data have to be able to overcome cloud cover (REQ-FOR-05), but the timing is as not as strict as observations only need to be conducted once or twice a year (REQ-FOR-06) due to long growth span of trees.

It was mentioned earlier that the majority of Japanese forests is located on steep terrains, which makes it difficult to carry out logging and maintenance activities, and transport the trees that have been cut. Therefore, the interviewees expressed advised potential EO products and services need to be able to determine optimum logging approach and transportation route using ground elevation data for example (REQ-FOR-08). Additional functionalities such as expected revenues from the logs obtained and other account-keeping functions would also be of interest of the Japanese forest owners.

Lastly, the damage to forests caused by pests and diseases is a major issue among the forest owners in Japan. The two main problems are;

- Pine wilt disease – Pine nematodes carried by the Japanese pine sawyer beetle cause the disease by invading the body of a tree.
- Collective dieback of deciduous oak triggered by Raffaelea quercivora transmitted by the oak platypodid beetle (Platypus quercivorus)

If satellite imagery can be used to predict the outbreak of diseases and pests, and monitor the extent, the authorities can take preventive and damage mitigation actions (REQ-FOR-08). This may also open up new opportunities to collaborate with companies providing insecticides and other chemical products to develop fully-packaged, pests and disease prediction and control services.

4.3 Fishery

4.3.1 Overview

Japan is surrounded by the sea, and the custom of eating fish dates back over 3000 years (Facts & Details, 2016). Naturally, Japan is one of the world's largest consumers of marine products, and in terms of tonnage of fish caught, it is ranked second in the world behind China. It is the largest fish-eating nation in the world, consuming 7.83 bil tonnes of fish in 2013, which is equivalent to about 10% of the world's catch (Facts & Details, 2016).

Key Economic Figures (2014/2015) (MAFF, 2015):

- Gross Domestic Product: 713.8 bil JPY
- Total Output: 1.50 tril JPY
- Total no. of workers: 195,000

There are four sea currents around the Japanese archipelago as shown in Figure 4-26. The regions where warm and cold currents meets produce large volumes of plankton, which make them rich fishing grounds by gathering migratory fish. These mainly consist of Pacific saury, mackerel, jack mackerel and sardines, and are staple part of Japanese diet. Fishery in Japan is divided into four main categories shown in Table 4-10.

Fishing Type	Target Fish Species	Vessel Tonnage
Far-seas (outside the Japanese EEZ)	Skipjack tuna/Bonito, Tuna, Salmon	150 – 500
Offshore (> 5 km from the coastline)	Sardines, Horse mackerel, Skipjack tuna/Bonito, Saury	20 – 150
Coastal (< 5 km from the shore)	Sardines, Horse mackerel, Squid, Mackerel, Shellfish	5 – 10
Coastal Aquafarming	Shellfish, Seaweed, Snapper, Eel, Yellowtail	NA

Fishing Type	Target Fish Species	Vessel Tonnage
Far-seas (outside the Japanese EEZ)	Skipjack tuna/Bonito, Tuna, Salmon	150 – 500
Offshore (> 5 km from the coastline)	Sardines, Horse mackerel, Skipjack tuna/Bonito, Saury	20 – 150
Coastal (< 5 km from the shore)	Sardines, Horse mackerel, Squid, Mackerel, Shellfish	5 – 10
Coastal Aquafarming	Shellfish, Seaweed, Snapper, Eel, Yellowtail	NA

Table 4-10 Main types of fishing in Japan and the relevant fish species caught (Shizuoka, 2016)

The Japanese fishing industry has been declining since the peak in the 1980's in terms of annual production volume and value, particularly in far-seas and offshore fishing.

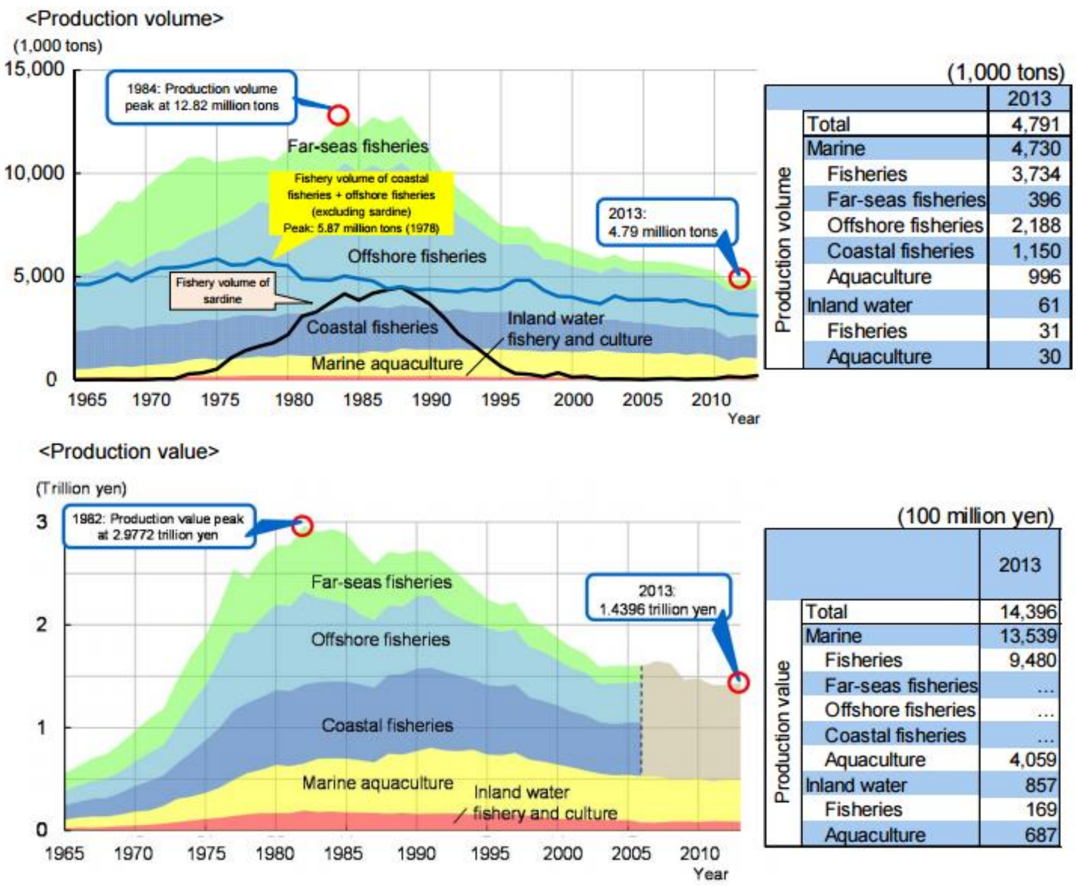


Figure 4-26 Fishing production volume and value for Japan (MAFF, 2015)

As shown in Figure 4-28, the number of fishery operators in 2013 was 94,507, declining 18% from 2008. The majority of operators are individual, family-run operators, and only a small portion is incorporated. The number of fishery workers in Japan in 2015 was 195,651 (MAFF, 2015). Currently, fishing in Japan is focused on the coast as 79% of the fishery workers and 94% of the fishery operators are involved in coastal fishing.

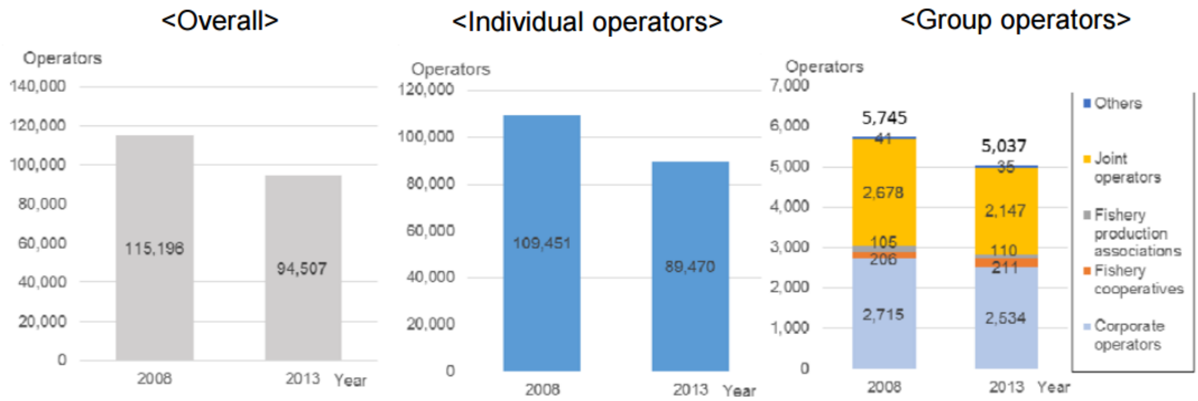


Figure 4-27 No. of fishing operators in Japan (MAFF, 2015)

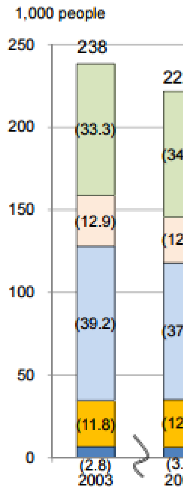


Figure 4-28 Workers' population and age distribution for the fishing industry in Japan (MAFF, 2015)

The main problem with the Japanese fishing industry is the lack of fish available due to decades of overfishing in the seas nearby Japan. As a result, fishing operators have to travel further and search for fish, which results in higher fuel cost and lower profit. As a reference, the average annual revenue, cost and profit in 2014 are shown in Table 4-11.

Table 4-11 Average income of fishing operators in Japan (MAFF, 2015)

Operator Type	Revenue	Cost	Profit
Individual	8.65 mil JPY	6.39 mil JPY	2.25 mil JPY
Corporation	285.78 mil JPY	305.29 mil JPY	-19.51 mil JPY

The reason for the overfishing is that Japan implemented the Total Allowable Catch (TAC) system in 1997 to control the output, and there is no official system for Individual Quotas (IQ) or Individual Transferable Quotas (ITQ) in Japan. The problem with the TAC is that because the quota is set on the whole country on a yearly basis, it becomes a race for the fishing operators to catch as much as possible before reaching the quota. This leads to catching fish that are not fully grown, which sell for a lower price. This impacts the fish biodiversity, further reducing the amount of fish available, reducing the profitability of the fishing operators further. As a result, workers population and the number of fishing operators have been declining over the years, leaving opportunities for overseas imports to slowly increase its share.

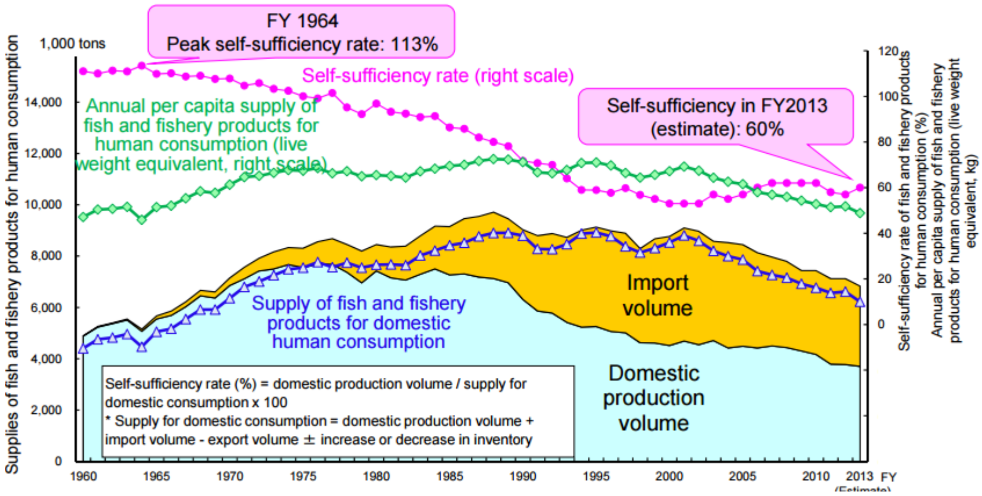


Figure 4-29 Change in domestic and import volume in Japan over the years (MAFF, 2015)

4.3.2 Stakeholder Analysis

The Fishery Agency under the Japanese Ministry of Agriculture, Forestry & Fisheries decides and implements policies related to the fishing industry. They also conduct surveys and publish industry analysis report annually. The agency announced the Basic Fisheries Plan in 2007 with the aim to establish sustainable, strong fisheries and fishery practices by promoting the overall restoration of the fishery industry. Their decisions are conveyed to the prefectural and municipal governments. These regional authorities give guidance to the fishery operators' cooperatives, and individual and corporate fishery operators.

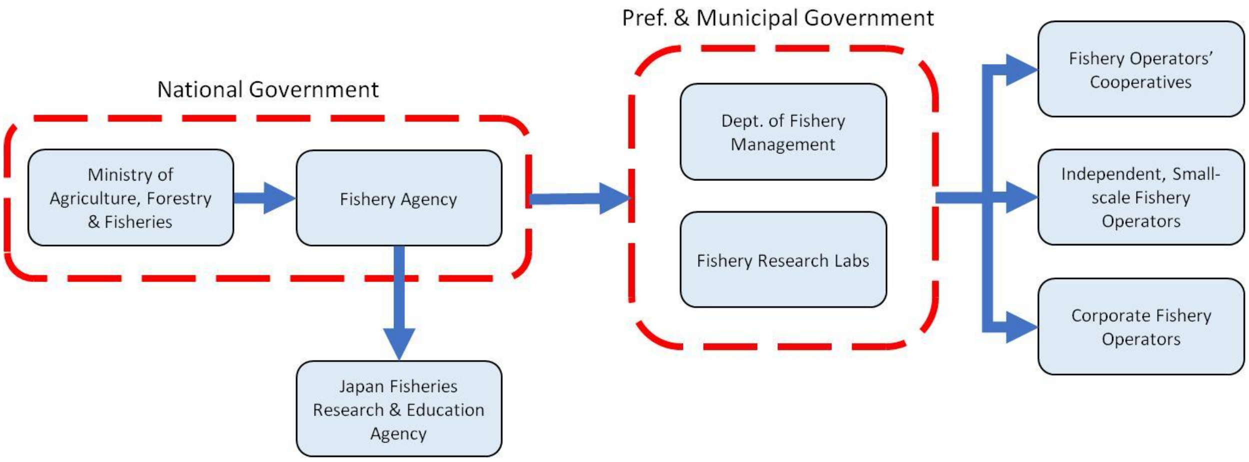


Figure 4-30 Stakeholders of the fishing industry in Japan

The main research body in fishery is the Japan Fisheries Research & Education Agency, which has many regional branch institutes. Also the fishery research labs of the prefectural governments often work closely with their local fishing communities to conduct research pertaining to that region. The corporate fishing operators only account for about 5% of the total, and the major companies include *Maruha Nichiro Corporation*, *Nippon Suisan Kaisha*, *Kyokuyo*, and *Hoko Co., Ltd*.

4.3.3 Existing Systems & Recent Developments

The use of the EO data in fishery has so far been focusing on providing support with fishing grounds prediction, and record-keeping of past fishing expeditions. No large EO data company in Japan has entered the fishing industry so far, and much of the development in this field has been undertaken by a small number of SMEs and university research groups. There are 3 organisations in Japan that develop software and services pertaining to fishing ground prediction. Each of them uses different satellite data sources to identify the location of promising fishing grounds, but the typical parameters used are:

- Sea surface temperature
- Current direction
- Current rip, i.e. where different currents meet
- Sea surface colour and chlorophyll-a concentration
- Internal sea temperature estimated from the sea surface height data

1) *Ebisu-kun* by Japan Fisheries Information Service Center (JAFIC)

The most widely distributed fishing support service is *Ebisu-kun* developed by the *Japan Fisheries Information Service Center* (JAFIC), which is an NPO established by the Fishery Agency of the Japanese Ministry of Agriculture, Fishery and Forestry. *Ebisu-kun* is an online information platform, which processes information obtained from the following sources to allow users to make their own predictions of the likely location of fishing grounds (JAFIC, 2016):

- NOAA and MetOp satellites
- AMSR-E instrument on-board NASA's *Aqua* satellite
- JAXA's GCOM-W satellite

JAFIC is also exploring the possibility of incorporating the in-situ data from the sensors on-board the users' ship to provide more accurate estimation and localised prediction services. The service enables fishermen to minimise the time they spend on searching for fishing grounds, thus cutting back on the time and fuel consumption for their expedition.

The service has 500-600 users across Japan, and is particularly popular among medium to large-size fishing companies involved in offshore fishing for tuna, skipjack tuna and pacific saury. The service currently covers seas in the vicinity of Japan. The users pay a monthly subscription of 40,000 JPY to access the information online via their own PCs, smartphones and tablets (JAFIC, 2016).

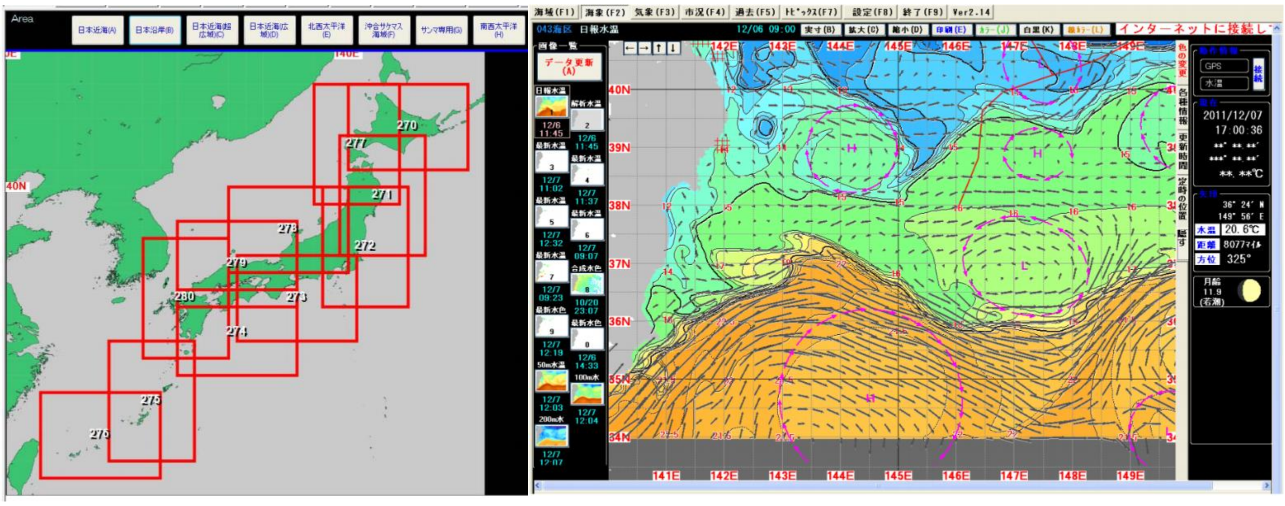


Figure 4-31 Areas near Japan covered by Ebisu-kun (left) and a screen shot of the sea current analysis (right) (JAFIC, 2016)

Ebisu-kun also provides key weather information 4 times a day, which includes wave height, wind direction and velocity, pressure distribution and cyclone information.

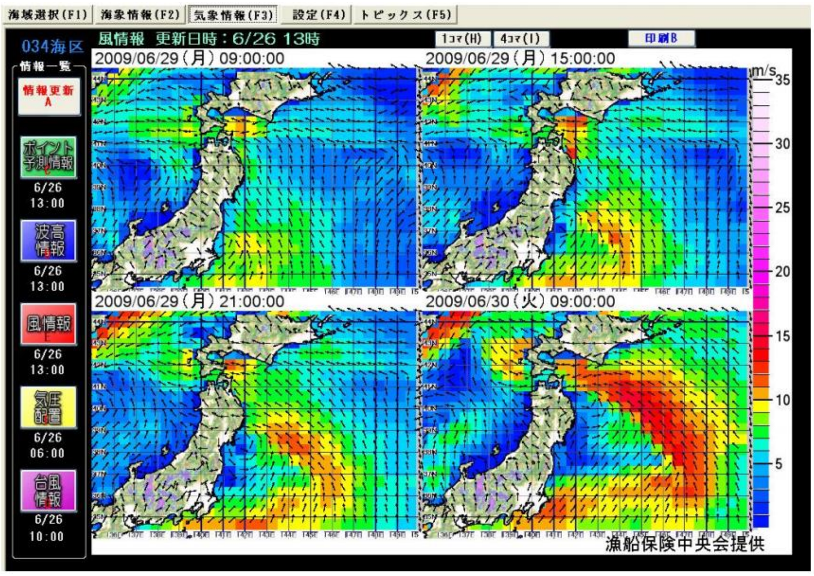


Figure 4-32 Screen shot of sea surface wind analysis of Ebisu-kun (JAFIC, 2016)

2) *TOREDAS* by Space Fish LLC, Hokkaido University and Fujitsu

The initial concept of *TOREDAS* was developed by Prof. Sei-ichi Saitoh of Hokkaido University, a prominent figure in the fishery research community in Japan. Prof. Saitoh later co-developed the TOREDAS with Fujitsu, a major Japanese IT and software company, and they founded a joint venture company *Space Fish* LLC in 2006 to provide daily fishing ground prediction service (Hokudai, 2016). TOREDAS is a decision-support tool for fishing expeditions, and it processes the data from the MODIS instrument on-board NASA's *Terra* and *Aqua* satellites.

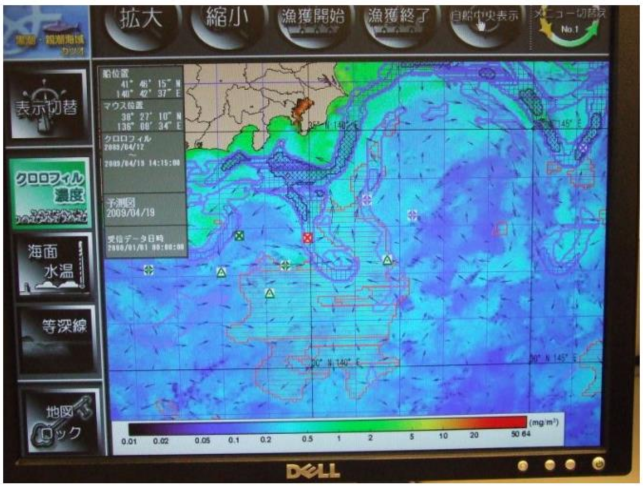


Figure 4-33 Screen shot of TOREDAS (Hokudai, 2016)

Different species of fish has a particular water temperature range that they prefer, and TOREDAS uses the sea surface height to estimate the internal water temperature. Combined with chlorophyll-a concentration, which is correlated to the amount of planktons, sea current, and the data on the previous locations where fishermen had a successful catch, TOREDAS makes a prediction on the likely location of the fishing grounds. The software can simulate up to 5 days ahead, and it has been found to be particularly useful for tuna, skipjack tuna, and pacific saury. It can also give predictions for the location of squids (*Sagittated Calamary*), and identify optimal coastal environments for seaweed farming.

TOREDAS consists of 1) online TOREDAS, where users pay a 6-monthly subscription of 20,000 JPY to access the information and fishing ground predictions from their own PCs, and 2) on-board TOREDAS, which is a full-package including a touch panel notebook PC and communication equipment that the users can install on their ship, for a 6-monthly subscription of 300,000 JPY (Hokudai, 2016).

3) *Tairyo-Ukeoi-Nin* bJPYvironment Simulation Laboratory Co., Ltd.

Environment Simulation Laboratory Co., Ltd (ESL) is a small company located in Saitama prefecture near Tokyo, and it provides various software solutions and consultancy related to fishing grounds prediction and data management for fishing expeditions. The company has also taken part in numerous feasibility studies on marine biodiversity funded by prefectural governments (ELS, 2016).

ESL's fishing ground prediction software, *Tairyo-Ukeoi-Nin* has similar functionalities to the ones already mentioned, but it also has a unique prediction algorithm, where the software refines its prediction using the data from previous fishing expeditions. The users record the locations where they had a successful catch, and the software uses the satellite data from that particular day to establish a set of criteria, such as sea surface temperature and colour, that makes up a favourable fishing ground location. It then searches for locations that satisfy the criteria, and present them as likely locations of fish.

4) Other Services

Several prefectural fishery research labs have also been engaging with their local fishing industry to provide free, daily updates on sea surface temperature and sea colour to assist with fishing ground prediction. The fishery research lab in Nagasaki, Saga, Iwate and Miyagi prefecture have been particularly active in this initiative. Among the academic communities, Hokkaido University is very active with research on fishing ground prediction and marine biology, and Tokyo University of Marine Science and Technology, Kyushu University and Yamaguchi University are also active in these efforts.

4.3.4 Needs & Opportunities

Over the years, finding fish is becoming increasingly difficult, and the offshore fishermen have to travel further to have a successful catch, and the coastal fishermen are finding it hard to catch enough fish to make a sufficient profit. With the cost of fuel being almost a third of the total cost, the interviews showed that there is a strong need for EO products and services to assist fishing ground prediction and catch fish more efficiently. The needs and requirements are summarized in Table 4-12.

Table 4-12 Summary of key needs and requirements from the Japanese fishing industry

Requirement ID	Requirement Description

REQ-FIS-01	For offshore fishing, spatial resolution of 1-2 km, temporal resolution of 3 hrs
REQ-FIS-02	For coastal fishing, spatial resolution of 100-300m, temporal resolution of 3 hrs
REQ-FIS-03	Localised fishing ground prediction service catered for coastal fishing, including sea surface temperature and colour
REQ-FIS-04	Fishing ground prediction accuracy with 1/3 chance of predicting correctly, ideally 1/2
REQ-FIS-05	Use of the data from meteorological satellites in geostationary orbit to achieve more frequent provision of data
REQ-FIS-06	Combining satellite EO with big data analysis to fill in the missing data due to factors such as cloud cover, and assist with fishing ground prediction
REQ-FIS-07	Estimation of ocean temperature in 3D, ie. not just the surface but internal layers, possibly by combining in-situ data and big data analysis
REQ-FIS-08	Monitor night fishing activities to record successful fishing grounds for future prediction
REQ-FIS-09	Greater access to sea altimeter data, and improvement in the estimation algorithm for internal sea temperature
REQ-FIS-11	Better understanding of red tide and its occurrence mechanism, development of an algorithm to predict the occurrence
REQ-FIS-12	Red tide monitoring system with 100-300 m resolution, once a day
REQ-FIS-13	Monitoring service for coastal aquafarming facilities such as seagrass
REQ-FIS-14	Capability to estimate the amount of fish still available to promote sustainable fishing practices

The interviews found that for both offshore and coastal fishing, the spatial resolution doesn't need to be high, but the key criteria is the timely delivery of satellite data, preferably near real-time (REQ-FIS-01 & 02). To achieve the near real-time delivery of data, some of the Japanese EO companies are investigating the possibility of using the data from meteorological satellites on geostationary orbits, which capture images every hour (REQ-FIS-05).

Fishing grounds prediction for coastal waters is another opportunity that hasn't been addressed (REQ-FIS-03). All of the existing prediction services are more for large-scale, offshore fishing companies with have adequate finance, IT infrastructure and human resources. The cost of implementing the prediction services is still too high for coastal fishing, which typically consists of small fishing companies and self-employed fishermen. The free, open-source data from Copernicus is a perfect solution for this situation as one of the Japanese SMEs advised that a spatial resolution of a few hundred meters would be sufficient for fishing ground prediction for coastal waters. However, as coastal waters are subject to more frequent fluctuation due to passing ships and other human activities, near real-time delivery of data would be even more important than offshore fishing.

The interviewees also raised concerns about the high level of expectations from the Japanese fishermen on the use of satellite data. Unless the fishing ground prediction services can offer significantly superior results, fishermen will most likely stick to their own instincts and experience. The interviewees suggested that delivery of information every few hours, and 1 in 3 chances of predicting the fishing ground location correctly as the benchmark to engage the interests of fishermen (REQ-FIS-04).

As for improving the prediction accuracy, one of the Japanese SMEs suggested the use of big data analysis to combine satellite and in-situ data, and incorporate into numerical modeling to estimate internal ocean temperature in 3D (REQ-FIS-06 & 07). Also, monitoring night-fishing activities more regularly may contribute to improving the prediction accuracy as it would give an indication of where good fishing grounds were located, which can be fed into big data analysis (REQ-FIS-08).

As Japan doesn’t have a satellite with a sea height altimeter on-board, several university researchers showed high level of enthusiasm to collaborate with European researchers to gain better access to altimeter data and exchange technical expertise to improve their estimation algorithm (REQ-FIS-09).

Another high priority area for the Japanese fishing industry that hasn’t been addressed is understanding of the red tide mechanism (REQ-FIS-11). Red tide is a phenomenon that occurs in coastal areas where a species of algae known as phytoplankton accumulate rapidly in the water, resulting in red coloration of the surface water. Red tide kills fish and other marine creatures, and thus, it is particularly damaging for coastal fishing and aquafarming activities. A support tool dedicated to aquafarming would greatly benefit the Japanese fishing industry as it is particularly active in this field, and the spatial resolution required can be readily catered with the Copernicus Sentinel-2 data (REQ-FIS-12 & 13).

Lastly, to tackle the problem of overfishing, and assist Japan to transition for more sustainable fishing practices, a tool that can assist with estimation of the abundance of marine creatures would have a huge impact on the Japanese fishing industry (REQ-FIS-14).

4.4 Urban Infrastructure Monitoring

4.4.1 Overview

Japan consists of 4 main islands, Hokkaido, Honshu, Shikoku and Kyushu that stretch over approximately 2000 km from North to South. About 73% of Japan is forested and mountainous, with a mountain range running through each of the main islands, leaving only 27% of the total land for agricultural, industrial or residential use, which is significantly lower compared to the major European countries (Wikipedia, 2016f).

Table 4-13 Difference in the habitable land area between Japan and selected countries (MLIT, 2015)

Country	Total Land Area ($x\ 10^3\ km^2$)	Habitable Area ($x\ 10^3\ km^2$)	Portion of Habitable Area
Japan	378.6	103.5	27.3 %
UK	243.8	206.3	84.6 %
France	547.9	397.2	72.5 %
Germany	356.7	237.9	66.7 %

Consequently, the habitable zones are mainly located in coastal areas, making Japan one of the most densely populated countries in the world.

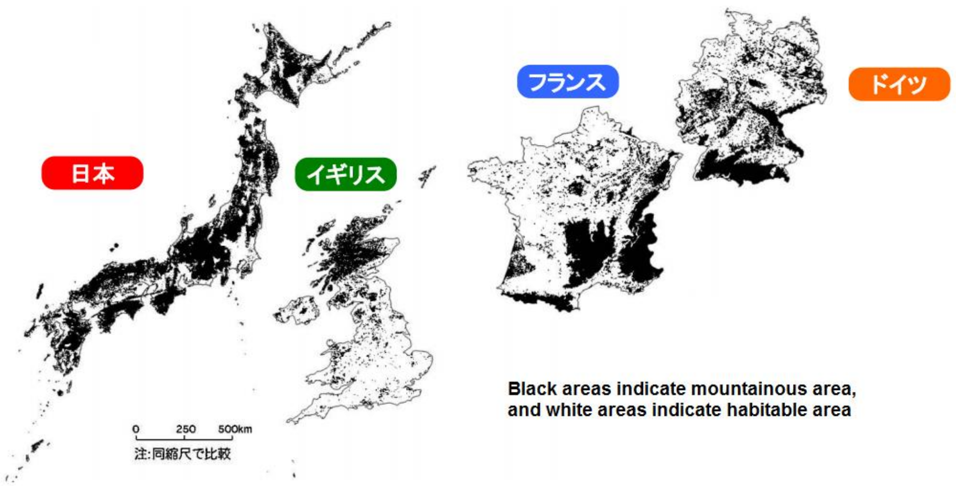


Figure 4-34 Visual representation of the habitable areas of selected countries (MLIT, 2015)

Japan is generally a rainy country with high humidity. The average annual rainfall is double that of the world, and the country experiences heavy rain particularly during June, and five or six typhoons pass over or near Japan every year from August to October, sometimes resulting in significant damage. Heavy rainfall combined with relatively short, swift rivers over considerable steep gradients due to the mountainous topography of the country makes Japan very susceptible to landslides and floods. This has led to extensive development of flood control measures consisting of waterways, aqueducts and drainage.

Japan is located in a volcanic zone on the Pacific Ring of Fire, which makes it extremely prone to earthquakes, tsunami and volcanic activity. Consequently, the country has the highest natural disaster risk in the developed world. Japan has 108 active volcanoes, which equal to 10% of the world's active volcanoes. As many as 1,500 earthquakes are recorded yearly, and magnitudes of 4 to 7 are common. Major earthquakes are less frequent, but occur several times each century. The great Kantō (the area surrounding Tokyo) earthquake in 1923 killed over 140,000 people. More recent major quakes are the 1995 Great Hanshin earthquake and the 2011 Tōhoku earthquake, a 9.0-magnitude quake that killed at least 15,000 people (Wikipedia, 2016f). As an island nation, Japan has the 6th longest coastline in the world, and combined with frequent seismic activities, the country is also exposed to danger from tsunamis and tidal waves (MLIT, 2015).

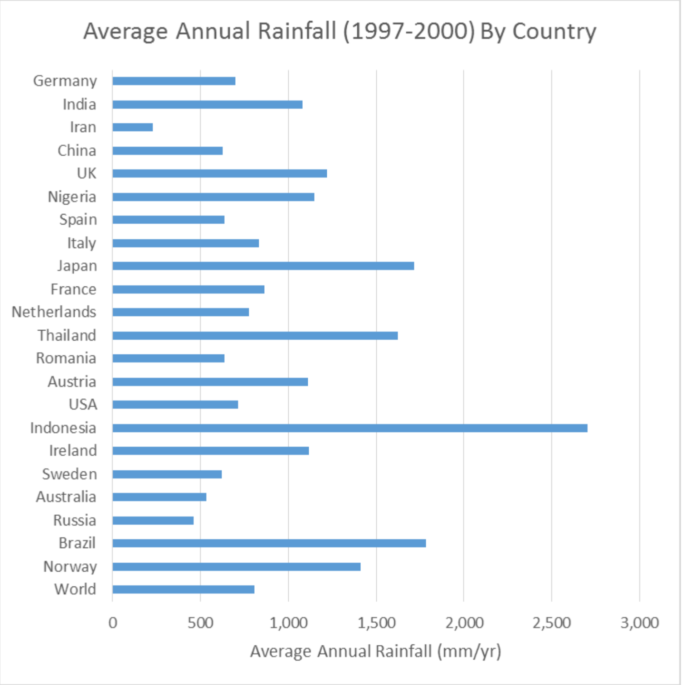


Figure 4-35 Average annual rainfall of selected countries (MLIT, 2015)

Due to frequent exposure to various natural disasters, Japan has implemented very high and strict standards and earthquake-resistant designs on the construction of buildings and infrastructures. An example is shown in Figure 4-37 where an elevated road in Japan has much larger support structure.

Figure 4-36 Strutted supports in Japan (left) and France (right) (MLIT, 2015)

As a result, the public infrastructures in Japan, such as highways, bridges, and tunnels, require extensive, additional structural supports, which increase the overall construction and maintenance costs. The steep topography of Japan also necessitates additional support structures. Public roads in Japan for example, the structural ratio ((*Tunnel length + Strutted section length) / Total road length*) is significantly higher than other major countries.

Table 4-14 A comparison of the road structure ratio of selected countries (MLIT, 2015)

Country	Road Structure Ratio	Comment
Japan	24.6 %	Average of the national highways
USA	7.0 %	Average of the interstate highways
UK	4.4 %	Average of the national highways and main roads
France	2.6 %	Average of the national highways and main roads
Germany	10.1 %	Average of the federal autobahns

In addition to various environmental considerations, aging and deterioration of public infrastructures is expected to become a serious problem for Japan in the very near future. Majority of them were built for the 1964 Tokyo Olympics and amid the high-growth period of the Japanese economy during 1960's and 70's. Portion of the public infrastructures older than 50 years is expected to increase rapidly in the next few decades as shown in

Table 4-15.

Table 4-15 Portion of different public infrastructure in Japan expected to be older than 50 years (MLIT, 2016)

Infrastructure Type	Approx. Qty.	2013	2023	2033
Road bridge	400,000	18 %	43 %	67 %
Tunnel	10,000	20 %	34 %	50 %
Waterway Structures (eg. dams, gates)	10,000	25 %	43 %	64 %
Sewage Pipeline	450,000	2 %	9 %	24 %
Coastal Structures (eg. wharfs, quays)	5,000	8 %	32 %	58 %

Another problem in Japan is ground subsidence, which has been observed throughout the country as shown in Figure 4-38. Ground subsidence used to be a significant problem for Japan during the economic boom in the post-war era. However, after laws were passed in the 1960's restricting the extraction of ground water for industrial and residential purposes, the amount of ground subsidence has decreased in the

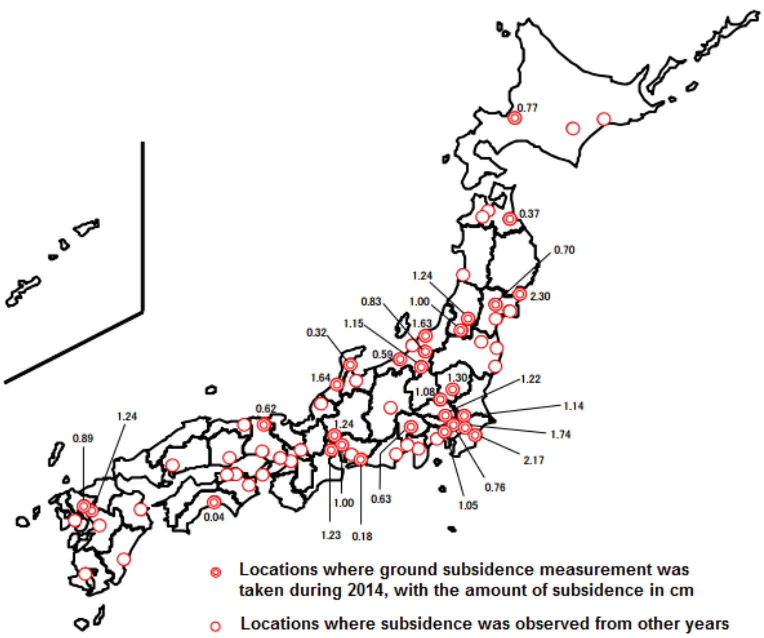


Figure 4-37 Locations around Japan where ground subsidence has been observed (MLIT, 2015)

recent decades.

Public infrastructures in Japan are currently monitored only through on-site visual inspections and sensor systems. However, this involves substantial cost for the personnel and the upkeep of the equipment, and the maintenance and upgrade cost is expected to increase from 3.6 trillion JPY in 2013 to 4.3 – 5.1 trillion JPY in 2023, and 4.6 – 5.5 trillion JPY by 2033 (MLIT, 2016).

Figure 4-38 Various forms of visual inspections carried out in Japan (MLIT, 2016)

Furthermore, inspections are time-consuming and can be ineffective as some parts are hard to reach, and can only be performed during certain times of the day for infrastructures such as railways and highways. With Japan’s aging and declining population, some of the regional authorities are already unable to perform scheduled inspections due to shortage of inspection staff and experience.

Despite the situation, the current regulations in Japan pertaining to construction and infrastructure maintenance only mention on-site inspection/surveying and sensor systems and the use of satellite-derived data is not included. As a result, the Japanese companies involved in construction and building maintenance, and civil engineering consultancies have completely based their service around on-site inspection and sensor systems.

Table 4-16 Monitoring methods used in Japan to check the health of public infrastructure (MLIT, 2016)

Monitoring Methods	Physical Parameters Monitored

• Staff inspection
• Vehicle equipped with camera and/or laser measuring device
• Sensors
  ○ Camera
  ○ Strain/stress gauge
  ○ Thermometer
  ○ Displacement gauge
  ○ Optic fibre network
  ○ Acoustic camera
  ○ Accelerometer
  ○ Pressure sensor
  ○ GPS sensor
	• Cracks
	• Structural defect
	• Deformation
	• Strain/distortion
	• Ground subsidence
	• Vibration
	• Inclination/tilt
	• Corrosion
	• Leakage

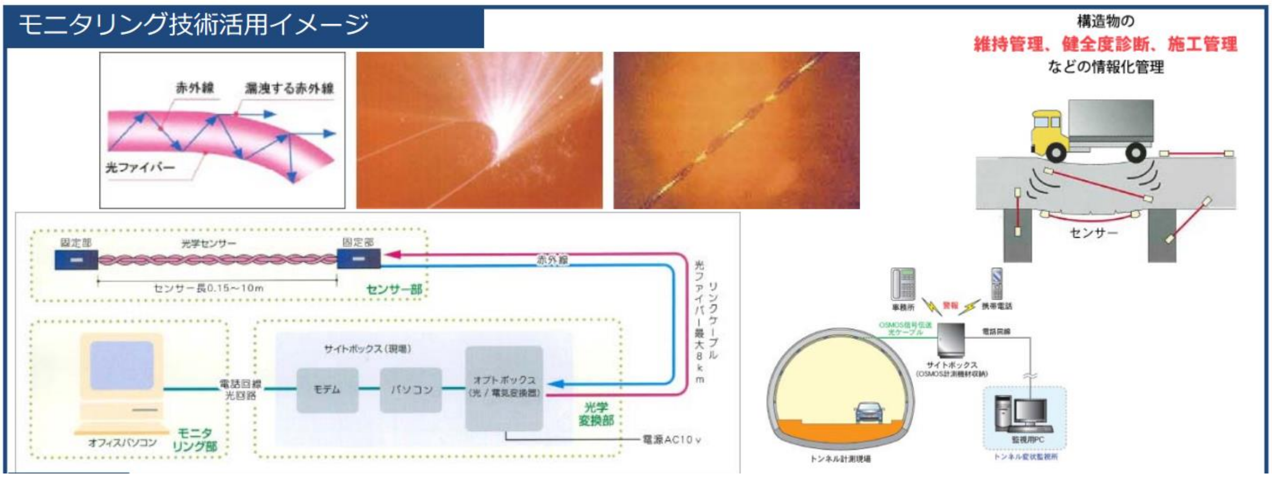


Figure 4-39 An example of a sensor-based monitoring system for tunnels in Japan (MLIT, 2016)

Furthermore, the concept of preventive maintenance is still in its early days in Japan, and hasn't been well-recognised by the building industry. Therefore, the potential cost benefits of preventive maintenance practices and the use of satellite data over conventional monitoring practice need to be clearly demonstrated to the building industry in order to gain their support.

4.4.2 Stakeholder Analysis

In Japan, public infrastructures are owned and managed by both public and commercial entities. Commercial entities consist of special governmental corporations and fully private, commercial companies as shown in Table 4-17.

Table 4-17 Ownership of different categories of public infrastructure in Japan (MLIT, 2016)

Infrastructure Type	National Govt.	Prefectural Govt.	Municipal Govt.	Special Govt. & Private Corp.
Gen. Roads	7 %	21 %	69 %	3 %
Strutted Roads & Highways	4 %	19 %	75 %	2 %
Tunnel Roads	13 %	46 %	26 %	15 %
Waterways / Aqueducts	35 %	65 %		-
Sewage Pipelines	-	2 %	98 %	-
Ports	9 %	-	-	91 %
Public Housing	-	43 %	57 %	-
Coastal Structures	-	100 %		-
Airports	29 %	68 %		3 %

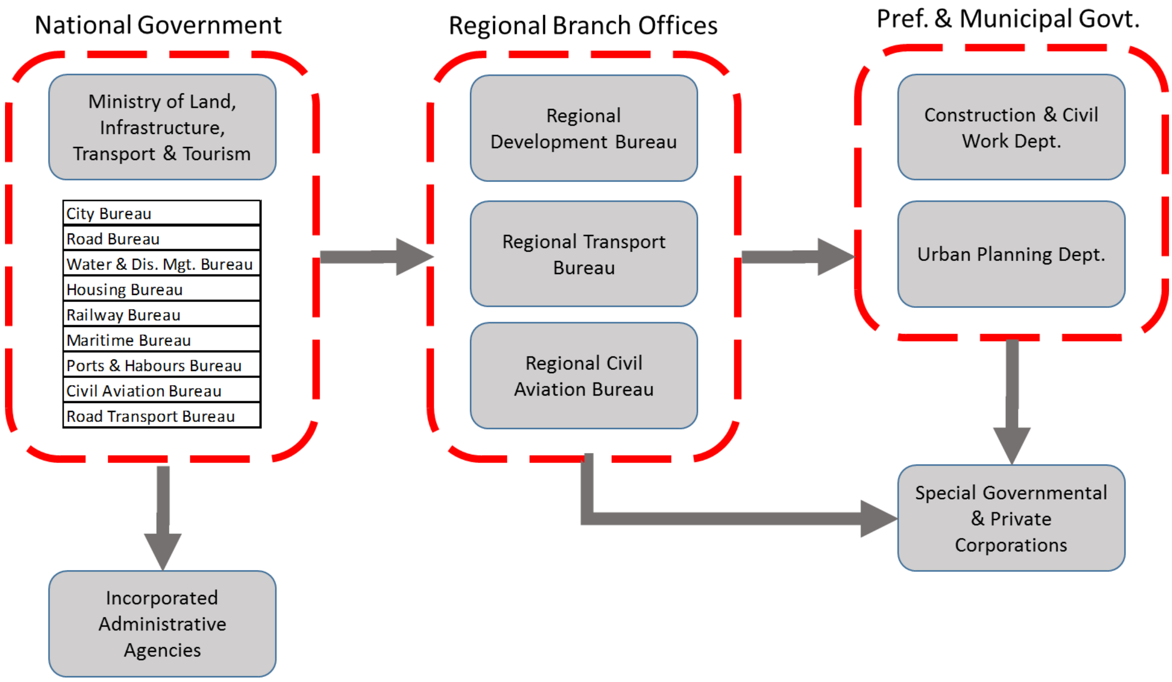


Figure 4-40 Summary of stakeholders involved in public infrastructure in Japan

The overall policy management and implementation are conducted by the Ministry of Land, Infrastructure, Transport & Tourism (MLIT), as well as by their respective section bureaus and regional branch offices. The regional branch offices are in charge of the prefectures in their regions, and they work with the relevant departments within the prefectural and municipal governments.

MLIT manages several public R&D and infrastructure management bodies known as the Incorporated Administrative Agencies, and they include:

- Public Works Research Institute (PWRI)
- Building Research Institute
- Japan Railway Construction, Transport and Technology Agency (JRTT)
- Organization for Environment Improvement around International Airport
- Urban Renaissance Agency
- Japan Expressway Holding and Debt Repayment Agency

The special governmental and private corporations that manage public infrastructures are summarised in Table 4-18.

Table 4-18 Summary of corporations in charge of different public infrastructure and transports

Infrastructure	Corporation
Railways & Subways	• Japan Railway (JR) Group – JR East Japan, JR West Japan, JR Hokkaido, JR Kyushu, JR Shikoku, JR Freight, JR Railway Information Systems • Tokyo Metro Co. Ltd. • Tokyo Prefectural Government Govt. Metro Service (Toei Metro)
Airports	• Kansai International Airport Co. Ltd. • Narita International Airport Co. Ltd.
Highways	• Nippon Expressway Company Ltd. (NEXCO) • Tokyo Metropolitan Expressway Co. Ltd. • Hanshin Expressway Co. Ltd. • Honshu-Shikoku Bridge Expressway Co. Ltd.
Dams (for power)	• Hokkaido Electric Power Company (HEPCO) • Tohoku Electric Power Company • Tokyo Electric Power Company (TEPCO) • Hokuriku Electric Power Company • Chubu Electric Power Company • Kansai Electric Power Company (KEPCO) • The Chugoku Electric Power Company • Shikoku Electric Power Company • Kyushu Electric Power Company
Electricity & Telephony Poles	Above power companies and NTT (Nippon Telegraph and Telephone Corporation)

4.4.3 Existing Systems & Recent Developments

Infrastructure monitoring through on-site inspections and sensor systems have been the accepted norm in Japan for the past half a century, and with the government regulations in its current state, the building industry is rather hesitant about moving away from the status quo. Consequently, satellite applications, such as using SAR interferometry (InSAR) to measure ground subsidence, have received very little recognition in the industry, and have been limited to several publicly funded, one-off feasibility studies for the MLIT. These studies were carried out by the major Japanese EO data companies, such as Kokusai Kogyo, Air Asia Surveying, PASCO, and RESTEC, and some of them are briefly described below.

Kokusai Kogyo monitored the ground subsidence of a rock-fill dam in Okinawa over 4 years using InSAR, working in conjunction with JAXA and the Public Works Research Institute (PWRI) (Honda, 2014).

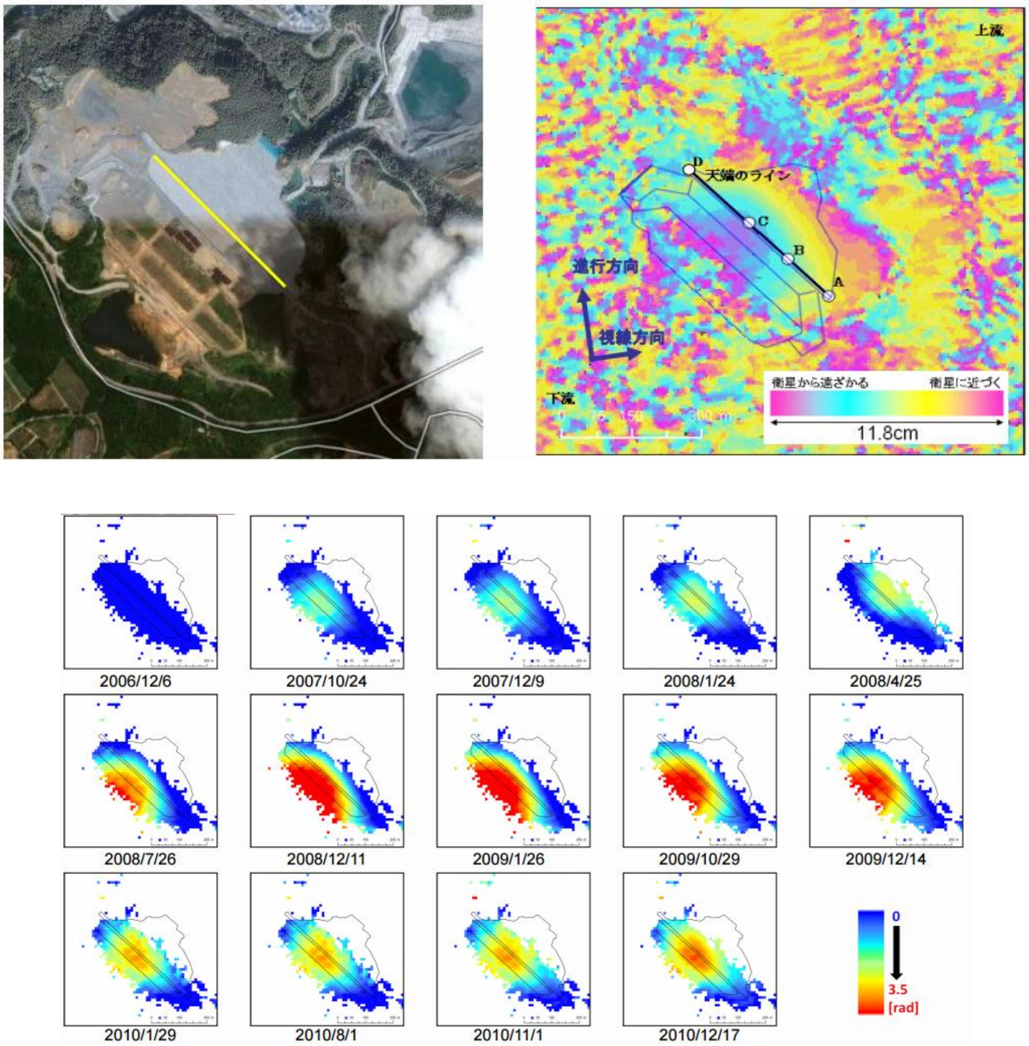


Figure 4-41 Analysis of the ground subsidence of a rock-fill damn using InSAR by Kokusai Kogyo (Honda, 2014)

PASCO has also conducted several projects both domestically as well as overseas. In 2009, they conducted a ground subsidence analysis of the Haneda Airport Runway-D using the *Small Baseline Subset Method*

(SBSM), and time series SAR analysis of the ground subsidence of Manila metropolitan area using the Permanent Scatters Interferometry SAR (PSInSAR) technique in 2014 (Yoshikawa, 2015).

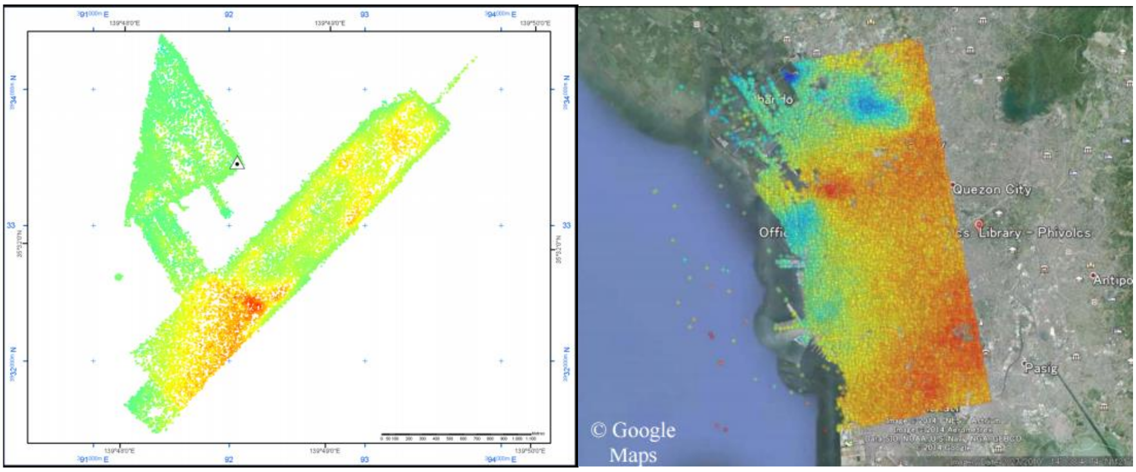


Figure 4-42 Ground subsidence analysis in Manila, Philippines using InSAR by PASCO (Yoshikawa, 2015)

PASCO has also conducted a study to analyse the ground subsidence of Zonguldak coal field in Turkey using the data from TerraSAR-X (Yoshikawa, 2015).

4.4.4 Needs & Opportunities

Due to several socio-economic factors, the use of satellite data for urban infrastructure management has been limited to serving the public sector, and no company in Japan so far has succeeded in establishing an on-going, viable business case for the private sector. However, the perception is changing among the construction companies and the owners of large infrastructures. With the majority of the public infrastructure in Japan being close to 50 years old, combined with the aging and declining workers population to carry out inspection and other maintenance activities, the building industry is aware that they need to implement cheaper and more effective monitoring systems in Japan. Furthermore, due to high risk of earthquakes and volcanic activities, it is absolutely vital for Japan to monitor ground subsidence and movement of the Earth's crust.

To address these concerns, several EO companies in Japan are already in advance stages of discussion with highway, railway and subway operators to implement SAR interferometry (InSAR) to monitor ground subsidence of their assets. Also, new construction projects are frequently executed in Japan, and there is a growing interest to use InSAR to assess the impact on the ground level of the surrounding areas. With the Tokyo Olympics scheduled in 2020, the number of new construction and re-development projects is expected to grow and monitoring of ground subsidence would become even more important.

Many of the airports in Japan are built on artificial land and island, and as a result, are facing serious ground subsidence each year. Japanese companies such as PASCO, and European companies such as TRE Altamira and GMV have taken part in feasibility studies to assess the ground subsidence of Japanese airports. The trend is expected to continue, and the success of several European companies should serve as a hint for further collaboration between Japan and the EU.

The interviews found the following needs and requirements summarised in Table 4-19.

Table 4-19 Summary of key needs and requirements for public infrastructure management in Japan

Requirement ID	Requirement Description
REQ-URB-01	Capability to detect ground subsidence with an accuracy in the order of mm
REQ-URB-02	Monitoring of ground deformation and subsidence once every few days in grid mesh with 5-10 m, near dams and other large public infrastructure
REQ-URB-03	Target area of 10-100 km^2 with 1-10 m spatial resolution once a month to once a year, depending on the target infrastructure and the environment
REQ-URB-04	Data to support the annual mapping activities conducted by the MLIT, where maps are updated typically 4 times a year, region-by-region, thus the whole update cycle goes on for 3-5 years
REQ-URB-05	Early detection of landslides and floods
REQ-URB-06	Monitoring of rivers, aqueducts and conduits in urban and rural areas for better prediction floods and management (once a month, 1 m resolution)
REQ-URB-07	Capability to monitor heat-island effect in cities in 10-20 m resolution in order to ascertain the heat source
REQ-URB-08	Research into complementary usage of SAR data of different bandwidths

The key requirement from the stakeholders in Japan was to measure ground subsidence in millimeter level accuracy (REQ-URB-01). The observation frequency doesn’t need to be high, but medium spatial resolution would be ideal (REQ-URB-02 & 03). In fact, Copernicus Sentinel-1 data is actually already being used by several Japanese companies to perform InSAR analysis, and the EU should look to capitalise on this situation to strengthen its relationship with the Japanese industries.

MLIT renews its map database several times a year, and thus, satellite images and efficient image processing tools are in high demand (REQ-URB-04).

Japan is characterised by many harsh, steep terrains and valleys, as well as many rivers running through them. These land features give rise to frequent landslides and floods, and several interviewees advised there is a strong need in Japan to predict and detect these natural disasters (REQ-URB-05 & 06). Also, reducing the heat island effect is gaining interests from city councils and urban planners to ensure more environmentally-friendly, sustainable building practices (REQ-URB-07).

Lastly, one of the interviewees advised that the owners of large public infrastructures are interested in monitoring long-term trend of the ground subsidence, but the satellite SAR data itself can only go back 10-20 years at most, and there may be gaps in the observation due to revisit time. Therefore, it would be beneficial for all users of SAR data to explore the possibility of combining different SAR bandwidth to fill in each other's observational gaps (REQ-URB-08).

As mentioned earlier, the recognition towards InSAR is changing in the recent years, and MLIT has been hosting several workshops and seminars to review the current status of infrastructure maintenance practice, and explore the use of InSAR techniques. It may therefore be wise for European entities to increase its presence in Japan during this early stage of development, and build up trust with the Japanese public and private sectors through information exchange and joint seminars on economic benefits of InSAR and preventive maintenance.

4.5 Sea Ice Monitoring

4.5.1 Overview

Sea ice is a serious problem for Japan's Hokkaido prefecture, particularly along the coastal regions facing the Sea of Okhotsk in the North-East to East of the prefecture.

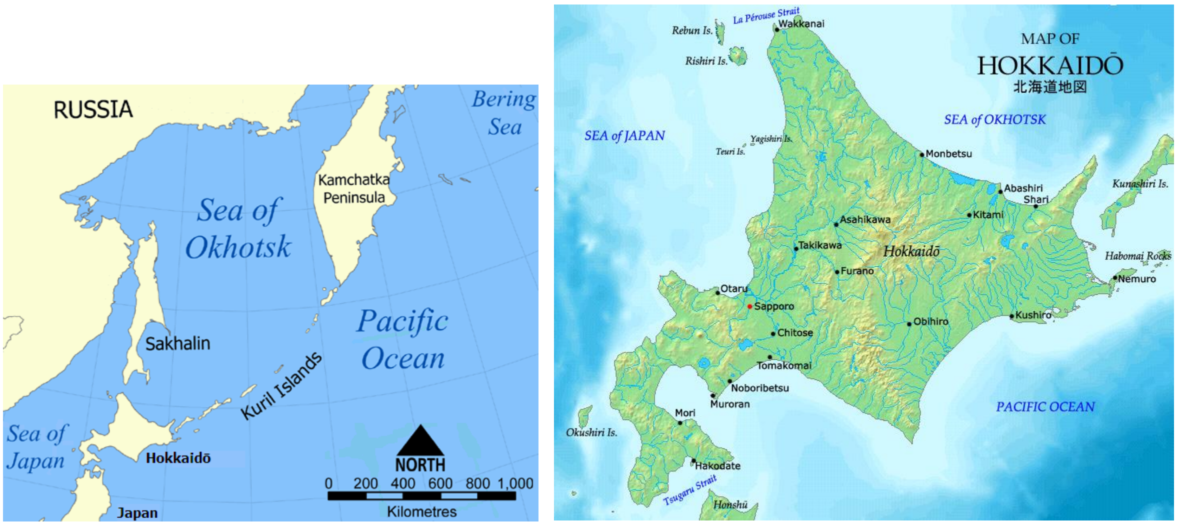


Figure 4-43 The Northern seas of Japan (left) and a map of Hokkaido (right) (Wikipedia, 2016c)

The coastal communities from Wakkanai through Monbetsu down to Nemuro encounter sea ice every year between December and April, and it causes significant damages to the port facilities the regions. The damages caused by drifting sea ice typically include:

- Damage to port facilities and ship
- Damage to fish farms, seaweed bed and other aquafarming facilities
- Disabling of port operation due to thick sheets of ice occupying the port
- Economic damage due to the inability to operate port and/or cancellation of fishing activities

Figure 4-44 Sea ice in the Northern coasts of Hokkaido (Cho, 2016)

A study conducted in 2000, which surveyed 11 ports and fishing harbours between Wakkanai and Nemuro, estimated that the sea ice during between December and April has a potential to cause a damage worth approx. 9.45 Bn JPY for the coastal communities annually (Omura, 2000).

Another topic related to sea ice that is relevant to Japan is the possible use of Arctic Ocean shipping routes known as the Northeast Passage (NEP, also known as the Northern Sea Route) that connects the Bering Sea to the Northern Atlantic, passing through the Northern coasts of Russia and Scandinavia. Due to the global warming, the thickness and area extent of the Arctic sea ice has experienced a significant reduction in the recent decades, allowing ship to pass through between July and October.

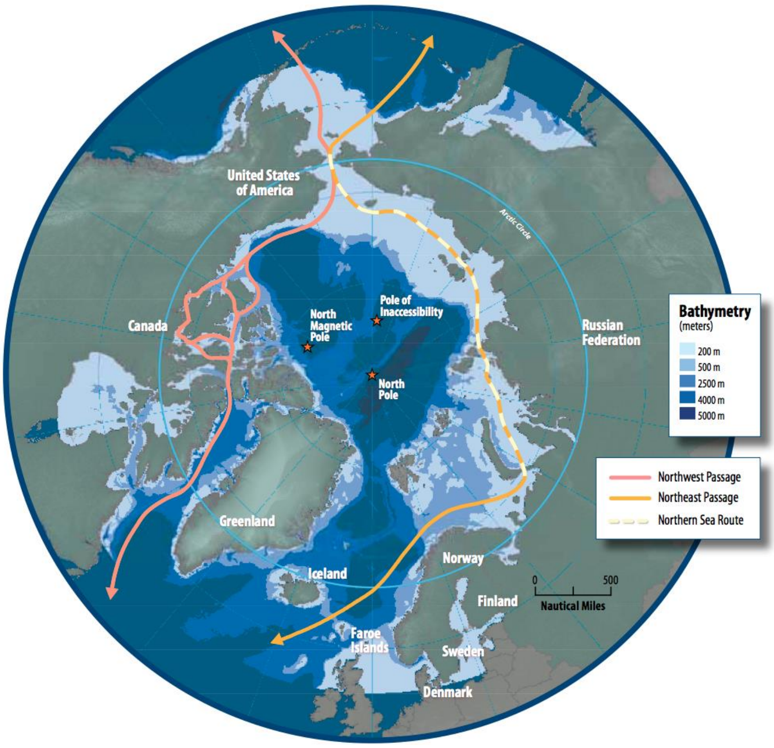


Figure 4-45 Arctic Ocean shipping routes (Wikipedia, 2016g)

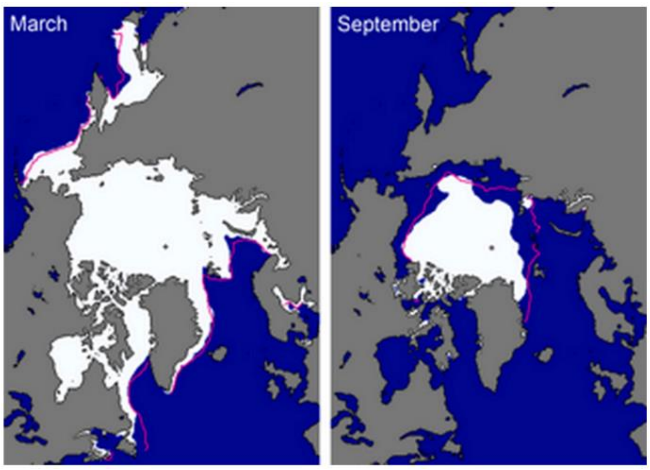


Figure 4-46 Melting of the ice in the Arctic Ocean (Cho, 2016)

The key interests for Japan with the Arctic Ocean shipping routes are 1) transporting natural resources from the Arctic regions and Northern Europe to Japan, and 2) the potential to reduce the travel distance, time and fuel cost for regular shipping service between Europe and Japan.

For the first point, Japan has significant interests in acquiring the natural resources in the Arctic regions and the Northern Europe, and Japanese shipping companies have used the NEP several times in the last few years to transport commodities from Europe to Japan. The details of these trips are summarized in

Table 4-20 Shipping deliveries to Japan that used the Arctic Ocean shippint routes in the recent years

Date	2012 Dec 5	2013 Aug 17	2013 Sept	2013 Oct 11
Client	Kyushu Electric Power Company	Asahi Kasei Chemicals, Mitsubishi Chemicals	Unknown	Tokoy Electric Power Company
Commodity	LNG	Naphtha	Petroleum products	LNG
Ship Name	OB RIVER	Propontis	SCF JPYisei	Arctic Aurora
Ice Class	IA (Arc4)	Arc4	Arc4	Arc4
Tonnage	84,582 t	117,055 t	47,187 t	73,920 t
Pt. of Origin	Hammerfest, Norway	Rotterdam, Netherlands	Murmansk, Russia	Hammerfest, Norway
Pt. of Arrival in Japan	Kita-Kyushu, Fukuoka Pref.	Mizushima, Okayama Pref.	Iwakuni, Aichi Pref.	Futtsu, Chiba Pref.

With the LNG gas plant project in Russia's Yamal Peninsula in starting 2017, Japan's interest in the region is expected to grow. In 2014, one of the three main shipping companies in Japan, *Mitsui O.S.K. Lines, Ltd.* announced that they will commence regular shipping service for the Yamal LNG plant to transport LNG to Europe and East Asia (Newsphere, 2016). The company has formed a joint venture company with *China Shipping Company*, and purchased 3 LNG carrier ship equipped with ice-breakers from a Korean manufacturer. The two companies will jointly own the ship and will start the service in 2018.

On the second point, there is a significant interest from government officials and academics for using the Arctic Ocean shipping routes to ship goods between Europe and Japan. The routes has a potential to drastically reduce the travel distance, time and fuel cost. For example, the NEP reduces the distance between North-East Asia and Western Europe by about a third compared to the existing Southern routes through the Cape of Good Hope or the Suez Canal, and cuts the travel time from 48 days down to approximately 35 days. Thus, there is a growing economic interests from the governments of Japan, South Korea and China to make NEP as a cheaper, alternative commercial shipping route.

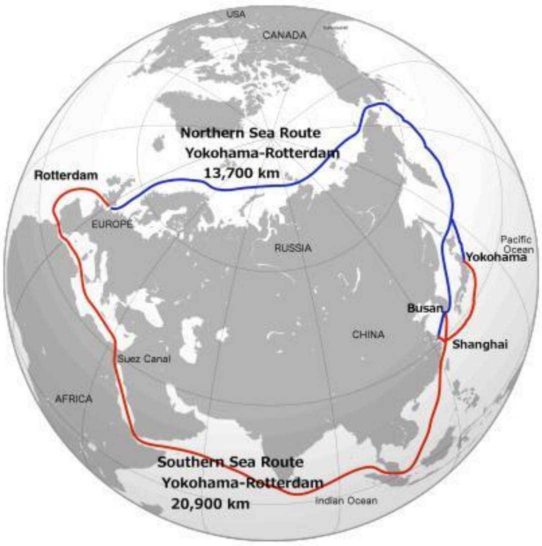


Figure 4-47 Comparison of the Northern and Southern route Norther Asia to Rotterdam (Wikipedia, 2016g)

Table 4-21 Comparison of the distance to travel from different cities in Asia to Rotterdam (MLIT, 2014)

From	To Rotterdam (in km), via:			
	Cape of Good Hope	Suez Canal	NEP	Diff. between Suez & NEP
Yokohama, Japan	26,758	20,618	12,983	37%
Busan, South Korea	26,084	19,898	14,199	29%
Shanghai, China	25,550	19,552	14,901	24%
Hong Kong, China	24,102	17,966	15,916	11%
Ho Chi Minh City, Vietnam	22,702	16,459	17,461	–6%

Despite the high levels of interest from government officials and researchers, the true commercial feasibility of the Arctic Ocean shipping routes remains to be seen. Consequently, the idea of utilising the Arctic Ocean shipping routes has received only a lukewarm response from the Japanese shipping companies, and their reasons are as follows (Gouda, 2012):

1) Dangerous environment of the Arctic Ocean

Although the amount of sea ice reduces during the summer, it doesn't necessarily imply that they are gone completely, the ships still faces the chance of clashing with a large sea ice or having to push through thick ice sheets. The Arctic Ocean is also known to have thick fogs and fast, powerful waves, all of which poses significant risks for operating ships in the region. Thus, although the distance is shorter, these poor weather conditions may actually prevent the ships from maintaining a constant speed.

2) Lack of accurate, reliable, long-term forecast of sea ice condition

Because of the dangers mentioned above, shipping companies need an accurate and reliable forecasting service for the sea ice. Although there are several forecasting services by Japanese and overseas organisation, they don't have enough details and certainty to support long-term operational planning.

3) Strict delivery schedule

The Japanese shipping companies are expected to deliver the cargos precisely on time. Suggesting a rather unclear routing plan, such as taking the Northern route *if* the sea ice has melted and the Southern route if otherwise, will probably not be accepted by the customers.

4) Shallow water level of the Arctic Ocean shipping routes

The size of typical container ships travelling from Japan to Europe is 8000 – 9000 TEU, and ships of this size cannot pass certain parts of the Arctic Ocean as the water is too shallow. Some parts of route can be shallow as 20 – 50 m, which means that shipping companies will have to revert to smaller ships with 4000 TEU. This would make it difficult to compete on price against the ships taking the Southern routes as they can use economies of scale to lower cost.

5) Other logistical costs

Ships taking the NEP will have to pay for permits from Russia, and it is expected there will be additional insurance costs for using the route. Also the cost of hiring icebreaker ships and guide ships have to be taken into account, all of which may negate the cost savings from reduced travel time and fuel.

6) Cost for ship modification and maintenance

Due to the severe operating environment, ships may need to undergo modifications to increase their strengths, and the ship maintenance cost may increase. Modifying the ships for the Arctic Ocean routes only to be used during the summer is not cost-efficient.

7) Shift in the global trading routes

The global shipping route is shifting towards the Southern Hemisphere, meaning the Arctic will become less important as a shipping route. Rather than going from Japan to Europe or from Europe to North America, a lot more trade is going from China to Brazil and Africa to the Middle East or Africa to India. There is not enough demand to have regular, direct transfer between Europe and Japan, and ships often stops at China, Singapore and South East Asia to pick up additional containers to ship to Europe in order to make the trip more cost effective.

After taking all the practical matters into consideration, the use of Arctic Ocean shipping routes by Japanese shipping companies is limited for certain commodities, for a certain time of the year. Currently, the Japanese companies are doubtful whether the routes would become a global maritime trade route that is available all-year-round, and without some concrete economic incentives, they are cautious on making any significant move.

4.5.2 Stakeholder Analysis

At national level, the Japanese Ministry of Land, Infrastructure, Transport & Tourism (MLIT) manages the Japan Coastal Guard and the Japan Meteorological Agency. Both organisations distribute information on the sea ice condition for shipping companies and the coastal communities in Hokkaido. The biggest proponent of the Arctic Ocean shipping routes in Japan is the Hokkaido prefectural government and associated public bodies. Their prime motivation is to build a large-scale port facility in Hokkaido as the new Northern shipping hub for Japan in order to stimulate economic growths and create jobs for the region.

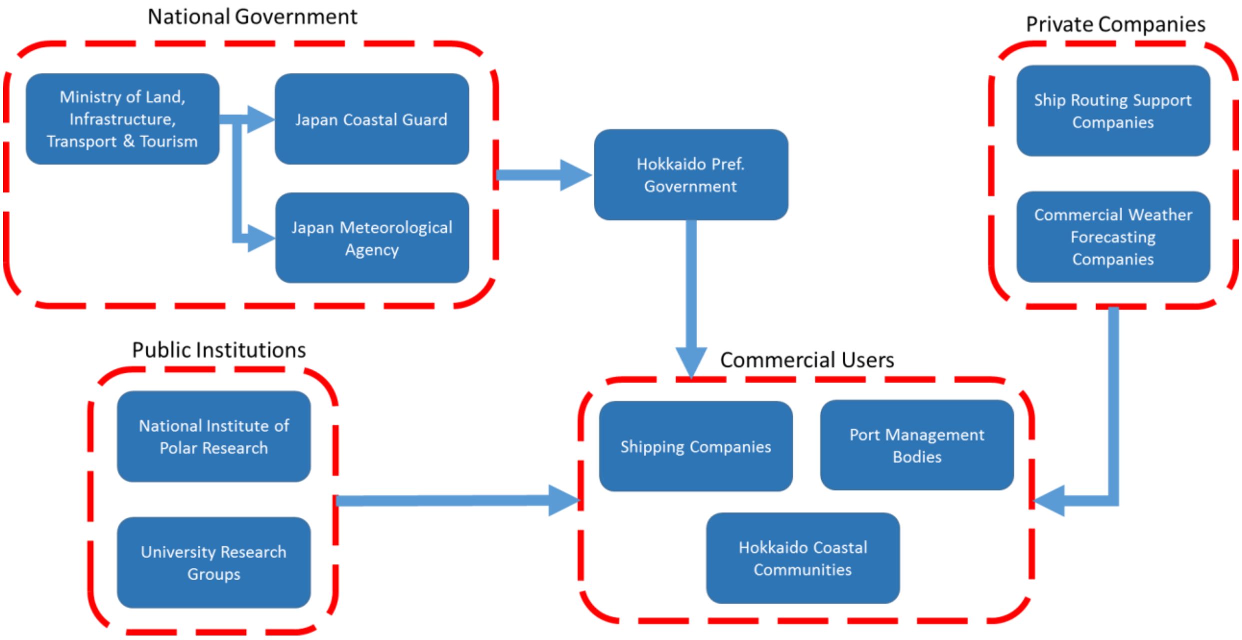


Figure 4-48 Summary of the stakeholders involved in sea ice monitoring in Japan

There are 3 major shipping companies in Japan, and they are *Nippon Yusen* (also known as *Japan Mail Shipping Line*), *Kawasaki Kisen Kaisha, Ltd.* (also known as *K-Line*), and *Mitsui O.S.K. Lines, Ltd.* These companies have been working together with the government officials and academia to investigate the feasibility of Arctic Ocean shipping routes.

The National Institute of Polar Research and several university research groups also use satellite data to provide free sea ice monitoring and forecasting for the shipping companies. Tokyo University of Marine Science & Technology, Tokai University, and Kyushu University are particularly active in this effort.

Lastly, there are several private companies looking to start sea ice monitoring and forecasting service. In particular, *WEATHERNEWS INC*, a commercial precision weather forecasting and meteorological information service, has been investigating the possibility of providing support services for the Arctic Ocean shipping routes, and is expecting to commence their Arctic sea ice monitoring service during 2016.

4.5.3 Existing Systems & Recent Developments

Currently in Japan, there are several organisations offering sea ice monitoring and forecasting for free, but they are limited to the Northern seas of Japan near Hokkaido, and the Okhotsk Sea:

- The Japan Meteorological Agency
- The Ice Information Centre under the Japan Coastal Guard
- JAXA’s Earth-Observation Research Centre (EORC)
- Sapporo Meteorological Observatory in Hokkaido
- Tokai University Information technology Centre (Prof. Kohei Cho’s research group)

The organisations use the data from PALSAR on-board ALOS-2, and the weather satellites *Himawari*, NOAA and MTSAT, and the data from the radiometers AMSR-2 on-board GCOM-W satellite, and AMSR-E and MODIS on-board NASA’s *Aqua* and *Terra* satellites respectively.

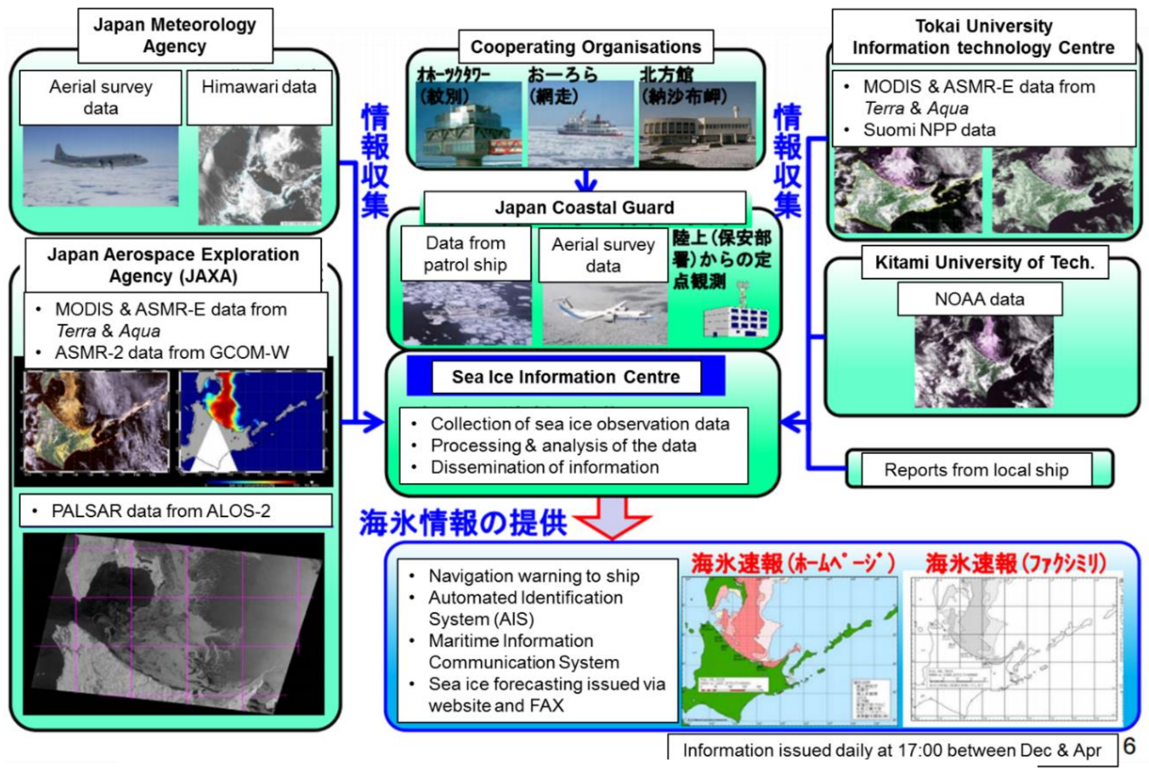


Figure 4-49 Japan’s current sea ice monitoring system and the participating entities (JCG, 2015)

The services offer daily updates on the sea ice condition near Hokkaido and in the Okhotsk Sea, as well as emergency alerts and forecasts up to one week ahead. The sea ice condition is presented in terms of average surface packing density, which describes how close the sea ice is to one another and is given a number between 1 and 10, where 10 describes a situation where sea ice is so densely packed that ships are unable to move.

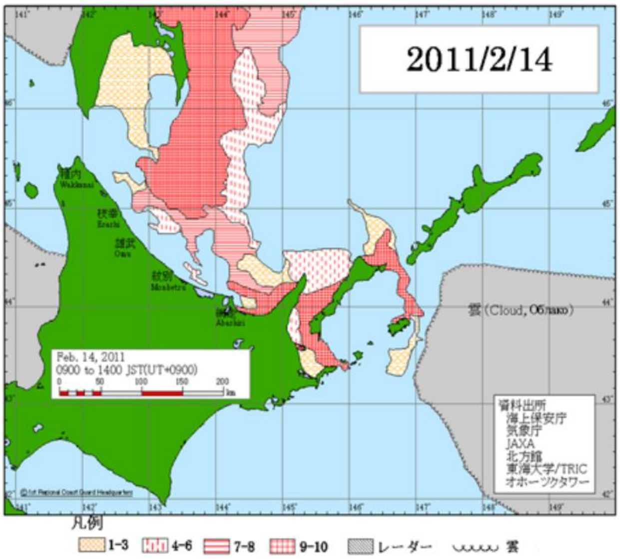


Figure 4-50 An example of sea ice information in Hokkaido (JCG, 2015)

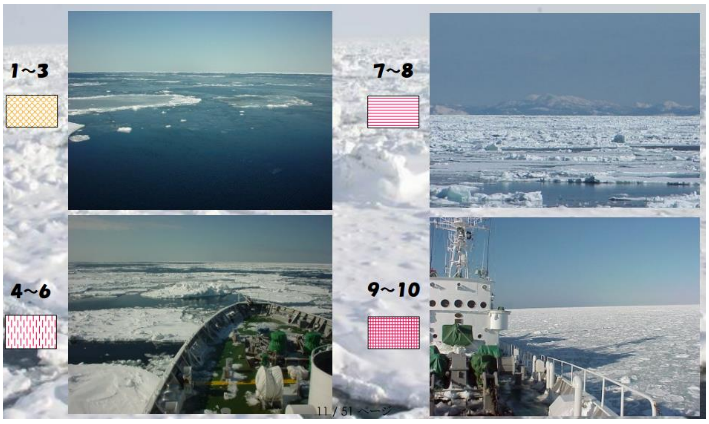


Figure 4-51 Different levels of sea ice packing density (JCG, 2015)

In the private sector, *WEATHERNEWS INC* has just started their new service called the *Global Ice Centre* in 2016, to provide information of the sea ice in the Arctic Ocean (WEATHERNEWS, 2016).

WEATHERNEWS has been offering precise weather forecasts and ocean forecasts for shipping companies, and they have been showing a high level of enthusiasm to expand their service to include sea ice monitoring and forecasting. They decided that they need to have their own satellite to provide the service, and in 2012, the company announced that they contracted *Axel Space*, a Japanese start-up specialising in the design, development and operation of smallsat, to build a microsatellite for monitoring the sea ice in the Arctic Ocean. The satellite is called WNISAT-1R, and was launched in early 2016. The satellite weighs 43 kg, and it is undergoing final checks and operational rehearsal (Axel Space, 2016).

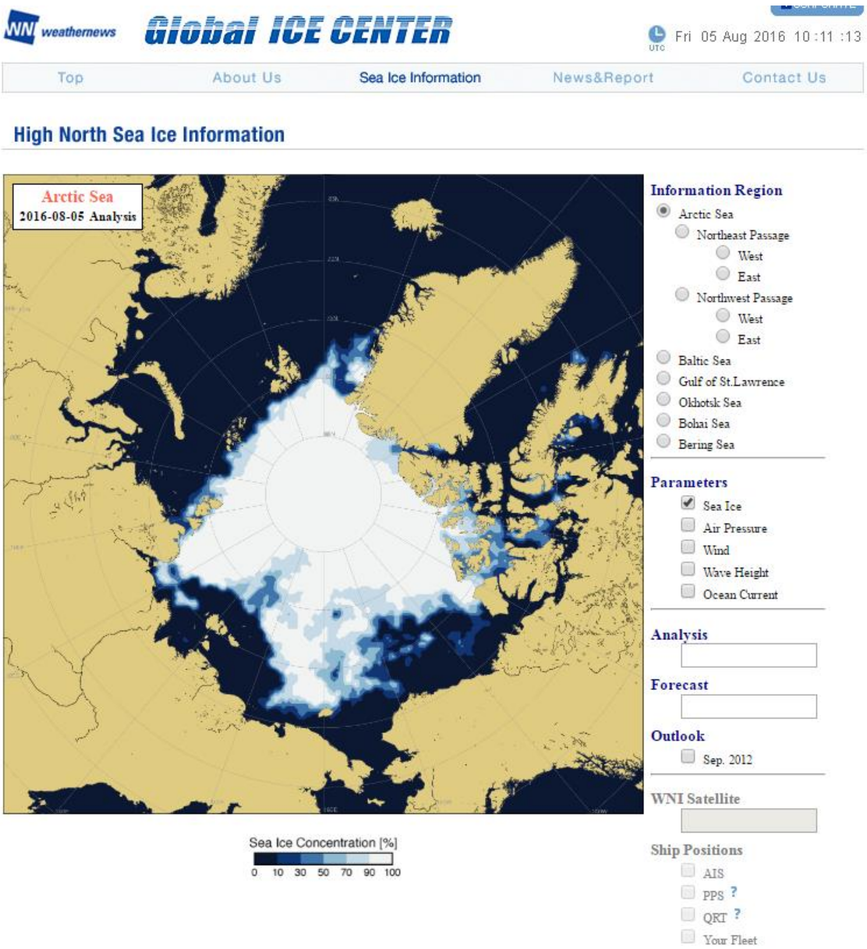


Figure 4-52 WEATHERNEWS' sea ice information service (WEATHERNEWS, 2016)

WEATHERNEWS hopes to address the skepticism from the Japanese shipping companies about the prospect of the Arctic Ocean shipping routes by offering them a clear, regular sea ice forecasts to assist with their operational planning.

Number of Cameras		4 (independent bands)
Spectral Bands	Panchromatic[1]	450-650 nm
	Green	535-607 nm
	Red	620-680 nm
	Infrared	695-1005 nm
Pixel Count		2048 × 2048
Bit Depth		12 bit
Ground Resolution	Infrared and Red	400 m
	Green and Panchromatic	200 m

Figure 4-53 Specifications of WNRSAT-1R developed by Axel Space (Axel Space, 2016)

4.5.4 Needs & Opportunities

Sea ice monitoring is a relatively new area of satellite application. No Japanese company has started any commercial service in area, which leaves possible opportunities for European SMEs to fulfill. The only commercial organisation in Japan monitoring sea ice using their own satellite is *WEATHERNEWS*, and there may be an opportunity to establish a collaborative operation of their WNISAT-1R satellite with other European satellites to increase the temporal resolution and coverage. The needs and requirements gathered from the interviews are summarized below.

Table 4-22 Summary of the key needs and requirements pertaining to sea ice monitoring in Japan

Requirement ID	Requirement Description
REQ-ICE-01	Need to establish reliable, accurate, long-term forecast of the sea ice condition in the Japan's Northern seas and the Arctic Ocean.
REQ-ICE-02	Dedicated EO satellite for monitoring the sea ice condition in the Japan's Northern seas and the Arctic Ocean.
REQ-ICE-03	Explore ways to combine satellite observation data with in-situ data.
REQ-ICE-04	Need to collect more in-situ data in the Japan's Northern seas and the Arctic Ocean using buoys, Argo Floats and ocean surveying vessels.
REQ-ICE-05	Improved algorithm for estimating ice thickness, type of ice, and snow cover on ice.
REQ-ICE-06	More refined resolution for estimating surface ice packing density.
REQ-ICE-07	More research efforts on estimating the speed of moving sea ice.
REQ-ICE-08	Investigate possible correlation between sea salinity and sea ice.
REQ-ICE-09	Must ensure data continuity for microwave radiometer data by securing a successor of AMSR-E and AMSR-2 in future EO missions.

The main need from the Japanese shipping companies is to have a regular, reliable sea ice forecasts so that they can make long-term operational planning of their shipping routes (REQ-ICE-01). Developing a dedicated satellite for Arctic monitoring (REQ-ICE-02) and combining in-situ data will probably improve the forecasting accuracy (REQ-ICE-03 & 04).

Although the Japanese shipping companies are still unsure about the economic viability of Arctic Ocean shipping routes, there is still a strong need in Hokkaido to monitor sea ice condition. The coastal communities of Hokkaido face significant damages due to sea ice during the winter every year, thus, they need to set up an accurate monitoring and forecasting service to alert the communities and take damage mitigation measures. Also, Hokkaido hopes to promote its tourism industry by creating new cruise ships to see the sea ice and explore the northern seas. All of these potential industrial applications will require accurate and reliable long-term forecasting of sea ice condition.

In terms of climate change, understanding the formation of sea ice is an important component, and Japan is an active member in many of the climate change research initiatives. Sea ice monitoring and forecasting is actively researched by JAXA's Earth Observation Research Centre (EORC) and several universities, and they have shown a high level of interests on possible research collaborations with Europe. The universities in particular have expressed strong enthusiasm to set up a relationship with Europe to exchange data and other information, and jointly work on algorithms for analysing sea ice (REQ-ICE-05, 06, 07 & 08). They have already developed an algorithm for analysing large pieces of sea ice, but more work is needed for identifying thin and smaller pieces. The biggest concern at the moment from the research communities in Japan with respect to sea ice is the data continuity when the microwave radiometers AMSR-E and AMSR-2 retire between 2018 and 2022 (REQ-ICE-09).

4.6 Other Industries

There are several areas of application for EO data which are either relatively new and the business model hasn't been established, or traditionally not commercially-oriented. These areas are briefly examined in the proceeding sections, with the description of the potential needs and opportunities as well as existing systems.

- **Maritime Management, Surveillance & AIS**

In terms of marine territory, Japan is the 6th in the world with its territorial waters and Exclusive Economic Zone (EEZ) combined amounting to a total 4.47 mil km^2. Therefore, Japan has a vast area of monitor, and there is a huge potential for maritime surveillance in Japan.

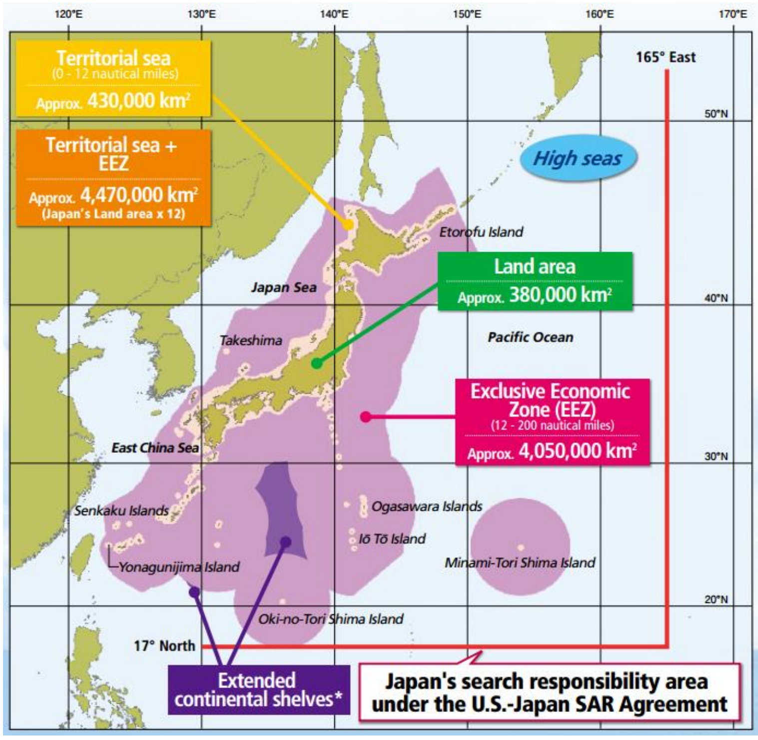


Figure 4-54 Japan's territorial waters and EEZ (Akiyama, 2013)

Due to its large maritime territory to manage, as well as growing tensions with China in the South China Sea, and the ongoing problem of illegal fishing activities in Japan's territorial waters, the Japanese government enacted the Basic Act on Ocean Policy (*Kaiyō Kihonhō*) in 2007 to increase its commitment to ensuring maritime surveillance and maritime domain awareness. Since then, there is a growing interest from the Headquarter for Ocean Policy of the Cabinet Office of the Japanese government, the Japan Coastal Guard, and public and private port management authorities. In response, there have been significant developments in both public and private sectors in Japan to provide vessel tracking and maritime monitoring services.

JAXA conducted a technology demonstration mission for AIS vessel monitoring, and launched *Small Demonstration Satellite-4* (SDS-4) in 2012, and ALOS-2 in 2014, both equipped with an AIS receiver, SPAISE (JAXA, 2016). The mission has completed the routine operation phase, which involved receiving ground-based AIS signals, monitoring the change in the number of ships and weather conditions. The mission is in its final stage, which will demonstrate vessel tracking, maritime territories, and emergency response.

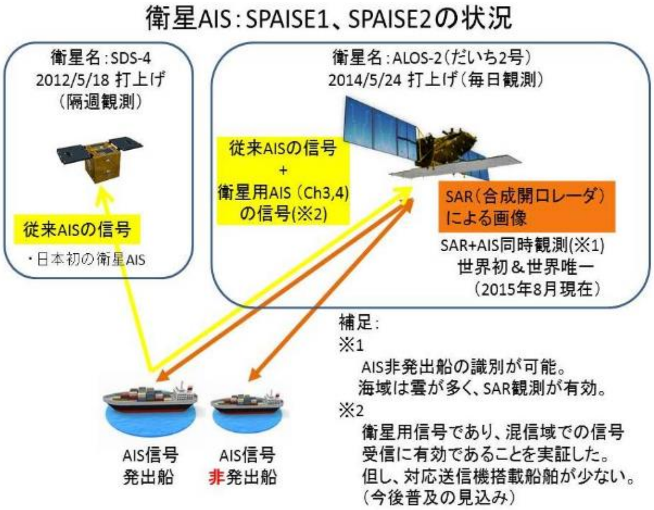


Figure 4-55 Maritime AIS demonstration project using ALOS-2 and SDS-4 (JAXA, 2016)

A major Japanese EO data company, PASCO has signed an exclusive distributor agreement with *exactEarth*, a Canadian company specialising in AIS vessel tracking services, to be in charge of the sales and promotion of their service, *exactAIS* (PASCO, 2016). Within Japan, *Monohakobi Technology Institute* is developing a system to better utilise AIS for their extensive services pertaining operational support for shipping companies (Monohakobi, 2016). Also a Japanese cubesat company *Advanced Engineering Services Co. Ltd.* is developing their own cubesat mission to demonstrate AIS vessel tracking (AES, 2016).

In fleet management and vessel operational support, *Japan Radio Co. Ltd.* has developed a cloud-based service called the *J-Marine GIS*, which provides weather routing, vessel management and precise weather forecasting (JRC, 2016). Their service provision is shown in Figure 4-57 and 4-58.

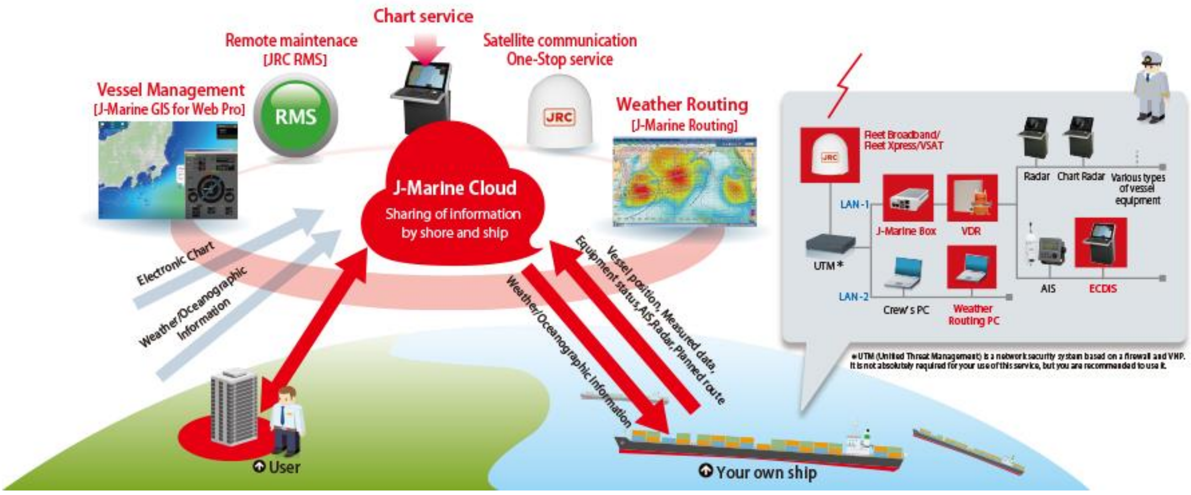


Figure 4-56 Fleet management system provided by *Japan Radio* (JRC, 2016)

Service Items

Weather Routing [J-Marine Routing]

- The highly accurate weather routing based on detailed weather forecasts is provided to vessels and shore.
- By linking JRC' s ECDIS with the weather routing, optimum routing is available *1.

Vessel Management [J-Marine GIS for Web Pro]

- The positions, engine and navigational equipment information of your own ships are monitored in real time on the shore.
- The failure and alarm conditions of navigational equipment can be monitored, allowing quick response and repairs to be made.
- Such various information and data can be selected to meet the individual purposes and the order of overlaying the information layers can be set.

Weather/Oceano graphic/Port Information [J-Marine GIS for Web Pro]

- The weather/oceanographic information layers including wave hei ghts and directions, wind directions and velocities, weather ch arts, typhoons, rainfalls can be selected and displayed.
- The vessel movement surveillance information and the weather/oc eanographic information collected by AIS, marine radars and meteorological sensors can be displayed through the JRC' s VTS*2.
- The measured distances and areas, the dangerous zones, and tags and memos can be displayed on a map, allowing sharing of infor mation between shore and ship.

Figure 4-57 Service description of J-Marine Cloud provided by *Japan Radio* (JRC, 2016)

Another venture worthy of noting is *Forecast Ocean Plus*, which provides ocean forecasting using satellite and in-situ sensor data for shipping companies and oil & gas companies [Forecast Ocean Plus, 2016]. The company was founded by the researchers from *Japan Agency for Marine-Earth Science & Technology* (JAMSTEC) as a venture company under JAMSTEC.

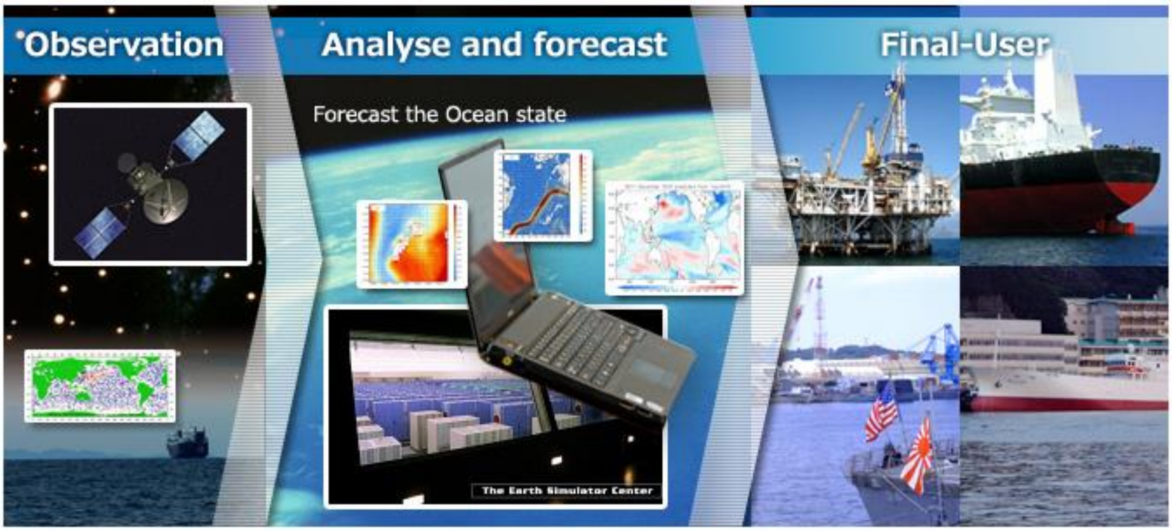


Figure 4-58 Service description of Forecast Ocean Plus [Forecast Ocean Plus, 2016]

Despite all these developments with respect to AIS and ship routing, using satellite optical and SAR images to detect mysterious ship and illegal fishing activities have not been achieved in Japan so far. There have been several studies to explore the effectiveness of using SAR images to provide day/night maritime surveillance, but the issue of revisit time has posed an obstacle for moving forward. To detect illegal fishing activities for example, SAR images must be provided every 2-3 hours at least; otherwise, by the time satellite returns to the same region, the target ship could escape to another location and avoid being detected. This is another reason to explore the feasibility of combining different SAR data to improve the temporal resolution. Single satellite alone can only offer revisit time of several days, but combining Japan's L-band and the EU's C-band could significantly improve the observational frequency. However, one must also note that maritime surveillance, particularly in the distant ocean, is of interest to only several stakeholders such as the Japanese coastal guard and possibly the Japanese navy. Therefore, with so little potential clients, whether there is a true business case in Japan for maritime surveillance needs to be investigated further.

- **Disaster Management**

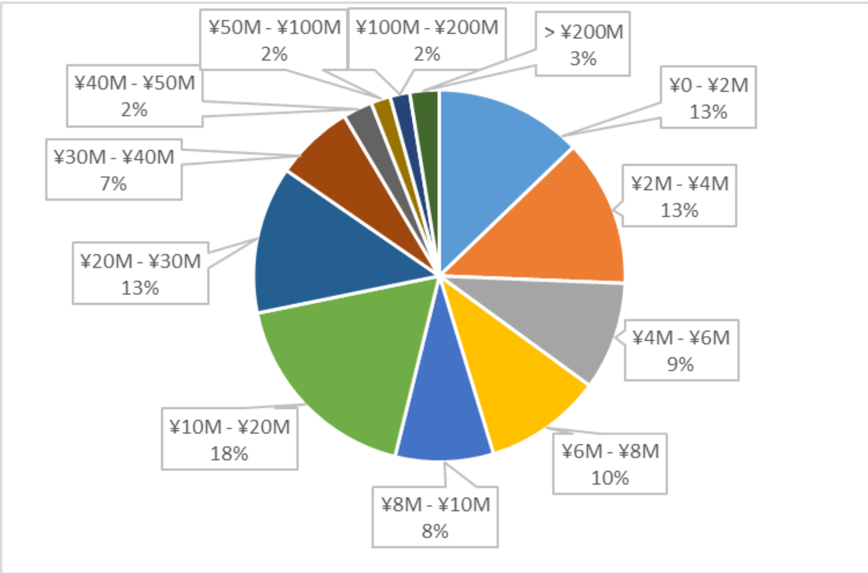
Japan is very prone to various forms of natural disasters, particularly earthquakes and typhoons. Thus, all the prefectural and municipal governments, as well as city and town councils have an internal department dedicated to developing disaster mitigation strategies and damage minimization measures. EO application companies in Japan use satellite images to provide various analyses and services to regional authorities before and after a disaster has struck.

During non-emergent, normal situations, Japanese regional authorities conduct a review of their emergency response strategy every few years. This consists of development of hazard maps, risk assessment of public infrastructures, and planning of community evacuation procedures, which at times, involves development of software tools that incorporate satellite imagery. These preemptive measures are contracted to private surveying companies, and the authorities make announcements on their website to request for tenders (RFT). To give an indication of the number of public procurement pertaining to disaster management by authorities during non-emergent times, a scan of the central public procurement database was conducted (Griek, Public Procurement Market Quick Scan, 2016) using a set of key words. The scan was conducted using 13 sets of keywords, and found a total of 167 public procurement tenders between 2015 and 2016, and they are shown in Table 4-23.

Table 4-23 Summary of the scan of the public procurement database

Keywords Set	No. of Hits
"Satellite Imagery"	74
"Artificial Satellite"	13
"Disaster-struck area" & "Comprehension"	2
"Disaster Information"	7
"East Japan", "Earthquake" & "Satellite"	10
"East Japan", "Earthquake" & "Map"	0
"East Japan", "Earthquake" & "Image"	0
"Disaster Prevention" & "Satellite"	2
"Damage" & "Satellite"	59
"Disaster Forecast Map"	0
"Hazard Map" & "Satellite"	0
"Evacuation Plan" & "Satellite"	0
Total	**167**

The scan showed that the average value of the procurement contracts is approx. 48 mil JPY (approx. 420,000 EUR in 2016 Sept exchange rate). A histogram of the contract sum is shown in Figure 4-59.



Range	Frequency
¥0 - ¥2M	15
¥2M - ¥4M	15
¥4M - ¥6M	11
¥6M - ¥8M	12
¥8M - ¥10M	10
¥10M - ¥20M	21
¥20M - ¥30M	15
¥30M - ¥40M	8
¥40M - ¥50M	3
¥50M - ¥100M	2
¥100M - ¥200M	2
> ¥200M	3

Figure 4-59 Histogram of public procurement tender sum related to disaster management in 2015-16 (modified from (Griek, 2016))

In 2015-16, PASCO won the most number of public procurement pertaining to disaster management, followed by Japan Space Imaging, NEC, Kokusai Kogyo, Green Kogyo, RESTEC and NTT Data.

The eligibility for these tenders typically stipulates the company to have a representation in the region administered by the local authority. For this reason, some of the larger companies set up regional offices in almost every prefecture so that they are eligible when a RFT is announced in a particular prefecture or a city. The major EO application companies have all taken part on these regional projects. Therefore, the European SMEs could enter is probably to establish a partnership with a Japanese company and jointly submit a tender.

In the case where a disaster has already struck, Japan is a member of *Sentinel Asia*, the inter-agency collaboration for sharing data and capabilities for disaster management, and receives satellite images from the member organisations.

The Earth Observation Research Centre (EORC) of JAXA is the representative agency for Sentinel Asia in Japan. In the case of an emergency, EORC receives data from domestic and foreign satellites, processes them before distributing them to various government bodies. Due to the extremely large amount of data received, the amount of resources needed to process and distribute the data has been the biggest problem for Japan.

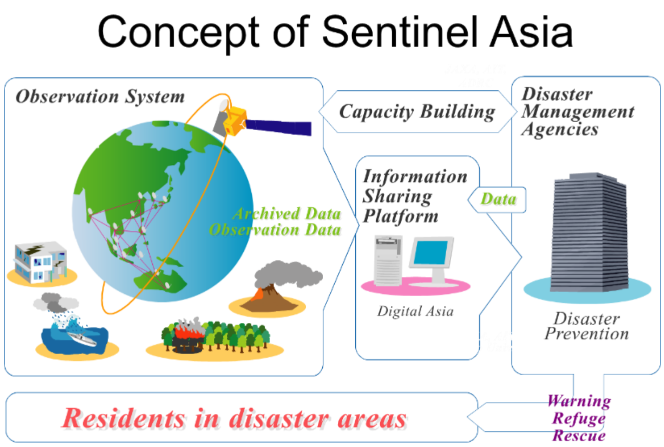


Figure 4-60 Overview of Sentinel Asia (APRSAF, 2016)

In response to this bottleneck, government bodies typically contact major EO application companies directly to conduct various analyses to support disaster response activities. This includes analysis of the impacted areas, the extent of the damage, and estimation on the amount of rubble, landslides or flooded areas. These requests are often made as a single tender procedure, where governments select a specific contractor for a project without putting out an official tender notice.

The EO application companies themselves conduct analyses in most cases as a voluntary, *pro bono* activity to support disaster response activities. For example, when the Great Eastern Earthquake occurred, Kokusai Kogyo estimated the amount debris caused by the subsequent tsunami.

The Japanese EO application companies also respond to requests from insurance companies to perform disaster impact assessment to assist with the calculation of insurance pay-outs.

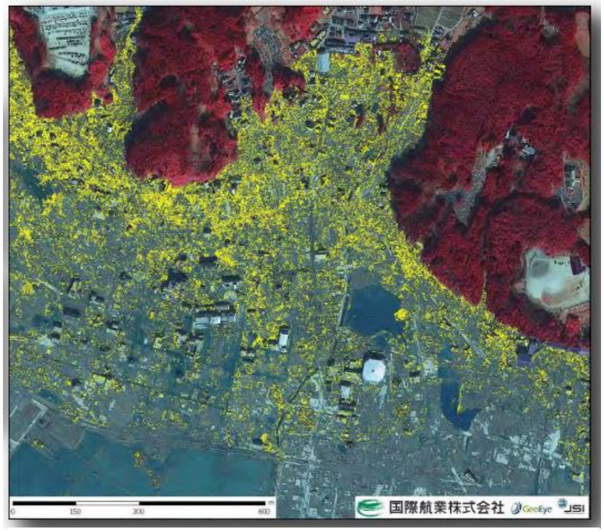


Figure 4-61 Debris analysis of the 2011 Tohoku Earthquake performed by Kokusai Kogyo (Arai, 2015)

- **Renewable Energy**

Japan is gradually building its power generation capability using renewable energy (RE) sources. Solar power plants are already in full commercial operation throughout the country, and several 10 MW-scale plants are operated by major Japanese power companies, such as Tokyo Electric Co. (TEPCO), Kansai Electric Co. (KEPCO) and Tohoku Electric Co. Almost all the prefectures in Japan have implemented onshore wind turbine to varying degrees, and several demonstration projects for offshore wind turbines and ocean/hydraulic power generation are being developed in Kyushu and Tohoku regions. For more details about the renewable energy in Japan, readers are encouraged to refer to the reports by

There may be opportunities to use EO data, such as solar irradiance and sea current information, to assist with estimating power generation capability and optimise plant operation. So far in Japan, NEDO, the New Energy & Industrial Technology Development Organisation, has developed an online wind and ocean current forecasting service for power generation purposes, but no commercial entity has entered into the field of renewable energy. The situation may change in the near future as the RE industry gains more momentum. In 2015, Unisys Japan, an ICT company, announced that it has formed a partnership with JAXA as part of JAXA's business incubation program, to develop an Energy Management System (EMS) to optimise solar power plant operation using EO data. The outcome of their project is expected in 2017.

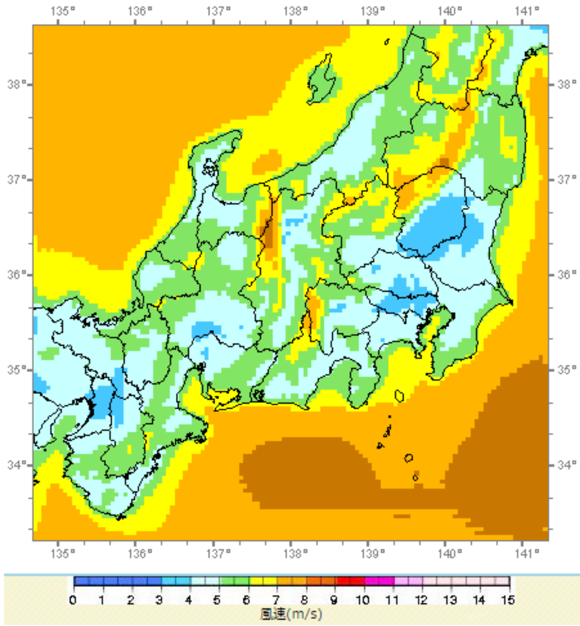


Figure 4-62 NEDO's wind speed monitoring system (NEDO, 2016)

4.7 Most Promising Areas

Examination of the key industries pertaining to EO data application gave valuable insights into their current status and needs to assess the feasibility of implementing EO-related products and services in Japan. Due to the declining and aging population in Japan, there is a strong interest and demand to implement more efficient monitoring system, and satellite Earth-observation is gaining more recognition as the suitable solution. The interviews identified the following industries as promising areas for collaboration between the EU and Japan for the reasons described below:

- Agriculture
- Maritime Management & AIS
- Fishery
- Urban Infrastructure Management

The agriculture industry in Japan, at least in Hokkaido and several other Northern prefectures, is fairly accustomed to utilising EO data to support farming activities. Several Japanese companies have succeeded in establishing their EO application service as an on-going business, and the key objective now is to expand the market by exploring ways to apply EO data for smaller prefectures and farmlands. Also, the industry has more corporate bodies involved with many food companies and ICT start-ups with greater focus on boosting the production efficiency. Thus, they are probably more open to implementing new technologies.

Demand for maritime management, such as ship routing and vessel monitoring using satellite images and AIS is expected to grow significantly in the very near future as it is one of the key strategic areas for Japan, as the country puts more emphasis on national security, and maritime domain awareness and governance. Amidst the political situation with China over Japan's EEZ, it is expected that Japan will strengthen its maritime monitoring capabilities in the coming years. Interviews with the Japanese EO applications companies hinted that they are giving some serious consideration to this relatively new area of application, and are closely watching the latest developments in the US and Europe. Some companies have already formed partnerships with overseas companies, which indicate possible opportunities for European SMEs with expertise in this area.

For fishing ground prediction, only three SMEs in Japan have developed services, and none of the major EO application companies have gone into this area. There is still unfulfilled needs in the Japanese fishing industry, particularly in coastal fishing, and the three SMEs expressed interests in having discussions with European companies to explore possible synergies and collaboration opportunities. Medium spatial resolution (10 – 50m) and high temporal resolution are the key requirements for this industry, and the data from Sentinel-2 and possibly from the meteorological satellites on the geostationary orbit have a significant potential to be utilised.

Lastly, a majority of the public infrastructure in Japan is several decades old, and there is a growing concern to implement a more efficient practice in monitoring phenomena such as ground subsidence. SAR interferometry is gaining more and more interest from private and public sectors, and the major EO application companies in Japan are already moving into this area.

On the other hand, the interviews also identified that the following industries may require further consideration before the use of EO application could gain momentum:

- Forestry
- Renewable Energy
- Sea Ice Monitoring
- Disaster Management

The forestry industry in Japan faces the same problem as the agriculture and fishing industries, and they urgently need a system to drastically improve their forest monitoring maintenance efforts. However, the harsh terrains of Japan and the level of spatial resolution needed make it difficult to readily implement satellite remote-sensing. Furthermore, a better monitoring system is only half of the problem as the Japanese forestry industry still needs to install various support infrastructures, such as forest road network and larger logging machines, to help forest owners reduce operational costs.

As for sea ice monitoring, the relevance for Japan is to 1) minimise damage for the coastal regions of North-eastern Hokkaido, and 2) transport oil and natural gas from the Northern coasts of Russia if the Japanese shipping companies are selected as the prime contractor, and satellite-based monitoring system could play a role particularly on the second point. Japanese government officials and academics are pushing the idea of using satellite observation to assist with Northern shipping routes between Japan and Europe, but the true economic worth requires further investigation.

The renewable energy sector in Japan, particularly wind and hydro energy, is still in its infancy, and the role that satellite observation could play is still to be seen. The only exception is solar energy, which is already a mature industry in Japan. Solar panel monitoring for preventive maintenance, and optimisation of solar power plant operation are probably the likely application areas where European SMEs could fulfill. However, the concept of preventive maintenance is still not well-recognised among Japanese companies, and it may take some time before satellite application can create a clear business case.

Lastly, for disaster management, it is unclear whether there are substantial business opportunities for European SMEs. During non-emergent situations, there is indeed a constant demand for disaster risk reduction activities by regional governments throughout Japan, but the eligibility to tender may include certain conditions that are difficult for EU SMEs to fulfill. In the case of a disaster, most of the services are offered to government bodies on a voluntary-basis or more likely, through a single tender process, which requires a certain level of track-record and relationship-building with the Japanese government for a company to be considered. Approaching the insurance companies in Japan may be a more feasible option for European SMEs.

4.8 Notes on Public Procurement

The interviews with various industries revealed that numerous government bodies and industry groups throughout Japan are conducting pilot projects and feasibility studies that, at times, use satellite data to develop software tools and applications. Initiatives such as Smart Agriculture and Smart Forestry are gaining momentum among the regional governments in Japan, and they are typically carried out under partnerships between regional governments and private companies. It may be possible for European SMEs with the right expertise to participate in these opportunities.

For projects carried out at the national level, they typically go through a formal tendering process, which may include conditions that are difficult for foreign entities to fulfill, such as having a representative office in Japan. However, in municipalities and cities, the tendering regulations are more varied, and the regional governments are allowed to set up tendering process at their own discretion, and some do not explicitly prohibit bids from overseas. For examples, in Northern prefectures of Japan, the city councils have set up a department dedicated to industry development, where esteemed companies can contact and directly propose solutions of interest to the city instead of going through a formal tendering process. Details about the government procurement in Japan can be found in one of the previous MINERVA research reports by (Griek, 2013).

5 Conclusions & Recommendations

5.1 Conclusions

This MINERVA research project investigated the Earth-observation (EO) application industry in Japan. The research focused on analyzing the current market climate, as well as determining the needs, challenges and opportunities in Japan for European SMEs pertaining to EO related products and services.

The analysis of the Japanese EO applications industry found that Japan has a highly capable EO program, with a proven track-record in a wide array of subject areas, ranging from agriculture to SAR interferometry. Therefore, any European SME or government organisations interested in cooperative ventures with Japanese entities have to understand that Japan isn't a country with a fountain of untapped needs and potential. It is a technologically matured country that is very comparable to Europe, and most of the common applications of EO data have already been trialed and tested. Some companies have even managed develop these efforts into sustainable, although small-scale business ventures. Having said that, it is also clear that the Japanese EO applications industry has been heavily dependent on government contracts, and the needs of the private sectors haven't been well-explored. Therefore, any consideration of possible partnerships between the EU and Japan must carefully examine the strengths and weaknesses of the both sides, and look for niche areas where they can complement each other's capabilities.

When considering to partner with Japanese entities to provide EO-related products and services, the EU SMEs must also be aware of the high level of standards expected by Japanese users. Japanese farmers wanting growth monitoring at 1-2 m ground resolution at a low cost, and fishermen requesting at least 1 in 3 chance of correctly predicting the location fishing grounds reflect the high service level expected by Japanese user communities. Although there many problems still exist, Japan has already implemented various systems to ensure efficient, high-quality service provision based on aerial surveying, sensor networks, and the diligent nature of Japanese working culture to carry out regular visual inspections. With this in mind, the level of expectation by potential user communities in Japan for the EO applications is to offer far superior outcome in terms of benefits, reliability and accuracy than the existing systems and practices. Services that only yield generic results or marginal benefits will not be enough to engage the interests of the user communities in Japan. Considering the general conservatism to stick with the status quo and risk-averse attitude of the Japanese society, EO applications must demonstrate strong, clear business case that is going to offer definitive cost reduction and/or revenue increase in order to convince potential Japanese users.

Having said that, the investigation has also identified that the Japanese industries are struggling with declining and aging population, and there is a clear need to implement more efficient monitoring practices, and satellite observation is slowly gaining recognitions. Some overseas firms have already conducted pilot projects in Japan, and some have even signed exclusive distributorship agreements for their satellite-based solutions with Japanese companies. Thus, there are opportunities for European and Japanese companies to work together and address the unfulfilled needs in the private sectors.

Furthermore, the open data policy of Japan for their satellite data clearly aligns well with the EU's Copernicus program, and the European Commission and the Japanese government should look to complementing each other's database. With the global EO market shifting toward near real-time provision of EO data, ESA and JAXA should also explore the possibility of collaborative operation of their satellites to improve the temporal resolution and response time.

The interviews showed that the EO application companies and government agencies in Japan are moderately interested in collaborating with European companies. They are keen to learn from Europe and expand their views on commercial EO downstream applications and the engagement of the private sector. There is a strong enthusiasm for information exchange and joint-research projects to increase each other's technical/commercial abilities.

For more business-oriented partnerships, one crucial point is that it must offer a *'win-win'* situation for companies from both sides. The field of EO downstream application is expected to grow in the next decade to a world market size of US$4.3 bil by 2024, but one must realize that it is still a relatively small *'pie'* in the space domain when the global GNSS industry alone is already estimated to be over 50 bil EUR in 2016. Therefore, any partnership that involves European companies entering the Japanese market, and vice versa, is simply eating into each other's already small *'pie'*, and it's a zero-sum game that doesn't contribute to increasing the size of the *'pie'* itself. Therefore, possible EU-Japan partnerships must be capable of increasing size of the *'pie'* than pursuing it alone.

Companies are influenced by profits and risks, and unless the objectives, format and expected benefits from partnerships are clearly defined, any agreements or policy made at the government level will not resonate in the industry.

5.2 Recommendations

<u>For the European Commission</u>

1) Start an EU-Japan dialogue focused on EO products and services

In order to truly establish the relationship between Europe and Japan on Earth-Observation applications, it is absolutely vital to have a formal, regular dialogue between the government bodies of the respective regions.

Although discussion between Europe and Japan is already underway at the space agency level, between JAXA, ESA, DLR and CNES, it is essential that the dialogue also needs to occur at the EU level, between the European Commission and the Japanese government. Considering that the EU-Japan Space Dialogue is expected in the timeframe of 2017, the European Commission should consider organizing a dedicated to event to discuss exploitation of EO data and downstream applications with Japan, and explore possible forms of collaborations as well as joint-goals in the long-term. The commission should also look to build on the *EU-Japan Strategic Partnership in Research and Innovation*, and establish additional dialogues and collaborative ventures.

To build relationship with Japan in the field of EO application, the European Commission should focus its efforts in strengthening the relationship with the National Space Policy Secretariat of the Japanese Cabinet Office and the four key government ministries – the Ministries of Internal Affairs & Communications (MIC), the Ministry of Education, Science, Technology, Culture & Sports (MEXT), the Ministry of Economy, Trade & Industry (METI), and the Ministry of Defense.

It is important to note that the Japanese government is actually considering the EU as a role model in structuring their own space policy. In terms of socioeconomic structure and history, Japan feels more affinity to Europe than the US, and they are much more interested in learning from the EU in regards to space and EO data policy, and more importantly, the exploitation and the development of EO downstream applications. Therefore, if the EU initiates a dedicated dialogue, it would give an opportunity for Japan to learn and gather information and help them in shaping their space policy. By doing so, the EU can build up the relationship with Japan, and gain greater commitment from them to take part in more concrete activities with the EU in the future.

From the author's personal experience with dealing with various members of the Japanese government, Europe has to lead the discussion and suggest various partnership ideas in order to instigate Japan to take action, not the other way around. Although the National Space Policy Secretariat is taking steps in changing Japan’s attitude towards space and EO application, the author feels that it is more likely to yield results if the EU takes the initiatives in encouraging Japan to take action.

2) Promote the EU’s Copernicus in Japan

Interviews with the Japanese companies revealed that the EU’s Copernicus program was not well-known in Japan. Even the Japanese EO application companies were not fully aware of the program, except for a few companies and JAXA. If the European Commission intends to expand the use of Copernicus-derived data in Japan, it is absolutely vital to conduct more intensive promotion activities.

The ideal channels for promotion will be via the National Space Policy Secretariat, the four key ministries, JAXA and Japan Space Systems (JSS) when they conduct workshops and seminars between the government officials and the industry. The European Commission should look for opportunities to present Copernicus in these events.

Another possible idea is to secure funding for the promotion of Copernicus in Japan and/or Asia under FP7/Horizon 2020. Promotion is already underway for the EU’s Galileo with *GNSS.Asia*, which has been playing an incremental role in building relationship between the EU and Asia in the domain of GNSS. A similar project needs to be implemented for Copernicus for it to truly gain recognition in Japan.

3) Sign a formal agreement between the EU and Japan on the use of Sentinel data

One of the comments from the Japanese industry about the free and open distribution of Copernicus data was whether the European Commission sees Japan as merely one of its many users, or as a strategic partner. In order for the Japanese industry to use Copernicus data for commercial activities, they advised that they would like to see greater commitment from the EU, and guarantee that reliable, long-term access to the data will be provided to Japanese corporate users. Forming a Copernicus user agreement between the EU and Japan may be the best way to address these concerns, as well as engaging the interests of the Japanese industry.

4) Resolve the issue of reciprocity of EO data

The difference in attitude between the EU and Japan towards open-source satellite data could be an obstacle in future discussion about potential partnerships. Although the EU is pushing for full, open-source distribution of its satellite data, there is some level of hesitation from the Japanese government on following this trend. Currently, only the data from JAXA’s past missions and some of the current missions are provided for free for both academic and commercial purposes, and at least for now, the provision of medium to high-resolution imagery from ALOS and ALOS-2, and the Advanced Optical Satellite expected to be launched in 2019, will continue to be a paid-service.

Considering that 1) ALOS and the Advanced Optical Satellite offer images comparable France's *SPOT Image*, and 2) JAXA and MEXT intend to create Japan's first commercial EO satellite operation business under a Public-Private Partnership with PASCO, it is highly unlikely that the images will be offered on a free, open-source basis. Furthermore, Japan's shift to increasing its national security measures and the implementation of the Remote Sensing Act expected in 2017 will certainly play a role Japan's future data policy, and the European Commission may need to look for an alternative resolution.

5) Form joint-research projects for the EO-related calls in Horizon 2020, to promote EU-Japan partnerships

The interviews with the Japanese EO application companies revealed that they are quite interested in expanding their business overseas and collaborating with European companies to complement their capabilities in the EO domain. In that respect, Horizon 2020 has been identified as an ideal *'first step'*, or a *'trial run'* for a joint-development of EO downstream application between the EU and Japan. However, the fact that the Japanese companies can't receive any funding for participating in H2020 has made it difficult for them to justify their participation over expected costs. Joint calls have already been established between the EU and Japan for ICT after series of dialogues. Thus, the European Commission should discuss with the Japanese government on making similar arrangements, most likely METI and MEXT, about establishing a joint call for EO to alleviate the amount of financial burden for the Japanese side.

6) Agree on a common set of goals and roadmaps for increasing the use of EO downstream applications

Even if H2020 provided financial support for Japanese companies, if there is no follow-up after the initial project duration of 3 years, it will simply finish as a one-off collaborative research project with little economic or industrial benefits. Going back to the earlier discussion about setting up a *'win-win'* scenario for both sides, the European Commission and the Japanese government must come together to agree on a set of global problems that they will address together using EO applications, and commit to a set of clear objectives and development roadmap. Examples of global problems include resolving food and water security, climate change, and widespread epidemic.

7) **Set up EU-Japan collaborative projects by consolidating the funds of JICA, ADB, WB and EIB, and form an alliance to solve global problems together**

One possible avenue for long-term collaboration with potential to bring a *'win-win'* scenario for the EU and Japan is to set up joint development projects between the financial institutions of the two regions. By doing so, it opens up markets to the both regions that were closed to them before. JICA and ADB have enabled Japanese EO application companies to have strong ties with countries in South East Asia, Brazil and some in Africa. Likewise, European companies enjoy a strong presence in Africa through the development projects under WB and EIB. Instead of overlapping each other's activities, establishing jointly funded programs consisting of international consortiums made up of companies from the two sides can open up new markets to each other.

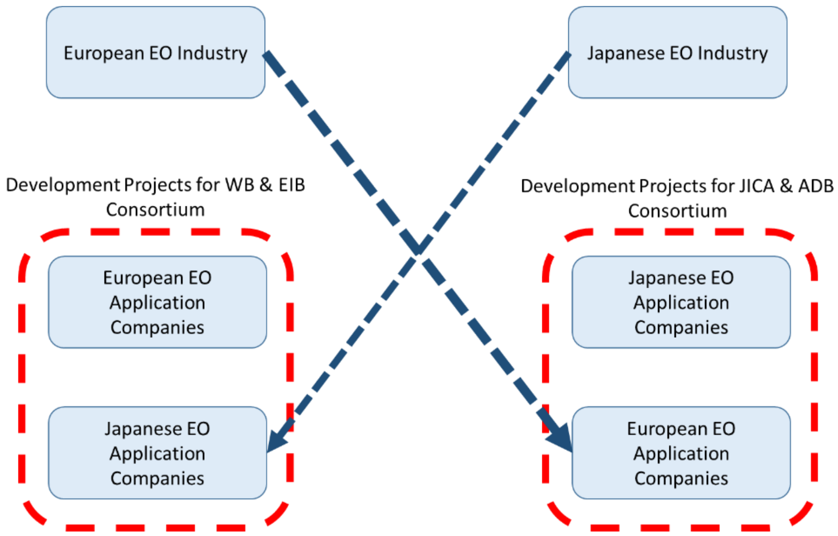


Figure 5-1 Possible form of EU-Japan consortium under international project initiatives

For the European Industry

1) **Build up relationship with Japanese companies through exchange of information, workshops and seminars**

From the interviews, it became clear that the Japanese EO application companies are interested to learn more about the trends and capabilities of Europe to explore the possibility of partnerships. However, the information is scarce due to the geographical distance and the lack of cooperation in Space between Europe and Japan in the past. It is well-known that Japanese companies spend significant time and effort when considering new business ventures. Therefore, as a first step, the EU and Japan should organise more workshops and seminars to introduce each other's companies, and identify possible areas of complementarity between them. Interested companies are encouraged to consult the EU-Japan Centre for

Industrial Cooperation in setting up such an event, as well as the Chamber of Commerce and Embassy of their respective countries.

2) Participate in trade shows to network with Japanese industries and promote European EO products and services

As another channel of promotion, there are many trade shows in Japan pertaining to agriculture, fishery and forestry and many more, and most of these events are also open to foreign entities to set up booths. *Japan External Trade Organisation* (JETRO) maintains a database with all the trade shows in Japan as well as some overseas. JETRO only operates as the initial contact point, and European companies need contact the event organiser to register and discuss about the feasibility of setting up a booth. Some examples are listed below:

- Techno-Ocean 2016 (http://techno-ocean2016.jp/)
    - Key words: fishery, maritime environment, marine resources, and related equipment and services
    - Oct 6 to Oct 8 2016, the last event had over 9000 visitors with 64 exhibitors
- Agritech Japan (http://www.agritechjapan.jp/en/Home_tokyo/)
    - Key words: agricultural machinery, fertilisers and chemicals, raising seedling systems. Greenhouse related products, harvesting systems
    - Oct 12 to Oct 14, 2016, the last event had over 22,000 visitors with 549 exhibitors

3) Use the findings from the industry needs analysis in Chapter 4, and partner with Japanese companies to jointly develop applications to address those needs

The industry needs analysis in Chapter 4 presents the underlying needs and opportunities in 8 key industries for EO application in Japan. The needs are largely from the private sectors in Japan, which are currently still unfulfilled by the existing players in Japan. This is a great opportunity for Europe, and interested European companies with the right capabilities should consider partnering with a Japanese entity to set up a distributorship agreement.

It is important to note that some of the larger companies in Japan may be somewhat hesitant on taking the risk of starting new ventures. Therefore, it may be more feasible to set up a joint venture company with a Japanese company, or perhaps partner up with their smaller, subsidiary company.

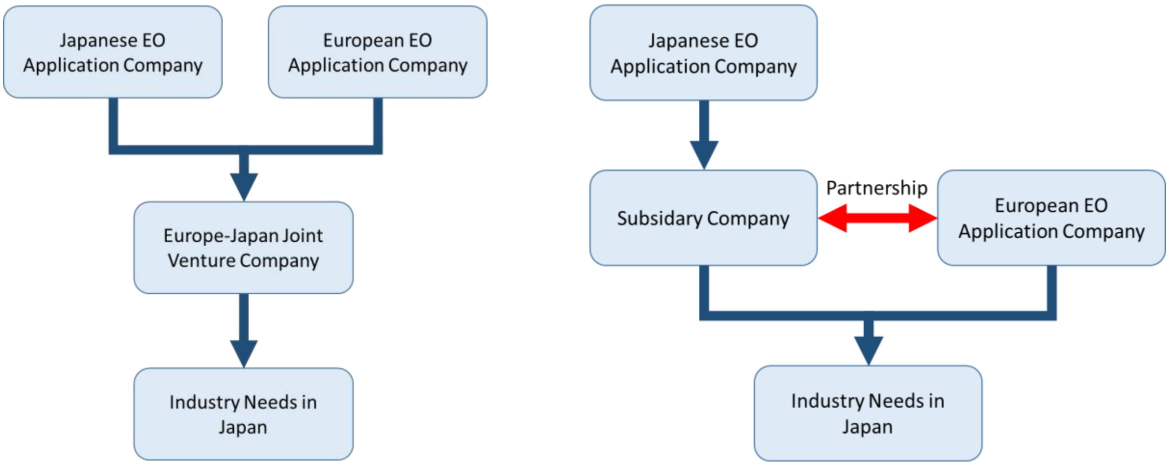


Figure 5-2 Possible forms of partnerships between European and Japanese SMEs

4) Explore possible cooperation with the Japanese ICT industry and *"New Space"* companies

The *"New Space"* in Japan is slowly growing with new companies entering the Japanese space industry. Axel Space and Canon Electric are particularly active in this domain, and are looking to develop smallsat system for global Earth-observation system. Also, in the agriculture industry in Japan, many ICT companies and start-ups are entering the smart agriculture business, and using their expertise to develop innovative sensor networks and monitoring systems for more efficient production. These companies are much more open to implementing new technologies, and it may offer an opportunity for the European SMEs to explore possible ways to integrate EO products and services.

ICT is one of Japan's main industries, and one of the key objectives of Japan Space System (JSS) is to foster greater collaboration between space and ICT through their *Space Business Court* platform.

5) Approach prefectural and municipal governments about smart agriculture, smart forestry and smart fishery initiatives, and also approach large food companies and super market franchise

More and more prefectural and municipal governments are conducting pilot projects and feasibility studies in smart agriculture, forestry and fishery. These projects are contracted to consortiums consisting of companies and other public entities, and there may be opportunities for European SMEs to take part in these initiatives. The tendering process can vary for each project, where some go through a formal, procurement process stipulating the participating companies to have a local subsidiary office, but it appears to be more common for the regional governments to conduct more informal tender process, where interested companies can approach the government departments directly to discuss about possible projects of interests. For example, Niigata city council has a section dedicated for smart agriculture, and interested companies can contact them directly to present their products and services. Furthermore, major food companies and super market franchise are entering the agriculture business to produce their own crops and vegetables. These companies are much more commercially oriented and willing to implementing more systematic farming practices.

6 References

Aero Asahi. (2016, August 25). *衛星データ販売コンテンツ (Satellite Data Sales)*. Retrieved from Aero Asahi company website: https://www.aeroasahi.co.jp/salesdata/satellite.php (in Japanese)

AES. (2016, August 26). Retrieved from Advanced Engineering Services official website: http://www.aes.co.jp/

Akiyama, M. (2013). Geopolitical Considerations of the Senkaku Islands. *Review of Island Studies*.

Aoki, S. (2011, December). The National Space Law of Japan: Basic Space Law and the Space Activities Act in the Making. Faculty of Policy Management, Keio University.

APRSAF. (2016, September 12). Retrieved from APRSAF official website: https://www.aprsaf.org/

Arai, K. (2015). Kokusai Kogyo's EO Data Solutions.

Asia Air Survey. (2016, August 25). *データ販売 (Data Sales)*. Retrieved from Air Asia Survey company website: http://www.ajiko.co.jp/product/list/CT7/SC16/ (in Japanese)

Axel Space. (2016, August 26). Retrieved from Axelspace official website: https://www.axelspace.com/en/

Axel Space. (2016, August 24). *Our Projects - WNISAT-1R*. Retrieved from Axel Space official website: https://www.axelspace.com/en/solution_/wnisat1r/

BizEarth. (2016, April 22). Retrieved from BizEarth official website: http://remosen.jp/

BizEarth. (2016, April 22). *Introduction of an overview of BizEarth and Solutions*. Retrieved from BizEarth: http://remosen.jp/pdf/pamphlet_en.pdf

Cabinet Office. (2009). Basic Plan on Space Policy - Wisdom of Japan Moves Space. Strategic Headquarters for Space Policy of the Cabinet Office. Retrieved from http://www.kantei.go.jp/jp/singi/utyuu/keikaku/pamph_en.pdf

Cabinet Office. (2012). リモートセンシング衛星の現状，課題及び今後の検討の方向 (Current status and the future direction of Japan's Earth-observaton satellites). Retrieved from http://www8.cao.go.jp/space/comittee/dai4/siryou4-1.pdf (in Japanese)

Cabinet Office. (2013). Basic Plan on Space Policy. Strategic Headquarters for Space Policy of the Cabinet Office. Retrieved from http://www8.cao.go.jp/space/plan/plan-eng.pdf

Cabinet Office. (2015, August). 宇宙システム海外展開タスクフォースについて (Task Force for Overseas Expansion of Space Systems, only available in Japanese). Strategic Headquarters for Space Policy of the Japanese Cabinet Office.

Cabinet Office. (2015). 平成 28 年度概算要求における宇宙開発利用関係予算について (Space-related budget allocation for 2016). Strategic Headquarters for Space Policy. Retrieved from http://www8.cao.go.jp/space/comittee/27-anpo/anpo-dai7/siryou6.pdf (only available in Japanese)

Cabinet Office. (2016, August 22). *Ministry of Internal Affairs & Communication e-Gov database*. Retrieved from Basic Space Law: http://law.e-gov.go.jp/htmldata/H20/H20HO043.html (available only in Japanese)

Cabinet Office. (2016, August 22). *Quasi-Zenith Satellite System official website*. Retrieved from Overview of the Quasi-Zenith Satellite System: http://qzss.go.jp/en/overview/services/sv01_what.html

CAS. (2014). G空間情報プロジェクトの推進について (Current Status of the Geospatial Information Projects). Retrieved from http://www.cas.go.jp/jp/seisaku/sokuitiri/yosan/h26_gsuishin.pdf (in Japanese)

Cho, K. (2016, June). The need for a successor of AMSRE-2 for sea ice monitoring (海氷観測における AMSR2 後継機の必要性).

Durst, P. (2010). *Japan Forestry Outlook Study.* Bangkok: Food & Agriculture Organization of the United Nations.

EARSC. (2015). *EARSC EO Industry Survey Report.*

ELS. (2016, July 21). Retrieved from Environmental SImulations Laboratory official website: http://www.esl.co.jp/

ELS. (2016, July 14). *Regions of Japan*. Retrieved from ELS Weekly: http://eslweekly.com/japan.html

eoPortal. (2016, August 25). *ASNARO*. Retrieved from eoPortal Directory: https://directory.eoportal.org/web/eoportal/satellite-missions/a/asnaro

eoPortal. (2016, June 24). *Missions - ADEOS-II*. Retrieved from eoPortal Directory: https://directory.eoportal.org/web/eoportal/satellite-missions/a/adeos-ii

Export to Japan. (2015). *A Changing Spacescape: Japan's New Basic Space Plan and the Japanese Space Program.*

Facts & Details. (2016, July 20). *Commercial Fishing In Japan*. Retrieved from Facts and Details website: http://factsanddetails.com/japan/cat24/sub159/item937.html

Forecast Ocean Plus. (2016, September 24). *Business Activities*. Retrieved from Forecast Ocean Plus official website: http://forecastocean.com/e/outline.html

Foust, J. (2016, March 22). *UAE books Japan's H-2A rocket for 2020 Mars orbiter launch*. Retrieved from Space News: http://spacenews.com/uae-books-japans-h-2a-rocket-for-2020-mars-orbiter-launch/

GEO. (2016, September 13). Retrieved from Group on Earth Observations (GEO) official website: http://www.earthobservations.org/index.php

GESTISS. (2016, May 12). Retrieved from GESTISS official webpage: http://gestiss.org/en/

Gouda, H. (2012). *Economic Value of Arctic Sea Route (商業性から見た北極海航路).* Japan Institute of International Affairs.

Griek, L. (2013). *Government Procurement in Japan Obstacles and opportunities for European SMEs.* EU-Japan Centre for Industrial Cooperation.

Griek, L. (2016). *Public Procurement Market Quick Scan.* Uluru.

G-space. (2013, June). Bringing novel innovation to our lives by converging G-Spatial information and Information Communications Technology. Retrieved from http://www.soumu.go.jp/main_sosiki/joho_tsusin/eng/presentation/pdf/130628_1.pdf

Harvey, B., Smid, H. H., & Pirard, T. (2010). *Emerging Space Powers: The New Space Programs of Asia, the Middle East and South-America.* Springer Praxis Books.

Hata, S. (2015). 日本の宇宙産業の現状と今後の展望 (Current situation and future prospects of Japan's space industry, available in Japanese). *Japan Space Industry Seminar.*

Hayakawa, Y. (2014, June). キャノン電子の宇宙ビジネスに対する取り組み (On Canon Electric's activities in the space business). Retrieved from http://www8.cao.go.jp/space/seminar/fy26-dai1/hayakawa-1.pdf (in Japanese)

Hitachi. (2016, August 25). *DigitalGlobe images sales*. Retrieved from Hitachi Solutions company website: http://www.hitachi-solutions.co.jp/hgiis/ (in Japanese)

Hitachi. (2016a, July 14). *Geomation Farm*. Retrieved from Hitachi Solutions official website: http://www.hitachi-solutions.co.jp/geomation_farm/

Hokudai. (2016, July 21). *Faculty of Fisheries Sciences*. Retrieved from Hokkaido University official website: http://odyssey.fish.hokudai.ac.jp/

Honda, K. (2014). Potential applications of Synthetic Aperture Radar for infrastructure monitoring (ダム等インフラのモニタリングに対する合成開口レーダの利用可能性).

ITA. (2016, Aug 20). *Enforcement and Compliance*. Retrieved from International Trade Administration, United States Dept. of Commerce: http://tcc.export.gov/Trade_Agreements/All_Trade_Agreements/exp_005580.asp

JAFIC. (2016, July 21). *Ebisu-kun*. Retrieved from Japan Fishery Information Centre: http://www.jafic.or.jp/

JAXA. (2010, July 21). *Cooperation to Promote Satellite Technology Application in Developing Countries in the Asia-Pacific Region*. Retrieved from JAXA Press Release: http://global.jaxa.jp/press/2010/07/20100721_adb_e.html

JAXA. (2016, April 20). Retrieved from JAXA official website: http://global.jaxa.jp/

JAXA. (2016, September 24). *GCOM data provision service*. Retrieved from GCOm official website: https://gcom-w1.jaxa.jp/auth.html

JAXA. (2016, September 20). *JAXA Field Centres*. Retrieved from JAXA Official Website: http://global.jaxa.jp/about/centers/index.html

JAXA. (2016, August 25). *SPAISE Mission Concept*. Retrieved from JAXA official website: http://www.satnavi.jaxa.jp/experiment/spaise/

JAXA. (2016, April 20). *衛星データサービスソリュション企業一覧 (List of companies pertaining to EO data & services)*. Retrieved from http://www.sapc.jaxa.jp/company/ (in Japanese)

JAXA. (2016, September 20). *世界から高く評価される JAXA の地球観測衛星 (JAXA's world-acclaimed Earth-observation satellites)*. Retrieved from JAXA Recent Features: http://www.jaxa.jp/article/special/geo/ochiai_j.html (in Japanese)

JAXA. (2016b, April 12). *JAXA Press Release*. Retrieved from "Open Innovation Hub for Expanding Humanosphere and Domain of Human Activity through Solar System Frontier Development": http://global.jaxa.jp/press/2015/06/20150611_ihub.html

JAXA. (2016c, August 24). Retrieved from New Enterprise Promotion Department official website: http://aerospacebiz.jaxa.jp/en/

JAXA. (2016d, September 20). *Satellites and Spacecraft*. Retrieved from JAXA official website: http://global.jaxa.jp/projects/sat/

JAXA. (2016e, August 25). *About AMSR*. Retrieved from AMSR/AMSR-E: http://sharaku.eorc.jaxa.jp/AMSR/

JAXA. (2016f, August 25). *"Aqua" Earth Observation Satellite/AMSR-E*. Retrieved from JAXA - Satellites & Spacecraft: http://global.jaxa.jp/projects/sat/aqua/

JAXA G-Portal. (2016, August 24). Retrieved from JAXA G-Portal official website: https://www.gportal.jaxa.jp/gp/top.html#

JCG. (2015). Use of ALOS-2 Data at Sea Ice Information Centre (海氷情報センター におけるだいち 2 号の活用). Retrieved from http://www.sapc.jaxa.jp/topics/2015/ALOS2_pdf/12_.pdf

JPL. (2016, August 26). *Mission*. Retrieved from ASTER official website: http://asterweb.jpl.nasa.gov/mission.asp

JRC. (2016, August 26). *J-Marine GIS*. Retrieved from Japan Radio Co official website: http://www.jrc.co.jp/eng/casestudy/case0001/index.html

JSI. (2016, August 25). *Products & Services*. Retrieved from Japan Space Imaging company website: http://www.spaceimaging.co.jp/product/index.html

JSS. (2016, April 20). Retrieved from Japan Space Systems official website: http://www.jspacesystems.or.jp/en_/

JSS. (2016, September 6). Retrieved from Space Business Court: https://www.bizcourt.space/

JSS. (2016, August 25). *HISUI : Hyper-spectral Imager SUIte*. Retrieved from Japan Space Systems official website: http://www.jspacesystems.or.jp/en_project_hisui/

JSS. (2016, August 17). *Projects*. Retrieved from Japan Space Systems official website: http://www.jspacesystems.or.jp/en/project/index.html

JST. (2016, June 22). *Japan Science Portal*. Retrieved from 宇宙活動法案を閣議決定 宇宙ビジネス拡大狙う (Decision to discuss Space Activities Act, which aims to expand space business in Japan, in the next parliamentary session):

http://scienceportal.jst.go.jp/news/newsflash_review/newsflash/2016/03/20160304_01.html (in Japanese)

Kachi, M. (2011). Overview of the First Satellite of the Global Change Observation Mission - Water . *EUMETSAT Meteorological Satellite Conference.* Oslo.

Kachi, M. (2016). JAXA Agency Report. *GSICS/GRWG Meeting.* Tsukuba: Earth Observation Research Centre (EORC).

Kagome. (2016, July 14). Retrieved from Kagome official website: http://www.kagome.co.jp/english/

Kasai, R. (2016). User-oriented Operation of ASNARO. *SpaceOps Conference.* Daejeon. Retrieved from http://arc.aiaa.org/doi/pdf/10.2514/6.2016-2581

Kataoka, H. (2010). Japanese Space Law - Legislation on Space Activities. *COPUOS Legal Subcommittee 49th session.* Strategic Headquarters for Space Policy. Retrieved from http://www.unoosa.org/pdf/pres/lsc2010/tech-07.pdf

Kawai, T. (2015a). Space Activities in Japan. *Horizon 2020 Space Information Day.* Brussels.

Kawai, T. (2015b, June 24). JAXA Activities. *Global Space Innovation Conference.* Munich.

Kawano, M. (2016, March). New developments in smart agriculture attracting high expectations (期待が集まるスマート農業の新展開).

KKC. (2016, Sept 24). *History.* Retrieved from Kokusai Kogyo official website: http://www.kkc.co.jp/english/company/history.html

KKC. (2016, August 25). *Satellite Imagery.* Retrieved from Kokusai Kogyo company website: http://biz.kkc.co.jp/data/keisoku/satellite/ (in Japanese)

Kobayashi, R. (2016, July 14). *Current status & problems of Japanese agriculture industry.* Retrieved from Marketing & Manuals: http://www2s.biglobe.ne.jp/~kobayasi/aguri/nougyou.html

Komiya, Y. (2015). New Basic Plan on Space Policy. Office of National Space Policy of the Cabinet Office. Retrieved from http://www.jsforum.or.jp/debrisympo/2015/pdf/06%20150226_DG_Komiya.pdf

Komizo, Y. (2009). Japanese Space Policy - Basic Space Law. *COPUOS Legal Subcommittee 48th Session.*

Kozuka, S. (2016, June 22). *民間宇宙ビジネスを促すために法の枠組みづくりを (Need for a legislative framework to promote private space business)*. Retrieved from BizLaw: http://www.bizlaw.jp/interview_kozuka_01_03/ (in Japanese)

Lele, A. (2012). *Asian Space Race: Rhetoric or Reality?* Springer Science & Business Media.

Luxton, E. (2016, January 11). *Which countries spend the most on space exploration?* Retrieved from World Economic Forum: https://www.weforum.org/agenda/2016/01/which-countries-spend-the-most-on-space-exploration/

MAFF. (2015). *Annual Report on Food, Agriculture and Rural Areas in Japan.* Ministry of Agriculture, Forestry & Fishery.

MAFF. (2015). *Annual Report on Forest & Forestry in Japan.* Ministry of Agriculture, Forestry & Fishery.

MAFF. (2015). *Annual Report on the Developments in Japan's Fisheries.* Ministry of Agriculture, Forestry & Fishery.

MAFF. (2016, July 20). *Seafood*. Retrieved from Ministry of Agriculture, Forestry & Fishery official website: http://www.maff.go.jp/e/oishii/ingredients/seafood.html

MAFF. (2016, July 15). *Smart Agriculture Initiatives*. Retrieved from MAFF official website: http://www.maff.go.jp/j/kanbo/kihyo03/gityo/g_smart_nougyo/

METI. (2009). 宇宙産業の発展に向けて (On the development of Japan's space industry, available in Japanese). Japanese Ministry of Economy, Trade & Industry (METI). Retrieved from http://www.meti.go.jp/policy/mono_info_service/mono/space_industry/pdf/space_industry.pdf

MEXT. (2011). リモートセンシングの今後の方向性と文部科学省/JAXA の基本的役割 (Future direction of remote-sensing and the basic role of MEXT and JAXA). Retrieved from http://www.kantei.go.jp/jp/singi/utyuu/senmon/dai13/siryou2_3.pdf (in Japanese)

MIC. (2015). G 空間 xICT プロジェクトの取組状況について (On the current status of collaborative projects between G-spatial Information System & ICT). Ministry of Internal Affairs & Communications. Retrieved from http://www.soumu.go.jp/main_content/000362512.pdf (available only in Japanese)

MLIT. (2014). MLIT presentation material.

MLIT. (2015). Disaster Risk of Japan. Retrieved from http://www.mlit.go.jp/river/bousai/library/pdf/kokudo.pdf

MLIT. (2016). *Annual Report on National Land, Infrastructure and Transport.* Ministry of Land, Infrastructure & Transport.

MOFA. (2016, September 11). *Official Development Assistance*. Retrieved from MOFA official website: http://www.mofa.go.jp/policy/oda/

Monohakobi. (2016, August 25). *Satellite AIS*. Retrieved from Monohakobi Technology Institute official website: https://www.monohakobi.com/en/service/bigdata/satellite_ais/

Muraki, Y. (2014, December 1). Asian Development Bank Projects Applying the Result of SAFE Project. Retrieved from https://www.aprsaf.org/annual_meetings/aprsaf21/pdf/safe/10_adb.pdf

Muraki, Y. (2014). *Space Technology and Geographic Information Systems Applications in ADB Projects.*

Nakajima, T. (2015). Current status and challenges of Earth-observation satellites (衛星地球観測の現状と課題). *Workshop on Earth-Observation and Inter-organisational Network.* JAXA Earth Observation Research Centre.

NASA. (2016, June 24). *The Afternoon Constellation*. Retrieved from NASA official website: http://atrain.nasa.gov/intro.php

NEDO. (2016, August 25). *NEDO Local Wind Speed Map*. Retrieved from NEDO website: http://app8.infoc.nedo.go.jp/nedo/

Newsphere. (2016, August 24). *Mistui O.S.K. Line to start regular transportation of LNG using the Arctic Ocean shipping routes (商船三井、北極海航路でLNGの定期輸送へ　輸送期間の大幅短縮に海外も注目)*. Retrieved from Newsphere: http://newsphere.jp/business/20140710-5/

NIES. (2016, September 24). *About GOSAT*. Retrieved from GOSAT official website: http://www.gosat.nies.go.jp/en/about_7_imformation.html

NTT Data. (2016, August 25). *Satellite imagery provision service*. Retrieved from NTT Data company website: http://satelliteimage.jp.nttdata.com/ (in Japanese)

Omura, T. (2000). Damages caused by sea ice on the port facilities in the coastal regions of Hokkaido (北海道沿岸の港湾・漁港周辺における海氷被害の現状について). *Maritime Development Symposium.*

PASCO. (2016, September 24). *PASCO Group Worldwide*. Retrieved from PASCO official website: http://www.pasco.co.jp/eng/corporate/office/

PASCO. (2016, August 25). *Satellite Imagery*. Retrieved from PASCO company website: http://www.pasco.co.jp/products/satellite/ (in Japanese)

PASCO. (2016, August 26). *Vessel Monitoring Service*. Retrieved from PASCO official website: http://www.pasco.co.jp/eng/products/ais/

Regina, V. L. (2014). *Business partnership opportunities and technology transfer in the Space sector between EU and Japan.* Tokyo: EU-Japan Centre for Industrial Cooperation.

RESTEC. (2016, July 20). *Forest Management*. Retrieved from RESTEC official website: https://www.restec.or.jp/solution/service/service-forest

RESTEC. (2016, September 12). *Forest Monitoring*. Retrieved from RESTEC official website: https://www.restec.or.jp/en/solution/service/service-forest

RESTEC. (2016a, July 14). *Agriculture solutions*. Retrieved from RESTEC official website: https://www.restec.or.jp/en/business/solution-agriculture

SED. (2016, August 25). *Satellite Image Products*. Retrieved from Space Engineering Development company website: http://www.sed.co.jp/sug/contents/satelliteinfo.html#1 (in Japanese)

Shashin. (2016, August 25). *Satellite Imagery*. Retrieved from Shashin Kagaku company website: http://www.shashin-kagaku.co.jp/geo/satellite.html (in Japanese)

Shinken. (2016a, July 17). *Air Asia Survey start a nation-wide service for aerial laser surveying of forests (アジア航測、航空レーザ測量を活用したＩＣＴ林業支援サービスを全国展開)*. Retrieved from Shinken Housing Digital: http://www.s-housing.jp/archives/55450

Shiroyama, H. (2014, 12 3). Space Policy & Governance in Japan. *Space Policy and Law for Social Development in Asia.* University of Tokyo Policy Alternatives Research Institute.

Shizuoka. (2016, July 20). *Types of Fishing in Japan*. Retrieved from Shizuoka Prefectural Fishery Research Laboratory official website: http://fish-exp.pref.shizuoka.jp/04library/4-3-1.html

SIM. (2016, August 25). *Satellite Imagery*. Retrieved from Satellite Image Marketing company website: http://www.satim.co.jp/satellite/ (in Japanese)

Spaceflight101. (2016, August 23). *Spaceflight101.com*. Retrieved from Information gathering Satellites: http://spaceflight101.com/spacecraft/information-gathering-satellites/

Spitzer, K. (2015, November 25). *Japan struggles to save shrinking, aging agriculture industry*. Retrieved from USA Today: http://www.usatoday.com/story/money/2015/11/25/japan-struggles-save-shrinking-aging-agriculture-industry/75825884/

Sumitomo. (2016, July 15). *Forest Management in Japan*. Retrieved from Sumitomo Ringyo official website: http://sfc.jp/english/information/society/environment/performance/forest_conservation/domestic.html

Suzuki, K. (2012, February 27). Satellite use in JICA projects and hopes for the future (JICA 事業における人工衛星利用と今後への期待).

Takayama, H. (2016, September 6). Space Business Court Concept. Retrieved from http://www.jspacesystems.or.jp/ersdac/lecture/6_JSS_Takayama.pdf (in Japanese)

Teraoka, Y. (2016, March). G 空間情報と ICT を利用した人吉市でのスマート林業の展開 (Development of Smart Forestry in Hitoyoshi city using ICT and Geospatial Information). Kyushu G-spatial Information System Promotion Committee. Retrieved from http://g-hitoyoshi.jp/files/hitoyoshisympo04_teraoka.pdf (available in Japanese)

Tokyo IT News. (2016, Jul 16). *Smart Forestry - Economic impact of 2 bil yen (スマート林業…経済効果 20 億、ICT が森林をお金に換える)*. Retrieved from Tokyo IT News: http://itnp.net/article/2016/05/01/2802.html

Tsutsumi, C. (2016). 先進光学衛星民間事業者としての展望 (Future prospects on the Adv. Optical Satellite as the prime contractor). *Advanced Optical Satellite Utilisation Workshop.* Tokyo.

VN Express. (2016, September 20). Japan to build satellite for Vietnam's climate observation. pp. http://e.vnexpress.net/news/news/japan-to-build-satellite-for-vietnam-s-climate-observation-3470718.html.

VT. (2016, August 25). *Satellite Image Products*. Retrieved from VisionTech company website: http://www.vti.co.jp/data.html (in Japanese)

VT. (2016a, July 14). *Agri-Look* . Retrieved from VisionTech official website: http://www.vti.co.jp/english/e-service.html

WEATHERNEWS. (2016, August 24). *Global Ice Center*. Retrieved from WEATHER NEWS Inc official website: http://weathernews.com/GIC/

Wikipedia. (2016a, August 17). *Japan's Space Development*. Retrieved from Wikipedia: https://en.wikipedia.org/wiki/Japan%27s_space_development

Wikipedia. (2016b, August 19). *NEC スペーステクノロジー (NEC Space Technology, only available in Japanese)*. Retrieved from Wikipedia: https://ja.wikipedia.org/wiki/NEC%E3%82%B9%E3%83%9A%E3%83%BC%E3%82%B9%E3%83%86%E3%82%AF%E3%83%8E%E3%83%AD%E3%82%B8%E3%83%BC

Wikipedia. (2016c, May 7). *ASTER*. Retrieved from Wikipedia: https://en.wikipedia.org/wiki/Advanced_Spaceborne_Thermal_Emission_and_Reflection_Radiometer

Wikipedia. (2016c, August 20). *Hokkaido*. Retrieved from Wikipedia: https://en.wikipedia.org/wiki/Hokkaido

Wikipedia. (2016d, August 24). *Global Change Observation Mission*. Retrieved from Wikipedia: https://en.wikipedia.org/wiki/Global_Change_Observation_Mission#GCOM-W

Wikipedia. (2016e, September 11). *Official Development Assistance*. Retrieved from Wikipedia: https://en.wikipedia.org/wiki/Official_development_assistance

Wikipedia. (2016f, August 10). *Geography of Japan*. Retrieved from Wikipedia: https://en.wikipedia.org/wiki/Geography_of_Japan

Wikipedia. (2016g, August 22). *Northern Sea Route*. Retrieved from Wikipedia: https://en.wikipedia.org/wiki/Northern_Sea_Route

WSJ. (2016, July 14). *ADB plans to increase its investment in agriculture in Asia from 2013 (アジア開発銀行、13 年からアジア農業投資を増強へ)*. Retrieved from Wall Street Journal: http://jp.wsj.com/public/page/0_0_WJPP_7000-535447.html

Yamamoto, S. (2016, May). 先進光学衛星プロジェクト移行審査の結果について (On the outcome of the project review for the Advanced Optical Satellite).

Yoshikawa, K. (2015). Trend of ALOS-2 Data Distribution in the Global Market and SAR Application (世界市場におけるだいち 2 号データ配布動向と SAR アプリケーション).

Zeng, K. (2004). *Trade Threats, Trade Wars: Bargaining, Retaliation, and American Coercive Diplomacy.* University of Michigan Press.