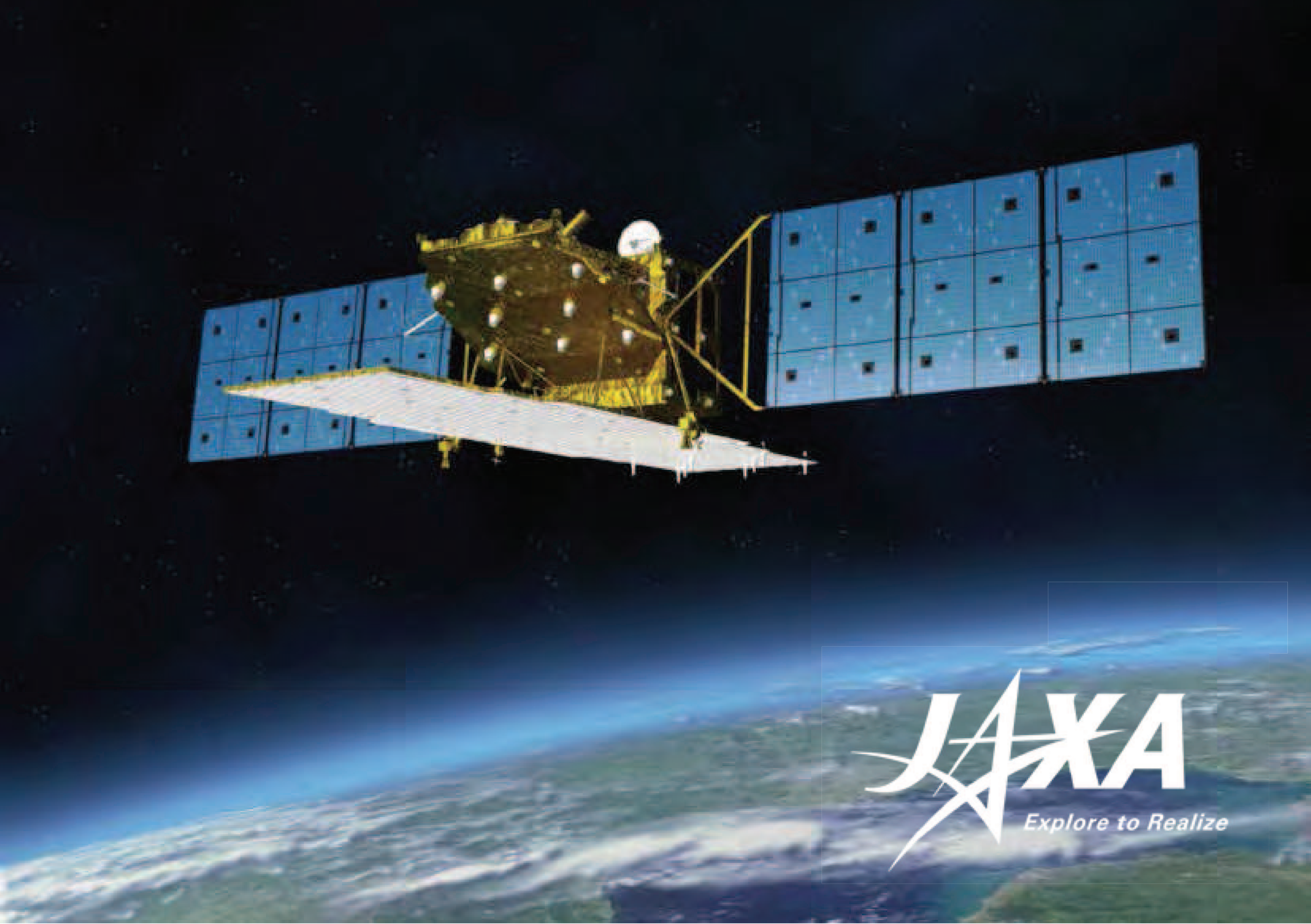
Advanced Land Observing Satellite-2 (ALOS-2)

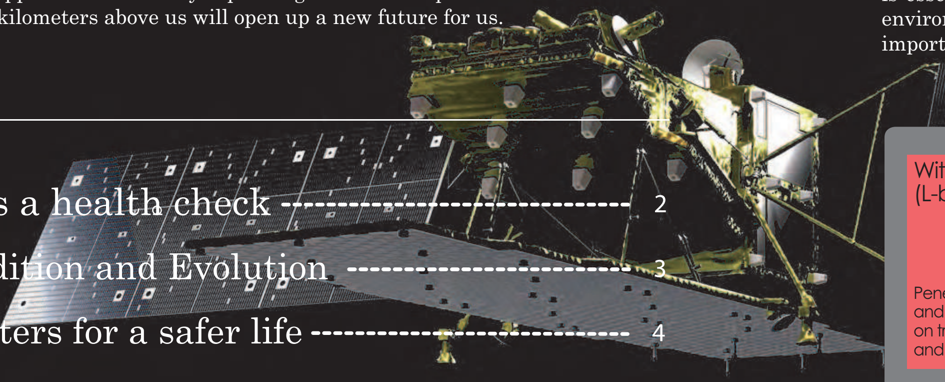
「DAICHI-2」

The Earth needs a health check.



The Earth needs a health check

The land underneath our feet is constantly changing even at this moment due to various reasons including natural phenomena, such as earthquakes, floods, volcanic activity, landslides and man-made destruction.
On such a changing Earth, we hope to live as soundly as possible. For that, we need to understand the current conditions of the Earth. It is the same as us taking a health check regularly, and a detailed examination if necessary, to maintain our well-being.
JAXA has developed the Advanced Land Observing Satellite-2 “DAICHI-2” (ALOS-2), the successor of the DAICHI, which observed the Earth between 2006 and 2011.
The DAICHI-2 is equipped with the Panchromatic L-band Synthetic Aperture Radar (PALSAR-2) as an observation device.
The Synthetic Aperture Radar (SAR) has a special feature of being able to observe regardless of time (day and night) and weather. With the L-band radar, the PALSAR-2 has an advantage in capturing conditions of land deformation, forestry and vegetation. Japan has been accumulating technology and know-how for the L-band SAR field and has been leading the world in this area. Compared to the DAICHI, on which three sensors (two optical and one microwave devices) were onboard, the DAICHI-2 is exclusively installed with the PALSAR-2 using microwaves to maximize its ability.
The DAICHI-2 can perform health checks on various targets in detail from space. It can grasp conditions of a disaster-stricken area, and also examine the health conditions of forests, which are a lifeline for us, and for the Earth. The DAICHI-2 can also watch over navigating ships, and support agricultural development. Its application is broadly expanding with further possible utilization.
The new global eye, some 628 kilometers above us will open up a new future for us.



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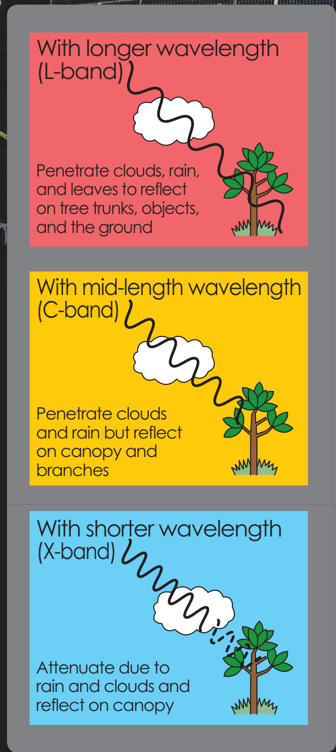
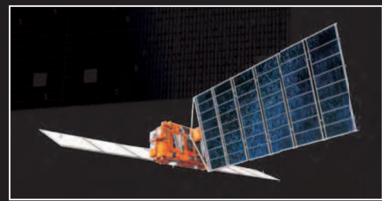
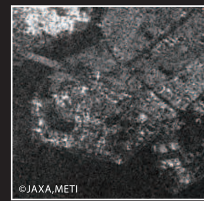
L-band SAR Tradition and Evolution

The Synthetic Aperture Radar (SAR) is an onboard radar on a moving vehicle such as an aircraft or a satellite to emit radio waves called microwaves towards observation targets, receive their reflection from the target objects and process them in a special way for observation. Digital camera and other optical sensors usually perceive the Sun’s reflection from a target object, but in the case of the SAR, it receives the reflection of the radio wave that is emitted from the SAR itself. That is why it can perform observations day and night. In addition, the radio wave can penetrate rain and clouds to enable observations regardless of weather. The L-ban is a radio wave whose wavelengths are especially long at about 24 cm. The SARs aboard oversea satellites use X-band (about 3 cm) and C-band (about 6 cm), and they reflect on leaves (forest canopy) when observing forests. On the other hand, the L-band has an unique advantage of partially penetrating vegetation and reaching the ground to acquire information on both vegetation and the ground. In addition, the L-band, which is not affected by the growth of vegetation, is suitable for technology called “Interferometry (SAR interference analysis),” which is useful for studying land deformation. The L-band is, therefore, highly beneficial for earthquake-prone Japan, where two-thirds of the land is covered by vegetation, and that was why we want to apply the L-band at an early stage to lead the world. Beginning with its use on the Earth Resource Satellite “FUYO-1” (JERS-1), the L-band SAR was also aboard the Land Observing Satellite “DAICHI” in 2006 and has been passed on to the DAICHI-2, during which the radar technology has been evolving. Since the FUYO-1, we have accumulated data acquired by the L-band SAR for 11 years. Using the DAICHI-2, the latest information will be further gained. Accumulation of such information is essential to learn about changes in forests and predict their future, which is key for the Earth's environment. As global warming progresses, Japan, which possesses the L-band SAR, will play a more important role.

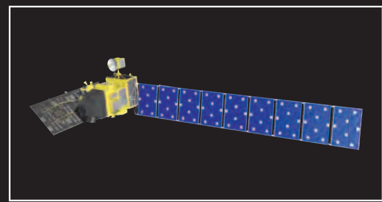




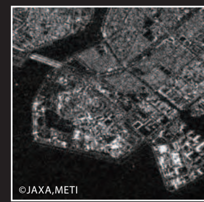
JERS-1 (1992-1998)



JERS-1 SAR Image, Resolution 16m



ALOS (2006-2011)



PALSAR Image, Resolution 10m

ALOS-2

Simulation Image, Resolution 3m

How can we utilize DAICHI-2 observation data? We would like to introduce DAICHI-2's missions and specific examples of data application. Various possibilities proven by the L-band SAR aboard the DAICHI will be further improved and achieved by the DAICHI-2.

Monitoring disasters for a safer life

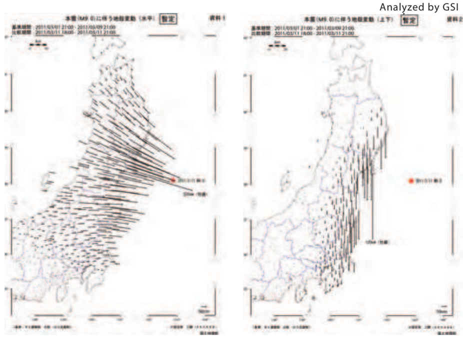
To understand land deformation due to earthquakes

The land deformation due to the Great East Japan Earthquake was clearly observed by the PALSAR aboard the DAICHI (left figure.) The topographic change and movement was drawn using a method called "interferometry" by observing one location multiple times and finding differences through comparing (or "interfering") such multiple data.
Data at the GPS-based control stations established by the Geospatial Information Authority of Japan (GSI) is used for measuring land deformation (right figure) but GPS can measure changes and movement only by "points." On the other hand, satellite data captures changes by "areas". Under collaboration between JAXA and GSI, we can understand the changes and movement more precisely by combining GPS and satellite data.
In addition, the DAICHI-2, whose precision in keeping its orbit and position has improved, will be able to perform more accurate interferometry. The DAICHI-2 will help compile the base map for the interferometry criteria in Japan and overseas. In the case of an earthquake in Japan, data for the interferometry will be acquired within three days to understand the land deformation at an early stage. In addition, we can capture high-resolution images by selecting a spotlight mode, or other means, to learn detailed conditions of a disaster-stricken area, such as finding if a skyscraper, bridge, or other large building collapses, to determine which routes should be taken for relief activities.

©JAXA,METI Analyzed by GSI

Rainbow-colored stripes indicate the scale and pattern of land movement (protrusion, subsidence, or horizontal movement.) Stripes with higher density show larger land deformation in the same manner as the contour lines.

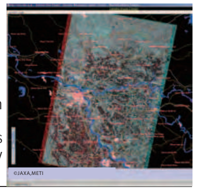
Analyzed by GSI



During the Great East Japan Earthquake on March 11, 2011, a large land deformation of about 5.3 meters in the horizontal direction and about 1.2 meters (the numbers are the largest on record) in the vertical direction was observed.

International cooperation through disaster information provision to the world

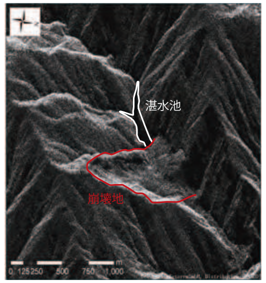
Swiftly acquiring observation images of a damaged area is very important at the time of a disaster, but a satellite belonging to a disaster-stricken country is not necessarily flying over it in a timely manner. Therefore, we now hold some international cooperation frameworks to help provide appropriate observation data for each other. One example is the "International Charter". The number of large-scale disasters that require emergency relief operations, such as earthquakes, floods, and typhoons, amounts to about 300 per year. For example, the International Charter was mobilized 51 times for 330 such disasters in 2010. Over 20 countries including the U.S., European countries, China, South Korea, and Russia are Charter members, and Japan joined it just after the launch of the DAICHI.
The Sentinel Asia is an Asian version of the International Charter. Following Japan's lead, Asian countries such as India, Thailand, and Taiwan participate in the framework. In addition, Japan has made agreements with the Italian, German, and Canadian space agencies to exchange satellite data at the time of disasters. Following the DAICHI's contribution to the International Charter and Sentinel Asia, Japan is again expected to play an important role after the launch of the DAICHI-2. Central government ministries and municipalities of each member country will utilize data from the DAICHI-2.



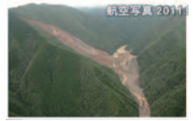
Vietnam flood water observed in Oct. 2008
JAXA's analyzed PALSAR data was provided to Vietnamese Academy of Science and Technology.

Promptly responding to water disasters due to torrential rain and landslides

Totsugawa village in Nara Prefecture was heavily damaged by Typhoon No. 12 in September 2011. Due to bad weather, only partial amounts of information were acquired through helicopters, but by analyzing images acquired by the SAR aboard the German satellite TerraSAR-X, we obtained information for determining evacuation orders. With the DAICHI-2, observation requests can be filed as late as one hour prior to the observation time, with data provision taking as little as one hour after observations are performed. We are aiming at much prompter provision of data compared to overseas satellites. The DAICHI-2 will exhibit its ability to acquire data of a disaster-hit area immediately after the disaster when helicopters and aircrafts cannot observe it, and data that covers broader areas to understand the comprehensive situation. Using the DAICHI-2's spotlight mode and high resolution mode, we can provide disaster-related ministries and agencies of the central government and municipalities with high-resolution high-quality images.



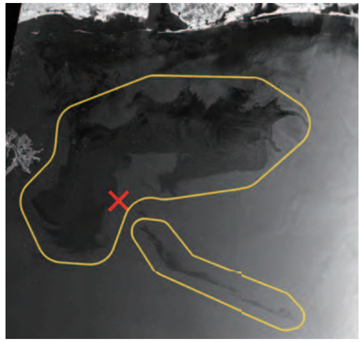
hanks to images acquired by the SAR, which can observe regardless of rain clouds or night. The images led to the evacuation of the lower reaches.




Provided by Kinki Regional Development Bureau, Ministry of Land, Infrastructure and Transport

Monitoring any kind of disaster

Images taken by the DAICHI-2 will contribute to monitoring and understanding situations of various disasters including land subsidence, forest fires, and volcanic activities in addition to earthquakes and water-related disasters. For example, in Japan, a volcanic country, 110 active volcanoes are regularly monitored by the Japan Meteorological Agency (JMA) and other organizations, and images taken by the DAICHI were also utilized for that purpose. After the completion of the DAICHI's operations, satellite monitoring of the volcanoes are currently performed by other overseas SAR satellites in response to requests by the JMA and Coordinating Committee for Prediction of Volcanic Eruption. The DAICHI-2 will take over that duty with higher accuracy. Regarding land subsidence, the DAICHI-2's observation data is expected to be useful for private infrastructure related companies as they will be helpful for degradation of large structures such as dams.



Oil spill in the Gulf of Mexico.
(Areas surrounded by yellow line mark the spills.)
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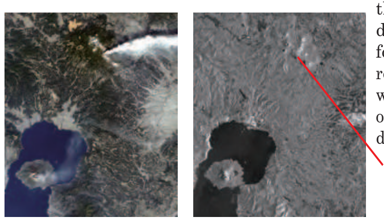

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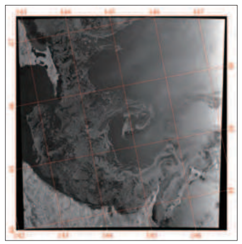
Images of the volcanic explosion of Mt. Kirishima (Shimoe Dake) in January 2011. The left one is an optical image, and the right is a SAR image. You can see that the latter penetrated not only clouds but also volcanic smoke.

Sea ice monitoring

Learning about the movement of sea ice is essential for boats to navigate safely in cold districts. The Japan Coast Guard (JCG) publishes and updates the "Sea Ice Condition Chart" of the Sea of Okhotsk every day in winter in cooperation with information from other related organizations.
The DAICHI observed the Sea of Okhotsk regularly by the Scan SAR mode of the PALSAR from December to May every year to provide sea ice analysis information to the JCG. With the strength of the SAR to be able to observe without any influence from clouds, the DAICHI proved its observations over the rough winter ocean in harsh weather are effective. On the other hand, some issues were also raised such as not having enough observation frequency and difficulty in identifying thin ice. The DAICHI-2 will improve its observation frequency thus it can provide more sea ice information in the Sea of Okhotsk in winter. In addition, a HV channel is also used in the Scan SAR mode, thus a further increase in the amount of information on sea ice is expected.



Floating sea ice on the Sea of Okhotsk observed by PALSAR (at 3rd February)
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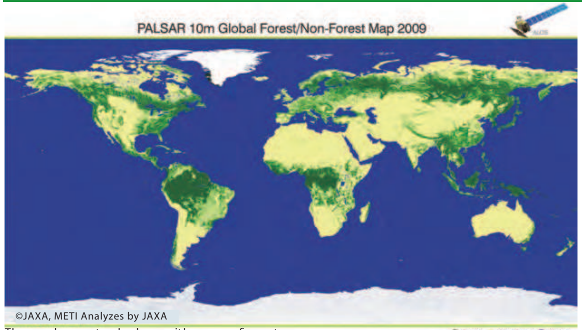
Tackling global-scale environmental problems

Deforestation monitoring by global forest map



The color gets darker with more forests.
We can find deforestation by comparing year-on-year images.

The L-band SAR, whose special observation feature is an ability to penetrate vegetation and to be less impacted by clouds, can efficiently observe forests, such as tropical rainforests, which are often covered by clouds. Therefore, JAXA has constantly monitored forests using the L-band SAR on the FUYO-1 as well as on the DAICHI. Data had been obtained for a prolonged time of over 11 years between 1992 and 2010 although there were some blank periods.
The DAICHI-2, equipped with a HV channel (a channel that transmits a vibrating wave in a horizontal direction against the ground [H] and receives it vertically [V]) even in the Scan SAR mode, is expected to acquire more detailed observation data on forests. By fully utilizing the different observation modes with polarimetry (four polarized waves) or with an operation that clarifies differential interference, there is a possibility for the DAICHI-2 to observe the height and type of a tree. If we can learn such detailed information of forests, we can estimate carbon volume and CO2 absorption amounts in forests with more accuracy. Such details are very important for global warming solutions. Hence JAXA is aiming to establish L-band SAR forest monitoring as a global standard through the DAICHI-2 project.

Monitoring deforestation

By overlapping two PALSAR images taken at different times, we can specify the area that was deforested during that period. With the DAICHI, newly grown bushes or existence of water made difficulty to determine a deforested area. The DAICHI-2 is expected to offer us more precise information to specify the area.

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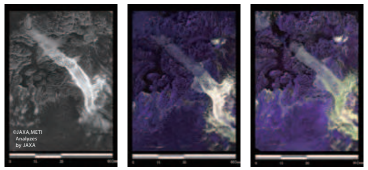
Illegal deforestation frequently occurs in Brazilian forests, and SAR images by the DAICHI played an important role in the solution. In Brazil, forests were monitored by satellites with an optical sensor such as the Landsat and CBERS, but observations were hampered due to a rainy season that covers about a half of a year because optical sensors do not see through rain clouds. Consequently, the number of deforestation cases increased. Once JAXA started to provide images acquired by the SAR aboard the DAICHI, which can observe forests by penetrating rain and clouds, to the Instituto Brasileiro do Meio Ambiente e dos Recursos Naturais Renováveis (IBAMA, Brazilian environment agency) in 2007, deforestation cases have been decreasing. As a result, JAXA contributed to the reduction of the deforestation area (including legal cases) from 12,000 km2 in 2008 to 7,000 km2 in 2009. The PALSAR-2 with higher performance aboard the DAICHI-2 is expected to identify deforestation areas with more accuracy. In addition, in order to catch an illegal deforester red-handed, the police must be mobilized as soon as such an act was captured by the satellite. An illegal deforester is said to usually stay at one site for about two weeks, thus the DAICHI, whose recurrent period was 46 days, did not have enough opportunities to capture illegal deforestation activities. The DAICHI-2 will be more useful in this regard as its recurrent period is 14 days. Apart from the IBAMA, many environment-related organizations in various countries hold high expectations for the DAICHI-2

Polar ice reduction



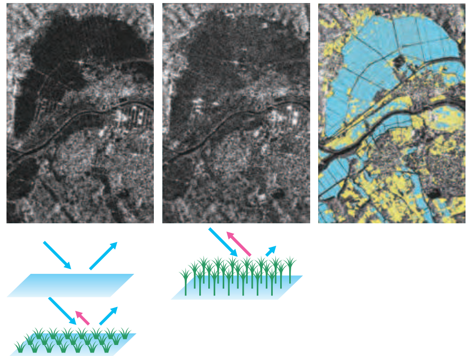
Monitoring regression of a glacier in Greenland.

The Polar Regions are vulnerable to global warming and entailing climate changes, hence observing them for a prolonged period is imperative as an indicator for global warming. The SAR observation, which is not affected by clouds, is very effective for the Polar Regions, which are always covered by clouds. Due to a reduction of sea ice, a navigation route through the Arctic Ocean to connect Europe and Asia seems a more likely development in the future. The DAICHI-2's accurate sea ice observation data will play an important role for the feasibility research and study of such a route. Through an interferometry method, we can learn the movement of ice sheets and glaciers, thus it can be a very strong tool for polar science.

Economical and social contributions

Uninterrupted food supply

For Asian countries, understanding their respective agricultural status is important as food shortages have become a serious issue due to their population increase. Agricultural statistical information for rice in detail is especially important for Asian countries because Asia accounts for 90% of rice production and consumption in the world. The current survey on rice, however, is not highly reliable. In addition, paddy rice is planted during the rainy season which makes it difficult to observe from space. However, the SAR is very useful for its ability to observe through clouds. Many people await the arrival of the DAICHI-2.
In the images taken by the SAR, water surfaces look dark. When paddy rice is planted, paddies are filled with water, thus they look dark in the image. After rice grows, they look brighter as water is covered by the green of the plant. In other words, if the darkness changes in a SAR image when time elapses, that area with changing brightness is where the rice paddies are. From the SAR images, we can learn the area of rice paddies.
In some areas in Thailand, we have already used the above method to verify the area of rice paddy area using DAICHI's data. We will further utilize DAICHI-2's data in other regions in Thailand as well as in other countries to gradually move to a practical use of this method. We are currently confirming its validity in cooperation with Vietnam, Indonesia, Laos, and the Philippines, in addition to Thailand. The DAICHI was used in a relatively limited area, but the DAICHI-2 is expected to be utilized by each country through a broader area ranging from one prefecture/state to even-the whole country to compile basic data for food security measures. SAR images are also expected to be able to identify some fairly large products such as corn and sugar cane, thus we are also studying the possibility of such use.



A rice paddy filled with water before planting works as a mirror which reflects microwaves in the opposite direction, thus the microwaves do not come back to the satellite. As a result, it appears dark in an image. Just after planting, the microwave reflection on the paddy is weak, and the image is still dark. As rice grows, the reflection becomes stronger to make the paddy area on the image brighter. Using the changes in the darkness, we can determine the area of rice paddies. Blue represents the paddy rice and yellow represents the other areas which are not paddy rice.

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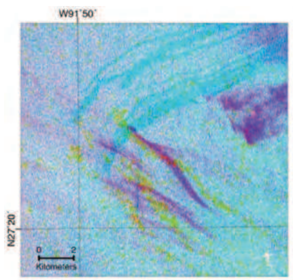
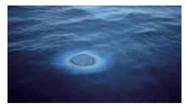
（RESTEC ホームページより）

Probing underground resources and understanding land subsidence

Saudi Arabia had been leading the world in oil deposits for a long time, but in 2010, Venezuela took the top position by suddenly increasing its deposit amount by 40.4% thanks to the remarkable evolution of resource mining technology. In Japan, technological improvements in digging seabed resources have attracted people's attention in recent years to excavate in neighboring seas. The SAR can exhibit its ability in this area. At the location of a seabed oil field, leaked oil often floats on the surface to create an oil slick. During an oil slick, the sea surface is glassier than normal sea surface, thus an oil slick area looks darker in a SAR image. If you can find an oil slick in multiple SAR images taken at different times in a certain area, it means that oil is leaking in that location, and that is one of the indicators for a seabed oil field. Therefore, the DAICHI-2 possesses the high probability to exhibit its ability to acquire more accurate data for new resource development, and accordingly energy related public organizations and private businesses are expected to use its data. With the interferometry method, the DAICHI-2 can measure land subsidence, due to oil digging, to a few centimeters, hence its data is also expected to be utilized for environmental assessment operations to monitor land subsidence.





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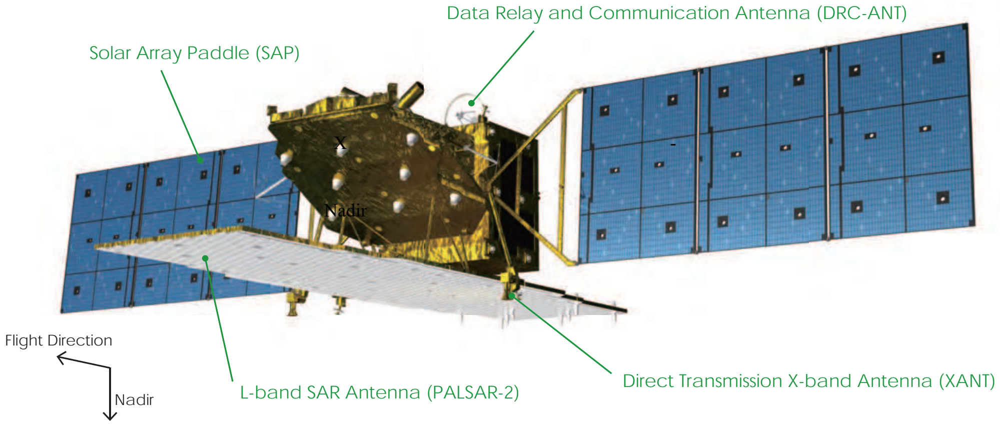
Overview of Advanced Land Observing Satellite-2 “DAICHI-2”

The configuration of satellite



As the name indicates, the DAICHI-2 is the successor of the DAICHI, but the structure of the new satellite is quite different from its predecessor. The DAICHI is equipped with three sensors namely the Advanced Visible and Near Infrared Radiometer type 2 (AVNIR-2), Panchromatic Remote-sensing Instrument for Stereo Mapping (PRISM), and Phased Array type L-band Synthetic Aperture Rader (PALSAR), but the DAICHI-2 is specialized for the SAR. By focusing on one specific instrument, we can maximize the SAR’s performance for the DAICHI-2 to be best suited for its primary purpose of monitoring disasters regardless of the time of day and weather conditions. PALSAR-2 of the DAICHI-2, has been significantly improved from the DAICHI’s PALSAR in all aspects including resolution, observation band, and time lag fordata provision.In addition, the satellite’s basic capability has also been enhanced for supporting the radar performance such as data transmission speed and high position retention accuracy thanks to new technology.

While the DAICHI-2 is equipped with the necessary ability for swift disaster monitoring, its development has also generated a variety of new technologies that can be applied for future satellite development.

Shape	Launch Configuration	Approx. 4.5m (X) x 3.5m (Y) x 3.1m (Z)
	On-orbit Configuration	Approx. 10m (X) x 16.5m (Y) x 3.7m (Z)

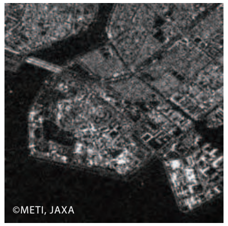
Main characteristics of ALOS-2

Orbit	Type	Sun-synchronous sub-reccurent orbit
	Altitude	628km above the equator
	Local sun time	12:00 +/- 15min above the equator, at descending node
Life time		5 years (target: 7 years)
Launch	Target Launch Date	May 24, 2014 (Nominal)
	Launch vehicle	H-IIA launch vehicle #24

Satellite	Mass	Approx. 2t
Mission Data Downlink		Direct Transmission or via Data Relay Satellite
SAR Frequency range		L band (1.2GHz)
Observation Mode	Spotlight	Resolution: 1-3m Swath: 25km
	Strip map	Resolution: 3m, 6m or 10m Swath: 50 or 70km
	Scan SAR	Resolution: 100m Swath: 350km

1. More detailed

The DAICHI-2’s resolution has been improved from the DAICHI to be able to observe more details using the L-band. The resolution of the DAICHI’s PALSAR was a maximum of 10 meters, but that of the DAICHI-2’s PALSAR-2 has been improved to 1 to 3 meters. This improvement became possible by adding a “spotlight mode” which enables the satellite to change its radio wave radiation direction to its moving direction (vertical direction) while flying to keep observing one specific target location for a long time. In addition, a “Dual receiving antenna system (explained later) is adopted to secure enough observation band with high resolution. As a result, the observation band is 50 km with 3-meter resolution in the “strip map mode”, and 25 km with 1 to 3-meter resolution in the “spotlight mode”.



PALSAR Image
Resolution 10m

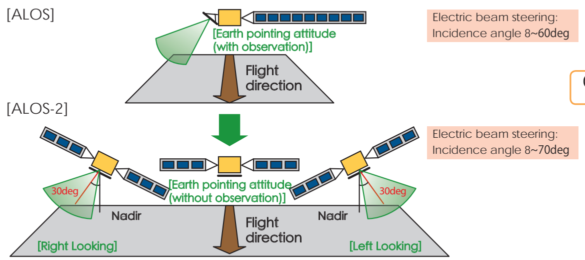
PALSAR-2 Simulation Image
Resolution 3m

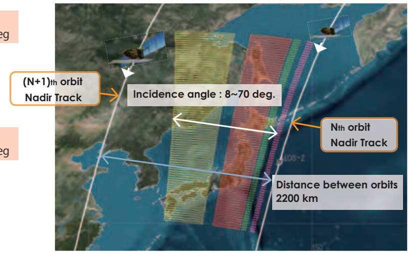
2. Much faster

High responsiveness is required for monitoring disasters. In order to cope with requests from DAICHI users, the DAICHI-2 has been improved in various ways. First of all, the DAICHI’s SAR antenna was fixed to face the lower right direction toward the moving direction of the satellite, thus it observed only one orientation. To broaden the observable area, the DAICHI-2’s antenna plane is upgraded to face to the nadir direction of the satellite, thus, by changing the satellite‘s attitude right or left during observations, both sides of the satellite can be observed. Accordingly, the observable area was drastically improved from 879 km to 2,320 km. In addition to this right and left looking function (meaning monitoring a vast area from one orbit,) the revisit time is also significantly reduced from 46 days to 14 days (so that the satellite can go back to the target location sooner-), and data transmission capability is strengthened to be more efficient (to transmit data faster.) As a result, when a disaster monitoring request comes in within Japan, we can provide images of the stricken area as fast as two hours from request.

Q: How is the revisit time determined?

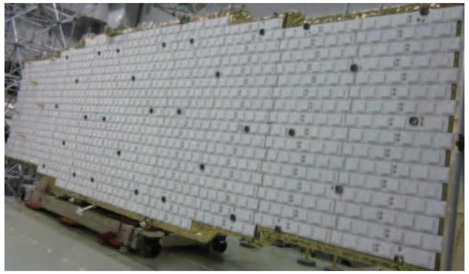
revisit time is how many days a satellite on Earth's orbit takes to come back to the same location. It is determined mainly by two factors, the altitude and the inclination of a satellite.
The altitude of DAICHI and DAICHI-2 is different, 691 km for the former, and 628 km for the latter. This difference results in the DAICHI-2’s revisit time of 14 days compared to that of the DAICHI at 46 days.





Pink width：Swath 50 km (Ultra-Fine and High-sensitivity)
Green width：Swath 70 km (Fine mode)
Red width ：Swath 350 km (ScanSAR nominal mode)
Yellow width：Swath 490 km (ScanSAR wide mode)

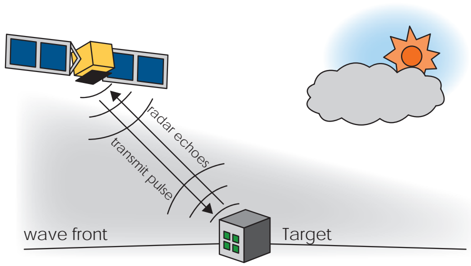
Observations are possible day and night regardless of weather: Phased Array type L-band Synthetic Aperture Rader (PALSAR)



The PALSAR-2 aboard the DAICHI-2 is a microwave sensor that emits L-band radio waves and receives their reflection from the ground to acquire information. It does not rely on other sources of light such as the sun, thus its strongest point lies in its ability to observe the Earth regardless of the time of day.
The bandwidth of the transmitting and receiving radio waves are in microwaves, hence they are less affected by clouds or small water drops and can penetrate them. As it is an all-weather sensor it is best suited for monitoring disasters, which are very difficult to predict when and where they occur. In addition, the wavelength of the L-band is relatively long among microwaves, allowing it to travel all the way down to the ground through vegetation. Not only can information be, obtained about vegetation but information of the ground surface can be obtained as well.
Japan's L-band SAR debuted aboard the FUYO-1 launched in 1992, and was inherited on the DAICHI/PALSAR in 2006, leading up DAICHI-2/PALSAR-2 today. The PALSAR-2 now becomes a unique and highly useful sensor in the world by expanding its radio-frequency bandwidth-, and adopting the "Dual receiving antenna system," which can control two separate receiving radio waves, and achieve a high resolution and broader observation band.

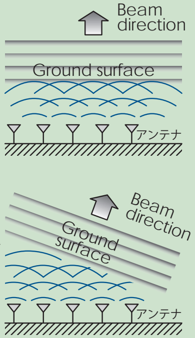
Achieving the phased array antenna with various cutting-edge technologies

The thousand antennas observing the Earth



Q: What is the phased array antenna?

Instead of a parabolic antenna, which looks like a huge umbrella, PALSAR-2's phased array antenna consists of multiple small antennas lined up in rows. A radio wave emitted from an antenna is electronically controlled to change its direction so that beams can freely shift their direction although the antenna is fixed. A phased array antenna, which can open in space, is suitable to expand to become a large-size antenna of a size of about 10 meters by 3 meters with swinging beams, hence this method is widely used in space.

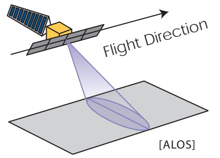


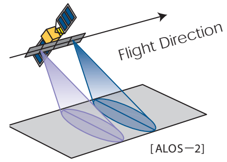
Attaining high resolution by spotlight mode

A new observation mode called a "spotlight mode" was added to the PALSAR-2, which enables it to gain high resolution. As the name shows, this mode works like a spotlight by moving beams to keep aiming at a specific observation target along the flight path of the satellite. More information can be acquired by emitting beams to the same location for a prolonged time (13 to 26 seconds) in the same manner as we can receive more knowledge when we keep looking at one spot while moving. As a result, high resolution of 1 to 3 meters can be achieved. In other words, we will be able to specify an object or a shape of something that cannot be distinguished by the DAICHI/PALSAR, whose resolution was about 10 meters.

Dual receiving antenna system to broaden observable area

The PALSAR-2 adopts the "Dual receiving antenna system", the leading-edge technology in the world, to enable itself to maintain a broader observation swath with high resolution. In this method, the whole antenna plane works as one aperture plane (or one radio frequency transmission plane) when it emits radio waves, while the antenna plane plays as two aperture planes consisting of front and back antennas when receiving the radio waves. By dividing the antenna into two for receiving, two separate waves can be accepted at once, and reception time for each beam can be kept longer. One characteristic of a synthetic aperture radar is that the observation band becomes broader when the reception time gets longer. Therefore, using this method, we can secure a broader observation band of 50 km with a resolution of 3 meters.





Expanding bandwidth and higher power transmission

In order to achieve the high observation resolution and image quality required for the PALSAR-2 aboard the DAICHI-2, the radio wave strength must be improved from that of the PALSAR. For the improvement we need either to enlarge an antenna to concentrate radio waves (in the case of a phased array, increase the number of antennas) or to enhance transmitting power. We applied the latter method by using the world's first antenna amplifier made of GaN HEMT to expand the radar bandwidth for transmitting radio waves with higher output. This improvement will support the DAICHI-2's detailed observation.

Variety of observation modes

Another special feature of the PALSAR-2 is the availability of various observation modes. Apart from the "spotlight mode" (observation band of 25 km), which achieves the most detailed observation of 1 to 3 meters in resolution, the PALSAR-2 is also equipped with the "strip map mode" (band of 50 or 70 km), which is inherited from the PALSAR with more choices of resolution of 3, 6, or 10 meters, and the "scan SAR mode" (band of 350 or 490 kilometers, resolution of 60 to 100 meters), which can observe a broader area at the same time. By selecting one observation mode from these options according to the objective, the most suitable monitoring method can be performed. Furthermore, the HV channel can be used at the scan SAR mode (in the case of the PALSAR, only the HH channel was available) thanks to the achievement of the "full polarimetry" (observation with four polarized waves) of 6-meter resolution, so that we will be able to gain more information from one observation location (for example, a type of tree in a forest can be detected.)

Observation Mode		Resolution	Swath
Spotlight		1m(Az)×3m (Rg)	25km×25km (Rg)
Strip map	Ultra Fine	3m	50km
	High sensitivity	6m	70km
	Fine	10m	70km
Scan SAR	Nominal	100m	350km
	Wide	60m	490km

Every satellite requires a main body that preforms basic needs to achieve its special mission. That body is called a “bus.” The DAICHI-2’s bus has been actively incorporated with various new technologies as we foresee future applications to other satellites.

Improvement of data transmission capacity

X-band Modulator

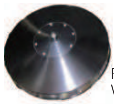
Faster

High speed transmission is imperative for promptly delivering large-volume observation data acquired by the DAICHI-2 to users. For fulfilling our responsibility, the “X band Multi-mode High Speed Modulator (XMOD)” is installed. In addition to the QPSK method, modulation with 16QAM method is also available to enable transmission of 800 Mbps. This transmission speed is the fastest in the world as a communication method using a single X-band wave, and over five times faster than that of the DAICHI (138 Mbps.)

More efficient

The XMOD is available only when the DAICHI-2 is flying within the view area of a ground station, but data transmission is possible through a data relay satellite “KODAMA” in areas outside the view path. Although the data relay transmission speed is about 278 Mbps (QPSK method), we can achieve efficient data transmission with the help of the XMOD.

Improved data acquisition opportunity and storage capacity



Reaction Wheel

Mission Data Processor

More agility

The DAICHI-2 can rotate its attitude right and left against its moving direction. Using this function, the PALSAR-2 beam can be emitted in broader areas to increase image shooting opportunities. For quicker attitude shifting, five “high torque reaction wheels” are onboard. Dynamic movement of 30 degrees rotation in 120 seconds is attained through the generation of large torque.

More voluminous

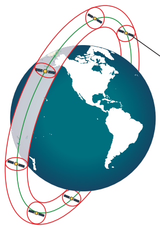
Data volume for one observation by the DAICHI-2/ PALSAR-2 is larger than that of the DAICHI/PALSAR as the former is higher in resolution and broader in observation band. In addition, image shooting opportunities are increased thanks to its right-and-left observation function, thus data storage until completing data transmission to the ground will increase. The ALOS-2 data recorder volume is expanded to a maximum of 128 Gbyte (96 Gbyte for the ALOS) of memory storage.

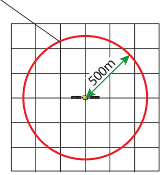
Improving position accuracy and recurrent precision

GPS Antenna

More precisely

A data analysis method called the “interferometry” of the PALSAR-2 is expected to be applied in various fields. In order to utilize this method with high precision, the satellite has to observe exactly the same location twice or more. Therefore, it is important to know the satellite position accurately to use this method. The GPS aboard the DAICHI-2 can determine a position within one meter of the margin by using technology called the “dual-frequency GPS receivers for L1 and L2 band.” A satellite’s orbit is gradually shifting due to outside forces such as altitude decrease due to atmospheric resistance and orbit plane change by solar attraction. The new “precise autonomous orbit maintenance technology” is adopted for the DAICHI-2 to correct its orbit by itself. The orbit is autonomously maintained within a 500 meter radius from the basic orbit.





Enhanced operability

More promptly

The DAICHI-2 adopts an “observation table.” This is a pattern or a sample of a series of pre-registered information for each specific operation, such as turning on/off a certain device for observations. Each observation mode has its own table. When we start a new observation mode, we simply pick up the table for that mode and set up the parameter unique for that observation plan. With this clear procedure, we can promptly cope with an emergency disaster monitoring request without any incorrect commands.

Improved survivability

From one paddle to two paddles

The DAICHI was installed with only one set of solar array paddles which extended long to the left side against it moving direction. With one paddle, each onboard mission sensor can secure a broader view, but there is no alternative if that one paddle is broken. The DAICHI-2 does not have any issues with the onboard radar’s view because it faces toward the nadir direction, thus the satellite is equipped with two sets of paddles to be advantageous for securing electricity even when one of paddle is broken. In the case that power generation is reduced in half if one of the paddles fails, the mission can continue in the “degenerate mode” meaning conducting limited observation operation by reducing the burden on power.

Safety mode for emergencies

If an emergency occurs with a satellite and observations have to be halted or continuing observations may induce a serious problem with the satellite system, the satellite stops observations and shifts to the “safety mode.” This is a mode to reduce its power burden to the minimum level to study the satellite’s condition. The DAICHI-2 increases its survivability by appropriately and automatically shifting to the “safety mode” when a problem arises.

Development for the future

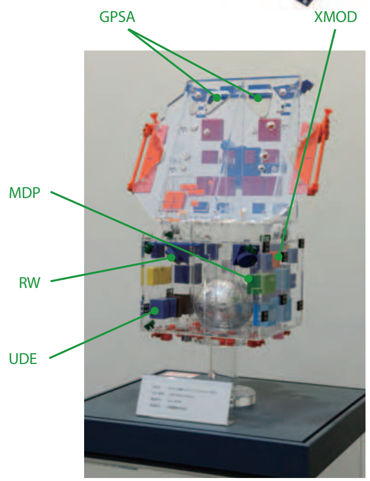
Unified Driver Electronics

Lithium-ion battery

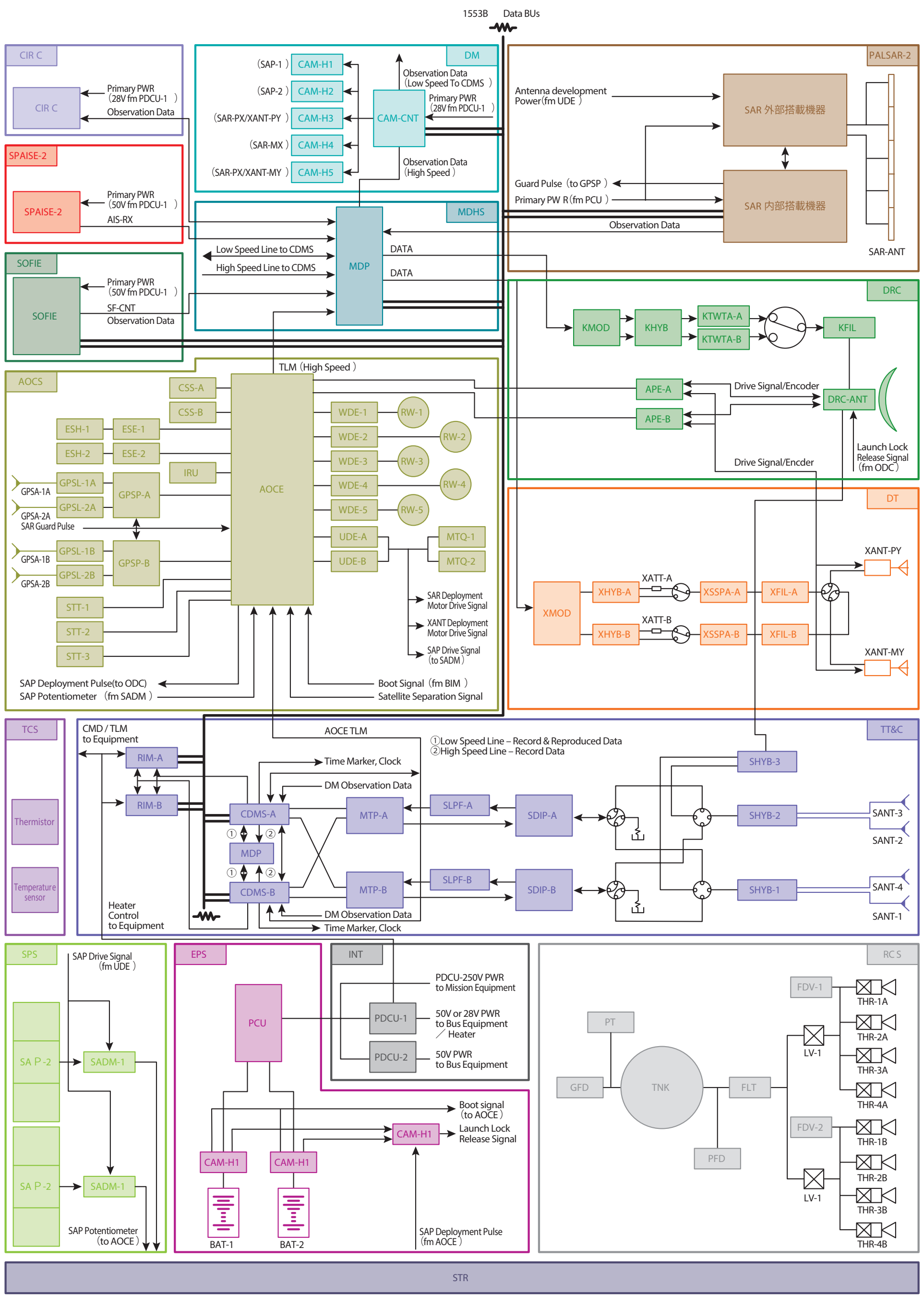
The NiCd (nickel cadmium) battery aboard the DAICHI had a memory effect, which means that a rechargeable battery gradually loses its maximum energy capacity if it is repeatedly recharged after being only partially discharged. Therefore, reconditioning to recover its capacity had to be performed for the DAICHI from time to time by discharging more than its capacity. The DAICHI-2 adopts a lithium-ion battery which does not entail a memory effect as part of design development that can be applied for future satellites, hence reconditioning is not necessary anymore. In addition, we successfully made the battery lighter.

Development of the Unified Driver Electronics (UDE)

In order to make the DAICHI-2 lighter by reducing the number of onboard devices, we reviewed the function of onboard devices. As a result, we integrated some driving functions into one, namely driving functions of propellant valves, latch valves, SADM, SAR deployment motor, XANT deployment motor, and MTQ. The integrated driver is called the “Unified Driver Electronics (UDE.)” We will apply the UDE for future satellites.



ALOS-2 Satellite bus skeleton model



Subsystem Constitution

PALSAR- 2	Phased Array type L-band Synthetic Aperture Radar
SOFI E	SOI FPGA In-orbit Experiment
CIRC	Compact Infrared Camera
SPAISE- 2	Space based AIS Experiment -2
AOCS	Attitude & Orbit Control System
AOCE	Attitude & Orbit Control Electronics
IRU	Inertial Reference Unit
CSS	Coarse Sun Sensor
ESE	Earth Sensor Electronics
ESH	Earth Sensor Head
STT	Star Tracker
GPSP	Global Positioning System Processor
GPSA	Global Positioning System Antenna
UDE	Unified Driver Electronics
WDE	Wheel Driver Electronics
RW	Reaction Wheel
MTQ	Magnet Torquer
TT&C	Telemetry Tracking and Control Subsystem
CDM S	Command & Data Management System
RIM	Remote Interface Module
MTP	Multi-mode integrated Transponder
SDIP	S-band Diplexer
SLPF	S-band Low Pass Filter
SHYB	S-band Hybrid
SANT	S-band Antenna
DT	Direct Transmission Subsystem
XANT	X-band Antenna
XFIL	X-band Filter
XHYB	X-band Hybrid
XSSPA	X-band Solid State Power Amplifier
XMOD	X-band Modulator
XATT	X-band Attenuater
DRC	Data Relay and Communication
APE	Antenna Pointing Electronics
KMOD	K-band Modulator
KHYB	K-band Hybrid
KTWTA	K-band Traveling Wave Tube Amplifier
KFIL	K-band Filter
DRC-ANT	Data Relay and Communication Antenna
MDHS	Mission Data Processing Subsystem
MDP	Mission Data Processor
EPS	Electrical Power System
PCU	Power Control Unit
BIM	Battery Interface Module
BAT	Battery
ODC	Ordnance Controller
SPS	Solar Paddle Subsystem
SAP	Solar Array Paddle
SADM	Solar Array Drive Mechanism
DM	Deployment Monitor
CAM-CNT	Monitor Camera-Controller
CAM-H	Monitor Camera-Head
TCS	Thermal Control System
RCS	Reaction Control Subsystem
THR	4N-Thruster
TNK	Fuel Tank
LV	Latching Valve
FDV	Fill and Drain Valve
PFD	Propellant Fill and Drain Valve
GFD	Gass Fill and Drain Valve
FLT	Filter
PT	Pressure Transducer
STR	Structure
INT	Integration Hardware
PDCU	Power Distribution Control Unit

Satellite operation after separation from H-IIA

The DAICHI-2 will be launched from the Tanegashima Space Center by the H-IIA Launch Vehicle. It will be separated from the H-IIA about 16 minutes after liftoff to be injected into orbit at an altitude of 628 kilometers with an inclination of 97.9 degrees. The DAICHI-2 will perform a series of post-separation operations automatically, namely a rate damping to stop its rotation (angular velocity) caused by the separation, solar array paddle deployment, and sun acquisition. After that, it will acquire the Earth, establish its stable attitude to face to the Earth (three-axis stabilization in the Earth orientation mode), then track the sun to face solar array paddles toward the sun all the time. The onboard equipment will then be under function verification following the deployment of the L-band SAR antenna and direct transmission antennas, while correcting orbit to the observation orbit.

Satellite separation to rate damping

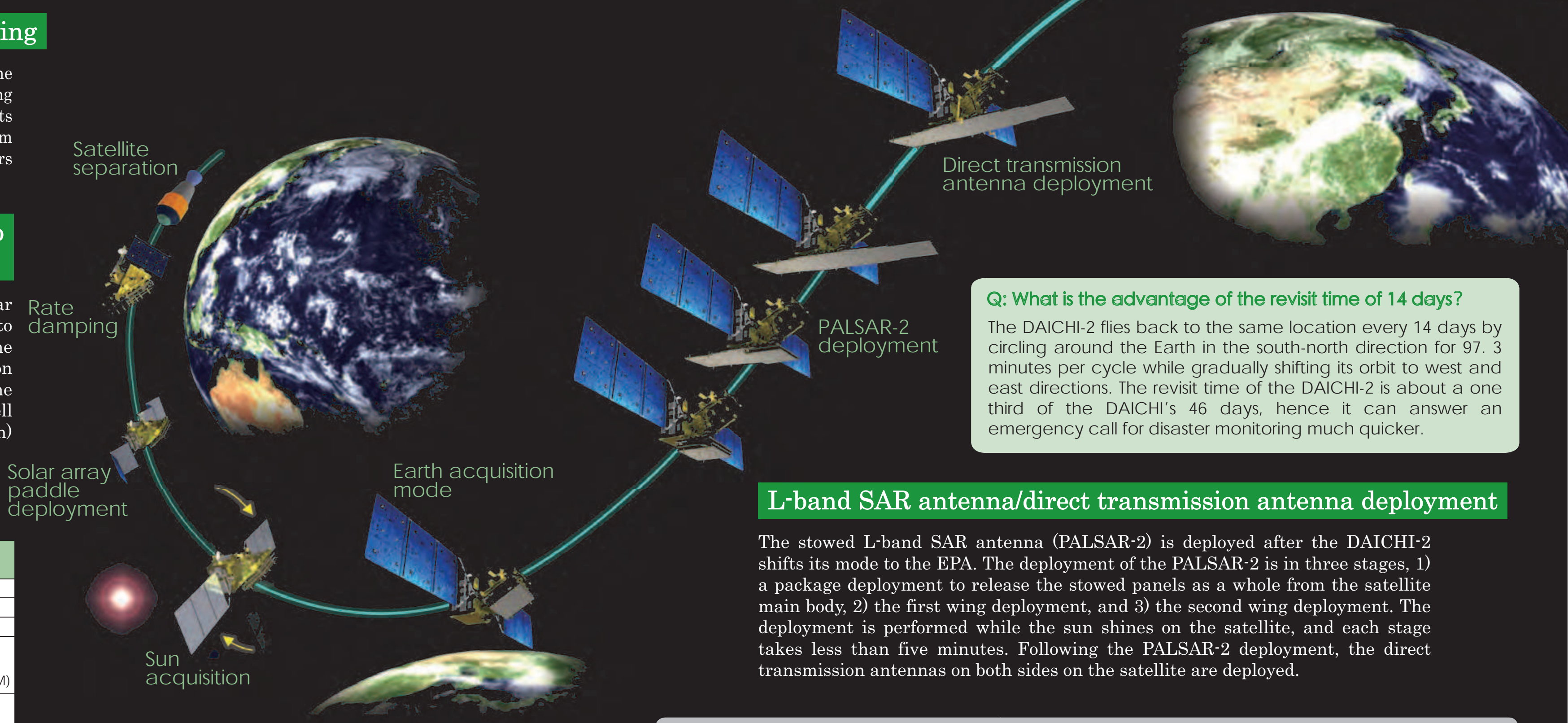
After being separated from the launch vehicle, the DAICHI-2 automatically shifts to the Rate Damping Mode (RDM). In this mode, the satellite stops its rotation (angular velocity) caused by separation from the launch vehicle to be stable by jetting the thrusters installed onto the satellite.

Solar array paddle deployment to sun acquisition

Upon completion of the rate damping, the solar array paddle is automatically deployed to move to the sun acquisition mode (SAM). In this mode, the satellite is rotating around the sun's orientation axis (the direct line connecting the sun and the satellite) while facing the solar array paddle's cell side (the side which solar batteries are lined on) toward the direction of the sun.

Main Event Schedule

Time from liftoff	Satellite Event
Approx. 30 min	Rate Damping Solar Array Paddle deployment Start the Sun Acquisition Mode (SAM)
Approx. 8-9 hour	Start the Earth Acquisition Mode (EAM) and followed by the Earth Pointing Mode (EAM)
Approx. 13 hour	SAR Antenna deployment #1 (package deployment)
Approx. 24 hour	SAR Antenna deployment #2 (first wing deployment)
Approx. 34 hour	SAR Antenna deployment #3 (first wing deployment)
Approx. 37 hour	Direct Transmission Antenna PY deployment
Approx. 47 hour	Direct Transmission Antenna MY deployment
Approx. 51 hour	Start the Fine Normal Mode



Earth acquisition mode

After the sun is successfully acquired, the DAICH-2 progresses to the Earth acquisition mode (EAM) following a command from the ground to acquire the Earth, then automatically shifts to the Earth pointing mode (EPM.) In the EPM, the satellite controls its attitude to face its L-band SAR antenna side to the Earth while it starts sun acquisition to always direct its solar array paddles toward the sun.

Fine normal mode

As the L-band SAR antenna and direct transmission antennas are deployed, the DAICHI-2 shifts to the fine normal mode (FNM) following a command sent from the ground. In the FNM, the attitude is controlled using a wheel to face toward the Earth. After moving to the FNM, onboard equipment is functionally verified and the DAICHI-2 orbit is corrected to start observation operations.

Q: What is the advantage of the revisit time of 14 days?

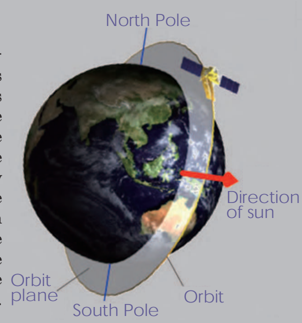
The DAICHI-2 flies back to the same location every 14 days by circling around the Earth in the south-north direction for 97. 3 minutes per cycle while gradually shifting its orbit to west and east directions. The revisit time of the DAICHI-2 is about a one third of the DAICHI's 46 days, hence it can answer an emergency call for disaster monitoring much quicker.

L-band SAR antenna/direct transmission antenna deployment

The stowed L-band SAR antenna (PALSAR-2) is deployed after the DAICHI-2 shifts its mode to the EPA. The deployment of the PALSAR-2 is in three stages, 1) a package deployment to release the stowed panels as a whole from the satellite main body, 2) the first wing deployment, and 3) the second wing deployment. The deployment is performed while the sun shines on the satellite, and each stage takes less than five minutes. Following the PALSAR-2 deployment, the direct transmission antennas on both sides on the satellite are deployed.

ALOS-2 orbit

The DAICHI-2 will utilize the sun-synchronous sub-recurrent orbit, which makes a north-south circle around the Earth. In this orbit, the positional relationship between the orbit plane of a satellite and the sun are constant (sun-synchronous) while a satellite flies over the same location on the Earth every recurrent period of days (subrecurrent.) The time of passing the equator is also constant in this orbit, thus the satellite flies over one location at around the same time of day. The "local sun time" is the time when a satellite passes over the equator, and it is 12:00 (a.m. and p.m.) +/- 15 minutes for the DAICHI-2.



「だいち2号」軌道概要　Alos-2 Orbit

軌道種類	太陽同期準回帰軌道
軌道高度	628km
軌道傾斜角	97.9deg
降交点通過地方時	12:00　± 15mi n
回帰日数	14 日
軌道周期	97.3　分

Ground system and observation operation

The ground system for the DAICHI-2 consists of the following four major systems: “Spacecraft Control and Mission Operation System,” “Earth Intelligence Collection and Sharing System”, “Tracking Network System ,” and “Data Analysis System.” They are at the Tsukuba Space Center.

1 Receiving requests, compiling observation requests

Receiving requests from users at the “Earth Intelligence Collection and Sharing System , ” and compiling observation requests.

2 Operation planning

Planning observations according to requests by the “Spacecraft Control and Mission Operation System.”

3 Satellite control and tracking operation

Performing telemetry and command operations and ground station operations using the “Tracking Network System .”

4 Observations

Data acquisition through satellite observations.

5 Observation data reception

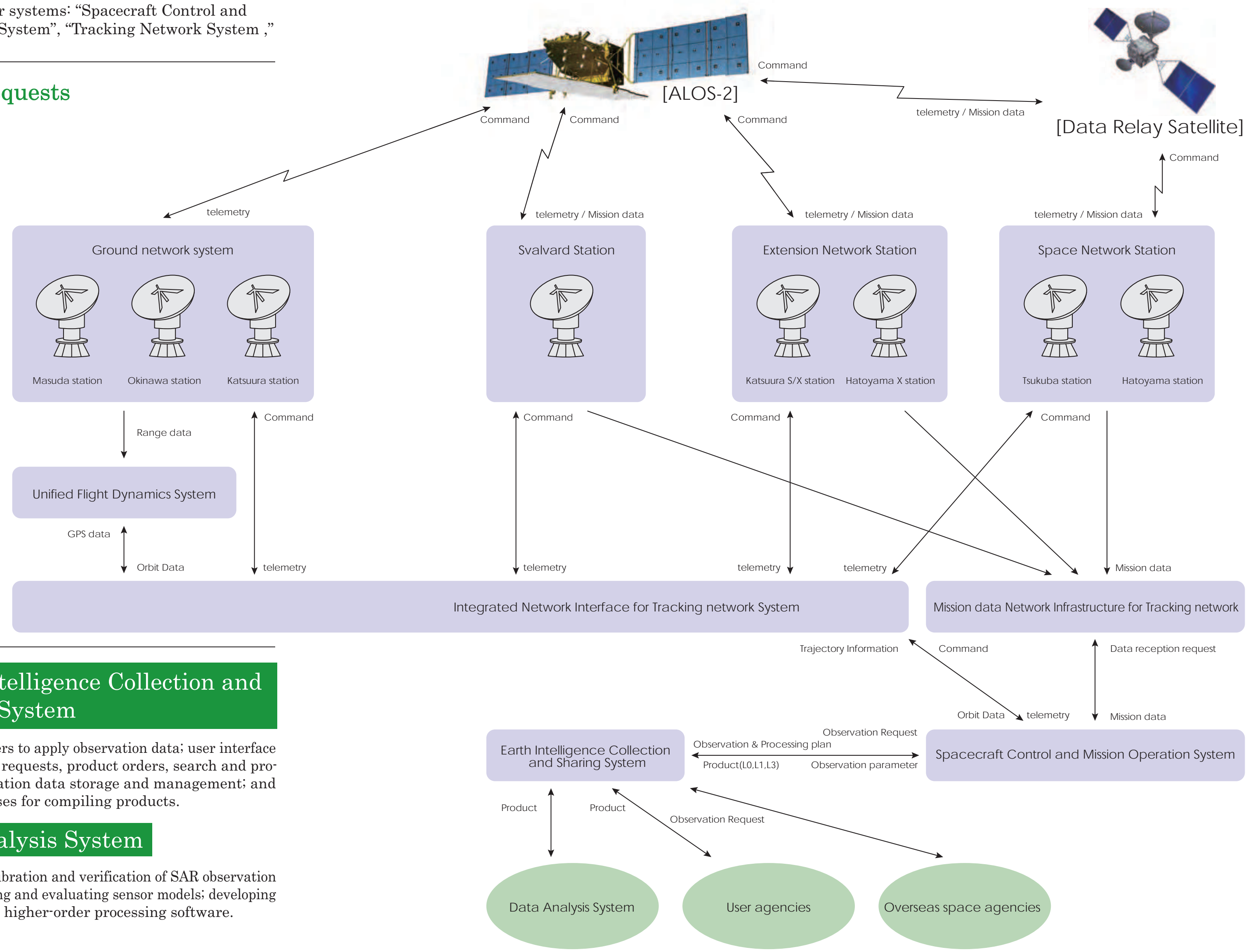
Receiving and recording observation data by the “Mission data Network Infrastructure for Tracking network.”

6 Observation data processing

Compiling various products by the “Earth Intelligence Collection and Sharing System ”

7 Observation data delivery

Providing products to users from the “Earth Intelligence Collection and Sharing System .”



Spacecraft Control and Mission Operation System

A system for compiling an observation plan; generating a command, monitoring and controlling satellite conditions; transmitting observation data of the mission instrument and processing them with the level 0 process; and processing emergency observation data with the level 1 process.

Tracking Network System

A system for compiling the network operation plan for satellite control operations; orbit determination; monitoring and controlling ground stations; monitoring and controlling ground stations for observation data receiving operations.

Earth Intelligence Collection and Sharing System

A system for users to apply observation data; user interface for observation requests, product orders, search and provisions; observation data storage and management; and various processes for compiling products.

Data Analysis System

A system for calibration and verification of SAR observation data; constructing and evaluating sensor models; developing and evaluating higher-order processing software.

Data provision and utilization during disasters

The approximate observation time frame of the DAICHI-2 over Japan is at 12:00 a.m. and 12:00 p.m. (with a margin of about one hour before and after the top of the hour.) The DAICHI-2 can cope with an emergency observation request an hour prior to the observation time at the latest, thus, if a disaster occurs around 11:00 o’clock, the satellite can observe the disaster-stricken area in an hour in the best-case scenario. Then, one hour after the observation, the data (with standard process) can be provided. In two hours after the observation, a quick analyzed product can be compiled and sent to the damaged area. In the case of a disaster within Japan, data can be provided within 12 hours.

Q: How will the DAICHI-2 operations start after the launch, and around when will the DAICHI-2 data be available?

The DAICHI-2 will first move into the fine normal mode (FNM, which is the regular operation mode) after launch, then, in the FNM, it will take about three months for initial functional verification of the satellite bus and the PALSAR-2. After that, it requires three more months of the initial calibration and verification period to calibrate and verify the PALSAR-2. The data provision to users will then begin about six months after launch.

ALOS-2 Project Team
Satellite Applications Mission Directorate I
Japan Aerospace Exploration Agency

Tsukuba Space Center
2-1-1, Sengen, Tsukuba, Ibaraki, 305-8505 Japan

http://global.jaxa.jp/

DAICHI-2 special site
http://global.jaxa.jp/projects/sat/alos2/index.html

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