The FORMOSAT-2 Rapid Response for Emergency Observation

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ABSTRACT: FORMOSAT-2 is an EO-type remote sensing satellite, launched by National Space Organization, National Applied Research Laboratories of Taiwan in 2004. The 2-m PAN and 8-m MS spatial resolutions may no longer be considered as state-of-the-art in 2011 standard; however, the one day temporal resolution is still the best.

The daily revisit orbit together with the efficient operating capability of the FORMOSAT-2 operation team resulted in FORMOSAT-2's next day imaging feature in response to most of the unexpected emergency events.

The FORMOSAT-2 multi-stripe imaging capability implemented by fully utilizing its maneuvering agility, can contribute good benefits to an overall disaster assessment in its early stage. However, the large data volume can slow-down the data processing speed and increase the data latency. The problem was resolved by implementing a multi-processing-unit system and run the image processing in parallel. A semi-automatic speedy orthorectify system was also included in the processing chain to provide near real-time semi-ortho image product.

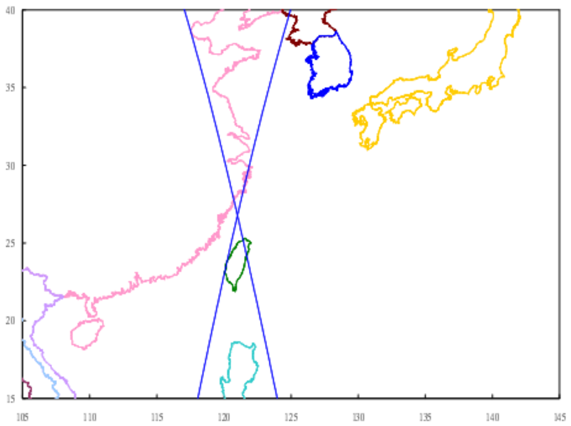
The FORMOSAT-2 rapid response capability was fully demonstrated in 2011 East Japan Earthquake. The earthquake happened on March 11, the image was taken next morning and within 4 hours the data was ready for download. The whole campaign consists of 15 consecutive days of daily covering on the disaster area with multi-stripe image.

1. Introduction

FORMOSAT-2 is an EO-type remote sensing satellite with 2m Ground Sampling Distance (GSD) in Panchromatic (PAN) band and 8m GSD in Multi-spectral (MS) bands in the Nadir direction. It was launched by National Space Organization, National Applied Research Laboratories of Taiwan in 2004 and remains in good operating condition after 7 years of service. The most distinctive feature of the satellite is its orbit.FORMOSAT-2 was put into a sun-synchronous mission orbit at altitude of 891 Km and inclination of 99.1° . This is a specially designed orbit so that the satellite will have exactly 14 revolutions per day and passes the same spot of Taiwan almost the same time everyday, so called daily revisit. The one-day temporal resolution is still considered as among the best in 2011 standard, and make it very suitable for continuous monitoring type applications.

2. Emergency Programming

There are two chances that ground station of Taiwan can make contact with FORMOSAT-2 satellite. As shown in the Figure 1, the satellite passes over Taiwan around UTC 2 in the descending pass and around UTC 13 in the ascending pass. The nominal satellite imaging programming is implemented by utilizing these two contact windows to send command loads to instruct satellite how to take images. The tasking request is due by 0400 UTC in normal situation. However, in the event of the emergency, NSPO will re-schedule the satellite activity and give higher priority for this urgent tasking. Figure 2 shows the FORMOSAT-2 orbit numbering convention, the orbit pass over Taiwan is numbered as the orbit 1. From the practice, FORMOSAT-2 can achieve next-day imaging in most cases, except for some rare events either due to the orbit 8~1 request came in too late to allow adequate programming operation time for UTC 13 up-load or the resource constraints. The programming timeline are shown as Figure 3.



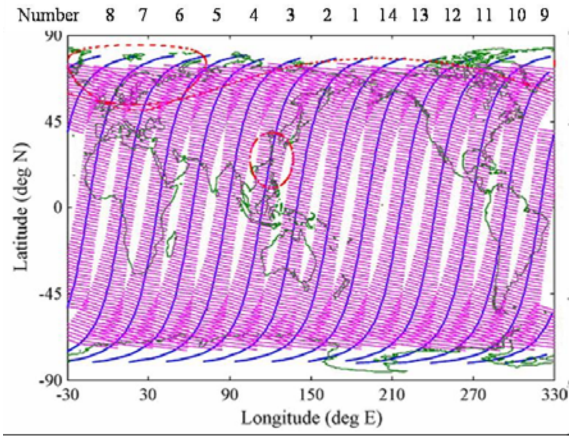


Figure 1 Ascending and Descending pass over Taiwan. Figure 2 FORMOSAT-2 orbit numbering convention.

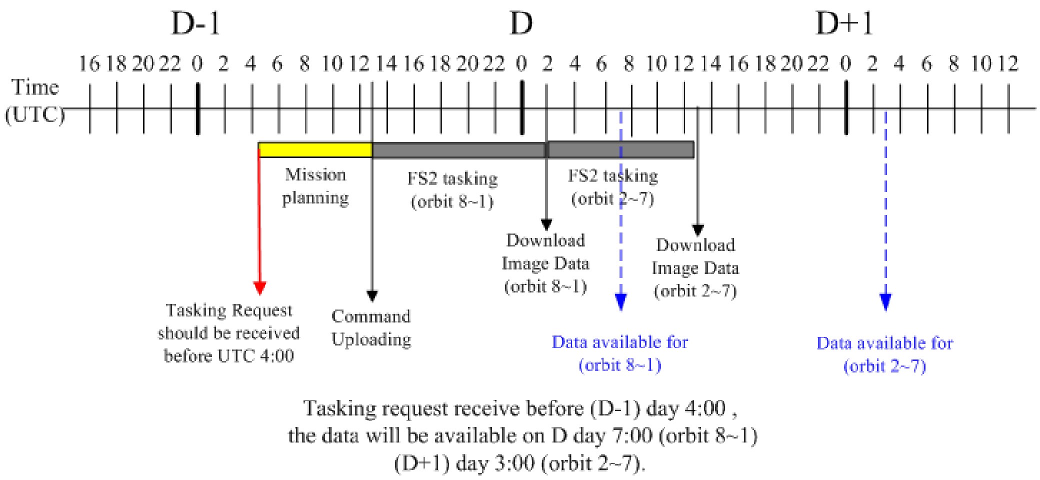


Figure 3 FORMOSAT-2 programming time-line

3. Multi-stripe Imaging

By fully utilizing its maneuver agility, FORMOSAT-2 can scan the ground multiple times to overcome the narrow swath disadvantage of a high-resolution satellite. Figure 4 shows an extreme case to cover whole Taiwan in just one pass. The feature can be used for early stage assessment for disaster when large area coverage is required.

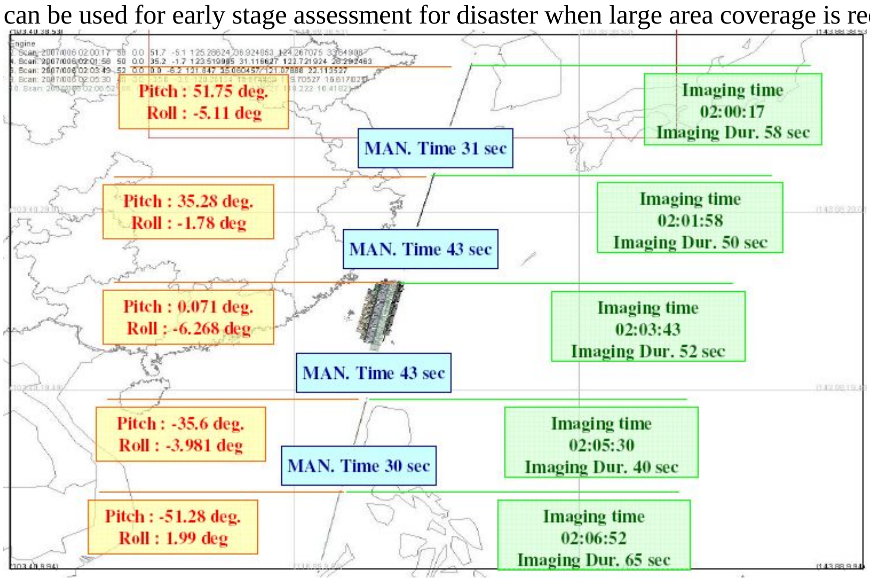


Figure 4 Multi-stripe Imaging to cover whole Taiwan in one pass

4. Fast Data Processing

4.1 Image Processing System

The FORMOSAT-2 data processing system, Image Processing System (IPS), is an in-house R&D product of National Space Organization (NSPO). The architecture of IPS consists of five subsystems known as: Planning & Scheduling Subsystem (PSS), Data Ingestion Subsystem (DIS), Data Manager Subsystem (DMS), Data Processing Subsystem (DPS) and Image Quality Subsystem (IQS). Figure 5 depicts the system architecture. For now, the system is able to generate 3 types of product known as level 1A, level 1C and level 2 products. Basically, level 1A processing generates radiometric corrected images. Level 1C products are similar to level 1A products with additional processing to remove instrument's non- linearity. The level 2 processing applies radiometric and geometric corrections such that the product is aligned with the selected map projection.

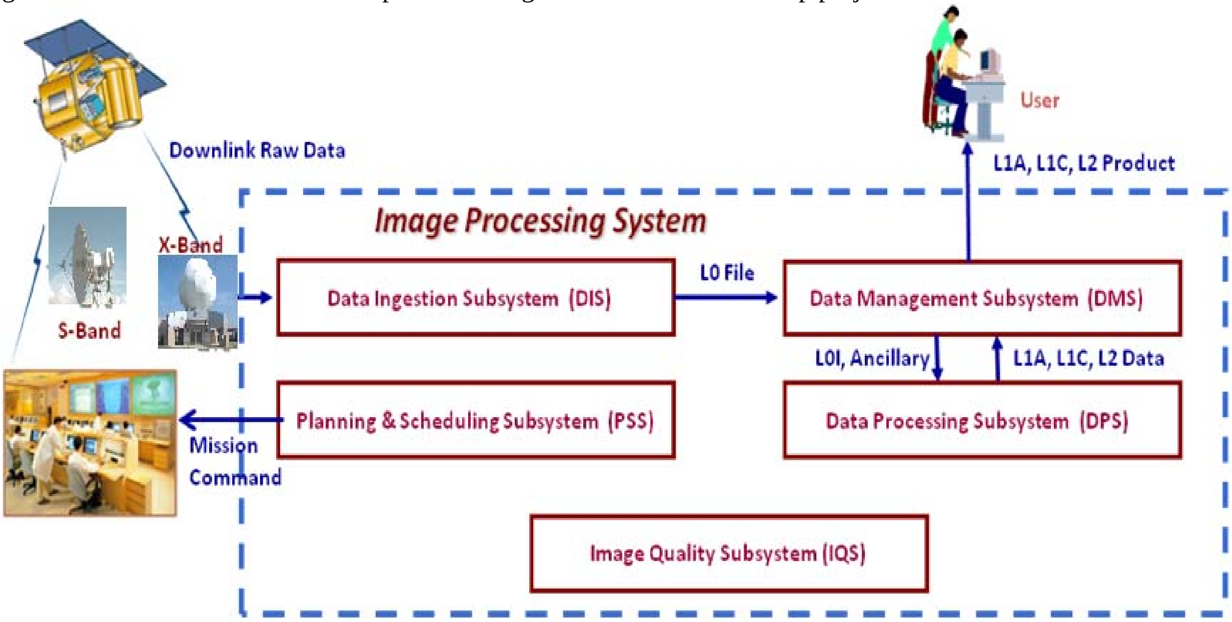


Figure 5: FORMOSAT-2 Image Processing System Architecture

4.2 Multi-processing-unit System

The IPS has proven to be a reliable system for FORMOSAT-2 routine operation. However, with the newly developed multi-stripe imaging feature, the raw data volume has grown far exceed to the original design specs. The large data volume can slow-down the data processing speed and sometimes cause system problem. The issue was resolved by implementing a multi-processing-unit system and run the image processing in parallel. Figure 5 depicts the architecture of this system, the front part basically involves in porting core functions from UNIX-based IPS to Linux-based system, and the later part is a hardware-accelerated ortho-rectification system, the Mojave™ IOPS, which will be explained in next session. By using this multi-processing-unit product generation system, NSPO can handle several segments at the same time for standard level 1A and level 2 products generation, and also provide the qusi-orthorected products in 4 hours after the satellite downlink raw data are received from X-band antenna. It's proven to be very useful in an emergency situation when data-latency is critical.

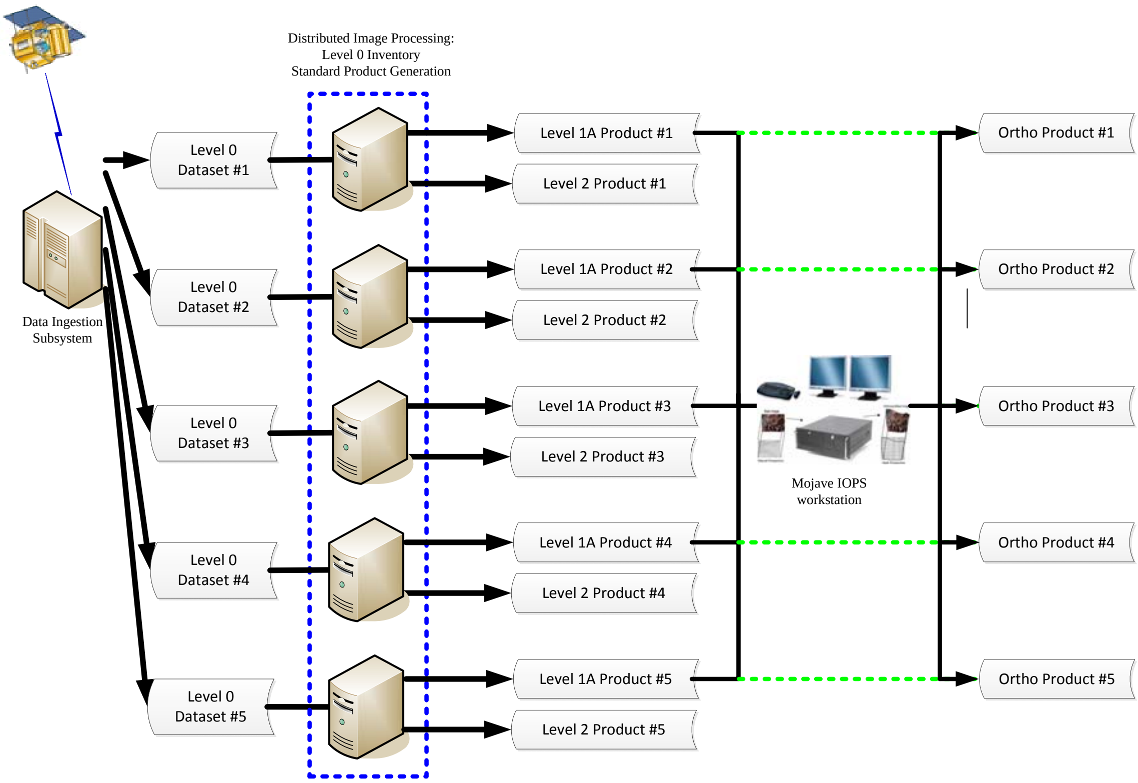
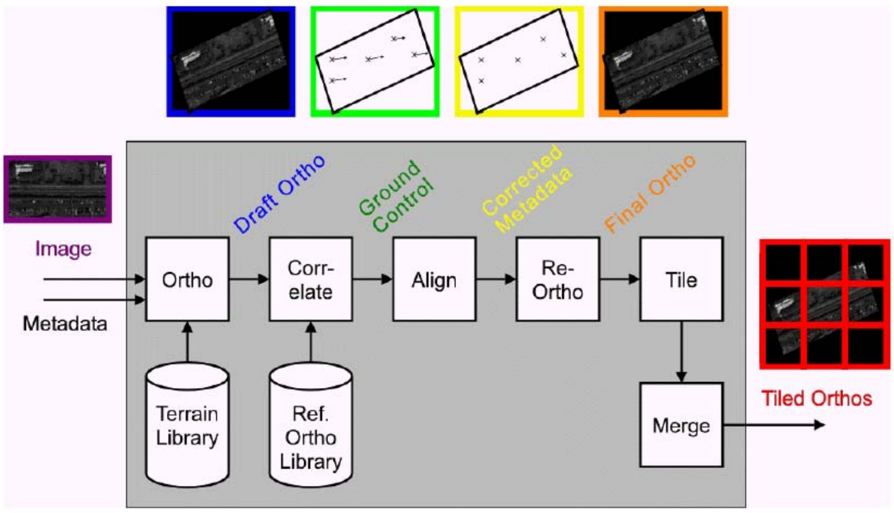


Figure 5 Architecture of Multi-processing-unit Product Generation System

4.3 Fast Ortho-rectification Procedures

With its unique daily revisiting capability, the FORMOSAT-2 data are widely used in many time-critical applications. In some application, the image orthographic rectification is required for further processing. To provide the orthographic rectified images in a near-realtime way for a domestic disaster reduction application, NSPO introduced a hardware-accelerated ortho-rectification system, the MojaveTM IOPS (Image Ortho-rectification Processing System) developed by Cardio Logic, Inc (David, 2010). According to the data sheet Cardio Logic provided, with the hardware acceleration board, the MojaveTM IOPS is able to ortho-rectify a 1.6 GB single-band image in 1.5 minutes. Figure 6 illustrates the workflow of MojaveTM IOPS.



Figures 6 Mojave IOPS™ Process Workflow (Davie, 2010.)

To make Mojave™ IOPS work properly, user has to build, for each area of interest (AOI), a terrain library and a reference ortho library. In the domestic disaster reduction application case, instead of using conventional approach by defining a large number of AOIs, we try to treat the whole Taiwan as a single AOI. Though nobody tried to handle an AOI of this size before, the idea is to simplify the operation procedures and hence improves the overall throughput. The SRTM data from the Internet is used to build the terrain library. The archived FORMOSAT-2 ortho-rectified images are used as the reference ortho library. For Mojave™ IOPS to ortho-rectify a given raw image, the rational polynomial coefficients (RPC) are also required as metadata.

In the test case, a FORMOSAT-2 panchromatic scene of size 12000 * 12000 is used as input. It takes the system 1 minute to generate ortho-rectified product with geographic coordinates, and 2 minutes to generated product ortho-rectified to 2 degree Transverse Mercator projection. The geometric accuracy is about 5 to 20 meters. The geometric accuracy could be improved by adjusting GCP manually; however, the overall throughput will be impacted. In practice, we provide the system product without manual intervening when data latency is more critical and claim the product as qusi-ortho- rectified instead of ortho-rectifed.

5. FORMOSAT-2 supports to the East Japan Earthquake

A 9.0-magnitude (MW) undersea earthquake, off the Japanese Pacific coast of Tohoku, occurred on 11 March 2011 at 14:46 JST (05:46 UTC). The earthquake resulted in a major tsunami which brought destruction along the Pacific coastline of Japan's northern islands and resulted in the loss of thousands of lives and devastated entire towns. Follows the occurrence of the event, NSPO received an Emergency Observation Request (EOR) issued by Japan Aerospace Exploration Agency (JAXA). The FORMOSAT-2 emergency programming procedure was immediately activated. The disaster area images were successfully taken next morning, and the entire operation last for two weeks till March 24. Each day, more than one segment (stripe) images were taken to provide the maximal extent of monitoring coverage. The multi-processing-unit system was also used to shorten the data latency. Figure 7 shows the data availability timeline of March 12.

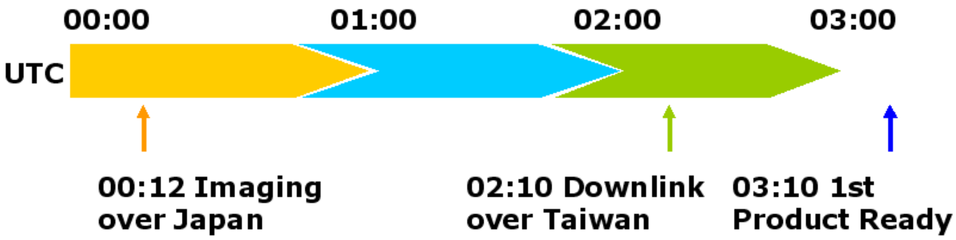


Figure 7 Data availability timeline of East Japan Earthquake

Actually FORMOSAT-2's imaging of the disaster area started two days earlier due to a 7.2-magnitude pre-quake occurred on 9 March 2011 in the very close location. According to NSPO's major disaster support procedure, the7.2-magnitude was big enough to trigger the emergency support activities. Figure 8 shows the time sequence of FORMOSAT-2's activity in supporting to the event. The images of March 10 and 11 provided a very good base for comparison, especially the image of March 11, was taken 5.5 hours before the major earthquake. Figure 9 shows the 4-days serial image of Sendai Shiogama Port.

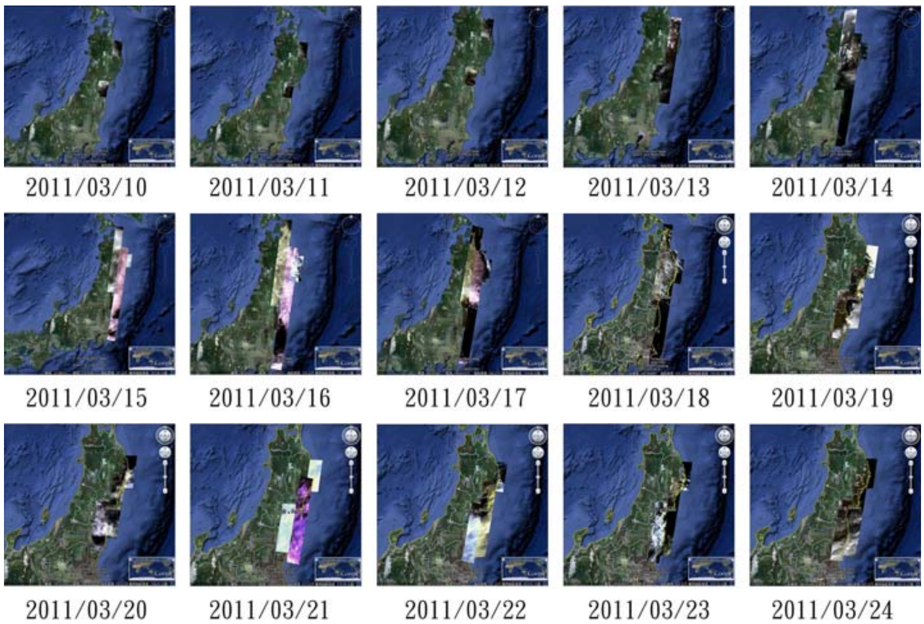


Figure 8 FORMOSAT-2 time-serial images of 311 Earthquake

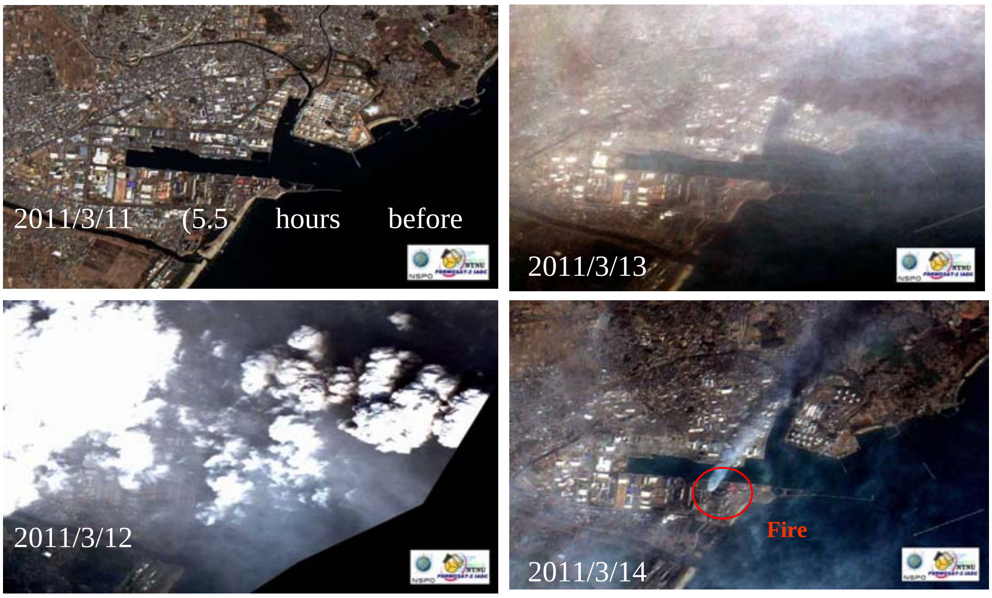


Figure 9 Serial image of Sendai Shiogama Port

6. Conclusion

FORMOSAT-2 distinct itself from other commercial high resolution satellites is the fully devoting to humanity relief. The disaster related imaging always takes priority. The FORMOSAT-2 team dedicated themselves to rapidly respond and to deliver the disaster image in the shortest time. In the past seven years of service, FORMOSAT-2 supported to numerous major disasters, including South Asia earthquake and tsunami (2004), Hurricane Katrina (2005), Ethiopia Flood (2006), California wildfire (2007), Sichuan Earthquake (2008), Flood caused by Typhoon Morakot (2009), and of course East Japan Earthquake (2011). FORMOSAT-2 also extended this effort through international organizations to aggregate the relief efforts. For example, images had been provided to International Charter of disaster since 2006, UNOSAT since 2006, and to Planet Action since 2008. Starting form June, 2010, FORMOSAT-2 provided humanity relief support to Sentinel Asia, the number of supports has accumulated to more than 30 in 12-months period. NSPO also developed new systems, operation mechanisms, and procedures to enhance the overall FORMOSAT-2 performance to better utilize its capacities especially in an emergency situation. The improvement efforts and FORMOSAT-2's dedicate to the rapid disaster supports will go on as a NSPO's commitment to the humanity relief.

7. Reference

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