Overview of Sentinel Asia & the Great East Japan Earthquake

Makoto Kawai[1] and Kazuya Kaku[*1]
[1]Engineer, Satellite Applications and Promotion Center, Japan Aerospace Exploration Agency
5F Dai-ichi Tekko BLD, 1-8-2 Marunouchi, Chiyoda-ku, Tokyo 100-0005, Japan; Tel: +81-50-3362-3026, 7129
Email: kawai.makoto@jaxa.jp, kaku.kazuya@jaxa.jp

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ABSTRACT: Sentinel Asia is the international cooperation among the Asia and Pacific to support the disaster management activity in each country. When the member of Sentinel Asia faced the major disaster, Sentinel Asia provides the data of Earth observation satellite of member space agencies, such as ALOS, FORMOSAT-2, IRS, KOMPSAT-1 and THEOS, based on their request. Sentinel Asia is the powerful initiative for the Asia and Pacific countries to get the space based information for disaster management, especially for countries which don't have own satellite, and in case of huge disaster which is difficult to be managed just by one satellite and country. In addition to the participating satellites of Sentinel Asia, Sentinel Asia has the close collaboration with International Charter for Space and Major Disasters, and International Charter also supports the disaster response activity of member in case of serious disaster. In recent cases, Sentinel Asia provided many satellite data for the Great East Japan Earthquake, and these data were very useful for the response against this catastrophic disaster. In the Great East Japan Earthquake, the advantage of Sentinel Asia was fully produced, such as covering the quite wide disaster afflicted area spatially and temporally by the constellation of various satellites. Sentinel Asia performs not only Earth observation satellite observation after disaster happening, but also the utilization of communication satellite, working group and joint project for disaster preparedness, capacity development, etc for the more practical supports of disaster management in member countries and the strengthening of human network over the Asia and Pacific region.

1. INTRODUCTION

1.1 Background

According to statistics (by the Natural Disasters Data Book-2009), the Asian region has been seriously damaged by natural disasters over the last 35 years as shown in Figure 1. This is compounded by its high levels of population (close to 3 billion). Disasters occurring in Asia comprise 37 percent of the worldwide total. The region sustained 61 percent of global fatalities and has 88 percent of the total victims associated with such disasters.

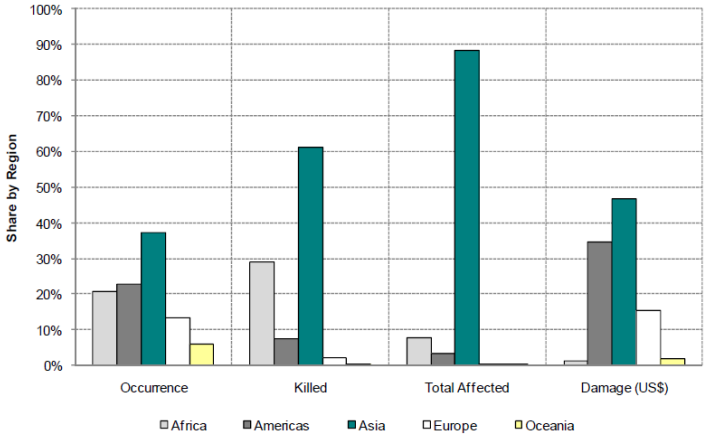

Figure 1. Natural Disaster Damages in Asia, 1975-2009
(quoted from "ADRC-Natural Disasters Data Book-2006" originated in CRED-EMDAT, 2009)

Under these circumstances, the Asia-Pacific Regional Space Agency Forum (APRSAF) proposed Sentinel Asia in 2005 to showcase the value and impact of Earth observation technologies combined with near real-time Internet dissemination methods and Web-GIS mapping tools for disaster management support in the Asia-Pacific region (Kaku et al., 2006; Kozawa and Kaku, 2007). Sentinel Asia was initiated from 2006, and a step-by-step approach for the implementation was adopted as follows. Step 1 had achieved its overall goals, and it had served as a good demonstrator project to share disaster-related information obtained by several Earth observation satellites on web

based system including Web-GIS. Now we are conducting the Step 2 phase activity, and Sentinel Asia has applied the new concepts, such as the utilization of communication satellite 'Kizuna', the more efficient collaboration among the participating Earth observation satellites, the cooperation with International Charter, the operation of data analysis framework, etc.

-Step 1: Implementation of the backbone Sentinel Asia data dissemination system as a pilot project, to showcase the value and impact of the technology using standard Internet dissemination systems (2006-2007). (Kaku et al., 2006)
-Step 2: Expansion of the Step 1 with new satellite communication systems, and enhancement of activities based on experiences in Step 1 and new requirements (2008-2012). (Kaku, 2008)
-Step 3: Establishment of a comprehensive disaster management support system (2013 onwards).

1.2 Framework of Sentinel Asia

Sentinel Asia is promoted with cooperation among the space community (APRSAF), the international community (UN ESCAP, UN OOSA, ASEAN, the Asian Institute of Technology (AIT) etc.), and the disaster reduction community (the Asian Disaster Reduction Center (ADRC) and its member countries). To support the implementation of Sentinel Asia, a Joint Project Team (JPT) was organized. Membership in the JPT is open to all the disaster prevention organizations and regional/international organizations that are prepared to contribute their experiences and technical capabilities and wish to participate in technical aspects of disaster information sharing activities. Totally 77 organizations participate in JPT at the time of writing. The Japan Aerospace Exploration Agency (JAXA) is a secretariat of the JPT.

1.3 Characteristics of Sentinel Asia

1.3.1 Utilization of Communication Satellite 'Kizuna': In order to solve the narrow-band Internet problem in the region, Sentinel Asia Step 2 system can transfer the Earth observation satellite data via communication satellite 'Kizuna'. By Kizuna large volumes of satellite data can be delivered to user immediately after observation. For example, it takes over one day to transfer the one Giga Byte data in some countries, but Kizuna can transfer such data less than 10 minutes. Sentinel Asia has 10 Kizuna receiving stations, and plans to install two new stations as shown in Figure 2 at the time of writing.

1.3.2 Sentinel Asia Constellation and Ground Network: Currently Sentinel Asia has five participating satellites (ALOS, FORMOSAT-2, IRS, KOMPSAT-1 and THEOS) of the Data Provider Nodes (DPN) (JAXA, NSPO/NARL, ISRO, KARI and GISTDA) including archive data provision. The collaboration among these satellites is called as 'Sentinel Asia Constellation', and the more efficient operations are studied, such as joint programming of observation plan. In addition, now Sentinel Asia has been constructing the mechanism to share the THEOS ground receiving stations for FOMOSAT-2 called 'Sentinel Asia Ground Network' as shown in Figure 3. By Sentinel Asia Ground Network the latency of FORMOSAT-2 data provision for the South East Asia will be decreased from about 22 hours to about five hours after observation.

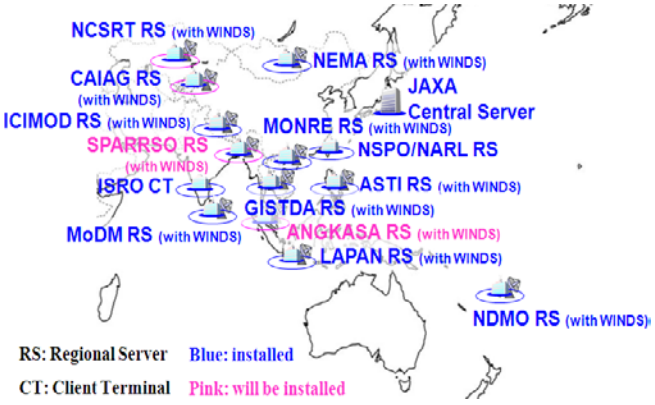

Figure 2. Kizuna Receiving Stations

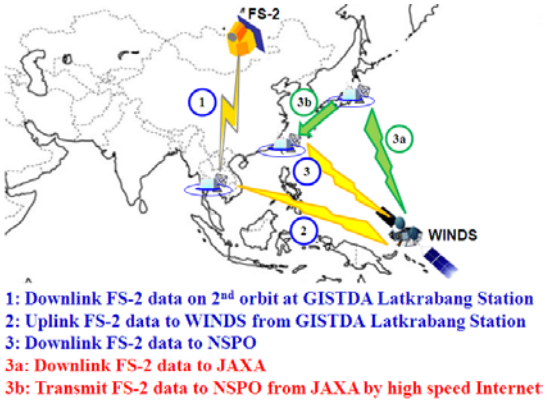

Figure 3. Sentinel Asia Ground Network

1.3.3 Cooperation with International Charter: In addition to the participating satellites, Sentinel Asia initiated the collaboration with the International Charter for Space and Major Disasters from 2009. In case of the serious disaster Sentinel Asia can also activate the International Charter in order to increase the number of Earth observation satellites which observe the disaster afflicted area.

1.3.4 Data Analysis Framework: As the framework for satellite data analysis, the Data Analysis Node (DAN) of Sentinel Asia, is organized to provide value-added information and easily comprehensible interpretations from images. DANs analyze the satellite data provided by DPNs together with their own data, such as local maps, and make value-added products. The local information are very important to get the well understandings from satellite data. Therefore Sentinel Asia tries to expand DAN network over our region. Sentinel Asia has 18 DAN organizations over the Asia and Pacific region at the time of writing, and AIT is the Principle DAN which manage the data analysis activity of DAN.

2. ACTIVITIES OF SENTINEL ASIA

2.1 Emergency Observation

When the member of Sentinel Asia faced the major disaster, Sentinel Asia can accept the satellite observation request from member and provide the data of Earth observation satellite of DPNs, such as ALOS, FORMOSAT-2, IRS, KOMPSAT-1 and THEOS as the emergency observation in Sentinel Asia. The operation flow of Sentinel Asia emergency observation is shown in Figure 4. ADRC conducts the role of unified contact point of emergency observation, and the request from JPT and ADRC member is passed to DPNs through the ADRC. After that DPNs observe the disaster afflicted area by their Earth observation satellite and provide the data to requestor through Sentinel Asia Step 2 system. The provided data is used by requestor for the disaster response activity, in addition DANs also use the data to create the value-added information for easy understanding of the disaster situation by users. The example of value-added product of DAN is shown in Figure 5. This is the product of the International Centre for Integrated Mountain Development (ICIMOD) for Pakistan flood in 2010. Sentinel Asia corresponds with 102 emergency observation requests at the time of writing.

Figure 4. Flow of Emergency Observation

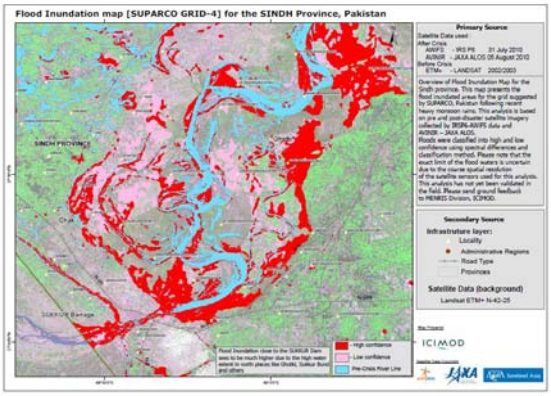

Figure 5. Inundation Map of Pakistan in (ICIMOD)

2.2 Working Groups

Sentinel Asia contributes not only in disaster response by emergency observation but also in disaster preparedness. Four working groups are established under Sentinel Asia to make the study for monitoring and mitigation in the specific disaster.

2.2.1 Wildfire Monitoring WG: Wildfire Monitoring WG has been providing the near real-time wildfire observing system in the Asia and Pacific region using space based technology in cooperation with AIT, University of Tokyo, the Center for Remote Imaging, Sensing and Processing (CRISP) and the Commonwealth Scientific and Industrial Research Organization (CSIRO) in order to control the wildfire which is big generator of carbon dioxide (CO2). In addition, to perform more practical activity, Wildfire Monitoring WG collaborates with JST-JICA project in Indonesia.

2.2.2 Flood Monitoring WG: Flood is a major and recurring phenomenon affecting many countries in the Asia and Pacific region. As the input information for monitoring and mitigating the flood damage, Flood Monitoring WG has been providing the long-term and short-term (hourly and daily) precipitation data (GFAS from International Flood Network (IFNet), GSMaP from JAXA), meteorological satellite data (MTSAT from Japan Meteorological Agency (JMA)), etc. In addition to provide these data, Flood Monitoring WG provides the flood forecasting system called IFAS and the training of IFAS utilization in cooperation with the International Center for Water Hazard and Risk Management (ICHARM).

2.2.3 Glacial Lake Outburst Flood (GLOF) Monitoring WG: In order to correspond with the increasing of glacial lake and its danger of outburst caused by global warming in the Hindu Kush Himalayan region, Sentinel Asia initiated the study of glacial lake inventory, identification of potential outburst glacial lake, hazard mapping for GLOF, monitoring and early warning system including local awareness in Nepal and Bhutan from 2010.

2.2.4 Tsunami WG: As the response of the Great East Japan Earthquake, Sentinel Asia established Tsunami WG in July 2011. The activity of this WG will be defined among JPT members.

2.3 Joint Project in the Philippines

For the more practical utilization of various space based data in disaster preparedness, Sentinel Asia has promoted the joint project with the Philippines. As the first phase, the participating organizations of the Philippines made the hazard maps of 3 study areas (Lahar hazard map in Mt. Mayon shown in Figure 6, Flood hazard map in Iloilo city, Landslide hazard map in Antique province). From April 2010 the project moved to second phase, and initiated the study to apply the space based rainfall data (GSMaP) for the landslide warning and the interferogram technology for the monitoring of land subsidence, earthquake and volcanic eruption. The preliminary result of land subsidence analysis in Manila is shown in Figure 7.

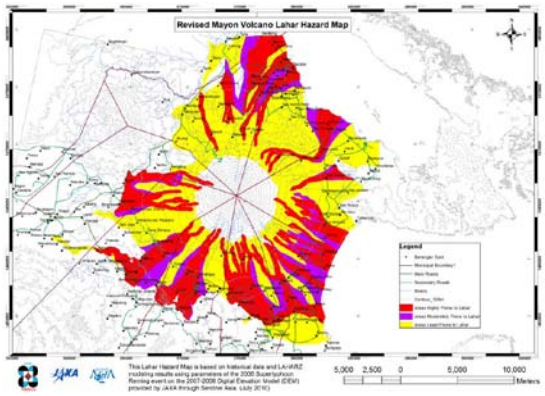

Figure 6. Lahar Hazard Map in Mt. Mayon

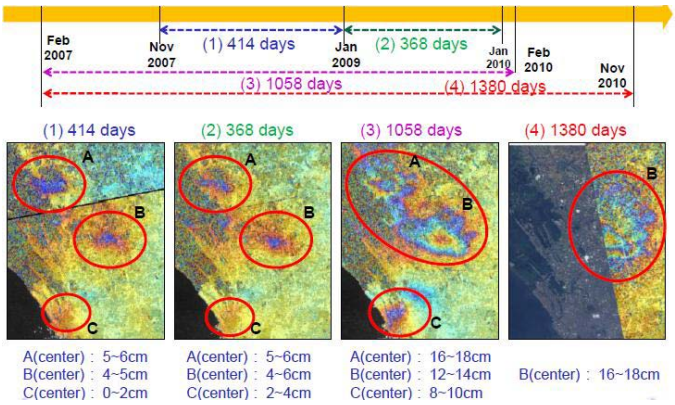

Figure 7. Land Subsidence Analysis in Manila

2.4 Capacity Development

Capacity development is essential to construct the human resources and human network to utilize the information provided by Sentinel Asia. JAXA has held the Sentinel Asia System Operation Training to convey the utilization of Sentinel Asia and the basics of remote sensing in cooperation with DPNs and DANs every year, and provided the several opportunity of more high level training for remote sensing in the Asia.

3. THE GREAT EAST JAPAN EARTHQUAKE

The catastrophic M9.0 earthquake and Tsunami hit the northeast coast of Japan main island at 14:46 (JST) on 11st March 2011, and caused the unprecedented damage, especially in the coastal area. The quake focal zone was 500 km by 200 km, and around 400 square kilometers area was destroyed by Tsunami reaching 15 meters at its highest point. The victims reached more than 15,000, with about 4,400 still missing, and more than 80,000 people are evacuated. In all means the consequences of the earthquakes were far beyond what we could possibly imagine before.

3.1 Contribution of Sentinel Asia and International Charter

Just after the earthquake and confirmation of safety of staffs, JAXA activated Sentinel Asia (15:24 JST) and International Charter (15:35 JST). Through Sentinel Asia, International Charter, etc JAXA could receive the over 5000 scenes Earth observation satellite data in addition to 400 scenes of ALOS. These cooperation made the daily observation of whole damaged area possible beyond the ALOS capability. Totally 21 satellites data were provided from various organization as shown in Table 1, and Figure 8 shows the observation area of each Sentinel Asia satellites. Sentinel Asia Constellation could interpolate the observation gap very well both temporally and spatially.

Table 1. Contributed Satellite List

Organization	Satellite	Organization	Satellite
JAXA	ALOS	USGS	LANDSAT-5,7
NSPO/NARL	FORMOSAT-2		EO-1
GISTDA	THEOS		IKONOS-2
ISRO	Cartosat-2		GeoEye-1
KARI	KOMPSAT-2		QuickBird-2
DLR	RapidEye		WorldView-1,2
	TerraSAR-X	ASI	COSMO-SkyMed
CNES	SPOT-4,5	DEIMOS	DEIMOS-1
CNSA	HJ	RSOCOSMOS	RESURS-DK
CSA	Radarsat-1,2	EIAST	DubaiSat-1
ESA	ENVISAT		

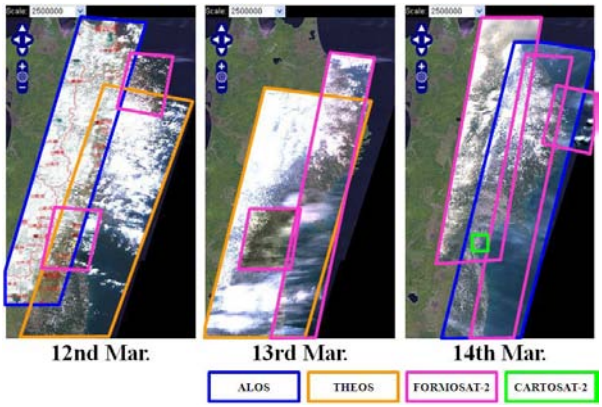

Figure 8. Sentinel Asia Constellation

3.2 Utilization of Earth Observation Satellite

3.2.1 DAICHI Disaster Prevention Map: Daichi Disaster Prevention Map is the image of ALOS in normal times with public infrastructure information. Totally 70 pieces of map were handed to the Cabinet Office until 12nd morning. In addition, JAXA created the post-disaster map for Tohoku region by the provided data, and provided it to disaster prevention agencies and public. The post-disaster map by THEOS is shown in Figure 9.

3.2.2 Time-series Evaluation of Water Covered Area: As the one of the big concerns JAXA evaluated the water covered area, mainly by radar sensor data together with optical sensor data. Because of the availability of many satellite data through Sentinel Asia and International Charter, JAXA could estimate the inundated area day by day as shown in Figure 10, and provided the results to Ministry of Land, Infrastructure, Transport and Tourism.

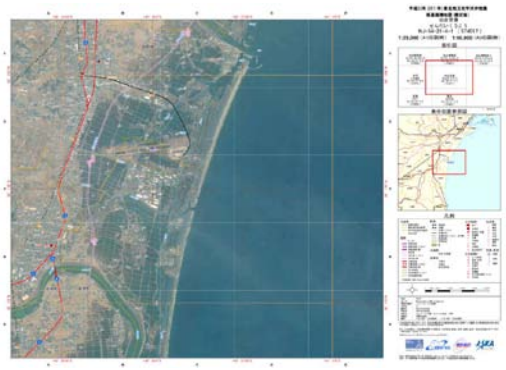

Figure 9. Post-Disaster Map by THEOS

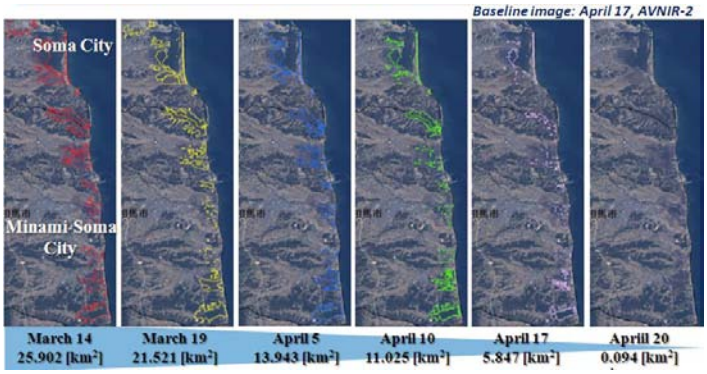

Figure 10. Time-series Water Covered Area Map in Fukushima

3.2.3 Detection of Crustal Deformation by Differential InSAR: Figure 11 shows the crustal deformation caused by main quake on 11th March and the following after quakes detected by differential InSAR analysis. About 4m ground surface shift was caused around Oshika Peninsula in Miyagi Prefecture by main quake on 11th March, and this analysis is consistent with the results of the Geospatial Information Authority. In addition to the deformation caused by main quake, there are the deformation caused by after quakes.

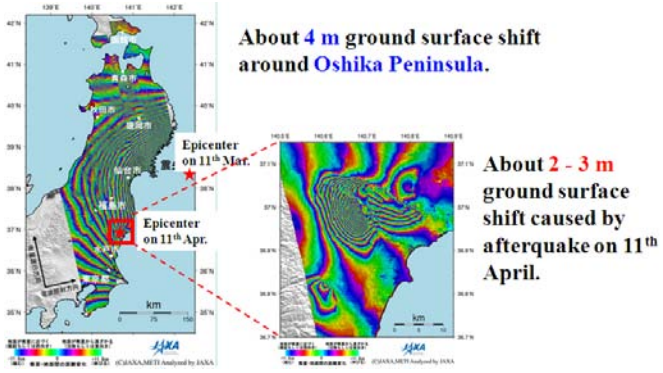

Figure 11. Crustal Deformation detected by Differential InSAR

3.3 Utilization of Communication Satellite

In addition to the Earth observation satellite data & its analysis results, JAXA provided the communication links by two communication satellites, Kizuna and Kiku-8. In stead of the ground based telecommunication infrastructure completely destroyed by earthquake and Tsunami, JAXA installed Kizuna and Kiku-8 transportable ground station in Iwate and Miyagi prefectures based on their requests. By Kizuna, the broadband lines with the capacity of up to 20 Mbps were connected among Iwate Prefectural Office in Morioka, Kamaishi and Ofunato city from 20th March to 24th April. By Kiku-8, the communication lines with the capacity of up to 768 Kbps were connected among Ofunato City Hall, Otsuchi Town and Onagawa Town from 24th March to 21st May. These communication lines were used for the video conference among Disaster Measures Headquarters. In addition, Internet was opened to residents and rescue team to communicate and get the information, such as evacuation lists, information from government, missing people information, map information, etc.

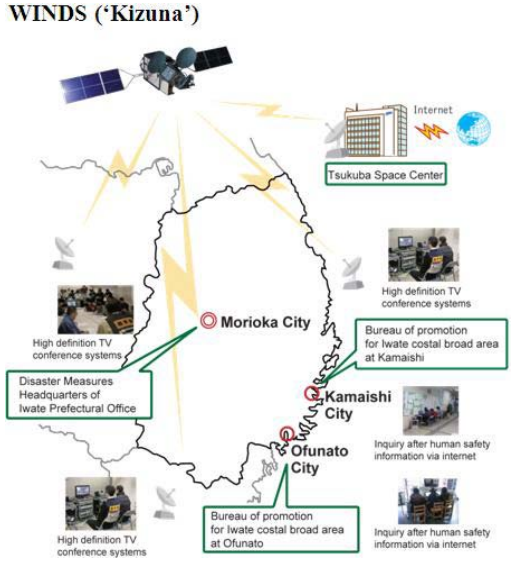

Figure 12. Communication Link by Kizuna

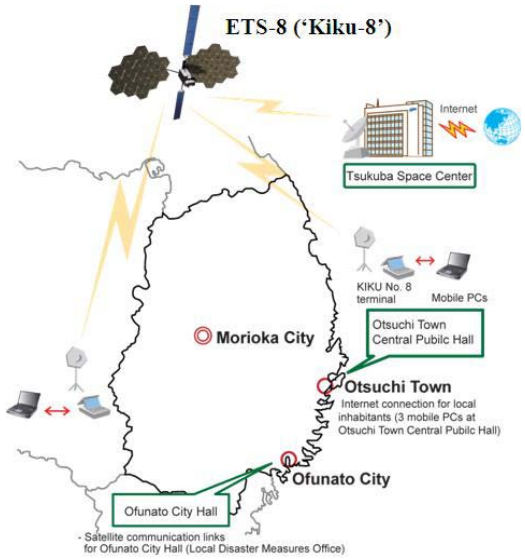

Figure 13. Communication Link by Kiku-8

4. CONCLUSION

Sentinel Asia has been developed steadily since operations began in October, 2006 by JPT members, and moved to Step 2 phase from 2008 enhancing and strengthening its activities. Now Sentinel Asia has became the one of most powerful international cooperation for disaster management support, and the various close collaboration among members came out from Sentinel Asia. In case of the Great East Japan Earthquake in this March, Sentinel Asia proved that how well and how efficient Sentinel Asia framework worked for disaster management, and how much important it is. Finally, it must be noted that a human network is the most fundamental underpinning of the project, and a good human network has been constructed through Sentinel Asia over the Asia and Pacific region.

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