A Study of Disaster Monitoring System using the Near Real-Time Small Satellite Constellation

By Norishige OMOTO [1)], Hironori KATO [1)], Koji WAKAMORI [1)], Yoshihiko KAMEDA [1)], Kenji SUZUKI [2)], Nozomu NISHINAGA[2)] and Yuzo SUGA[3)]

[1)]*Japan Manned Space Systems Corporation, Tokyo, Japan*
[2)]*National Institute of Information and Communications Technology, Tokyo, Japan*
[3)]*Hiroshima Institute of Technology, Hiroshima, Japan*

This paper describes about a study of disaster monitoring system using the UK-DMC satellite that is one of satellites constituting disaster monitoring constellation. We need satellite constellation to take images in a short time when a disaster occurs. As a result of study, we succeeded to download an image file from the UK-DMC satellite on the NICT earth station, to analyze downloaded image and to transfer image files with IPv6 and IPsec on the ground network.

Key Words: Disaster, Near Real-Time, Image, Small Satellite Constellation

1. Introduction

It is said that there are a great many disasters in Asia. In Japan, there is a great deal of natural disaster, landslides and floods by the typhoon, tsunami by the earthquake to affect human life. If a disaster occurs, we must grasp what is taking place where in a short time. A satellite is convenient to observe a very large area. However, plural satellites are necessary in a surface so that a satellite observes a disaster area in a short time after the disaster occurs. In the other words, satellite constellation is necessary. It takes 6 hours till we get possible to view an image after download an image file from the satellite. We must shorten this time.

There are research institutes, companies studying the disaster monitoring constellation all over the world. We have studied about disaster monitoring system using the UK-DMC satellite that is one of satellites constituting disaster monitoring constellation. As a result of study, we succeeded to download an image file from the UK-DMC satellite on the National Institute of Information and Communications Technology (NICT) earth station, to analyze downloaded image and to transfer image files with IPv6 and IPsec on the ground network, Japan Gigabit Network (JGN) 2 plus for the first time in Japan.

2. Disaster Monitoring Constellation

The Disaster Monitoring Constellation is the first Earth observation constellation of multiple low cost small satellite providing daily images for applications including global disaster monitoring [1)]. The first constellation consisted 5 satellites. It is unique in that each satellite is independently owned and controlled by each nation, but all satellites have been equally spaced around a sun-synchronous orbit to provide daily imaging capability. The satellite, AISAT-1 was launched on November at 2002. The UK-DMC, Bilsat-1 and NigeriaSat-1 were launched on September at 2003. The Beijing-1 was launched on October at 2005. The Bilsat-1's mission was completed at 2006. The UK-DMC2 and the Deimos-1 are going to be launched at 2009. The satellites are all designed built at Surrey Satellite Technology Ltd (SSTL) in the UK. SSTL owns and operates the UK-DMC satellite in the constellation. The DMC satellites provide a unique earth observation resource that enable daily revisit anywhere on the world. This is possible with a few satellites because they are designed to image a large area of up to 600 km × 600 km [2)].

2.1. UK-DMC satellite [3)]

The UK-DMC is a satellite of the standard DMC design, with added research and development payload including the Cisco mobile router. While the satellite's primary purpose is to provide images of the environment on earth, its onboard router is the focal point of a second payload. The satellite was already using Internet Protocol for communication between onboard computer payloads and with the ground station network. Table 1 shows the specifications and Figure 1 shows the picture of the UK-DMC satellite.

Table 1. UK-DMC satellite.

Mass	80 kg
Orbit Type	Sun Synchronous (Inclination 98.1 deg)
Orbit Height	686 km
Design Lift Time	5 years
Payload	2 three-band linear array CCD camera , Mobile Router
Sensor Spectral Bands	0.52 – 0.62 μm (Green) 0.63 – 0.69 μm (Red) 0.52 – 0.62 μm (Near Infrared)
Image Resolution	32 m
Swath	600 km
Onboard Data Storage	1.5 GB SSDR
S - band Downlink	8.1 Mbps
S - band Uplink	9600 bps

Fig. 1. UK-DMC satellite

Fig. 2. Antenna

Fig. 3. Indoor Equipments

2.2. Collaborative Research

To start a study about disaster monitoring system, we have thought that it is necessary to download an image file from the UK-DMC satellite and to make image processing and image analysis with collaborative research. NICT and Japan Manned Space Systems Corporation (JAMSS) were in charge of the earth station. And Hiroshima Institute of Technology (HIT) and JAMSS were in charge of the image processing and analysis.

3. Earth Station

The S-band earth station is necessary to communicate with the UK-DMC satellite. We decided to use an antenna and transmission and receive equipments for the S-band which NICT owned. NICT submitted license application as an experimental radio station to establish a radio station at 2007, and got a license at 2008. JAMSS provides that demodulator, router, MODEM/SWITH, signal generator and PCs.

We had succeeded in the first download an image file from the UK-DMC satellite in 2008.

3.1. Specifications

Table 2 shows the specifications of the NICT earth station [4)] at Koganei in Tokyo.

Table 2. NICT earth station .

Mount Method	X-Y mount
Maximum Drive Angle	10 deg/sec
Beam Width	About 3.5 deg
Antenna Tracking Method	Program Tracking
TX Frequency	2,025 – 2,120 MHz
RX Frequency	2,220 – 2,320 MHz (catalogue value: 2,200 – 2,300 MHz)
Polarization	TX : Right-Handed Circular RX : Left-Handed Circular
Antenna Gain	30.6 dB (ϕ 2.4 m) <
Tracking Angle Accuracy	0.2 deg rms (Max instantaneous wind speed 20 m/s)
HPA TX Power	36 dBm (4W) <

3.2. Antenna and Indoor Equipments

Figure 2 shows the 2.4 m antenna on roof of the building. Figure 3 shows the indoor equipments.

4. Image File Download

We had some image file download experiments to monitor disaster area by the UK-DMC satellite.

4.1. Planning Observation Request

To examine the latitude and the longitude of the target area to observe. This latitude and longitude become base for path analysis.

4.2. Path Analysis

To analyze paths of the UK-DMC satellite that could take an image of the target area and take the communication link from the NICT earth station.

4.3. Order the Path

To check the weather forecast of the target area . When it is fine with no cloud, to order to take an image and send it to the NICT earth station to SSTL or DMC International Imaging Ltd. (DMCii) by 3 business days.

4.4. Orbit Calculation for Program Tracking

To calculate orbit of the UK-DMC satellite by the day before, to prepare for the program tracking. To start the earth station system by 15 minutes and stand by.

4.5. Image File Download

It is the path start time, and the antenna tracking is started, to turn on uplink power. And to confirm that the demodulator is locked on . Next, to confirm that downloading an image file and a syslog file from the SSDR of the UK-DMC satellite is carried out on the screen shown in the Figure 4.

It shows the file transaction status and antenna tracking status. The file transfer transaction status is shown in the middle of the window. Any corrupted frames will automatically be retransmitted. This can be seen by observing the number of "Holes" in the transaction status. It will increase if the link receives errors, but it will decrease again automatically [5]. To confirm that the number of the "Holes" finally became zero.

After the path, to review a downloaded image file and a syslog file in the PC.

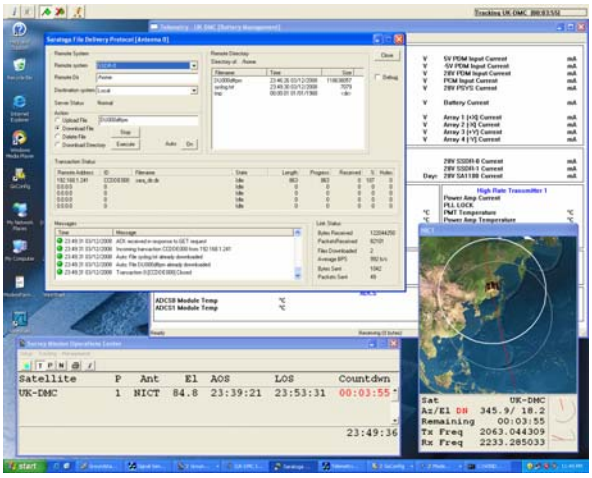


Fig. 4. Saratoga Main Window, Antenna Track Window

4.6. Image Processing

It is necessary to do image processing for the raw image from the satellite. At first, do radiometric image corrections by software for further processing [6] .

5. Image Analysis

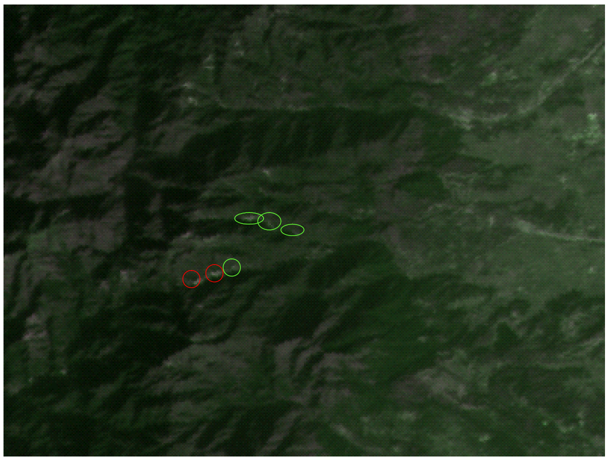
We had analyzed images for disaster monitoring and agriculture.

5.1. Disaster Monitoring

Many avalanches of earth and rocks flow has occurred on the north slopes of Mt. Gozaiyo in Mie prefecture due to concentrated heavy rain on 2-3 September, 2009. On December 4, the UK-DMC satellite observed the large area including the disaster area. After image processing, as a result of having analyzed an image, we found that the landslide occurred at many points.

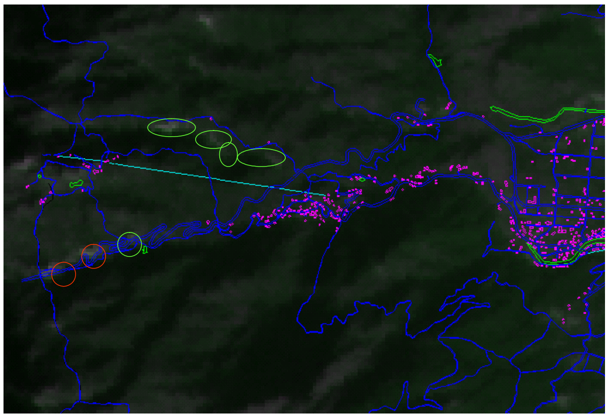
Figure 5 shows that landslide point. Based on the map of the town office, It show the points where we were able to confirm the spot with green.

Figure 6 is the image which put an image which we analyzed and the Geographic Information System (GIS) on top of one another. The dark blue lines are roads. The image resolution of the UK-DMC satellite is 32 m, sensor spectrum are full compatible for the 2, 3 and 4 channel of the LANDSAT. However, such 32 m resolution is useful to find the landslide point, which size is about 60 m wide, showed with red circle in the picture.



Landslide point   Ground truth point   (1/80,000)

Fig. 5. Landside place of Mt. Gozaisyo



Landslide point   Ground truth point   (1/40,000)

Fig. 6. Landside place with GIS of Mt. Gozaisyo

5.2. Agriculture

In a time of peace except disaster time, to utilize an image of the UK-DMC satellite, we analyzed images and evaluated that images were usable to the field of agriculture.

JA (Japan Agricultural cooperative) MEMURO in Hokkaido has been adapting the crop collection system to grasp the growth situation of the wheat, and to estimate the most suitable time of the harvest using images (resolution 10 m, swath 60 km) of the SPOT satellite since 2001. Issue of this case is that the revisit time of the SPOT satellite is 26 days, if weather is bad; it is the back for 26 days at the next opportunity. We found that it is possible to take images every day by the DMC satellites, and that there was business opportunity, besides, if we could reduce the cost , and offer images in appropriate price.

Figure 7 shows an image by Normalized Difference Vegetation Index (NDVI) in MERURO. And figure 8 shows an image put an offered farm figure on top of one another from JA MEMURO. Even as that resolution is 32m, we were able to measure NDVI which showed activity of the chlorophyll to be included in the leaf of the sugar beet just before the crop.

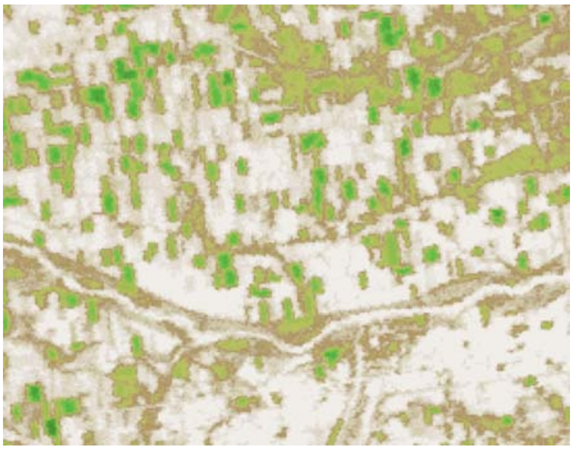


Fig. 7. NDVI of MEMURO

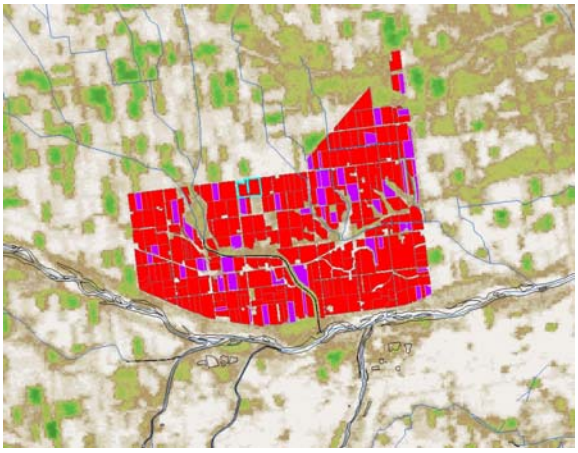


Fig. 8 . Farm Figure Polygon put it on top of one another
(Red means field and purple means sugar beet field)

6. Image File Transfer Experiment

Because the earth station is far from the where organization performs image processing and image analysis, we forward image files to the organization after having downloaded an image file on the earth station.

6.1. Security for Image

We use the IPv4 of the Internet for normal file transfer. File Transfer Protocol (FTP) of the IPv4 usually does not encrypt data to send. Encryption is necessary for the file transfer of the value-added expensive image data. Encryption for IP packet is Security Architecture for IP (IPsec) [7] .

6.2. Experiment

There we had an experiment to transfer image files on the ground network, JGN2 plus. Experiment cases were IPv4, IPv6 and IPv6 with IPsec. The cases of the IPv4 and the IPv6 were no encryption. We evaluated file transfer time. Before the experiment, we expected that the time of the IPv6 with IPsec was longer that the IPv4 and the IPv6. But when we start the experiment, the time of the IPv6 with IPsec was almost the same with the IPv4 and the IPv6.

7. Study of Satellite Constellation

We assumed the case that a disaster occurred in any area of the Japanese Islands; we studied the satellite constellation that one of the satellites could take an image average less than 1 hour. The system to shown in Table 3 satisfies the demand.

Table 3. Satellite Constellation.

Constellation	10 satellite (10 orbital planes by each one)
Orbit Type	Sun Synchronous Orbit
Inclination	98.137 deg
Orbit Height	687.4 km
Revisit Time	5 days
Image Resolution	< 30 m
Swath	1400 km

8. Issues

1) Shorten image processing and analysis time

Users for disaster, environment, and agriculture want to view the image in rear real time. We handle geometric correction and ortho correction by manual. They need for a few days. Therefore we must largely shorten image processing and analysis time by software.

2) Download in plural earth stations

When we can not download all of the image file, we must wait for the next path (at least over 90 minutes). Therefore, it is necessary to study handover technologies to download it in plural earth stations.

3) IPv6 and IPsec on the satellite and the earth station

To update Internetworking Operating System of the router on the earth station and demonstrate to download an image file with IPv6 with IPsec.

9. Conclusion

We modified the NICT earth station for the UK-DMC satellite, to study about disaster monitoring system. As a result of study, we succeeded to download an image file from the UK-DMC satellite on the NICT earth station, to analyze downloaded image and to transfer image files with IPv6 and IPsec on the ground network.

Acknowledgments

JAMSS thanks for NICT and HIT with collaborative research, JA MEMURO, DMCii and SSTL with cooperation.

References

1) William, I. and Dave, S,: Secure, Network-Centric Operations of a Space-Based Asset : Cisco Router in Low Earth Orbit（CLEO）and Virtual Mission Operations Center（VMOC）, NASA/TM‐2005‐213556, May 2005, pp.6.
2) DMC Constellation, http://www.dmcii.com/about_us_constellation.htm
3) William, I. and Dave, S,: Secure, Network-Centric Operations of a Space-Based Asset : Cisco Router in Low Earth Orbit（CLEO）and Virtual Mission Operations Center（VMOC）, NASA/TM‐2005‐213556, May 2005, pp.4.
4) Suzuki, K and Nozomu, N : Operations of the Disaster Monitoring System using the S-band earth station, No.10 Kansai Space Initiative, May 2009
5) James, W : JAMSS SSTL Equipment Installation and Operation, SPJB, Jun. 2008, pp.31.
6) Andrew,S :Smart-I User Manual, SPJB-0102072, Feb. 2008, pp.6-7.
7) William, I. and Dave, S,: Secure, IPv6 and IPsec of a Space-Based Asset : Cisco Router in Low Earth Orbit（CLEO）, NASA/TM‐2008‐215203, May 2008, pp.3.