TECHNICAL CONSIDERATIONS IN REAL TIME GLOBAL EARTH RESCUE SYSTEM OF SYSTEMS (GERSS)

Jeng-Shing Chern

Department of Aviation Mechanical Engineering, China University of Science and Technology
200 Chunghwa Street, Henshan Village, Hsinchu County, Taiwan 31241, ROC - jschern@cc.hc.cust.edu.tw

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ABSTRACT:

For the purposes of linking and expanding the Earth observation systems, over 100 governments and leading international organizations have founded the Group on Earth Observations (GEO) in February 2005. It was established after the World Summit on Sustainable Development, the Group of Eight leading industrialized countries (G8) and three ministerial Earth Observation Summits each called for improving observation systems. According to the 10-year plan of GEO, it is to coordinate the construction of a Global Earth Observation System of Systems (GEOSS) by the year 2015. There are 9 GEOSS social benefit areas: disasters, health, energy, climate change, water, weather, ecosystems, agriculture, and biodiversity. Disasters are considered to be the first social benefit area of GEOSS. For humankind, the best strategy is to prevent the occurrence of any kind of disasters. However, many kinds of disasters are so far unpredictable and inevitable. Therefore, what we can do is to go to "rescue as soon as possible" whenever disaster happens. The purpose of this paper is to discuss the idea of a real time Global Earth Rescue System of Systems (GERSS) from the technical point of view. In other words, to discuss "to what degree" or "how real time" we can reach by coordinating the current Earth observation satellites (EOSs) using the FORMOSAT-2 as an example.

1. INTRODUCTION

The FORMOSAT-2 (or FS2, Formosa satellite #2, was previously called ROCSAT-2 or RS2, Republic of China satellite #2) is the first remote sensing satellite (RSS) owned by Taiwan for the purposes of earth and upward lightning observation. It is a small satellite of 746 kg mass for two remote sensing missions. Its mission orbit is sun-synchronous of 888.47 km altitude for exactly 14 revolutions per day. The design life and mission life are 7 and 5 years, respectively. For earth observation, the payload is an advanced high resolution remote sensing instrument (RSI) with ground sampling distance (GSD) 2 m in panchromatic (PAN) band and 8 m in four multi-spectral (MS) bands. For upward lightning observation, the payload is an imager of sprite and upper atmospheric lightning (ISUAL). 〔1-14〕 It was launched from Vandenberg, California on 20 May 2004. In other words, FS2 is completing its 6th year mission operations (MO).

As a high resolution Earth observation satellite (EOS), FS2's typical mission operations in disaster observation consist of the following processes:

1) Acquisition of information: to know the type and place of the occurrence of disaster.
2) Settlement of observation strategy: to pinpoint the observation area and arrange the satellite time slot for observation, including weather check of the observation area.
3) Programming of command: to transform the observation strategy to command program that can be uploaded to FORMOSAT-2.
4) Command uploading: to upload the command to FORMOSAT-2.
5) Disaster observation: to observe the disaster and take images.
6) Image downloading: to download the observed images.
7) Image processing and distribution: to process the observed images and deliver to the rescue agency.

For the purposes of linking and expanding the Earth observation systems, over 100 governments and leading international organizations have founded the Group on Earth Observations (GEO) in February 2005. It was established after the World Summit on Sustainable Development, the Group of Eight leading industrialized countries (G8) and three ministerial Earth Observation Summits each called for improving observation systems. According to the 10-year plan of GEO, it is to coordinate the construction of a Global Earth Observation System of Systems (GEOSS) by the year 2015. There are 9 GEOSS social benefit areas: disasters, health, energy, climate change, water, weather, ecosystems, agriculture, and biodiversity. Disasters are considered to be the first social benefit area of GEOSS. For humankind, the best strategy is to prevent the occurrence of any kind of disasters. However, many kinds of disasters are so far unpredictable and inevitable. Therefore, what we can do is to go to "rescue as soon as possible" whenever disaster happens. Based on the current and near future EOSs, the network of ground stations, and the above typical processes, the shortest time from disaster occurrence to initiation of rescue action can be estimated using the FORMOSAT-2 as an example. We call it the Global Earth Rescue System of Systems (GERSS).

2. COSPAS-SARSAT PROGRAMME

2.1 SARSAT System 〔15-16〕

The Search and Rescue Satellite-Aided Tracking (SARSAT) system relays distress signals from emergency beacons carried by aviators, mariners and land-based users to search and rescue (SAR) services. The mission of the National Oceanic and Atmospheric Administration's (NOAA) SARSAT program is to: *Protect life and property by providing timely, accurate and reliable distress alerts to search and rescue services worldwide in an effective and efficient manner*.
The mission of the SARSAT program is fulfilled by:

- collecting and distributing reliable and accurate distress alert data in a timely fashion using satellite receiving stations and a mission control center;

- coordinating with national and international organizations on frequency management, satellite, emergency beacon and search and rescue issues;

- maintaining a national register for 406 MHz emergency beacons;

- serving as the lead agency within the United States, and representing the United States to the international Cospas-Sarsat Program.

2.2 COSPAS System〔15-16〕

Cospas is a Russian acronym that stands for "Cosmicheskaya Systyema Poiska Aariynyich Sudov" which translates loosely into "Space System for the Search of Vessels in Distress."

2.3 COSPAS-SARSAT Programme〔15-16〕

The International Cospas-Sarsat Programme (the Programme) is an intergovernmental organisation established in 1988 under the International Cospas-Sarsat Programme Agreement (the Agreement) signed by Canada, France, the former USSR, and the USA. The Russian Federation replaced the USSR as Party to the Agreement in January 1992. In addition to the four Parties to the Agreement, Thirty-six States and two regional organisations are currently formally associated with the Programme and actively participate in the management and the operation of the Cospas-Sarsat System (the System). Its headquarters are located at 700 de la Gauchetière West, Suite 2450 Montréal, Québec H3B 5M2 Canada.

The mission of the Programme is to provide accurate, timely and reliable distress alert and location data to help Search and Rescue (SAR) authorities assist persons in distress. The objective of the Cospas-Sarsat system is to reduce, as far as possible, delays in the provision of distress alerts to SAR services, and the time required to locate a person in distress at sea or on land and provide assistance to that person, all of which have a direct impact on the probability of survival. To achieve this objective, Cospas-Sarsat participants implement, maintain, co-ordinate and operate a satellite system capable of detecting distress alert transmissions from radio beacons that comply with Cospas-Sarsat specifications and performance standards, and of determining their position anywhere on the globe. The distress alert and location data is provided by Cospas-Sarsat participants to the responsible SAR services.

As shown in Figure 1, the System is available to maritime and aviation users and to persons in distress situations. Access is provided to all States on a non-discriminatory basis, and free of charge for the end-user in distress. Since the beginning of System operations in 1982, over 27,000 persons in over 7,200 incidents have been rescued with the assistance of Cospas-Sarsat alert and location data.

The System is composed of:

- about one million distress beacons operating at 406 MHz;

- SAR payloads on 11 satellites in low-altitude Earth orbit and in geostationary orbit;

- seventy-six ground receiving stations spread around the world;

- a network of 30 Mission Control Centres to distribute distress alerts and location information to SAR authorities, worldwide.

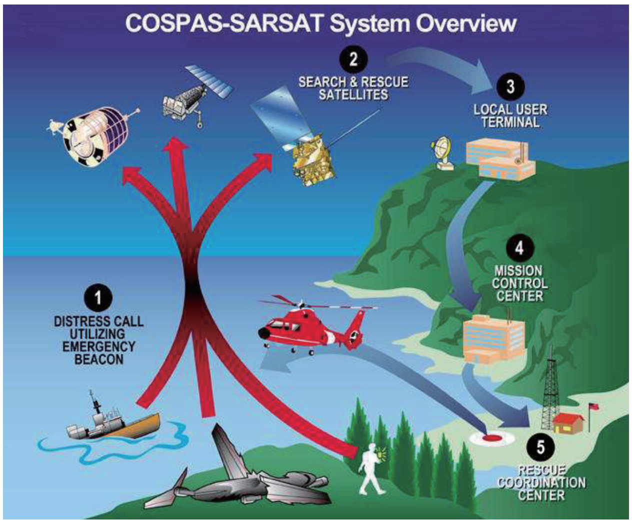

Figure 1. COSPAS-SARSAT system overview

After 28 years of successful operation, the Cospas-Sarsat System is entering an era of rapid evolution with the planned integration of new satellite constellations in medium-altitude Earth orbit. This evolution is challenging, both technically and from a management perspective. It is also expected to open opportunities for significant enhancements to the services provided to SAR authorities. There are about one million beacons currently in use worldwide and this population has been increasing at a swift rate in the last few years (+25% in 2008). Further information about the Programme and the System is available on the Cospas-Sarsat website at www.cospas-sarsat.org.

It is seen in Figure 2 that the Cospas-Sarsat System includes two types of satellites: 1) satellites in low-altitude Earth orbit (LEO) which form the LEOSAR System; and 2) satellites in geostationary Earth orbit (GEO) which form the GEOSAR System .

Cospas-Sarsat has demonstrated that the GEOSAR and LEOSAR system capabilities are complementary. For example the GEOSAR system can provide almost immediate alerting in the footprint of the GEOSAR satellite, whereas the LEOSAR system:

- provides coverage of the polar regions (which are beyond the coverage of geostationary satellites);
- can calculate the location of distress events using Doppler processing techniques;
- is less susceptible to obstructions which may block a beacon signal in a given direction because the satellite is continuously moving with respect to the beacon.

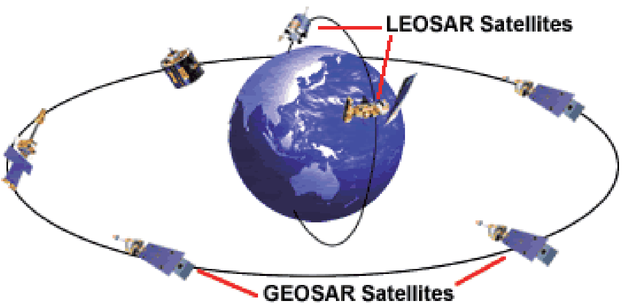

Figure 2. Two types of satellites in Cospas-Sarsat System

3. INTERNATIONAL CHARTER: SPACE AND MAJOR DISASTERS

3.1 International Charter 〔17-18〕

The International Charter is the "Charter On Cooperation To Achieve The Coordinated Use Of Space Facilities In The Event Of Natural Or Technological Disasters". Charter's purposes are "In promoting cooperation between space agencies and space system operators in the use of space facilities as a contribution to the management of crises arising from natural or technological disasters, the Charter seeks to pursue the following objectives: 1) supply during periods of crisis, to States or communities whose population, activities or property are exposed to an imminent risk, or are already victims, of natural or technological disasters, data providing a basis for critical information for the anticipation and management of potential crises; and 2) participation, by means of this data and of the information and services resulting from the exploitation of space facilities, in the organization of emergency assistance or reconstruction and subsequent operations." NSPO joined the International Charter in 2006. Since then NSPO has provided images captured by FS2 in more than 50 events.

3.2 UNOSAT 〔18〕

UNOSAT is the UN Institute for Training and Research (UNITAR) Operational Satellite Applications Programme, implemented with the UN Office for Project Services (UNOPS) and the European Organization of High Energy Physics (CERN). It is a people-centered programme delivering satellite solutions to relief and development organizations within and outside the UN system to help make a difference in the life of communities exposed to poverty, hazards and risk, or affected by humanitarian and other crises. The UNOSAT core team consists of UN fieldworkers as well as satellite imagery experts, geographers, geologists, development experts, database programmers and internet communication specialists. This unique combination gives it the ability to understand the needs of its users and to provide them with suitable, tailored solutions anywhere at any time.

NSPO makes its contributions to the UNOSAT through one of its partners, the Spot Image of France. Table 1 shows the statistics of FORMOSAT-2's typical support in global disaster observations up to 6 May 2008. 〔14〕

Table 1. Typical support in global disaster observations of FORMOSAT-2 〔17-18〕

ID #	Location	Date	Disaster	Project Management
125	Choele	2006/07/30	Flood	CONAE
125	Neuquen	2006/07/30	Flood	CONAE
125	PIRAN	2006/08/10	Flood	CONAE
131	Pont a Mousson	2006/10/07	Flood	CNES
132	Bulgaria	2006/10/11	Oil Spill	JRC
133	Sri Lanka	2006/11/01	Flood	UNOSAT
134	Ethiopia	2006/11/08	Flood	UNOSAT
135	Somalia	2006/11/16	Flood	UNOSAT
135	Somalia	2006/11/18	Flood	UNOSAT
137	Kenya	2006/11/22	Flood	USGS
135	Somalia	2006/12/03	Flood	UNOSAT
139	Philippine	2006/12/03	Typhoon	Pacific Disaster Center
140	Indonesia	2006/12/30	Flood	UNOSAT
141	Tucuman Province	2007/01/19	Flood	CONAE
143	Pilcomayo River	2007/01/23	Flood	CONAE
145	Mutarara	2007/02/11	Flood	UNOSAT
145	Caia	2007/02/11	Flood	UNOSAT
151	Solomon Islands	2007/04/04	Earthquake, Tsunami	Pacific Disaster Center
152	Afganistan	2007/04/07	Earthquake	USGS
155	New York	2007/04/18	Flood	CSCIC
156	New Foundlands	2007/04/23	Ice Jam	CSA
158	Aisen	2007/04/28	Earthquake, Landslides, waves	ONEMI
159	Treinta y Tres	2007/05/11	Flood	SNE
161	UK	2007/07/02	Flood	UK Environment Agency
165	Hechuan	2007/07/15	Flood	NDRCC
166	Birtsmorton	2007/07/27	Flood	UK Environment Agency
167	Tenerife Island	2007/08/05	Forest Fires	DLR
167	Gran Canaria Island	2007/08/05	Forest Fires	DLR
171	Pisco	2007/8/17	Earthquake	INDECI
173	Dean Hurricane	2007/8/22	Hurricane	Cathalac-Servir, Panama
175	Areas	2007/8/31	Fires	ESA
179	North Western Slovenija	2007/09/21	Floods and Landslides	DLR
180	North Korea	2007/09/26	Floods, Typhoon	ESA
182	California	2007/10/26	Fires	ESA
186	Bay of Bengal	2007/11/21	Floods and cyclone	DLR
187	Antofagasta	2007/11/25	Earthquake, Landslides, waves	ONEMI
189	Statfjord oil field	2007/12/15	Oil Spill	European Maritime Safety Agency
193	Rwanda	2008/02/10	Earthquake	UNOSAT
196	Valparaíso region	2008/03/08	Forest Fires	ONEMI
197	Southern Angola	2008/03/21	Flood	ESA
201	New Brunswick	2008/05/03	Flood	CSA
202	Michimahuida Volcano	2008/5/6	Volcano	ONEMI
203	Myanmar	2008/5/6	Flood	UNOSAT

3.3 Observation of FORMOSAT-2 on Sichuan Earthquake

On 12 May 2008, an earthquake of Richter magnitude scale 8.0 occurred in the Wenchuan County of Sichuan Province, China. NSPO immediately scheduled FS2's first priority to observe the status of the epicenter and its surrounding areas. The images taken were processed and provided to China free charge for rescue and relief purposes at the first time without any delay. It is seen from Figures 3 and 4 that the Beichuan County is almost completely destroyed. The Dujingyan Irrigation System, a UNESCO registered World Heritage Site, is basically in healthy condition. However, the buildings including some ancient temples located at its surrounding area are severely damaged by the earthquake. 〔13,19〕

Figure 3. Beichuan County of Sichuan Province, China, before (above, taken in 2006) and after (below, taken on 14 May 2008) the earthquake

3.4 Contribution of RSS on Disaster Observation and Rescue

There are many RSSs worldwide, obsolete and operating ones, old and new ones, various resolution ones, etc. FORMOSAT-2 is just one of them. Whenever a disaster occurs, a near real-time observation of the disastrous area can be performed by one of the nearby RSS if proper coordination is fulfilled beforehand. The coordination consists of the three segments: space segment (all RSSs), mission operations segment (all ground stations, satellite scheduling groups), and rescue operations segment (local user terminals, mission control centers, rescue coordination centers, etc.). A good coordination as a prerequisite condition can decide whether a prompt rescue action can be initiated as soon as possible after the occurrence of a disaster. In this paper, we

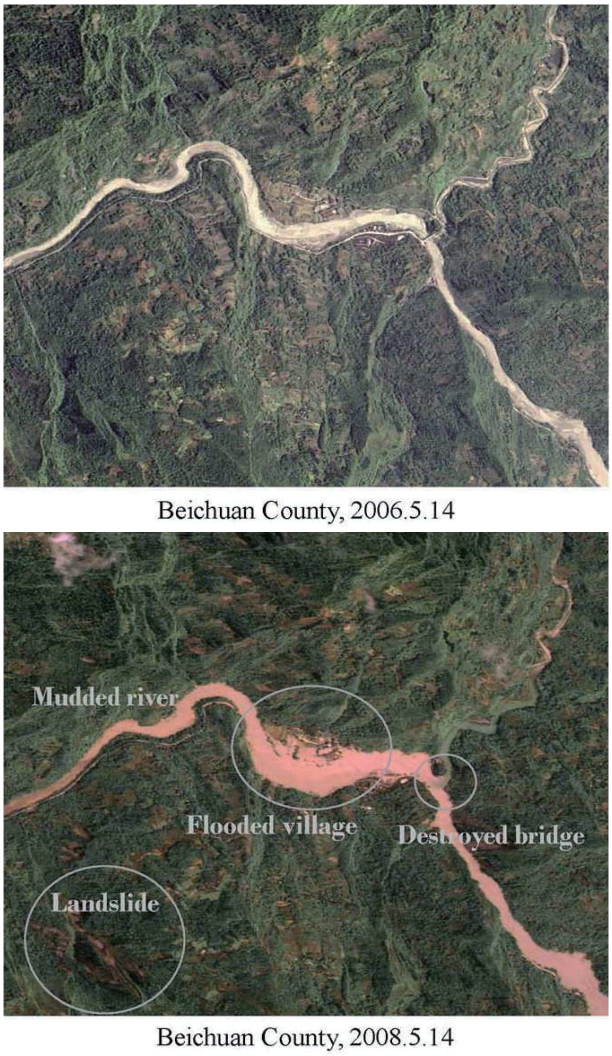

Figure 4. FORMATSAT-2 images of Beichuan County taken before (above) and after (below) the quake showing the great impact to the city.

shall consider only the influencing factors from the technical point of view.

4. GERSS

Now, we have COSPAS-SARSAT system, UNITAR, UNOSAT, and GEOSS, I think it is time to consider the establishment of GERSS. Technically it would be very feasible, although, politically it could be very or even extremely difficult. Using FORMOSAT-2 as a typical example with good coordination as a prerequisite condition, the estimation of required time in each process from disaster occurrence to SAR initiation is as follows:

1) Acquisition of information about the type and place of the occurrence of disaster: 5 min.
2) Settlement of observation strategy to pinpoint the observation area and arrange the satellite time slot for observation, including weather check of the observation area: 5 min.

3) Programming of command to transform the observation strategy to command program that can be uploaded to FORMOSAT-2: 10 min.
4) Command uploading to FORMOSAT-2: 10 min.
5) Disaster observation, image taking and downloading: 90 min.
6) Image processing and distribution: 30 min.
7) Initiation of SAR: 30 min.

The total time estimated is about 180 min or 3 hr. In case we have enough satellite resources, the time required in item 5) can be shortened to 30 min. Then 2 hr could be the total time required.

5. CONCLUSIONS

Based on the Global Earth Observation System of Systems (GEOSS), the Cosmicheskaya Systyema Poiska Aariynyich Sudov (COSPAS), the Search and Rescue Satellite-Aided Tracking (SARSAT), the UN Institute for Training and Research (UNITAR), the UNITAR Operational Satellite (UNOSAT), and FORMOSAT-2, the idea of the Global Earth Rescue System of Systems (GERSS) is introduced. By coordinating the COSPAS-SARSAT and the remote sensing satellites (RSSs) together, an efficient GERSS can be established. Using FORMOSAT-2 as an example, along with the networking of so many RSS, ground stations, local user terminals, mission control centers, and rescue coordination centers, the time from the occurrence of disaster to the initiation of rescue action could be shortened to about 2 hr.

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