GEOSS Architecture for the Use of Remote Sensing Products in Disaster Management and Risk Assessment

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1. Introduction / Overview / Motivation

International efforts in disaster management and risk assessment involve activities by many players, linked by complex, often *ad hoc* arrangements. This makes it hard for new suppliers of data or services to participate, or for new would-be users to tap into these data or services. This complexity also limits the efficiency and effectiveness of disaster management and risk assessment: simply trying to ascertain what resources are shared (by different entities, different kinds of disasters, or different jurisdictional levels) can require lengthy inquiry. Determining what resources are missing (i.e., in clear demand but absent or scarce); interdependent; or isolated; can be a challenge as well. Efforts to coordinate or collaborate are also hampered by a lack of shared technical standards, common vocabulary, or jointly understood models of disaster management and risk assessment processes, and their use of satellite and other observations and related systems and services. In order to address and respond to disaster events in a timely, streamlined fashion, stakeholders need to establish these kinds of shared “infrastructure” in advance of disaster events.

For these reasons, the Committee on Earth Observing Satellites (CEOS) Working Group on Information Systems and Services (WGISS) has set out to describe and document a high-level reference model for the use of satellites, sensors, models, and associated data products to support disaster response and risk assessment. This effort is based on real-life experience of practitioners in these areas, and draws on results of the Group on Earth Observations (GEO) task for the Disasters Societal Benefit Area (SBA) and the GEO Global Earth Observation System of Systems (GEOSS) Architecture Implementation Pilot (AIP). Using this model, CEOS-WGISS aims to streamline the efforts of GEOSS and other organizations to give decision makers access to disaster and risk assessment information from global data and service providers.

The architecture defined here is only a starting point; it will undergo ongoing changes to reflect evolving insights, additional experience, or new technologies.

1.a. Audience and scope

The audience for this architecture consists of the following (overlapping) categories of people:

- Providers of satellite and other data relevant to disaster management / risk assessment;
- Providers of value-added services that process (interpret, transform, summarize, filter, combine) data to produce information products for end users;
- Distributors of original or processed data;
- Decision-makers who prioritize investments in data sensing, distribution, or use.

This architecture is focused on areas that are peculiar to disaster management and risk assessment and their use of satellite information. Thus it omits topics that are either generic (much broader or more specific), or adequately treated elsewhere – *e.g.*, in GEOSS-wide definitions or technical standards. Where such "outside" topics are relevant to the topic of satellite information support to disaster management or risk assessment, this architecture document references appropriate documents; if none exist, then it includes short "stubs" to be replaced by external references at a later date.

1.b. Goals and Requirements

This reference model provides a high-level, enterprise perspective for managing distributed data systems and services for disaster management. In particular, it is intended to provide a common vocabulary to describe the system-of-systems building blocks and how they are composed in support of disasters.

This model describes Disaster Response and Risk Management concepts and processes as they are conducted today; but it also takes a strategic view, using current experience to envision improved processes and information support.

However, the model is intended not as a set of prescriptions or policies, but as a tool to facilitate coordination among organizations (international, national, regional and local) and interoperability among technology implementations (data archives, processing services, catalogs, portals, and end-user applications). It is also intended to clarify the relationship between ongoing activities – in particular, pilot studies and proof-of-concept prototypes – and the disaster management enterprise as a whole, to assist planners and decision-makers in prioritizing investments in data infrastructure, based on gaps or redundancies in data, metadata, functions, services, networks, *etc.* The goal is to improve both the effectiveness of disaster management efforts (doing the right things at the right times) and their efficiency (maximizing performance while minimizing costs).

1.c. Approach: Reference Model for Open Distributed Processing

Several frameworks exist for describing the structure and functions of an enterprise. This document employs the ISO / IEC Reference Model of Open Distributed Processing (RM-ODP) to structure its descriptions of disaster management operations and processes. RM-ODP is especially suited to an information-intensive set of activities that involve many diverse and dispersed data sources, services, providers, and users. RM-ODP structures descriptions of an enterprise according to five "viewpoints":

- The *Enterprise* viewpoint describes the purpose, scope, and policies for the system. These are often articulated by means of scenarios or use cases.
- The *Information* viewpoint is concerned with the semantics of the information and the information processing performed.

- The *Computation* viewpoint is concerned with the functional decomposition of the system, and models it as objects interacting at interfaces.
- The *Engineering* viewpoint describes the mechanisms and functions required for distributed interaction between objects.
- The *Technology* viewpoint pinpoints technology choices for implementing the system.

RM-ODP is also the basis for numerous other reference models in related areas, including the GEOSS Architecture Implementation Pilot, the European Union's INSPIRE Spatial Data Infrastructure and ORCHESTRA disaster management framework, and the OGC Reference Model. This common structure may facilitate comparisons or links with these other communities.

1.d. Approach: practitioner case studies

This document aims to synthesize a general understanding of disaster management processes, and their use of satellite data streams, from real-world experience. So, rather than work from abstract / hypothetical use cases, this synthesis relies on documenting and analyzing how practitioners went about managing real disaster events or assessing or mitigating risks from actual hazards. Inputs for this come from a number of use cases, among the following:

Disaster response scenarios and lessons:

- China earthquake 2008
- Japan tsunami 2011
- Thailand flood 2011

Technology pilots:

- Namibia flood sensor web/dashboard
- NASU / NSAU Wide Area Grid (WAG) Testbed for Flood Monitoring
- Caribbean disasters task for CEOS
- Thailand wildfire sensor web
- Virtual Mission Operation Center (VMOC) support to USGS Hazards Data Distribution System (HDDS)

Experiences with the International Charter:

- USGS member view
- NOAA member view
- NASA support view
- UK member view
- NASA EO-1 provider view
- Namibia end user view
- Japan earthquake data for E-DECIDER

Other data brokers

- Disaster Management Constellation – Satellites built by Surrey Ltd. SSTL & operated by DMC International Imaging for Spain, Turkey, China, Algeria, United Kingdom (x2: UK-DMC), and Nigeria (x3)
- Sentinel Asia for Environment (SAFE) – Satellite tasking / data requests from Aqua, Terra, MTSAT
- GEONETCAST – Radio-frequency broadcast of data products from NOAA, WMO, EUMETSAT, and NASA

Value-added services / Decision support:

- NASA SERVIR
- NASA Earthquake Data Enhanced Cyberinfrastructure for Disaster Evaluation and Response (E-DECIDER) – Earthquake-related UAVSAR and InSAR interferograms, optical imagery; via WMS
- NASA Land Atmosphere Near real-time Capability for EOS (LANCE) – Rapid dissemination of MODIS products via OGC Web Map Service (WMS)
- SErvice Régional de Traitement d'Image et de Télédétection (SERTIT) / U. Strasbourg – Rapid Mapping Service serving International Charter and DMCii
- EU Global Monitoring for Environment and Security (GMES) Emergency Response / powered by Seismic eArly warning For EuRope (SAFER)
- EU ORCHESTRA project (Open Architecture and Spatial Data Infrastructure for Risk Management)
- UN Platform for Space-based Information for Disaster Management and Emergency Response (SPIDER) – within UN Office for Outer Space Affairs (UNOOSA)

This architecture ties findings and analysis from the use cases to the broader picture of Disaster Management work through ongoing review of conferences, published literature, and activities by international groups such as UN-SPIDER, the World Bank, EU ORCHESTRA, Global Monitoring for Environment and Security (GMES), GEMS, and Sentinel Asia / Space Applications for Environment (SAFE).

2. Enterprise Viewpoint

This first Viewpoint forms the basis for the others: it describes the purpose and scope of the enterprise; its stakeholders, its processes, and its guiding principles.

2.a. Purpose and scope

The enterprise of concern here is the use of data from satellites in disaster management and risk assessment processes (decisions, operations, *etc*.). In keeping with the CEOS WGISS charter to *"enhance international coordination and data exchange and optimize societal benefit,"* the emphasis is on the systems and services needed to streamline access to earth-observing satellites operated by CEOS members. This architecture supports the following GEOSS Strategic Target[1]:

> *By 2015, GEO aims to enable the global coordination of observing and information systems to support all phases of the risk management cycle associated with hazards (mitigation and preparedness, early warning, response, and recovery).*

In particular, the Enterprise described here aims to encompass and integrate data support to all aspects of Disaster Response and Risk Management. These are often treated as disjoint sets of activities, but (especially for the purposes of information support) they may be envisioned as a continuum of analysis and decision-making, from risk awareness and preparedness, through forecasting and preparation, to disaster response and recovery.

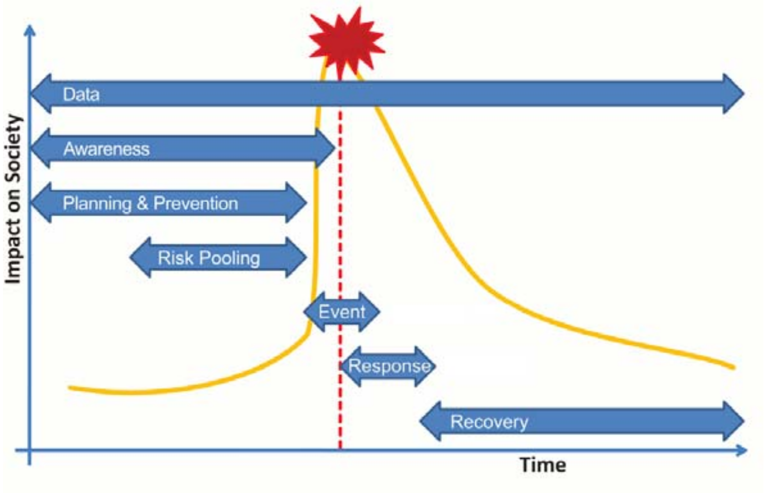

Figure 1. Information support to Risk Management and Disaster Response and Recovery[2]

****** INSERT RISK MANAGEMENT PARAGRAPH HERE ******

Streamlined, integrated processes and information support across this entire set of activities is an important goal of this enterprise. For example, the activities depicted in Figure 1 above present an ongoing, interrelated, and overlapping set of information needs:

- global (thus low-resolution) observations to assess risks everywhere;
- higher-resolution observations in known high-risk areas or for location-specific forecasts;
- highest resolutions where disaster response is currently needed or underway.

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[1] From GEOSS Strategic Targets, GEO-VI Doc. 12 (Rev1), 17-18 November 2009

[2] Based on World Economic Forum, 2011, "A vision for managing natural disaster risk: proposals for public/private stakeholder solutions," p. 21.

The enterprise described here serves GEO 2012-2015 Work Plan Task DI-01, "Informing Risk Management and Disaster Reduction" in achieving the following[3]:

- More timely dissemination of information from globally-coordinated systems for monitoring, predicting, risk assessment, early warning, mitigating, and responding to hazards at local, national, regional, and global levels;
- Development of multi-hazard and/or end-to-end approaches to disaster risk reduction, preparedness and response in relevant hazard environments;
- Supporting the implementation of the *Hyogo Framework for Action 2005-2015: Building the resilience of nations and communities to disasters* (HFA).
- Improved use of observations and related information to inform policies, decisions and actions associated with disaster preparedness and mitigation.
- More effective access to observations and related information to facilitate warning, response and recovery to disasters.
- Increased communication and coordination between national, regional and global communities in support of disaster risk reduction, including clarification of roles and responsibilities and improved resources management.
- Improved response to natural and man-made disasters through delivery of space-based data, resulting from strengthened International Charter on Space and Major Disasters.

More specifically, this enterprise shares the following Task DI-01 *focus areas*:

- Provide support to operational systems;
- Enable and inform risk and vulnerability analyses;
- Conduct regional end-to-end pilots with a focus on building institutional relationships;
- Conduct gap analyses in order to identify missing data, system gaps, and capacity gaps.

It also integrates the *components* of Task DI-01 defined in the GEO Work Plan:

- Disaster Management Systems;
- Geohazards Monitoring, Alert, and Risk Assessment (including Geohazards Supersites);
- Tsunami Early Warning and Hazard Assessment;
- Global Wildland Fire Information System;
- Regional End-to-End Pilots.

Finally, the GEO Work Plan tentatively identifies 18 resources available for implementing DI-01, including the International Charter, the CEOS Geohazard Supersites, catalog and metadata efforts by JAXA, and technology pilot projects at regional and global scales. These serve as points of reference for this enterprise, confirming and validating its scope and structure.

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[3] These goals were first spelled out in GEOSS Strategic Targets, GEO-VI Doc. 12(Rev1), 17-18 November 2009.

Further details on DI-01 and GEO objectives may be found in the GEO 2012-2015 Work Plan, as well as in “GEOSS Strategic Targets” (GEO-VI Plenary Document 12 (Rev 1), 17-18 Nov. 2009), and the 2-, 6-, and 10-year targets for the GEOSS Disasters Societal Benefits Area.

Fulfilling these goals collaboratively requires a precise, shared understanding of the processes involved in disaster-related decision-making, operations, planning, *etc.;* of the satellite observations used *(or usable)* by these processes; and of the data access methods -- either direct (from data suppliers) or indirect (through intermediate value-added services).

This enterprise encompasses communities that differ significantly in their policies, economics, language, *etc.*; and it accounts for a variety of disaster types. It also builds on and ties to existing GEOSS architectures and semantics, including those of the GEO 2012-2015 Work Plan and GEOSS Architecture Implementation Pilot (AIP).

2.b. Disaster types and lifecycle phases

The disaster management and risk assessment enterprise is also defined by a set of disaster types and phases. Several sources provide useful points of reference in this regard: to streamline comparisons and coordination, this reference model will adopt the structure outlined in the CEOS / GEO DI-06-09 report, “Use of Satellites for Risk Management” (Nov. 2008):

Disaster types:

- Flooding (slow on-set and flashfloods);
- Windstorms;
- Earthquakes;
- Landslides;
- Volcanoes;
- Wildfires;
- Drought;
- Tsunamis.

These eight disaster types were selected (both in the 2008 report and in this document) not because they are exhaustive, but because of their widespread impact, and the potential impact of using satellite imagery and its associated applications.

Disaster phases:

- Disaster Mitigation;
- Disaster Warning;
- Disaster Response;
- Disaster Recovery.

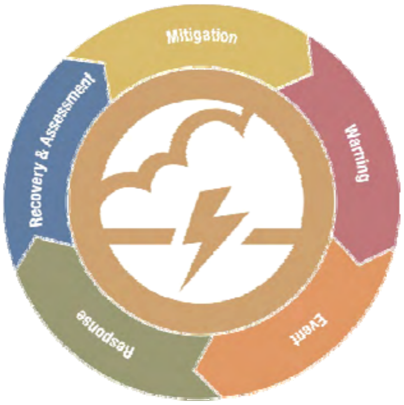


Figure 2. Disaster phases

These phases may last from a few hours (Warning) to months or years (Mitigation, Recovery). Figure 2 (right), from the CEOS / GEO 2008 report, depicts these phases, including the Disaster Event itself (which may only last a few seconds).

This document generally follows the structure from the CEOS / GEO 2008 report, but with occasional links to others. For example, the GEO report on Critical Earth Observations Priorities (Oct. 2010) bases its analysis on nearly the same disaster types as above – but omits

Drought and Tsunamis; and limits Windstorms to Tropical Cyclones. The GEOSS 10-Year Implementation Plan Reference Document (Feb. 2005) also omitted Drought, but it distinguished Extreme Weather and Tropical Cyclones in lieu of Windstorms; and added Sea/Lake Ice and Pollution events.

2.c. Stakeholders

Many documents and plans by CEOS, GEOSS, and others refer to the stakeholders for Disaster Management and Risk Assessment and the Use of Satellite Data in such activities; but these stakeholders are seldom enumerated or characterized. One exception is a recent GEOSS Architecture Implementation Pilot report (AIP-3, Jan. 2010, #2.4.1.1), which calls out several “targeted or supported” communities for disaster management:

- National agencies concerned with disaster management, meteorology, hydrology, and emergency response, and their providers of data, services, research, and analysis;
- CEOS's Strategic Implementation Team (SIT) and WGISS;
- GEOSS' DI-06-09 Task, and
- UN-SPIDER, the United Nations Platform for Space-based Information for Disaster Management and Emergency Response.

The GEOSS AIP-3 “reference scenario” on Disaster Management abstracts four kinds of “actors”: *Initiators* (who trigger and coordinate the disaster response), *Actuators* (who carry out the disaster response – *e.g.*, regional civil protection, insurance companies, NGOs), *Processors* (providers of raw data or derived information), and *Coordinators* (who facilitate interactions among the other actors).

A full description of the enterprise will need to consider a broad set of stakeholders, well beyond the intended audience for this document (listed in 1.a above) -- ranging from regional and international organizations to local community organizations. Stakeholders may potentially include individual citizens as well (recipients of information for decisions at a wide range of scales; sources of relevant data (crowdsourcing), participants in decision-making processes). Given such a broad set of stakeholders, prioritizing their requirements will be crucial.

2.d. Processes

Disaster Management and Risk Assessment activities share a set of high-level processes. The recent GEOSS AIP-5 Architecture abstracts the information support to these processes into five generic categories, depicted in Figure 2 below.

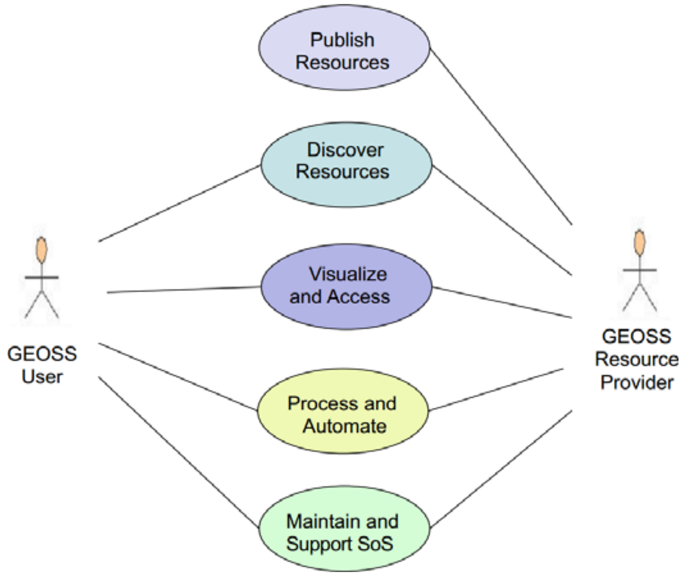


Figure 2. GEOSS AIP-5 Use Case Summary Diagram

2.e. Principles

As a voluntary partnership of (88) governments and (65) intergovernmental, international, and regional organizations, GEO provides a framework within which these partners can coordinate their strategies and investments towards building GEOSS. The GEOSS 10-Year Implementation Plan provides several principles as the basis for this joint framework:

- GEOSS is a *System of Systems* – not a single integrated system but a set of Earth Observation systems that each member operates autonomously for its own needs, but also to interact with other GEOSS systems to provide more than the sum of the individual systems.

- *Data Sharing Principles*, required of all GEOSS participants, call for full and open exchange of data and metadata with minimum time delay and minimum cost. Use of data need not imply an endorsement of its original intent. Members are “encouraged” to share these data either free of charge or at reproduction cost in support of research and education.

- *Interoperability Arrangements* are also required for all GEOSS participants; they enable interaction among GEOSS’ different systems. These arrangements generally consist of software interfaces based on industry standards; they are adopted by the GEOSS Standards and Interoperability Forum and maintained in a Standards Registry.

(These principles are spelled out in the GEOSS Strategic and Tactical Guidance to Contributors.)

GEO and CEOS also have policies defining their structure and governance (such as the GEO Rules of Procedure): these are not directly related to satellite information support for disaster management and risk assessment, but they may have a significant indirect impact.

2.f. Enterprise view: initial inputs

In advance of interactions with practitioners in the case studies, a few initial findings serve as a point of comparison when gathering additional data and detecting patterns or gaps.

One example is the International Charter on Space and Major Disasters, an international agreement among Space Agencies and national bodies to supply space-based data to relief efforts in the aftermath of major disasters. Upon “activation” by one of its members, the Charter brokers the delivery of data from its members at no cost in support of emergency response efforts. The International Charter’s process is depicted in Figure 2.

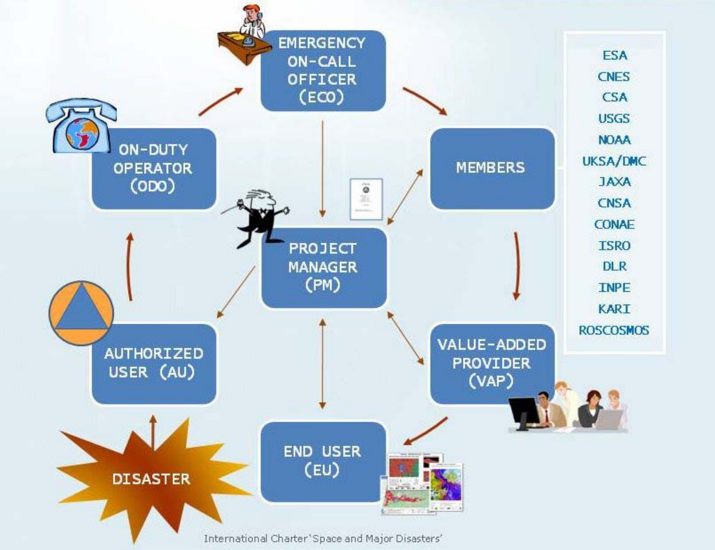


Figure 2. International Charter process sketch

The Enterprise Viewpoint highlights at least two significant differences between the International Charter’s scope and that of CEOS / GEOSS’ support to disaster management and risk assessment. First, the International Charter supports only short-term relief activities – not rehabilitation, reconstruction, prevention, preparedness, or scientific research. Furthermore, the Charter limits its role to obtaining and distributing its members’ data; it relies on third-party value-added providers to turn these data into maps suitable for end users in the field. By contrast, CEOS / GEOSS are concerned with the entire chain of data services and transformations that make the data accessible and usable by end users.

The GEOSS Geohazard Supersites provide another point of comparison. These provide access to data for a dozen global reference sites around the world, including spaceborne Synthetic Aperture Radar (SAR), *in situ* GPS crustal deformation measurements, and earthquake observations.

Figure 3. GEOSS Geohazard Supersites concept

The data are intended for research and disaster preparedness, but may also support operational agencies in disaster response. Supersites have been established in geologically active regions (Istanbul, Tokyo, Los Angeles, Vancouver), near active volcanoes in Italy and Hawaii (USA), and in the aftermath of major earthquake events in Chile, China, Japan, and Haiti. The Supersites bear several similarities to the enterprise described here, with their emphasis on open access to information and their fit to the GEO objectives and work plan. However their scope is different: they limit their focus to seismic risks, leaving floods, storms, and other types of disasters to others; and (so far at least) they have emphasized research over operational uses.

3. Information Viewpoint

3.a. Overview

With the above enterprise definition as a basis, the information viewpoint emphasizes the information used or produced by the enterprise. The GEOSS AIP Architecture, Part 3 ("Information Viewpoint: Earth Observations"), provides generic starting points for the information viewpoint: spatial referencing; observations and features; environmental models; maps and alerts, data quality (esp. uncertainty and provenance); semantics and ontologies; registries and metadata; and data policy (including rights management and licensing). It portrays these conceptual topics as in Figure 4.

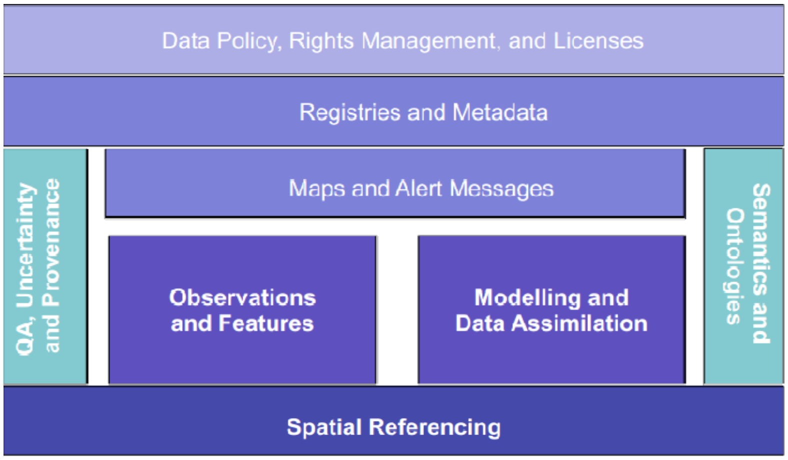


Figure 4. AIP-5 Information Viewpoint topics

These general-purpose definitions provide a basis for additional specifics in the area of Disaster Management and Risk Assessment:

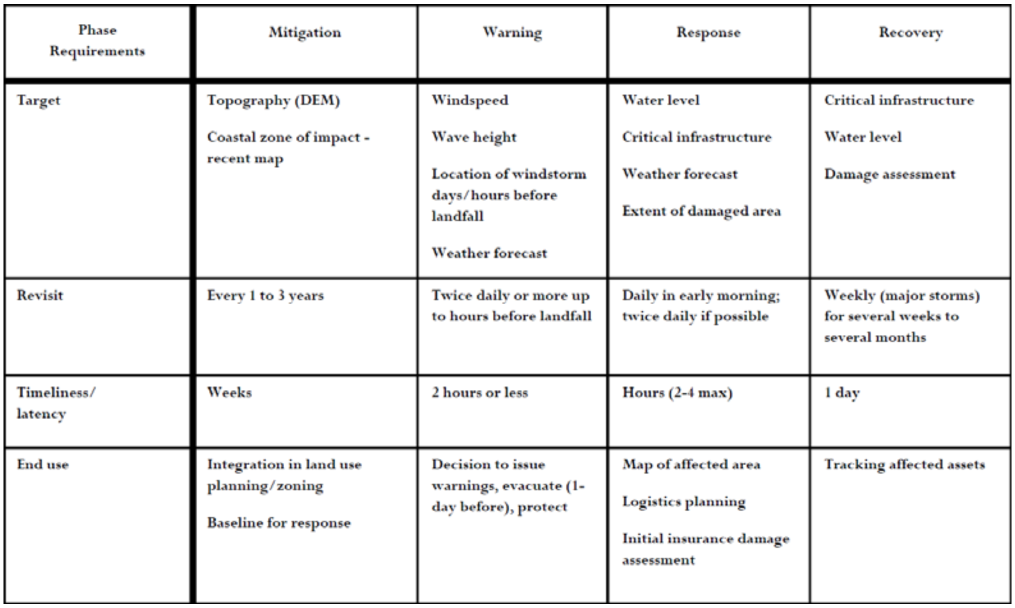
- The observations or parameters needed to address different kinds of disasters;
- The metadata that enable finding and choosing data and that maximize its utility in a disaster management context;
- Vocabulary schemes related to disaster management and risk assessment by different organizations and communities (including multilingual data and systems);
- The types of data transformation, interpretation, extraction, synthesis, *etc.* operating (or needed) between sensors and users.

The information viewpoint is concerned with the semantic or conceptual aspects of these matters: details on the syntax, encoding, or transport of information appear in the engineering and technology viewpoints.

The following subsections provide more detail on each of these topics.

3.b. Observations and parameters by disaster type

The CEOS / GEO DI-06-09 report, "Use of Satellites for Risk Management" (Nov. 2011) details information needs for each of the eight disaster types outlined previously (flooding, windstorms, earthquakes, landslides, volcanoes, wildfires, drought, and tsunamis). It distinguishes four phases in disaster management (mitigation, warning, response, recovery) resulting in tables like the one in Figure 5.



Phase Requirements	Mitigation	Warning	Response	Recovery
Target	Topography (DEM) Coastal zone of impact - recent map	Windspeed Wave height Location of windstorm days/hours before landfall Weather forecast	Water level Critical infrastructure Weather forecast Extent of damaged area	Critical infrastructure Water level Damage assessment
Revisit	Every 1 to 3 years	Twice daily or more up to hours before landfall	Daily in early morning; twice daily if possible	Weekly (major storms) for several weeks to several months
Timeliness/ latency	Weeks	2 hours or less	Hours (2-4 max)	1 day
End use	Integration in land use planning/zoning Baseline for response	Decision to issue warnings, evacuate (1-day before), protect	Map of affected area Logistics planning Initial insurance damage assessment	Tracking affected assets

Figure 5. GEO-DI-06-09 report (2011) - Information needs for wildfires[4]

Several additional sources inform the view of information needs and usage for satellite data support to disaster management. For example, the GEO report on Critical Earth Observations Priorities (Oct. 2010) highlights the following priorities across a range of disaster types:

1. Elevation / Topography
2. Precipitation
3. Surface Deformation
4. Wind Properties
5. Soil Properties
6. Seismicity
7. Atmospheric Properties
8. Flood Monitoring Properties
9. Wave Properties
10. Stream / River Properties
11. Gravity Field
12. Water Properties
13. Ice / Snow Properties
14. Magnetic Field
15. Thermal Properties

The GEOSS 10-Year Implementation Plan Reference Document (Feb. 2005) details information needs for each of 10 different kinds of disasters (Figure 6).[5]

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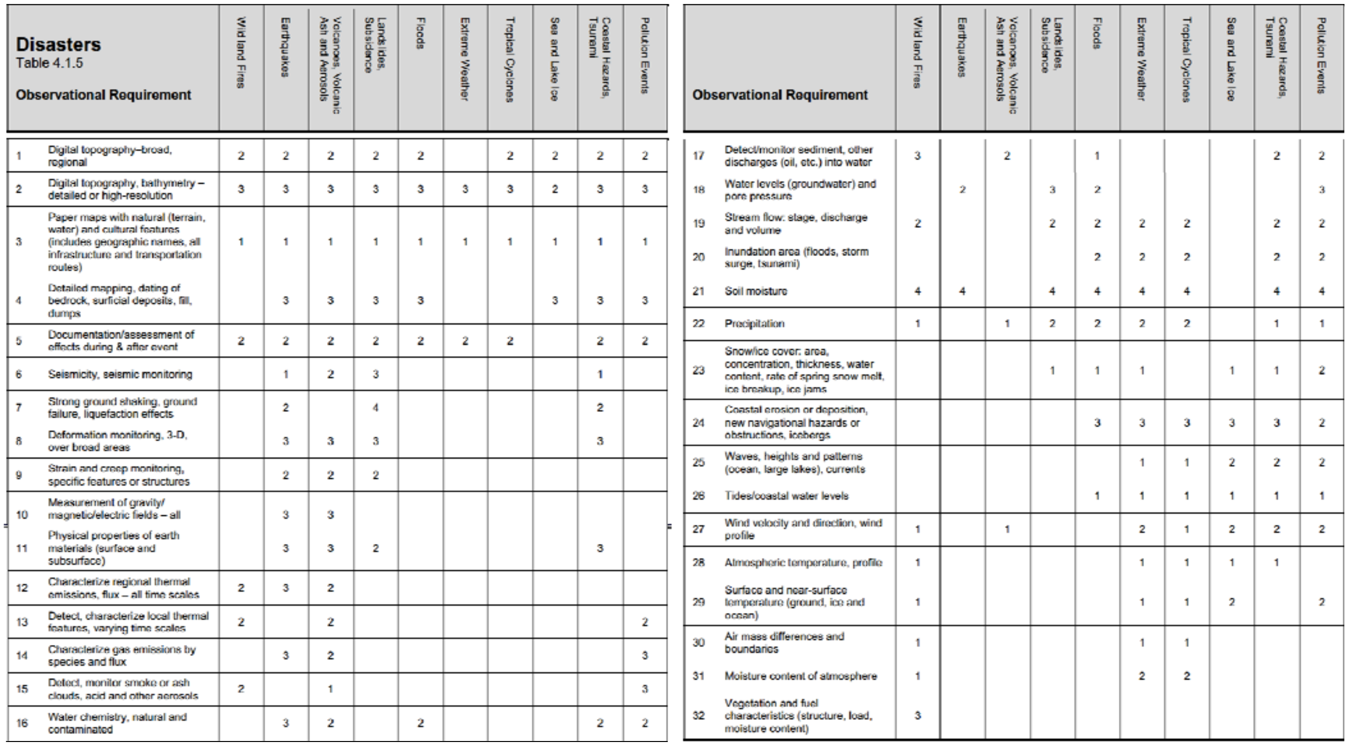
[4] From CEOS / GEO DI-06-09 report, "Use of Satellites for Risk Management" (Nov. 2011)

[5] Another useful way to structure the information view for satellite data would be by sensor types (microwave soundings (passive and active), optical imaging (visible, near-infrared, thermal), radar, laser / LIDAR, etc.) and orbit types (geostationary, polar-orbiting, etc.). Revisions of this architecture may need to revisit these categorizations.

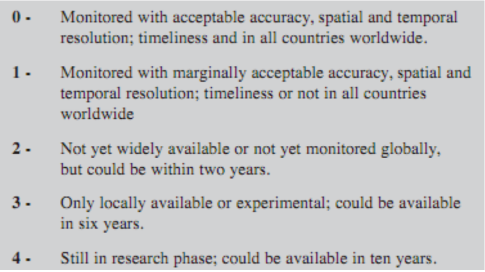


Disasters
Table 4.1.5

	Observational Requirement	Wild land Fires	Earthquakes	Volcanoes, Volcanic Ash and Aerosols	Landslides, Subsidence	Floods	Extreme Weather	Tropical Cyclones	Sea and Lake Ice	Coastal Hazards, Tsunami	Pollution Events
1	Digital topography–broad, regional	2	2	2	2	2		2	2	2	2
2	Digital topography, bathymetry – detailed or high-resolution	3	3	3	3	3	3	3	2	3	3
3	Paper maps with natural (terrain, water) and cultural features (includes geographic names, all infrastructure and transportation routes)	1	1	1	1	1	1	1	1	1	1
4	Detailed mapping, dating of bedrock, surficial deposits, fill, dumps		3	3	3	3			3	3	3
5	Documentation/assessment of effects during & after event	2	2	2	2	2	2	2		2	2
6	Seismicity, seismic monitoring		1	2	3					1	
7	Strong ground shaking, ground failure, liquefaction effects		2		4					2	
8	Deformation monitoring, 3-D, over broad areas		3	3	3					3	
9	Strain and creep monitoring, specific features or structures		2	2	2						
10	Measurement of gravity/ magnetic/electric fields – all		3	3							
11	Physical properties of earth materials (surface and subsurface)		3	3	2					3	
12	Characterize regional thermal emissions, flux – all time scales	2	3	2							
13	Detect, characterize local thermal features, varying time scales	2		2							2
14	Characterize gas emissions by species and flux		3	2							3
15	Detect, monitor smoke or ash clouds, acid and other aerosols	2		1							3
16	Water chemistry, natural and contaminated		3	2		2				2	2
17	Detect/monitor sediment, other discharges (oil, etc.) into water	3		2		1				2	2
18	Water levels (groundwater) and pore pressure		2		3	2					3
19	Stream flow: stage, discharge and volume	2			2	2	2	2		2	2
20	Inundation area (floods, storm surge, tsunami)					2	2	2		2	2
21	Soil moisture	4	4		4	4	4	4		4	4
22	Precipitation	1		1	2	2	2	2		1	1
23	Snow/ice cover: area, concentration, thickness, water content, rate of spring snow melt, ice breakup, ice jams				1	1	1		1	1	2
24	Coastal erosion or deposition, new navigational hazards or obstructions, icebergs					3	3	3	3	3	2
25	Waves, heights and patterns (ocean, large lakes), currents						1	1	2	2	2
26	Tides/coastal water levels					1	1	1	1	1	1
27	Wind velocity and direction, wind profile	1		1			2	1	2	2	2
28	Atmospheric temperature, profile	1					1	1	1	1	
29	Surface and near-surface temperature (ground, ice and ocean)	1					1	1	2		2
30	Air mass differences and boundaries	1					1	1			
31	Moisture content of atmosphere	1					2	2			
32	Vegetation and fuel characteristics (structure, load, moisture content)	3									

Figure 6. GEOSS 10-year plan: types of observations vs. types of disasters

Of these observations, only a few (3-7, 9, 11, 18, 19) rely entirely on non-satellite data sources; most are satellite-based (or can be). For each observation type, a numeric code indicates its applicability and availability for each disaster type (Figure 7):



0 -	Monitored with acceptable accuracy, spatial and temporal resolution; timeliness and in all countries worldwide.
1 -	Monitored with marginally acceptable accuracy, spatial and temporal resolution; timeliness or not in all countries worldwide
2 -	Not yet widely available or not yet monitored globally, but could be within two years.
3 -	Only locally available or experimental; could be available in six years.
4 -	Still in research phase; could be available in ten years.

Figure 7. Availability of observation types for each type of disaster

The case studies suggest additional specifics: for example, the Namibia flood pilot relies on satellite data both directly (Landsat, MODIS, EO-1, RADARSAT) and indirectly through flood forecast models (RiverWatch, CREST, GFM). These models use rainfall estimates from the Tropical Rainfall Measurement Mission (TRMM) microwave sounder, and predictions based on geostationary and polar-orbiting satellites. When these models and the imagers indicate a flood risk, the Pilot system lets users submit satellite tasking requests to both NASA’s EO-1 and the Canadian Space Agency’s RADARSAT for high-resolution imagery in high-risk areas.

The Chinese case shows the importance in emergency response of current, high-resolution imagery from both aerial and orbital platforms. The response phase in this case drew on radar and multispectral (visible and IR) imaging from a variety of orbital sensors; however aerial imagery was especially important to supply near-real-time, submeter imagery to rescue and immediate recovery operations.

The Namibia case also shows that the availability of some “tried-and-true” data types like digital terrain models (DTMs) or water boundaries cannot simply be assumed. Many areas of the world have on hand only coarse or inaccurate data on terrain and water bodies; so targeted flood forecasts require more detailed elevation data, either from concurrent monitoring or from static datasets such as SRTM (the Shuttle Radar Topography Mission of 2000).

3c. Metadata needs in a disaster management context

The Namibia pilot and Chinese case both highlight the need for accurate georeferencing metadata for satellite imagery. The International Charter experience suggests the importance of systems that let users (or data custodians themselves) identify suitable datasets more quickly and accurately based on their fitness for a particular use.

3d. Semantics and ontologies

(To be completed… Starting points include controlled vocabularies, GCMD, SWEET, and probably RDF, OWL, SPARQL. Need to highlight parts specific to disasters.

References might also include
Xu and Zlatanova, Ontologies for Disaster Management Response (2007);
Joshi et al., Ontology for disaster mitigation and planning (2007); and
Hristidis et al., Survey of data management and analysis in disaster situations (2010).)

3e. Data operations needed in a disaster management context

The Namibia case and others underscore the importance in disaster management of several operations related to data from orbital sensors:

- *Decoding raw satellite data into grids of sensor measurements.* The result of this operation is often referred to as a “Level1” data product, or a Sensor Data Record: its grid values consist of signal strengths (i.e., radiance / reflectance / return) at various wavelengths, estimated based on intrinsic sensor characteristics. Although often considered an intermediate product, these data are often used as-is, without further processing, especially in time-sensitive applications such as disaster warning or response.

- *Georeferencing*. This operation uses satellite orbit characteristics (and sometimes a detailed earth terrain model) to compute the earth location of the values shown in satellite data, and is a necessary step in applying satellite data to applications on the ground. Often this is used in *georectification* of the satellite image, a process that resamples (regrids or warps) the data grid to one aligned with the axes of a well-known earth coordinate reference system (*e.g.*, longitude and latitude), to facilitate overlaying the image with other geospatial data or images. This latter operation is important in disaster management given the broad variety of users (many unfamiliar with satellite orbit or swath details) who need to put the information to use on their own, in often hard-to-predict ways.

- *Atmospheric correction* is usually needed before using satellite imagery: this process uses meteorological data to cancel out the effect of aerosols or other atmospheric conditions and to estimate true radiance and reflectance values at the earth's surface.
- *Image interpretation* is an important part of turning satellite data into actionable products for use by decision-makers. Interpretation can be based on a wide variety of algorithms and may draw on many different ancillary data sources. Interpretation may apply a simple threshold (such as thermal hotspots indicating likely fires), statistical clustering across several optical wavelengths (image classification), or more complex inferences of physical conditions such as atmospheric chemistry or biomass density. All phases of disaster management draw on image interpretation in myriad ways to estimate physical conditions and trends on the ground and in the atmosphere. *Feature extraction and data reduction* are particular cases of image interpretation: they detect discrete physical phenomena in the data (such as water / inundation boundaries; topography; storm cells) and output geometric representations of these phenomena.
- *Pan-sharpening* is a process often applied to multi-spectral imagery to maximize its spatial resolution by convolving it with finer-grain panchromatic imagery. This is especially useful in a disaster response setting, given the frequent need for high spatial resolution.
- Finally, whenever satellite image products are intended for interactive (multi-resolution) browsing in a graphical user interface, they must be resampled and stored at multiple resolutions (often 1/2, 1/4, 1/8 ... of the native resolution), resulting in *"image pyramids."* This simple but compute-intensive process allows rapid response as the user requests reduced-resolution views of large areas.

4. Computation viewpoint

4.a. Overview

The computational viewpoint describes the kinds of objects that comprise the overall system of systems and the services and interfaces that allow them to interact. The GEOSS AIP Architecture, Part 4 defines a Service Oriented Architecture (SOA) featuring the following service types:

- *Catalog* registration and search services;
- *Portrayal and display* services, including services for map styling and symbology;
- *Data access and ordering* services for files, geographic features, and gridded data;
- Services for describing, finding, and running *data processing algorithms*;
- Services for describing, accessing, and tasking *environmental sensors*; and
- Services for *user management* (chiefly authentication and authorization).

These might be described as “infrastructure-level” services. Supporting disaster management and risk assessment with satellite data builds on these service types, with a few additional specifics:

- An emphasis on data access, processing (image interpretation), portrayal, and sensor tasking; and less emphasis on catalog search or discovery;
- Additional constraints and requirements on these services and their interfaces (*e.g.,* near-real-time performance, cross-community interoperability, ease of use);
- Finally, although the GEOSS AIP Architecture emphasizes a user-driven Service-Oriented Architecture, many disaster management contexts require data broadcasts (*e.g.,* GEONETCAST) or distribution of physical media.

The following sections detail each of these topics.

4b. Service types needed for disaster management and risk assessment

The classes of services most relevant to disaster management and risk assessment are Data Access, Data Processing (especially image interpretation and modeling); Portrayal; and Sensor Tasking. User management (esp. authentication) services are also important when tasking satellite data, or when data are provided with restrictions on access. These services may be employed as follows:

- *Event detection*, often based on global or regional monitoring (remote or *in situ*);
- *Sensor Tasking* for high-resolution observations of areas threatened or impacted by an event;
- *Image Analysis and Interpretation* of data obtained via satellite tasking or from other sources;
- *Modeling and Prediction* to pinpoint priority times and locations of response and recovery efforts.

Figure 8 below illustrates how these services are combined in the Namibia Flood Pilot: when flood forecasting models detect a flood risk, the user may task a satellite to observe the affected area, and apply a variety of processing algorithms to interpret it. (The Namibia pilot exposes image classification as a service.) The resulting data, along with data from *in situ* rain and stream gauges, feeds another model to determine detailed flood areas.

Figure 8. NASA Flood Sensor Web Concept

The Namibia case and others show a limited role for traditional catalog search and discovery in the disaster response phase: this phase is more likely to rely on near real-time data from well-known sources, or on contributions or referrals. However, the International Charter experience shows that even for known data sources, choosing the right data for a given purpose (based on cloud cover, spatial / temporal / spectral coverage, or other criteria) can be a challenge with data from multiple sources: effective browsing services have a significant role to play in speeding the selection of appropriate data.

The Chinese case highlights the use of (and the need to improve) visualization services, especially user-interactive and/or 3-dimensional display capabilities. It also raises the topic of simulations in the disaster recovery phase (in that case, to assess hydrologic impacts of major earth-moving operations).

Satellite tasking – that is, submitting requests for future data from an earth-orbiting sensor – is an important service that is traditionally (and still mostly) an internal, manual process but which a few providers are beginning to expose as a service. This service may use proprietary / *ad hoc* protocols (as does NASA's Virtual Mission Operation Center (VMOC) in requesting DigiGlobe imagery); or it may implement industry standards such as OGC's Sensor Planning Service (SPS) and Sensor Observation Service (SOS) (employed by the Namibia Pilot system in requesting data from NASA's EO-1 satellite).

4c. Constraints and requirements specific to disaster management

One key need for disaster response is near-real-time performance of the necessary services. Traditional satellite ground segments may not be able to deliver data in a timely fashion for rapidly-changing weather or flooding conditions, or for search and rescue operations. Some satellites (such as NASA's Terra, Aqua, and Suomi NPP polar-orbiting satellites; or geostationary satellites such as GOES) offer unencrypted direct broadcast of imagery, making it immediately available to any receiving station in range of their transmitter. In the China case however, only aerial imagery offered the rapid access and sub-meter resolution they needed for damage assessment and rescue operations after the Sichuan earthquake.

Cross-community interoperability and ease of use are also important in disaster management, given the wide variety of end users, few of whom are data specialists and not all of whom can be identified in advance.

The Namibia pilot highlights the advantages of a RESTful interface for *easy system configuration* with limited staff resources. This may be an important consideration in other contexts as well, as people seek to build flexible systems for handling and sharing information in a disaster context.

4d. Role of non-Service-Oriented approaches

Although the AIP computation view strongly emphasizes a service-oriented architecture, the disaster management context may require extending AIP's emphasis to non-service-oriented broadcast or "push" of data over networks (using a protocol such as Unidata's Local Data Manager (LDM) – used in every field office of the US National Weather Service). This mode of data access allows for the most rapid dissemination of data over networks – data centers can disseminate data to users immediately upon receiving or creating it. However it requires data centers to know who all their data recipients are; would-be recipients of data must make themselves known to the data center (in contrast with service-oriented architecture, in which services are visible to all users). *(Insert GEONETCAST description here)*

Finally, in a disaster response setting, one may not have a functioning network available for data dissemination. Therefore the use of physical media must also be part of the generalized service architecture. The Japan earthquake case provides a real-life example: JAXA printed some 50 satellite images and hand-delivered them to disaster response agencies.

5. Engineering Viewpoint

This part of the architecture describes the classes of components (that is, bundles of services with information flowing in & out through interfaces) needed to perform the computations and information interchanges described in the previous viewpoints. Examples of such component types include data servers, registries / clearinghouses, visualization services, alert services, data access clients, end-user applications, *etc.* The GEOSS AIP Architecture, Part 5, distinguishes component types in three tiers: user interface, business processes, and data access.

The engineering viewpoint highlights the following kinds of topics in Disaster management and Risk Assessment:

- The types of components needed to provide useful information products to end users.
    - Examples include data access and catalog servers; end-user clients (esp. specialized portals) for catalog search and service invocation, and intermediating ("middleware") services for user authentication, data processing, notification, *etc.*

- The interface standards needed to support interoperation between different communities, and ensure resilience of the system

The Disaster Response context may require particular types of clients and services over & above those listed in the AIP-3 Architecture, or it may impose requirements on the functions or performance of certain components. Here again, the use cases will shed light on how service components are being used, and suggest how they might be made more effective.

The engineering and technology viewpoints are not yet a major focus of this architecture; they will become more important once current practice in Disaster Management has been characterized at a conceptual level via the enterprise, information, and computation viewpoints.

6. Technology viewpoint

This last tier of the architecture deals with specific service instances (*e.g.,* servers available at particular URLs) of the types described in the Engineering viewpoint. For international disaster management and response, this includes particular satellite sensors and data streams; data catalogs; forecasting facilities, *etc.* These resources may be provided in part by the GEOSS Common Infrastructure.

As with the Engineering viewpoint, the Technology viewpoint is not yet a major focus of the Disaster Management & Risk Assessment architecture.

References

CEOS Disaster SBA Team / GEO DI-06-09 Report, Use of Satellite Data for Risk Management, Volume I - Establishing Global Requirements for Earth Observation Satellite Data to Support Multi-hazard Disaster Management throughout the Disaster Cycle *(Nov. 2008)* http://www.ceos.org/images/Global_User_Requirements_For_Disaster_Management_Nov2008_small.pdf

GEO 2012-2015 Work Plan *(Dec. 2011)* http://www.earthobservations.org/documents/work plan/GEO 2012-2015 Work Plan_Rev1.pdf

GEO report on Critical Earth Observations Priorities *(Oct. 2010)* http://sbageotask.larc.nasa.gov/Final_SBA_Report_US0901a_Apr2011.pdf

GEO Strategic Guidance for Current and Potential Contributors to GEOSS *(Oct. 2007)* http://www.earthobservations.org/documents/portal/25_Strategic%20Guidance%20Document.pdf

GEO Tactical Guidance for Current and Potential Contributors to GEOSS, GEO-IV Doc. 24 *(Nov. 2007)* http://www.earthobservations.org/documents/portal/24_Tactical%20Guidance%20for%20current%20and%20potential%20contributors%20to%20GEOSS.pdf

GEOSS 10-Year Implementation Plan Reference Document *(Feb. 2005)* http://www.earthobservations.org/documents/10-Year Plan Reference Document.pdf

GEOSS 10-year implementation plan *(Feb. 2005)* http://www.earthobservations.org/documents/10-Year Implementation Plan.pdf

GEOSS Strategic Targets, GEO-VI Plenary Document 12 (Rev 1) *(Nov. 2009)* http://www.earthobservations.org/documents/geo_vi/12_GEOSS Strategic Targets Rev1.pdf

GEOSS Architecture Implementation Pilot (AIP), Phase 5 Call for Participation *(March 2012)* http://earthobservations.org/geoss_call_aip.shtml

GEOSS AIP-5 Architecture *(March 2012)* http://earthobservations.org/documents/cfp/201202_geoss_cfp_aip5_architecture.pdf

GEOSS Data Sharing Principles: http://www.earthobservations.org/geoss_dsp.shtml

GEOSS Standards and Interoperability Forum http://seabass.ieee.org/groups/geoss/index.php?option=com_content&task=view&id=17&Itemid=61

GEOSS Standards Registry: http://seabass.ieee.org/groups/geoss/

INSPIRE Spatial Data Infrastructure http://inspire.jrc.ec.europa.eu/reports/position_papers/inspire_ast_pp_v4_3_en.pdf

International Charter on Space and Major Disasters http://www.disasterscharter.org/home

OGC Reference Model: http://www.opengeospatial.org/standards/orm

ORCHESTRA disaster management framework: http://www.eu-orchestra.org/

World Economic Forum, “A vision for managing natural disaster risk: proposals for public/private stakeholder solutions” *(April 2011)* http://www3.weforum.org/docs/WEF_VisionManagingNaturalDisaster_Proposal_2011.pdf

Appendix 1: Case Study Summaries

Case Study 1. Namibia Flood Pilot (2011)

Based on interviews with Dan Mandl (NASA) and Stuart Frye (SGT/NASA)

In the first quarter of 2011, unusually heavy rains in Northern Namibia led to the highest floods in the country's history. A state of emergency was declared after flood waves peaked in late March and again in early April, leading to severe flooding which claimed 62 lives.

To support response and recovery efforts with satellite data, the International Charter (Space and Major Disasters) was activated; with the following parties leading the effort in the field:

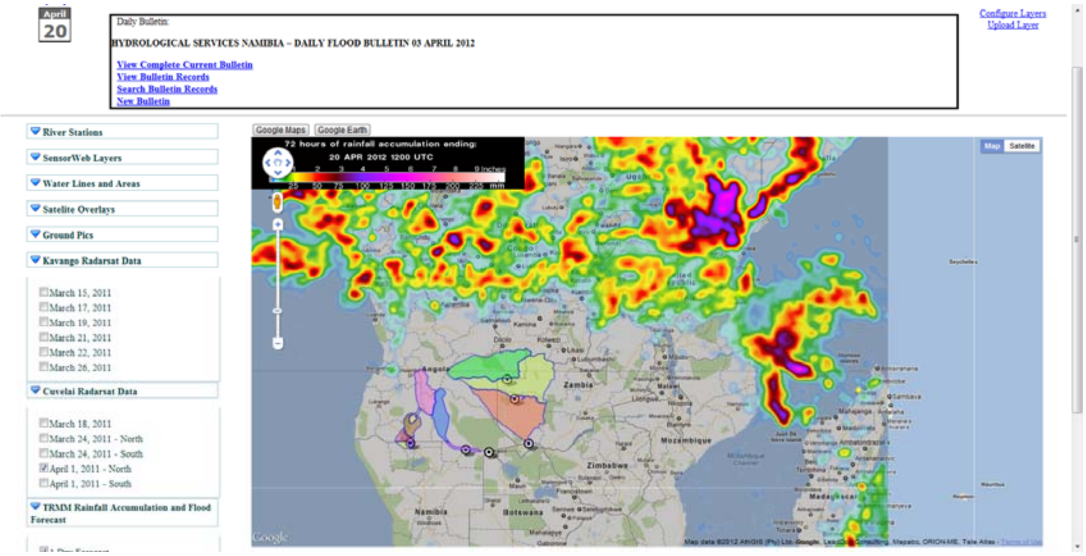
- Namibia Dept. of Hydrology (with Mr. Guido Langenhove as local coordinator)
- United Nations (UNDP, UNOOSA)
- Int'l Charter (in concert with the Canadian Space Agency and the Pacific Disaster Center)
- NASA

Dan Mandl and Stuart Frye were involved in preparing for, and responding to, this and other flood events in the region. They describe their efforts in three phases. First was a rainfall estimate via satellite data, rain gauges, and hydrologic models – in particular the RiverWatch model (from the University of Colorado) which they validated based on microwave soundings from NASA's Tropical Rainfall Measurement Mission (TRMM). The Coupled Routing and Excess Storage (CREST) water balance model (from Oklahoma University and NASA SERVIR) also served to estimate flow rates; and a Global 15km flood model by Robert Adler (of the University of Maryland) provided both a nowcast (using TRMM rainfall estimates) and a forecast (based on GOES / POES based rainfall predictions). Global monitoring imagers (NASA's MODIS and Landsat in particular) also supplied data to these rainfall estimates.

When these models & data indicated a likely flood, the NASA team worked with local organizations such as the Namibia Hydrology Department to identify areas for acquiring high-resolution data from NASA's Earth Observation 1 (EO-1) satellite and the Canadian Space Agency's RADARSAT satellite. All of the above was in advance of the International Charter activation (before disaster was declared).

The process of supplying satellite data to preparation and response efforts began with acquiring data from the EO-1 and RADARSAT satellites, and harvesting products from global monitoring platforms (MODIS, Landsat). These raw data first underwent basic "Level 1" preprocessing (decoding, radiometric calibration, geolocation) and atmospheric correction. Then they could be interpreted in a variety of ways – in particular to identify water-covered areas (the "water mask") and compare them to the non-flooded extent of water bodies. The algorithms for image interpretation and classification can be very specialized (e.g., detecting oil on water) and are often computationally demanding. So to facilitate broader access to these algorithms, Mandl and

Frye and their team have built a Web-based “Flood Dashboard,” operating in a cloud computing environment (http://matsu.opencloudconsortium.org), which allows users to run some 80 different image interpretation algorithms from anywhere. (Fig. 1)



Daily Bulletin:

HYDROLOGICAL SERVICES NAMIBIA – DAILY FLOOD BULLETIN 03 APRIL 2012

Figure 1. Namibia Flood Dashboard

Based on this experience, the team outlines three types of challenges for the future of these efforts (yearly flooding continues to occur in northern Namibia, though with lesser impacts than in 2011). First are technical challenges, such as more accurate image interpretation (for example, to identifying water with vegetation (reeds) growing in it). In Namibia, the lack of detailed elevation data exacerbates the challenge: better digital elevation models would help pinpoint terrain details and their hydrological impacts much more accurately and precisely.

A second set of challenges lies in coordination with the International Charter, to more easily identify areas of interest for data requests; to obtain quantitative data (not just pictures or maps) in a timely fashion, and to allow data sharing among all all participants in a disaster response effort.

For future support to disaster preparation and response, the NASA team are establishing additional arrangements for satellite tasking – with Japan’s space agency (JAXA) for the GCOM satellite; with the French firm SPOT Image for the SPOT-5 satellite; and with DigitalGlobe, Inc. for the GeoEye and DigiGlobe satellites.

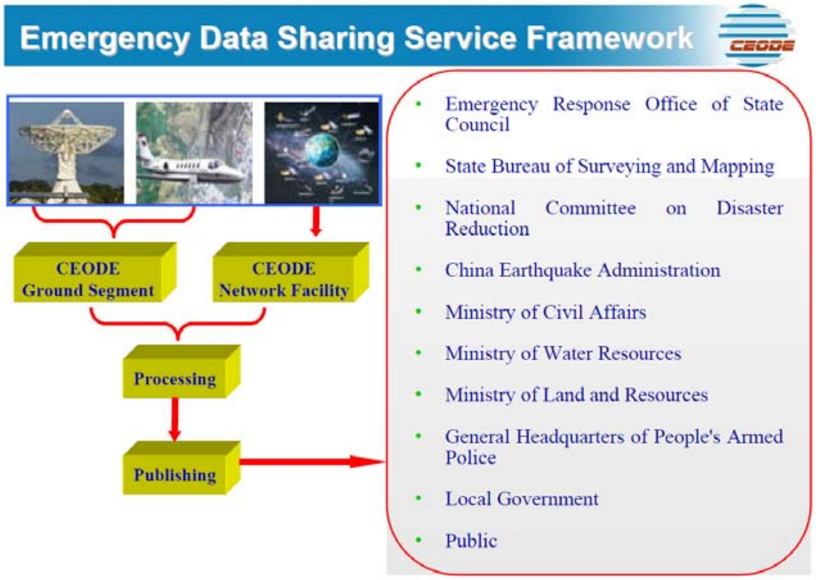
Appendix 1: Case Study Summaries *(continued)*

Case Study 2. China Sichuan / Wenchuan earthquake (2008)

> *Based on email exchanges with Dingsheng Liu (Chinese Academy of Sciences) and on published articles by Deren Li (Wuhan University) and Huadong Guo et al. (Center for Earth Observation and Digital Earth, Chinese Academy of Sciences)*

On Monday, May 12, 2008 at 14:28:01 local time, an earthquake of magnitude 7.9-8.0 struck the Sichuan Province (Wenchuan County) of China, ultimately claiming 69,170 lives, with over 17,000 more missing, 374,000 injured, and over 48 million severely affected.

To respond to the disaster, the Chinese Ministry of Science and Technology (MOST) and the Chinese Academy set up an earthquake data sharing mechanism involving 13 different government ministries such as the Ministry of Land Resources, Ministry of Water Resources, and others. They established a data sharing "pool" operated by the Center for Earth Observation and Digital Earth (CEODE). (Figure 1.)



Emergency Data Sharing Service Framework

- Emergency Response Office of State Council
- State Bureau of Surveying and Mapping
- National Committee on Disaster Reduction
- China Earthquake Administration
- Ministry of Civil Affairs
- Ministry of Water Resources
- Ministry of Land and Resources
- General Headquarters of People's Armed Police
- Local Government
- Public

Fig. 1. Center for Earth Observation and Digital Earth (CEODE) Emergency Data Sharing Service Framework

The immediate priority for disaster response (in the first 6 days) was rescuing survivors. This required rapidly identifying the worst-hit areas, routing rescue teams and dispatching disaster relief. Timely decision support was paramount, using high-resolution aerial (optical and Synthetic Aperture Radar) and satellite images (to locate collapsed buildings) and data on local population distributions (to plan and manage rescue efforts). This phase also relied on pre-disaster imagery from IRS-P6, LANDSAT-5, RADARSAT-1, SPOT (2/4, 5), IKONOS, and from these and many others post-disaster (TERRASAR-X,EROS-B, QUICKBIRD, ALOS, *inter alia*). Activation of the International Charter provided access to several other data products such as

NASA's ASTER, Landsat TM/ETM, IKONOS, WorldView, ALOS, TERRASAR-X, EROS-B, and COSMOS. Data processing operations performed on aerial and satellite imagery included georectification, contrast stretch, joining image scenes, image interpretation, and extracting graphics and digital elevation models. This phase required quite high spatial resolution (<=1m pixels); so airborne remote sensing was clearly the most important data source.

The next phase in the disaster response (from May 19 to June 12) was preventing secondary disasters from landslides and mudslides, which blocked rivers, creating "quake lakes" that could inundate low-lying settlements upstream – or downstream if trapped water suddenly breached the barriers. Settlements threatened by such lakes had to be identified quickly based on airborne and space-borne optical imagery and radar data. Surveys supporting this phase required 5m to 30m pixels; so airborne optical remote sensing remained crucial; along with airborne synthetic aperture radar (SAR) which offered all-weather data acquisition.

This phase also relied on three-dimensional computing and simulation to assess secondary geological risks, and to facilitate collaboration, auxiliary mitigation, and analysis. Monitoring for secondary threats relied heavily on traditional man-machine interactive visual interpretation technology, given that automated algorithms were still inadequate for high-resolution observations, and 3D interactive analysis technology was immature.[6]

The third phase of responding to this disaster – reconstruction and risk assessment – is still ongoing; it is expected to span five to ten years post-event.

Throughout the response to this event, high-resolution airborne and space-borne remote sensing data proved timely and effective. However, future efforts would be aided by improved earth observations: Satellite imagery at 0.5~1.0 m resolution; Aerial imagery at 0.1~0.5 m; with at least daily revisits over disaster-struck areas and improved geometric and radiometric quality.

Improved processing / interpretation capabilities would also be beneficial: for example, automated, near-real-time methods for data processing and reduction, given that photogrammetry specialists cannot rely on ground control after major earthquakes. Another need is fast, accurate, automated methods for processing multispectral optical and multi-polarization radar data.

The final need is improved data sharing and coordination – e.g., via a network unifying all high-resolution earth observations. This experience also highlighted the importance of international cooperation in geospatial technology; and participation in programs like GEO and GEOSS.[7]

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[6] From Huadong Guo et al. (2012), Earth Observation for Earthquake Disaster Monitoring and Assessment. In *Earthquake Research and Analysis - Statistical Studies, Observations and Planning*, Dr Sebastiano D'Amico (Ed.). InTech: http://www.intechopen.com/books/earthquake-research-and-analysis-statistical-studies-observations-and-planning/earth-observation-for-earthquake-disaster-monitoring-and-assessment

[7] Deren Li (2009), Earth Observation for Earthquake Disaster Monitoring and Assessment, *Photogrammetric Engineering & Remote Sensing Vol. 75 No. 5*, May 2009, pp. 506-509. http://www.asprs.org/a/publications/pers/2009journal/may/highlight1.pdf

Appendix 1: Case Study Summaries *(continued)*

Case Study 3. Japan Sendai / Tohoku earthquake & tsunami (2011)

> *Based on a March 2012 report on "JAXA's Response to the Great East Japan Earthquake: assistance using earth observation satellites and communication satellites"*

On March 11, 2011, at 14:46 local time, a 9.0-magnitude earthquake occurred in the Pacific Ocean east of Japan, triggering an 11.8-meter tsunami wave that caused widespread damage along the Pacific coast from Tohoku to Kanto. These events caused an industrial disaster at the Fukushima Dai-ichi Nuclear Power Station that unfolded throughout the spring. These events, together with numerous strong aftershocks, have collectively become known as the Great East Japan Earthquake, claiming 15,783 lives, with nearly 6,000 more injured and over 4,000 missing.

JAXA's Disaster Management Support Systems Office (DMSSO) oversaw the process of supporting disaster relief efforts with satellite data, working through preexisting relationships with Japan's Cabinet offices and local governments throughout the country (Fig. 1)

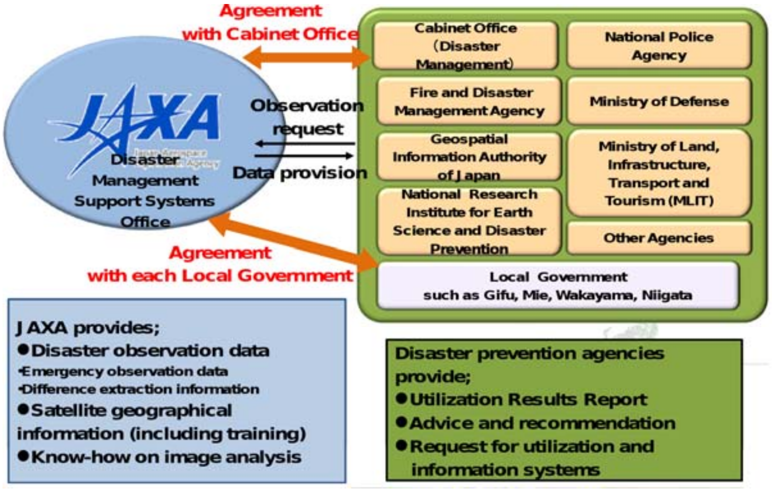

Figure 1. Data dissemination arrangements for disaster response between JAXA and national and local governments[8]

In the immediate aftermath of the earthquake, DMSSO tasked Japan's Daichi Advanced Land Observation Satellite (ALOS) satellite: it obtained a total of 643 images between March 12 and April 20, 2012 (when the satellite suffered permanent failure and was later decommissioned). JAXA also submitted requests for intensive satellite observations to two international coordinating bodies, the International Charter and Sentinel Asia. In the subsequent weeks, the space agencies of 14 nations supplied approximately 5,700 images from 27 satellites including Landsat-7, the Worldview series, RADARSAT, IKONOS, the SPOT series, FORMOSAT-2, RapidEye, THEOS, GeoEye, TERRASAR-X, KOMPSAT-2, DubaiSat-1, and others. Through

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[8] From a presentation by Kengo Aizawa (JAXA) at the CEOS WGISS-33 meeting in Tokyo, Japan, April 25, 2012.

the International Charter, the space agencies of Germany, Canada, the European Union, and Italy provided Synthetic Aperture Radar (SAR) data; and the United States, France, Germany, South Korea, China, and the UAE provided optical image data. Meanwhile, Sentinel Asia quickly coordinated data capture by Thailand's THEOS satellites, India's CARTOSAT-2, and Taiwan's FORMOSAT-2 – the latter providing twice-daily observations for two weeks, with near-real-time data delivery. Adding these data to JAXA's own greatly increased the frequency of observations.

Daichi's SAR data was used to detect crustal movement and pinpointing landslide risks. Interferometric SAR (inSAR) helped to clarify the fault mechanisms of aftershocks in the weeks following March 11. Commercial, high-resolution satellite data were used to assess damage to buildings and infrastructure, including the Fukushima Dai-ichi nuclear power plant.

To analyze the data, the DMSSO worked with JAXA's Earth Observation Research Center and with the Asian Institute of Technology in Thailand; and the International Charter coordinated the creation of image products by groups in the United Nations, the USA, Germany, and France.

JAXA overlaid newly-acquired and archive satellite imagery with geographic data (roads, *etc.*) to produce topographic maps for widespread distribution among national and local disaster-management agencies. It also produced false-color composites of multi-spectral (incl. infrared) imagery to highlight and assess infrastructure damage, flooding and landslide extents, and other conditions of interest. True- and false-color composites made from multispectral imagery also served to detect liquefaction and fires caused by earthquakes.

In all, JAXA created over 1,700 products from its own Daichi satellite data and from data received from others through the International Charter and Sentinel Asia. These products fell into 5 broad categories: satellite-based maps (usually at reduced resolution, with roads and major landmarks overlaid), damage analyses (including before/after pairs and SAR interferograms), flood damage assessment, assessments of the Fukushima Dai-ichi nuclear power plant, and accident analyses (fires, sediment damage, debris).

All of the resulting products were distributed in the form of digital images (in JPEG, GeoTIFF, or PDF format), digital data (shapefiles, spreadsheets) – or even large sheets of printed paper, some of which were hand-carried across Tokyo to Cabinet offices of the Japanese government for use by individual prefectures.

Based on this experience, JAXA outlines several areas for improvement: sharing workloads with external institutions for timely delivery of a wide range of data products; building regional bases across Japan for data handling and interpretation; quickly restoring communication and information services to affected areas; and keeping stakeholders and the media informed of its activities. It has accelerated preparations for the launch of Daichi's successor satellites, including a Data Relay test Satellite, to be able to image any part of the country on any given day (Daichi observations of the March 11 disaster areas weren't possible until the next day, March 12). JAXA has also begun to promote research into new sensors for monitoring thermal change and detecting tsunamis, two needs that the March 2011 events made clear.

Appendix 1: Case Study Summaries *(continued)*

Case Study 4. Perspectives on the International Charter (Space and Major Disasters)

Based on interviews with Brenda Jones (USGS), Michael Goodman (NASA), and Stuart Frye (SGT/NASA); and reference documents

Charter Overview

The International Charter on Space and Major Disasters facilitates acquiring satellite data and delivering it to disaster response efforts. It acts as a data broker between end users and many of the world's space agencies, in a process known as a "Charter Activation," depicted below:

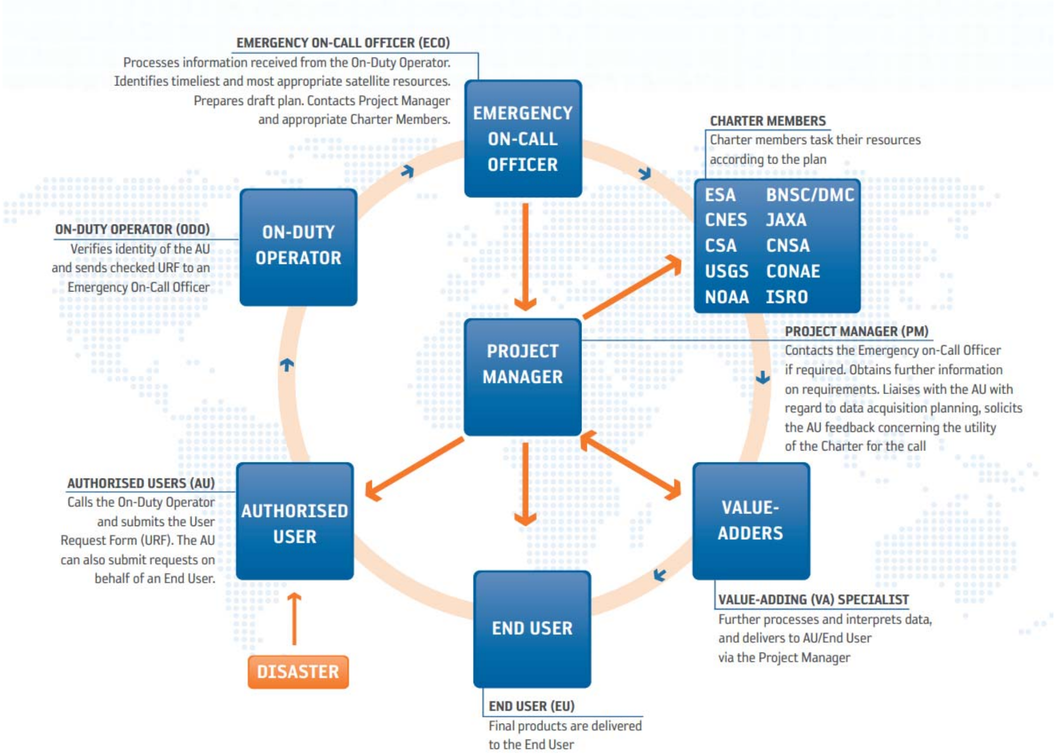

Fig. 1. International Charter Activation Process

(For more on the Charter's membership, process, and goals, see *http://www.disasterscharter.org/*.)

Member perspective

The US Geological Survey (USGS) is a member of the International Charter: it receives requests for Charter activation from anyone, but especially US entities; and responds with data from USGS, NASA & other agencies, US vendors, and others. Brenda Jones of USGS coordinates this process; she points out that finding, choosing, and requesting data, or tasking sensors to capture data, is a mostly manual process, due in part to license / usage restrictions stipulated by many data providers. (She estimates that satellite owners are unlikely to accept automated requests for 10-15 years). The process does however use a planning / tasking tool based on ESA's SAVOIR (Space Avionics Open Interface Architecture – see for example *http://www.erts2012.org/Site/0P2RUC89/6C-1.pdf*).

Ms. Jones' experience with the International Charter suggests that easing restrictions on data access would be beneficial: for example, granting use of Charter-brokered data by entire end user communities (not just the requester); or access to post-event products for recovery and research.

She has also found that it can be a major effort to identify just the right data to meet users' requests and to avoid data overload (*e.g.,* in March 2011 JAXA got 'too much data' for the tsunami and damage assessment). Furthermore, the products are complex; and end users are often under pressure in a crisis situation. This underlines the need to work with end users in advance of the crisis; to deploy tools that can help end users get (only) the information they need; to match products to audiences; and to facilitate the use of these products.

Provider Perspective

NASA is a provider of data to the International Charter; for domestic events, it works under the auspices of the Interagency Remote Sensing Coordination Cell (IRSCC – a group of US Federal agencies chaired by the US Dept. of Homeland Security). As NASA's Michael Goodman recalls, in the aftermath of Hurricane Irene (2011) NASA provided MODIS flood products and EO-1 and ASTER data; and several NASA specialists formulated ASTER and EO-1 requests (bounding boxes) based on cloud cover, imagery swaths, and other criteria. This experience showed that first responders need both simple images and real data for analysis, and confirmed that better tools and methods for choosing data would enable faster support.

User Perspective

The Namibia Flood / Sensor Web Pilot also interacted with the International Charter, as an end user requesting data related to the 2011 floods in Namibia. Working with the Pacific Disaster Center as their Project Manager, Stuart Frye (of SGT, Inc. / NASA) and his team found that the Charter's policies for data access were difficult to understand, or not well explained. They also found that because the Charter sent data to a Value-Adding Specialist *(see diagram above)* rather than directly to the requester, the end-users they worked with received only static pictures (in PDF or JPEG format), rather than quantitative observations that they could analyze or interpret for themselves. (Brenda Jones, USGS' liaison to the Charter, suggests that this may have been a lack of communication, as the Project Manager can also send the data directly to end users, without generating products from the data.) They also found the process for requesting data through the Charter could be improved: for example, even though a Charter activation requires the submission of latitude and longitude coordinates, they were instructed to specify areas of interest by place-names, which tended to reduce the precision and efficiency of their requests.

Appendix 2: Case Study Questionnaire

What follows is a set of questions intended to be used either in an email exchange or as an interview structure with practitioners in disaster management or risk assessment. They are phrased to pertain to a single event; however with minor adjustments they can be applied to a pattern of events or to concrete activities or capabilities for monitoring, prediction, or analysis.

1. Overview: Please summarize the disaster event in a few sentences, referring if possible to published or online articles (from news media, published articles, Wikipedia, or other sources).

2. Please indicate which organizations or individuals participated in
    - Responding to the disaster
    - Forecasting the disaster, or identifying high-risk times or places *(if forecasting was possible)*
    - Reducing the risk or impact of the disaster *(e.g., evacuating populations, operating alert systems; setting building codes; operating sensor networks)*

3. How did these organizations or individuals interact or collaborate with each other?

4. Who was involved in supplying satellite information to these activities?

5. What satellite information was used *(or needed)* to support these activities? In particular:

- What types of observations?
  (e.g., meteorology / atmosphere; hydrology; seismic changes; vegetation...)
  What other observations might have been useful?
- How frequent were the observations? Were they frequent enough?
- How much detail did these data show? *(pixel size, spectral bands)* Was it enough?

6. What processing was performed on the data before users obtained it?
   (e.g., reformatting files; clipping / joining image scenes; contrast stretching; georectification; interpreting or classifying multispectral pixels, extracting graphics, etc.)

7. How do you think the information support to these activities could have been streamlined? Or, how could these activities have taken better advantage of available information?