A Framework for Disaser Management Support with Space Inputs

(invited paper)

K.V. Venkatachary, B. Manikiam and **S.K. Srivastava**
Indian Space Research Organisation, Bangalore, India
manikiam@isro.org Fax : + 091 80 3415408

Keywords : disaster management, remote sensing applications, search & rescue, data collection platforms, GIS

Overview

1. Introduction
2. Space systems in disaster management – Indian perspections
3. Potential application of satellite data
4. Pilot scale study of Brahmaputra floods for proto-type design of DMS
5. GIS database & applications in disaster management
6. Space-based disaster management support
7. International charter on space & major disasters
8. Conclusion
9. Rererences

1. Introduction

Indian landmass is prone to several natural disasters such as floods, cyclone, landslide, earthquake etc. While the East and West coasts are prone to severe cyclones, most of the major river systems such as Ganges, Brahmaputra are prone to large-scale flooding affecting over 40 million ha every year. The hilly tracts of Himalayas are prone to major landslides associated with heavy rainfall. The super cyclone that hit Orissa coast in Oct. 1999 and the devastating earthquake that affected Gujarat State in January 2001 are some of the recent major events. A statistics of the disaster events shows the alarming trend of increasing damage and economic loss due to increasing population and development activities in vulnerable areas.

An ideal system need to support the activities related to the various phases of disaster management viz., pre-disaster planning, warning and emergency relief and post-disaster recovery. Space based systems from their vantage position have unambiguously demonstrated their capability in providing vital information and services in a disaster situation. Besides providing vital inputs for taking preventive measures through vulnerability analysis, hazard zonation and prior risk assessment at regional and local levels, satellite data have helped in minimizing loss of life/property though advance warnings of severe weather facilitating timely and effective rescue, relief and rehabilitation of the affected population.

2. Space systems in disaster management - Indian perspectives

ISRO ventured into operational remote sensing era with the successful launching of first Indian Remote Sensing Satellite (IRS 1A) in 1988, which was followed by IRS 1B launched in 1991, carrying LISS cameras to provide imageries in four spectral bands with a resolution of 72.5 and 36.25 m. IRS 1C and IRS 1 D satellites that followed incorporated improved LISS sensors with 23.5 m resolution, a middle infrared sensor with resolution of 70.5 m and panchromatic camera with 5.8 m resolution. The microwave payload onboard IRS P4 has capability to provide meteorologic and oceanographic data on an all-weather basis.

The geostationary satellites, INSATs have capability to image on a continuous basis over large areas, which is particularly important for tracking cyclones and measurement of wind vectors. Many of these satellites have also incorporated data collection platforms that can periodically interrogate meteorological information from unattended platforms located in inaccessible and remote areas and transmit them to a central location. The communication systems onboard INSAT support mobile telephony and V-SAT based communications, which are useful in providing emergency support to disaster affected areas. Some of the key applications of Indian satellites are given in **Table 1**.

3. Potential applications of satellite data

Satellite remote sensing permits monitoring of disaster events and assist in damage assessment, providing a quantitative base for relief operations. Following sections briefly summarise the Indian experiences in operational use of satellite data for disaster management.

3.1 Inundation mapping and damage assessment: Mapping of flood-affected areas is one of the most successful applications of satellite remote sensing in flood management. Because of the unique spectral signature, it is possible to map areas under standing water, areas from where flood water has receded, submerged standing crop areas, sand casting of agricultural lands, breaches in the embankments, marooned villages and towns, etc. Using multi-date satellite imageries, the extent of damage due to crop loss, destruction of infrastructure facilities etc., can be assessed. Space technology for flood monitoring and management has been successfully operationalised in India. Near real time monitoring and damage assessment of all major flood events are being carried out operationally. Satellite remote sensing and GIS techniques have been integrated[2] in Brahmaputra river basin to provide information on flooded area and damage to croplands, roads and rail tracks. Global Positioning

Table 1: Key applications using satellite data

Sl. No.	Satellite	Spatial resolution (m)/swath (km)	Repeat cycle (days)	Application areas
1	IRS-1A	LISS-1: 72.5/148 LISS-II: 36.25/148	22	Earth resources, survey and management of resources in areas like agriculture, geology and hydrology.
2	IRS-1B			
3	**IRS-1C**	PAN : 5.8 /70.5 LISS-III : 23.6/141 : 70.8/148 WiFS : 188/774	24	Agriculture, Forestry, Urban, Land use, Soil, Geology, Terrain, Water resources, DEMs, Environment, **Disasters (damage assessment/relief)**
4	IRS-P3	WiFS : 188/ 810 MOS-A : 1570/195 MOS-B : 525/200 MOS-C : 645/192	5	Remote sensing of earth resources, study of X-ray astronomy, periodic calibration of PSLV radar located at tracking stations
5	**IRS-1D**	PAN : 5.8/70.5 LISS-III : 23.6/141 : 70.8/148 WiFS : 188/ 774	24	Agriculture, Forestry, Urban, Land use, Soil, Geology, Terrain, Water resources, DEMs, Environment, **Disasters (damage assessment/relief)**
6	IRS-P4	OCM : 360/1420 MSMR : 120, 80, 40/1360 PAN : <2.5/13	2	Systematic data for Oceanography, Coastal, Atmospheric applications
7	INSAT – 1	Visible & TIR	Continuous	Clouds, CMVs (2 level), SST, QPE, OLR (**meteorological applications**)
8	INSAT – 2	Visible, TIR, WV & CCD		Clouds, CMVs (3 levels), SST WV image, QPE, OLR
9	INSAT – 3	Visible, TIR, WV & Sounder, CCD		Clouds, WV image, SST, OLR
10	METSAT	Visible/thermal, water vapour		SST, Cloud, CMVs, WV, mesoscale, temp./humidity profiles

System (GPS) is being used to aid in the development of a Digital Elevation Model (DEM) for a flood prone area in Andhra Pradesh, to enable assessment of spatial inundation at different water levels in the river. When satellite derived land use/cover and ancillary ground based socio-economic data is draped over the DEM, flood vulnerability can be assessed to provide location specific flood warnings. Remote sensing data are evaluated for integration with existing forecasting models. Also microwave data from RADARSAT is used in conjunction with optical data to overcome the limitation of cloud cover.

3.2 Cyclone monitoring and warning: Meteorological satellites are valuable for monitoring and forecasting cyclones. INSAT/VHRR images are being used to identify cloud systems over the oceans, where no observational data is available, as well as for cyclone tracking, intensity assessment and prediction of storm surges, etc. They need to be supplemented by ground meteorological observations and radar data for accurate assessment of rainfall intensity. An innovative use of INSAT has been in the implementation of the unique, unattended, locale specific Cyclone Warning Dissemination System (CWDS) consisting of over 250 disaster warning receivers installed in cyclone prone areas of the country, designed to provide warning to coastal villages about an impending cyclone. Since the commissioning of DWS and its first operational use for disaster warning in 1987, CWDS has become a vital disaster mitigation mechanism. Current research around the globe is concentrating on use of meso-scale models with satellite data inputs to improve the cyclone intensity and track prediction.

3.3 Drought management: Monitoring and assessments of droughts are required for taking corrective measures at appropriate times to minimize the reduction in agricultural productivity in drought prone areas. Satellite derived vegetation index (VI) which is sensitive to moisture stress is now being used continuously to monitor drought conditions on a real time basis often helping the decision makers initiate strategies for recovery by changing cropping patterns and practices. A remote sensing based National Agricultural Drought Assessment and Monitoring System (NADAMS) for countrywide monitoring in India has been developed. Monthly drought assessment reports are being generated under NADAMS. With the operationalization of IRS-1C WiFS and IRS-P3 WiFS and SWIR bands, in season agricultural drought monitoring capability has been further improvised.

3.3 Landslides: A number of studies have been carried out in India using satellite data and aerial photographs to develop appropriate methodologies for terrain classification and preparing maps showing land hazard zonation. Using GIS techniques, the thematic layers on geology, soils, slope, landuse/cover etc. are suitably integrated to arrive at relative classes of landslide zonation. Such work has been carried out for Garhwal Himalayan region, Nilgiri Hills in Southern India and in the Sikkim forest area. In the Tehri dam reservoir periphery, these imageries have helped in identifying 71 potential landslide areas. Recently landslide zonation maps have been generated for 2000 km stretch of pilgrimage route in sub-Himalayas. The studies are to be supplemented by aerial photographs for high-resolution contour mapping with intervals of better than 2 m.

3.4 Earthquakes: Earthquake risk assessment involves identification of seismic zones through collection of geological/structural, geophysical (seismological) and geomorphologic data and mapping of known seismic phenomena in the region (mainly epicentres with magnitudes). Satellite imagery could be used in delineating neotectonic structures and to clarify seismo-tectonic conditions in earthquake risk zones. Accurate mapping of geomorphologic features adjoining lineaments reveal active movement or recent tectonic activity along faults. Studies carried out earlier have highlighted the correlation between major lineaments and the seismic activity in Latur area in Maharashtra, India. Space inputs provided for the recent Bhuj Earthquake in January 2001 including tectonic mapping of the area using IRS 1C data, emergency communication support and aerial flying of worst-affected towns.

3.5 Forest fires: Satellite imagery in infrared region and ground/aerial photographs have been employed to map areas damaged by forest fires and assess the extent of area that needs to be reclaimed. Thermal infrared sensors on board the NOAA/AVHRR and IRS have been used for monitoring moisture conditions and assessment of forest fire prone areas. The normalized difference vegetation index (reflectance ratio of NIR and IR) were the most suitable to map burnt areas.

3.6 Search & rescue system: An international programme for transmission of distress signals have become operational using transponders onboard Russian and US weather satellites (SARSAT/COSPOS). Doppler tracking using multiple satellite overpasses allows precise (with in a few km) location of a distress beacon. Thus far the beacons have been installed primarily aboard ships and aircraft, so that they may be located in case of an accident. The system may also be of use in disaster relief operations. India is participating in the programme and since INSAT 2A, INSATs have search and rescue transponders. Geostationary satellite while not being able to locate the site of the emergency transmission can relay messages with out delay that might occur in the case of polar orbiting satellites as they are not always in the sight of an emergency.

4. Pilot Scale Study of Brahmaputra floods for Proto-Type Design of DMS

With the vast experience gained through operational use of space data, the concept of a space based observation and communication system for disaster management is being evolved in the country. The most important need is to assess the overall requirements of users at various levels and the delivery mechanisms that could provide the services effectively towards monitoring, forecasting, warning, assessment, prediction and reduction of natural disasters. The information required by disaster managers in each of the critical phase of disaster management, which includes mitigation and preparedness, response and recovery/relief need to be met with. The elements of such a system therefore will consist of: (i) database design (ii) near real time monitoring/mapping (iii) modelling framework (iv) networking solutions and (v) multi-agency interface.

Taking into account the above aspects, a pilot scale study was initiated by ISRO in 1998 to design a proto-type system that will integrate space inputs with conventional data. The study area selected was Brahmaputra floods in Assam. The system consisted of comprehensive database design, space-based near real-time monitoring tools, modelling framework, networking and user interface. With appropriate synthesis of these core elements, flood monitoring and damage assessment was carried out during 1998-2001 for selected districts in Assam. A typical satellite based flood map at district level showing marooned villages is shown in **Fig.1**. Through use of networking, the space-based inputs were disseminated to the users. The study has led to a realistic assessment of the gaps in the current system and conceptual framework for disaster management system.

5. GIS database & applications in disaster management

The success of disaster management largely depends on availability, dissemination and effective use of information. The information needs include current information on weather, infrastructure (roads, hospital, administrative boundaries), demography etc. to assess the disasters. Currently such data are being generated by multiple users and stored in multiple formats and media making it difficult to bring the data together to support disaster management activities. In addition there is a need to assess the disaster in terms of location, extent and likely impact so as to plan relief and recovery actions. An integrated system adequately equipped with necessary infrastructure and expertise to constantly monitor the risk profiles on all possible disasters and maintain a national database will become relevant. In this context, the GIS technique offers a tool to analyse multiple layers.

Database is crucial for the information generation for disaster management. The success of disaster management largely depends on availability, dissemination and effective use of information. The information needs include current information on weather, infrastructure (roads, hospital, administrative boundaries), demography etc. to assess the disasters. Currently such data are being generated by multiple users and stored in multiple formats and media making it difficult to bring the

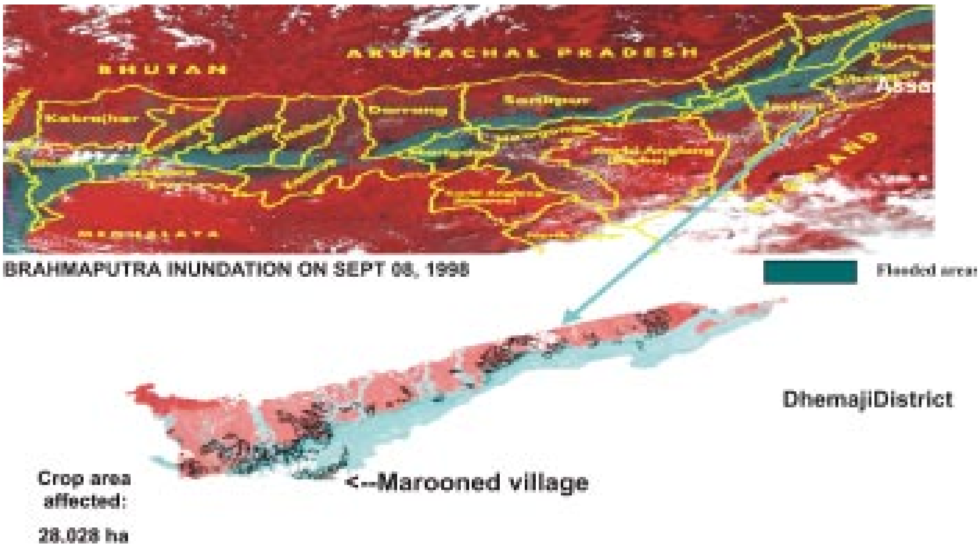

Fig. 1 : MONITORING OF BRAHMPUTRA FLOODS IN ASSAM

data together to support disaster management activities. In addition there is a need to assess the disaster in terms of location, extend and likely impact so as to plan relief and recovery actions. An integrated system adequately equipped with necessary infrastructure and expertise to constantly monitor the risk profiles on all possible disasters and maintain a national database will become relevant. In this context, the GIS technique offers a tool to analyse multiple layers. The critical thematic layers required for various disasters are given in **Table 2**.

Table 2: GIS layers for various disasters

Thematic layers **Disaster**	**Landuse/ Cover**	**DEM/ DTM**	**Hydro-Geomor-phology**	**Soils**	**Geology/ Tectonics**	**Watershed/ Drainage**	**Isohydal**	**Admin. Boundary**	**Infra-Structure**
Drought	1	3	1	1	-	1	1	1	1
Flood	1	1	3	2	-	2	1	1	1
Cyclone	1	1	3	3	-	3	2	1	1
Landslide	2	1	1	1	1	2	1	1	1
Earthquake	2	3	1	2	1	2	3	1	1
Forest fire	1	3	3	2	-	-	1	1	1

Priority : 1 - Highest priority; 2 - Medium priority; 3 - Low priority

6. Space-based disaster management support

With the vast experience gained through several studies and operational use of space data, a space based disaster management support is being evolved in the country. The crucial elements of this Decision Support Centre (DSC) are conceived as (i) database design (ii) near real time monitoring/mapping (iii) modelling framework (iv) networking solutions and (v) multi-agency interface.

The key aspects of the DSC are:

- Satellite/aerial data acquisition strategy
- Turn-around-time for analysis and output generation
- User required information and formats
- Dissemination to users and networking
- Availability of resources, database, close contour etc,

6.1 Core elements of DSC: The mechanism encompasses several capacity building measures viz., establishment of a Decision Support Centre (DSC) interfacing with National/State disaster management systems, re-organizing the infrastructure for the real time and the conjunctive use of aerial and satellite services, and supportive R & D efforts. A schematic giving the proposed interface mechanism is given in Fig. 2. Finally, DSC will evolve as a single-window information service provider to start with, while the long term vision is diffusion and internalisation of space applications to the line departments.

The brief details of the core elements of the Decision support Centre are as follows:

- **Creation of digital database**

This is an essential element towards generating the information required by users at the Central and State levels. The database consisting of various thematic layers such as landuse/cover, topography, hydro-geomorphology etc. needs to be created which can be used to overlay disaster related information from satellite/

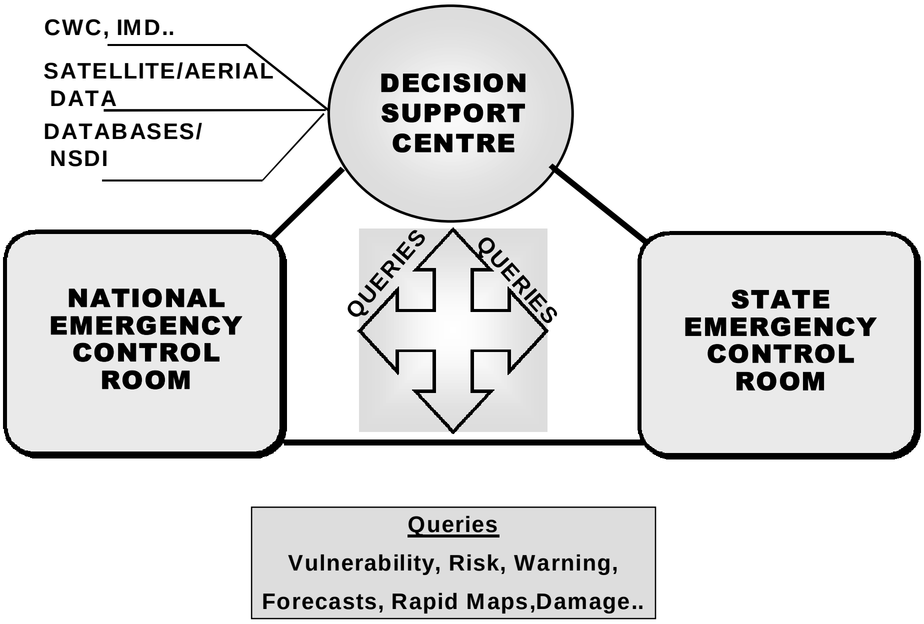

Fig. 2. Decision Support Centre (DSC) Institutional Mechanism towards Info Support for Disaster Management.

aerial data and assess the extent and impact of disasters. The major steps involved in creation of the database are: generation of base maps, generation of spatial data on themes from satellite data analysis, collection and compilation of non-spatial data and creation of district-wise GIS database. The areas to be covered for database creation consist of several priority districts in the country that are prone to various disasters. The database created will contain information in the spatial domain in the form of thematic layers and non-spatial domain to socio-economic infrastructure data and resource attribute parameters. The databases with in a State will be suitably networked using existing network facilities and also to the central co-ordinating agency for use in the event of disasters. Already substantial work towards database development has been done under various projects which has to be compiled and the additional requirements have to be executed. A common projection system has to be adopted so as to avoid incompatibility problems.

- **Creation of close-contour information**

Contour information is essential for spatial analysis and also for planning mitigative measures. Currently available contour data (at 20 m resolution) is inadequate to carry out such analysis. Close contour information (with sub-meter accuracy) is required to be generated for large parts of the flood-plains and cyclone affected coastal areas. The laser terrain mapping system will be used for generation of close-contour information over large areas.

- **Query shell development**

The query shell development is needed so as to reach the data and information in a user-friendly format to the end-users. The query-shell will be organised so as to integrate spatial and non-spatial data and with capability to select area of interest, view selected layers, overlay one layer over another, simple and complex querying, multi-thematic query, tiled displays, display options with zoom/pan etc., statistical evaluation, morphometric analysis etc. Thus the query system will assist the users and administrators in decision making and impact assessment.

- **Networking**

This is a very key element in the effective use of information in the disaster management. Suitable networking of data generators, technology providers and administrators is essential. Using the existing communication links including web enabled technologies, an effective networking system has to be developed.

- **Research and development efforts**

These efforts will be concentrated on two key areas, namely, modelling techniques for improved forecasting and use of new sensor data. Satellite inputs that are required for modelling will be identified and efforts made for assimilation of these inputs in the models being used by agencies. Specific studies will be mounted to assess the impact of satellite data. Use of data from new sensors/missions is also proposed.

- **Networking scientific institutions**

Disaster management being a multi-agency task, needs the coordination and support of several scientific organisations to achieve success. A suitable mechanism will be evolved for networking scientific institutions and for closer interaction to improve disaster related services.

ISRO/DOS is building up the necessary men and machine to operationalise DSC with the active support from other agencies. DSC will evolve into an integral part of the National Response Mechanisms for Disaster Management in the country.

7. International Charter on Space & Major Disasters

Considering the potential contribution that space can provide to the prevention and mitigation of natural disasters, an initiative was launched by ESA and CNES in the year 2000, namely the International Charter on Space and Major Disasters. ISRO has joined the Charter in September 2001, after due governmental approval. Currently, NOAA and Canadian Space Agency are the other members of the Charter, in addition to CNES and ESA. The Charter is aimed at efficient use of space technology in disaster management through developing long-term working relationship between civil protection authorities and space agencies. In the event of a major disaster, the member countries interact and decide on the best way to provide critical information based on space inputs. The support to the Charter by the members is voluntary and limited to the availability of requisite resources. In order to support participation in the International Charter and provide required inputs in a timely manner, appropriate mechanisms are being established in ISRO.

8. Conclusion

The recent developments in space technology in terms of communication and remote sensing has led to improved capabilities to support disaster management. In several areas such as cyclone monitoring, flood mapping, landslide zonation etc. satellite remote sensing has become operational. The emergency communication and warning systems have become an integral part of disaster management. The future thrust areas are improved forecasting through use of models, networked systems for on-line decision support and advanced communication systems for warning and relief.

9. References

[1] Kasturirangan, K., Chandrasekhar, M.G., Nageswarara Rao, P.P., Srivastava, S.K., Ganesha Raj, K., and Sebastian, M., in Proc. United Nations/ IAF Workshop, 28 Sept. – 1 Oct. 1995, Oslo, Norway, pp. 135-166.

[2] Venkatachary K.V., K. Bandyopadhyay, V. Bhanumurthy, G.S.Rao, S. Sudhakar, D.K. Pal, R.K. Das, Utpal Sharma, B. Manikiam, H.C. Meena Rani & S.K. Srivastava, Defining a Space-based disaster management system for floods : A case study for damage assessment due to 1998 Brahmaputra floods, Current Science, Vol. 80 (30), pp. 369-377, Feb. 2001.