United Nations Economic and Social Commission for Asia and the Pacific

A POLICY FRAMEWORK TOWARDS ENHANCING THE OPERATIONAL UTILIZATION SPACE INFORMATION PRODUCTS AND SERVICES FOR FLOOD MANAGEMENT IN ASIA THE PACIFIC

Study report synthesizing the recommendations of the Meeting of Experts on Policy Framework on Space Information Products and Services for Disaster Management, Beijing, 17-19 November 2004

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I. Utilization of Space Information Products and Services for Flood Management in Asia and the Pacific

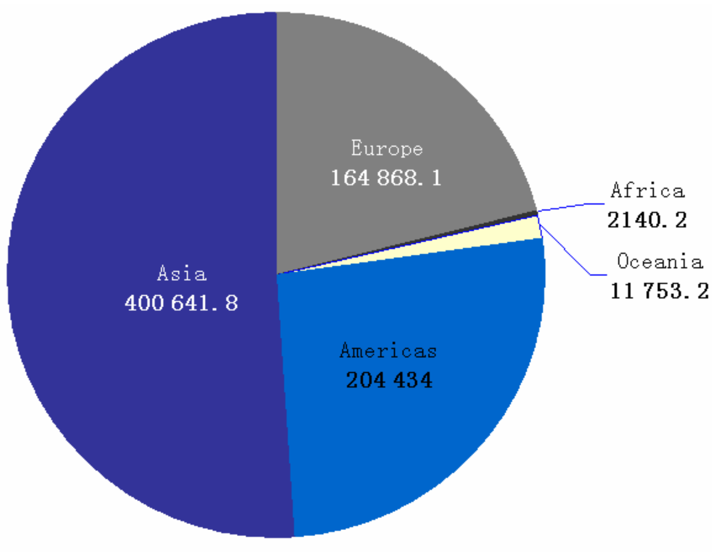
1. Floods in Asia and the Pacific

United Nations statistics show that losses caused by natural disasters in the world totalled US$40 billion in the 1960s, US$60 billion in the 1970s, and US$120 billion in the 1980s (CAST n.d.). Global disaster statistics for 1996-2000 revealed staggering economic costs estimated at US$235 billion and 425,000 lives lost (IFRC 2000). Asia and the Pacific are among the most disaster-prone regions in the world. Every year, disasters of all kinds result in huge loss of lives and property in the region, causing severe setbacks to the development process. Asia bears much of the brunt, absorbing 80 percent of the total number of affected persons, 40 percent of total deaths, and 46 percent of the total economic losses (CRED n.d.). What is more, the secondary effects and indirect costs of disasters have also caused long-term effects on societies, regardless of their level of development.

In absolute terms, the recorded economic cost of disasters has been increasing over decades. The World Disaster Report for 2002 estimates the annual average damage due to natural disasters at US$69 billion. Two thirds of those losses were reported from countries with low socio-economic development.

Figure 1.1 shows economic losses counted by region, for disaster events triggered by natural hazards between 1991 and 2000. The unequal distribution of impacts is clear. Asian countries experience the greatest economic losses from disaster, with flood being a common hazard in this region, and human development may be even more at risk here than these data suggest (UNDP 2004).

Of all natural disasters, floods are considered the most severe. As floods often appear in the middle and lower basin of main rivers, which normally are important economic areas with high population density, they cause the most economic loss and affect the most people. Among the losses caused by natural disasters in the whole world in 1991, the ones that arose directly from flood accounted for 44 percent (CAST n.d). About 196 million people in more than 90 countries were found to be exposed, on average, every year, to catastrophic flooding (UNDP 2004).



(*Source*: EM-DAT: The OFDA/CRED International Disaster Database)

Figure1.1: Total amount of disaster damage between 1991 and 2000 in millions of US dollars

Table 1.1 presents a basic comparison of the intensity of flood disaster effects in Asia and the Pacific region; flood disaster records were analysed for 22 countries in the Asia-Pacific region, where 14 countries are severely affected by floods; five are moderately affected; and only two suffer relatively little.

Table 1.1: Relative intensity of flood disasters faced by some countries in the region

Country	Flood	Country	Flood
Australia	S	Nepal	L
Bangladesh	S	Pakistan	M
China	S	Philippines	S
Cook Islands	L	Papua New Guinea	S
Fiji	S	Sri Lanka	S
India	S	Viet Nam	S
Indonesia	M	Solomon Islands	S
Lao PDR	M	Tonga	M
Malaysia	S*	Vanuatu	S
Myanmar	M	Samoa	S

S: Severe; M: Moderately Severe, L: Low; S*: Coastal Flooding
(*Source*: IFRC 2000)

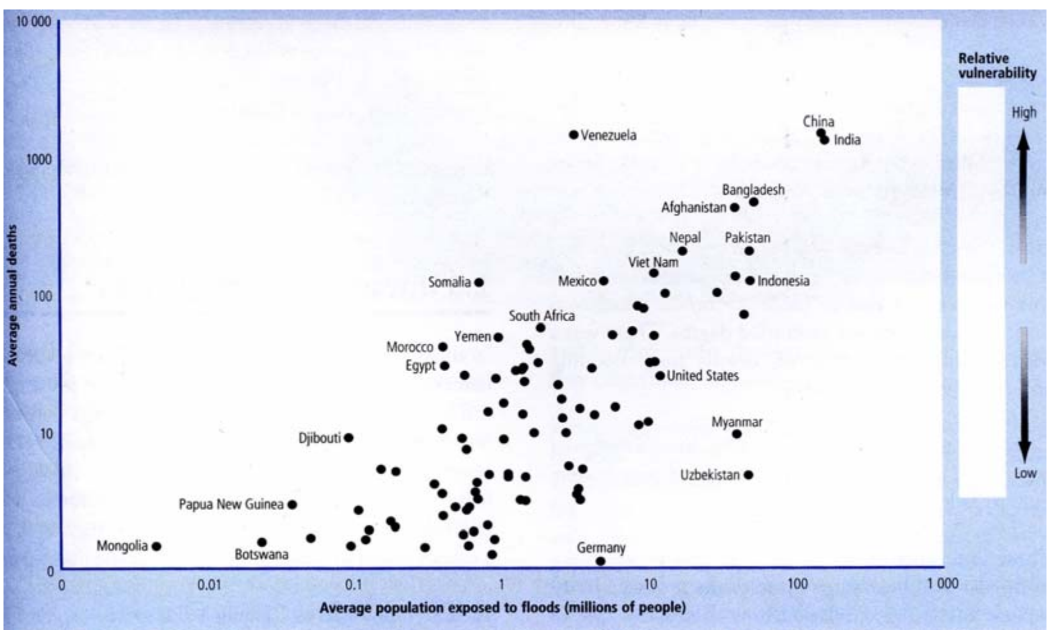
Table 1.2 shows statistics of the 2002 flood disasters, which indicate that losses caused by floods are quite enormous in Asia and the Pacific, especially in Bangladesh, China, India, Thailand, Viet Nam and several others.

Table 1.2: Floods in countries in the Asian and Pacific (2002 summary)

Country	No. of Floods	People Killed	People Affected	Property Damage (in US$) millions
Bangladesh	1	10	1,500,000	
Cambodia	1	29	1,470,000	
China	10	1,228	113,255,696	5,236,680
India	6	732	42,005,250	30,772
Indonesia	7	230	133,180	16,000
Korea, Rep	1	20	27,507	173,224
Lao PDR	1	2	74,500	
Myanmar	1	21	50,000	
Philippines	4	85	150,567	392
Russia	4	174	336,313	507,970
Sri Lanka	1		500,000	
Tajikistan	4	32	4251	2,836
Thailand	2	154	3,290,920	35,827
Viet Nam	3	207	1,514,816	43,500

Source: <www.adrc.or.jp/>.

Figure 1.2 shows a range of countries with higher human vulnerability to floods than countries in other continents (UNDP 2004). In Asia and the Pacific, some countries suffered seriously from flooding, such as Afghanistan, Bangladesh, China, India, Indonesia and Pakistan.



(*Source*: EM-DAT: The OFDA/CRED International Disaster Database and UNEP/GRID-Geneva)

Figure 1.2: Relative vulnerability to floods, 1980-2000

2. Major Characteristics of Floods in Asia and the Pacific

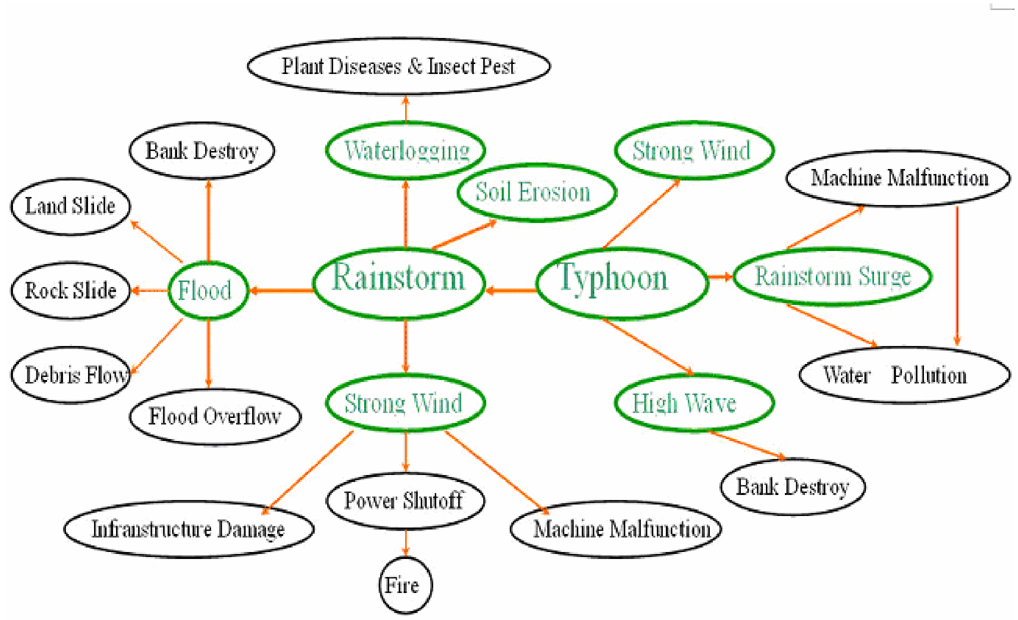
The causes of floods are varied, such as typhoons, monsoons, hydrology and so on. Generally, floods depend on two factors (Wu Hualin and Shen Huanting 1999): one is the degree of time and space distribution; the other is the capacity and ability of the geo-biosphere system (including rivers, lakes, reservoirs, vegetation and soil) to cope with the load. The quality of the geo-bio factors in preventing flooding has an extremely close relation with human activities, such as deforestation, reclaiming wasteland, enclosing lakes, building dams and so forth, which change the original appearance and function of the geo-biosphere directly. Human activities also have influences on the first factor; for example, the use of Freon causes greenhouse effects, which cause abnormal changes in the climate. We can divide the causes of flooding into two aspects: natural causes (uncontrollable at present) and man-made causes (which can be improved at present).

The forms of flood occurrence involve primarily flash floods and river-basin floods, and in some situations, windstorms and tidal surges can also cause floods. Their totally different flood management mechanisms need different space information products and services.

Asia, especially East Asia, South-East Asia and South Asia, suffers from monsoons and typhoon/cyclone-related floods. Meteorologists find that as an important component of the global climate system, the monsoon in Asia has a very close relationship with ENSO, temperatures in the northern hemisphere, Eurasian snow overlays, and other factors. In summer, while the break and development of the southwest monsoon can bring abundant rainfall to this area and alleviate the hot weather, it often causes destructive floods and serious drought as well (Li Xiaoyan 1997).

The Indo-China peninsula is hit by frequent monsoons, typhoons and rainstorms. The drought and flooding in East Asia are part of an intricate system. The most serious flooding usually happens in the flood season, which is influenced by the wet monsoon in East Asia. The “plum rains” in the midstream and downstream parts of the Yangtze River are an important aspect of the monsoon activities in East Asia, which sometimes lead to flooding in this region (Li Xiaoyan 1997).

Usually, the impacts of flooding are not one-sided but include many kinds of incidental disasters, such as mud and rock flows, landslides, structure collapses and so on, thus building up a great disaster chain. These incidental disasters cause great losses to local economic development in this region; figure 1.3 illustrates the disaster chain.



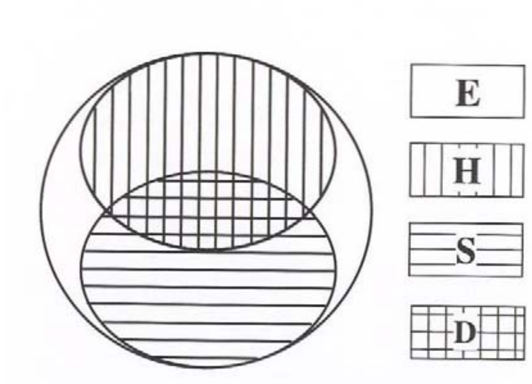
(*Source*: Atlas of Natural Disaster System of China 2003)

Figure 1.3: Disaster chains

3. Space Information Products and Services for Flood Preparation, Early Warning, Monitoring, Assessment and Relief

3.1 Introduction

Living in the geo-biosphere environments, we inevitably suffer many adverse effects from natural disasters, which can be regarded as a great system. This great disaster system consists of several factors: hazard-formative environments (E), hazards (H), hazard-affected bodies (S), and disaster effects (D). Disaster effects involve casualties and psychological impacts, direct and indirect economic losses, collapse of buildings, and damage to the ecological environment and resources, to mention only a few (Atlas of Natural Disaster System of China 2003). Figure 1.4 shows a disaster system.



(*Source*: Atlas of Natural Disaster System of China 2003)

Figure 1.4: Disaster system

In order to get enough information to support disaster management, the three key aspects of disasters – H, S and D – should all be monitored. Space information technology, especially remote sensing technology, can do this task effectively. It has many advantages for disaster monitoring other than routine methods.

The applications and sharing of space information products and services in flood management require the joint efforts of space information providers, local service providers and end-users at different levels.

Space information providers (including satellite operators) hold the top level of space technology applications in flood management, and may offer many useful kinds of data and services for less developed and least developed countries (LDCs), which involve many interim and final products and services, such as remote sensing and geographic information system data of different temporal and spatial resolutions, application models and flood management information systems and so forth. They can become the strong backup force of flood management.

Local service providers offer technological support and application guidance for local flood management, and they need original data or interim products from space information providers. Interim products and services are processed into final forms for end applications, and they need data guarantees from providers.

Flood managers and administrators are the end-users of space information technology applications, and they need final products for direct application. What will be used by end-users are those decision-supporting models and tools developed on the information platform.

The relation between space information providers and end-users is indicated in Figure 1.5; space information providers offer interim products and services for local services providers, and final products and services may be offered by space information providers, but mainly by local service providers.

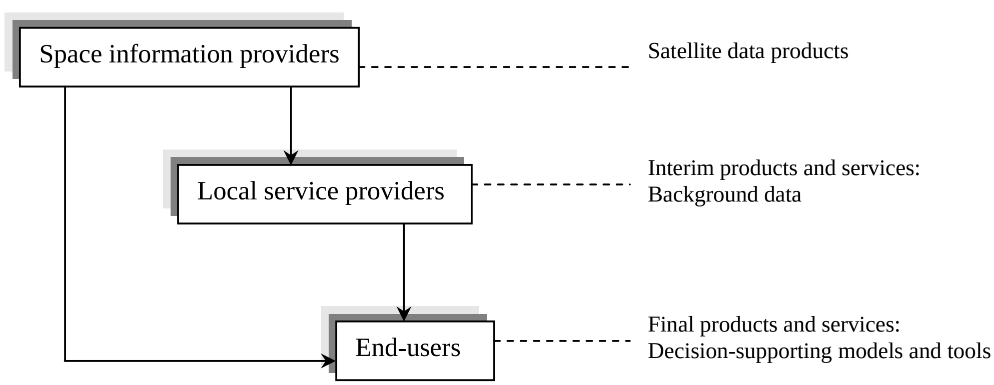


Figure 1.5: Relation between product and service providers and users

3.2 Space Information Products and Services for Flood Management

The operational satellite images have different spatial resolutions, spectrum resolutions and temporal resolutions. They can be used in different stages of flood management.

3.2.1 Low-resolution satellite images (1km-4km)

Currently, most of the low-resolution satellites used for flood management include meteorological satellites, whose resolutions are generally over 1 km (Appendix III). The two kinds of meteorological satellites operating at present are polar orbit and geostationary meteorological satellites. Meteorological satellites have long been used to support forecasting of intensive weather hazards such as tropical cyclones, severe storms and flash flooding. Hurricanes and storms that form in tropical oceans have been monitored successfully every year since meteorological satellites came into use, and no cases have been omitted (Chinawater 2004).

Rainstorms, which are the most direct cause of flood disasters, can be seen in photographs of clouds (nephograms) taken from meteorological satellites. Precipitation and areas likely to receive heavy rainfall can be predicted by nephograms. The strength of a storm, its movement and route, and debarkation time and site can be predicted by satellite nephograms, so alarms can be put out 24 hours - 48 hours ahead and people and important establishments in the endangered area can evacuate, so casualties and property loss can be reduced significantly (Chinawater 2004).

There are three main functions of meteorological satellites in flood management: (a) they can monitor and potentially catastrophic weather, thus allowing meteorologists to give out early warnings, so that defences can be set up and evacuations started; (b) weather data, which can provide the important parameters necessary for hydrological models, can be retrieved from real-time monitoring of weather conditions during the flood period, so some dependable scientific proof can be provided for studying the development and evolution of the disaster; and (c) although the meteorological sensors cannot penetrate cloud cover, observations are possible from other satellites, which pass over the area at different times every day and may avoid clouds. Furthermore, the thermal infrared channel can be used for monitoring the disaster-affected area and obtaining information on the flood.

More than 130 meteorological satellites have been launched, and they send images and meteorological data to the ground day and night. With the harmonizing efforts of the World Meteorological Organization (WMO), an operational observation system of meteorological satellites has been built up, composed of polar orbiting meteorological satellites and geostationary meteorological satellites; the system can provide relative observational data free to any country in the world (Xinhuanet 2002).

3.2.2 Moderate-resolution satellite images (100m-1km)

The moderate-resolution satellite images, with resolutions between 100 m and 1 km are used mainly for Earth observation. There are two principal ways to use moderate-resolution images in flood management:

(a) Preparation for floods: These satellites have become the main resource for building large-scale background databases because, with their moderate resolution and their spectrum range, information is abundant. Small-scale (1:1,000,000) background databases can be built using these satellite images.

(b) During the flood: The moderate-resolution satellites generally pay return visits in a relatively short time (from 12 hours to 3 days), so they may avoid some of the cloud and mist, and they may observe the disaster-affected area at more frequent intervals, thus offering more data about the developing state of the flood.

The MODIS sensor offers many spectrum channels (36 channels) and a choice of spatial resolutions (250 m, 500 m, 1000 m); the Wide Field Sensor (WiFS) of Indian IRS-1C/1D can offer a spatial resolution of 188 m; the Ocean Colour Monitor (OCM) of the Indian marine satellite (Oceansat, also called IRS-P4), SeaWiFS of SeaStar (OrbView-2) and VEGETATION sensors of SPOT-4 and 5 can offer continual observation over a large range. The Wide Field Instrument (WFI) of CBERS-1 has a wider scanning ability in the visible light band, so the Earth’s surface can be observed at high repetitive rate in a short period of time (Appendix IV).

In addition, the land and water boundary in radar images is very obvious, so radar can be used for monitoring large areas. Envisat can provide a resolution of 150 metres (wide scanning mode) and 1 km (global scanning mode). The Wide mode of Radarsat ScanSAR can offer a spatial resolution of 100 m, as well.

3.2.3 High-resolution satellite images (5m-100m)

High-resolution satellite images are images with 5m-100m resolution. The resolutions of these satellites are suitable for each stage in flood management:

(a) Preparation before floods: Satellite images with high resolution can be used in the building of the background databases, for instance, extraction of land use/cover, normal water body extent, vegetation distribution, cities, towns and some important infrastructure (roads, dams, etc.). The depth of water, water quality, and shoals and topography under water can be drawn by using these images’ spectral information, so these images can be used for reflecting the state of deposit piling up and spreading in the river mouth and river channels. Furthermore, some images can be used in the generation of digital elevation models (DEM) (Appendix VII). The depth of the flood can be estimated and the trend of the flood can be predicted based on the dynamic simulation of terrain and situation of flood-submerged areas;

(b) Monitoring and loss assessment during floods: Images with high resolution are generally used for abstraction of the water body boundary, observation and location of landslides, monitoring of damage to important facilities, etc. The visible and infrared images will be very favourable for flood monitoring and assessment of flood damage if they can be obtained during the disaster period. But these satellites generally have a longer period of return, and often clouds and mist build up during a disaster, so visible light images are not so practical. Remote sensing with radar can retrieve data all day and all night long under all weather conditions, and radar can penetrate some surface features, so it is a most efficient method of monitoring floods. Many satellites equipped with radar sensors pass over areas at complementary periods, so they can observe the same area in succession. So during a flood, radar images are often used to carry out the detection of water bodies, thus drawing the extent of flooding, and they can be used for monitoring and assessing some important facilities (such as roads, bridges and dams) and essential, “lifeline” systems (traffic system, electric power system, water supply system, post and telecommunication system, etc.).

(c) Loss assessment after the flood: It is used for assessing losses and evaluating the effect of the relief efforts.

Land resource satellites (Landsat-5 and Landsat-7), the charge-coupled device (CCD) and multi-spectrum sensor of CBERS-1, Indian IRS-1C, IRS-1D, IRS-P6 (also called Resourcesat-1), and the ASTER sensor on SPOT-4 and SPOT-5 can offer high-resolution images (Appendix I and Appendix V).

As for microwave remote sensing images, ERS-1/2, the Fine mode of Radarsat-1, Envisat/ASAR, and the Fine mode of ALOS/PALSAR also can offer high-resolution SAR images (Appendix II and Appendix V).

3.2.4 Very-high-resolution satellite images (less than 5m)

Very-high-resolution satellite images can be used in each stage of flood management:

(a) They can be used in the construction of background databases during the preparation for floods. These images are used mostly for investigating the situation of the population, architecture, houses, lifeline systems and important facilities, extracting such information to prepare for quick assessment during the flood and for evaluation after the disaster. Furthermore, we can acquire highly accurate DEM based on these images and precise ground control points (GCPs).

(b) Monitoring and assessment during the flood: They are used primarily in the monitoring and evaluation of the population, buildings, important facilities and lifeline systems.

(c) Precise assessment after the disaster: We must assess the losses to the lifeline systems and important structures after extracting information on the extent of the flood. Furthermore, we also need to evaluate the effect of relief efforts after the disaster, and the safety of areas for transferring the people who survived the disaster. The very–high-resolution images are necessary to fulfil these needs.

The following satellites and sensors can provide very-high-resolution images: the panchromatic band of SPOT-5, multi-spectrum and panchromatic band of Ikonos, multi-spectrum and panchromatic image of QuickBird, panchromatic band of IRS-1C and 1D, panchromatic image of EROS satellites, and SPIN-2 of Russia (Appendix VI).

These very-high-resolution images can be used for extracting information on important facilities such as construction, roads, bridges and dams. We can evaluate the damaged conditions of lifeline systems, and, what is more, we can obtain DEM, ortho-images and other data products (Appendix V and Appendix VI).

These very-high-resolution satellite images have very high value in the management of floods. But the price of these images is quite high and the revisit time is rather long. As a result, it is difficult to make effective use of these products now.

Now many commercial and non-commercial entities (Appendix IX) can provide satellite products and remote sensing services (Appendix I and Appendix VIII). However, most of them produce images for general applications, so they need to be processed further before flood disaster managers can use them directly. Only some of these entities can provide space information products and services for floods to end-users, which is far from meeting all requirements of disaster managers, even though we have many remote sensing satellites.

3.3 Non-commercial and Commercial Space Information Products and Services for Flood Management

Space information technology has been applied in flood management, not only for research but also for operations in certain areas.

SERTIT Rapid Mapping Service in France has been involved in rapid mapping for 19 major disasters since 1999. When a natural disaster occurs, the Rapid Mapping Service provides the organization in charge of major risk management (ministries, civil defence, local authorities, United Nations, NGOs, etc.) with readily exploitable maps. Within eight hours, the Service converts satellite images of the disaster area into a map showing the geographical extent of the damage.

Depending on available data, the Service may produce some value-added products, such as detailed maps of smaller areas, maps indicating the intensity of the event, a statistical summary of the damage, and others. As regards the "post-crisis" analysis of an event, it also provides maps to the services in charge of issuing the natural disaster declaration, so victims may be eligible for compensation.

At the client's request, space agencies launch the acquisition of data relating to the area to be mapped. The countdown starts as the Rapid Mapping Service team receives satellite images.

Remote Sensing Technology Application Centre of China is responsible for developments in the application of remote sensing and geographic information system technology in water resources management sectors. It provides services, especially for information acquisition and the establishment of databases for flood control and drought prevention, disaster mitigation and rescue, investigation of water and soil resources, environmental monitoring, irrigation and drainage, planning, construction and management of water projects and so on (RSTAC n.d.).

The Centre can provide rapid flood monitoring and assessment services, such as data sources for flood monitoring (including Landsat TM, ETM+, SPOT CBERS, Radarsat, ERS-1/2, Envisat, ADEOS, MODIS, NOAA, FY-1/2) and results of flood disaster monitoring and assessment. The rapid flood mapping will be finished within two hours after receiving a remote sensing image; a primary disaster assessment will be finished within six hours; and the result of disaster assessment is transmitted to the State Council and State Headquarters of Flood Control and Drought Relief by communication satellite within 12 hours after getting a remote sensing image.

National Satellite Meteorological Centre (NSMC) of China (Fang Zongyi et al.**)** has two major tasks: rainfall estimation and flood area monitoring with meteorological satellite data. For the first task, NSMC developed a rainfall estimate technique using meteorological satellites data (NOAA, GMS-5 and FY-2 geostationary satellite). The systems have been installed in 60 Middle Scale Data Utilization Stations in over 28 provinces and they are put into operational use during the flood season.

As an example of the second task, NSMC closely monitored floods with the data from NOAA satellites and provided much useful information to the related government departments during the severe flood of China in 1998. Based on the continuous monitoring with the NOAA/AVHRR data from May to October of 1998, NSMC could calculate the size of water bodies.

In Germany, **the Centre for Satellite Based Crisis Information (ZKI)** of the Applied Remote Sensing Centre (CAF) of the German Aerospace Centre (DLR) is engaged in the acquisition, analysis and provision of satellite-based information products on natural disasters, for humanitarian relief actions and in the context of civil security (DLR 2004).

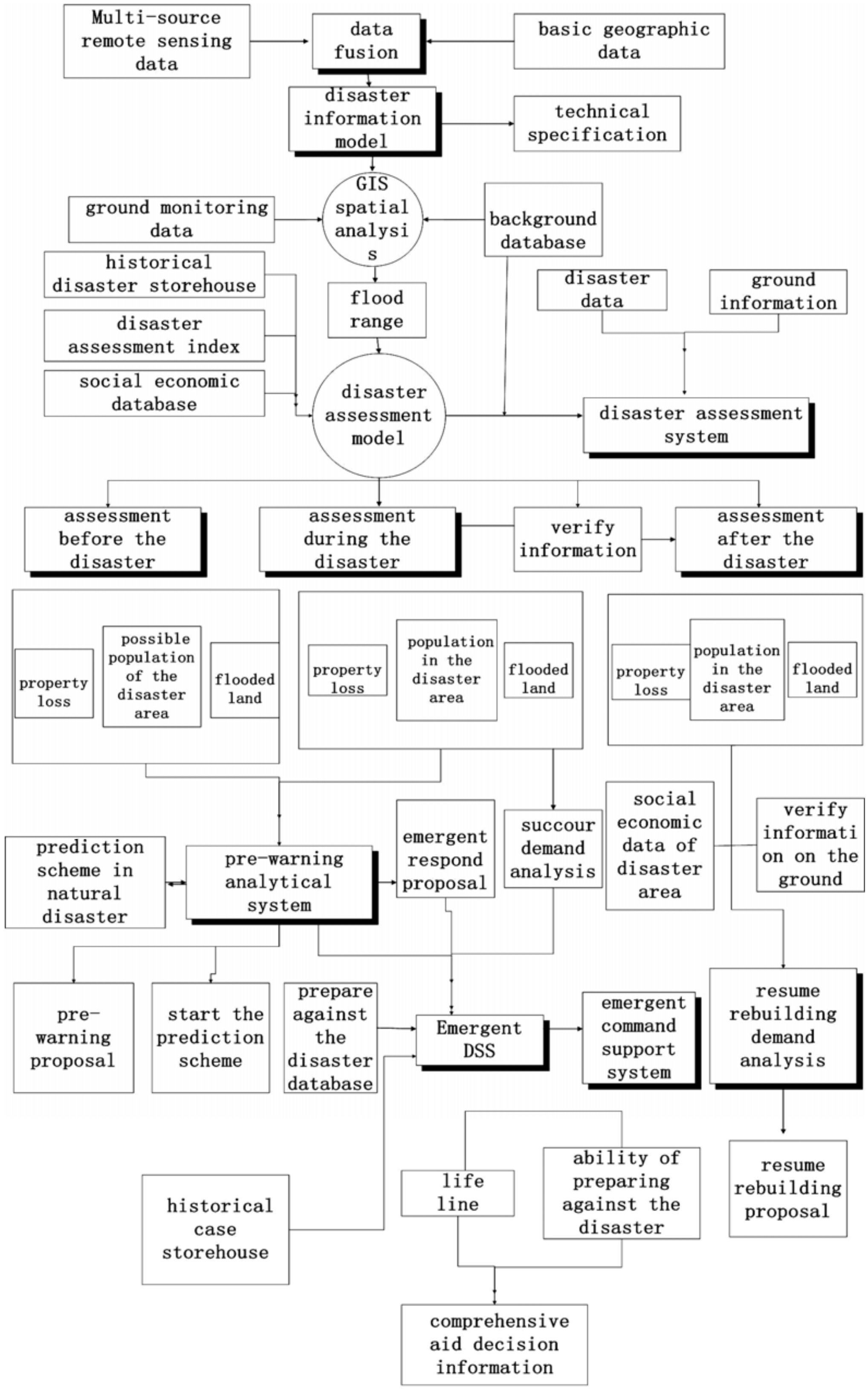
Aside from response and assessment activities, ZKI focuses on geo-information for medium-term rehabilitation, reconstruction and prevention activities.

DLR participates in the International Charter on Space and Major Disasters, which is a major cooperative activity in the context of natural and man-made disasters. In case of a natural disaster in Germany, and where required globally, ZKI coordinates the acquisition and analysis of satellite imagery as project manager within the scope of the International Charter.

(For more information on non-commercial and commercial entities providing space information products and services for floods, please refer to Appendix IX.)

3.4 Technical Guidance for Operational Provision and Utilization of Space Information Products and Services for Flood Management

Flood management includes many techniques for reducing flood hazards, such as land use planning, floodplain restoration, flood warning / emergency response, and public education. Space information products and services can be used in each stage in flood management, as shown in Figure 1.6.



(*Source*: Jiqun Zhang et al. 2002)

Figure 1.6: Flowchart for flood management

3.4.1 Preparation for floods

The most practical contribution of space information to flood management is in the area of preparation. This phase includes some detailed stages, such as risk assessment, mitigation and preparedness. All these types of information should be integrated in information systems at different levels. It is not practical to rely on complicated technical systems for real-time/quasi-real-time data acquisition, processing, delivery and dissemination.

Nowadays, many space information products and services have already been applied to flood preparation successfully; meteorological satellites and land resource satellites (including those providing optical and radar data) are often used in preparations for disasters.

The background database is very important for each stage in flood management. It is the major part of the information system, and it is the most important one in flood preparation, as well. It is the technical platform for informed, or knowledge-based, disaster management; meanwhile, it can offer necessary parameters for building a meteorology and hydrology model. With use of the database, risk assessment and mitigation planning could also be conducted. Meteorological satellites and land resource satellites (including those with optical and radar data, such as Landsat, SPOT 1-5, Ikonos, Radarsat, ERS and Envisat) may offer the required products; they have data at different resolutions for different objects, such as MODIS or ETM (Landsat) for land use and land cover, and Radarsat or Envisat for water bodies.

The aim of the water body background database is to extract the normal water body range, which will be used to get the extent of the flood area. Utilizing both the satellite images of the flood and the normal water body range, we can monitor and assess the development and the change of the flood. The land use/cover background database, which normally is established by remote sensing, is very useful for loss assessment during the disaster, such as planning disaster relief schemes and rebuilding after the disaster, along with many other activities.

The analysis of a flood disaster requires socio-economic characteristics. The thematic information is closely related to human activities, such as residences, key facilities, and land use. Various data, including remote sensing data, are needed in order to build up socio-economic and statistical databases.

The digital elevation model (DEM) is one of the most important parts of the background databases, and it is one of the essential parameters for the hydrology model, too. In addition, many kinds of products can be derived from a DEM, such as aspect, slope, slope length, 3D model, density of drainage networks, etc. Supported by GIS, and making use of the remote sensing images, map information, socio-economic information and DEM during the disaster, we can simulate the situation of the flood dynamically, analyse and predict the flood trend, and offer a basis for decisions on a scientific flood prevention scheme. The DEM provides the foundation for calculating the inundated area and estimating the depth of the flood.

The precision of the DEM will directly affect the precision of the data on the flood area. The DEM background database may be based on the local topography maps; some large-scale maps may satisfy the need for different spatial resolutions, such as 1:50,000, 1:10,000, 1:5000 or 1:2000-scale topography maps. The second approach to building a DEM background database is directly interpreting from the stereo pairs of remote sensing images.

For instance, SPOT data agents may offer stereo pair images for extracting high-resolution DEM data.

The construction of background databases will benefit greatly from the value-added products. For example, if space information providers or local service providers offer DEMs generated from satellite images (SPOT, Ikonos, Radarsat etc.), it is more useful and easier to apply than stereo pairs. Now, most such DEMs are produced locally, so providing appropriate interim products and services is a recommended strategy for local service providers who wish to produce DEMs. Because of the lack of appropriate capacities in less developed countries, appropriate interim products and services for local service providers at different development levels are very important. Space information products and services can contribute a great deal of relevant information when combined with other technical measures and information sources. These information systems could be operated by end-users' technical supporting teams or by independent local service providers.

Another possibility is to provide flood risk maps instead of satellite images. It may increase the information capacity, and at the same time, the information mass will be decreased greatly, and these maps could be delivered through the Internet.

3.4.2 Early warning before floods

Early warning represents a cornerstone of flood disaster reduction, and it needs more international/regional cooperation. There is no country that would deny that it may need other counties' satellite data. For this purpose, a generally agreed set of products and services is very important for the local service providers and end-users.

For early warning, speed and dynamic monitoring are necessary, so products and services should provide the following information: location of air mass, location of weather front, location of flood peak, inundated area and water depth, and similar data, with a time resolution of about 12 hours, and it should be transmittable through the Internet to local service providers and end-users. Meteorological satellites have been widely applied to early warning purposes. They have high temporal resolution, and they can monitor the weather and make possible early warning and predictions from meteorologists.

Successful early warning requires that space products and services be available. More and more disaster managers and politicians want to invest in strengthening early warning systems. In the United States, for example, it is believed that improvements associated with the National Weather Service (NWS) modernization will more than pay for themselves. A National Institute of Standards and Technology cost-benefit analysis for the modernized NWS estimates that economic benefits to the nation will be about eight times greater than the costs involved, realizing annual benefits to the extent of US$7 billion (ISDR 2002). Nowadays, many countries have constructed their own disaster warning system (DWS) or a data collection platform (DCP) using space technology, and they are widely used in obtaining all kinds of information on floods.

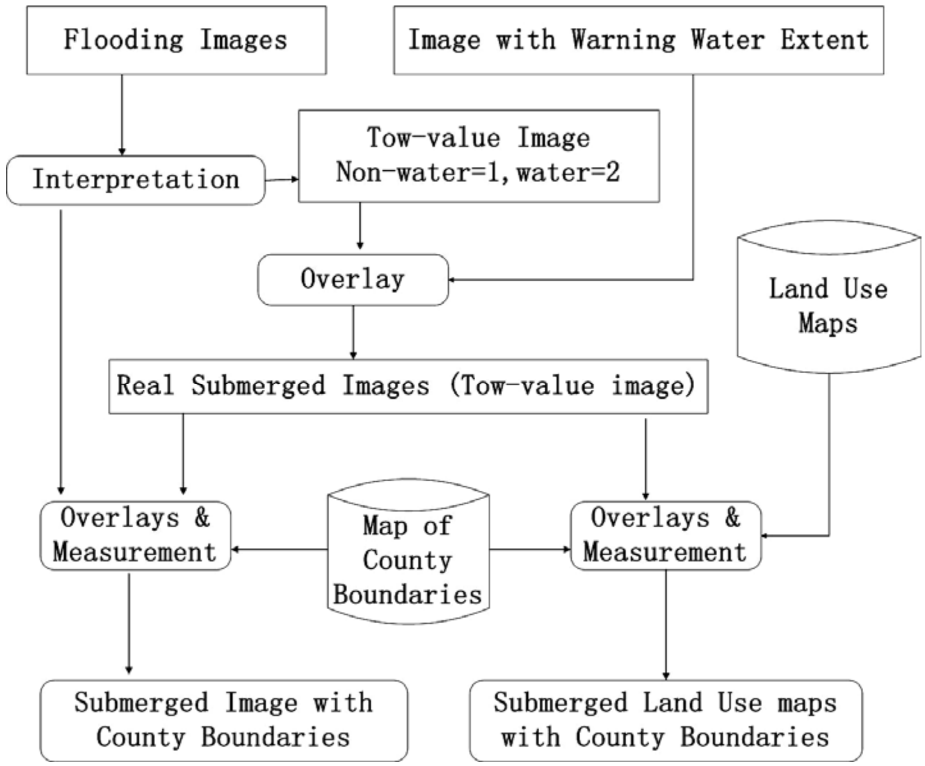
3.4.3 Monitoring and quick damage assessment during floods

Monitoring floods, cartography, and fast evaluation of flood-affected areas are among the most successful applications of space information technology in flood management. The various satellite images can reveal the trends and changes of floods. With the support of these images, we can plot disaster areas, flooded crops, dilapidated dikes and dams, submerged and destroyed towns, and much more. Furthermore, we can make policies to prevent floods, and carry out important measures for disaster prevention and relief promptly and accurately, according to these powerful images and information.

Loss assessment, which can be made based on the predictions, survey results and inundated areas extracted by remote sensing, is often used to calculate the range of the flood-affected area, the number of people suffering from floods, population migration, and other post-disaster aspects. Based on the loss assessment during a flood, some measures and countermeasures can be taken in order to reduce losses in time, arrange relief for the stricken population, make plans to rebuild, and so on.

Confirming the boundaries of the flood and defining the inundated area are the main purposes of monitoring in a flood. River bed loads are carried away when a flood comes, and spectrum characteristics change markedly in comparison with the characteristics of clean water. If clouds and mist are present over the flood-affected area, it is hard for visible remote sensing to retrieve a clear, useful image. Instead of visible light remote sensing, microwave sensors are used to assist the measurement of the water body extent. We can determine the scope of inundation by comparing new data with data on the normal water body recorded in the background database.

The first task is to make all the data sets from a variety of data sources register exact agreement with one another via precise geometric correction, so that they can be used together in a GIS environment for overlay analysis and dynamic monitoring of floods. Data sets used in this process include digital satellite images (such as Radarsat, Landsat, SPOT, and airborne SAR), digital elevation model data sets, socio-economic data, and topographic maps. The second task is to make image interpretation much easier through image enhancement and composites, so that flood information can be extracted from enhanced images (Jiqun Zhang et al. 2002).



(*Source*: Jiqun Zhang et al. 2002)

Figure 1.7: Flowchart to estimate the flooded area and distinguish flood-damaged areas

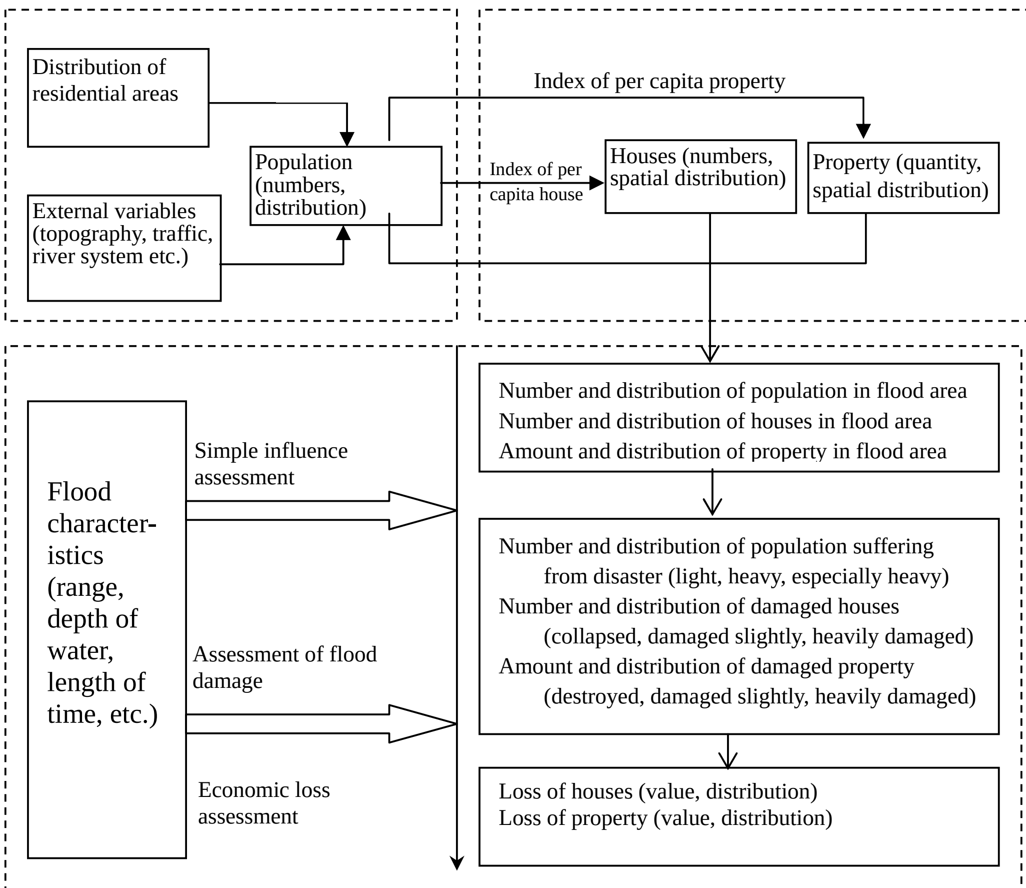
Figure 1.7 is a flow chart for the process of extracting inundation information and estimating flood disaster. There are two main tasks. One is identification of flood information and extraction from the pre-processed image. The other is to estimate the degree of severity of the flood, in terms of the sizes and types of the flooded areas (roads, cities, fields, etc.).

It is essential that information be accurate and timely, in order to address emergency situations (for example, dealing with diversion of flood water, evacuation, rescue, resettlement, water pollution, health hazards, and handling the interruption of utilities). For these tasks, the preferred tools will be the value-added products and services. For example, the extraction of hydrological parameters from satellite images is very important and time-saving for modelling purposes. Monitoring and fast evaluation will benefit from the products that extract the flood extent. Furthermore, the delivery channel will have no problems if the precipitation forecasts and potential flood extent estimation (such as the safe areas for population migration) can be given by the space information providers.

3.4.4 Loss assessment and relief after floods

The time factor is not as critical in this stage as in the other stages. Loss assessment includes the extent and intensity of flood damage, economic losses, “lifelines” (transportation system, power system, water supply system, gas supply system, post and telecommunications system, etc.), statistics on victims, the number of damaged/destroyed houses, the number of dead and injured, environmental pollution, disease propagation and the impacts on society and many other elements.

Various remote sensing images, together with a geographic information system, can help in the planning of many tasks. High-resolution images (Landsat, SPOT, Radarsat etc.) can establish the extent of damage and can be used to establish new flood boundaries. They can also locate landslides and pollution due to discharge and sediments. Very-high-resolution data (QuickBird, Ikonos, SPOT etc.) are suitable for pinpointing locations and the degree of damage. They can also be used to develop reference maps to aid in rebuilding bridges, washed-out roads, homes and other facilities. Finally, these data can be used to validate and refine hydrological models that are used for flood prediction.



(*Source*: Chen Deqing 1999)

Figure 1.8: Flowchart of loss assessment for flood damage

3.5 Other Technologies Supporting Effective Production and Utilization of Space Information Products and Services

The supporting technologies for space product and service applications in flood management have been developed very quickly in the last decade. Thanks to developments in space technology and computer technology, we can use them much more easily in flood management now, but some new technologies should also be used for more efficient applications in flood management, some of which are described below:

1) Image processing technology for remote sensing images

A series of complicated image processing steps have to be performed from receivers to end-users. Processing technology has a direct impact on the precision of the results, and it is the first stage in preparing for information extraction.

Remote sensing image processing technology includes atmospheric radiant correction, geometric and geographic correction, orthography, projection transform, image division, images mosaic, and various kinds of image enhancement processing, to name only a few.

According to the end-users' technological abilities and needs, they may choose different product levels. Relevant information should be offered to data producers for processing, and relevant technological training should be carried out if the technological ability is lacking.

2) Technology for flood data extraction from remote sensing images

Satellites can monitor in real time various kinds and states of floods, offering the most up-to-date information. How to extract the most relevant information from the satellite images is the key issue in satellite support for flood monitoring and relief.

The flood data that is extracted include flooded area, the depth of the water, land use/cover in the submerged area, villages and crops submerged, and the like.

3) Spatial analysis technology

Foundational geographic information, which provides assisting information on the inundated area, can greatly support flood management, such as dealing with an emergency and salvation decision, and many other situations.

Foundational geographical information contains a great deal of thematic layer data, such as streams, traffic, residential areas, terrain, etc. These information layers can be combined with remote sensing images and with some information extracted from remote sensing images. Spatial analysis includes buffer analysis, overlay, network analysis and virtual analysis, and others.

4) Models for flood management

Countries in all parts of the world are using many different models for flood management, such as flood prediction model, risk assessment model, loss valuation model, salvation decision model, flood routing model, victims of calamity withdrawal model, and others. Some countries are in the state of studying and development, while others have done nothing at all. Can these flood disaster models be shared? What are the ways they can be shared? What is the extent of sharing? These and other questions need to be resolved for the countries suffering from floods.

5) A quick turn-around time for information delivery (subject to the technology and related institutional factors) is very important, especially in the case of flooding.

6) Open-source supporting system and data management

Most countries already have their own information support systems with different levels, since their requirements for space information products and services might be very different. It is impossible for the space information providers to meet all their requirements. For this reason, the supporting system should be open-source, so that the providers can provide appropriate products and services and so that less capable countries will benefit from the opening of the source code.

The graphical nature of satellite data and associated products means that larger and more efficient data networks are needed, along with state-of-the-art data compression capability. Satellite data must also be compatible with GIS software to maximize utility. Few end-users will be experts in the field of remote sensing techniques, so there is a need for an increase in education and outreach on the increasing number of data types and products that are available and the potential uses for each.

II. Operational Mechanism of Space Technology in Flood Management

1. Knowledge-based and Information-intensive

Nowadays flood management has become more knowledge-based and information-intensive, and has therefore improved its practical realization and its time and cost efficiency.

Space information technology is playing an important role now. Some countries applied information technology to flood management in Asia and the Pacific region very early; some operational systems were established, beginning with processing raw data. The reinforcing of the basic ground establishments offer a better service platform for the application and development of space technology, accelerating the application of relevant products and services in flood disaster management. But most of the least developed countries, because of the lack of technical and human capabilities, cannot deal with these satellite data or extract useful information to support decision-making.

2. Obstacles to Sharing Products and Services

In the matter of sharing products and services (P/S) in flood disaster management in Asia and the Pacific region, there are some gaps between data producers and data users, between application demand and actual capability, followed by inadequate institutional and technical capacity or resources and lack of policy support in the developing countries.

The principal problem is that when there is no operational policy or institutional mechanism for efficient access to and use of existing and planned space information resources, end-users cannot obtain suitable P/S for flood management in time, especially in the fast-response phases.

2.1 Data Users Lack Value-added Products and Services

On the one hand, since there are no uniform criteria for data producers, it is difficult for end users to apply P/S because of the different formats, and on the other hand, the P/S offered by producers are usually general products, and so must be processed further before end-users can use them. The lack of high-level products that can be used directly in flood management leads to many inconveniences for end-users.

The absence of conceptual and spatial models capable of representing the social, economic and cultural dimensions of vulnerability is another problem.

With regard to the demand for space technology products and services, the data users want data producers to offer P/S that are more efficient and meet their requirements for flood management. These products and services, such as remote sensing and GIS data products, as well as software and hardware development and technical support, include the following:

- **Value-added products that can be used directly in flood management.** For instance, thematic maps which describe land use, inundated area, water depth, water area and coverage boundaries of rivers and lakes, are suitable for disaster monitoring and quick assessment. Change-detection products can be used to extract information concerning houses, roads and so on, which can be adapted for accurate disaster assessment.

- **Data products with high spatial and temporal resolution, all-weather and successive observation capability.** Such products can be applied to flood disaster management tasks such as abstraction of the inundated area, disaster loss assessment in the quick-response phase, and accurate evaluation of property loss to assist in rehabilitation of lives and in reconstruction.

2.2 Data Producers Lack Background Data on Vulnerable Countries

The precise processing of data products needs the support of a geographic foundation database. Because of the differing development levels of disaster-prone countries, some have set up background databases, which offer basic guarantees for the rapid application of space technology in the flood disaster managements. But the process of digitization in some of the disaster-prone countries is very slow, so they should invest more time, energy, and money in information construction and set up their national background database as soon as possible.

Data producers used to lack background data such as ground control points (GCPs) and large-scale, high-resolution DEM data on the disaster-prone countries. These data aid in the accurate registration of remote sensing data, extracting altitude and disaster areas, and the like. Lacking such important data, they cannot process general data products with enough precision and cannot produce data products specially adapted to flood disaster management.

2.3 Data Users Cannot Obtain Products or Services in Time

Presently, because of various policy mechanisms, software and hardware establishments and data producers dispatch and transfer data by such traditional modes as parcel and post when they are requested, which makes it difficult to satisfy emergency demands for flood disaster management; as a result, the users facing the disaster lose much precious time, thus leading to economic loss and serious social impacts. Therefore, a comprehensive way to solve this problem through policy mechanisms and basic establishments needs to be found.

2.4 Poor Data Processing Capability in Least Developed Countries

Flood disasters take place more frequently in Asia and the Pacific region than in other parts of the world, so these disaster-prone countries have many application needs and demands, and because of the overall low level of economic development in this area, their capabilities in processing data products are obviously behind the capabilities of developed countries. When disasters take place, data producers may offer general products, but data users are not likely to have the technology or capability to process these general data, or they may lack corresponding technical support, so the application of the data products in disaster management is hampered, and an opportunity to reduce damages and casualties is lost.

2.5 Lack of Financial Support

Space technology is an application that requires high investment in many areas, all of which need a large input of funds for disaster relief operations. Usually, less developed countries cannot afford to purchase all the necessary data products for flood disaster management, which means that their use in disaster relief management is limited, because of the too-high cost of high-resolution data products and other high-end products.

3. A Policy Framework: Comprehensive and Cooperative

The impacts from flood disasters are enormous; the importance of reinforcing cooperation in the area of space technology products and service between developed countries and the least developed countries is obvious. In order to impel better comprehension and cooperation in this area, an operational policy framework should be set up in Asia and the Pacific region.

3.1 Special Organization for Flood Management

To realize improved sharing of space technology products and services in Asia and the Pacific region, a particular organization for disaster management should be established, under the United Nations disaster relief policy framework, organized and managed by UNESCAP. The organization would organize and harmonize disaster supervisory work in Asia and the Pacific region and map out a policy for sharing, and at the same time push for the development of disaster products and services, in order to supply data users with final, high-grade, real-time products. The following paragraphs describe the roles and characteristics of this organization:

A) Firstly, the organization should be based on existing and planned initiatives, to promote regional cooperative mechanisms among space information providers, local service providers and flood managers for identification and definition of practical final and interim products and services, and encourage their production and provision.

It would integrate UNESCAP initiatives with other international initiatives on disaster management. With the harmonization work of this special institution, we can develop a series of comprehensive cooperation arrangements to improve sharing of space technology products and services:

- **Making policies and encouraging data producers to open data resources for sharing.** The data producers possess rich data resources, adapted to flood disaster management work such as disaster early warning, monitoring, and post-disaster rehabilitation and reconstruction, but having different sharing mechanisms of space technology products in some countries results in little sharing of products and services. Some policies should be established to make data producers open their data services, to fulfil data users' requirements and promote data sharing. In this regard, WMO has had some success; they devised a policy framework to increase the distribution and transfer of P/S, but there are still some gaps when it comes to sharing flood disaster data in Asia and the Pacific region, mainly owing to the lack of a harmonious policy mechanism. Although an international disaster relief charter has been established, there is not a specific policy under a United Nations policy framework adapted to flood management in this region.

- **Mapping out homogeneous product criteria, including product grade and data format.** Space technology products and services that are presently submitted by data producers are mostly primary products of image data, and are given only preliminary processing, such as radiation rectification or rectification of projection, which is not yet enough to make them directly or immediately applicable to flood disaster management. Further disposition and processing are needed, such as more precise rectification of image and detailed information extraction. It is very important to establish uniform product format and grade criteria for direct services in flood disaster management.

B) Secondly, the organization should help national disaster managers to establish working relations with their local service providers and the initiatives. In this way, it would play a catalytic role to increase the sharing of space technology products and services.

C) Harmonizing the roles of these mechanisms in order to identify commonly agreed upon and consistent final products and services for flood managers. Some products and services could be produced with archived information.

D) To explore approaches to long-term institutional and regional arrangements for operational provision of space information products and services.

E) Identifying countries' capabilities (in groups) for production and provision of final products and services, since their capabilities will determine their needs for interim products and services from space information providers.

3.2 Integrating Earth Observation Products and Services as Part of the Disaster Management Strategy

It is important to turn EO information into knowledge-based, value-added products and services, which will provide decision-making support information that is acceptable to end-users. As an approximate indicator, the requirements could be measured by their information mass, from 10^{15} of the raw data to an amount of 10^{6} for decision-support products and services, which could be deliverable through the Internet.

To accomplish this step, the region needs some appropriate institutionalization arrangements at national level under the United Nations policy framework, organized and harmonized by this special institution of UNESCAP.

3.3 Regional and International Cooperation Efforts

In order to promote regional/international cooperation efforts, we should have a clear understanding about the demands of three different levels, which are space information providers, local service providers and end-users. The appropriate sharing of products and services will demand joint efforts from these three levels.

Final P/S for disaster managers
End-users need final products and services for disaster management; the following aspects of final products and services should be thought over:

- Because disaster managers work with different levels of information supporting systems, their requirements for final products and services will be different, but the differences should not be very large at this level, so a generally agreeable set of final products and services probably could be identified and defined.

- Since the less capable countries will eventually improve their ability to apply knowledge-based disaster management, the final products and services should fit both the existing practices and planned improvements.

- The products and services should also consider the requirements of disaster managers at various levels, possibly penetrating to the community level.

- The products and services could be grouped for different disaster management stages, such as risk assessment, background information database and so forth.

Interim P/S for local service providers
Local service providers need some interim products and services for flood management:

- Local service providers have the most variation of capabilities, so the interim products and services provided by space information providers will have to be different.

- In this process, more attention should be given to less capable countries: more interim products and services, with sufficient information extraction, should be provided for them, to make it easier for them to create final products and services.

- Human resources development activities could be focused on the need of local service providers for creating final products and services from interim products and services.

- The charging policy could be established based on interim products and services and their delivery channels.

Below are some strategies that data producers and data users may use for cooperating and sharing:

- **User-tailored products and services within hours for emergency response.** Encourage or require data producers to have products that are “deeply” processed to fulfil data users' needs, and to produce more value-added products of higher quality, including image products of high spatial resolution and high temporal resolution. By fulfilling the special demands of different operating departments, space technology can exert a powerful influence on flood management.

- **Partnership of service providers and users.** Mapping out homogeneous policies for data users will make it easier for data producers to offer necessary support, and encourage data producers to continue to process data products and produce more high-precision and high-end products. For instance, distressed countries may render DEM data, ground control point data, local fundamental geographic data, and local statistical material when conditions permit

- **Standardization and promotion of open source software.** It is essential to standardize and promote open source software for sharing in this region, and to establish uniform product formats and grade criteria for direct services in flood disaster management.

In order to realize regional/international cooperation, some commitment should also be arranged. Less developed countries need to establish such minimum technical capacities for accepting assistance from these initiatives; in some situations, such technical capacities of less developed countries may be established through international financial assistance.

As for the beneficiary countries (contributory countries may also be considered beneficiary countries), they should enhance or establish local service providers for the development, production and provision of such final products and services.

And as for space information providers (at national government level), they should develop and provide interim products and services for local service providers at different levels and should establish favourite charge policies for these services with government support.

3.4 Capacity-building Activities in LDCs with the Support of UNESCAP

- **Strengthening international exchange and cooperation, and dispatching experts to engage in technology guidance regularly.** UNESCAP may manage exchange and cooperation through its own harmonious organization, which would strengthen the connection between countries and promote the technology progress of less developed countries.

- **Promoting the setting up of background databases in the disaster-prone countries, and supporting the use of remote sensing images.** The database includes a fundamental geographical database, a database of ground control points (GCPs), DEM database etc. These fundamental data are indispensable material by which primary products can be precisely rectified for use on the ground.

3.5 Establishing Product and Service Network Exchange Platforms

Networking is important and could include three levels – regional, national and professional – which could increase accessibility of space technology products and services.

- **Easy access though network platforms, and through the Internet.** Network platforms offer a substantial foundation for quick dispatching and transfer of space technology products and services. There are some demands for building a transmission network switching platform for data products in Asia and the Pacific region, to share products and services expeditiously.

- **Increasing processing technology though network platforms.** Development and transfer could be enhanced mostly through regional or international cooperation networking, which would be important for space technology product and service sharing in this region.

- **Ensuring expeditious communication and networking.** These networks are also a very important part of the infrastructure for sharing products and services in this region.

3.6 Financing Mechanism for Sharing

Financing arrangements and financial support from international organizations, groups and private agencies would be essential; financial pressure on LDCs would be reduced with this assistance, which is an effective way to increase affordability in less developed countries.

- **Mechanisms for concessional charges for products and services.** Taking into account the humanitarian aspect of the products and services, entities could offer financial support and assistance to less developed countries, and could give some practical help, such as early warning, dynamic or real-time monitoring of disasters, disaster evaluations, and reconstruction aid, while at the same time promoting their emergency capability by manpower training and technical guidance.

- **PPP (public-private partnerships) between service providers and user communities.** Among the success stories of the PPP model for enabling EO for disaster management, UNOSAT is a good example, which provides satellite information for humanitarian assistance. Similarly, the Pacific Disaster Centre provides access on the Web to the vulnerability atlas of selected disaster-prone areas.

- **Maximize the use of existing infrastructure, including freely available Web-based products.** Complementary data are available for space technology products and services for least developed countries.

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Appendix I:

Parameters of Satellites for Flood Disaster Management

Appendix I. Parameters of Satellites for Flood Disaster Management: Visible and Infrared

Satellite	Country/ Operator	Sensor	Resolution (m)	Swath Width (km)	Revisit Time (days)	All Weather	Stereo	Inundation Area	Inundation Period	Back-ground	Evaluate	Launch	Status
ALOS	NASDA	PRISM	2.5	70	46	N/A	☆☆☆☆☆	☆☆☆☆☆	☆	☆☆☆☆☆	☆☆☆☆☆	-	Planned
		AVNIR-2	10	70	46	N/A	N/A	☆☆☆☆	☆	☆☆☆	☆☆☆		
ADEOS-2	NASDA	GLI	250	12	N/A	N/A	N/A	☆☆	N/A	☆☆	☆	2002	Operational
		GLI	1000	12	N/A	N/A	N/A	☆	N/A	☆	☆		
CBERS-1	China and Brazil	CCD	20	113	3	☆☆	N/A	☆☆☆☆	☆	☆☆☆☆	☆☆☆	1999	Operational
		IR-MSS	80	120	26	N/A	N/A	☆☆☆	☆	☆☆☆	☆☆		
		WFI	260	890	5	☆☆	N/A	☆☆	☆	☆	☆		
EROS-A	ImageSat International	PAN	1.8	13.5	2.5	☆	☆☆☆☆	☆☆☆☆☆	☆☆	☆☆☆☆☆	☆☆☆☆☆	2000	Operational
FY-1C/1D	China	MVISR	1100	N/A	N/A	☆☆☆	N/A	☆☆	☆☆☆	☆	☆☆	N/A	N/A
FY2-2A/2B	China	S-VISSR	1250	N/A	N/A	☆☆☆	N/A	☆☆	☆☆☆	☆	☆☆	1997	N/A
FY2-2C	China	MVISR	1250	9164	N/A	N/A	N/A	N/A	N/A	N/A	N/A	2004	Operational
GMS-5	NASDA	VISSR	1250	N/A	N/A	☆☆☆	N/A	☆☆	☆☆☆	☆	☆☆	1995	N/A
GOES	NOAA	IMAGER	1000	N/A	N/A	☆☆☆	N/A	☆☆	☆☆☆	☆	☆☆	2001	Operational
GOMES	Russia	N/A	N/A	N/A	N/A	☆☆☆	N/A	☆☆	☆☆☆	☆	☆☆	N/A	N/A
Ikonos	Space Imaging	OSA/MS	4	11	3	☆	N/A	☆☆☆☆☆	☆	☆☆☆☆☆	☆☆☆☆	1999	Operational
		OSA/PAN	1	11	3	☆	☆☆☆☆☆	☆☆☆☆☆	☆	☆☆☆☆☆	☆☆☆☆☆		
INSAT	ISRO	VHRR	2000	N/A	N/A	☆☆☆	N/A	☆☆	☆☆☆	☆	☆☆	1999	Operational
IRS-1C/1D	ISRO	LISS 3	23.5	142	24	N/A	N/A	☆☆☆☆	☆	☆☆☆☆	☆☆☆	1995	Operational
		PAN	5.8	70	24	N/A	☆☆☆	☆☆☆☆	☆	☆☆☆☆	☆☆☆☆☆		
		WiFS	188	774	5	☆☆	N/A	☆☆	☆	☆	☆	N/A	N/A
JERS-1	NASDA	OPS	18.3	75	44	N/A	N/A	☆☆☆	☆	☆☆	☆☆	1992	N/A
Kompsat-1	Korea Aerospace Research Institute	PAN	6.6	40	2-3	☆☆	N/A	☆☆☆☆☆	☆☆	☆☆☆☆☆	☆☆☆☆☆	1999	Operational
		MS	13	40	2-3	☆☆	N/A	☆☆☆☆☆	☆☆	☆☆☆☆	☆☆☆☆		
Landsat-7	NASA	ETM/MS	30	185	16	☆	N/A	☆☆☆☆	☆	☆☆☆☆	☆☆☆	1999	Operational

Satellite	Country/ Operator	Sensor	Resolution (m)	Swath Width (km)	Revisit Time (days)	All Weather	Stereo	Inundation Area	Inundation Period	Back-ground	Evaluate	Launch	Status
		ETM/PAN	15	185	16	☆	N/A	☆☆☆☆	☆	☆☆☆	☆☆☆		
		ETM/TIR	60	185	16	☆	N/A	☆	☆	N/A	☆		
METEOR-3	Russia		3000	3100		☆☆☆	N/A	☆☆	☆☆☆	☆	☆☆	1999	Operational
Meteosat	EUMETSAT	VISSR	2500		0.02	☆☆☆	N/A	☆☆	☆☆☆	☆	☆☆	2002	Operational
NOAA-14/15	NOAA	AVHRR	1100	3000	0.5	☆☆☆	N/A	☆☆	☆☆☆	☆	☆☆	1994	Operational
Orbview-3	OrbImage	MS	4	8	3	☆	N/A	☆☆☆☆☆	☆	☆☆☆☆☆	☆☆☆☆☆	2003	Operational
		PAN	1	8	3	☆	☆☆☆	☆☆☆☆☆	☆	☆☆☆☆☆	☆☆☆☆☆		
QuickBird	Digital Globe	MS	2.44	16.6	3	☆	N/A	☆☆☆☆☆	☆	☆☆☆☆☆	☆☆☆☆☆	2001	Operational
		PAN	0.61	16.6	3	☆	☆☆☆☆☆	☆☆☆☆☆	☆	☆☆☆☆☆	☆☆☆☆☆		
Resourcesat-1 (IRS-P6)	ISRO	LISS-4/PAN	5.8	70.3	24	N/A	☆☆☆	☆☆☆☆☆	☆	☆☆☆☆☆	☆☆☆☆☆	2004	Operational
		LISS-4/MS	5.8	23.5	24	N/A	N/A	☆☆☆☆☆	☆	☆☆☆☆☆	☆☆☆☆☆		
		LISS-3/MS	23.5	140	24	N/A	N/A	☆☆☆	☆	☆☆☆	☆☆☆		
		AWiFS	56	740	5	☆☆	N/A	☆☆	☆	☆☆	☆☆		
SPIN-2	Russia	PAN	2/10	180	N/A	N/A	☆☆☆	☆☆☆☆	N/A	☆☆☆☆☆	☆☆☆☆☆	N/A	N/A
SPOT-4	SPOT Image	HRVIR/MS	20	60	5/26	☆	N/A	☆☆☆☆	☆	☆☆☆☆☆	☆☆☆☆	1998	Operational
		HRVIR/PAN	10	60	5/26	☆	☆☆☆☆	☆☆☆☆☆	☆	☆☆☆☆☆	☆☆☆☆☆		
		Vegetation	1000	2200	1	☆☆☆	N/A	☆☆	☆☆☆	☆	☆☆		
SPOT-5	SPOT Image	HRG/MS	10	60	5/26	☆	N/A	☆☆☆☆☆	☆	☆☆☆☆	☆☆☆	2002	Operational
		HRG/PAN	2.5	60	5/26	☆	☆☆☆☆	☆☆☆☆☆	☆	☆☆☆☆	☆☆☆☆		
		HRS	10	120	5/26	☆	☆☆☆☆☆	☆☆☆☆	☆	☆☆☆☆	☆☆☆		
		Vegetation	1000	2200	1	☆☆☆	N/A	☆☆	☆☆☆	☆☆	☆☆		
TERRA/ AQUA	NASA	MODIS	250	2330	2	☆☆	N/A	☆☆☆	☆☆☆	☆☆☆☆	☆☆	1999	Operational
			500	2330	2	☆☆	N/A	☆☆☆	☆☆☆	☆☆	☆☆		
			1000	2330	2	☆☆	N/A	☆☆☆	☆☆☆	☆☆	☆☆		
TERRA/ AQUA	NASA	ASTER	15	60	16	N/A	☆☆☆	☆☆☆☆	☆	☆☆☆☆	☆☆☆☆	1999	Operational
			30	60	16	N/A	N/A	☆☆☆☆	☆	☆☆☆☆	☆☆☆		

Satellite	Country/ Operator	Sensor	Resolution (m)	Swath Width (km)	Revisit Time (days)	All Weather	Stereo	Inundation Area	Inundation Period	Back-ground	Evaluate	Launch	Status
			90	60	16	N/A	N/A	☆☆☆	☆	☆☆☆	☆☆		

EUMETSAT: European Organization for the Exploitation of Meteorological Satellites
ESA: European Space Agency
ISRO: Indian Space Research Organization
NASA: National Aeronautics and Space Administration
NASDA: National Space Development Agency
NOAA: National Oceanic and Atmospheric Administration

Appendix II. Parameters of Satellites for Flood Disaster Management: Microwave

Satellite	Country/ Operator	Sensor	Resolution (m)	Swath Width (km)	Revisit Time (days)	All Weather	Stereo	Inundation Area	Inundation Period	Back-ground	Evaluate	Launch	Function State
ALOS	NASDA	L-PALSAR/Fine	10-44	40-70	46	☆☆☆☆☆	☆☆☆	☆☆☆	☆☆	☆☆	☆☆	-	Planned
		L-PALSAR/Fine	14-88	40-70	46	☆☆☆☆☆	☆☆☆	☆☆☆	☆☆	☆☆	☆☆		
		L-PALSAR/ScanSAR	100	250-350	46	☆☆☆☆☆	N/A	☆☆	☆☆	☆	☆		
Envisat	ESA	ASAR	30	56	Several hours to several weeks	☆☆☆☆☆	☆☆☆☆	☆☆☆☆	☆☆	☆☆☆	☆☆☆	2002	Operational
		ASAR/Wide Scan	150	406		☆☆☆☆☆	N/A	☆☆☆	☆☆☆	☆	☆		
		ASAR/Globe watch	1000	512		☆☆☆☆☆	N/A	☆☆	☆☆☆	☆	☆		
ERS-1	ESA	C-SAR	30	100	Tandem, 1 day	☆☆☆☆☆	☆☆☆☆	☆☆☆☆	☆☆	☆☆☆	☆☆☆	1991	Operational
ERS-2	ESA	C-SAR	30	100		☆☆☆☆☆	☆☆☆☆	☆☆☆☆	☆☆	☆☆☆	☆☆☆	1995	Operational
JERS-1	NASDA	L-SAR	18	75	44	☆☆☆☆☆	N/A	☆☆☆☆	☆☆	☆☆☆	☆☆☆	1992	N/A
Radarsat-1	CSA	C-SAR/Fine	8	50	3-24	☆☆☆☆☆	☆☆☆	☆☆☆☆☆	☆☆	☆☆☆	☆☆☆☆	1995	Operational
		C-SAR/STD	30	100		☆☆☆☆☆	☆☆☆	☆☆☆☆	☆☆	☆☆☆	☆☆☆		
		C-SAR/EH	25	75		☆☆☆☆☆	☆☆☆	☆☆☆☆	☆☆	☆☆☆	☆☆☆		
		C-SAR/EL	35	170		☆☆☆☆☆	☆☆☆	☆☆☆☆	☆☆	☆☆☆	☆☆☆		
		C-SAR/SCN	50	300		☆☆☆☆☆	☆☆	☆☆☆	☆☆	☆☆	☆☆		
		C-SAR/SCW	100	500		☆☆☆☆☆	☆☆	☆☆☆	☆☆	☆	☆		

CSA: Canadian Space Agency
ESA: European Space Agency
NASDA: National Space Development Agency

Appendix III. Low-resolution Satellites (1km-4km)

Satellite	Country/ Operator	Sensor	Resolution (m)	Swath Width (km)	Revisit Time (days)	Launch	Function State
ADEOS-2	NASDA	GLI	1000	12	N/A	2002	Operational
FY-1C/1D	China	MVISR	1100	N/A	N/A	N/A	N/A
FY2-2A/2B	China	S-VISSR	1250	N/A	N/A	1997	N/A
FY2-2C	China	MVISR	1250	9164	N/A	29/10/2004	Operational
GMS-5	NASDA	VISSR	1250	N/A	N/A	1995	N/A
GOES	NOAA	IMAGER	1000	N/A	N/A	2001	Operational
INSAT	ISRO	VHRR	2000	N/A	N/A	1999	Operational
METEOR-3	Russia	N/A	3000	3100	N/A	12/1999	Operational
Meteosat	EUMETSAT	VISSR	2500	N/A	0.02	2002	Operational
NOAA-14/15	NOAA	AVHRR	1100	3000	0.5	1994	Operational
SPOT-4	SPOT Image	Vegetation	1000	2200	1	03/1998	Operational
SPOT-5	SPOT Image	Vegetation	1000	2200	1	03/2002	Operational
TERRA	NASA	MODIS	1000	2330	2	18/12/1999	Operational
Envisat	ESA	ASAR/Globe Watch	1000	512	Several hours to several weeks	2002	Operational

Appendix IV. Moderate-resolution Satellites (100m-1km)

Satellite	Country/ Operator	Sensor	Resolution (m)	Swath Width (km)	Revisit Time (days)	Launch	Function State
ADEOS-2	NASDA	GLI	250	12	N/A	2002	Operational
CBERS-1	China and Brazil	WFI	260	890	5	1999	Operational
IRS-1C/1D	ISRO	WiFS	188	774	5	1995	Operational
TERRA	NASA	MODIS	250	2330	2	18/12/1999	Operational
			500	2330	2		
ALOS	NASDA	L-PALSAR/ ScanSAR	100	250-350	46	2004	Operational
Envisat	ESA	ASAR/Wide scan	150	406	From several hours to several weeks	2002	Operational
Radarsat-1	CSA	C-SAR/SCW	100	500	3-24	1995	Operational

Appendix V. High-resolution Satellites (5m-100m)

Satellite	Country/ Operator	Sensor	Resolution (m)	Swath Width (km)	Revisit Time (days)	Launch	Function State
ALOS	NASDA	AVNIR-2	10	70	46	-	Planned
CBERS-1	China and Brazil	CCD	20	113	3	1999	Operational
		IR-MSS	80	120	26		
IRS-1C/1D	ISRO	LISS 3	23.5	142	24	1995	Operational
		PAN	5.8	70	24		
JERS-1	NASDA	OPS	18.3	75	44	1992	OFF
Kompsat-1	KARI	PAN	6.6	40	2-3	1999	Operational
		MS	13	40	2-3		
Landsat-7	NASA	ETM/MS	30	185	16	1999	Operational
		ETM/PAN	15	185	16		
		ETM/TIR	60	185	16		
Resourcesat-1 (IRS-P6)	ISRO	LISS-4/PAN	5.8	70.3	24	2004	Operational
		LISS-4/MS	5.8	23.5	24		
		LISS-3/MS	23.5	140	24		
		AWiFS	56	740	5		
SPIN-2	Russia	PAN	2/10	180	N/A		
SPOT-4	SPOT Image	HRVIR/MS	20	60	5/26	03/1998	Operational
		HRVIR/PAN	10	60	5/26		
SPOT-5	SPOT Image	HRG/MS	10	60	5/26	03/2002	Operational
		HRS	10	120	5/26		
TERRA	NASA	ASTER	15	60	16	18/12/1999	Operational
			30	60	16		
			90	60	16		
ALOS	NASDA	L-PALSAR/Fine	10-44	40-70	46	2004	Operational
		L-PALSAR/Fine	14-88	40-70	46		
ENVISAT	ESA	ASAR	30	56	Hours to weeks	2002	Operational
ERS-1	ESA	C-SAR	30	100	Tandem, 1 day	1991	N/A
ERS-2	ESA	C-SAR	30	100		1995	N/A
JERS-1	NASDA	L-SAR	18	75	44	1992	N/A
Radarsat-1	CSA	C-SAR/Fine	8	50	3-24	1995	Operational
		C-SAR/Standard	30	100	3-24		
		C-SAR/EH	25	75			
		C-SAR/EL	35	170	3-24		
		C-SAR/SCN	50	300	3-24		

Appendix VI. Very-high-resolution Satellites (<5m)

Satellite	Country/ Operator	Sensor	Resolution (m)	Swath Width (km)	Revisit Time (days)	Launch	Function State
ALOS	NASDA	PRISM	2.5	70	46	-	Planned
EROS-A	ImageSat International	PAN	1.8	13.5	2.5	2000	Operational
Ikonos	Space Imaging	OSA/MS	4	11	3	24/09/1999	Operational
		OSA/PAN	1	11	3		
Orbview-3	OrbImage	MS	4	8	3	2003	Operational
		PAN	1	8	3		
QuickBird	Digital Globe	MS	2.44	16.6	3	10/2001	Operational
		PAN	0.61	16.6	3		
SPIN-2	Russia	PAN	2/10	180	N/A	N/A	N/A
SPOT-5	SPOT Image	HRG/PAN	2.5	60	5/26	03/2002	Operational

Appendix VII. Satellites with Stereo DEM Generation Capability

Satellite	Operator	Sensor	Resolution (m)	Swath Width (km)	Revisit Time (days)
TERRA	NASA	ASTER	15	60	16
IRS-1C/1D	ISRO	PAN	5.8	70	24
Resourcesat-1	ISRO	LISS-4/PAN	5.8	70.3	24
SPOT-4	SPOT Image	HRVIR/PAN	10	60	5/26
SPOT-5	SPOT Image	HRG/PAN	2.5	60	5/26
		HRS	10	120	5/26
Ikonos	Space Imaging	OSA/PAN	1	11	3
QuickBird	Digital Globe	PAN	0.61	16.6	3
EROS-A	ImageSat International	PAN	1.8	13.5	2.5
SPIN-2	Russia	PAN	2/10	180	N/A
Orbview-3	OrbImage	PAN	1	8	3
Envisat	ESA	ASAR	30	56	Several hours to several weeks
Rocsat-2	NSPO	PAN	2	60	1-2
Radarsat-1	CSA	ALL MODE	8-100	50-500	3-24
ERS-1	ESA	C-SAR	30	100	Tandem, 1day
ERS-2	ESA	C-SAR	30	100	
ALOS	NASDA	PRISM	2.5	70	46
		L-PALSAR/Fine	10-44	40-70	46
			14-88	40-70	46

Appendix VIII. Satellites and Products

1. ALOS

The Advanced Land Observing Satellite (ALOS) is a satellite following the Japanese Earth Resources Satellite-1 (JERS-1) and Advanced Earth Observing Satellite (ADEOS), which will utilize advanced land observing technology.
(*Source*: <ceos.cnes.fr:8100/cdrom-00b2/ceos1/satellit/alos/alos_e.htm>)

ALOS has three remote-sensing instruments: the Panchromatic Remote-sensing Instrument for Stereo Mapping (PRISM) for digital elevation mapping, the Advanced Visible and Near Infrared Radiometer type-2 (AVNIR-2) for precise land coverage observation, and the Phased Array type L-band Synthetic Aperture Radar (PALSAR) for day-and-night and all-weather land observation. In order to utilize fully the data obtained by these sensors, ALOS was designed with two advanced technologies: the former is the high speed and large-capacity mission data handling technology and the latter is the precision spacecraft position and attitude determination capability.
(*Source*: <ceos.cnes.fr:8100/cdrom-00b2/ceos1/satellit/alos/alos_e.htm>)

ALOS Products

Product ID	Description
Level 0 (generated in the ALOS Data Recording Subsystem)	This is raw data generated by every downlink segment and every band. This product is divided into an equivalent size for each scene.
Level 1A	This is raw data extracted from the Level-0 data, expanded and generated lines. Ancillary information such as radiometric information and the like, required for the processing superior to the Level 1B, is added.
Level 1B1	This is the data that performs radiometric correction to Level-1A data, and added the absolute calibration coefficient. Ancillary information such as radiometric information etc. required for the processing superior to the Level 1B2 is added.
Level 1B2	This is the data that performs geometric correction to Level-1B1 data. The following correction options are available. ● R: Geo-reference data ● G: Geo-coded data ● D: Rough DEM (digital elevation model) correction: this option corrects the topographical influence on the areas the DEM covered. DEM correction is effective only in Japanese region. There is a possibility that DEM correction error will occur in images of rough terrain. In this case, processing that does not select option D is carried out.

(*Source*: <landsat.gsfc.nasa.gov/main/PDF/L7_L0L1_usgs.pdf>)

2. CBERS-1

China and Brazil agreed on 6 July 1988 to start a cooperative programme to develop two remote sensing satellites. This joint China-Brazil Earth Resources Satellite (CBERS) Programme pools the technical skills and financial resources of the two countries to establish a complete remote sensing system that is both competitive and compatible with present international needs. There are three kinds of cameras on the CBERS-1: CCD, IRMSS and WFI.
(*Source*: <www.dgi.inpe.br/html/eng/cbers.htm>)

The CCD Camera has a nadir spatial resolution of 19.5 metres and a swath width of 113 km. It has four spectral bands in the visible and near-infrared range and one panchromatic band. The maximum side-looking angle is ±320. It can perform on-orbit focal length adjusting and onboard calibration using an internal lamp calibration system.

The IRMSS instrument has spatial resolution of 78 metres (for three visible to short-wave infrared spectral bands) and 156 metres (for one thermal infrared band). It has internal lamp calibration system as well as a solar calibration system. Its swath width is 119.5 km.

The WFI camera has a nadir spatial resolution of 256 metres in two visible to near-infrared spectral bands. It has a swath width of 890 km. Its relatively wider swath makes it possible to achieve repeated ground coverage in a short time period. The on-board calibration system on WFI consists of a diffuse reflective window for relative radiometric calibration.
(*Source*: <www.cresda.com.cn/en/products_01.htm>)

CBERS Products

Product ID	Description
Level 1	Radiometrically corrected and geometrically raw data
Level 2	Radiometrically and geometrically corrected using systematic model (no ground control points: GCPs)
Level 3	Radiometrically and geometrically corrected using GCPs
Level 4	Radiometrically and geometrically corrected using GCPs and digital terrain model (DTM) for terrain parallax correction
Level 5	Deeply processed remote sensing thematic mapper and image

(*Source*: <www.cresda.com.cn/en/products_service.htm>)

3. Ikonos

Ikonos was launched successfully on 24 September 1999. This is the first in a new generation of satellites collecting very-high-resolution image data. Ikonos has a 1-metre resolution panchromatic sensor and a 4-metre resolution multispectral sensor. The satellite is an "agile platform", meaning that it can position itself to collect imagery for specific areas of interest.
(*Source*: <www.ersi.ca/ikonos.html>)

OSA (Optical Sensor Assembly): This instrument features a Cassegrain-type telescope with a 70-cm diameter primary mirror, a 10-m focal length (folded optics design). Pushbroom detector technology (a large focal plane detector array, generation of 6500 lines/s of panchromatic image data) is employed. Simultaneous imaging in panchromatic and multispectral (MS) modes is provided. The MS bands correspond to those of Thematic Mapper (TM) on Landsat in the visible range of the spectrum. The instrument light level is governed by a 70-cm aperture and a choice of 10, 13, 18, 24, or 32 TDI (Time Delay Integration) stages for panchromatic (grey-scale) imaging. The detector array offers a cumulative exposure concept for panchromatic imaging.

The location knowledge accuracy of the imagery is 2 m horizontal (relative), i.e. with ground control points, and 12 m (absolute), i.e. without the use of ground control points. Smooth scanning is provided with accurate gyros, low disturbance torques (smooth antenna gimbals and reaction wheels), and a rigid high-frequency structure of the satellite.

The satellite camera may also be rotated about its imaging axis for proper (broadside) detector array orientation. This technique permits, for instance, the full-swath imaging of a particular feature of interest on the Earth's surface, such as a coastline, which traverses under some angle through the in-track direction.
(*Source*: <directory.eoportal.org/pres_IKONOS2.html>)

Ikonos Products

	Positional Accuracy			Ortho Corrected	Target Elevation Angle	Mosaicks Available	Stereo Option	Applications
	CE90	RMS	NMAS					
Geo	Better than 15.0 meters*	N/A	N/A	No	60° to 90°	No	No	Visual and interpretive applications
Reference	Better than 25.4 meters	Better than 11.8 meters	1:50,000	Yes	60° to 90°	Yes	Yes	Regional, large area mapping and general GIS applications
Pro	Better than 10.2 meters	Better than 4.8 meters	1:12,000	Yes	66° to 90°	Yes	No	Transportation, infrastructure and utilities planning and economic development site evaluations
Precision	Better than 4.1 meters	Better than 1.9 meters	1:4,800	Yes	72° to 90°	Yes	Yes	High positional accuracy for regional and large-scale urban planning, forestry assessments
PrecisionPlus	Better than 2.0 meters	Better than 0.9 meters	1:2,400	Yes	75° to 90°	Yes	No	Precision mapping and advanced analysis for detailed urban, cadastral and infrastructure mapping applications

** Exclusive of terrain effects*

CARTERRA Geo is a geometrically corrected product that has been rectified to a pre-specified ellipsoid and map projection. The rectification process removes image distortions introduced by the collection geometry and re-samples the imagery to a uniform ground sample distance and a specified map projection.
(*Source*: <www.agriors.com/ikonos-main.htm>)

Space Imaging's orthorectified product line provides data that has been orthorectified to a specified ellipsoid and map projection. The orthorectification process removes image distortions introduced by the collection geometry and by relief of the terrain, and re-samples the imagery to a uniform ground sample distance and a user-specified map projection. This product is available at three metric accuracy levels; **Reference, Pro** and **Precision**:

CARTERRA Reference is useful for Large Area Mapping, particularly international coverage, and GIS applications requiring low positional accuracy. This product will be of interest to media, real estate, insurance and other commercial markets. The deliverable has a 25-metre horizontal accuracy (CE 90%) and meets 1:50,000 NMAS (National Map Accuracy Standards).

CARTERRA Pro is suitable for city and local governments, telecommunications and utilities customers with applications such as transportation and infrastructure planning, utilities planning and economic development site evaluations. This product has a horizontal accuracy of 10 metres (CE 90%) and meets 1:12,000 NMAS.

CARTERRA Precision is a premium product ideal for urban mapping, cadastre mapping, and GIS applications requiring high positional accuracy. This product is produced using ground control and digital elevation models, has a 4-metre horizontal accuracy (CE 90%) and meets 1:4800 NMAS.
(*Source*: <www.agriors.com/ikonos-main.htm>)

Ikonos Terrain Model - 1 or ITM-1, is a terrain model extracted from stereo pairs of Ikonos imagery. This product is available globally, has one arc-second (~ 30 m) post spacing, horizontal accuracy of 25 m (CE 90%) and a vertical accuracy of 11.5 m LE 90% (~7 m RMSE). Elevations are edited to ground elevation by removal of building and canopy height.
(*Source*: <ggscratchy.swansea.ac.uk/>)

4. IRS-1C and IRS-1D

IRS is India's dedicated Earth resources satellite system operated by ISRO and the National Remote Sensing Agency (NRSA). The primary objective of the IRS missions is to provide India's National Natural Resources Management System (NNRMS) with remote sensing data.
(*Source*: <www.science.edu.sg/ssc/detailed.jsp?artid=3692&type=4&root=140&parent=140&cat=239>)

IRS-1D carries a combination of three cameras: (a) a panchromatic camera (PAN) with a spatial resolution of 5.8 m, (b) Linear Imaging Self Scanner (LISS-III) operating in four spectral bands with spatial resolution of 23.5 m in visible and near-infrared bands and 70.5 m in shortwave infrared band, and (c) a Wide Field Sensor (WiFS) with a ground resolution of 188 m.. Availability of high-resolution data from IRS-1D and its predecessor IRS-1C have enabled newer remote sensing applications to be taken up, especially in the areas of urban sprawl, infrastructure planning and other large-scale thematic mapping projects.
(*Source*: <asia.spaceref.com/news/viewsr.html?pid=1242>)

IRS Products

Product		Properties	Description
Geo	Geo 5m	Standard IRS Geo 5-metre products include: 5-metre 23 x 23 km black-and-white scene 5-metre 23 x 70 km black-and-white scene 5-metre 70 x 70 km black-and-white scene	Geo 5-metre IRS products are ideal for area-wide spatial analysis and regional base mapping project requirements. Geo-level IRS products are radiometrically and geometrically corrected, and oriented to a specified datum and map projection system. IRS geo products are available as individual black and white scenes.
	Geo 180m	Standard IRS GEO 180-metre products include: 180-metre 812 x 812 km scenes	The IRS WiFS sensor acquires two bands of 180-metre multispectral data that are specific to vegetation analysis. With a 812-km swath, WiFS is capable of providing vegetation index imagery at regional level, helping in assessment of crop condition and drought monitoring.
Reference	Ref 5m	Standard IRS Reference 5-metre products include: 5-metre black-and-white, colour 70 x 70km scene 5-metre black-and-white, colour DOQ 5-metre black-and-white mosaic 5-metre colour mosaic custom cut 5-metre colour counties 5-metre colour states 5-metre colour regions	Reference 5-metre IRS image products provide the basis for a robust suite of affordable orthorectified medium-resolution solutions. These products are valuable for users requiring moderate positional accuracy for mapping roadways, pipelines, and corridors, and updating existing base maps and feature layers. Colourized data yields information on habitat delineation, ecosystem boundaries, and land use monitoring. The colourization process utilizes pan sharpening of Landsat true and false colour bands with IRS panchromatic data.
	Ref 20m	20-metre multispectral 140 x 140 km scene	
1m/5m ImageStak: 5-metre Reference Colour 25m CE90 with 1-metre Pro Colour 10-metre CE90 Custom overlays		Standard 1m/5m ImageStak products include: 1 metre Pro Colour 5 metre Reference Colour	1m/5m ImageStak combines the benefits of a 5m regional base map with the detailed visual and spatial information contained within 1-metre Ikonos Pro imagery of customer-specified areas of interest. This unique combination provides cost-effective access to medium-resolution data for county, state or regional coverage – and it incorporates high-resolution inserts for areas requiring detailed analysis. The image layers are delivered as GIS-ready integrated data sets that are tonally balanced and positionally corrected.

(*Source*: <www.spaceimaging.com/products/irs/geo.htm>)
(*Source*: <www.spaceimaging.com/products/irs/reference.htm>)
(*Source*: <www.spaceimaging.com/products/ikonos/imagestak.htm>)

5. Landsat

Landsat-5 Products

~~Level~~	~~Description~~
~~Product Level 0~~	~~Raw data; there are no fundamental corrections applied to the data.~~
~~Product Level 1~~	~~Radiometrically corrected data~~
~~Product Level 2~~	~~Radiometrically and systemically corrected data~~
~~Product Level 3~~	~~Radiometrically and geographically corrected data with GCP~~
~~Product Level 4~~	~~Radiometrically and geographically corrected data with GCP and DEM~~

(*Source*: <www.cresda.com.cn/en/products_service.htm>)

Landsat-7 Products

Level	Description
Landsat-7 Level 0R	The primary user product is Level 0R data, an essentially raw data form that is marginally useful prior to radiometric and geometric correction. A Landsat-7 0R product contains all the ancillary data required to perform these corrections, including a Calibration Parameter File (CPF) generated by the Landsat-7 Image Assessment System. The Landsat-7 Processing System (LPS) spatially reformats Earth imagery and calibration data into Level 0R data. This involves shifting pixels by integer amounts to account for the alternating forward-reverse scanning pattern of the ETM+ sensor, the odd-even detector arrangement within each band, and the detector offsets inherent to the focal plane array engineering design. All LPS Level 0R corrections are reversible; the pixel shift parameters used are documented in the CPF.
Landsat-7 Level 1R	The Level 1R product is a radiometrically corrected 0R product. Radiometric correction is performed using either gains in the Calibration Parameter File or gains computed on the fly from the Internal Calibrator (IC). The choice is available to a user when the product is ordered. The biases used are always calculated from the IC data. Image artefacts such as banding, striping, and scan correlated shift are removed prior to radiometric correction. Radiometric corrections are not reversible. The Level 1R product geometry is identical to the input Level 0R data. During Level 1R product rendering, image pixels are converted to units of absolute radiance using 32-bit floating point calculations. Pixel values are then multiplied by 100 and converted to 16-bit integers prior to media output. Two digits of decimal precision are thus preserved. The 16-bit 1R product is twice the data volume of a similar 0R product.
Landsat-7 Level 1G	The Level 1G product is a radiometrically and systematically corrected 0R image. During processing, the Level 0R image data undergoes two-dimensional resampling according to user-specified parameters, including output map projection, rotation angle, pixel size, and resampling kernal. The end result is a geometrically rectified product free from distortions related to the sensor (e.g. jitter, view angle effects), satellite (e.g. attitude deviations from nominal), and Earth (e.g. rotation, curvature). The systematic Level 1G correction process does not employ ground control or relief models to attain absolute geodetic accuracy. Residual error in the systematic Level 1G product will be approximately 250 metres (1 sigma) in flat areas at sea level. Precision correction employs ground control points to reduce geodetic error of the output product to approximately 30 metres. This accuracy is attained in areas where relief is moderate. Terrain correction processing employing both ground control points and digital elevation models can further reduce geodetic error of the output product to less than 30 metres in areas where terrain relief is substational. Users requiring higher level products of this accuracy would be best served ordering Level 0R data for in-house processing or contacting a value-added service organization with such capabilities.

(*Source*: <landsat.gsfc.nasa.gov/guides/LANDSAT-7_dataset.html>)

6. QuickBird

QuickBird satellite was launched in 2001, and it is one of the first commercial remote sensing

satellites capable of gathering sub-metre resolution data over a very wide swath.
(*Source*: <www.kodak.com/US/en/government/rs/spotlight/digitalglobe.shtml>)

The QuickBird satellite incorporates a Kodak-designed and built sensor subsystem, consisting of the focal plane array, image compression and electronics. The subsystem captures 0.61-metre-resolution panchromatic imagery, and 2.4-metre multispectral imagery. It will produce 11 x 11-km snapshots to 11 x 225-km strip maps. In addition to green, red and near-infrared wavelengths, the multispectral image sensor can also process a blue channel, enabling true colour imaging from space.
(*Source*: <www.kodak.com/US/en/government/rs/spotlight/digitalglobe.shtml>)

QuickBird Products

Product Level	**Processing**	**Absolute Accuracy**		**Geographic Availability**
		CE90%	**RMSE**	
Basic imagery	Sensor corrected (raw)	23-metres*	14-metres*	Worldwide
Standard imagery	Georectified	23-metres**	14-metres**	Worldwide
Ortho 1:50,000	Orthorectified	25.4-metres	15.4-metres	Worldwide
Ortho 1:12,000	Orthorectified	10.2-metres	6.2-metres	US and Canada
Ortho 1:5,000	Orthorectified	4.23-metres	2.6-metres	Worldwide
Ortho 1:4,800	Orthorectified	4.1-metres	2.5-metres	US and Canada
Custom ortho	Orthorectified	Variable	Variable	Worldwide

*Attained using supplied Image Support Data files and a user supplied DEM, excluding sensor and viewing geometry and topographic displacement
**Excluding viewing geometry and topographic displacement

(*Source*: <www.sovzond.ru/articles/article_cartog.html>)

Basic Imagery products are the least processed of the QuickBird imagery products and are designed for customers having advanced image processing capabilities. Basic Imagery, together with the supplied attitude, ephemeris, and camera model information, is suitable for advanced photogrammetric processing (i.e., orthorectification).

Basic Imagery products are radiometrically corrected and sensor corrected, but not geometrically corrected nor mapped to a cartographic projection and ellipsoid. Image resolution varies between 61 centimetres (at nadir) to 72 centimetres (25°off-nadir look angle) for black and white products, and 2.44 metres (at nadir) to 2.88 metres (25°off-nadir look angle) for multispectral imagery. The image is resampled to a coordinate system defined by the ideal Basic Imagery camera model. The resulting GSD varies over the entire product as a function of the attitude & ephemeris during the imaging process. Basic Imagery products are not available with pan-sharpening.

Standard Imagery products are suitable for users requiring modest absolute accuracy and/or large area coverage. Users of Standard Imagery products usually possess sufficient image processing tools and knowledge to manipulate and exploit the imagery for a wide variety of applications.

Standard Imagery products are radiometrically corrected, sensor corrected, geometrically corrected, and mapped to a cartographic projection. Standard Imagery products are available

as black and white, colour, or pan-sharpened with a 60-centimetre or 70-centimetre GSD, or multispectral with a 2.4-metre or 2.8-metre GSD. All Standard Imagery products have uniform pixel spacing throughout the entire product. The radiometric corrections applied to this product include relative radiometric response between detectors, non-responsive detector fill, and a conversion for absolute radiometry. The sensor corrections account for internal detector geometry, optical distortion, scan distortion, any line-rate variations, and registration of the panchromatic and multispectral bands. Geometric corrections remove spacecraft orbit position and attitude uncertainty, Earth rotation and curvature, and panoramic distortion.
(*Source*: <www.eurimage.com/products/quickbird.html>)

Standard Imagery comes in two varieties:

- **Standard Imagery**: Standard Imagery has a coarse DEM applied to it, which is used to normalize for topographic relief with respect to the reference ellipsoid. The degree of normalization is relatively small, so while this product has terrain corrections, it is not considered orthorectified. It has an average absolute geolocation accuracy of 23-metre CE90%, excluding any topographic displacement and off-nadir viewing angle. Ground location is derived from refined satellite attitude and ephemeris information without requiring the use of ground control points (GCPs).
(*Source*: <www.digitalglobe.com/downloads/QuickBird%20Imagery%20Products %20-%20FAQ.pdf>
(*Source*: <www.digitalglobe.com/downloads/QuickBird%20Imagery%20Products %20-%20Product%20Guide.pdf>
(*Source*: <www.eurimage.com/products/quickbird.html>)

- **Ortho Ready Standard Imagery**: Ortho Ready Standard Imagery has no topographic corrections, making it suitable for orthorectification. Ortho Ready Standard Imagery is projected to a constant base elevation, which is calculated on the average terrain elevation per QuickBird scene. These products have a delivered absolute geolocation accuracy of 23-metre CE90%, excluding any topographic displacement and off-nadir viewing angle. When processed using supplied RPCs, a high-quality DEM (e.g., DTED Level 2), and sub-metre GCPs, accuracies in the range of 3 to 10 metres RMSE may be achieved.
(*Source*: <www.geoict.net/Resources/Publications/Final-report-Jeff.pdf>)
(*Source*: <www.digitalglobe.com/downloads/QuickBird%20Imagery%20Products %20-%20Product%20Guide.pdf>)

Orthorectified Imagery products are GIS-ready and are used as an image base map for a wide variety of applications. Orthorectified Imagery products are an ideal base for creating and revising mapping and GIS databases, or for registering existing feature layers. These products can also be used for change detection and other analytical applications that require a high degree of absolute accuracy.
(*Source*: <www.sovzond.ru/products/quickbird_eng.html>)

Orthorectified Imagery products are radiometrically corrected, sensor corrected, geometrically corrected, orthorectified, and mapped to a cartographic projection and datum. Orthorectified Imagery products are available as black and white, colour, or pan-sharpened, with a 60-centimetre or 70-centimetre resolution, or multispectral, with a 2.4-metre or 2.8-metre resolution. The radiometric corrections applied to this product include relative radiometric response between detectors, non-responsive detector fill, and a conversion for absolute radiometry. The sensor corrections account for internal detector geometry, optical distortion, scan distortion, any line-rate variations, and registration of the multispectral bands. Geometric corrections remove spacecraft orbit position and attitude uncertainty, Earth rotation and curvature, and panoramic distortion.

Orthorectified Imagery products require DEMs or GCPs to remove relief displacement and to place each pixel into its correct map location. Before an order for an Orthorectified Imagery product is accepted, DigitalGlobe will determine whether it can obtain the appropriate support data to make the desired product. The accuracy of the DEMs and GCPs used to make each product depends on the scale of the Orthorectified Imagery product ordered. For Orthorectified Imagery products with stated accuracies (1:50,000, 1:12,000, 1:5000 and 1:4800), it is DigitalGlobe's responsibility to acquire the support data necessary to make the product.
(*Source*: <www.eurimage.com/products/docs/quickbird.pdf>)
(*Source*: <www.sovzond.ru/products/quickbird_eng.html>)

DigitalGlobe also offers customers the opportunity to order Custom Orthorectified Imagery products. To create these products DigitalGlobe uses customer-provided support data to orthorectify QuickBird Imagery. There is no stated accuracy associated with the Custom Orthorectified Imagery product because the quality and accuracy of the finished product is directly dependent on the quality and accuracy of the support data. DEMs and GCPs are the most typical types of support data that customers provide to DigitalGlobe. Alternate forms of control, such as existing orthorectified data or high-accuracy GIS data, may also be accepted.
(*Source*: <www.digitalglobe.com>)

7. SPOT-4 and 5

The first SPOT satellite, developed by the French Centre National d'Etudes Spatiales (CNES), was launched in early 1986. The second SPOT satellite was launched in 1990 and the third was launched in 1993. The sensors operate in two modes, multispectral and panchromatic. SPOT is commonly referred to as a "pushbroom scanner", meaning that all scanning parts are fixed and scanning is accomplished by the forward motion of the scanner. SPOT pushes 3000/6000 sensors along its orbit. This is different from Landsat, which scans with 16 detectors perpendicular to its orbit.

The SPOT satellite can observe the same area on the globe once every 26 days. The SPOT scanner normally produces nadir views, but it does have off-nadir viewing capability. "Off-nadir" refers to any point that is not directly beneath the detectors, but off to an angle. Using this off-nadir capability, one area on the earth can be viewed as often as every three days.

This off-nadir viewing can be programmed from the ground control station and is quite useful for collecting data in a region not directly in the path of the scanner or in the event of a natural or man-made disaster, where timeliness of data acquisition is crucial. It is also very useful in collecting stereo data, from which elevation data can be extracted.

The width of the swath observed varies between 60 km for off-nadir viewing and 80 km for outmost off-nadir viewing at a nominal height of 832 km.
(*Source*: <www.csrsr.ncu.edu.tw/english.ver/service/resource/spot/spot.html>)

SPOT Products

	Product ID	Description
SPOT Scene	Level 1A	Radiometric correction of distortions due to differences in sensitivity of the elementary detectors of the viewing instrument. Intended for users who wish to do their own geometric image processing.
	Level 1B	Radiometric correction identical to that of level 1A. Geometric correction of systematic effects (panoramic effect, Earth curvature and rotation). Internal distortions of the image are corrected for measuring distances, angles and surface areas. Specially designed product for photo-interpreting and thematic studies.
	Level 2A	Radiometric correction identical to that of level 1A. Geometrical correction done in a standard cartographic projection (UTM WGS84 by default) not tied to ground control points. Allowing for possible differences in location, this product is used to combine the image with geographical information of various types (vectors, raster maps and other satellite images).
SPOT View	Level 2B (Precision)	This product comes in a map projection with ground control points taken on maps or from GPS-type measurements taken in the field. The image is corrected for a mean elevation in a projection and a standard map frame. This product is used when deformations due to relief are not that important (flat ground, etc.).
	Level 3 (Ortho)	Map projection based on ground control points and a DEM based on Reference3D data to eliminate distortions due to relief.

(*Source*: <www.spotimage.fr/html/_167_224_555_234_.php>)

8. MODIS

The Terra and Aqua missions are part of NASA’s Earth Observing System. Originally the missions were named “EOS AM” for Terra and “EOS PM” for Aqua because of their morning (Terra) and afternoon (Aqua) equatorial crossing time. The focus for the Terra and Aqua satellites is the multidisciplinary study of the Earth’s interrelated processes (atmosphere, oceans, and land surface) and their relationship to changes in Earth systems.

A set of precise atmospheric and oceanic measurements to understand their role in the Earth’s climate and its variations will be obtained from the instruments on the Terra and Aqua platforms. The on-board sensors will measure clouds, precipitation, atmospheric temperature / moisture content, terrestrial snow, sea ice, and sea surface temperature during its six-year mission.

The MODIS instruments on the Terra and Aqua platforms provide measurements on a global basis every 1-2 days with a 16-day repeat cycle.
(*Source*: <daac.gsfc.nasa.gov/MODIS/products.shtml>)

There are many products from MODIS:

- MODIS/Terra Radiometric and Geolocation Products
- MODIS/Terra Atmosphere Products
- MODIS OCEAN PRODUCTS:
  - Level 2 Data Products
  - Level 3 Binned Data Products
  - Level 3 Mapped Data Products, 4-km Spatial Bins
  - Level 3 Mapped Data Products, 36-km Spatial Bins
  - Level 3 Mapped Data Products, 1-Degree Spatial Bins
  - Level 4 Binned Data Products
  - Level 4 Mapped Data Products, 4-km Spatial Bins
  - Level 4 Mapped Data Products, 36-km Spatial Bins

Level 4 Mapped Data Products, 1-Degree Spatial Bins
(*Source*: <daac.gsfc.nasa.gov/MODIS/Terra/product_descriptions_modis.shtml#ocean>)

9. ASTER

ASTER is one of the five state-of-the-art instrument sensor systems on board Terra, with a unique combination of wide spectral coverage and high spatial resolution in the visible near-infrared range through shortwave infrared to the thermal infrared regions. It was built by a consortium of Japanese government, industry, and research groups. ASTER data is expected to contribute to a wide array of global change-related application areas, including vegetation and ecosystem dynamics, hazard monitoring, geology and soils, land surface climatology, hydrology, and land cover change.
(*Source*: <edcdaac.usgs.gov/aster/asteroverview.asp>)

The ASTER sensor has 14 spectral bands; three in the very-near-infrared (VNIR) range at 15-m pixel resolution, six for shortwave infrared at 30-m resolution, and five for thermal infrared at 90-m resolution.

A DEM created automatically from ASTER imagery can be expected to have a vertical accuracy of 25 metres on average. This can improve to approximately 11 metres in areas with less vegetation or fewer man-made features. It is therefore useful for small- to medium-scale mapping applications, 1:50,000 to 1:100,000 in scope. ASTER-generated elevation models at this scale can prove a useful source of information in areas where DEM data is currently not available, or as an alternative to commercial off-the-shelf or government-owned DEM products. In addition to creating the DEM, ASTER imagery can be orthorectified to create a useful, map-accurate orthoimage describing the land cover.
(*Source*: <www.geoconnexion.com/magazine/article.asp?ID=869>)

ASTER Products

	Product No.	Standard Data Products	Description	Resolution[1]
Standard	Level 1A	Level 1A (reconstructed, unprocessed instrument data)	Products which are processed by parallax correction or geometric correction to level 0 data and cut by each scene	V (15 m) S (30 m) T (90 m)
	Level 1B	Level 1B (radiance registered at sensor)	Products which are re-sampling processed to level 1A data using radiometric coefficients and specified map projection method	V (15 m) S (30 m) T (90 m)
	2A02	Relative spectral emissivity (D-stretch)	Products which are generated from the products of level 1B by the no-correlation stretch process. 2A02 is made respectively by an independent processing demand.	90 m
	2A03V	Relative spectral reflectance (D-stretch) VNIR	Products which are generated from the products of level 1B by the no-correlation stretch process. 2A02 is made respectively by an independent processing demand.	15 m
	2A03S	Relative spectral reflectance (D-stretch) SWIR	Products which are generated from the products of level 1B by the no-correlation stretch process. 2A02 is made respectively by an independent processing demand.	30 m
	2B01V	Surface radiance VNIR	Products which are generated from products of level 1B	15 m
	2B01S	Surface radiance SWIR	Products which are generated from the products of level 1B, with atmospheric correction – VNIR, SWIR executed	30 m
	2B01T	Surface radiance TIR	Products which are generated from the products of level 1B, with atmospheric correction – TIR executed	90 m
	2B05V	Surface reflectance VNI	Products which are generated from products of level 1B	15 m
	2B05S	Surface reflectance SWIR	Products which are generated from products of level 1B	30 m
	2B03	Surface temperature	Products which are generated from the products at the same time by the temperature radiation rate separation process	T (90 m)
	2B04	Surface emissivity	Products which are generated from the products at the same time by the temperature radiation rate separation process	T (90 m)
Half standard	3A01A	Radiance registered at sensor with orthophoto correction	Products which are generated from level 1A by using relative digital elevation model XYZ (4A01X) products	V (15 m) + DTM S (30 m) + DTM T (90 m) + DTM
	4A01	Digital elevation model (relative)	Products which are generated by using the strap 3N and 3B from the level 1A products	Z (default 30 m)

Note: [1] V=VNIR, S=SWIR, T=TIR
(*Source*: <www.gds.aster.ersdac.or.jp/gds_www2002/exhibition_e/a_products_e/a_product2_e.html>)

10. ERS-1 and 2

The first and second European Remote Sensing Satellites (ERS-1 and ERS-2) are developed by the European Space Agency as a family of multi-disciplinary Earth observation satellites. They orbit the Earth in about 100 minutes and in 35 days have covered nearly every corner of the globe at least once.
(*Source*: <www.deos.tudelft.nl/ers/>)

The first one, ERS-1, was launched on 17 July 1991 by an Ariane-4 launcher from Kourou, French Guiana. ERS-2 was launched in 1995. The satellites have a sun-synchronous, near-polar, quasi-circular orbit with a mean altitude 785 km.

The Active Microwave Instrument on ERS-1/2 operates at 5.3 GHz frequency (C-band); it consists of two separate radar instruments with three modes of operation: SAR for Image and Wave Mode and a three-antenna Scatterometer for wind measurements.
(*Source*: <www.csrsr.ncu.edu.tw/english.ver/ers.htm>)

11. Radarsat-1

The Radarsat satellite was launched on 4 November 1995, and Radarsat International is the private Canadian firm holding the rights to supply Radarsat data worldwide.
(*Source*: <www.rsi.ca/news/media/rs1_prog.asp>)

The orbit for Radarsat is sun-synchronous and is flown at an altitude of 798 km, at an inclination of 98.6 degrees. Radarsat employs the use of a SAR sensor, which has the unique ability to shape and steer its beam from an incidence angle of 10 to 60 degrees in swaths of 45 to 500 km in width, with resolutions from 8 to 100 m. The repeat cycle is 24 days, although over the poles and high latitudes, the Radarsat system provides one-day repeat coverage, and at the mid-latitudes, the repeat coverage is approximately three days.
(*Source*: <www.agrecon.canberra.edu.au/Products/Satellite_Imagery/RADARSAT/
Radarsat.htm>)

The SAR sensor on Radarsat has the unique capability to acquire data in any one of a possible 25 imaging modes. Each mode varies with respect to swath width, resolution, incidence angle and number of looks. Because different applications require different imaging modes, Radarsat gives users tremendous flexibility in choosing the type of SAR data most suitable for their application. The following table shows most of the image modes available.
(*Source*: <www.ga.gov.au/acres/prod_ser/radadata.htm>)

Radarsat Products

Processing Level	Radarsat Mnemonic	Description	Software/Hardware Requirements
Signal Data	RAW	Unprocessed radar signal. Level 0 CEOS-formatted.	SAR processor
Single Look Complex	SLC	Amplitude and phase are preserved. Data remains in slant range. Data is calibrated. It retains the optimum resolution available for each beam mode. It is suitable for interferometric processing. Data from all beam modes, except ScanSAR, can be processed to this product.	Sophisticated image processing software (radar modules)
Path Image	SGF	Data is converted to ground range and multi-look processed. Image remains oriented in direction of orbit path. Image is calibrated. All beam modes can be processed to this product.	Image processing software or print media
Path Image Plus	SGX	Data is converted to ground range. Image remains oriented in direction of orbit path. Data has finer pixel spacing than Path Image. Image is calibrated.	Image processing software or print media to accommodate larger file size
Map Image	SSG	Image is corrected to a map projection. It is oriented with "north up" and is corrected to a user-requested map projection. The positional accuracy of Map Image processing depends on the terrain relief and the beam mode. Data from all beam modes, with the exception of ScanSAR, can be processed to this product.	GIS software and/or image processing software
Precision Map Image	SPG	Image is corrected to a map projection. Client-provided GCPs are used to improve positional accuracy.	GIS software and/or image processing software
Ortho-Image	ORI	Terrain distortions are removed. Ortho-corrected using client-supplied DEM and maps.	GIS software and/or image processing software

(*Source*: <www.ldeo.columbia.edu/rsvlab/glossary.html>)

Appendix IX. Some Non-commercial and Commercial Entities Providing Space Information Products and Services for Flood Management

- **National Aeronautics and Space Administration – United States**

The National Aeronautics and Space Administration (NASA) was established by the National Aeronautics and Space Act of 1958. Formed as a result of the crisis of confidence over the launch of Sputnik, NASA inherited the earlier National Advisory Committee for Aeronautics (NACA) and other government organizations, and almost immediately began working on options for human space flight. NASA is responsible for leading scientific research in air and space technologies.
(*Source*: <history.nasa.gov/brief.html>)

- **National Oceanic and Atmospheric Administration – United States**

The National Oceanic and Atmospheric Administration (NOAA) is the largest bureau within the Department of Commerce and is integral to providing the Department with an environmental perspective on issues having an impact on the nation's resources and its economy. NOAA's mission entails environmental assessment, prediction, and stewardship. It is dedicated to monitoring and assessing the state of the environment in order to make accurate and timely forecasts to protect life, property, and natural resources, as well as to promoting the economic well-being of the United States and to enhance its environmental security.

NOAA is structured into five primary, component line offices. These are the National Weather Service, the National Environmental Satellite, Data, and Information Service, the National Marine Fisheries Service, the National Ocean Service, and the Office of Oceanic and Atmospheric Research.
(*Source*: <nationalatlas.gov/federal.html>)

NOAA's National Weather Service (NWS) monitors conditions that lead to flooding 24 hours a day, and issues forecasts, watches and warnings. NOAA Weather Radio provides up-to-the-minute flood warnings. Receivers can be set to provide audible alarm even when they are turned off. This technology is critical to saving lives, particularly during night-time disasters. In addition, NWS works closely with national, state and local emergency managers to disseminate forecasts and warnings, as well as to support their flood response activities. Doppler radar provides a powerful tool to provide pinpoint warning information, particularly in the case of flash floods. By making forecasts more accurate and providing more lead time, public response to warnings appears to have improved, resulting in the saving of lives.

NWS is implementing the Advanced Hydrologic Prediction Service (AHPS), which leverages new technology and advances in hydrologic science to provide increasingly accurate forecasts. AHPS will allow better forecasting and response to flooding, and it will also transform water management activities, leading to improved reservoir management, and it can provide information on how long drought conditions will affect river levels.
(*Source*: <www.noaanews.noaa.gov/stories/s600c.htm>)

- **European Organization for the Exploitation of Meteorological Satellites – European Union**

EUMETSAT is an intergovernmental organization created through an international convention agreed by 18 European Member States.

EUMETSAT's primary objective is to establish, maintain and exploit European systems of operational meteorological satellites. EUMETSAT is responsible for the launch and operation of the satellites and for delivering satellite data to end-users, as well as contributing to the operational monitoring of climate and the detection of global climate changes.
(*Source*: <www.msgafrica.net/english/right_files/chapters/teach_files/partners.htm>)

EUMETSAT took over formal responsibility for the Meteosat system. Another important programme initiated in the 1990s was the EUMETSAT Polar System (EPS). This is a joint venture with the National Oceanic and Atmospheric Administration, by which EPS will provide data from a sun-synchronous orbit with an equator crossing time of 09.30h and the US satellites from the afternoon orbits.

EUMETSAT had become a mature organization with direct responsibility for the operation of its satellites in orbit and with new programmes to ensure the continuity of observations. At the same time, it has become one of the major partners in satellite systems for observing the entire planet. Its success has not only ensured the availability of key satellite data for Europe but also for many developing countries which now rely on its data and systems.
(*Source*: <www.eumetsat.de/en/area1/topic1.html>)

Small reception facilities can be installed in schools, flying clubs, and marinas, and are in addition set up by many private individuals. In all, a few thousand systems, located in over 100 countries, are installed for the direct reception of EUMETSAT image data. Of these, over 400 are high-performance Primary Data User Stations, for which an annual license fee may be required.
(*Source*: <www.eumetsat.de/en/area1/topic1.html>).

- **European Space Agency – European Union**

The European Space Agency (ESA) is Europe's gateway to space. Its mission is to shape the development of Europe's space capability and ensure that investment in space continues to deliver benefits to the citizens of Europe.

ESA has 15 Member States. By coordinating the financial and intellectual resources of its members, it can undertake programmes and activities far beyond the scope of any single European country.

The job of ESA is to draw up the European space programme and carry it through. The Agency's projects are designed to find out more about the Earth, its immediate space environment, the solar system and the universe, as well as to develop satellite-based technologies and services, and to promote European industries. ESA also works closely with space organizations outside Europe to share the benefits of space with the whole of mankind.

ESA is an entirely independent organization, although it maintains close ties with the European Union through an ESA/EC Framework Agreement. The two organizations share a joint European strategy for space and together are developing a European space policy.
(*Source*: <www.esa.int/esaCP/GGG4SXG3AEC_index_0.html>)

National Space Development Agency – Japan

The Japan Aerospace Exploration Agency (JAXA) was born on 1 October 2003, merging the Institute of Space and Astronautical Science (ISAS), the National Aerospace Laboratory of Japan (NAL), and the National Space Development Agency of Japan (NASDA), and a new JAXA website was created.

<www.jaxa.jp/index_e.html>

Currently NASDA is working on ALOS, ADOES and GMS satellite programmes.

- **Indian Space Research Organization – India**

The main objective of the ISRO space programme includes the development of satellites, launch vehicles, sounding rockets and associated ground systems. Present operational space systems include Indian National Satellite (INSAT) for telecommunication, television broadcasting, meteorology and disaster warning, and Indian Remote Sensing Satellite (IRS) for resource monitoring and management. Space science activities include SROSS and IRS-P3 satellites, participation in international science campaigns, and ground systems, such as MST Radar. ISRO's cooperative arrangements cover several countries and space agencies. ISRO provides training in the space field to personnel from other countries, and its hardware and services are available commercially through Antrix Corporation.
(*Source*: <www.bangalorebio.com/institutions.htm>)
(*Source*: <www.isro.org/about_isro.htm>)

The Indian Space Research Organization activated the IRS-1C and IRS-1D Earth observation satellites as a part of the Indian Remote Sensing Satellite Programme. Each of these satellites provides 5-metre black and white, 20-metre multispectral, and 180-metre multispectral data. Ground receiving stations are positioned across the globe and define the areas of available coverage. With multiple on-board sensors, these imaging systems provide systematic and repetitive data acquisition for a wide variety of potential applications.
(*Source*: <www.spaceimaging.com/corporate/sats.htm>)

- **Korea Aerospace Research Institute – Republic of Korea**

The main research and development areas of the Korea Aerospace Research Institute (KARI) are classified mainly into the development of aircraft, artificial satellites and rockets. KARI also performs quality assurance services for aircraft and space devices in accordance with delegation from the government. For advanced aircraft, KARI has been developing the Smart Unmanned Aerial Vehicle, Unmanned Stato-Airship and

Next Generation Helicopter.
(*Source*: <www.korea.net/Search/Directory/DirView.asp?code=n0>)

In the area of artificial satellites, KARI pushed ahead development of the second multi-purpose satellite, and started developing a satellite for communications, oceanography and meteorology; the satellite was put into a geostationary orbit in the second half of 2003. As for rockets, KARI successfully completed the trial launch of the liquid-fuel scientific rocket KSR-III for the first time in the Republic of Korea on 28 November 2002. At present, KARI is undertaking the construction of a space centre and a space launch site.
(*Source*: <www.kari.re.kr>)

- **Digital Globe**

DigitalGlobe was the first company ever to receive a high-resolution commercial remote sensing license from the Government of the United States under the Land Remote Sensing Policy Act. With the launch of its QuickBird satellite in October 2001, DigitalGlobe became the world’s highest-resolution commercial satellite imagery provider.
(*Source*: <www.digitalglobe.com/about/factsheet.shtml>)

DigitalGlobe’s QuickBird system features high spatial resolution, precise geolocational accuracy, large area collection, and variable imaging collection times.
(*Source*: <www.imagery-central.com/files/digitalglobe.asp>)

- **OrbImage**

Established in 1993, OrbImage, an affiliate of Orbital Sciences Corporation, is a provider of both satellite and aerial data with head offices in Dulles, Virginia, and St. Louis, Missouri. Their current satellite suite consists of OrbView-1 and 2, launched in 1995 and 1997 respectively. OrbView-1 is for atmospheric imaging and provides valuable weather-related data to Government customers. OrbView-2 is an ocean and land multispectral imaging system. OrbView-2 is the world’s first commercial satellite to image the Earth’s oceans and land surfaces in colour on a daily basis.

OrbImage is also a provider of high-resolution, 1-m panchromatic aerial imagery products. OrbView Cities™ currently features imagery of major US and non-US urban areas. OrbImage will significantly expand this archive with the planned launch of its next high-resolution imaging satellites, OrbView-3 and 4. OrbView-3 will provide 1-m resolution panchromatic imagery and 4-m resolution multispectral imagery of the Earth’s surface.
(*Source*: <www.imagery-central.com/files/orbimage.asp>)

- **SPOT Image**

SPOT Image is the worldwide distributor of geographic information products and services derived from the SPOT Earth observation satellites, including the Vegetation instrument flown on SPOT-4 and 5.

SPOT Image also distributes complementary optical and radar data acquired by other

satellites, offering low to very-high-resolution images. SPOT Image was appointed by the Centre National d'Etudes Spatiales (CNES) as sole commercial operator of the SPOT satellites and it acquires the SPOT data through a receiving station at its premises in Toulouse and via a network of partner stations around the world.
(*Source*: <www.spot.com/html/SICORP/_401_456_.php>)

- **Space Imaging**

Space Imaging LLC is a provider of various satellite and airborne data. Based in Thornton, Colorado, they were the first company in the world to successfully launch and operate a 1-m resolution imagery satellite commercially. In addition, they are the sole American distributor of Indian IRS-1A, B, C and D data, and they provide Landsat-4 and 5 and Radarsat-1 data, as well as aerial data.

Space Imaging was formed in 1994 to enter the commercial imagery market. They acquired the Earth Observation Satellite Company (EOSAT) in Lanham, Maryland, in 1996. EOSAT operated Landsat-4 and 5 satellites and was the processor and seller of the data. Between 1996 and 1998, Space Imaging added the Indian IRS satellite and Radarsat-1 data to their suite of imagery products. They also formed the Mapping Alliance Programme (MAP), which brought together the resources of a number of aerial providers. The launch of the Ikonos-1 satellite in 1998, however, was unsuccessful. But in 1999 they successfully launched Ikonos-2, with 1-m panchromatic / 4-m multispectral imagery capability. Pacific Meridian Resources was acquired in 2000 as a wholly owned subsidiary to complement Space Imaging with their remote sensing, GIS and mapping capabilities. In December 2000, Space Imaging was granted licensing permission to acquire and sell 0.5-m imagery in the year 2004.
(*Source*: <www.imagery-central.com/files/spaceimg.asp>)

- **ImageSat International**

ImageSat International is a commercial provider of high-resolution, satellite earth imagery collected by its Earth Resources Observation Satellite (EROS). ImageSat successfully launched its first satellite in 2000, EROS-A, aboard a Russian Start-1 launch vehicle. In so doing, ImageSat became the second company in the world to successfully deploy a non-governmentally owned, high-resolution imaging satellite.
(*Source*: <www.spacelinks.com/SpaceCareers/Careers_Satop.html>)
(*Source*: <www.imagesatintl.com/aboutus/satellites/satellites.shtml>)

One of the four global service providers in the high-resolution satellite imagery niche, ImageSat is distinguished by several features: (a) exclusive service packages, including exclusive use of the EROS satellite over a designated footprint; (b) flexible imaging parameters; (c) international (non-US) operation; (d) fast image acquisition and delivery; (e) competitive pricing; and (f) no risk – pay only for services received.

ImageSat is also unique in that it has a second satellite in advanced stages of development and a third in the planning stages. The EROS-B satellite is due to be operational at the beginning of 2006. Operating simultaneously with EROS-A, EROS-B will increase the revisit frequency, enabling customers to better monitor designated targets.

(*Source*: <www.imagesatintl.com/aboutus/aboutus.shtml>)

- **SERTIT**

SERTIT is a centre for the promotion and transfer of technology related to the Graduate Physics School (ENSPS) of the Université Louis Pasteur (ULP), a science university in Strasbourg. Although it is integrated into the scientific fabric of one of the most prominent French universities, which is recognized at the international level in matters of multidisciplinary research studies, SERTIT has to provide the funds necessary for its own development and services. "SERTIT is an example to be followed, in particular with regards to the quality of services provided. A crisis map may be delivered within eight hours and this is a remarkable achievement," says Alain Beretz, ULP vice-president, business and promotion portfolio.

The Rapid Mapping Service is part of SERTIT, a regional service for image processing and remote sensing. SERTIT's mission is to extract and format information produced by Earth observation satellites. Beside analysing and providing remote sensing crisis images, SERTIT is a pioneer in exploiting data produced by radar systems. It also takes part in numerous simulation programmes for the assessment and validation of future space sensors. Finally, it shares its know-how with clients and partners and organizes professional training sessions.
(*Source*: <www.meceo.info/index.php?lang=en&page=news>)

When a natural disaster occurs, the Rapid Mapping Service provides organizations in charge of major risk management (ministries, civil protection, local authorities, United Nations, NGOs, etc.) with readily exploitable maps. Within eight hours, the Service converts satellite images of the disaster area into a map showing the geographical extent of the damages caused.

Depending on available data, the Service may complement initial information with maps and summaries:

- Detailed maps of smaller areas;
- Maps indicating the intensity of the event;
- Successive maps allowing for the evolution of the disaster to be followed up;
- Statistical summaries of the damage caused.

Where areas are not well known, the Service offers a basic map providing information allowing numerous uses:

- Facilitating location identification;
- Identifying refugee camps;
- Establishing emergency camps, and others.

As regards the "post-crisis" analysis of an event, it also provides maps to the services in charge of issuing the natural disaster declaration so that victims may be eligible for compensation.
(*Source*: <www.infosyssec.net/infosyssec/buscon1.htm>)

Eight hours for an operational crisis map

At the client's request, space agencies launch the acquisition of data relating to the area to be mapped. The countdown starts as the Rapid Mapping Service team receives satellite images.

Receipt of data: Satellite data for the disaster area are transferred via the Internet. Where conditions are favourable, these images are complemented with reference maps.
Homogenization of information: All the crisis data is recorded according to an identical format. Images are positioned within the same frame of reference and topographic effects are corrected.
Information extraction: Raw information on the actual crisis is extracted by combining image processing and expertise in photo-interpretation. Comparing images of the area before and after the disaster allows for quantifying its intensity and extent.
Designing the crisis map: Information on the crisis is put into shape. The geographical extent of damages is transposed onto a standard map background or onto a satellite image, or it may be summarized as statistical data.
Dispatching the crisis map: Disaster management and intervention teams working in the field receive the map via the Internet in a matter of minutes.

SERTIT Rapid Mapping Service has been involved in rapid mapping action for 19 major disasters since 1999.

➢ **Remote Sensing Technology Application Centre, Ministry of Water Resources – China**

The Centre is responsible for developments in the application of remote sensing and geographic information system technology in water resource management sectors. It provides a number of services, especially for information acquisition and the establishment of databases in flood control and drought prevention, disaster mitigation and rescue, investigation of water and soil resources, environmental monitoring, irrigation and drainage, planning, construction and management of water projects and so on.
(*Source*: <www.iwhr.com/rstac/index-e.html>)

The Centre can provide the following rapid flood monitoring and assessment services:

1. Data sources for flood monitoring

(a) Landsat (TM, ETM+), SPOT , CBERS-1 images, used for background data extraction, baseline of water body extraction, land use classification, monitoring;
(b) Radarsat, ERS-1/2, Envisat, ADEOS-2, ALOS images, used for extraction of water body during a flood;
(c) MODIS, NOAA (AVHRR), FY-1, FY-2 images, used for macro and dynamic monitoring.

2. Results of flood disaster monitoring and assessment

Flood monitoring and assessment are processed with the support of remote sensing images and GIS-based database. Results of flood monitoring and

assessment include the inundated area of each county, inundated residential area of each county, inundated cultivated land area of each area, affected population, and a treated image with notations of place, thematic map (inundated area and land use classification), statistical table, and analysis report.
(*Source*: <www.ceos.org/utilization/original_templates.pdf>)

3. Time requirement

The rapid flood mapping will be finished within two hours after getting a remote sensing image; the primary disaster assessment will be finished within six hours; and the results of the disaster assessment are transmitted to the State Council and State Headquarter of Flood Control and Drought Relief by communication satellite within 12 hours.
(*Source*: <www.ceos.org/utilization/original_templates.pdf>)

- **National Satellite Meteorological Centre – China**

Rainfall estimation and flooding area monitoring with meteorological satellite data are the two major tasks of NSMC among all of its services, as they are closely related with water resources. For the first task, NSMC developed a rainfall estimate technique using meteorological satellite data (NOAA, GMS-5 and FY-2 geostationary satellite). This technique derives rainfall intensities with a series of cloud characteristics, which include cloud top temperatures, temperature gradients, the expansion of convective cloud cluster, the occurrence of overshooting tops, and other features. The systems have been installed in 60 Middle Scale Data Utilization Stations over 28 provinces and they are used operationally in the summer season.

As an example of the second task, NSMC closely monitored the floods with the data from NOAA satellites and provided much useful information to the related Government departments during the severe flood of China in 1998. Identification of the types of land cover in remote sensing images is based mainly on the spectral characteristics. In the near-infrared waveband of NOAA/AVHRR, the water surface has lower reflectivity, while the reflectivity for vegetation and other types of land surface are higher. Based on data obtained from the continuous monitoring with NOAA/AVHRR from May to October of 1998, the statistics on the size of water bodies in three affected areas could be done by NSMC.
(*Source*: <www.lanl.gov/chinawater/documents/fangzongyi.pdf>)

- **Centre for Satellite Based Crisis Information – Germany**

The Centre for Satellite Based Crisis Information (ZKI) of the Applied Remote Sensing Cluster (CAF) of the German Aerospace Centre (DLR) is engaged in the acquisition, analysis and provision of satellite-based information products on natural disasters, for humanitarian relief actions and in the context of civil security.

Beside response and assessment activities, ZKI focuses on geoinformation for medium-term rehabilitation, reconstruction and prevention activities.

ZKI operates in national, European and international contexts, closely networking with public authorities (civil security), non-governmental organizations (humanitarian relief organizations), satellite operators, and other space agencies.

DLR participates in the International Charter on Space and Major Disasters, which is a major cooperative activity in the context of natural and man-made disasters. In case of a natural disaster in Germany, and also where required globally, ZKI coordinates the acquisition and analysis of satellite imagery as project manager within the scope of the International Charter on Space and Major Disasters.

The current and long-term goals of ZKI are the following:

- Bundling existing technical and scientific resources and capacities at DLR, especially within the Applied Remote Sensing Cluster, to increase their effectiveness and coordination for crisis management;
- Developing and establishing methods to generate specific information products and services in the range of disaster management, humanitarian relief and civil security;
- Developing and establishing a distributed European network for civil satellite-based crisis information;
- Enhancing relevant information technology and infrastructure.

(*Source*: <www.zki.caf.dlr.de/zki_intro_en.html>)