United Nations

International Decade for Natural Disaster Reduction

IDNDR Early Warning Programme

Report on

Earth Observation, Hazard Analysis and Communications Technology for Early Warning

Convener of International Working Group, and first Author:

Mr. John C. Scott

President, Center for Public Service Communications

Arlington, Virginia 22207

U.S.A.

IDNDR 1990 - 2000
Building a Culture of Prevention

IDNDR Secretariat, Geneva October 1997

REPORT ON EARTH OBSERVATION, HAZARD ANALYSIS AND COMMUNICATIONS TECHNOLOGY FOR EARLY WARNING

CONTENTS

FOREWORD

In 1989, the member states of the United Nations declared the period from 1990 to the year 2000 to be the International Decade for Natural Disaster Reduction (IDNDR). Its objective is to "reduce the loss of life, property damage, and social and economic disruption caused by natural disasters, through concerted international action, especially in developing countries".

The fundamental importance of early warning for realizing this objective of disaster reduction was recognized in 1991. The IDNDR's Scientific and Technical Committee declared the subject a program target, by which the success of the Decade would be judged by the year 2000. By drawing on global scientific knowledge and practical experience, the Decade's advisory committee encouraged all countries to ensure the ready access to global, regional, national and local warning systems as part of their national development plans. The IDNDR Secretariat has since coordinated an international multi-disciplinary framework to promote this issue. In doing so, it has been able to draw on the comprehensive views and abilities of the United Nations system, needs and concerns of individual countries, and related global expert knowledge.

The critical nature of early-warning for the protection of vital resources and for addressing national development objectives was highlighted by a technical committee session devoted to the subject at the United Nations' World Conference on Natural Disaster Reduction held in Yokohama, Japan in May 1994. Several of the expert presentations cited the importance of public policy commitment for successful early warning. The primary outcome of the Conference, The Yokohama Strategy for a Safer World: Guidelines for Natural Disaster Prevention, Preparedness and Mitigation further emphasized the importance of applied scientific knowledge and the public's awareness of hazard risks as essential components for more effective early warning practices.

The IDNDR Secretariat was requested by the United Nations General Assembly in 1995 to coordinate a review of the existing early warning programs and to suggest means by which global practices could become better coordinated and made more effective. Initial information was conveyed by the Secretary General's Report on Early Warning to the Fiftieth Session of the United Nations General Assembly in October 1995. (UN Document A/50/256, 9 October 1995). At that time, a further examination of new scientific and experimental concepts for accurate and timely short-term forecasting was requested of the IDNDR for the purpose of making recommendations on the applicability and development of more effective early warning in the context of international cooperation.

For the current work, six international expert working groups were convened to study different aspects of the early warning process: geological hazards, hydrometeorological hazards including drought, fire and other environmental hazards, technological hazards, the use and transfer of related modern technologies, and national and local capabilities pertinent to the effective use of early warning. Guiding Principles for Effective Early Warning were also compiled by the conveners.

This following report of the Working Group on Early Warning Capabilities for Geological Hazards summarizes global experience and reviews the current state of knowledge and practice on the subject. Recommendations are also made for improvements and areas that require additional international attention. The conclusions reflect the views of scientific and technical experts as well as those of the United Nations departments and agencies concerned. An effort was made to ensure that views of government authorities, non-governmental organizations and other elements of civil society were also represented, particularly as they relate to factors which determine the efficacy of early warnings.

This report is one of a series issued by the IDNDR Secretariat in October 1997 to review the current state of early warning systems. By the end of the Decade, these views will contribute to final recommendations for improved, and better coordinated, practices in fulfillment of the initial

IDNDR program target for the subject. They will first be considered by an International Conference on early warning systems for the reduction of natural disasters which has been held in Potsdam, Germany in September, 1998. This technical and scientific conference focusing on the application of successful warning practices was sponsored by the Government of Germany with the collaboration of United Nations' agencies and international scientific organizations. As a major topical event of the IDNDR closing process and the consolidation of global views, the conference has identified those accomplishments and local experiences which can best improve organizational relationships and practical effectiveness for early warning into the 21st century.

The following titles compose the series of information reports of the IDNDR Early Warning Programme:

Early Warning Capabilities for Geological Hazards
Early Warning for Hydrometeorological Hazards, Including Drought
Early Warning for Fire and Other Environmental Hazards
Early Warning for Technological Hazards
Earth Observation, Hazard Analysis and Communications Tech. for Early Warning
National and Local Capabilities for Early Warning
Guiding Principles for Effective Early Warning

The Secretary General's Report on Early-warning Capacities of the United Nations System with Regard to Natural Disasters presented to the Fiftieth Session of the United Nations General Assembly, October 1995. (UN doc. A/50/526).

The Secretary General's Report on Improved Effectiveness of Early-warning Systems With Regard to Natural and Similar Disasters presented to the Fifty-second Session of the United Nations General Assembly , October 1997. (UN doc. A/52/561).

These reports may be accessed on the IDNDR web site: http://www.idndr.org or on the EWC'98 web site at http://www.gfz-potsdam.de/ewc98/ They also may be obtained from the IDNDR Secretariat, Palais des Nations, CH-1211 Geneva 10 Switzerland. or by Fax: +41-22-917-9098, or E-mail: idndr@dha.unicc.org

EXECUTIVE SUMMARY

A discussion about technology used in early warning is more than a discussion about those technologies that improve our capacity to make people aware of their vulnerability to disasters. Not surprisingly, a serious look at earth observation, hazard analysis and communications technologies used in the early warning process exposes a much more intricate set of issues. These involve not only technology, but also a host of political and human factors that ultimately affect selection and application of technologies. These issues include:

What technologies are currently available to assess risk, to determine vulnerability and to disseminate warning ? How accessible are they to the people or areas that require them most, paying special attention to their availability in developing countries ? What do they cost, to construct, to use, and, equally importantly, to maintain ? Do the appropriate institutions and individuals have the answers to these questions ?

There are other fundamental questions that pertain to the hazards which early warning seeks to address. What are the types of hazards types, how imminent are their onset, and to what extent can each be predicted or monitored ? Each type of hazard (i.e., earthquake, volcanic eruption, tsunami, hurricane, flood, wildfire, disease epidemic) has different characteristics that affect an ability to issue timely and effective warnings to targeted populations. For example, tropical cyclones can be anticipated and tracked for some time before their worst effects are experiences. This provides time and opportunities to issue warnings, an advance indication that is not possible in the case of earthquakes. On the other hand, the known locations of probable geological hazards such as fault lines and areas of landslide risks can enable a sustained commitment to mitigation practices such as micro-zonation based on crucial hazard assessments.

How many people of different professional skills, different cultural and educational experience, and different political responsibilities will be involved in the early warning process ? Scientists, engineers, technicians, politicians, and disaster managers at local, regional, subregional, international levels are frequently involved in early warning. Educators, the media, commercial interests and members of the public are also recognized as having crucial roles to play in effective warning systems that address the actual needs of local communities.

The following report discusses how earth observation, hazard analysis and communications technologies are used in the early warning process. From there the discussion broadens to include observations and recommendations about these issues and the next steps that the United Nations might take and which the international community can endorse. Views are presented in the context of possible forms of international technical assistance, the exchange of information, and cooperation guided by the resolutions and decisions adopted by the World Conference on Natural Disaster Reduction (Yokohama, Japan, 23-27 May 1994) and later expressed in the Yokohama Strategy and Plan of Action for a Safer World.

I. INTRODUCTION

The International Decade for Natural Disaster Reduction (IDNDR) recognizes the valuable roles technology plays in being able to prevent or reduce the worst effects of natural disasters. These have been, undisputedly, shining moments in the history of technological contribution to humanitarian efforts to protect life and property. Importantly, IDNDR's efforts have encouraged public commitments to move beyond the natural desire to respond to catastrophes. Through this decade of effort and attention the world community has been led to understand the need to be more effective in using technologies, including remote sensing, Geographic Information Systems, and telecommunications for early warning so that communities at risk might prepare for, mitigate and, as possible, prevent natural disasters.

Successful early warning systems are a direct result of the ability to collect, interpret, and disseminate reliable and timely information to populations at risk. Increasingly, earth observation, hazard analysis and telecommunications technologies are used to support this process. Many of the technical and human infrastructures that make them possible have been unavailable, unaffordable or totally inadequate for application in many developing countries and other under served areas of the world. This is changing.

An increasing body of evidence is encouraging disaster managers and politicians alike to invest in strengthening early warning systems. This provides additional opportunities for scientists and technical professionals, working in both public and private sector endeavour, to provide the benefits of their knowledge for improvements in early warning. 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. Once modernization is completed, it is expected that the United States should realize annual benefits beginning at $7 billion.

II. EARTH OBSERVATION AND REMOTE SENSING

Remote Sensing technologies have proved to be valuable tools to support effective early warning for disasters. They enable the collection and monitoring of data about atmospheric conditions and characteristics of the Earth's surface leading to processes which may bring about natural disasters. Such information can be used to help determine appropriate actions to reduce the disastrous effects of these processes.

Although this paper focuses on the early warning phase of disaster management, it is also valuable to appreciate the breadth of benefits that remote sensing can provide to disaster management. To prepare for and reduce the impacts of natural disasters with the help of satellite remote sensing, a complete strategy for disaster management would include the following applications:

Disaster Prevention

- Hazard analysis: assessing the probability of occurrence of potentially damaging phenomena.

- Vulnerability analysis: assessing the degree of loss expected to population, infrastructure and economic activities as the consequence of an event of a certain magnitude.

- Risk assessment: assessing the numbers of lives likely to be lost, the persons injured, damage to property and disruption of economic activities caused by a particular natural phenomenon.

- Land use planning and legislation: implementation of the risk map in the form of building codes and restrictions.

Disaster Preparedness

- Forecasting, warning or prediction of disasters (e.g., hurricane warning).

- Monitoring: Evaluating the development, over time, of disasters (e.g., floods).

Disaster Relief

- Damage assessment shortly after the occurrence of a disaster.

- Defining safe areas, to indicate possible escape areas.

- Infrastructure monitoring, to ensure an undisturbed supply of aid.

III. CHARACTERISTICS OF REMOTE SENSING TECHNOLOGIES

Technology

Earth observation satellite systems provide a high degree of detail and a wealth of information at a global level for early warning activities. This information includes two categories of data: first, numerical values of detected geophysical parameters or related measurements, and second, imaging data sensed in various electromagnetic bands. Many different space systems exist, with different characteristics related to:

- spatial distribution: the size of the area on the terrain that is covered by the instantaneous field of view of a detector;

- spatial resolution: the minimum distance at which two adjacent targets are detected as individually separated;

- temporal resolution: the time taken for a satellite to revisit the same part of the Earth's surface;

- spectral resolution: the number and width of the spectral bands recorded; and

- radiometric resolution: the accuracy of the sensor response to the changes of signal to be detected.

Overhead imagery from space is captured through a variety of technologies, that apply to both "passive" and "active" earth observation. Whatever the wavelength of the electro-magnetic radiation, "passive" systems are meant to use natural radiation sources (e.g., sunlight), whereas active systems (e.g., radar) emit and retrieve radio waves bounced off the Earth's surface.

Ultraviolet-to-infrared systems are sensitive to reflectance, which is a measure of molecular resonance of surface materials, whereas the backscatter of EM microwaves is sensitive to their roughness and dielectric constant.

The undebated advantage of active microwave systems (e.g., Synthetic Aperture Radar) is that they can "illuminate" the Earth's surface and detect relief features regardless of light and weather conditions on Earth. Passive observation of the Earth is carried out essentially at micrometric wavelength, usually between less than 0.3 microns (UV band, suitable for Ozone and SO2 detection, e.g.) and ca. 11 microns (thermal far-IR). It includes the Visible (0.3-0.7 micron) and the near-IR bands (0.7-1.2 micron), like those used to forecast the weather, and the mid-IR (ca. 4 micron) sub-band that also senses variations in heat levels. Though less common, passive observation is also carried out in the upper microwave bands (between ca. 50 and 90 GHz) for advanced meteorological studies on cloud systems.

Image acquisition techniques may be either film-based (analog) or electro-optical (digital). In the first case, optical or near-IR systems capture light reflected from the surface of the Earth with standard camera technology, and drop film canisters into the atmosphere to be retrieved and processed in hard copy form. In the latter case, systems collect images in spectral bands with charge-coupled devices similar to those used in video-cameras and fax machines. The images are transferred to binary code, and transmitted to the Earth through satellite communication down-links. These images may then be manipulated using software, or produced in hard copy form. Similar digital acquisition is used for SAR data, that contain the additional information on the phase changes the signals have undergone after leaving the transmitter. Reconstruction of detailed altitude maps is then obtained by "unwrapping" the phase information across the pixels that constitute the entire SAR image.

High Resolution Imaging Satellites

Besides the use of conventional aerial photographs, which often remain the most useful tools in many types of disaster studies, the application of satellite data has increased enormously over the last decades. After the initial low spatial resolution images of the LANDSAT MSS (60 x 80 metres), LANDSAT also offers thematic mapper images with a spatial resolution of 30 metres (except for the thermal infrared band) and an excellent spectral resolution with six bands covering the whole visible and the near and middle infrared part of the spectrum, and with one band in the thermal infrared. LANDSAT has a theoretical temporal resolution of eighteen days, however, weather conditions are a serious limiting factor in this respect, as clouds can hamper the visible band acquisition of data from the ground surface during overpasses. Another limitation of the LANDSAT System is the lack of an adequate stereo vision. Theoretically a stereomate of a TM image can be produced with the help of a good digital terrain model (DTM), but this remains a poor compensation as long as very detailed DTM's are not currently available.

The French SPOT satellite is equipped with two sensor systems, each covering adjacent paths of a 60 kilometre width. The sensors have an off-nadir looking capability, offering the possibility for images with good stereoscopic vision. The option for side views, results in a higher temporal resolution. SPOT senses the terrain in a wide panchromatic band and in three narrower spectral bands (green, red and infrared). The spatial resolution in the panchromatic mode is 10 metres, while the three spectral bands have a spatial resolution of 20 metres. The system lacks spectral bands in the middle and far (thermal) infrared.

LANDSAT has the longest record of widely available high resolution multi-spectral image data series. However, image data in optical bands can be provided by devices carried on board spacecraft of other countries, such as the Russian Federation (COSMOS, MIR and other missions), Japan (MOS) and India (IRS). Radar satellite images, available from the European ERS, the Japanese JERS and the Canadian Radarsat satellites offer an all-weather capability, as the system penetrates clouds. Theoretically, this type of image can yield detailed information on surface roughness and micro-morphology, however, the applied wavelengths and viewing angle have made its application in mountainous terrain difficult. Early results of research with radar interferometry are promising, indicating that detailed terrain models with an accuracy of around one metre can be created. This offers the possibility of monitoring slight movements related to landslides, fault displacements or bulging of volcanic structures. The elaboration of ERS complex image data has demonstrated the possibility of detecting vertical changes of land surfaces down to the precision of few centimetres, thus providing an excellent tool for earthquake studies.

Remote sensing data should generally be linked or calibrated with other types of data, derived from mapping, measurement networks or sampling points, to derive the parameters which are useful in the study of disasters. The linkage is done in two ways, either via visual interpretation of the image or via digital data merging and integration. Geographic Information Systems are powerful tools that facilitate the combination of the different types of data required for disaster management and the presentation of information in a form best understood by managers.

If all of the currently scheduled government and commercial land-viewing satellite systems orbit as planned, in the year 2000, a minimum of 19 satellites will be in polar orbit providing land data at resolutions from 1 to 30 metres in panchromatic, multi-spectral and radar formats. This will then provide considerable opportunity of data acquisition for improved early warning capabilities.

Meteorological Satellite Data for Monitoring the Earth

A global meteorological satellite system monitors the Earth's atmosphere, ocean and land surface areas almost in real time from equatorial and polar orbits. Existing geosynchronous satellites include the Geostationary Operational Environmental Satellites (GOES) operated by the United States (at 75 and 135 degrees West), METEOSAT, operated by the European Organization for the Exploitation of Meteorological Satellites, at 0 degrees longitude, the Geostationary Meteorological Satellite (GMS) operated by Japan at 140 degrees East, the Geostationary Observation Meteorological Satellite (GOMS) operated by the Russian Federation at 70 degrees East, and the Indian National Satellite (INSAT) operated by India at around 90 degrees East.

Their geo-synchronous equatorial position at 35,800 km of altitude allows them to observe the same regions every few minutes. Moreover, their capacity to provide synoptic observations of regional cloud distributions, atmospheric and ocean temperature, relative humidity, wind velocity, distribution of precipitation and other parameters that could be derived from the satellite images have become essential elements in weather forecasting. Among the latter, two of the most useful parameters for early warning activities that could be derived from these satellite data are cloud-top temperature and height.

Sun-synchronous meteorological satellites in quasi-polar orbit fly at lower altitudes, in a range between 500 and 1,500 km, and can provide a higher spatial resolution than their geo-synchronous counterparts, although with a much longer revisiting time (6 or 12 hours). Such satellites provide global coverage of the Earth twice every 24 hours, and can be used to determine sea surface temperature with a higher accuracy than what could be achieved from the geostationary orbit. Land-surface data obtained by these satellites have been found particularly useful, and inexpensive, for determining green bio-mass indices. Analysis of this data is used to monitor the encroachment of desert into previously vegetated areas, thereby marking the onset of a slowly developing disaster. The polar-orbiting meteorological satellites currently in use are those operated by the United States (NOAA-N series), by the Russian Federation (Meteor series) and by China (Feng Yung 1 series).

Although their spatial resolution is relatively low, the geostationary and polar-orbiting meteorological satellites together provide operational and high-frequency coverage of the entire Earth at very low cost. Thus, the use of their data in early warning, disaster prevention and mitigation practices should be easily achievable by most national and regional emergency planning and response services.

Applications

Remote sensing technologies are excellent tools in the mapping of the spatial distribution of disaster related data within a relatively short period of time. Applications of using data from satellites to predict weather-related disastrous phenomena, such as extreme storms and rainfall, are widely known and frequently utilized. Satellite data can be used before, during and after a disaster, for prevention, monitoring, mitigation and relief operations, respectively. Remote sensing also plays a role in early warning and other phases of management of geological hazards such as earthquakes, volcanic eruptions, and landslides. Various applications of remote sensing technology are reviewed below with respect to different types of hazards.

Flooding

Areas affected by flooding are typically large in size. Many different types of flooding occur, each with different requirements for satellite imagery. Two general categories are first, river floods, which can be seasonal and are related to big rivers or flash floods in smaller catchments, and second, coastal floods, frequently related to tropical cyclones or to high tides.

Many factors play a role in the occurrence of flooding, such as the intensity and duration of rainfall, snow melt, deforestation, poor farming techniques, sedimentation in river bed, and natural or man-made obstructions. In the evaluation of flood hazards, the following parameters should be taken into account: depth of water during flood, the duration of flood, the flow velocity, the rate of rise and decline, and the frequency of occurrence.

In prevention exercises, SPOT stereo-pair images and ERS radar images can be used to generate digital terrain models for the simulation of potentially disastrous conditions and the identification of vulnerable areas. During and after the event, mapping of sequential inundation phases is possible, including the duration, depth of inundation, affected areas and direction of current. This can be done with automated classification from optical and radar satellite imagery. However, the most crucial data are derived from the calculation of the peak discharges and return periods, using supplemental data from gauging stations.

Since this category of disaster is often associated with heavy cloud cover, the use of radar data from ERS, JERS and Radarsat permits the imaging of flooded areas through the clouds even when prohibitive airplane flight conditions exist. Multi-temporal radar images map flooded zones almost automatically, when image data from before, during and after the event are merged in a single coloured image where data of the imaging dates are displayed in one of the three basic colours (red, green or blue).

It has been demonstrated that using satellite data for flood mapping becomes economically advantageous with respect to ground survey for areas larger than a couple of ten square kilometres. However, a disadvantage in this domain is the long revisiting time of current high resolution satellites, which sometimes cannot allow the spacecraft to observe an event occurring between two successive passes.

For the prediction of floods, promising results have been reported recently on the use of NOAA images combined with meteorological satellites and radar data in the calculation of rainfall over large areas. For the monitoring of floods in large catchments, such as in Bangladesh, NOAA images have been successfully applied.

Earthquakes

The area affected by earthquakes are generally large, but they are restricted to well-known regions (plate contacts). Typical recurrence periods vary from decades to centuries. Observable associated features include fault rupture, damage due to ground shaking, liquefaction, landslides, fires and floods. The following aspects play important roles in determining these consequences: distance from active faults, geological structure, soil types, depth of the water table, topography, and construction types of buildings.

With respect to disaster prevention, satellite remote sensing can play an important role in the mapping of active faults, using neotectonic studies, with the use of high resolution optical or radar image data, and the measurement of fault displacements, using Satellite Laser Ranging (SLR), Global Positioning System (GPS), or radar interferometry. The most important data for seismic hazard zonation is derived from seismic networks. In seismic micro-zonation, the use of satellite remote sensing is very limited, as the needed data is derived from accelerometers, geotechnical mapping, groundwater modelling, and topographic modelling, at large scales.

Earthquakes cannot be predicted with the current state of knowledge, and therefore satellite remote sensing cannot play a role in that phase of earthquake disaster preparedness. However, remote sensing can identify risks associated with earthquakes, such as those of potential landslides, and time differential radar interferometry (DInSAR) also may allow the detection of major indications of precursory ground deformation. In particular, DINSAR may work well if the nucleation zone of earthquakes is relatively shallow and the background terrain is clear of urban settlements, trees, snow, etc., that may create additional noise.

The use of interferometric techniques with radar imagery, in particular that derived from European ERS SAR, allow an accurate *a posteriori* study of events, that may lead to a better understanding of these phenomena.

Volcanic Eruptions

The areas affected by volcanic eruptions are generally small and restricted to well-known localities or regions. While the distribution of volcanoes is known, missing or limited historical records can make the distribution of active volcanoes less well known, particularly in developing countries. Many volcanic areas are densely populated. Volcanic eruptions can lead to a large diversity of processes, such as explosion (Krakatau, Mount St. Helens), pyroclastic flow (Mt. Pelée, Pinatubo), lahars (Nevado del Ruiz, Pinatubo), lava flows (Hawaii, Etna), and ashfall (Pinatubo, El Chincon). Satellite remote sensing can be used in the warning phase of disaster preparedness in the mapping of the distribution and type of volcanic deposits, using LANDSAT TM, SPOT, or radar.

Other data are required for the determination of eruptive history, such as morphological analysis, tephra chronology, and lithological composition. Volcanic eruptions occur within minutes to hours, but are mostly preceded by clear precursors, such as fumarolic activity, seismic tremors and surface deformation (bulging). SAR interferometry is particularly well-suited for the identification of the latter, as well as for following the deflation phase that usually heralds the end of large eruptions. Conversely, the thermal band of LANDSAT TM can be used to monitor the thermal characteristics of a volcano and for depicting shape and extent of lava flows with good resolution in space but relatively long intervals between two overpasses. Finally, NOAA-AVHRR data (gathered twice per day with an average resolution of 1 sq. km) can be used for the mid-to-low resolution monitoring of lava flows or ash plumes. Meteosat, GOES or TOMS (Nimbus-7) can be used to monitor the extent of volcanic ash clouds and the S02 content.

An important issue related to volcanic ash clouds, that can be distributed over large areas, is the attempt to warn aircraft of ash clouds caused by erupting volcanoes that can put passengers at risk. In response to several situations where jet aircraft have flown into the invisible ash cloud of an erupting volcano and experienced severe engine and avionics damage and windscreen abrasion, NOAA, the U.S. Federal Aviation Administration (FAA), and the U.S. Geological Survey have implemented the Volcano Hazards Alert Plan. This is a cooperative, operational system to coordinate information on ongoing eruptions and to issue warnings of the presence of airborne ash to aviation interests. The plan is activated whenever an eruption occurs which may endanger aircraft within U.S. Flight Information Regions (FIR), which include the continental United States, Alaska, and adjacent areas of the Atlantic Ocean, and much of the Central Pacific Ocean. In addition, it may be formally activated for areas outside the FIRs at the request of appropriate authority (e.g., the Department of Defence requested activation during the eruption of Mt. Pinatubo in 1991), or information may be transmitted on an advisory basis. Using an interactive computer system, analysts can overlay volcano locations, coordinates and major air routes on geostationary satellite imagery.

Landslides

Individual landslides are generally small, but they are very frequent in many mountain regions. Landslides occur in a large variety, depending on the type of movement (slide, flow, fall), the speed of movement (mm/year - in/sec), the material involved (rock or soil), and various possible triggering mechanisms, such as earthquakes, rainfall, or different types of human interaction.

In terms of disaster prevention, satellite imagery with sufficient spatial resolution and stereo capability (SPOT) can be used to make an inventory of previous landslides, and to collect data on the relevant parameters involved, such as those involving soil, geology, slope, geomorphology, land use, hydrology, rainfall, faults, etc.

In the phase of disaster preparedness, use can be made of the same systems used in the prediction of floods discussed above. Monitoring the displacements of large landslides can be done with radar interferometry from ERS SAR data. The assessment of landslide damage by satellite is only possible if the spatial resolution is very good, or if the individual landslides are large.

IV. CHARACTERISTICS OF HEALTH EMERGENCIES AND THE ROLE OF REMOTE SENSING

Earth observation, hazard analysis and communications technologies also have been valuable instruments for health surveillance and monitoring and for disease forecasting and control. The health consequences of large-scale natural disasters can be of enormous proportions. Characteristically, disasters create situations where there are many casualties, the majority of whom are in serious or critical condition and require immediate assistance. These casualties occur in a relatively short period of time and existing health facilities and personnel are not able to deal with the nature and scope of the health emergency this presents.

In addition, the medical and public health impacts are often exacerbated by difficulties of access to affected areas, damage to medical facilities, hospitals, clinics and supply stores as well as disruption of the supply chain. Long distances, low population density and the absence of stable communications can further increase the isolation of an area hit by a disaster and create a major challenge to provide timely medical help for large numbers of people.

Many communities and countries are putting in place disaster preparedness plans. These local and national preparedness plans and rapid mobilization of assistance in health emergencies can be supported and enhanced by remote sensing technologies. The areas in which remote sensing technologies can support go beyond disaster response to disease prevention and control following disaster.

Public Health Consequences

In addition to the search and rescue operations mobilized immediately after a disaster, public health measures must be assessed and restored as quickly as possible. The basic public health functions after a disaster are the provision of temporary shelter, an adequate and clean water supply, food, and health and injury assessment and treatment for the inhabitants of the affected area. These efforts are frequently hampered by the absence of electricity, disruption of telecommunications, damage and pollution of water supplies, destruction of roads and bridges, the collapse of the transportation systems, destruction of housing and shelter, and lack of medical instruments and drugs. The destruction of air fields, road and rail links means that independent supplies of food need to be made available directly in disaster zones. The high probability of destruction of public health facilities means that mobile hospitals are needed close to the site of a disaster to offer treatment of shock and injuries, and that medical evacuation to other facilities has to be organized.

Remote sensing technologies can help to assess and communicate the areas of damage and the extent of damage with respect to all of these conditions. An accurate description of the disaster, including the location, the estimated number of people, the number and types of facilities affected, and the likelihood of further events in an area are important to enable a coherent response and to plan for the institution of public health measures. This type of assessment can help better distribute the resources throughout an area and help to inform health and medical facilities and personnel of the likelihood of epidemics and other adverse public health consequences of a disaster.

Any early warning mechanisms in place that can help to notify a network of centres for disaster prevention and mitigation should include public health, defence, communication and transport centres. Early warning mechanisms can help to mobilize existing disaster control systems and to ensure that emergency procedures are initiated. Remote sensing can identify safe areas for evacuation. The infrastructure monitoring capabilities can ensure an undisturbed supply of aid.

Disease Prevention and Control

Disease control takes on a different dimension after disasters, where there may be a breakdown of public health measures, lack of sanitation and clean water. Besides these considerations, other factors such as endemic diseases in an area, or their seasonality can contribute to the spread of disease. Frequently a disaster onset, and the subsequent assessment of vulnerability to potential outbreaks of disease serve as the stimulus for early warning to the public and throughout the health community.

Baseline surveillance data on endemic disease distribution in an area provided by GIS can be used to assess the nature of disease threats to displaced people and enable public health action, such as immunization, to be taken to protect groups at risk. These types of data are crucial to obtain, in order to evaluate the evolution of eventual outbreaks or epidemics and to adapt disease control strategies.

The 1990 Baguio City earthquake in the Philippines provides an example. In the wake of the earthquake, the Philippines Department of Health issued a warning of the potential spread of typhoid fever, diarrhea, amoebiasis, cholera and other gastro-intestinal sickness in the temporary refugee camps that had developed in Baguio. The unsanitary disposal of wastes in the refugee encampments, the litter of spoiled foods and rubbish, and the lack of potable water, all aggravated by the intermittent inclement weather condition, were conducive to the epidemic incidence of deadly diseases. By employing public warning systems, health authorities appealed to the public to cooperate with measures designed to check the incidence of epidemic diseases and urged the fleeing residents to observe recommended preventive measures.

Early warning technologies can help mitigate the delayed public health impact of disasters by enabling public health officials to obtain the earliest information about the occurrence and extent of a disaster and to mobilize and coordinate appropriate and adequate resources quickly. Early communication about potential problems is critical. The rapid location of supplies, such as vaccines, treatment drugs, laboratory reagents and other specialized supplies may be the factor that prevents the development of a public health emergency. The importance for public health of emerging and re-emerging infectious diseases creates an urgent need to monitor situations locally and nationally, and as may be necessary, to respond in an effective manner. Strong surveillance systems are proactive, providing immediate reports of disease outbreaks and permitting timely response. Wide geographic coverage is thus important, as is the capability to link specialized networks, such as military laboratories, for expanded coverage or specialized expertise.

V. GLOBAL POSITIONING SYSTEM (GPS)

Originally designated the NAVSTAR (Navigation System with Timing And Ranging) Global Positioning System, GPS was developed by the US Department of Defence to provide all-weather round-the-clock navigation capabilities for military ground, sea, and air forces. Since its implementation, GPS has also become an integral asset in numerous civilian applications and industries around the globe, including disaster management. GPS employs 24 spacecraft in 20,200 km circular orbits inclined at 55 degrees. These spacecraft are placed in 6 orbit planes with four operational satellites in each plane. The full 24-satellite constellation was completed on 9 March 1994.

GPS receivers use triangulation of the GPS satellites' navigational signals to determine their location. The satellites provide two different signals that provide different accuracies. Coarse-acquisition (C/A) code is intended for civilian use and is deliberately degraded. The accuracy using a typical civilian GPS receiver with C/A code is typically about 100 metres. The military's Precision (P) code is not corrupted; it provides positional accuracy to within approximately 20 metres. Numerous on-line tutorials on how GPS works and its applications are available, including those at the Univ. of Texas and Rentec International. GPS satellites are controlled at the GPS Master Control Station (MCS) located at Falcon Air Force Base outside Colorado Springs, Colorado, USA. The ground segment also includes four active-tracking ground antennas and five passive-tracking monitor stations.

VI. HAZARD ANALYSIS TECHNOLOGY: CHARACTERISTICS OF GIS APPLICATIONS AND VULNERABILITY MAPPING

A Geographic Information System is a tool for assessing, integrating and distributing large spatially-reference sets of data. Spatial data are data about geographic areas. For example, in a single geographic location there are layers of information. First, a location contains environmental data such as soil composition, vegetation, water supply, temperature and geology. Other data may indicate political boundaries, school districts and zoning classification, types of water supply, as well as population demographics or wildlife in a particular habitat. All this is obtained from a variety of sources including existing maps, remote sensors, or geographical positioning systems, GPS. These large volumes of spatial or geographic data are then stored, enhanced, combined and analysed to produce interpretable information, in the form of a line map or value-added satellite images that allows the user to use the information productively. Analysis of this information is vital for making decisions, such as planning city expansion or conserving a forest.

GIS can be visualized as consisting of a number of layers or planes, each of which contain thematic information on one or more variables over a surface area being considered. Through user queries, GIS can superimpose all, or a subset, of these layers and can then report the results of the query in the form of a tabular or statistical report. It can also produce an image on a television monitor from which a hard copy can be made or, otherwise conveyed in digital form on a storage medium (magnetic tape, CD-ROM, and others) from which a map-like product can be generated.

Many different GIS systems exist today, with different characteristics with regards to the type of data structure (vector or raster), data compression techniques (Quadtrees, run-length coding), two-dimensional or three-dimensional data storage, mainframe, mini-, and microcomputer hardware and user interfaces (pop-up menus, mouse driven, help options, and others).

Spatial data, used in GIS, is data with a geographic component, such as maps, aerial photography, satellite imagery, rainfall data and borehole data. Many of these data will have a different projection and coordinate system, and need to be brought to a common map-basis, in order to be superimposed. GIS allows for the combination of these different kinds of spatial data, with non spatial, attribute data, and can use them as input data in complex models. One of the main advantages of using the powerful combination techniques of GIS, is the possibility to evaluate several scenarios, and to analyse the sensitivity of the models by varying some of the input data. For example, an important use of GIS is to analyse predictive models. While such an analyses would not indicate actual future conditions, they would be useful for mapping potential vulnerability, indicating the conditions that might be expected if a particular trend (such as land degradation) continued at the current rate, or if specific climatic conditions occurred (such as drought or flooding associated with the El Niño phenomenon).

VII. TELECOMMUNICATIONS TECHNOLOGY

The benefits of interactive real-time telecommunications links between and among meteorologists, geologists, epidemiologists and the host of other professional disciplines within the disaster management community has long been appreciated. Realizing these perceived benefits, though, has been a challenge in many areas of the world. In urban centres of countries with highly developed economies (locations that provide the economic stimulus frequently needed to motivate the development of new technologies) some of these systems can be found operating. But in remote areas of these same countries -- and in developing countries in general -- if such networks are available at all, they are not likely to be widely spread.

Within three to five years there will be dozens of geostationary (GEO), low earth orbiting (LEO) and medium earth orbiting (MEO) satellite systems covering the entire world. They will consist of from one to as many as 325 satellites per system and will be a part of the Global Mobile Personal Communications by Satellite (GMPCS). These systems will make it possible and affordable to maintain early warning communications regardless of the nature of a disaster, its location, or the terrain of the affected area. This was not possible five years ago.

These emerging systems will have a wide range of capabilities ranging from narrow band (data-only) to broadband (making possible video, voice and data) communications. A recent worldwide telecommunications market study forecasts that 1,062 LEOS and MEOS will be launched by the year 2006 (many of these by 1998) for a total cost of $ 11.2 billion (excluding launch expenses). Add to this the $12 billion 24-satellite U.S. Global Positioning System (GPS), numerous geostationary orbit satellite systems, at least four vehicle tracking systems, it is clear that the world-wide investment will be in the neighbourhood of $30 billion dollars to pursue, what many studies indicate will be, an enormous multi billion dollar global market.

Modes of Communications

Modalities and Applications

- Voice (telephone consultation, conferencing)
- Data (e-mail, Internet, World Wide Web, GIS)
- Video (conferencing: computer/Internet, desktop, compressed VTC, full motion, high definition)
- Broadcast television and radio, cable (production and distribution)
- Terrestrial telecom (twisted copper, fibre, microwave, HF, VHF, packet, amateur radio, cellular, etc.)

- Communications satellites (fixed & mobile, "big" and "little" LEOs)

Terrestrial Telecommunications

Traditional terrestrial telecommunications have often been costly to install, difficult to repair and vulnerable to disruption or extensive damage, particularly in remote areas of developing countries. Accordingly, such systems have not been reliable in areas where geography or climate inhibit their installation and maintenance. Thus, although they may play a role in early phases of warning, they may not be reliable for continued use during a disaster event.

Fixed Satellite Service

Fixed Satellite Service is at its best in populated urban areas of the world, where the numbers of users and the variety of uses can sustain the high capital costs as well as the cost of maintenance and training. It is of less use in the field where similar levels of use do not exist. In many instances it provides the external telecommunications linkages that are marketed by national Postal, Telephone and Telegraph agencies (PT&Ts). It can usually be relied upon in early warning situations, at least up to the onset of the event. As is the case with most other terrestrial telecommunications links, fixed satellite services are susceptible to damage or destruction at the onset of a disaster. For this reason, national governments should be strongly encouraged to strengthen their terrestrial and Fixed Satellite links and to make them resilient to the type of disasters to which their area is vulnerable. For this same reason, national governments and disaster managers should not rely solely on these systems for warning and post-onset applications.

Mobile Satellite Service

Mobile satellite services are less expensive than traditional fixed satellite services. They are easily transportable and are not technologically dependent on terrestrial telecommunications infrastructure. They are far less vulnerable to natural disasters and, because they can be used reliably to call anywhere in the world, their use in the field has grown rapidly in recent years. Though lower in cost than fixed services, they are not inexpensive, and are still used almost exclusively by UN agencies and larger Non-governmental Organizations (NGOs). Although some national or domestic systems are available, the most widely used -- and the only system available world-wide at this time -- is the international consortium INMARSAT. Costs range from $4,000 - $35,000 for hardware and $1 - $13 per minute for use.

Single Sideband (SSB) High Frequency (HF)

Disaster managers in the field most frequently communicate over long distance using HF radio. This communication is point-to-point and permits voice and low speed data communications between and among fixed installations at field headquarters and regional offices. Mobile HF SSB units can also be used in a similar manner (although frequently these "mobile" units are too heavy and cumbersome to be considered portable). A significant advantage of HF SSB networks is that hardware costs are minimal ($4,000 - 5,000) and use is free. The effective distance of HF voice communications is 2,000 - 3,000 kilometres, typically sufficient for communications between field operations and national headquarters. The use of more advanced technology, namely the „Pactor Level 2" data mode and enhanced modems, can permit effective data communications world-wide.

VHF Hand Held Radio Communication

For short distance communication among staff or local facilities, and within cities or regions, the use of VHF hand held radios is common among national authorities, UN Agencies and NGOs. Like HF radios for longer distance, VHF radios are inexpensive to purchase and free to operate. However, the use of VHF equipment is subject to the delivery of a license with assigned frequencies requiring a significant amount of negotiation with telecommunications authorities. In the absence of regular telephone communications these VHF radios provided a basic and vital administrative function. Another important function which they provide is security, or maintaining contact with travelling staff.

Amateur Radio

Historically, amateur radio operators have frequently established and operated communication networks locally for governmental and emergency officials, as well as non-commercial communication for private concerns affected by the disaster. Amateur radio facilities can generally be characterized as having a high survival capability. Although amateur radio operators are most likely to be active after disasters that damage regular lines of communication such as power outages and destruction of telephone lines, they frequently support the delivery and relay of warning information. They are frequently well prepared for work under often extreme conditions encountered during acute emergencies, where both solid technical knowledge and the ability to improvise are required. The International Amateur Radio Union (IARU) coordinates the activities of the service and actively supports its introduction in those countries where its value has not yet been fully recognized.

The Future

In the future we will be a further reduction in the cost of currently available technologies and software and applications that make their use more efficient. Additional new technologies such as Low Earth Orbit (LEO) Satellites and Medium Earth Orbit (MEO) Satellites will provide new, or more effective ways of communicating warnings. LEOs are based on the use of small, low-cost, satellites orbiting near to the Earth (unlike Fixed Satellite Service which uses geosynchronous satellites hovering at some 36,000 km over the Equator).

"Big" LEOs and MEOs

The big LEOS and MEOS will offer narrowband services, such as voice, data, paging and facsimile. Most of these systems, for example, Iridium (66 low earth orbiting satellites), Globalstar (32 low earth orbiting satellites) and Teledesic (325 satellites) and INMARSAT-P are operated by international partnerships or consortia. They will provide global land, aeronautical and maritime mobile communications via satellite (two-way voice, data, fax, high resolution still frame video images and position location). Most services will be affordable; at least competitive in price with terrestrial services. Hand held, simple, dual mode (satellite/terrestrial) mobile terminals will be used. Interoperability with cellular mobile telephone and public switched wireline telephone systems will be possible.

"Little" LEOs

The little LEOS, such as Orbcomm, are similar to big LEOS but only provide a store and forward function similar to two-way paging systems and are targeting the position location & data messaging markets.

Applications of Telecommunications Technology for Early Warning

There are essentially three types of communications technologies or systems for early warning. The first is the telemetry associated with the relay of information from sensing technologies, usually to or among scientists involved with the specific the phenomenon, e.g., meteorologists, seismologists, etc. The "system" of these technologies is usually dedicated to the particular application and managed by the scientific establishment.

The second is the system of communication between and among the community of disaster managers. This may mean the national civil defence establishment, the military, the scientific community, selected governmental ministries or agencies, NGOs and others. These systems of telecommunications are also frequently dedicated for this purpose and managed independently of the "public" telecommunications services, although they also rely on national telecommunications infrastructure such as normal telephone lines.

Third, there are the systems and networks used to transmit or broadcast warning messages and information to the public. Some elements of these networks are managed by the "public" broadcasting entities (such as radio or television station broadcasting towers) while others are operated by local or national telecommunications entities or commercial enterprises, (such as PT&Ts or telephone companies).

The function of technology that has, historically, been referred to as early warning technology could more accurately be considered early *detection*. The telecommunications component to these applications consist of the telemetry between the detection device and the scientific institution. These technologies provide data -- usually via dedicated telecommunications systems, and often with their own specific frequency allocations -- to scientists, thus making them aware of the occurrence (or possible occurrence) of a disaster and its parameters, or its real or potential characteristics.

In recent years a better understanding of the history and a higher awareness of many aspects related to disastrous events, has led to the development of automatic systems for alerting operators to pre-set alarming conditions. Such systems collect signals arriving from on-site sensors, integrate them with other types of information and provide an alarm to operators when the value of one or more parameters goes beyond pre-set thresholds. To date, these systems are still very specialized, customized to specific individual needs (as in the case of nuclear plants or water level monitoring in rivers or along the coasts). The use of satellite data as an additional input in such systems is promising.

The awareness of an impending event, even one of potentially catastrophic proportion, is often not sufficient information to make decisions important to safeguarding life and property. Warning, itself, is an added value and function. Scientists, disaster managers, and politicians determine the relevance of this data to populations at risk, and transform this data into information for warning which is transmitted by broadcasting or other means of public telecommunications technology. Some "detection" technologies can transmit data to an automated processing facility to be retransmitted to the public. Other systems can provide data directly to the public. Though in some cases this is the only way in which to get vital information directly to the public, the difficulty with either of these approaches, however, is in bypassing the important function of making the message relevant to the specific audience who would be potentially affected. This is a human function requiring insight and understanding of the local political and cultural situation.

VIII. TOWARDS A GLOBAL SYSTEM

Of the organizations attempting to facilitate, monitor, and coordinate world-wide collection and exchange of information valuable to early warning, the World Meteorological Organization (WMO) has developed, by far, the most extensive organization and operational capabilities. It may serve as a model for other sectors or, with appropriate consideration and organizational modification, add scope to its own mission.

Meteorological services are required for safety of life and property, the protection of the environment, and for the efficiency and economy of a wide range of weather-sensitive activities. The receipt of observational data, analyses and forecasts by National Meteorological Centres is crucial to the provision of these services. The World Weather Watch (WWW) is the international cooperative programme which arranges for the gathering and distribution of real time meteorological information on a worldwide basis required by individual Members. This information is also used by other programmes of WMO as well as by relevant programs of other international organizations.

The overall objectives of the WWW programme are to:

i) Maintain an effective worldwide integrated system for the collection, processing and rapid exchange of meteorological and related environmental data, analyses and forecasts.

ii) Make available observational data, analyses, forecasts and other products, in both real-time and delayed access, as may be appropriate, in order to meet the needs of all Members of WMO programmes and of the relevant programs of other international organizations.

iii) Arrange for the introduction of standard methods and technology which enable Members to make best use of the WWW system to ensure an adequate level of services and also to provide for compatibility of systems essential for cooperation with other agencies.

iv) Provide the basic infrastructure for the Global Climate Observing System (GCOS) and other WMO and international programs for climate monitoring and studying of climate issues.

The WMO operates at global, regional and national levels. It involves the design, implementation and further development of three closely linked and increasingly integrated core elements:

i) **The Global Observing System** (GOS), consists of facilities and arrangements for making observations at stations on land and at sea, and from aircraft, environmental observation satellites and other platforms. The system is designed to provide observational data for use in both operational and research work. The baseline space-based subsystem of GOS comprises two operational near-polar-orbiting satellites and five operational geostationary environmental satellites. Over 1,000 satellite receivers located worldwide within the National Meteorological or Hydrometeorological Services were registered by the WMO Secretariat at the end of 1996.

ii) **The Global Telecommunications System** (GTS), is composed of an increasingly automated network of telecommunications facilities for the rapid, reliable collection and distribution of observational data and processed information (currently the GTS comprises 311 circuits, 262 of which are operational at signal speeds that vary from 50 baud to 64 kbps).

iii) **The Global Data-processing System** (GDPS), consisting of World and Regional or Specialized and National Meteorological Centres to provide processed data, analyses, and forecast products.

The implementation and integration of these three core elements are supported through two additional programmes. The first is the **Data Management** (WDM), which addresses standards and practices for the efficient handing and flow of data and products within the WWW system. The other one is composed of WWW **System Support Activities** (SSA), which provide guidance, assistance and training related to the planning, development, and operation of WWW.

IX. GENERAL CONCLUSIONS

Remote Sensing and GIS

Non-technological costs and benefits

Remote sensing, Geographical Information Systems and telecommunications can be valuable tools for disaster managers. The costs associated with using these technologies have been reduced over recent years, and are likely to become even more affordable. They have also become easier to use. Nonetheless, the fact that they are not commonly available to everyone, is evidence that there still is a long way to go before the benefits are fully realized world-wide.

Further research is needed to assess the costs and benefits of using these technologies for various types of applications as there remain a number of constraints that are not related to the qualitative or quantitative performance of the technologies. These are the organizational, institutional and political issues that must be addressed. They are not reduced in complexity at a rate equal to the increased performance of the technology itself. They include needs for better data access, improved data exchange, the acceptance of data standards, more training and lower associated costs.

Data access

Remote sensing technologies collect billions of "bits" of data. Geographic Information Systems can process this data with other types of data to provide information needed to address complex problems faced by disaster managers. But how do users of these technologies survey what data exists, where, and in what form ? Then, how do they learn how it may be acquired ?

Disaster managers around the world need access to information about data for many of their applications. They need to know not only what data is available about their own countries, but also what is available at the regional, continental and global scales. Access to data of different kinds -- primarily "ground truth" data to verify remotely-sensed information and other "conventional" data, such as maps and statistics for use in a GIS -- remains a major problem.

Exchange of data

A related difficulty arises from the data policies implemented by the various space agencies and data distributors. Although the availability of remote sensing data is guaranteed by the UN Open Sky Policy (allowing for the non-discriminatory access to space remote sensing information), the actual distribution of Earth observation data is carried out with different pricing policies by the entities concerned. This needs to be reviewed and taken into account in any planning process.

Exchange of data within and among local, state, regional, provincial or national agencies is another important and complex issue. Some countries feel that certain types of resource information could be sensitive and are reluctant to make them readily available. However, addressing certain issues, such as the identification of risk and the issue of warnings affecting more than one country, requires data exchange across national boundaries. Sharing data at the local level is also important to addressing problems of risk and assessing vulnerability.

Operational standards

Standardization of technology and terminology has long been an impediment in many facets of disaster management. It is the case in early warning too. The use of differing standards for data collection and archiving can be a further impediment to the optimum use of remote sensing and GIS technologies.

Analysing resources over large areas with GIS is facilitated by having reporting standards that apply over a series of scales from local to global perspectives. To accomplish this, data should be of similar types, classes, quality, precision, and resolution. These requirements are difficult to meet when, as is often the case, the data has been collected by using different methods.

Standards for data archiving similarly need to be considered. What data should be kept, for how long, on-line or off-line, and how often it should be updated are some of the important questions which need to be addressed and agreed. The outcome of efforts to move towards standardization will be a critical factor in determining whether multi-source data sets in specific fields can be fully and optimally integrated in early warning practices.

Training requirements

Remote sensing and GIS are complex technologies that require trained personnel for their effective exploitation. Training is required at a variety of levels and in a number of forms, from one-day to one-week seminars for senior resource management personnel, to two-week to three-month training classes for more technical personnel. University degree training at undergraduate and graduate levels is essential to develop and ensure local capabilities. Overviews and in-depth introductions and updates on new development, operations, and maintenance should also be anticipated in order to keep up with technology as it evolves.

Policy acceptance of technological values

It is important for both users and managers to realize that the benefits from the initial investment of GIS will not become available immediately. Users need to be sure to educate managers, administrators and politicians of this time lag and to gain their long-term support.

Investments in such technologies also need to account for the rapid progress of the technology itself, whereby hardware and software tools change or are upgraded often, and frequently, too quickly for the bureaucratic "updating rhythm" of many institutions concerned. Therefore, the choice of technological systems requires a careful analysis, along with needs to be accounted for in the budget and in future maintenance and operational plans.

Telecommunications

Satellite availability and utility

Traditional terrestrial telecommunications -- particularly in remote areas of disaster-prone countries -- have been costly to install, difficult to repair, and vulnerable to damage. Accordingly, these systems have been virtually useless in areas where geography or climate inhibited their installation and reliable maintenance; thus they have been of limited value to disaster managers. Fixed Satellite Services -- though useful in disaster preparedness and warning -- have demonstrated relatively limited effectiveness in disaster response, principally because of their own vulnerability to disasters. Their relative utility has also been affected by the need for large receiving and transmitting antennas with their associated high power requirements.

Mobile services by satellite have been one of the more recent and dynamic communications technologies available to disaster managers. This low-cost communication capability has proven, even in the relatively short time of its commercial availability, to offer dramatic results in relief efforts which have not been possible before. Furthermore, as a complement to remote sensing, GPS space technology, and GIS information management applications, it has the capability to improve risk assessment, disaster preparedness, early warning, and relief operations dramatically. This service is now available to areas previously considered inaccessible because of location, terrain, weather or demography.

International collaboration

Various international institutions and individual countries have filed, or have indicated their intention to file for mobile satellite orbital slots. Most of these will be available only on a national or regional basis. Further, the world is eagerly awaiting the realization of promising Low Earth Orbiting satellite systems that would provide hand-held transceiving capability anywhere in the world. Applications of the mobile satellite service currently available throughout the world by INMARSAT have proven the worth this technology ably in numerous and varied emergency settings. Several typical examples of the type of endeavours anticipated are, the joint venture between INMARSAT and the European Space Agency (ESA), and the ESA European Mobile Services (EMS) payload currently operational on the Italian communications satellite ITALSAT F2.

The disaster management community has recognized the commitment of INMARSAT to develop services responsive to the needs of the disaster management community. They have further recognized the generosity of the nation-members of the INMARSAT consortium for granting free space segments during catastrophic disasters and the additional support of many signatory countries that support this offering with free associated ground service.

While mobile satellite and other space-based communications have proven their worth in disaster preparedness and response, it is nevertheless important to relate these technologies to the terrestrial systems that are still the most characteristic means of communications within many countries, including VHF, HF and amateur radio.

Equipment reliability and durability

Disaster planners must ensure that terrestrial systems are retrofitted with technologies resistant to the worst effects of disasters that frequent the regions concerned. Further, as new systems are planned to replace the older ones, governments must insist that the new systems are sufficiently durable. In this respect, it would be helpful if international and bilateral providers of technical assistance were encouraged to include a disaster communications component in any of their telecommunications infrastructure development projects.

Private Sector Involvement

Historically, the understanding and use of technology for disaster preparedness and early warning has been largely a matter of public sector attention, with national governments and local authorities bearing the burden of plan formulation, financing and the execution of operational strategies. However, pre-disaster planning (e.g. risk assessment and vulnerability analysis) and early warning can be effective only if disaster-prone countries are able to implement the policies and can incorporate them into a regular institutional process. To do so requires an informed and committed degree of community involvement.

To reduce the reliance on a frequently overtaxed public sector, and recognizing the need to generate local capacity to prevent and prepare for disasters, more attention should be given to drawing community groups and institutions outside the government structure into prevention, mitigation, and preparedness planning. The business community with its financial, technological, and logistical capabilities should be viewed as a valuable and virtually untapped resource for improved early warning practices that is not to be ignored.

X. SPECIFIC RECOMMENDATIONS

Recommendation 1

Because of the typically high investment in infrastructure required for constructing and managing space-based programs, national, and certainly local, systems are out of reach for most countries particularly vulnerable to natural disasters. Therefore, the United Nations should seek ways to encourage the understanding and acceptance of cooperative approaches for sharing space-based resources. Recognizing the importance of national sovereignty of countries affected by disaster, the planning and administration of this process must include the participation of recipient countries.

Parenthetically, the development of an autonomous basic research capability in the scientific and technical disciplines concerned, including the space-related fields should be an objective of focus as has been advocated in ongoing activities within the United Nations, most notably through the Office for Outer Space Affairs. Such a capability would promote creative thinking to adapt, modify and create new technologies which could contribute to national development and the reduction of loss of life and property damage.

These are long-term goals that can only be reached through developmental initiatives over time. They require commitment at high levels of national government, supportive legislative action, and investment in technological infrastructure before they will be translated into results. It is only such sustained attention that can provide local and national self-sufficiency in operating space-based systems for effective early warning and the broader requirements of disaster management. Further, this developmental process requires attention and commitment by the private sector, international institutions, Non-governmental Organizations, the international donor community, and other funding agencies.

Recommendation 2

The United Nations should provide a forum for the discussion of critical issues related to the application of existing, new, and emerging technologies for early warning (and disaster management in general). In this context, there are several factors which can influence the effective use of space technologies and their terrestrial counterparts. The United Nations should facilitate the discussion of the following issues:

1. An accurate and realistic understanding of the capability and availability of existing, newly established, and emerging technology.

2. The affordability of technology relative to the intended application and to comparable options that could accomplish similar objectives.

3. The adequate understanding of institutional relationships and protocols required for the optimal use of technologies, ensuring that all parties, including the private commercial sector, are a part of the process.

4. Development of education and training programmes in the use of technologies that will lead to its regular availability and related access to derived data by affected countries.

5. Support for research in the development of terrestrial systems and data management applications that complement space hardware.

6. National and international political issues that may impede the acquisition and application of technology for improved early warning.

7. National and international regulations that either encourage or inhibit the effective application of these modern technologies.

Further, it will be the case for the foreseeable future, that applications of new and emerging technologies will have to be evaluated on an on-going basis. The United Nations should also play a facilitating and catalytic role in this process.

Recommendation 3

Though it is difficult to overemphasize the difficulties associated with the practical lack of access to technology, both industrialized and developing communities share the challenge of negotiating regulatory, institutional, and professional protocols for applying those technologies that are available. In short, the challenge in applying technology to disaster management is frequently less a question of the suitability, or even the availability, of the technologies themselves, but more the demands of establishing the collaborative and mutually productive relationships among the users.

Organizational mandates and specific professional or sectoral interests understandably encourage individuals involved in data gathering to focus on priority needs most likely to be served by the resources of the individual institution. The result of this bias can be a set of data which fulfills the organization's own needs, but which may in fact, wholly neglect other critical needs of the affected populations.

The United Nations should encourage the body of interests within the early warning community to ensure that these common needs are not overlooked. In this respect, the formation and funding of joint, "inter-agency", or "interdisciplinary" assessment, monitoring and evaluation teams can increase the probability that the critical needs of affected population are taken into account.

Recommendation 4

During the past year there has been a revival of interest in pursuing the recommendation of the May 1991 Tampere, Finland Conference on Disaster Communications. Though it was, primarily, response-oriented when written, the first Tampere Declaration identified the issue of inequity of access to communications technology and software for effective early warning and proposed that a disaster Convention "should establish mechanisms for international cooperation in the use of terrestrial and satellite telecommunications technologies in the prediction, monitoring and early warning of disasters, especially the early dissemination of information to those in the at-risk communities." This being said, however, the Working Group on Emergency Telecommunications (WGET), through escalating efforts of the past year, have adopted the view of the main recommendation of Tampere Conference, e.g. obtaining international agreements that facilitate entry and exit and operations of communications equipment by relief teams in stricken countries. The primary focus of the WGET has been one of emergency telecommunications in the field during acute emergencies. It will be important, therefore, if the Tampere Declaration is to be invoked in the name of preparedness and early warning, to focus attention on the specific, albeit brief, mitigation language.

In the Declaration, the main discussion of what should be the focus of the proposed Convention on Disaster Communications appears as paragraph 12, after "Communications in Disaster Relief", but before the brief mention of "Communications in Disaster Mitigation." It is unfortunate that it was only Paragraph 12 (relief-oriented) that was specifically endorsed in Resolution 36 of the October 1994 ITU Plenipotentiary Conference (Kyoto). Although this must be kept in mind, certainly all is not lost. The language of the Kyoto resolution is general, and it urges administrations "to take all practical steps for facilitating the rapid deployment and effective use of telecommunications equipment for disaster mitigation and for disaster relief operations by reducing and, where possible, removing regulatory barriers and strengthening transborder cooperation between States". Resolution No. 7 of the First World Telecommunication Development Conference of the International Telecommunications Union is even more inclusive of language focusing on telecommunications requirements for disaster mitigation and warning.

Both Res. No 7 & and Res. 36 underline the need to adopt the Convention on Disaster Communications. Since 1995, six drafts have been developed by the WGET and presented to a large number of telecommunications as well to humanitarian partners. The adoption of such a convention requires an intergovernmental conference to be convened by a host country, and the Government of Finland generously agreed to host such a conference in Tampere, Finland in June 1998.

Recommendation 5

With respect to disease surveillance specifically, for early warning mechanisms to be effective, and particularly across international boundaries, relevant policy implications must be considered prior to the actual reporting of diseases by individual countries. The cost and access of telecommunications technology, an appropriate system of early warning (e.g. to whom, when) and the requirements of reporting (e.g. disease syndromes, confirmed cases) will facilitate rapid collection and analysis of data and transmission of information for prevention of communicable diseases. The United Nations should take steps to include the health sector and health issues in the broader process of enhancing early warning capacities.

Recommendation 6

The UN enjoys unique relationships, privileges and immunities with respect to the ability to operate with most countries of the world. These relationships include both the access to technology and entry into countries. Each sector, discipline, or scientific field has, by virtue of collegial relationships, access to information that transcend geographical and political boundaries. Many private sector enterprises, by virtue of their entrepreneurial spirit and their ownership of capital resources have been able to transcend many of these same boundaries. The United Nations should serve as the catalyst that could lead to harnessing these disparate resources. It could bring the energies of these various organizational relationships to bear on their mutual interests for improved early warning.

Recommendation 7

There is a continuing need to inventory early warning initiatives, by region and by sector, referencing technologies and software, and specifying distinctive communications frequencies and types, classes, quality, precision, and resolution of data available.

Recommendation 8

The United Nations may encourage countries providing technical and developmental assistance to consider modifying traditional funding strategies that presently exclude funding for recurrent telecommunications costs. Although they are vulnerable to the effects of some disasters, terrestrial telecommunications, have proven to be sufficient in many cases for preparedness and initial warning functions. They should, therefore, be used first, rather than considering dedicated or specialized systems. Support to meeting the regular recurrent costs of available technology that is able to serve as the backbone of local early warning systems should be considered as an initial strategy, rather that the more costly option necessarily of building a new or overly sophisticated infrastructure for a dedicated system.

Recommendation 9

Attention needs to be given to the growing public and private sector initiatives in commercialization of weather services (i.e., Accuweather, The Weather Channel, CNN, etc.). Availability of information, and the opportunities for its distant delivery, is increasing with the accessibility of the Internet, satellite television, mobile satellite and cellular telephones. There are growing concerns about the accuracy, or possible contradictions of, multiple broadcast weather warnings. The increased availability of externally-derived information also underlines the importance for continued discussion about how these trends can impinge on the issue of national authorities to issue definitive warnings.

Recommendation 10

The commitment of the nation-members of the INMARSAT consortium was mentioned as an example of special tariff structuring for disaster relief by granting free telecommunications satellite space segment during catastrophic disasters. This initiative has enjoyed the additional support of many signatory countries by their extending free associated ground service. A similar rationale and approach to specialized tariff and usage costs for pre-disaster warning also needs to be developed.

Recommendation 11

The United Nations is encouraged to consider providing a forum, possibly though a collaborative effort of the International Decade for Natural Disaster Reduction and the World Meteorological Organization, to explore the need for a single entity (within or outside the United Nations structure) to coordinate and facilitate early warning technology, its development and applications.

Recommendation 12

In the absence of an international body dedicated to technological applications for early warning practices (as referred above), the United Nations should act to provide an institutional platform that brings together national space agencies and other public and commercial space interests. This could facilitate a consolidated and coherent process to assess current observation requirements for improved early warning operations and could solicit the participants' coordinated contributions when new space missions or sensing systems are planned.

XI. ADDITIONAL SOURCES

Niek Rengers and Kees van Westen, Application of Remote Sensing for Natural Disaster Reduction in Developing Countries, International Institute for Aerospace Survey and Earth Sciences, Enschede, The Netherlands, 1994

Jonathan Ball, Policy Analyst, Office of Air and Space Commercialization, U.S. Department of Commerce, "Satellite Remote Sensing", Trends in Commercial Space, 1996.

Montrese Chandler, Policy Analyst, Office of Air and Space Commercialization, U.S. Department of Commerce, "Geographic Information Systems", Trends in Commercial Space.

Fabrizio Ferrucci, "Natural Disasters in the 21st. Century: Disaster Alert Systems," UNESCO Courier, Paris.

XII. LIST OF CONTRIBUTORS

John C. Scott (Convener and Author)
President, Center for Public Service Communications
5315 Lee Highway, Arlington, Virignia 22207, USA

Phone: 1-703-536-5642
Fax: 1-703-536-5652 E-mail: jcscott@cpsc.com

Adigun Ade Abiodun
Expert on Space Applications, Office of Outer Space Affairs
United Nations, Room F0832, Vienna International Center
A-1400 Vienna, Austria
Phone: 43-1-211-31-4951
Fax: 43-1-21-34-558-30
E-mail: aabiodun@unov.un.or.at

Maurizio Fea
Earth Observation Promotion, European Space Agency
Via Galileo Galilei, 00044 Frescati, Italy
Phone: 39-6-94180580
Fax: 39-6-94180280 E-mail: mfea@esrin.esa.it

Mohamed Harbi
Special Advisor to the Secretary-General
International Telecommunication Union
CH-1211, Geneva, Switzerland
Phone: 41-22-730-5571
Fax: 41-22-730-5484 E-mail: harbi@itu.ch

David Heymann, M.D.
Director, Division Emerging and Other Communicable Diseases Surveillance and Control
World Health Organization
CH 1211 Geneva 27, Switzerland
Phone: 41-22-791-2660
Fax: 41-22-791-4860 E-mail: heymannd@who.ch

Roderick Sanatan
Secretary General, Caribbean Telecommunications Union
17 Queen's Park West, Port-of-Spain, Trinidad and Tobago
Phone: 809-628-3185
Fax: 809-628-6037
E-mail: ctu@trinidad.net

ADDITIONAL CONTRIBUTORS

Joan H. Dzenowagis
Division Emerging and Other Communicable Diseases Surveillance and Control
World Health Organization
CH 1211 Geneva 27, Switzerland
Phone: 41-22-791-2504
Fax: 41-22-791-0746
E-mail: dzenowagisj@who.ch

Fabrizio Ferrucci
Presidenza del Consiglio - Dip.Della Protezione Civile
Via Ulpiano 11, Rome, Italy
Phone: 39-984-493688
E-mail: faber@ccusc1.unical.it

Jerry Freibaum
Communications Consultant
6535 Elgin Lane, Bethesda, Maryland 20817 USA
Phone: 1-301-320-5550
Fax: 1-301-229-9694
Hans Zimmermann
UN Department of Humanitarian Affairs
Palais des Nations
CH 1211 GENEVA 10, Switzerland
Phone: 41-22-917-3516
Fax: 41-22-917-0023