Mapping for emergency situations: the Canadian experience

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An overview of Canadian disasters

Canada experiences the same natural and human-caused emergencies as other countries. However, to date, Canada has not had to deal with hurricanes, severe earthquakes or active volcanoes in populated areas. Emergency Preparedness Canada (EPC), the federal agency responsible for coordinating the national response to emergencies, has a record of 145 floods, 98 storms, 69 transportation, 60 hazardous chemical and 55 drought related emergencies that have occurred since 1900. Of the 662 emergencies in the EPC database 68% have been attributed to natural causes and 32% to human activities. ***Table 1*** indicates the types of disasters. Disaster types with an asterix are not common in Canada.

Over the past 25 years, disasters in Canada have caused more than $1 billion damage per year. In addition, forest fires cause about $0.5 billion damage per year. However, these are not counted as disasters unless they affect communities or cause loss of life. In recent years, Canada has suffered its three most expensive natural disasters. The tragic loss of life and extensive damage to property that resulted from the 1996 Saguenay flood, the 1997 Red River Basin flood and the 1998 ice storm, all reflect Canada's growing vulnerability to disasters.

The freezing rain that fell over a six day period in January, 1998, produced ice build ups of over 8 cm on trees, power lines and other structures causing wide spread damage. 1,300 hydro towers and 35,000 hydro poles were destroyed and 1.6 million customers in Canada and a further 0.5 million in the United States were without electricity for up to two weeks. 30 deaths were attributed to storm and the estimated damage exceeded $4 billion.

Figure 1 shows the increasing costs of natural disasters in Canada from 1970 onward.

Factors contributing to the increased vulnerability of Canadian society to disasters include:

- ***More people with more personal belongings live in Canada***. In the past, many storms occurred in open spaces. Today, continuing population and economic growth are reflected in a greater accumulation of property and public infrastructure.
- ***We live closer together in urban centres***. More than half of all Canadians live in large urban centres where they are more vulnerable to technological accidents and failures. Also, some communities continue to build in areas susceptible to floods.
- ***Our infrastructure is ageing***. Much of our infrastructure was designed years ago when building codes were less strict: for example, public and private buildings in the earthquake prone Vancouver area on the West Coast.
- ***The climate is changing***. In recent years, Canada has experienced a warming trend and severe weather events have increased in frequency.

Types of disasters	
Natural disasters	
Drought/Famine	
Earthquakes	shock wave, tsunami
Floods/fire	forest and bush
High wind	cyclone, tornado, storm, hurricane, *typhoon
Mass movements	landslides and avalanches
*Volcano	
Other	heat and cold waves, epidemics, infestation, food and water shortages
Man-made disasters	
Accidents	transportation, structural collapse
Technological accidents	chemical, nuclear, explosions, atmospheric, oil pollution
Agricultural/ environmental fires	

Table 1: disaster types

Disaster response

Canadian Centre for Emergency Preparedness was incorporated in 1993 with a mandate to assist communities, governments and private businesses to prepare for, prevent, respond to, and recover from man-made or natural disasters. This Centre is the most recognised emergency response educational organisation in Canada. It also performs research and analysis to safeguard lives and reduce damage o property by fostering better preparedness for emergencies in Canada. The centre organises the World Conference on Disaster Management in June of every year in Hamilton, Ontario Canada.

More than 600 delegates from the five continents attend over 50 educational sessions ranging from mass evacuations due to flooding to civic trauma arising from aeroplane crashes. This conference provides a forum for partnership among regional, national & international organisations, including the federal Government of Canada, the Canadian Association of Chiefs of Police, the Canadian Red Cross, the Association of Public Safety Communications Officials, the National Coordinating Council on Emergency Management, the Disaster Recovery Institute International, and many others.

Responsibility for dealing with emergency situations rests first with the individual or company whose life or property is at risk.

If the individual or company (for example, in the case of a major fire in an oil refinery) cannot deal with the emergency, then the municipal authorities are asked to help. If the emergency is beyond the capability of this level of government, requests for help go to the provincial government and, eventually, if needed, to the federal government (which can provide military assistance and emergency funding).

The common theme throughout this progression is ***communications.*** This may be voice or possibly video, communications between the response teams at the location of the disaster and higher level coordination centres. Or it may involve the communications.

Geomatics products, generally in the form of maps, are a vital element of the communications effort that portray where the emergency has occurred, how response teams can gain access to the site, and the means to delineate evacuation areas to on-site response teams.

Current use of Geomatics products

Geomatics is the science and technology of gathering, analysing, interpreting, distributing and using geographic information. It encompasses a broad range of disciplines, including surveying & mapping; remote sensing; geographic information systems (GIS); and global positioning systems (GPS).

Canada's Geomatics community is a recognised world leader in providing the software, hardware and value-added services. It presents opportunities in areas like land management, development planning, infrastructure management, natural resource monitoring, and coastal zone management and mapping. Canadian-developed Geomatics products and services are being used throughout the world, by clients ranging from government agencies in industrialised and developing nations to large and small businesses and remote communities.

Geomatics products include maps, in paper or digital format, showing everything from commercial site plans, administrative boundaries, municipal road systems, utilities (water, electricity, gas, telephone, etc), to more specialised information such as flood plains and seismic risk zones.

The role of Geomatics is reviewed at each disaster stage: pre-disaster (mitigation, forecasting and preparedness); disaster (emergency response); and post-disaster (damage assessment, recovery and remediation). ***Figure 2*** portrays the Emergency Management Cycle incorporating all stages of an emergency.

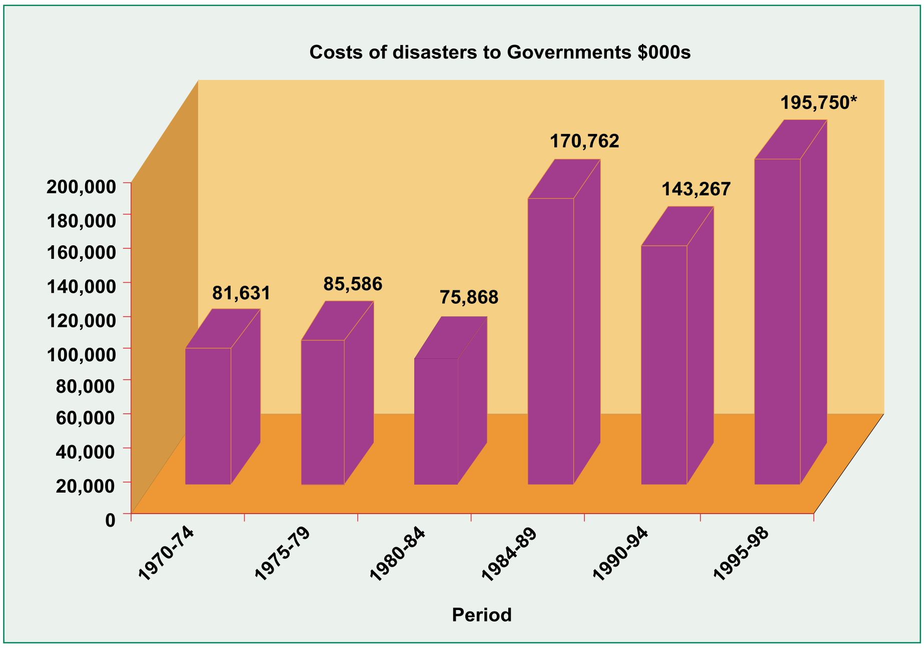

Figure 1: costs of natural disasters in Canada

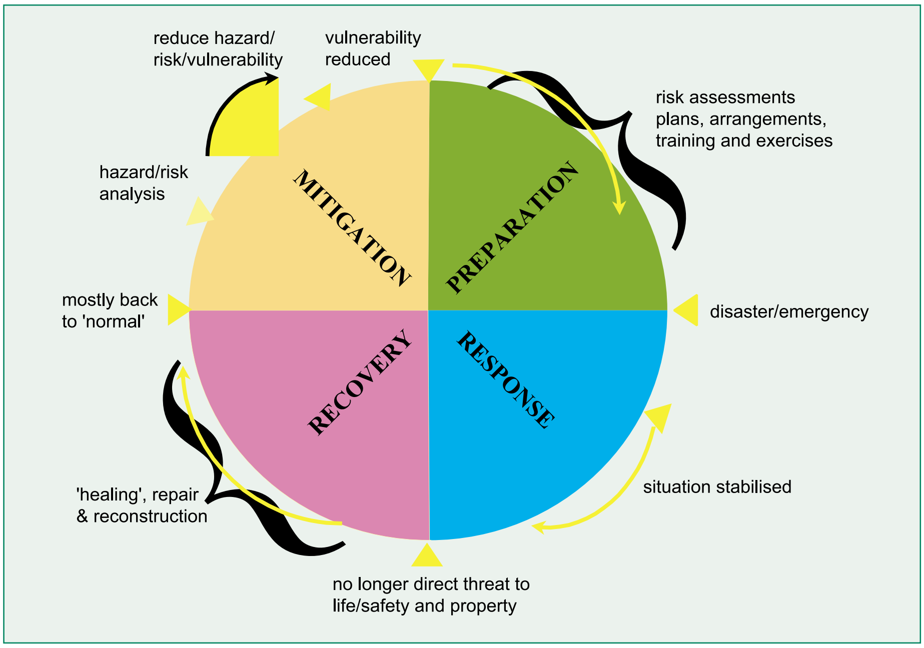

Figure 2: Emergency Management cycle

Pre-Disaster (Mitigation, Forecasting and Preparedness)

In 1998, more than 400 people across Canada participated in discussions about our preparedness for disasters. The consensus that emerged from these discussions was that a National Mitigation Policy was required.

Geomatics products, whether based on satellite imagery, air photography or ground surveys, are the foundation for disaster mitigation planning efforts. Scales range from 1:500 for detailed plant plans, electricity, gas and water utilities, through typical municipal mapping scales 1:2,000 to 1:5,000 that show individual buildings, to provincial scales of 1:10,000 to 1:25,000, and federal mapping scales of 1:50,000 to 1:250,000. Ortho-imagery of urban centres that is updated at one to five year intervals is becoming increasingly common for the larger municipalities. Digital versions of the ortho-imagery at scales up to 1:1,000 can be obtained by scanning the original air photographs. Other Geomatics products used in pre-disaster planning include geological maps, soil maps, seismic risk maps, and building code maps. Each set of data has a role in planning disaster mitigation measures.

Geographic information systems (GIS) uses computer technology to integrate,

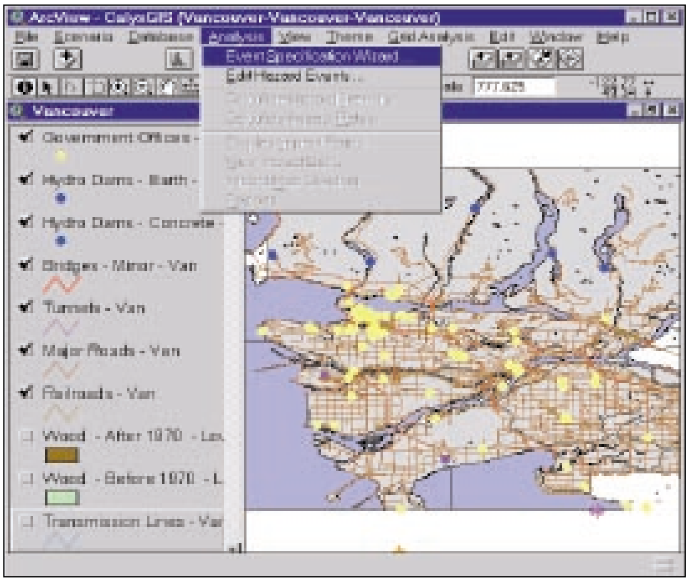

Figure 3: functionalities of the NEHMATIS system

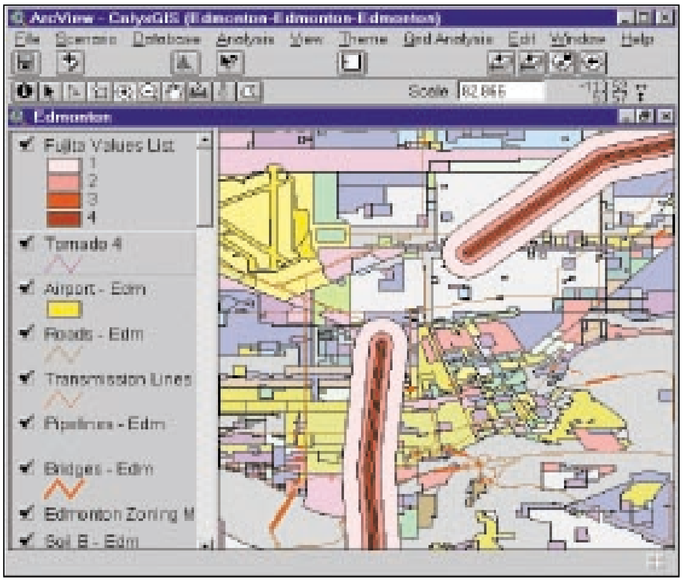

Figure 4: Applications of the NEHMATIS System

manipulate and display a wide range of information to create a picture of an area's, environment and socio-economic characteristics. GIS begins a computerised topographic map as its base, and overlays and integrates graphic and textual information from separate databases. The end result is a customised and reliable tool that can support decision making and problem solving.

GIS are becoming increasingly common as a means of overlaying and analysing different sets of spatial information. However, there are at least a dozen different software packages in common use. Fortunately, it is generally possible to move files from one system to another. For example, Natural Hazards Electronic Map and Assessment Tools Information System (NEHMATIS) is a geographic information system produced within the Canadian Framework for the International Decade for Natural Disaster Reduction.

It is an integrated suite of electronic maps and assessment tools used to assess human vulnerabilities to natural hazards and present information to a wide audience.

The system used data sources such as National Hazard Maps, Land use/Zoning, National Topographic Survey (Schools, Fire halls, roads, railways), Soil maps, Census data [population, Residential & buildings (types, age)], and Local data (hazardous materials etc.). ***Figures 3 and 4*** indicate some of the functionality and applications of this system.

Another system that has used remote sensing data for Flood disaster management is the Flood Emergency Remote Sensing Information Tool (FERSIT). FERSIT uses the satellite imagery in digitised form to quickly analyse near-real-time visual data relating to flood events. It incorporates ArcView GIS to allow the user to display, query, manage, store and analyse data and images. The FERSIT prototype used Canadian RADARSAT imagery, taken June 16, 1996, to capture peak spring run-off levels (possible flooding) of the Fraser River Delta (***Figure 5***).

Information Tools are important due to the fact that they are the means of integrating diverse types of knowledge and data and act as a vehicle for sharing knowledge related to emergency preparedness.

They are also an information presentation tool, a research tool and an educational tool. However, the three common problems that are encountered when trying to build a GIS database are:

- merging information from maps of different scales
- merging map information with different publication or revision dates
- when dealing with larger areas, combining information that has been processed using different map projections.

Maps showing ground elevations are vital in combating Canada's commonest type of environmental disaster, floods. The benefits of mitigation actions have been clearly demonstrated. Following a disastrous flood of the City of Winnipeg in 1950, a decision was made to build a ditch to carry flood waters around the city. The ditch cost $63 million, but has been used to divert spring floodwaters during 18 of the past 40 years, saving lives and billions of dollars of property damage.

A general flood plain damage reduction program was instituted in 1975 in response to increased disaster costs. Local authorities were encouraged to stop development in flood-prone areas. Federal funding for the program ceased in 1977 after the majority of high-risk areas had been mapped. Statistics suggest that where construction zoning has prevented development on flood-prone areas, the loss of life and property damage has been significantly lower than in areas where no such controls exist.

For instance, in 1986 there was a severe rainstorm over the Michigan-Ontario border. Rainfall, run-off characteristics, population densities, etc were similar on both sides of the border.

However, the storm caused $400 million of property damage in Michigan, but only $0.48 million in Ontario where the flood plains have been mapped and building on them is forbidden.

Disaster (Emergency Response)

Timeliness of information is the most important factor during the initial stages of response to a disaster. Consequently, traditional paper maps are the most common Geomatics resource, both in the response coordination centre and at the site of the emergency. However, the latest versions of these plans, etc may not be immediately available in the emergency co-ordination centre and the centre is faced with the problem of assembling the latest versions of these maps/plans in a place where they can be used as an aid to decision making.

With respect to satellite data, a controlled test showed that RADARSAT data could not reach an emergency co-ordination centre in less than 48 hours after a disaster. This was despite having the satellite in the right position to view

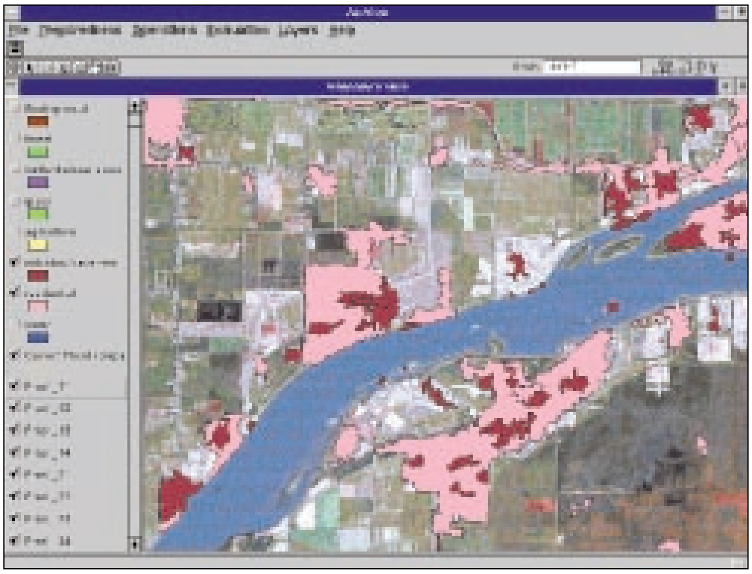

Figure 5: a demo of remote sensing in the operation of flood emergency responses to the flooded Fraser River, B.C.

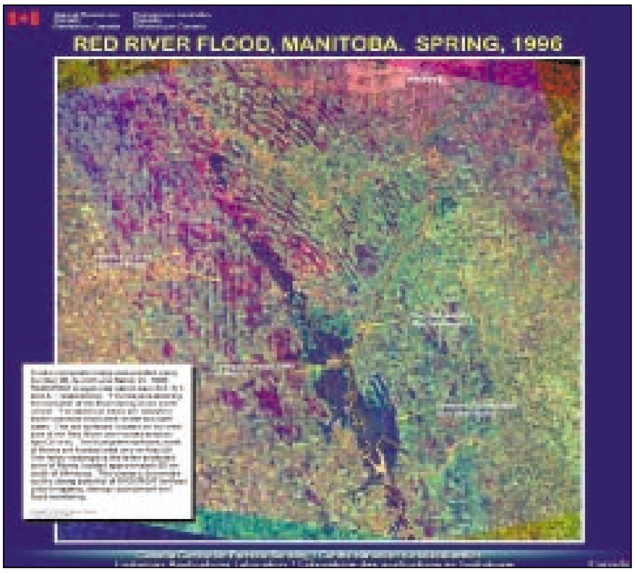

Figure 6: the Red River flood of Spring 1996 in Manitoba Canada

the site at the time of the emergency. At present, satellite imagery with the present resolution and timeliness limitations has no operational role in disaster response.

Post-Disaster (Damage Assessment, Recovery and Remediation)

It is reported that over 17,000 maps and air photographs were used in the course of dealing with Ice Storm ’98 in Canada which affected an area of 300,000 square kilometres with ice up to 30 times design loads over an area of 50,000 square kilometres. RADARSAT data were obtained at the height of the 1997 Red River flood and the microwave imagery combined with that from LANDSAT to produce a poster several months after the event.

Following the recent disaster in Honduras caused by heavy rainfall from hurricane Mitch, RADARSAT imagery (which can be gathered under any light and weather conditions) was used to assess the extent of flooding in rural areas. Air photographs were used to assess damage at specific locations such as bridges (***figures 6,7,8 & 9***).

Figure 7: the Radarsat image showing the Mississippi River flood of April 1998

Launched in 1995, the RADARSAT earth observation satellite was developed under the management of the Canadian Space Agency, and provides Canada and the world with an operational radar satellite system capable of timely delivery of large amounts of data.

At the heart of RADARSAT is an advanced radar sensor called Synthetic Aperture Radar (SAR), which provides its own microwave illumination and thus operates day or night, regardless of weather conditions.

RADARSAT-1 circles the Earth at an altitude of 798 kilometres and an inclination of 98.6 degrees to the equatorial plane. With its sun-synchronous orbit, RADARSAT’s solar arrays are in almost continuous sunlight, enabling it to rely primarily on solar power.

The satellite’s SAR 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 kilometres in width, with resolutions ranging from 8 to 100 metres.

Geomatics use in the 21st century

The major role for Geomatics will continue to be in support of pre-disaster planning: mitigation, forecasting and preparedness. The use of sophisticated technology under emergency conditions will increase, but will evolve slowly outside the major urban areas. The use of computers for geographic information systems for planning purposes will increase, which means that the demand for digital map products will increase. The increased use of GIS will also lead to more sophisticated pre-disaster planning activities, including the use of simulation models. The resolution and timeliness of satellite imagery will improve and will find increasing use in the pre-disaster planning phase.

Emergency Preparedness Canada is developing a computer-based model to simulate various environmental and man-made disasters as a tool to help plan for possible emergencies. This model simulates the damage caused by an earthquake

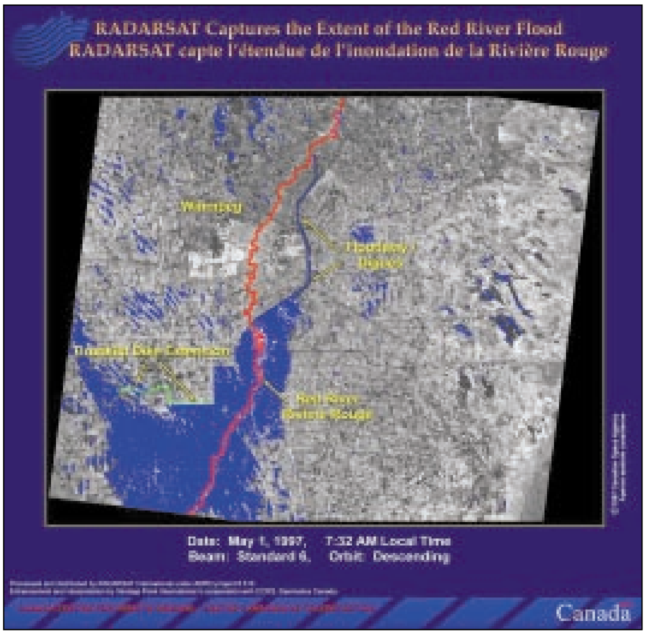

Figure 8: RADARSAT image of Red River flood of 1997

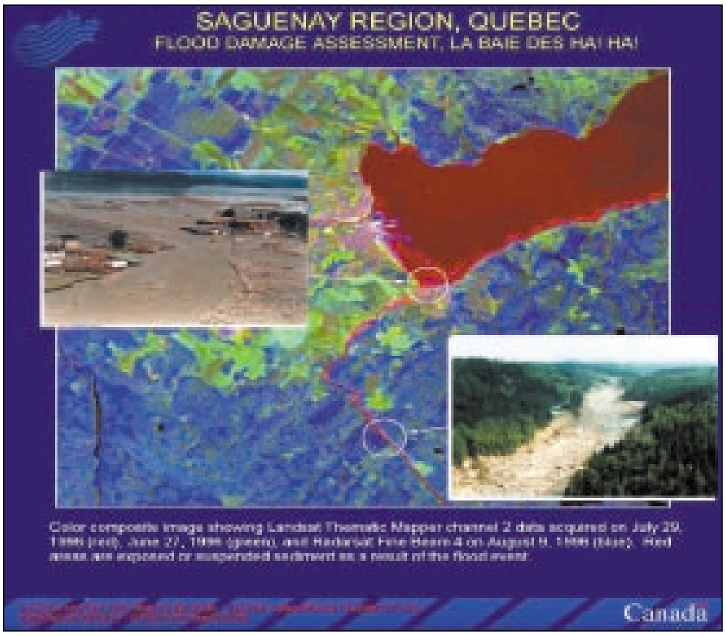

Figure 9: satellite image of Saguenay flood of 1996

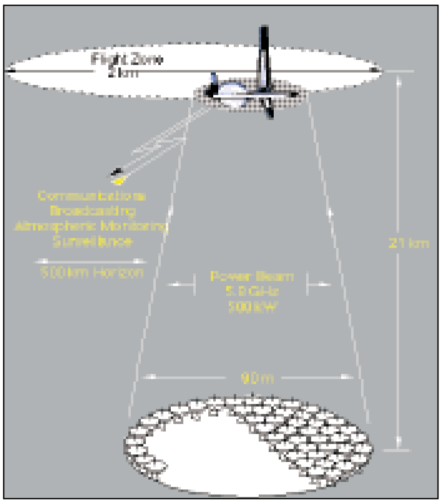

Figure 10: the SHARP system

near Vancouver. The simulation estimates such things as building damage (based on building codes at the time of their construction), possible damage to bridges over the Fraser River, and floods due to damage to dykes along the river.

Communication is the most important aspect in emergency response and post-disaster operations. Microwave powered aircraft such as the flying PEANUT and Stationary High Altitude Relay Platform (SHARP) provide an alternative system for provision of wireless communications services.

SHARP is an unmanned aircraft circling at 20 km altitude and could provide new surveillance and remote sensing applications in emergency situations. It has a long endurance (1-year) for cost-effective reliable operations and provides a wide-area communications coverage of up to 600 km in diameter (***Figure 10).***

The following services could be provided on an integrated basis by SHARP. Cellular telephone and personal communications (PCS) extension to rural/remote areas (Single-cell or multiple cell coverage; Wide-area relay (cell site to network centre); Wide-area mobile radio; Wide-area paging; Broadband multimedia services (Point to point & point-to multipoint (12, 20, 30, 40 GHz); Wide-area digital TV broadcast (NTSC, HDTV, 12/20 GHz) and Digital audio broadcast (1.7/12/20 GHz).

Non-communications applications of SHARP include: atmosphere monitoring (such as greenhouse effect gases and ozone depletion); remote sensing (e.g. Forest fire detection, ice reconnaissance and crop studies) and radar surveillance (such as coastal economic zone enforcement, sovereignty assertion (air, land and sea) and military surveillance applications (security).

As disaster response becomes more sophisticated, it is possible to envisage emergency coordination centres having their own remotely piloted vehicles (RPV) that can be launched from the roof of their building.

Using existing technology, such an aircraft could be positioned using GPS and could carry a small video camera and transmitter, similar to that used by television companies for sporting events.

One can envisage a computer display showing the digitised map of the disaster area with the position of the RPV superimposed.

At the same time, an inset on the screen could show the video images transmitted by the RPV, giving the response coordinator first hand information from the site of the emergency.

References

Canada Centre for Remote Sensing: National Remote Sensing Disaster Management Advisory Group 1999, ***1998 Annual Report***.

Canadian Space Agency 1998, ***Disaster Management User Requirements Study: Space Technologies***, March.

Institute for Catastrophic Loss Reduction and Emergency Preparedness Canada, 1998, ***A National Mitigation Policy: Findings from national consultations on Canada's preparedness for disasters***, December.

Personal Communication, February, 1999, Dr Chris Tucker, Senior Science Advisor, Emergency Preparedness Canada.

Personal Communication, February, 1999: Paul Kovacs, Executive Director, Institute for Catastrophic Loss Reduction.

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