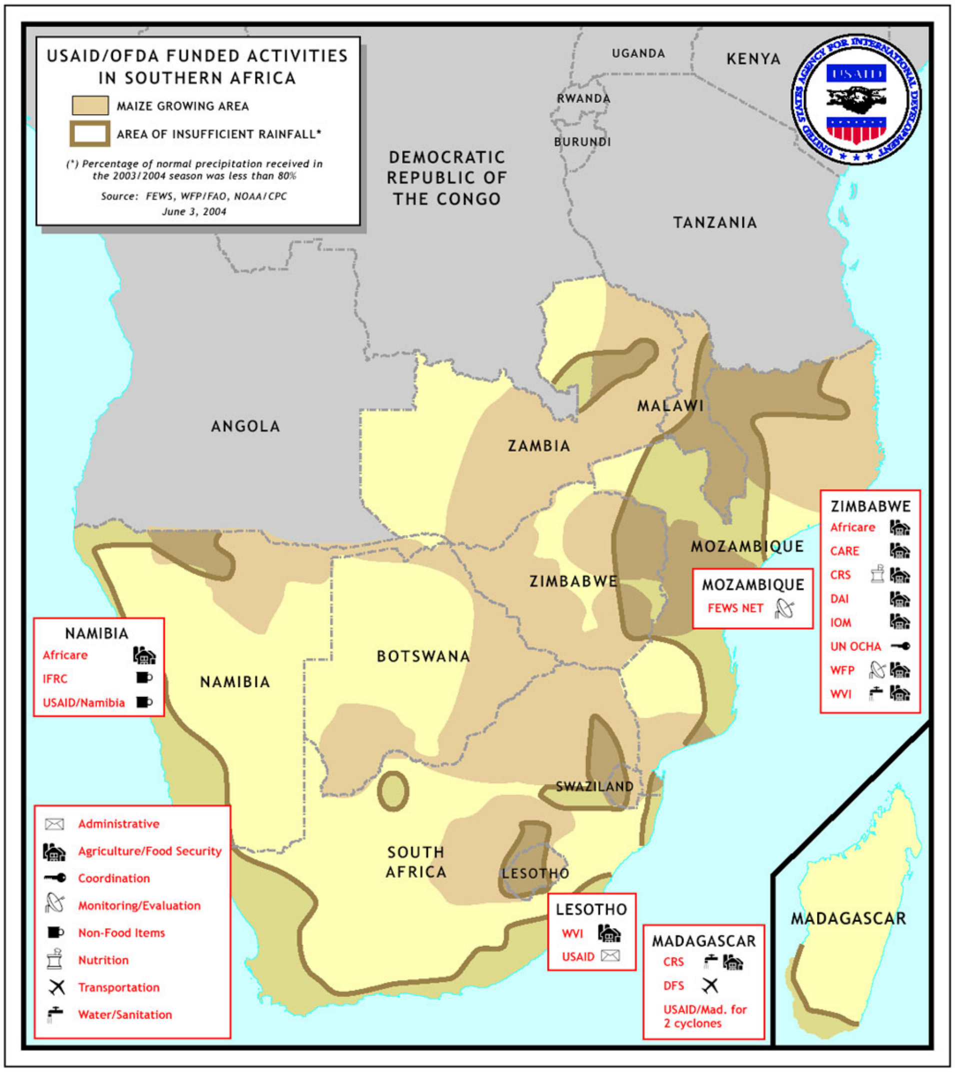
The Application of Geomatics in Complex Humanitarian Emergencies



Source: USAID

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"Peace operations could benefit greatly from more extensive use of geographic information systems (GIS) technology, which quickly integrates operational information with electronic maps of the mission area, for applications as diverse as demobilization, civilian policing, voter registration, human rights monitoring and reconstruction"

Lakhdar Brahimi, Chairman of the Panel on UN Peace Operations, August 2000[1]

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Section 1 – Introduction

Since the mid-1990s the media has been increasingly dependent on satellite images, maps and three-dimensional terrain visualizations to communicate stories about natural and human-induced disasters around the globe. Almost any report on the Darfur Crisis, Iraq War, or the Indian Ocean Tsunami exploits a host of powerful geospatial technologies. What are these technologies, and how are they currently being used to respond to complex humanitarian emergencies (CHEs)[i]?

Geomatics[ii] involves the integrated acquisition, modeling, analysis, presentation and management of spatially referenced data (i.e. any type of data that includes its location on earth), to support decision-making. Historically the primary domain of Cold War-era military agencies, geomatics has grown to include a thriving civilian user base, thanks to several key industry trends.

This paper illustrates how these underlying trends have impacted the response to humanitarian crises. First, the key milestones in the statutory and technological origins of geomatics are presented, followed by a review of the international charters drafted to mitigate losses arising from humanitarian emergencies. Second, examples of the application of geomatics are presented using several case studies; this section illustrates how humanitarian intervention has benefited from the use of geomatics. The case studies also clarify the UN's special role in facilitating geomatics, and identify some of the realities it has faced in using the technology. Finally, the paper concludes with a discussion of the challenges and potential for the use of geomatics in response to CHEs.

The primary objective of the paper is to introduce the non-specialist to the state-of-the-art in the use of geomatics to respond to CHEs, and to inspire a greater appreciation of the capabilities of this emerging technology. The reader is encouraged to visit some of the websites listed in the Appendix to learn more about the specific technologies and applications discussed herein.

Section 2 - Key Trends in Geomatics & Relevant Policymaking

From its Cold War-era origins, modern geomatics has rapidly spread from the exclusive domain of the US & Soviet militaries to the widespread use by governments and non-governmental organizations in every industrialized country, and in many less developed countries. Military applications continue to be a principle source of funding and technological advancement in geomatics, however civilian applications such as agriculture, forestry, mineral exploitation, surveying/mapping, and disaster management are also key markets[iii,2,3].

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[i] The precise meaning of CHE varies widely – in this paper, it is used in a manner consistent with the United Nations Inter-Agency Steering Committee definition: "A humanitarian crisis in a country, region or society where there is a total or significant breakdown of authority resulting from internal or external conflict and which requires an international response that goes beyond the mandate or capacity of any single agency and/or the ongoing UN country program. Common characteristics include: civilian casualties, and populations besieged or displaced; serious political or conflict-related impediments to delivery of assistance; inability of people to pursue normal social, political or economic activities; high security risks for relief workers; and international and cross-border operations affected by political differences."

[ii] Commonly defined to include the tools & techniques used in land surveying, remote sensing, Geographic Information Systems (GIS), Global Positioning System (GPS), and related forms of earth mapping. Originally coined in Canada, the term "geomatics" has been adopted by the International Standards Organization, the Royal Institution of Chartered Surveyors, and many other international authorities, although users (especially in the United States) have shown a preference for the term "geospatial technology".

[iii] Frost & Sullivan estimated the total worldwide commercial market for remote sensing imagery, data, GIS software, and value-added services at US$5.744 Billion in 2004, and project a market of over $8 Billion by 2010. ABI Research estimates the current worldwide GPS market at U$15 Billion, with global demand expected to rise to $22 Billion by 2008.

There are several major trends that have occurred over the past 15 years that have made such ubiquitous usage possible:

1. The growth of civilian access to precise geo-locational information, as a result of the US government's decision to end the intentional degradation of Global Positioning System (GPS) signals;
2. The growth of civilian access to the military-quality photo intelligence of almost anywhere in the world, as a result of the US and Russian governments' declassification and commercialization of high-resolution satellite imaging sensors, and
3. The widespread availability of user-friendly, powerful geomatics software and low-cost, Internet-driven PC systems.

These trends have not only made it possible for any humanitarian organization to exploit geomatics, but they have also inspired an unprecedented number of public-private sector partnerships specifically devoted to providing geospatial solutions to the humanitarian sector. Each of these phenomena is discussed in more detail below.

2.1 Unrestricted GPS Availability

The Global Positioning System is a satellite-based radio-navigation network comprised of a constellation of twenty-four satellites, used to obtain precise positions of targets on, or near, the surface of the Earth. Each satellite orbits the Earth every 12 hours at an altitude of about 20,000 km in six evenly distributed orbital planes around the Earth (see Figure 1). Using a process comparable to "triangulation", a GPS receiver on the surface of the Earth calculates its position based upon the known positions of three or more satellites, each of which is constantly transmitting a unique signal with a precise time stamp.[4]

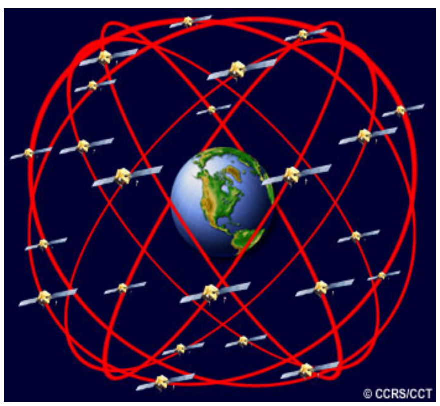


Fig. 1 – GPS Constellation
(*Source: CCRS)*

By providing the capability to accurately determine latitude, longitude, and elevation using portable receivers, GPS has revolutionized surveying, navigation, and the collection of geospatial data. GPS receivers can be small, lightweight, and relatively inexpensive, and are used to track mobile assets, navigate unfamiliar routes, update infrastructural maps, and improve the positional accuracy of satellite imagery. Personnel in the field can collect data using GPS equipped PDA's and laptop computers, which automatically input the location data with every field record. Traditional surveying techniques can be complemented or replaced by GPS survey methods, improving the efficiency of the map-making process.

Originally conceived in the 1970's for purely military purposes, the US Government recognized that GPS technology should and could be adapted to the benefit of worldwide civilian users as well.[5] When US Department of Defence (DoD) launched and commissioned its constellation of 24 GPS satellites in 1993, it was able to provide two levels of navigational accuracy: Standard Positioning Service and Precision Positioning Service. The Standard service was available to any GPS user around the world at no charge; however it was degraded to less than 100 metres positional accuracy, in order to prevent civilian GPS equipment from being used in a military attack on US interests. This deliberate distortion of signal quality was called "Selective Availability". The DoD's Precision service was only available to authorized users of US military GPS systems, which had the ability to decode the GPS signals at much higher positional accuracy.[6]

In the mid-1990's, after significant consideration, the White House began to re-evaluate the need for Selective Availability, and on May 1, 2000, President Clinton signed an order to end the policy[iv]. Today, a GPS device worth less than $200 can be used to identify its location anywhere on the surface of the earth, with better than 10 metres positional accuracy.

The utility of GPS can be categorized as follows:

- *Location*: determining a basic position
- *Navigation*: getting from one location to another
- *Tracking*: monitoring the movement of people and things
- *Mapping*: creating maps of the world
- *Timing*: providing precise timing worldwide[7]

For organizations delivering humanitarian assistance, the low-cost availability of modern GPS technology permits the easy and rapid collection of field data at a precision entirely sufficient for mapping hazard zones, planning logistics for distribution of aid, optimizing emergency stockpile locations, measuring refugee movement, tracking relief convoys, and any other task which is "spatially-dependent". The Appendix provides a list of websites that provide more information about the technology and application of GPS.

2.2 Declassification of High-Resolution Satellite Imaging

Traditionally the domain of a very exclusive user community, detailed satellite photography of the earth is now a publicly available commodity. What has inspired this unprecedented availability of high-resolution imagery, and what are the primary satellites used for CHE applications?

The development of high-altitude observation platforms, which dates back to beginning of the Cold War, has had several important evolutions. First, cameras were mounted on high-altitude warplanes and air balloons to facilitate enemy reconnaissance. Then in 1955, US President Dwight Eisenhower presented his Open Skies proposal to the post-War "Great Powers", in an attempt to advance world security through mutual transparency and confidence building. Unfortunately, Eisenhower's proposal, and the first U-2 flight over the USSR in 1956, only aggravated Soviet insecurities. It responded by launching the first earth-orbiting satellite, *Sputnik*, in 1957, and by developing improved ability to intercept U-2 spy missions. By 1963, both superpowers had launched first-generation reconnaissance satellites.[v]

This duopoly of high-resolution satellite sensors continued for most of the Cold War. By the time the Soviet Union collapsed in 1991, France (and more recently Israel, India, Canada, Europe, Taiwan, Korea, Japan, etc.) had ended American & Russian dominance of satellite earth observation by developing and launching satellites capable of discriminating objects initially of 10 metres (and now up to 2 metres) in size. [8] (This was a dramatic improvement over NASA's Landsat satellite series, which had been the primary source of satellite imagery available to civilian users – it provided 30-metre resolution imagery, which was and still is suitable for many civilian applications.) It was this

[iv] A Presidential Decision Directive (NTSC-6) in 1996 announced the White House's intention to discontinue Selective Availability within a decade, based upon inter-agency recommendations. That process led to a final decision to abandon the Selective Availability policy; however, the US government retains the technical ability to degrade GPS signals available to civilian users when and if necessary. The European Galileo satellite constellation is largely inspired due to concerns about the world's total dependency upon a fundamental navigational system controlled by one nation, due in part by the failure for Russia to maintain the Soviet Union's GLONASS constellation after the end of the Cold War. In December 2004, India announced its decision to help Russia fix the disrepair of GLONASS, as well as maintain its earlier commitment to join Europe's Galileo program. Galileo is should be operational by 2008, and be totally interoperable with GPS and GLONASS.

[v] It was not until 1978, however, that under the Carter Administration the US Government acknowledged the existence of its spy satellite program.

rush of competitive image sources that led to President Bill Clinton's decision, in 1994, authorizing US firms to launch and operate commercial high-resolution satellites. Due to obvious security concerns, the US government retains "shutter control", or the right to limit acquisition over sites of strategic interest, and to block data acquisition or distribution during periods of war.

Today, several US firms own and operate private, commercial observation satellites capable of discerning objects on the earth's surface as little as 70cm in size. At several hundred to several thousands of dollars per scene, their products are not exactly cheap for the typical humanitarian relief agency, however the ability to quickly acquire high-quality imagery over disaster zones anywhere in the world, without having to obtain "overflight" authorization, is a major advantage provided by the commercialization of satellite remote sensing. Also, the relative ease of image interpretation of high-resolution imagery makes remote sensing technology much more accessible to less-sophisticated humanitarian organizations.

The following table lists the primary satellites used by humanitarian organizations. While there are many other civilian earth observation platforms in operation, most remain unproven in their ability to effectively support CHE applications. For more information about the price, availability and applications of these and other remote sensing technologies, visit the websites listed.

Table 1: High Resolution Civilian Earth Observation Satellites

Sensor	Origin	Launch	Features	Comments
IKONOS 2	US	1999	✓ 1 m pan / 4 m multi-spectral ✓ 11 km swath width ✓ 1.5-5 day revisit depending on latitude	✓ Suitable for refugee camp assessment, near real-time navigational planning, and fine-scale mapping ✓ To be succeeded by IKONOS 3 in 2006 ✓ www.spaceimaging.com
QUICKBIRD 1	US	2001	✓ 0.6 m pan / 2.4 m multi-spectral ✓ 16.5 km swath width ✓ 1.5-5 day revisit depending on latitude	✓ Highest resolution satellite imagery commercially available ✓ Same applications as IKONOS 2, especially when precision mapping without ground control is required ✓ To be succeeded by WorldView in 2006 ✓ www.digitalglobe.com
SPOT 5	France	2002	✓ 2.5 & 5 m pan / 10 m multi-spectral ✓ 60 km swath width ✓ 2-5 day revisit depending on latitude	✓ Suitable for most CHE applications, including thematic mapping ✓ Strong reputation with humanitarian agencies, and proven track record ✓ www.spotimage.fr
SPOT 2 & 4	France	1990 & 1998	✓ 10 m pan / 20 m multi-spectral ✓ 60 km swath width ✓ 1-2 day revisit depending on latitude	✓ Suitable for thematic mapping and other medium scale applications ✓ Strong reputation with humanitarian agencies, and proven track record ✓ www.spotimage.fr
IRS 1C/D & RESOURCESAT	India	1995, 1997 & 2003	✓ 5.8 m pan / 23 m multi-spectral ✓ 70 km swath width ✓ 5 day revisit depending on latitude	✓ Suitable for thematic mapping and other medium scale applications ✓ Unreliable image delivery and radiometric quality ✓ www.nrsa.gov.in
RADARSAT 1	Canada	1995	✓ 8-100 m C-Band Synthetic Aperture Radar ✓ 50-500 km swath width ✓ 2-5 day revisit depending on latitude/mode	✓ Difficult to interpret ✓ Best system dependability due to all-weather capability of radar ✓ Proven track record in disaster management applications ✓ To be succeeded by RADARSAT 2 in Fall 2005 ✓ www.rsi.ca
LANDSAT 7	US	1999	✓ 15m pan / 30 m multi-spectral/ 60 m thermal infra-red ✓ 180 km swath width ✓ 16 day revisit	✓ Not a "high-resolution" satellite but still suitable for CHE applications such as thematic base mapping and vegetation assessment ✓ Not suitable for fine-scale mapping beyond 1:50,000 scale ✓ No copyright or data sharing restrictions, low cost

2.3 Information Technology Revolution

The reader is no doubt familiar with importance of the advancement of information technologies over the past 20 years. It is probably sufficient to simply state that the world of geomatics is totally indebted to the digital revolution, and the power of geospatial technologies would not have been realized without low-cost and powerful personal computers, user-friendly geomatics software, and high-speed global Internet connectivity.

Today, disaster managers can order imagery and other spatial data on-line, and then download raw or processed products within minutes. They can also download free or inexpensive image-processing software, which allows them to analyze, manipulate and combine their satellite data to extract meaningful intelligence about a specific CHE. That intelligence can be directly imported into a spatial database, or Geographic Information System (GIS), which enables any information to be analyzed according to location. Since location is the common denominator, GIS provides a powerful platform with which to ingest, compute and communicate diverse information. For example, a humanitarian agency can plan navigation routes within a GIS by overlaying the location of its warehouses and its heavy trucks (collected by GPS in the field), with an image showing migrating refugee populations and passable roads and bridges (collected by a satellite but geo-corrected using a local topographic map or Digital Elevation Model).

But this example does not imply that the process is easy or inexpensive. Indeed the greatest failure of the geomatics industry has been its overzealous simplification of the effort necessary to realize the full potential of the technology. Most of the required investment is not in geomatics data, software or hardware, but in the skills necessary to maintain a robust geomatics capability that can provide useful and timely intelligence throughout the disaster management process. Many organizations have purchased the technology and expected magical results to emerge soon thereafter, only to have been greatly disappointed. The steady, sustained investment in geomatics personnel is key to developing an internal capability. For organizations not ready to commit to an in-house program, many other options exist to exploit the power of geomatics, at least at a generic level, at little to no cost. The Appendix provides a list of geospatial resources available to disaster managers.

2.4 International Cooperation in Geomatics for CHEs

As a result of the aforementioned trends, a variety of public and private sector partnerships have been established to begun to jointly promote the use of geomatics for CHEs. Although there is an obvious struggle between the competing interests of for-profit vendors and a non-profit clientele, the keen interest for collaboration marks an important phase in the development of a civilian, humanitarian intelligence community.

The following examples illustrate how the international geomatics community has cooperated to supply geomatics products and services to humanitarian agencies during and after major disasters, at little or no cost to those agencies.

2.4.1 International Charter on Space & Major Disasters

Conceived in July 1999 by the European and French space agencies, the “Disasters Charter” now includes the Canadian Space Agency (since October 2000), National Oceanic and Atmospheric Administration and the Indian Space Research Organization (since September 2001), the Argentine Space Agency (since in July 2003), and the Japanese Space Agency (since February 2005). [9]

Each member agency operates one or more earth observation satellites and other useful space assets, and the Charter attempts to provide a unified system to request use of those assets in a timely manner. At the time of a disaster, authorized users (typically a participating country’s emergency management agency) can call 24-hour hotline to request the mobilization of available space and ground-based resources to obtain up-to-date imagery of a disaster occurrence.

In July 2003, the Charter was also made available to support all United Nations agencies involved in natural or man-induced disaster management.[10] As of August 2005, the Charter has been activated by the UN and its other members on over sixty occasions, primarily to assist the response to wildfires, floods, volcanic eruptions, oil spills and earthquakes.

Despite its reliance on the voluntary participation of just a few satellite image providers, the Charter is considered to be an important and unique alliance in the geomatics community. (It should be noted that the Charter members are not committed to provide free interpretation or cartographic services, although this does occur frequently as part of the members' contribution.[11])

2.4.2 UNOSAT

Headed by United Nations Institute for Training & Research (UNITAR) and operated by the United Nations Office for Project Services (UNOPS), UNOSAT is a non-profit consortium funded by ESA's Earth Observation Market Development Program, together with the French space agency (CNES) and Ministry of Foreign Affairs. [12]

In many ways, UNOSAT provides a parallel service to the Disasters Charter. It procures geographical information products for UN agencies and the international humanitarian and development communities, using special relationships with private-sector geomatics service providers. The purpose of UNOSAT is "to encourage, facilitate, accelerate and expand the use of accurate geographic information derived from EO-satellite imagery by professionals involved in achieving vulnerability reduction, crisis management and recovery as well as sustainable development at the local level."[13]

Using a web-based user interface as well as direct contact, UNOSAT provides 24/7 support in geomatics: methodological guidance, satellite imagery selection and procurement, image processing, cartography, etc. Any institution involved in humanitarian no-profit activities aiming at crisis prevention, management and sustainable recovery and development in-line with UN policies can qualify to use UNOSAT's services.[14]

2.4.3 RESPOND Consortium

UNOSAT also happens to be a partner of the RESPOND Consortium, an even larger but less formal effort to combine the expertise of the geomatics community with the needs of the international humanitarian community. The RESPOND Consortium has committed itself to making geomatics much more accessible to the humanitarian community, by improving access to maps, satellite imagery and geographic information.

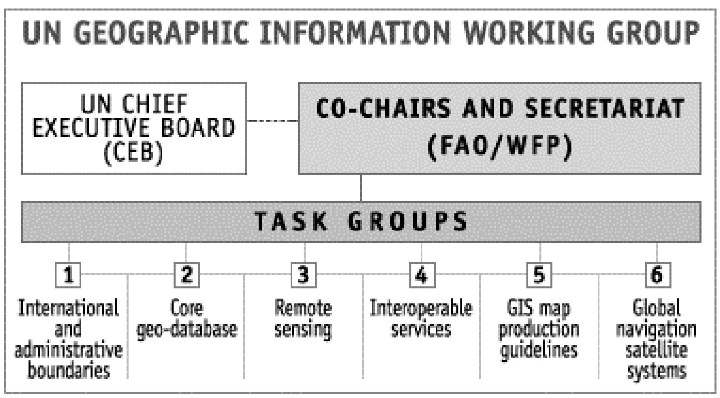
Sections 3.2 and 3.3 feature geomatics case studies in Darfur, Sudan. The ability to efficiently procure data and services from multiple providers is the primary advantage of alliances like UNOSAT and RESPOND - it allows them to swiftly meet the operational demands of many organisations on the ground, including UN's Humanitarian Information Centre (HIC), which is based in the Khartoum, the Sudanese capital.

The RESPOND Consortium is expecting to grow its client base to over 400 humanitarian organizations by 2009.[15] Although it is wise be cautious about such grand designs, the direction of public-private partnerships in humanitarian applications of geomatics is impressive. The European geomatics community appears to be most active in leading such initiatives, and it remains to be seen if players in the North American or Asian geomatics scene will begin to take more aggressive leadership roles.

2.4.4 United Nations Geographic Information Working Group (UNGIWG)

In January 2004, Hiroshi Murakami, the former Chief of the UN Cartographic Section, stated, "UN decisions and operations depend on geographic information in activities such as brokering agreements on boundaries, coordinating humanitarian relief, planning and deploying peacekeeping initiatives, eradicating disease, removing land mines, promoting sustainable agriculture and development and protecting the environment. Geographic information in the United Nations is maintained independently by different UN organizations. This distributed approach demands an open and networked system, which is now possible through Open GIS specifications."[16]

Established in March 2000, UNGIWG is the current effort within the United Nations to coordinate mapping and geographic information[vi]. In order to promote and coordinate geospatial activity within the United Nations, UNGIWG focuses upon issues such as maps, boundaries, data exchange & standards. The ultimate purpose, of course, is to promote a high quality of geographic information within the United Nations System, and to build the UN Spatial Data Infrastructure in partnership with the International Standards Organization (ISO), and the Open Geospatial Consortium.[17] Management of this mission is currently shared by the UNGIWG co-chairs from the Food & Agriculture Organization and the World Food Program. The following diagram describes how UNGWIG's activities translate into six distinct task groups. (No attempt will be made to detail the activities of these task groups here, as the recently updated UNGIWG website www.ungiwg.org, provides an excellent and current review of recent and forthcoming task group activities.)



The reader can easily imagine the challenging nature of tasks such as:

- updating the ever-changing and disputed boundaries of UN member states;
- exploiting economies of scale when procuring high-priced geospatial data;
- ensuring that meta-data and coding schemes are consistent throughout UNGIWG dozens of member agencies, and distributing internationally-acceptable products to users around the world using web-based GIS, portals and partner sites.

These types of tasks can be key to the success of the international community in mitigating and responding to humanitarian disasters; facilitating correct, consistent, timely, and high-quality geo-information is the ultimate mandate of the UNGIWG. Again, the central role of the UN agencies in facilitating humanitarian assistance makes UNGIWG a strategically important partner in the development of the HDM, although the mechanics of their involvement is at this stage unclear.

[vi] The need to coordinate "cartographic services" has long since been recognized within the UN, initially by Economic and Social Council Resolution 131 (VI), February 19, 1948.

2.4.5 Humanitarian GIS Data Model

In August 2005, an international consortium was established to create a Humanitarian Data Model (or "HDM").[18] Expected to be released by mid-2006, the HDM will be free, open, and non-proprietary, as it is intended to promote more effective GIS usage, data sharing, and system interoperability by organizations which provide humanitarian assistance: United Nations agencies, donor agencies, research institutes, consultants and non-governmental organizations (NGOs) are all potential beneficiaries. The HDM, at a minimum, will provide a starting point for these organizations to build their internal GIS applications using a geodatabase design that "really works" and an application framework that allows those organizations to quickly become productive.

Data models are not the most exciting part of designing and implementing a GIS system, but they are one of the most essential. A data model describes the process of converting tangible ideas or objects into useful and accessible information in a geodatabase. That has traditionally meant depicting things in the real world as points, lines, or polygons with certain attributes. When linked together, these form features.

Once a model is completed and available, it serves as the architecture upon which geodatabase projects can be based. Data model implementers can take the common application model and use it as the basis of their own data model, customized to suit their own purposes. If a humanitarian organization in Sudan wanted to establish an internal GIS to support its programs, but generally consistent with typical humanitarian operations, it could download the HDM and then modify it by removing some features that were not applicable, or including some features that were applicable, to its activities. The wider humanitarian GIS community could also use the model as the basis for dynamically importing and exporting data, dramatically reducing the barrier imposed by non-standard designs.

Just as the applications for humanitarian GIS are wide-ranging, the developers and users of humanitarian applications are a diverse group with a variety of skills and interests. Examples of potential HDM "clients" include (1) a small NGO which does GIS-based natural hazard management but which has very limited data and financial resources; (2) a disaster management agency which has a national mandate to prevent, mitigate and respond to natural and man-made disasters but which does not have access to geodatabase design expertise; or (3) the Field Information Services unit of UNOCHA, which manages the deployment of Humanitarian Information Centres wherever the UN needs to coordinate large-scale emergency relief operations.

Each of these clients will probably demand different functionality, and different levels of precision in their data. Yet all are bound by several commonalities, including their need for accurate base maps which support universal layers such as critical infrastructure, settlements, land usage, simple geography and political boundaries. Therefore, the HMD will support the themes of geospatial information required by the vast majority of humanitarian organizations.

2.4.6 Conclusions about International Cooperation in Geomatics

The above initiatives are representative of how public-private sector partnerships are attempting to exploit the capabilities of geomatics within the context of CHE response. Beyond CHE applications, the geomatics community collaborates extensively to promote interoperability of technologies, data integrity, web-based accessibility, and other geospatial applications such as urban planning or environmental management.

The primary body for maximizing the accessibility of geographic information and services across networks, applications and platforms is the Open Geospatial Consortium (www.opengeospatial.org), which boasts over 270 member organizations from around the world.[19]

The Appendix lists some of the many publicly accessible repositories and web-based tools sponsored by various alliances interested in promoting the use of geomatics for humanitarian assistance and sustainable development.

Section 3 - Case Studies

The following case studies illustrate how geomatics are being used to support the response to Complex Humanitarian Emergencies (CHEs).

3.1 Infrastructure Mapping in the Beldangi Refugee Camp (ENVIREF)

One of the first assessments of the potential for civilian geomatics to assist with CHE response was a project called ENVIREF ("ENVIronmental monitoring of REFugee camps using high-resolution satellite images"). Started in early 1998 by a consortium of European satellite remote sensing agencies and the UNHCR, ENVIREF investigated how commercially available medium and high-resolution imagery might be beneficial to specific refugee situations in the Balkans, Kenya and Nepal.[20]

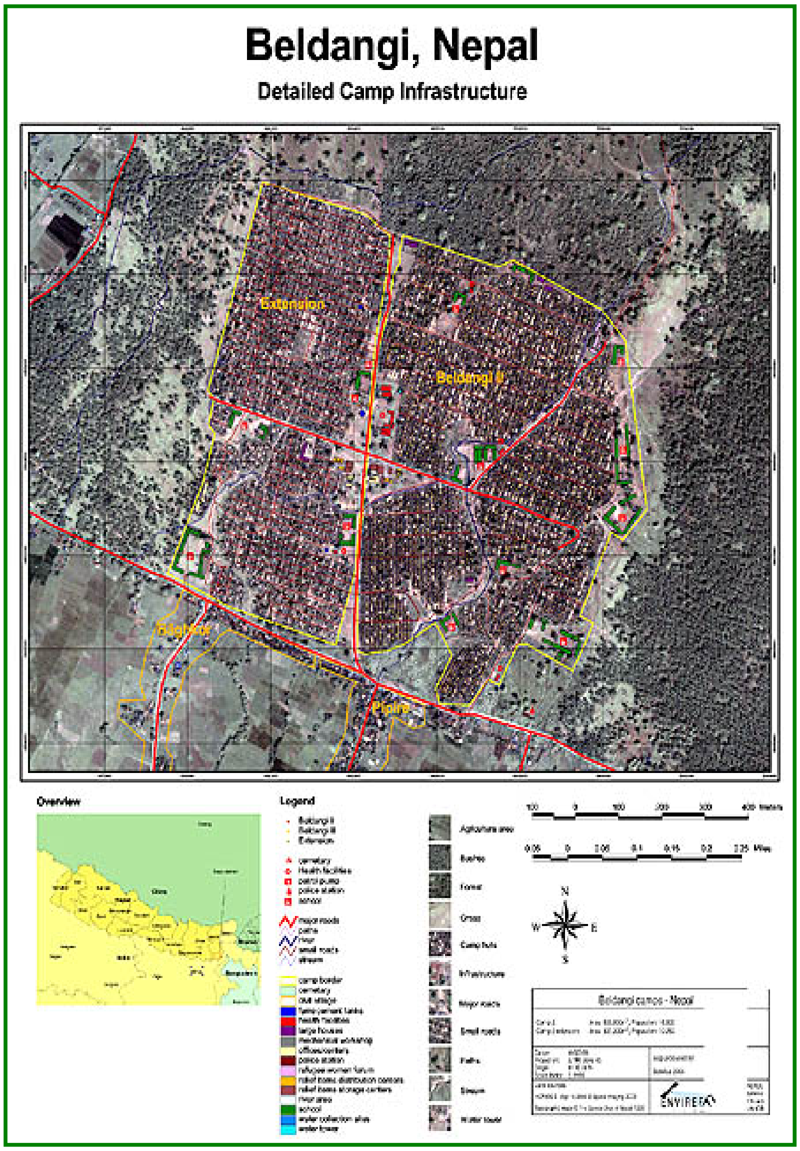


Fig. 2 – Detailed Refugee Camp Infrastructure Map
(Source: ENVIREF, Courtesy: Space Imaging)

Refugee camps are rarely temporary. On average they last seven years, but some last for decades - far longer than the media's attention span. Humanitarian agencies need to track camp migration, population flux, lines of communication (e.g. bridges, roads, airfields, etc), water supply, soil conditions, deforestation, natural hazards, camp security, etc.[21] The ENVIREF project partners attempted to illustrate the type of humanitarian intelligence that could be feasibly extracted from civilian imaging satellites to support remote relief operations.[22]

Figure 2 shows a 1m resolution panchromatic image of the Beldangi Camp in Jhapa District, Nepal, captured by the IKONOS satellite on May 15, 2000. Refugees from Bhutan have existed in the region since the early 1990's. The image was used to map refugee camp infrastructure, and surrounding land conditions.[23]

The UNHCR considered deforestation to be the most serious hazard created by the influx of refugees. Land clearing, deforestation, and other human activity created highly vulnerable conditions for local populations, who were already at risk of seasonal monsoon flooding.[24]

To assess the rate of deforestation, the ENVIREF scientists used multi-temporal, medium resolution (30 metre) radar[vii] imagery to map the long-term loss of forests surrounding the refugee camps.

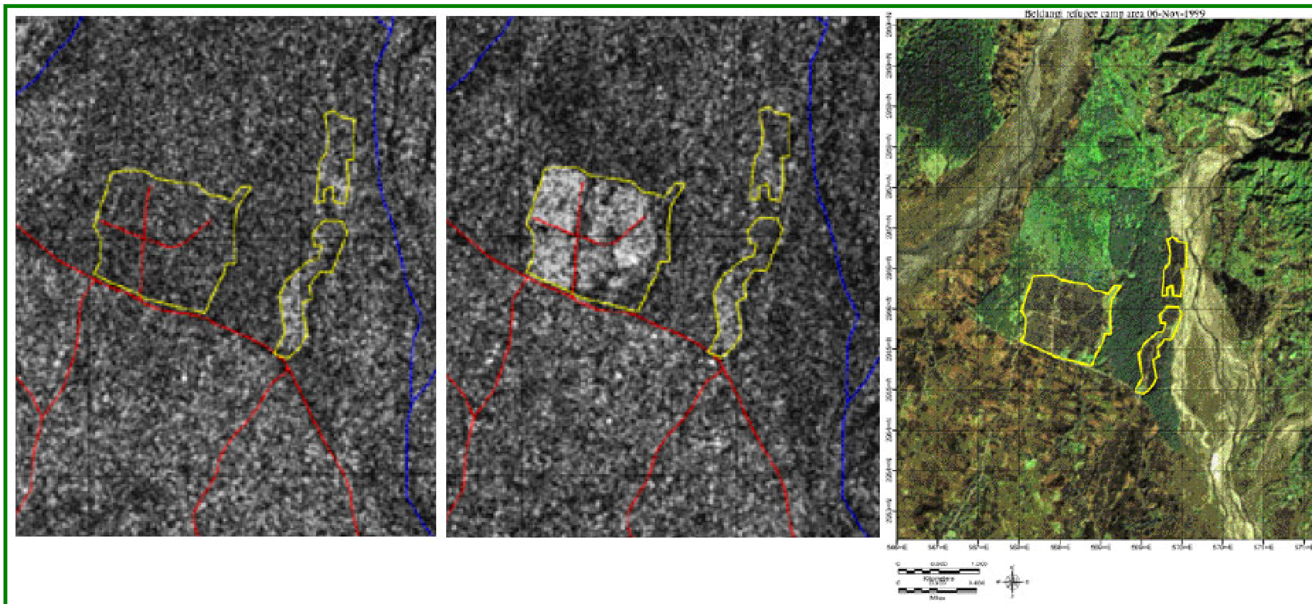


Fig. 3 - Beldangi Refugee Camp in 1992, 1996 and 1999 (from left to right) *(Source: ENVIREF)*

Figure 3 shows multi-temporal images of the Beldangi camp. On the left is a radar image acquired by the ERS satellite on June 21, 1992. In the middle is another ERS image, captured on May-15, 1996. Both radar images are approximately 30 metres in resolution. To the right is a Landsat-7 "pan-sharpened multi-spectral[viii]" image acquired on November 6, 1999. It is possible to discern the eastern part of the Beldangi refugee camp settlements that reportedly opened in May 1992, but not the part to the west, which was apparently settled after the 1992 image was captured. The ERS image taken in 1996 and the Landsat image taken in 1999 are consistent, as shown by the superimposed camp boundaries. The eastern camp appears quite similar in the two images, which confirms that the western camp had not be built when the first image was acquired.[25]

Radar images are much more difficult to interpret than optical images, since human vision is limited to the visible portion of the electromagnetic spectrum. Radar images represent the backscattering of microwave signals transmitted by a satellite, reflected off the earth, and then received by the same satellite. A simple analogy is that optical images are how we "see" the region, but radar images are how we would "feel" the region; our sense of vision detects color, and our sense of touch detects surface roughness and moisture level. Optical sensors passively record the radiation of light reflect off the earth, however radar sensors actively send and record their energy, making them independent of illumination from the sun or other light sources.

The ENVIREF study demonstrated that land use conditions of refugee camps could be assessed using multi-temporal analysis of commercial satellite imagery.

[vii] Persistent cloud cover or inadequate illumination can be major impediments to using optical satellite imagery. Synthetic Aperture Radar (SAR) imagery enables analysts to reliably obtain imagery even during monsoons, sandstorms, fog, and darkness. It also provides surface details not always discernable in optical imagery.

[viii] Pan-sharpening techniques enhanced the Landsat 7 satellite's multi-spectral (i.e. colour) image resolution of 30 metres with the satellite's higher-resolution panchromatic (i.e. black and white) images of 15-metre resolution. This improves visual interpretation by artificially "sharpening" the colour image.

3.2 Water Exploration in Chad (UNOSAT) [26]

Complex emergencies often require humanitarian agencies to provide vast populations with food, shelter, medical treatment and other basic necessities for survival. But the greatest single need is water: the UNHCR uses a benchmark of 15 litres of water per person per day, but in too many cases this is an unattainable standard. In March 2004, the UNHCR requested UNOSAT to help it locate groundwater reserves to support Sudanese refugees from Darfur, and to optimize locations for new camps in the region. At that time, the Darfur Crisis had already forced over 180,000 refugees into the deserts of eastern Chad.

"They asked us to address this major problem of obtaining water for refugees, and working with consultant firm Radar Technologies France (RTF) we designed a solution," said Olivier Senegas of UNOSAT. "By the beginning of July 2004 we supplied water target maps covering over 22500 square kilometres of territory around the refugee camps of Oure Cassoni, Touloum and Iridimi." By the end of July, the team had successfully confirmed their remotely derived target maps with ground truthing; this was followed by detailed *in situ* geophysical analysis that is necessary to assess the actual potential/productivity of such water sources. The entire process was much more efficient and timely compared to using ground survey techniques alone.

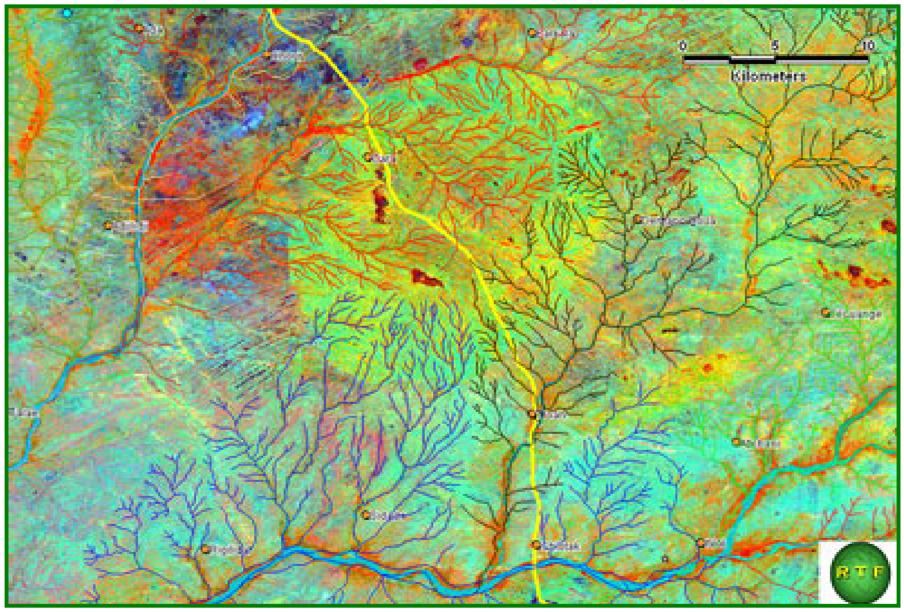


Fig. 4 - Study Area Geology enhanced by processing *(Source: RTF)*

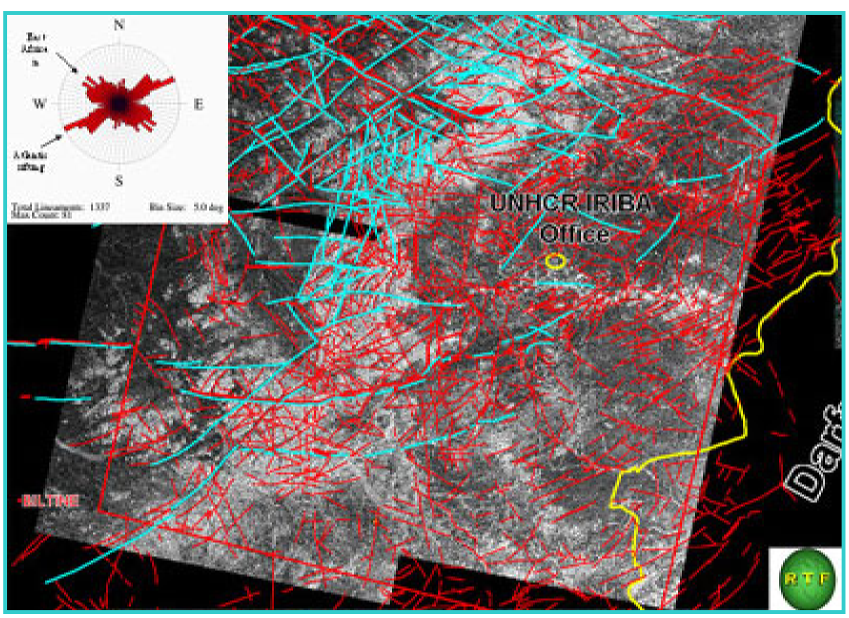


Fig. 5 - Radar structural Analysis of Study Area *(Source: RTF)*

RTF's technique involved merging information from several satellites such as multi-spectral optical imagery from Landsat-7, C-band and L-band radar imagery. In order to orthorectify the imagery for terrain distortion and earth curvature, a Digital Elevation Model (DEM) derived from NASA's Space Shuttle Radar Topography Mission (SRTM) was used to spatially-correct the images so that they could be used together with other data.

Landsat was used to develop a basic understanding of the vegetation and surface water conditions of the region, and to map basic geology. Radar C band

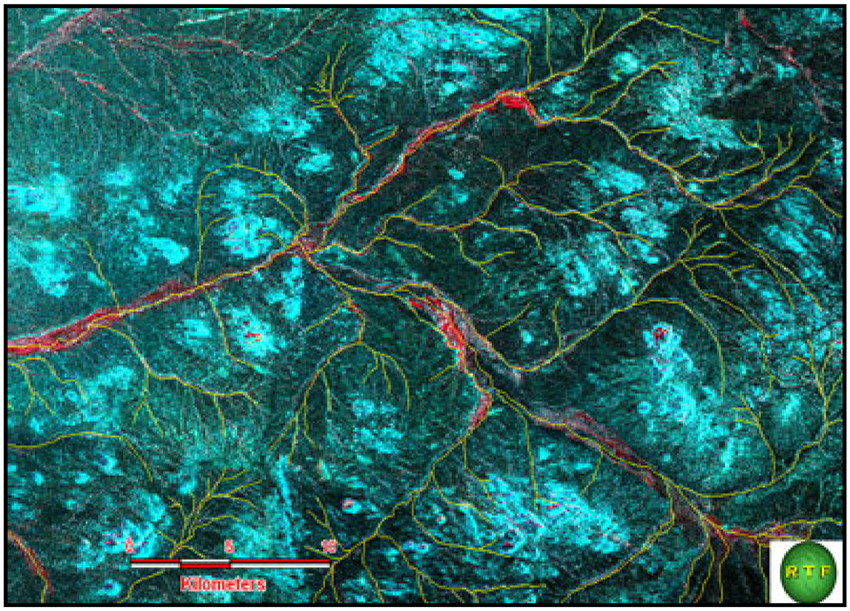


Fig. 6 - Buried Water Resources (red areas) *(Source: RTF)*

was then used to map surface and near-surface topography, including geological structures such as faults, dikes, and dry riverbeds (known as *wadis*) that often indicate water potential. Then L Band radar imagery, which has the ability to penetrate the desert sand even deeper than C band thanks to its longer microwave signal wavelength, was used to map sub-surface water structures.

The technique to create water potential maps in the region was based upon that employed for oil, gas and mineral exploration. According to Dr. Alain Gachet of RTF, "the optical imagery shows you the surface; C band sees to a depth of about 50 cm down, and L band goes down to a maximum 20 metres, so with them all together you obtain a kind of cross-sectional model of the landscape." Because microwaves are highly sensitive to the dielectric properties of water, multi-temporal images over an area can be used to detect underground humidity anomalies.

RTF has developed *WATEX,* a specialized groundwater exploration processing system that can produce, over extended areas in very short time, ground water target maps displaying geomorphology, geology, soil, slope, land use, drainage, drainage density, lineament, faults orientation and density, runoff isolines, watershed limits, water quality, ground water depth.[27] WATEX enhances humidity by removing roughness effects on radar images.

Once the success of the technology was proven, the UNHCR requested the project scientists to optimize the location of seven new camps, an addition to the nine camps already operating in the region. Suitable locations were selected based upon water potential, access to transportation routes, and topography. Much of this work was done within a Geographic Information System: GIS enables spatial analysis of layers of information, including satellite intelligence, topographic maps, UN activity, population statistics, land cover, and lines of communication.[28]

It's saved us months of running around and drilling test wells," says Geoff Wordley, a senior UN emergency officer in Chad. Without Gachet's data, he adds, "We might as well be using divining rods."[29] RTF estimates that its maps have theoretically improved local drilling success rates from 42% to 89%, based upon statistics from over 544 wells and boreholes.[30]

Interestingly, the maps being used to support refugees may also be used by Chadian farmers in the future. "The third aspect is, we hope, to benefit local people beyond this current crisis," said UNOSAT's Senegas. "Only up to 30,000 people live here ordinarily, but they have shared what little they have with the refugees. These maps can help them in a lasting way, telling farmers, if you dig in this area here, you will be more likely to find water for your fields.

A rudimentary GIS centre has also been proposed in Chad as a long-term contribution to the sustainable development of the region.

3.3 Thematic Mapping & Route Planning in Darfur (RESPOND)[31]

The RESPOND Consortium provides another excellent example of the use of geomatics to support the Darfur Crisis. Satellite remote sensing is an efficient tool to respond to the massive scale of the CHE in the Darfur region, which by December 2004 was measured to involve nearly 1.5 million people displaced over an area the size of France.

Key beneficiaries of RESPOND's analysis have included:

- the German Red Cross (DRK), which needed 1:50,000 and 1:10,000 scale maps of the Al Fashir and Al Junaynah areas, as well as 1:5,000 scale detailed maps of the Abu Shok camp and Guba Clinic[32];
- the German federal disaster relief agency Technisches Hilfswerk (THW), which needed updated water and transportation infrastructure maps to support reconstruction of roads, airports, and bridge infrastructure[33];
- the United Nations Office for the Coordination of Humanitarian Affairs (UN OCHA), which needed a full assortment of thematic and activity maps to support its mandate of coordination international relief efforts.

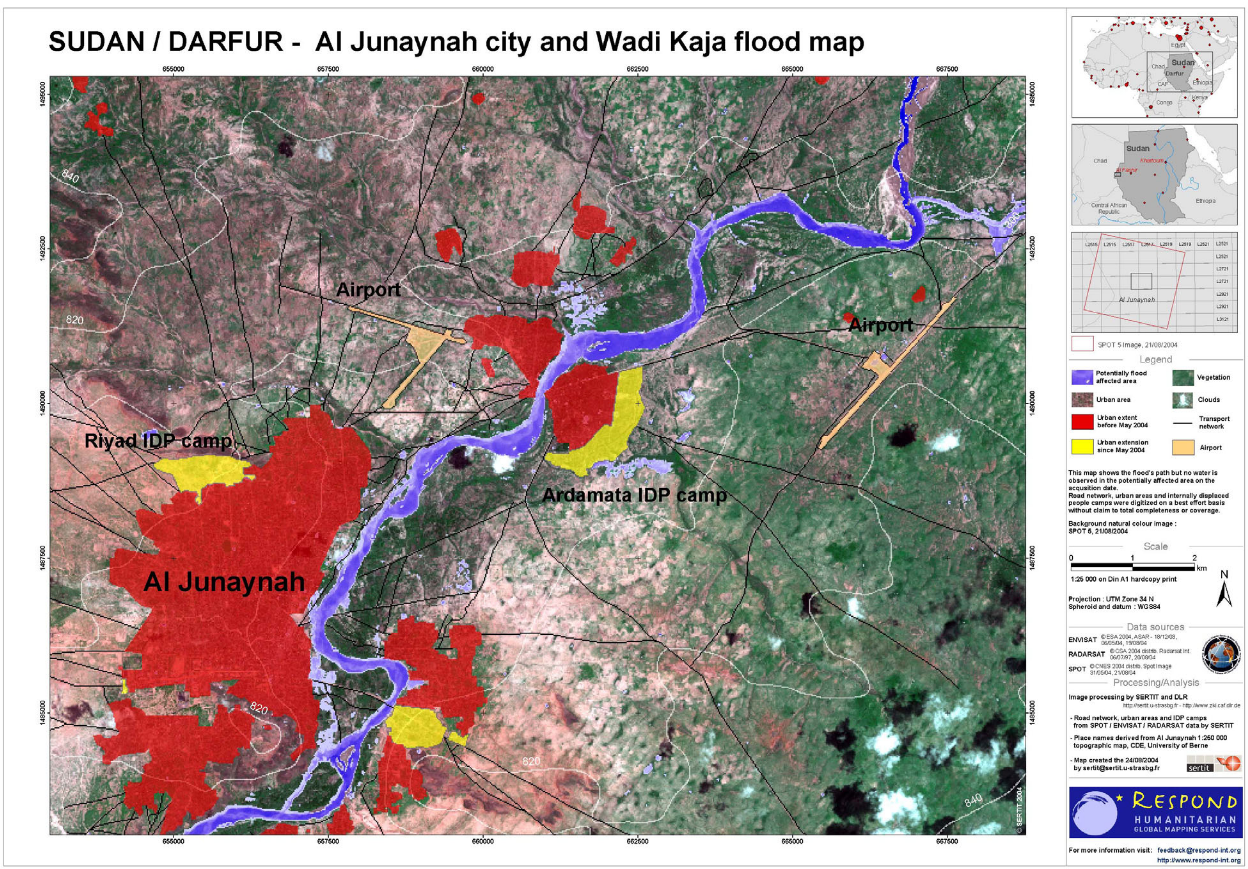


Fig. 7 - Envisat/RADARSAT/SPOT merge, showing pre-May 2004 settlements (red), post-May 2004 settlements (yellow), airports (peach) and potential flood inundation (blue) *(Source: RESPOND)*

The RESPOND team has used ten different sensors from nine separate spacecraft, with some imagery being analyzed with a few hours of acquisition; data has been provided under a variety of arrangements, including the Disasters Charter (see Section 2.4.1). The following table lists the sensors and applications of satellite data utilized by the project team.

Table 2 - Satellite Data used by the RESPOND Consortium in the Darfur Crisis[34]			
Sensor	**Satellite Operator**	**Application**	**Comments**
Landsat 7 ETM	NASA / USGS (US)	1:200K Baseline Thematic Mapping	Archived data
SPOT 4	CNES (France)	1:50K Baseline Infrastructure Mapping	Archived data
SPOT 5	CNES (France)	1:25K & 1:10K Detailed Mapping	Fresh acquisitions
Envisat ASAR	ESA (Europe)	Road & Flood Mapping	Near-real time acquisitions
Envisat MERIS	ESA (Europe)	Vegetation Change Mapping	Fresh acquisitions
DMC	Surrey Satellite Technology Ltd. (UK)	Vegetation Mapping	Near-real time acquisitions
RADARSAT 1	CSA / RSI (Canada)	Road & Flood Mapping	Near-real time acquisitions
IKONOS	Space Imaging (US)	1:5K & 1:2K Refugee Camp Mapping	Near-real time acquisitions
IRS 1C/D	ISRO / NRSA (India)	1:10K Detailed Mapping	Fresh acquisitions
SRTM Digital Elevation Model	NASA / USGS (US)	DTED Level 1 Topographic Mapping	Archived data

Radar imagery has been a critical requirement for some applications due to inclement weather conditions - roads in the Darfur region were flooded during the August 2004 rains, crippling lines of communication to remote areas. Some relief agencies needed up to ten days to travel 120 kilometres by road: using near-real time radar imaging over the region, the RESPOND analysts were able to produce up-to-date navigation maps, dramatically reducing delays in the distribution of aid. Without these maps, DRK were crossing the same *wadi* (flooded river bed) two or three times in their

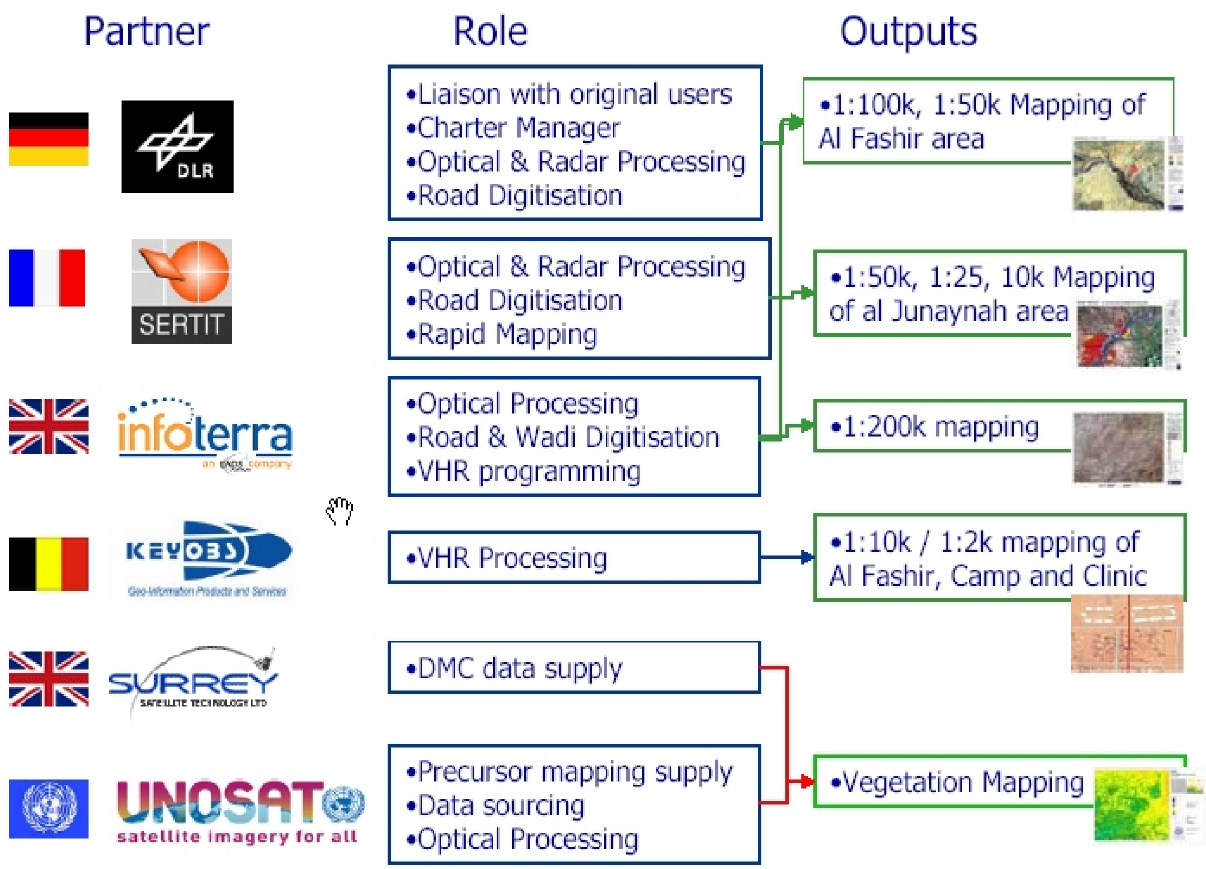


Fig. 9 - RESPOND Consortium's roles and outputs in the Darfur Crisis *(Source: RESPOND)*

efforts to find a route between population centres. The schematic above illustrates the project role and outputs of the RESPOND Consortium.

As Table 2 and Figure 8 indicate, the project has also involved vegetation mapping. Accurate estimates of brush and grassland have been used by relief agencies to manage fuel (firewood) distribution near refugee camps, and can also be used to direct cattle grazing and crop cultivation.

High-resolution IKONOS imagery has been used for camp and urban clinic mapping. The images below show the structures around Al Fashir, the capital of north Darfur state and distribution point for food and supplies. "The displaced populations often live in concentrated areas and small houses or tents," explains another RESPOND analyst. "The use of very high resolution imagery was needed to provide detailed mapping and analysis of the situation. This confirmed our past experiences with Médecins Sans Frontières and the International Committee of Red Cross who have already demonstrated their interest in this type of data."

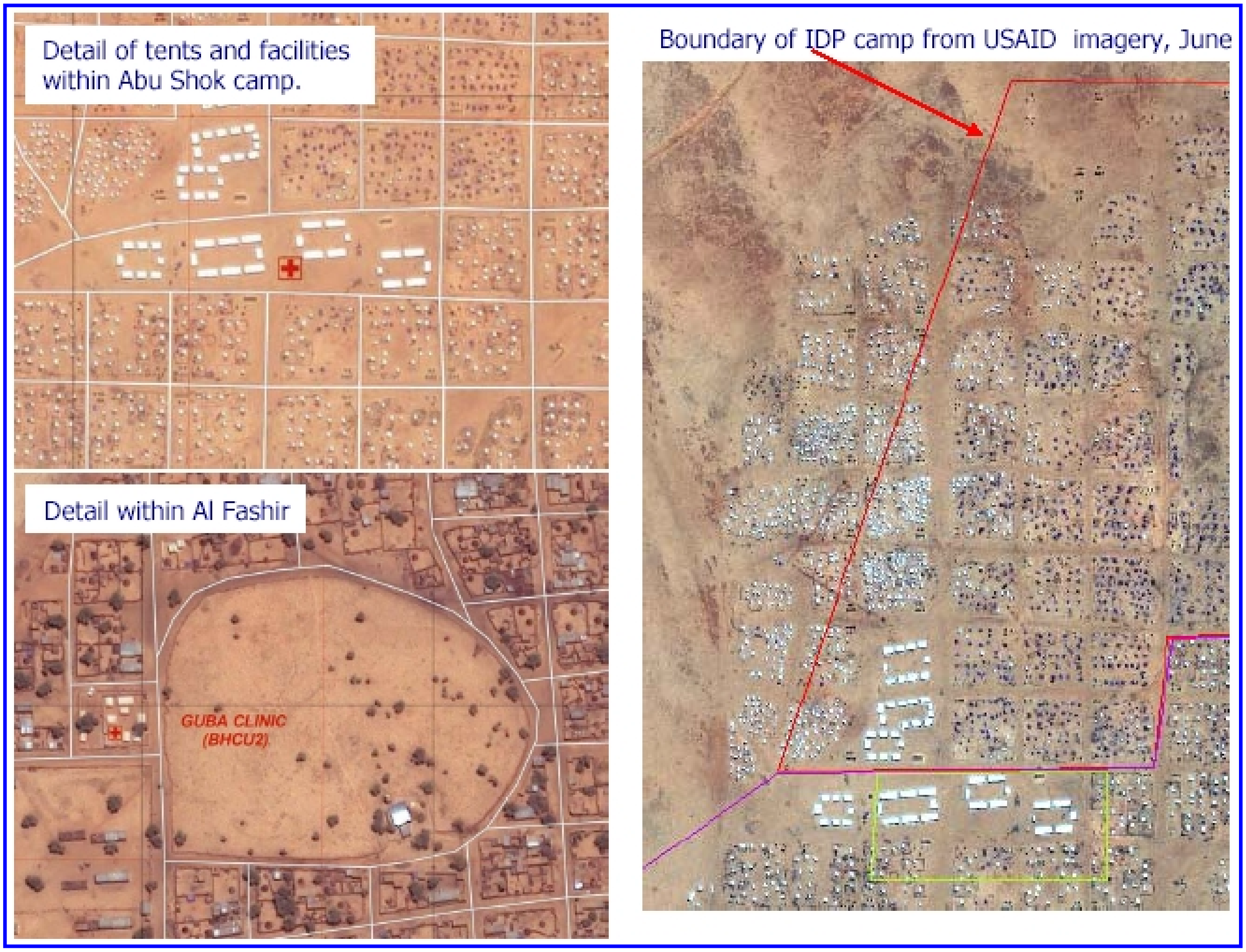


Fig. 9 - IKONOS Structural Maps of Camps in Abu Shok & Al Fashir, Sudan *(Source: RESPOND)*

3.4 Humanitarian Information Centre Afghanistan (UN OCHA)

No study of the use of geomatics for CHEs could be complete without a review of the role the United Nations plays in deploying and operating Humanitarian Information Centres (HICs). Located within the UN's Office for the Coordination of Humanitarian Affairs (OCHA), the Field Information Services (FIS) unit was formed in 2000, a year after OCHA had set up its first HIC in Kosovo with assistance from the UNHCR's Geographic Information Support Team (GIST). The FIS and GIST have since established HICs to coordinate global humanitarian response to CHEs in Sierra Leone (2000), North Korea (2000), Afghanistan (2001), the Occupied Palestinian Territories (2002), Iraq (2003), Liberia (2003), and Sudan (2004). Regional Information Centres have also been established in the Horn of Africa (2001) and South Africa (2002). [35] In response to the Indian Ocean tsunami that struck on December 26, 2004, the UN added HICs in Sri Lanka and Indonesia. [36] The unit deployed to the Banda Aceh works in unison with the Joint Disaster Management Centre hosted by the Indonesian Government, UN OCHA and Joint Logistics Cell.[37]

The HICs are designed to act as an information hub and a focal point for collection, analysis and dissemination of all types of humanitarian information. Within the context of geomatics, HICs produce a variety of standard cartographic products which are useful for a variety of humanitarian applications: maps showing land cover / land use, detailed refugee camp infrastructure, secure navigation routes, etc., are typically required by multiple organizations - each HIC's ultimate mandate is to provide demand-driven, timely, reliable information products and services to the humanitarian community.[38] The effectiveness of HICs is highly dependent on the staffing, conditions and nature of each deployment; the failure of some HICs to achieve their full potential was recognized in a September 2004 evaluation jointly conducted by USAID/OFDA and DFID.[39] The report assessed the successes and failures of the HIC experience to date, and proposed numerous recommendations to improve the quality and relevance of the HIC paradigm used around the world.

One of the HIC deployments reviewed in that evaluation was the Afghanistan Information Management Service (AIMS). The HIC experience in Afghanistan has been praised for its success in orienting the humanitarian community immediately after the fall of the Taliban in 2002, and for its most recent activity in capacity development and sustainable technology transfer to the Afghan government. But it has also been criticized for having failed to meet user expectations, mostly as result of inadequate management as opposed to technical shortcomings. A senior UN official who was based in Afghanistan between 1999-2001 told the OFDA/DFID evaluators that, "The HIC is a fraudulent concept. The sociological obstacles are insurmountable. It presented itself as a tool that could provide analysis but it can't do that. The HIC doesn't deliver - it just delivers maps."[40] Others have suggested that the HIC was not proactive enough in reaching out to the NGO community, and was unable to keep maps updated with the rapidly changing conditions on the ground.[41] The Afghanistan HIC therefore offers an excellent example of the issues and limitations of geomatics in the field, particularly under conditions of insecurity, dynamic population migration, on-going military engagement, political turmoil, and/or constantly changing humanitarian activities. As these are the characteristics that define CHEs, it is most important to understand the benefits and limitations of geomatics from a pragmatic and not an idealistic perspective, which is too often the case.

AIMS was established in 2001 by OCHA through the merger of the new Humanitarian Information Centre for Afghanistan and the existing Projects Management Information System (ProMIS), which had been run by the UNDP and FAO. By 2001, the HIC had amassed an extensive projects library, GIS and database expertise, and datasets on roads and settlements, although these proved nearly impossible to keep up-to-date.[42] Much of this data was declassified geospatial data donated by the US government. Medium and high-resolution satellite imagery, Soviet-era topographic maps, rudimentary and outdated demographic statistics - this was the best quality data that was publicly available at the onset of the US-led liberation of Afghanistan.

Starting off in Islamabad, the HIC initially concentrated on disseminating products that would orient agencies that were building their operations in Afghanistan. Products included standardized maps (e.g., Afghan geography, the security situation, location of land mines) and population data. In addition, a Who-What-Where (W3) database, revamped website and Place-code system[ix] were also developed.

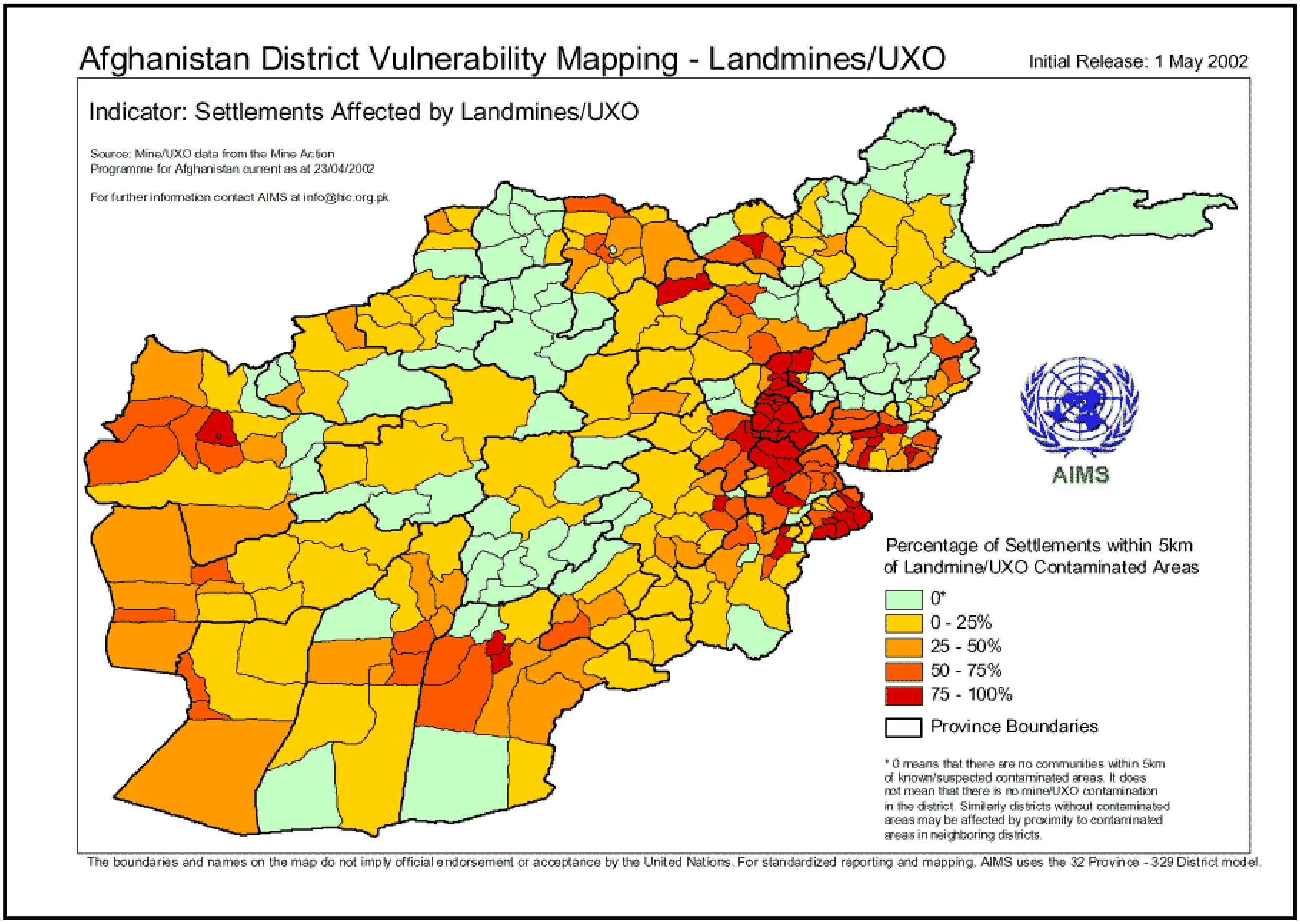


Fig. 10 – Analysis of Proximity of Settlements to Landmines & Unexploded Ordinance *(Source: AIMS)*

Key Challenges
According to the USAID/DFID evaluation, there was a high level of expectation from its donors that it would provide information on humanitarian action inside Afghanistan. The rate of change and scale of operations implied that each agency would, voluntarily, report its activity to AIMS frequently – an

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[ix] The P-code system is used to geo-locate widely disparate datasets that are being used together – they work like a postal or zip code. For example, using P-codes allows health data from the WHO to be linked to schools data from UNICEF, housing damage from another source and population figures from the last official census. The combined data sets can be displayed on maps, analyzed, or linked to additional datasets. Because P-codes contain latitude and longitude coordinates, data attached to P-codes can be rendered in a GIS, and linked to towns, villages and administrative units.

P-codes in Afghanistan had to be frequently updated, due to constant administrative boundary changes. To accommodate these changes, the P-code system has become a geo-code system that still provides place information, but also district, province and country information. For example, the geo-code AF 01 02 00044 consists of references to a Country (2 letters), a Province (2 numbers), a District (2 numbers), and a Village (5 numbers). This makes it a totally unique identifier, worldwide.

idealistic scenario given that NGO's often don't know, or don't want to share, information about their activities. At its peak, humanitarian activity in Afghanistan included more than 2,000 NGO's, an impossible number to track accurately in the W3 database. More and more, it was a case of "garbage in, garbage out".[43]

Another major shortcoming of AIMS was that it appeared reactive and not proactive, and it struggled to maintain the currency of its products – in many cases, its maps were outdated before they were disseminated. This was exasperated by the poor telecommunications and Internet connectivity in Kabul, and throughout Afghanistan: the HIC was perhaps too progressive in the use of web-based distribution of its products given the conditions faced by its users.

Finally, the tech-savvy staff of AIMS may have on occasion crossed the boundary between advising versus creating databases for its users. The DFID/OFDA evaluation cites examples where the HIC may have allocated a disproportionate and unjustifiable amount of resources towards building internal databases for the Afghanistan Research & Evaluation Unit (AREU) and the Danish Committee for Aid to Afghan Refugees (DACARR), which compromised its foremost mission of providing products and services of widespread benefit.

The evaluation was inconclusive about the net benefit or impact of AIMS to date. It clearly played a crucial role during the early stages of repatriation and post-Taliban reconstruction in Afghanistan, yet stumbled when information sharing and user demands were at their height in late 2002 and early 2003.

Today, AIMS has grown to become the Afghan Government's primary GIS and information management consultant. Although it still supports humanitarian relief applications, it is no longer under OCHA FIS. Since September 2003, AIMS became a Directly Executed (DEX) project of UNDP, administered and managed by UNDP and reporting to the Resident Representative. [44]

As a result of the Afghan experience, OCHA began an extensive redesign for its operations and the deployment of HICs. A positive outcome of this overhaul is the institutionalized of a standard set of cartographic products and services. OCHA has also begun using rapidly deployable, pre-configured HIC modules; completely self-contained on a trailer mount, the HIC module has a standard assortment of hardware, software, large-format printers, and supplies to quickly launch an HIC service. Further, a stable of senior and technical staff are trained by FIS in advance of specific OCHA deployments, enabling the UN to call-up field staff experienced in operating an HIC effectively during the time of greatest need. This new approach is working well, and has been most recently used as part of OCHA/DFID's response to the Indian Ocean tsunami.[45]

Section 4 – Conclusions

Geomatics enjoys an unprecedented level of use by humanitarian organizations involved in CHEs around the world. The declassification of military satellite data and international accessibility of geospatial technologies has made the use of geomatics in CHEs a reality, and a critical tool to decision makers at all levels.

Remarkably, it can be argued that the true power of geospatial analysis is not even close to being realized. Most of the humanitarian community's use of geomatics is cartographic in nature: simple but important activities like updating land use maps, creating transportation/logistics maps, and plotting the activity of NGO in the field. But very few humanitarian agencies are exploiting geomatics to optimize the efficiency of relief distribution – for example, choosing the location of grain storage warehouses based upon a spatial analysis of refugee camp locations, transportation routes, natural hazards and topography. Even fewer are using it to improve cost-effectiveness of relief activities, despite the obvious advantages that spatial analysis can provide – for example, by attaching economic value to each element of CHE intervention to identify inefficiencies in a NGO's operations. These more complicated applications of geomatics have the most room for growth, particularly amongst the larger and more technically proficient humanitarian agencies.

Key applications of geomatics for CHEs can be summarized as follows:

- *Cartography*: land use, infrastructure mapping, demographical analysis, logistics planning, etc.
- *Media / Communications*: status reporting, monitoring & evaluation, program assessment, etc.
- *Humanitarian Intelligence*: near real-time crisis analysis, command & control, mission planning, damage assessment, visualization, lines of communication assessment, etc.
- *Crisis Simulation:* mission rehearsal, nuclear/chemical/biological/radiological/environmental incident modelling, migration patterning, alternative response assessment
- *Engineering:* reconstruction, design, surveying, facility management, water & sanitation, etc.
- *Environmental Planning:* crop cultivation, resource assessment, vegetation analysis, etc.
- *Hazard Management:* seismic analysis, refugee camp planning, flood mitigation, slope stabilization, aid worker security, refugee protection, locust monitoring, terrorism, etc.
- *Vulnerability Assessment:* early warning systems, famine, pandemics, inter-ethnic crime, etc.
- *Risk Reduction:* "hotspots" identification, preventative CHE intervention, humanitarian law enforcement, international financial aid mobilization, education of affected populations, vaccination planning, public health, etc.
- *Organizational Management:* operational efficiency maximization, location optimization, financial analysis, program assessment, personnel training, donor communications, etc.

It is not clear when or if a genuine commercial market may exist for CHE applications of geomatics. The high price and copyright restrictions of high-resolution satellite imagery are a deterrent for most humanitarian agencies capable of developing internal image exploitation expertise. In the medium-term, consortiums and philanthropic offers by the private sector are likely to be the primary mechanism for the humanitarian community to access the economies of scale and expertise needed to effectively procure and exploit satellite imagery.

These challenges are not trivial. Even some of the UN agencies have encountered difficulty in becoming totally self-sufficient in remote sensing, despite their constant and sizeable demand for spatial intelligence. Table 3 describes the need and capacity for remote sensing within the UN's humanitarian organizations, when they were formally assessed in 2002.

Table 3 – Needs and Expertise of UN Humanitarian Agencies in Satellite Imagery[46]			
UN Humanitarian Organization	**Geographic Information Need**	**Expertise in satellite imagery**	**In-house and/or outsourced**
OCHA	Basic data layers, mechanism to share GIS data in order to facilitate coordination.	Supports purchase and coordination of satellite imagery, but no in-house experience *per se*.	Not applicable
UNHCR	Spatial information on areas of refugee locations for contingency planning emergency assistance, environmental monitoring, repatriation, and rehabilitation to assist field operations.	Extensive expertise since 1995. Has used data from most types of satellite sensors, including SPOT, Landsat, IRS-1D, KVR-1000, Ikonos, RADARSAT, ERS 1 and 2.	In-house and outsourced
WFP	Land cover and rainfall data for crop monitoring, food availability, and early warning assessments.	Some experience with imagery applicable for crop monitoring using Meteosat and NOAA Advanced Very High Resolution Radiometer (AVHRR).	In-house, some outsourced
UNDP	Wide range of environmental, population, health, logistics, and economic data to assist development programs to combat poverty.	Expertise using data from a wide rang of radar and optical satellites, such as RADARSAT, Landsat, and SPOT.	Outsourced
UNICEF	Spatial data to complement children's programs in areas such as education, health, and living conditions.	Limited experience in satellite imagery. Involved in use of imagery from RADARSAT, Landsat, and IRS 1C on a few occasions.	In-house
FAO	Spatial data with focus on temporal changes of vegetation cover, and use, and related parameters for early warning, crop monitoring, and food availability assessments.	Extensive expertise using data from optical satellites, such as Landsat, SPOT Vegetation, SPOT, IRS 1C/D, NOAA AVHRR.	In-house and outsourced
WHO	Distribution of population and health services, type and extent of diseases, climatic data to plan and monitor programs.	Limited experience in satellite imagery. Some experience with data from DMSP Operational Line Scanner (OLS) and other optical sensors.	In-house and outsourced
UNHCR	Information on population distribution and living conditions in regions and countries to strengthen field presence and work toward compliance with international human rights laws.	In general, no use of satellite imagery.	Not applicable
UNFPA	National, regional, and global population data and related parameters, such as health, to assist developing countries in finding solutions to population problems.	In general, no use of satellite imagery.	Not applicable

In the case of GIS and GPS, the problem lies not in the cost of procuring hardware, software or data, but in developing in-house expertise to fully exploit the power of the technologies. However, as geospatial skills become more common, and as the humanitarian community establishes a solid core expertise in using geomatics, it seems inevitable that every organization will want, and be expected by its donors, to incorporate geomatics as tool to improve effectiveness.

Just like other technologies like database systems, accounting software, or wireless communications, geomatics will become essential for humanitarian organizations - the challenge will be to ensure that these organizations adopt a pragmatic and sustainable approach, and not forget that geomatics is just one more tool in the process of providing humanitarian assistance.

Appendix – Information Sources about Geomatics on the Web

Geomatics Journals	
Directions Magazine	www.directionsmag.com
Earth Observation Magazine	www.eomonline.com
GIS@development	www.gisdevelopment.net
GIS Café	www.giscafe.com
GIS.com	www.gis.com
GeoCommunity	www.geocomm.com
GPS World	www.gpsworld.com
Geomatics Education	
CEOS Handbook	www.eohandbook.com/ceos/part3c.html
Committee on Earth Observation Satellites	www.ceos.org
Canada Centre for Remote Sensing	www.ccrs.nrcan.gc.ca
GIS Lounge	www.gislounge.com
NASA Remote Sensing Tutorial	rst.gsfc.nasa.gov
Netherlands Aerospace Laboratory	www.npoc.nl
GPS Receiver Vendors	
Garmin	www.garmin.com
Magellan	www.magellangps.com
Trimble	www.trimble.com
Imagery Providers	
DigitalGlobe	www.digitalglobe.com
Infoterra	www.infoterra-global.com
National Remote Sensing Agency	www.nrsa.gov.in
OrbImage	www.orbimage.com
RADARSAT International	www.rsi.ca
Radar Technologies France	www.radar-technologies.com
RESTEC	www.restec.or.jp
Space Imaging	www.spaceimaging.com
Spot Image	www.spotimage.fr
Software Providers	
ERDAS / Leica GeoSystems	gis.leica-geosystems.com
ERMapper	www.ermapper.com
ESRI	www.esri.com
Intergraph	www.intergraph.com
MapInfo	www.mapinfo.com
PCI Geomatics	www.pcigeomatics.com
Pixoneer Geomatics	www.pixoneer.com
Consortiums	
Global Disaster Information Network	www.gdin.org
International Charter on Space & Major Disasters	www.disasterscharter.org
Open Geospatial Consortium	www.opengeospatial.org
RESPOND Humanitarian Global Mapping Services	www.respond-int.org
UNOSAT	www.unosat.org

Government

EC Joint Research Centre Digital Map Archive	dma.jrc.cec.eu.int
US FEMA Mapping & Analysis Center	www.gismaps.fema.gov
US Dept of State Humanitarian Information Unit	www.state.gov/s/inr/hiu
USAID Famine Early Warning System	www.fews.net/imagery

UN Agencies

Cartographic Section	www.un.org/Depts/Cartographic/
Depository of Geographic Info Support Team	https://gist.itos.uga.edu
FAO Global Information & Early Warning System	www.fao.org/giews/
ReliefWeb	www.reliefweb.int
OCHA Humanitarian Information Centres	www.humanitarianinfo.org
Geographic Information Working Group	www.ungiwg.org
UNHCR Centre for Emergency Training	www.the-ecentre.net
WFP Vulnerability & Analysis Mapping	www.wfp.org/operations/vam
World Health Organization	www.who.int/csr/mapping

Other

Reuters AlertNet Imagery & Maps	www.alertnet.org
Perry-Castañeda Library Map Collection	www.lib.utexas.edu/maps
Vietnam Veterans of America Foundation	vvaf.org/programs/immap
World Bank Geography Network	www.geographynetwork.com

Note: All links last accessed January 14, 2005.

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