An Incident Management Preparedness and Coordination Toolkit

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Abstract—**Although the use of Geographic Information Systems (GIS) by centrally-located operations staff is well established in the area of emergency response, utilization by first responders in the field is uneven. Cost, complexity, and connectivity are often the deciding factors preventing wider adoption. For the past several years, Oak Ridge National Laboratory (ORNL) has been developing a mobile GIS solution using free and open-source software targeting the needs of front-line personnel. Termed IMPACT, for Incident Management Preparedness and Coordination Toolkit, this ORNL application can complement existing GIS infrastructure and extend its power and capabilities to responders first on the scene of a natural or man-made disaster.**

Keywords-incident management, emergency preparedness and response, geographic information systems, data fusion, modeling and simulation

I. Introduction

At all levels of government – federal, state, and local – examples of sophisticated emergency response centers employing Geographic Information Systems (GIS) may be found. Technically advanced fusion centers exist at the federal and many state emergency management agencies (EMAs) while even smaller counties and towns usually have some sort of E-911 call center with coordinated dispatching using electronic maps. Yet the authors have observed that in the field, utilization of GIS is mixed, notwithstanding the increasing proliferation of mobile devices like smart phones and tablets which are capable of displaying location information.

The reasons for this situation vary, but issues involving cost, complexity, and connectivity are at least part of the mix. Smaller EMAs may simply not be able to afford specialized hardware devices or software licenses for all of their staff. Commercial desktop applications geared more for the GIS professional may be too complex to use in a field situation. Even simple web-browsing solutions may not work in the aftermath of a disaster when cell phone towers are down, without power, or are saturated by survivors trying to reach family and friends [1] [2].

Building on previous work sponsored by the U.S. Department of Homeland Security (DHS) [3], the Oak Ridge National Laboratory (ORNL) has developed a flexible mobile GIS platform to address the needs of first responders. The Incident Management Preparedness and Coordination Toolkit (IMPACT) is an application built using the Geospatial Integrated Problem Solving Environment (GIPSE, pronounced *gypsy*) platform [4]. Basically, GIPSE enables a customized, GIS-centric application to be developed quickly for a particular user community. To keep costs to a minimum, applications use free and open-source software (FOSS) components. Modern user interface designs similar to those found on smart phones and tablets reduce the level of complexity for use during high-stress events. The applications work both with and without a network connection to ensure functionality in remote, damaged, or communications-denied areas.

ORNL is currently working with a small group of federal, state, and local EMAs to refine the functionality and data content of IMPACT. Although the focus is initially on U.S. first responders, there are no intrinsic restrictions barring use by other groups internationally. The software itself is cost-free and runs on existing laptops using the Windows, Macintosh, and Linux operating systems. Data and maps distributed with the application are copyright-free. The following sections provide some details about the application interface, discuss potential use cases, and present some simple examples.

II. System Design

IMPACT is comprised of a number of FOSS components augmented by custom code written in Python. The graphical user interface is constructed using the wxWidgets C++ library with Python bindings called wxPython. An integral map viewer is provided by the ORNL Geospatial Viewer (OGV) application. PostgreSQL with the psycopg2 module provides both a traditional database service for user-entered data as well as a geospatial storage and search engine for OGV. Hardware interface modules for items like Global Positioning System (GPS) receivers include pyserial and the GPSBabel application. The use of these components makes the cost-free distribution of the application possible.

The user interface design borrows heavily from user-familiar constructs found in personal computer (PC) operating systems and smart phones. Four tabbed panels labeled *Tasks*, *Applications*, *Documents*, and *Maps* are presented to the user. Fig. 1 shows the Documents panel which is representative of

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the other three. Buttons on each panel are used to initiate an operation or view a document. On the *Tasks* panel, the buttons launch a multi-step operation, similar to a software wizard, that walks a user through a set of activities that may include entering data into the database or drawing parts of a map. The *Applications* panel hosts shortcuts (aliases, links) for items that the user may need during the course of preparing for or responding to an incident. An example might be to run a specialized calculator for computing stand-off distances for a suspected bomb threat. File shortcuts are placed on the *Documents* panel. These are used for reference during an operation. Examples might include background reports, checklists, or after-action reports. The *Maps* panel is used to organize OGV files that are associated with an operation. The maps are not simply static files and can be used to display time-dependent data like moving asset positions and weather information. This simple organizational structure provides a clear and concise interface to the user during times of high stress.

Figure 1. IMPACT user interface showing the Documents panel.

Because IMPACT runs on existing hardware – either desktops or laptops, no new hardware or software costs are incurred by the user. Should the user desire a more compact, tablet-styled device, so-called tablet PCs or convertible PCs using a fold-over design and stylus or touch-screen may be employed. Rugged devices for outdoor use are offered by some vendors. The newer Android and iOS tablets and smart phones currently lack the power and memory for hosting IMPACT. This may change in the future as tablet capabilities improve.

III. Mission Relevance

It is generally recognized that one of the greatest advances in the area of preparedness has been associated with the increased availability of GIS technologies. Even in 2006, it was recognized that, “The widespread dissemination of GIS capabilities is also one of the most important technological advances in hazard mitigation.” [5] A U.S. Fire Administration document notes that, “Simple, low-cost GIS systems allow local authorities to properly plan the areas under their jurisdiction, and to incorporate the local knowledge and ensure community participation, combined with modeling results from experts.” [6] GIS technology can provide support for operational purposes such as, “…work with tactical, location-based information such as floor plans, utility control points, response plans, hazardous material contents and locations, surrounding exposures, aerial imagery, and hydrant locations. Access to this information while en route to or on scene allows responders to deploy more quickly, effectively, and safely.” [7]

GIS technology can assist communities in preparedness and response by providing, for example: a common operating picture, maps supplied to mutual-aid responders, current street and highway closures, and up-to-date (maintained) information such as call lists. As an example, during the I-35W bridge collapse in Minneapolis in 2007, GIS systems were able to enhance the response. A U.S. Fire Administration report on the Minneapolis response notes that, “Using computer-based GIS mapping applications, commanders and EOC personnel were provided a Web-based Common Operating Picture that included incident area maps (which helped responders establish and relocate perimeter security), access checkpoints, and Staging Areas with real-time changes that were made available to all city staff . . . Emergency personnel also had up-to-the minute street and highway closure information so they could plan the quickest route to the scene, again provided through the Web-based GIS Common Operating Picture.” [8]

A community’s response plans and preparedness can be enhanced by, “. . . identifying the location of schools, medical centers, staging areas, and evacuation routes. Analysis can identify transportation choke points near bridges or overpasses. During an emergency, GIS can be used to route response vehicles and quickly identify critical infrastructures such as water storage/treatment facilities, communications networks, electric generation facilities, refineries, and more.” [9]

Another mission that GIS tools can support is evacuation planning. As stated in project findings from the Evacuation Responsiveness by Government Organisations (ERGO) project, “The physical space to be evacuated is typically well known by experienced officials, but modelling and spatial data support can further strengthen their knowledge base.” [10] While responders and planners may be quite familiar with their jurisdictions, seeing simulations of events and evacuations often provides a perspective that provides new insight into their existing plans.

The U.S. Federal Emergency Management Agency (FEMA) currently offers training in using GIS for emergency management. As the introduction to Lesson 3 notes, “Since its development as an automated system, GIS has served emergency management well. GIS can provide the information needed to support decision making before a disaster. During the early response period, emergency managers use GIS as a key intelligence source for the information they need to make decisions. And as the response moves toward recovery, GIS can identify those in greatest need to manage priorities.” [11]

There are several U.S. national efforts to provide emergency planners with GIS capability and tools. An example is the Federal Interagency Geospatial Concept of Operations (GeoCONOPS) [12]. “When finalized, this GeoCONOPS is intended to serve as a guide to federal departments and agencies providing geospatial support under the Stafford Act.” Other federal efforts include the Geospatial Platform [13] and the National Geospatial Program [14].

While many tools exist to supply GIS solutions for preparedness, and the federal efforts search for a common solution, for many communities there remain barriers to the integration of GIS into their disaster preparedness, planning and response activities. Primary among these are the lack of resources, both financial and technical. Not only the cost of GIS technology, but also its complexity and the *learning curve* to effectively use it can be daunting. “It is common for fire departments, emergency managers, and other public safety agencies to become intimidated by GIS. And in these uncertain times it is even easier to become overwhelmed about the price and seeming complexity of GIS software.” [15]

Many emergency management departments suffer the same dwindling resources that have been noted in the public health sector. “’The sky is falling’ is no longer just a Chicken Little reference – but, rather, a timely warning about the state of U.S. public health emergency preparedness initiatives in the face of recent large-scale funding cuts by the federal government that may well continue for the foreseeable future.” [16]

Successful integration of GIS capabilities into local and community preparedness and response activities can be enhanced with FOSS tools such as IMPACT. Providing low cost and complexity, control and accuracy of local data, and the ability to interact with *upstream and downstream* solutions give communities workable solutions.

IV. Application Examples

To illustrate how IMPACT might be used to enhance emergency preparedness and response, some simple examples are presented. Both natural and man-made disasters are used. In three cases, the events are historical in nature. It should be stressed that IMPACT was not actually used during these events since they preceded the application's general availability. Instead, these incidents have been studied to help guide the functional development of the application. The last example is general in nature and could apply to many situations.

On April 27, 2011 an EF4 tornado cut a swath 800 yards wide and 37 miles long through portions of Hamilton, Bradley, McMinn, and Polk Counties in Tennessee [17]. A total of 13 fatalities, more than 200 injuries, and substantial property damage resulted. Normally, tornado ratings and tracks are determined several days after the fact once damage surveys have been conducted. One way in which IMPACT could be used in situations like this would be as a data-gathering tool. Since many emergency response vehicles are already outfitted with laptop computers, IMPACT could be installed on each one cost-free. As response vehicles are patrolling county roads and monitoring real-time weather displays with IMPACT, as shown in Fig. 2, they could report any tornado sightings or damage to their E-911 center. Locations can be placed on the interactive map viewer and either emailed or uploaded to a central repository using the built-in publish/subscribe capability. Collected data may be shared using a variety of open formats including Google Earth's KML, ESRI's shapefile, a comma-separated value (CSV) text file, or the native OGV archive format.

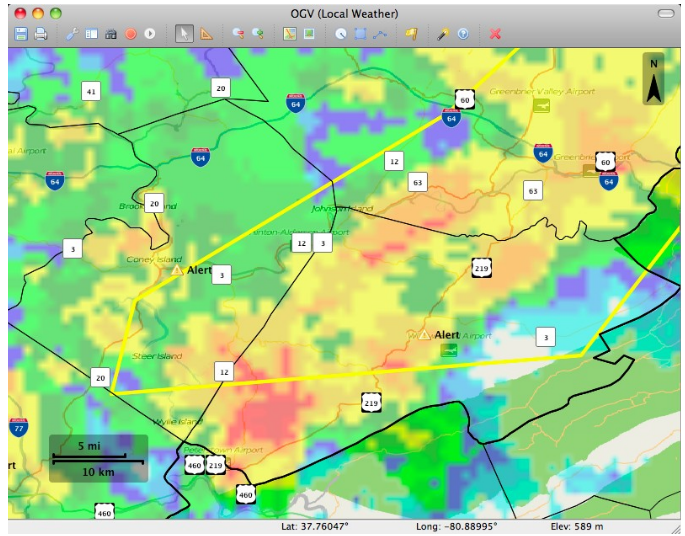

Figure 2. Real-time weather display showing NEXRAD precipitation layer with warning polygons and alert placemarks.

Once a preliminary tornado track has been identified, a buffer can be drawn around it and the population residing within it estimated using the built-in ORNL LandScan global database [18]. Local Emergency Medical Service (EMS) or hospital staff nearby could then be alerted to prepare for casualties. Fig. 3 shows the actual tornado track determined later by the U.S. National Weather Service on a false-color elevation base map with county boundaries, primary roads, and EMS facilities selected for display. Within the one-mile buffer shown, there are approximately 7,066 people enclosed. The choice of the base map and map features as well as their properties (color, line weight, opacity, etc.) can all be determined by the user.

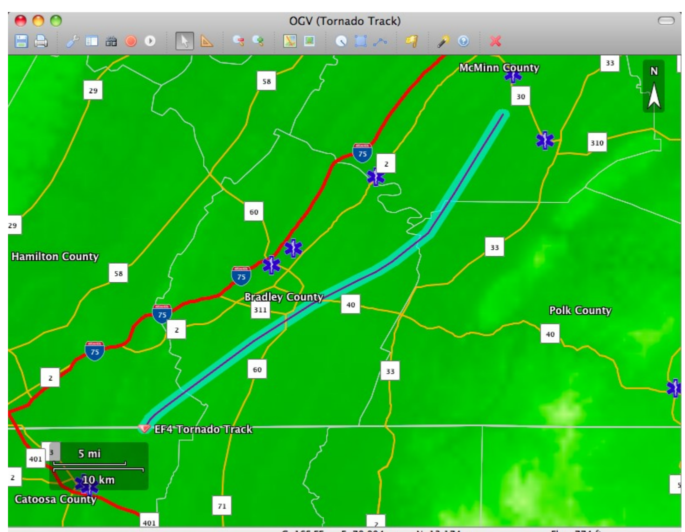

Figure 3. Tornado track of the April 27, 2011 event in southeast Tennessee.

Another natural disaster occurred on March 20, 2012 when a magnitude 7.4 earthquake struck Mexico near the border between Oaxaca and Guerrero states [19]. Fig. 4 shows the epicenter and three rings measuring 50, 100, and 150 km in radius. A population estimate for each of these rings may be seen. Although the distances were chosen only for the sake of illustration and have no relationship to local severity, it is still a useful measure for response planning. Should it be necessary to evacuate regions close to the epicenter, these population estimates might help determine routes used and vehicles required. The base map and boundaries are built into IMPACT so that the application can be used even if a mobile network connection is not available. Cell phone outages were reported after this incident due to physical tower damage and user demand which saturated the network [20].

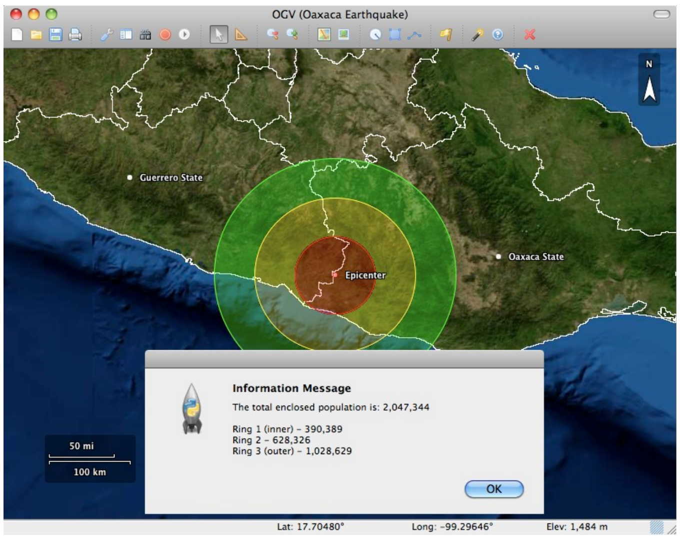

Figure 4. Oaxaca, Mexico magnitude 7.4 earthquake of March 20, 2012 showing population estimates based on distance from epicenter.

Man-made disaster response is another area where IMPACT may be employed. The U.S. State Department has indicated a concern about munition storage depots around the world and the potential for accidental detonation [21]. Such an accident occurred in the Mpila neighborhood Brazzaville, Republic of the Congo on March 4, 2012 claiming hundreds of lives and displacing thousands [22]. Using data from a United Nations building damage assessment report [23], an ORNL blast calculator tool, based on open U.S. Department of Defense standards [24] that is part of IMPACT, was used to estimate the net explosive weight. The associated damage rings were then plotted on a base map using OpenStreetMap data [25] as shown in Fig. 5. Thus IMPACT could be used for forensic purposes.

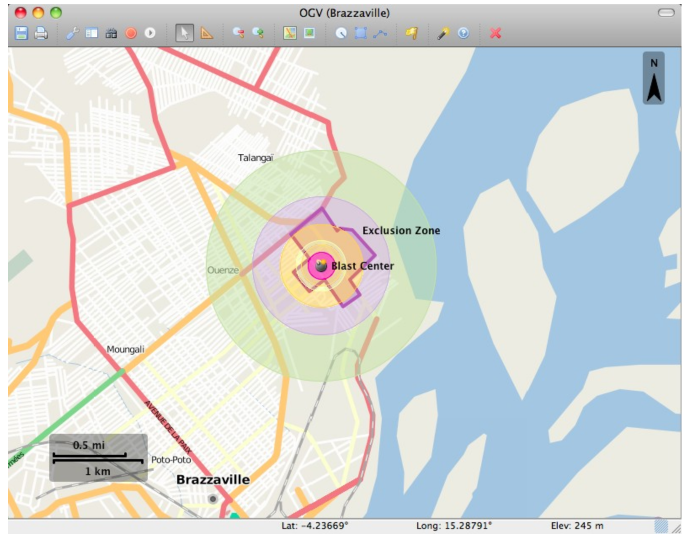

Figure 5. Brazzaville, Congo munitions depot explosion of March 4, 2012 showing damage rings based on reports and blast calculator tool.

All of the previous examples presented static map displays. IMPACT is also capable of producing dynamic simulations. The last example illustrates a possible terrorist event. Fig. 6 shows the Market Square area of downtown Knoxville, TN. Base map imagery was obtained from the U.S. Geological Survey. A user defines a boundary by drawing a region, exit locations, and the site of an explosive device. When the simulation is run, the user indicates the number of people to populate the space. The simulation plays out while displaying a clock. In the figure, the event has already occurred and people are exiting the area. A user can time how long it would take to evacuate an area due to a threat. Results then could be used to determine if additional exits need to be planned.

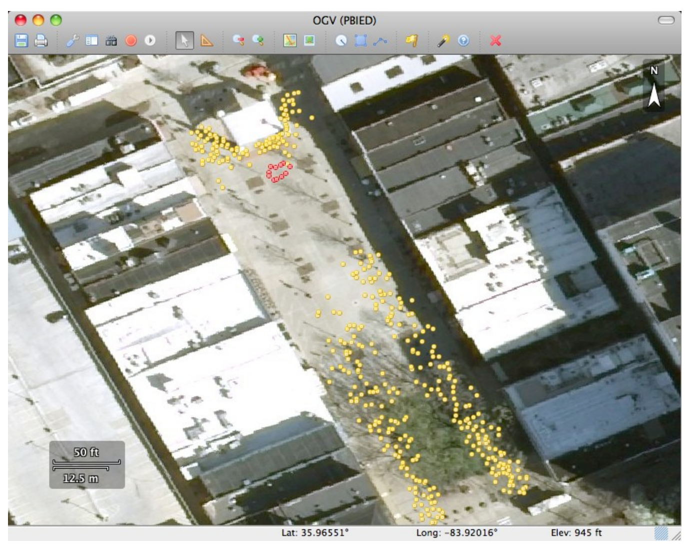

Figure 6. Evacuation simulation showing people exiting an area after an explosion has occurred. Casualties are shown in red.

V. Future Directions

Because IMPACT is an application built using the GIPSE framework, it can be easily extended. Additional tasks using the software wizard metaphor could be constructed for simple contagion spread and transportation evacuation simulations. With real-time data feeds, the interface could serve as a dashboard for situational awareness, personnel dispatch, or asset tracking. Work is ongoing to develop a 3D viewing mode. International agencies are being approached about using IMPACT for possible humanitarian purposes such as disease tracking and medical aid distribution.

VI. Conclusion

Although many free and commercial GIS packages are available which could address the needs of first responders in the field, some barriers exist to their widespread adoption. IMPACT is an attempt to address issues of cost, complexity, and connectivity. The goal is not to replace existing systems but rather to augment them. A number of simple examples for use have been presented to demonstrate current capabilities of the software. Future development will build on this feature set with the direct interaction of the user community.

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References

[1] The Washington Post. (2011, August 23). *Cellphone service falls short after earthquake* [online]. Available: http://www.washingtonpost.com/business/economy/cellphone-service-falls-short-after-earthquake/2011/08/23/gIQAnl52ZJ_story.html

[2] J. Wilson. (2012, February 13). *Addressing diverse human behavior issues in the new era of multi-layered emergency communications* [online]. Available:http://www.federalsignal-indust.com/Default.asp?pageID=13&lookup=5%7C25

[3] P.W. Payne and D.B. Koch, "A counter-IED preparedness methodology for large event planning," Proc. of the IEEE International Conference on Technologies for Homeland Security, pp. 185–189, November 15–17, 2011.

[4] D.B. Koch, "A geospatial integrated problem solving environment for homeland security applications," Proc. of the IEEE International Conference on Technologies for Homeland Security, pp. 211–215, November 8–10, 2010.

[5] M. Lindell, C.S. Prater, W. Perry. (2006, July). *Future directions in emergency management* [online]. Available: http://training.fema.gov/EMIWeb/edu/fem.asp

[6] National Institute of Disaster Management. (2011, November). *Applications of geoinformatics in disaster management* [online]. Available: http://nidm.gov.in/PDF/TrgReports/2011/November/21-25_NIDM_Brochure.pdf

[7] U.S. Fire Administration. (2011, November). *Infogram 45-11: November 10, 2011* [online]. Available: http://www.usfa.fema.gov/fireservice/subjects/emr-isac/infograms/ig2011/45-11.shtm

[8] U.S. Fire Administration. (2007, August). *I-35W bridge collapse and response Minneapolis, Minnesota* [online]. Available: http://www.usfa.fema.gov/downloads/pdf/publications/tr_166.pdf

[9] ESRI. (2005). *Mapping the future of public safety* [online]. Available: http://www.esri.com/library/brochures/pdfs/public-safety.pdf

[10] Aston Centre for Research Into Safety and Security (CRISES). (2011, July). *Evacuation responsiveness by government organisations (ERGO) final report* [online]. Available: http://crisis.aston.ac.uk/section/ergo-material/evacuation-responsiveness-government-organisations-final-report

[11] U.S. Federal Emergency Management Agency. (2012, February). *IS-922 applications for GIS for emergency management, lesson 3, GIS for emergency management* [online]. Available: http://training.fema.gov/EMIWeb/IS/is922.asp

[12] U.S. Dept. of Homeland Security. (2011, June). *Federal interagency geospatial concept of operations (GeoCONOPS)* [online]. Available: http://www.nsgic.org/public_resources/DHS_Geospatial_CONOPS_v30_85x11.pdf

[13] Federal Geographic Data Committee. (2012, May). *Geospatial platform* [online]. Available: http://www.geoplatform.gov/home/

[14] U.S. Geological Survey. (2012, May). *National geospatial program* [online]. Available: http://www.usgs.gov/ngpo/

[15] The National Alliance for Public Safety GIS Foundation. (2012, May). *Introducing GIS on the cheap* [online]. Available: http://www.napsgfoundation.org/blog/napsg-blog/90-introducing-gis-on-the-cheap

[16] DomPrep Journal. (2012, January). *Scrubbing source data at the local level* [online]. Available: http://www.domesticpreparedness.com/pub/docs/DPJJan12.pdf

[17] U.S. National Weather Service. (2012, February 6). *The historic tornado outbreak of April 27, 2011 across East Tennessee and Southwest Virginia* [online]. Available: http://www.srh.noaa.gov/mrx/?n=april272011outbreak

[18] Oak Ridge National Laboratory. (2012, May). *LandScan home page* [online]. Available: http://www.ornl.gov/sci/landscan/

[19] U.S. Geological Survey. (2012, March 20). *Magnitude 7.4 - Oaxaca, Mexico* [online]. Available: http://earthquake.usgs.gov/earthquakes/recenteqsww/Quakes/usc0008m6h.php

[20] The Huffington Post. (2012, March 20). *Mexico earthquake 2012: 7.4-magnitude quake rocks Mexico* [online]. Available: http://www.huffingtonpost.com/2012/03/20/mexico-earthquake-2012_n_1367682.html

[21] U.S. Dept. of State. (2012, January 23). *Dangerous depots: the growing humanitarian problem posed by aging and poorly maintained munitions storage sites* [online]. Available: http://www.state.gov/t/pm/rls/fs/182344.htm

[22] The Huffington Post. (2012, March 4). *Congo blast: Brazzaville arms depot explosion kills 200* [online]. Available: http://www.huffingtonpost.com/2012/03/04/congo-blast-brazzaville-arms-depot-explosion_n_1319390.html

[23] United Nations Institute for Training and Research. (2012, March 16). *Damage assessment: Regiment Blindé munitions explosion, Mpila, Brazzaville, Congo* [online]. Available: http://www.unitar.org/unosat/node/44/1649

[24] U.S. Dept. of Defense. (1999, July). *DOD ammunition and explosives safety standards 6055.9-STD* [online]. Available: http://www.ddesb.pentagon.mil/60559s99.pdf

[25] OpenStreetMap. (2012, May). *OpenStreetMap home page* [online]. Available: http://www.openstreetmap.org/