MASH-UP OR SPATIAL DATA INFRASTRUCTURE: APPROPRIATE MAPPING TOOLS FOR INTERNATIONAL SITUATION ROOMS

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ABSTRACT:

Analysts in international situation rooms have the difficult task of making sense of a very dynamic stream of information from multiple sources with various degrees of reliability, such as media reports, crowd sourcing data, volunteered geographic information, social networking, email, expert reports and sensor data. Most of this information is associated to location and can thus be mapped, providing an integrating platform for heterogeneous data. A wide range of mapping tools is available, ranging from professional GIS enterprise solutions to lightweight web-based maps and the open source community is very actively developing new web mapping software. Also with regards to base map data, various solutions exist, some commercial (such as Google, Bing or Yahoo), others open content (such as OpenStreetMap). However, no solution is tailored to the complex and strict requirements of international situation rooms.

Over the past 5 years, the authors analyzed geographical information requirements of situation rooms operating in the context of global security. The main requirements are that these tasks must be executed in an easy way (no training), in a time-critical environment, from any computer and using any data format. Research findings show that large amounts of dynamic information streams can be shown easily on a single map, enabling situation room analysts (even in different situation rooms) to have a common situational awareness. This is possible with a light-weight open source web-based client implementing some essential industry data format standards. An own spatial data infrastructure is optional, although required to integrate own databases in mash-ups, to handle data storage and for collaborative mapping.

1. INTRODUCTION

1.1 GIS for crisis management

Geographical Information Systems (GIS) are a powerful tool for the analysis of large amounts of data about a location. Situational awareness for crisis management is based on the location of disaster and has additional constraints: information is real-time and uncertain (Argote, 1982), analysis is performed under time pressure (Smith and Hayne, 1997), and unexpected elements are typical (unforeseen in original design of a system) (Longstaff, 2005). While GIS can help supporting situational awareness and decision making, it must be used in the right way (Mansourian et al., 2006). Besides spatial detail, temporal detail is important as well as a basic understanding of situation room staff of the possibilities of GIS (Zerger and Smith, 2003).

If GIS expertise and infrastructure is available in an organisation, complex spatial data infrastructures can be designed to support many crisis information management tasks (ESRI, 2008), including situational awareness (ESRI, 2000). However, such expertise and infrastructure is expensive, and low-cost alternatives are becoming more powerful. Increasingly, geospatial web services are available on-line providing global base maps, gazetteer functions and some analytical capabilities (such as routing).

Mash-ups, web applications combining one or more (geospatial) web services, can provide suitable solutions for some crisis management tasks, in particular if analytical tasks are limited and it is more important to be able to visualize data from multiple sources on the same map (Maiyo, Koebben and Kerle, 2009). In addition, mash-ups allow the integration of non-GIS services, such as communication or productivity services.

In this paper, we examine the advantages and disadvantages of geospatial mash-ups as an alternative to spatial data infrastructures, and make recommendations for international situation rooms.

1.2 International situation rooms

Crisis management for international organisations, such as the European Commission or the United Nations, is mostly related to sudden, unexpected events that can occur anywhere in the world. In European Institutions, situation rooms have primarily an advisory role, although some services have an operational role (including the European Commission Monitoring and Information Centre for Civil Protection) (European Commission, 2009). In general, the responsibilities of situation rooms include information processing for situational awareness and political response.

In contrast to relatively stable business environments, information and communications needs for disaster management are highly diverse in nature (Snowden, 2002). By nature, crisis scenarios are unpredictable and information and communication needs vary (National Research Council, 2007).

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Typically, because of their limited responsibilities (mostly advisory), international situation rooms have limited resources. They have a small number of staff, rarely working in 24h shifts although available on-call (European Commission, 2009). They have a wide scope both geographically (continental or global) and thematically (any kind of crisis). Because of the variety of crisis, standard operating procedures have limited applicability. Ad hoc handling of crisis, including improvisation, is the rule (Borkulo et al., 2005). Moreover, staff in emergency situation rooms has a high turn-over and are often generalist officials or specialists in response (fire safety, search and rescue) with limited knowledge or training in (IT tools for) situational awareness gathering. Training does not include advanced use of (mapping) tools, but rather focuses on decision making.

The situation rooms studied are:
European Commission:

- Monitoring and Information Centre (MIC): facilitates co-operation in civil protection assistance interventions in the event of major emergencies which may require urgent response actions.
- Crisis Room of Humanitarian Aid (ECHO): provides emergency assistance and relief to the victims of natural disasters or armed conflict outside the European Union.
- Crisis Room of Health and Consumer Protection (SANCO): coordinate member state response to health crises
- Crisis Room of External Relations (RELEX): Crisis Platform and policy coordination in the Common Foreign Security Platform
- Global Security and Crisis Management Unit (JRC): deliver technical support for crisis response
- Secretariat General: coordinated Commission's response mechanism (including Argus communication system)

United Nations

- World Food Programme (WFP) Emergency Preparedness and Response Branch: provide early warning and analysing impact for food crises (World Food Program, 2009)
- Emergency Relief Coordination Centre (ERCC) of the Office for Coordination of Humanitarian Affairs: facilitate information management with OCHA-Geneva and coordinate internal activities in an integrative and proactive manner.

These crisis rooms handle three different types of crisis (Table 1): humanitarian, political and health related. Some handle more sudden onset crises, while others deal with slow onset or continuous crises. Some respond directly to crises, while most make funding, policy or political decisions.

Table 1. International situation rooms active in various crisis types.

Time frame	Example	Action	Organisation
Humanitarian crisis			
Sudden onset	Earthquake	Response	MIC, OCHA
		Funding	ECHO
Slow onset	Food crisis	Response	WFP
		Funding	ECHO
Political			
Sudden onset	War	Response	OCHA, MIC
		Policy	RELEX
Slow onset	e.g. Darfur conflict	Policy	RELEX
Health			
Sudden onset	New pandemic	Policy	SANCO
Slow onset	Malaria, cholera, AIDS	Funding	ECHO

2. METHODOLOGY

2.1 Adaptive information management

To identify and develop appropriate IT systems for crisis management, we adopt an approach based on information management roles and dynamic capabilities required for adaptive information management (Bharosa and Janssen, 2009). From an organisation's mandate follow responsibilities, which are addressed by staff with various functional roles; each role has a set of tasks that can be fulfilled if the right capabilities are at hand. In the following, we will try to define the responsibilities, roles, capabilities and tasks.

Based on an internal inventory of crisis management in the European Commission (European Commission, 2009), interviews with heads of international situation rooms and various projects in which the authors provided training or developed IT systems for United Nations departments or European Institutions, the authors analyzed the main responsibilities of international situation rooms. The information management responsibilities include rapid evaluation of sudden onset disasters or crises in order to deploy teams, inform hierarchy, estimate humanitarian funds or recommend policy decisions. During non-crisis time, tasks include regular briefs on slow onset or continuous crises.

2.2 Case studies

Since the authors provide active support to situation rooms and policy makers in the European Commission, they were able to collect information requirements from real crises and system requirements for real challenges. Some case studies are discussed.

2.2.1 Mumbai terrorist attacks (Briefing on crisis). During the Mumbai terrorist attacks in India, tourists were held hostage. The support to citizens falls under national responsibilities, but since European tourist were affected, European Commission situation rooms required situational awareness. This event had a high media coverage, but reports were scattered over various newspapers. Each newspaper compiled a list of events (such as casualties or occupied buildings), but the most timely, complete and the only geo-referenced list was available as a KML file compiled by a private person. JRC created a web-based crisis mash-up using this file, along with official information and detailed satellite and infrastructure maps.

2.2.2 Multi-hazard disaster monitoring (Monitoring, Declare Crisis, Briefing of the State of the World). In 2003, the European Commission Humanitarian Office requested technical assistance to build a map of ongoing or imminent disasters, which might require their intervention. ECHO is organized in regional or country desks, each responsible for their geographic area. At the time, no integrated service existed, and these desks had to visit each day a list of bookmarks to collect the information. The JRC created the Global Disaster Alert and Coordination System (GDACS), which collects event information automatically and runs impact models. Events which might need international humanitarian intervention are sent to the responsible desk.

2.2.3 MIC Canadair Tasking System (Gather info for action). In 2009, two Canadair fire fighting planes were placed at the disposition of the European Community, with the MIC having the responsibility to task them to fires for which national or bilateral capacity was not sufficient. MIC requested technical support to have a tool to combine information of new or ongoing fires, forecasted fire extension (both provided by the European Forest Fire Information System, EFFIS) and population and assets at risk (available in JRC databases). Since both systems were available as web services, a often used mash-up application was created in a few days.

2.2.4 Georgia war (Briefing on disaster). In 2008, a brief but sudden conflict over South Ossetia required situation rooms to provide briefing on the situation. Maps were requested for both the whole province of South Ossetia and city maps for Tbilisi and other cities. On-line map services, including Google Map, Microsoft Virtual Earth, Yahoo and OpenStreetMap (OSM) all provide global maps, but their coverage of Georgia varied widely. In the first days of the conflict for instance, Google Maps did not have any data (not even at course scale), while OSM data was being created daily. In particular Tbilisi was best covered by OSM. A tool were all maps can be compared is essential to find the best base map available.

2.2.5 H1N1 Novel Flu (Briefing on State of the World). Epidemiological monitoring at European level is the responsibility of the European Centre for Disease Control (ECDC). However, at the onset of the Novel flu pandemic, ECDC did not have the technical capacity to produce daily briefings and maps on the spread of the flu. Therefore, SANCO asked JRC to provide support with this. With experience in crisis mapping, daily, and later weekly, quality maps were produced since then. Initially, own databases were maintained, until ECDC had its official database established. Even then, JRC maps occasionally include non-official, media based figures of interest, favouring timely information over official status of information.

2.2.6 Collaborative mapping of Sudan (Gather info for action). The Darfur conflict showed the lack of base maps over Sudan, which was addressed by a joint project between the European Satellite Centre and the JRC. Using high resolution satellite imagery, roads, settlements and land cover over a large part of Sudan was digitized in a collaborative way to support European decision making.

2.2.7 Frontex crisis room (Monitoring, Gather info for action). The European agency for border control (Frontex) has established a situation room, which is disconnected from the Internet for security reasons. This means they cannot use Internet based map services, such as Google Maps. JRC's Spatial Data Infrastructure was used to create a base map compatible and comparable to Google and Microsoft, but accessible on the Frontex Intranet.

2.2.8 European Windows (Monitoring). The MIC requested JRC to create an application where hazard alerts from as many systems as possible are shown in a seamless manner. Using Google Maps, JRC created the European Window, combining GeoRSS feeds of the European Flood Alert System (EFAS), EFFIS and GDACS, but also geo-referenced media reports.

From the various case studies and using the framework proposed by Bharosa and Janssen (2009), a list of common needs and functions was derived, based on frequent tasks. For each requirement, it was analyzed if it could be met with a solution based on mash-ups, or whether a spatial data infrastructure was needed.

At the same time, the case studies show that many solutions were based on information external to JRC (either geo-referenced information feeds or base maps), often combined with data provided from JRC's spatial data infrastructure.

3. RESULTS

3.1 Geospatial requirements in international situation rooms

Using the case studies, the inventory and interviews, an abstracted model of the information management responsibilities in international crisis rooms was developed (Figure 1). The responsibilities are defined as follows:

- **Monitoring**: Detecting new events of interest to the organisation as soon as possible.
- **Briefing on State of the World**: Summarizing current global situation for internal management or external communication.
- **Declare disaster**: Trigger internal mechanism for a new crisis.
- **Briefing on disaster (strategic)**: Internal analysis of disaster, for the purposes of its mandate (e.g. funding, response, logistics, communication), mainly to inform or provide options to decision makers.
- **Gather info for action (tactical)**: Planning of various tactical options for action. This can be done after a decision, but is more often started pre-emptively before a decision for action is made.
- **Action**: according to its mandate (e.g. funding, response, logistics, communication)

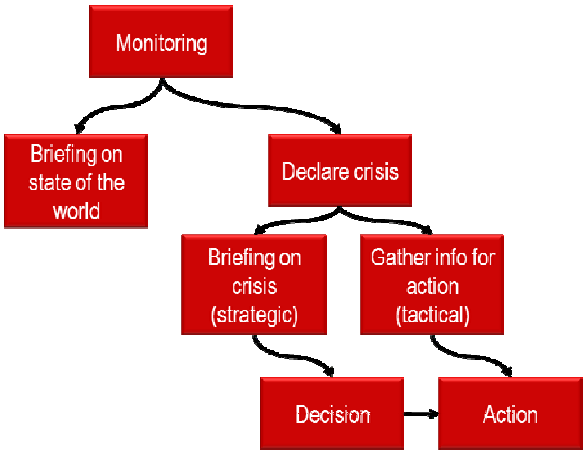

Figure 1. Responsibilities of information managers in crisis rooms

The authors found evidence for the following information management roles associated these responsibilities:

- **Finder**: searches information or information feeds, mostly real-time information (media, blogs) but also background information (political borders, economic indicators, country profile, satellite imagery)
- **Mapper**: visualizes geospatial information interactively (during meetings) and produces static (paper) or dynamic (mash-up) maps for sharing or briefing.
- **Briefer**: compiles information in a paper report, for informing hierarchy, partners or press.
- **Caller**: interacts with partners (mostly by phone, but also electronically), finds and consults experts.
- **Planner**: provides options for course of action, prepares briefing packages for mission teams, understand operational constraints.
- **Coordinator**: establishes appropriate framework for crisis management, divides tasks within team, sets assessment criteria, participates in decision making
- **Supporter**: prepares and maintains infrastructure, databases, systems, staff and operating procedures
- **Archivist**: compiles lessons learnt, stores information useful for future crises, improves operating procedures and systems based on feedback

These roles are roughly equivalent to the roles identified in field-based control rooms (Bharosa and Janssen 2009), i.e. plotter (mapper), chair (coordinator), aggregator (briefer), history and event manager (archivist), information searcher (finder) and expert panel (no equivalent). Apart from the "supporter" role (which is more a preparedness role, and isn't that important during a crisis), the main difference is the caller, who consults partners and experts. However, in contrast to field-based crisis management, in international crisis rooms information management is considered a full time process, although in most cases different roles are played by a single or few officers.

The role of most interest to this paper is the Mapper, who should have capabilities to create the following types of maps:

- **Map images**: communicating the situation globally (for state of the World) or locally (for a particular event); for inclusion in printed briefing reports.
- **Detailed printed maps**: cartographic product showing situational information on a topographic background.
- **Digital, shared map with real-time information**: for monitoring real-time evolution of the State of the World or an event.
- **Collaborative map**: adding own data to a situation map, either centrally or distributed.

However, finding appropriate information for the map is vital for good map products. The Finder must be able to find:

- **Best map available**: digital or paper map representing most detail (street level).
- **Event-specific geographic information**: near-real time information from sensors, media, citizens, third party organisations.

The Finder, Mapper and Briefer have to work together to analyze the situation (including spatial analysis) and summarize it into a briefing:

- **Find a place**: use gazetteers on place names, mountain names to locate a place from a spoken or written text in any language.
- **Explore local information**: on population, vulnerable infrastructure, response and logistics infrastructure, elements complicating or facilitating the crisis.

After a disaster finished, information is ideally kept in the organisation, in particular if it can be useful for future similar situations. In particular the Archivist should:

- **Store data**: It is uncommon for situation rooms to systematically store the data collected during a crisis for future use, although this is recommended by several evaluation studies (Bharosa and Janssen, 2009).

3.2 Mash-up, GIS or SDI

The purpose of this paper is to evaluate the appropriateness of mash-up technology to address the requirements above, with in mind the costs saved by avoiding installing and maintaining own GIS capacity or even a spatial data infrastructure.

Mash-ups are web-based clients that allow easy integration of geographical information, but the information must be available on a web server too. There are web sites available to allow users to upload data (such as the Google Earth Community, GeoCommons), after which it is available for mash-ups. However, the data becomes public and available to everyone.

Desktop GIS systems also allow easy integration of geographical information, but the information must be available on local systems. Some GIS systems (such as uDig) or extensions allow overlay of web-based data, but the integration is often not seamless (data must be converted to desktop formats for instance).

Spatial Data Infrastructures allow serving local data as a web service, thereby making it available for integration in mash-ups, but also in desktop GIS systems.

From the previous section follow the following (high level) technical requirements (the appropriateness or needs of mash-up, GIS or SDI technology is indicated between brackets).

- **Best base map available**: it must be straightforward to find the best open access map available for a given area of interest (**mash-up**). Often, these maps are better than in-house base maps (**GIS/SDI**) due to the update frequency. It is important that specific in-house data (e.g. own assets, thematic datasets) are compatible with existing open access base maps.
- **Visualizing own and 3rd party real-time information**: closed systems (**GIS**) are not fulfilling the requirements of international situation rooms (they might still be appropriate for local command & control systems). Support for geographic data standards such as KML, GeoRSS, WFS, WMS is essential to be interoperable with other information providers (**mash-up**).
- **Collaborative mapping or map annotation**: this is mostly (shared) map annotation (**mash-up**), but in some cases collaborative digitizing is required, where geographical data must be stored in databases (**SDI**).
- **Production of paper maps**: it must be possible to export and annotate maps (can be a screenshot to PowerPoint; **mash-up**); cartographic products (**GIS**) are rarely produced by situation rooms (unless they have GIS capacity), but they are requested and collected from partners.
- **Network**: while Internet is usually accessible in situation rooms, this is not always the case. Off-line mapping tools (with cached base maps) are sometimes a requirement (**GIS/SDI, no mash-ups**).

4. DISCUSSION

The discussion whether mash-ups can satisfy the requirements of international situation rooms depends on how much data an organisation wants to store itself. While there are currently enough services available on-line to build complex mash-ups (such as GeoCommons), the difficulty lies in integrating one's own data. If this is not needed, monitoring, analysis and briefing tasks can be executed by using mash-ups of open, free and on-line available web services, with a minimum cost to the organisation. This is, for instance, the case of most European Commission situation rooms (except MIC and RELEX) and OCHA's ERCC, which have no GIS capability installed.

If the data volume is substantial, own GIS capacity is required. However, traditional desktop GIS solutions make it hard to integrate this data with external information feeds. Therefore, the data must be made available as web services to be compatible with mash-up map clients, which then seamlessly integrate third party data with internal data. JRC and WFP have SDIs and GIS teams (JRC mostly in support of MIC), while RELEX has local GIS capacity, but no SDI.

In support of situation rooms that choose not to install GIS/SDI capacity, the authors developed a mash-up, the Crisis Map Viewer, addressing many of the requirements and which is now used operationally by a few international situation rooms (http://dma.jrc.it/map). The Viewer was developed with in mind that the identified tasks must be executed in an easy way (no training), in a time-critical environment, from any computer and offering the possibility to import a large number of different data formats. Therefore a web-based, client-side solution supported in all browsers was deemed most appropriate avoiding the need for installing software.

The Viewer makes it possible to add base map layers from Google, Bing and OpenStreetMap or overlays from a selection of pre-defined information sources (facilitating the task of finding data). These sources focus on real-time monitoring of crisis or disaster events, which is a typical task for international emergency situation rooms. Furthermore it is possible to save and load maps (customized mash-ups). At the moment standard maps can be loaded which co-visualize real-time information from several disaster monitoring systems (earthquakes, tsunamis, cyclones, volcanoes, floods and forest fires). Of course, overlays are not limited to these predefined sources. External GeoRSS or KML feeds can be loaded by entering the URL into a form, as can maps published as WMS or WFS.

The developed Viewer also offers some basic analysis functionalities, such as requesting "What's near?" to a point, resulting in an editable briefing report. This functionality accesses databases of specific interest to different situation rooms. Furthermore the viewer offers three different ways of geo-coding: place name searching using a spelling-tolerant, fuzzy search, address matching using the external geocoding services (e.g. Google) and through geographic coordinates.

Overall, this Crisis Map Viewer addresses several information management requirements of international situation rooms. Finding relevant geospatial information is made easy by providing catalogues of feeds, and by supporting dynamic adding of information feeds. Real-time dynamic information can be overlaid on high quality base maps, making analysis of affected areas straightforward. However, only used in combination with the JRC Spatial Data Infrastructure can it provide collaborative mapping, visualizing own databases (e.g. on critical infrastructure in Europe) and storing data.

For producing cartographic paper products, web-based applications are not appropriate and desktop GIS systems are required. However, this is a task that can be outsourced to GIS organizations (for instance in the context of GMES Safer (Safer, 2009), the International Charter Space and Major Disasters (Charter, 2009) or GDACS).

5. CONCLUSIONS

Information management in international situation rooms is more complex than in stable business environments. Analysts in international situation rooms have the difficult task of making sense of a very dynamic stream of information from multiple sources with various degrees of reliability, such as media reports, crowd sourcing data, volunteered geographic information, social networking, email, expert reports and sensor data. Because of the variety of crisis situations, information management tasks (including monitoring, analysis and briefing) must be executed with limited training in tools and systems, in a time-critical environment, from any computer and using any data stream.

To evaluate which tools are appropriate, the authors analyzed the tasks of staff in international situation rooms related to mapping, using a theoretical framework for information management linking organisational responsibilities, through roles and capabilities, to geospatial tasks. The most relevant roles identified where the mapper, the finder, the briefer and the archiver.

A wide range of mapping tools is available, ranging from professional GIS enterprise solutions to lightweight web-based

maps and the open source community is very actively developing new web mapping software. Also with regards to base map data, various open-source or commercial solutions exist. However, no solution is tailored to the complex and strict requirements of international situation rooms.

Web-based mash-ups are shown to address many, but not all of the geospatial requirements of international situation rooms. They have the advantage of low cost and high flexibility to co-visualize various sources of information. In addition, training needs are low and there is no need for installing software.

However, quality cartographic products and geospatial data creation, storage and management are out of scope of mash-ups. For these tasks, a GIS and SDI is necessary. However, the first can sometimes be outsourced (to a growing rapid-mapping industry) and the need for the second depends on the mandate of the situation room. Overall, though, the most complete solution has mash-ups for visualization and simple analysis, GIS for cartography and advanced analysis, and an underlying SDI to serve own data and web services.

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