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Multi-Domain Situational Awareness

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ABSTRACT: Diverse communities exist within the operational domains of war fighters, intelligence analysts and agencies, domestic first responders, civilian agencies, and Non-Government Organizations (NGOs), state and local governments, and foreign nations. All have the need to share and communicate common data, visualized in different mission-specific

contexts. Different data generated and consumed across these communities must be represented using a visual language and format they all understand. The success of any coalition/interagency operation depends on a shared understanding rapidly enabled through a common operational picture presented visually. The Department of Defense's mission in the support of natural disasters, joint and coalition missions and traditional missions continues to change and grow at an unpredictable rate. As a result it is impossible in any practical way to predict which specific organizations will need to work together in the next time critical mission. The requirements for a common operational picture therefore include both the ability to combine multiple inputs in different formats into geospatial and temporal (real time) displays and the ability to rapidly adapt the engine supporting the common operational picture.

The result of this requirement Thermopylae Sciences + Technology developed the iSpatial geospatial visualization and analysis framework. iSpatial framework has specific modules built on it that function as individual tools that Government users can exchange or mash together for any combination of features. The framework serves as an environment which can support rapidly developed inputs, and new capabilities as needed for a specific crisis, geospatial location, and set of players to provide a common operational picture in support of coordinated operations and planning. Users can visualize and explore geospatially referenced data on a globe with high-resolution geo-rectified imagery and 3D terrain, manage real-time intelligence feeds, sensor feeds, and mobile messaging devices, structural models and user-generated graphics. The framework extends to seamlessly interact with mobile devices such as Android, iPhone, iPads, or Blackberry smart-phones.

At the request of Southern Command (SOUTHCOM) Thermopylae expeditiously delivered and supported the iSpatial geospatial visualization analysis framework products and capabilities from the ground up to the coalition of agencies in Haiti and beyond supporting Operating Unified Response. The iSpatial platform was instrumental in coordinating the response following the Haiti Earthquake through a series of capabilities built on top of it called a User Defined Operating Picture (UDOP). In the future the iSpatial tool and development environment will be enhanced to include additional Domains including cyber security, and other current and predicted threats, enhancements to visualization across different domains, and additional intelligent systems (AI) and predictive tools to enhance planning and consequence analysis.

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1.0 Introduction

Diverse communities exist within operational domains such as war fighters, intelligence analysts and agencies, domestic first responders, civilian agencies, and Non-Government Organizations (NGOs), state and local governments, and foreign nations. All have the need to share and communicate data common to their overlapping missions, visualized in different mission-specific contexts. Different data generated and consumed across these communities must be represented using a visual language and format they understand. The success of any coalition/interagency operation depends on the shared understanding rapidly enabled through a common operational picture presented visually. The Department of Defense's mission in the support of natural disasters, joint and coalition missions and traditional missions continues to change and grow at an unpredictable rate. As a result it is impossible in any practical way to predict which specific organizations will need to work together in the next time critical mission. The requirements for a common operational picture therefore include both the ability to combine multiple inputs in different formats into geospatial and temporal (real time) displays and the ability to rapidly adapt the engine supporting the common operational picture.

In this paper we will investigate many of the different aspects of Situational Awareness (SA) and the issues in developing advanced SA tools. **Situation awareness**, or **SA**, is the perception of environmental elements within a volume of time and space, the comprehension of their meaning, and the projection of their status in the near future. It is also a field of study concerned with perception of the environment critical to decision-makers in complex, dynamic areas from aviation, air traffic control, power plant operations, military command and control, and emergency services such as fire fighting and policing; to more ordinary but nevertheless complex tasks such as driving an automobile or motorcycle.

Situation awareness (SA) involves being aware of what is happening around you to understand how information, events, and your own actions will impact your goals and objectives, both now and in the near future. Lacking SA or having inadequate SA has been identified as one of the primary factors in accidents attributed to human error (e.g., Hartel, Smith, & Prince, 1991; Merket, Bergondy, & Cuevas-Mesa, 1997; Nullmeyer, Stella, Montijo, & Harden, 2005). Thus, SA is especially important in work domains where the information flow can be quite high and poor decisions may lead to serious consequences (e.g., piloting an airplane, functioning as a soldier, or treating critically ill or injured patients).

Having complete, accurate and up-to-the-minute SA is essential where technological and situational complexity are a concerning burden to human decision-makers. SA has been recognized as a critical, yet often elusive, foundation for successful decision-making across a broad range of complex and dynamic systems, including aviation and air traffic control (e.g., Nullmeyer, Stella, Montijo, & Harden 2005), emergency response and military command and control operations (e.g., Blandford & Wong 2004; Gorman, Cooke, & Winner 2006), and offshore oil and nuclear power plant management (e.g., Flin & O'Connor, 2001).

Nowhere is it more important to have up to date SA than in military operations. Over the last twenty years in addition to fighting wars the military (practically the US military and NATO forces) have been used as the key coordination force in both peace keeping and humanitarian missions. These non-combat missions are in many ways much more demanding on systems because of the need to integrate information on and information about all the over actors in these complex environments.

In building a SA system one of the first considerations is what information is needed for the system. This is not just an issue of what information is needed to be presented to the human operators of the SA system but also what foundation knowledge and expertise is needed to build the system and populate it with required data and format to support the final display and visualization. We will look at these requirements as we investigate the overarching requirements to specify a SA system that will be flexible and capable to support complex multi-domain SA.

There has been a lot of research and development into what has been called Multi-Domain SA. We will look at the principle components of the multi domain problem and how they affect the development of a general purpose SA tool and development environment.

The field of information visualization has emerged "from research in human-computer interaction, computer science, graphics, visual design, psychology, and business methods. It is increasingly applied as a critical component in scientific research, digital libraries, data mining, financial data analysis, market studies, manufacturing production control, and military applications. Information visualization presumes that "visual representations and interaction techniques take advantage of the human eye's broad bandwidth pathway into the mind to allow users to see, explore, and understand large amounts of information at once. Information visualization focused on the creation of approaches for conveying abstract information in intuitive ways.

We will investigate the limits of visualization in SA tool development and then demonstrate how this new technology was used successfully use during the US response to the Haiti crisis. Finally we will discuss the future applications for this technology and research that can be done to increase the usefulness and effectiveness of SA technology.

2.0 Requirements

For any major system or technology, requirements are critical not only in order to evaluate if we have developed the systems and capability that we planned, but also as a guild in the development. The requirements for a general situational awareness would seem to be very straight forward. However the development of a situational awareness system is very complex in a lot of different ways. From the stand point of understanding a given situation there is a lot to possibly know. From the stand point of time we would like to observe and discriminate between what has happened, what is happening and will be happening next. In addition to the timing we need to understand all the different connections to the specific actions that are taking place. Basically, what we want is to have access to and a representation of all there is to know about a specific situation. We can think of everything that there is to know about a situation as a information eco-system, with different kinds of information based in specifics about the situation (location (geography, buildings, etc.), people, actions, weather, etc.) , and the different collection systems that are used to transmit the information to our SA system. In figure 1 we can see a simplified example of an information eco-system. Each circle would represent different aspects of the collection and analysis of information. The larger box would be all the information about the situation and the white space would be information about the situation that is not yet known by the SA system.

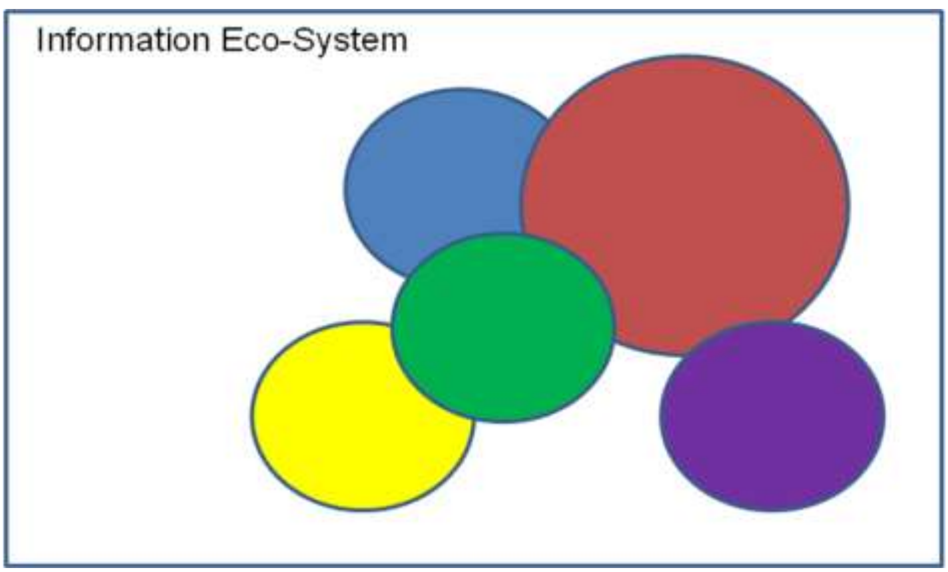


Figure 1 Information Eco-System

How we collect, integrate, reference, store and present the different data, images and information will determine how effective and useful a situational awareness tools will be, and how much of the eco-system in known to the SA system.

Looking at the different characteristics of the SA system required to learn about the situation (information eco-system) yields an understanding of requirements that must be met. Therefore any useful situation awareness system must have several major key elements.

1. The ability to ingest data, images and information.
2. The ability to store, organizes, reference, and analyzes the different data, images, and information in the system.
3. The ability to present useful information in a format that the operators of the systems can use.
4. The systems should be designed to minimize and constraints to easy operations and interface to, from, and with users and other systems.

In addition to these major key elements there are a number of other important aspects of a useful situational awareness tool that must be considered as we develop a comprehensive set of requirements. Several of these aspects of the requirements space are considered in the following sections.

2.1 Joint Operations (logistics)

One of the most important aspects of any operational situation is the fact that the operation is dependent on factors outside of the acute operational picture. Put more simply we need to understand all of the activities that are going on outside of the basic graphical view of what is going on. We can think of a picture in a movie, what we can see is on the screen, but there is a lot off screen that contributes to what we are seeing. The root causes of what is happening in a specific situation include all the supporting factors, including weather, supplies, people, equipments, and even rules and policies. The need to include these different elements of a situation is critical to being able to create a realistic and robust assessment of any situation.

This critical factor drives a number of critical requirements for a robust Situational Awareness (SA) tool, and adds to the complexity of the tool and the need for supporting analytical tools to support a good SA tool. Over the last twenty years the United States military and many other military forces throughout the world have shifted their operational focus to joint and combined operations. The nature of these whole-of-government operations goes well past the Army and Navy working together to many different governments, civilian and small group that may be engaged in a given operation and real time situation. The logistical support for these different organizations' varies from complex interactive IT systems in the case of the US military to handheld computers and cell phones to paper systems.

As a result we generate the following requirements:

1. The SA system must accommodate N numbers of users and M different classes of data.

2. The SA should accommodate real time input of data related to the current situation form system anywhere in the world over standard IP formats and protocols'.

3. The SA system will accept and reference data related to all aspects of the situation and all actors and participants acting to the situation and location.

4. The SA system will filter data to support different aspects of visualization and data sharing.

2.2 Visualization (Operating Picture)

Visualization allows the operator to "see" the operational picture and hopefully understand what is going on. When presenting a visional picture situation there may be significantly more data and information (including images) than can be reasonable presented in signal image. As a result a visualization system must be able to process and analyze date in a manner that allows for representing data in the form of icons and symology that can be added to a display in a manner consistent with the operator's ability to understand what data is available in request.

To see and share the awareness of a situation in real time it is necessary to share a common operating "picture". How that operating picture is built needs to be flexible in accommodate a wide range of operation form the battle field to humanitarian, and disaster relief efforts.

As a result we generate the following requirements:

1. The SA system must accommodate N numbers of users and viewers of the situation.

2. The SA system will support data visualization formats required to display a common operating on a wide verity of different commonly available display devices (plasma screens to cell phones) and data networks.

3. The SA system should store, reference and index image data in manner such that the images can be view rapidly if needed.

4. The SA system should support both 2-dimensional and 3-dimensional representation of the geo-location.

5. The SA system should support N number of possible overlays.
6. The SA system should support and standardized, flexible, and expandable set of icons and notations for different underlying information and links with in the visual presentation.
7. The SA system should support the use of color, motion and sound to enhance visual display of data to maximize the data transfer to the operators.

2.3 Data Sharing

Data sharing is not only a critical requirement of SA tools but a mandated requirement of US government IT systems and organizations. There are a number of different things that impact our ability to share data. First, the system need to accommodate the fact that all users and all data is not the same and that access to some data is limited. Next, the system design must support the fact that users can not reasonably be expected to request data to be share. As these systems get more and more complex an individual will never know in a reasonable amount of time what data is in the system and what data needs to be requested. As a result of that the default in any practical system should be to share all information to the limits of classification and sensitivity.

Figure 2 below shows some the different data types and formats that situational awareness systems use. All of this data and different type will need to be shared.

Figure 2 Data types

As a result we generate the following requirements:

1. The SA system must be able to share any and all of the data, images and other information.

2. The SA system must be able to translate data and data formats in a manner that will allow for the data to be shared.

3. The SA system should always allow access to a user the data, that user contributed to the system.

4. The SA system should be able to classify users so that the system automatically shares with uses all the data, images and information that each uses is authorized to have.

2.4 Threat Data

Traditionally threat data is used to see where an enemy is located, how they are moving and what their intent might be. However in more modern situational awareness tool and system the concept of threat needs to be significantly different. In the case of a humanitarian mission the threats might be a flood, hurricane or epidemic. Also we need to examine our understanding of threats to include new classes of threat including cyber threats. These new classes of threats are not located in only one location be can influence a number for different assets over a wide range of different locations.

Another aspect of characterizing threats that is different and requires new approaches is the introduction of many different organizations (military, civilian, and Non-Governmental Organizations (NGO's) in operations. In this case a threat may only be a threat to some of the organizations in an operation and not all. Also there may other multi-dimensional aspect to the threat itself.

As a result we generate the following requirements:

1. The SA system must accommodate N numbers threats, in M number of different configurations

2. The SA system must be able to assignment specific attributes to different threats so they can be applied differently to different assess.

3. The ability to support multi-dimensional aspects of threats
4. The ability to both tag/identify threats in the different databases within system and to identify them in visualizations and other interactions with the system uses.

2.5 Geo location

Geo location is one of the most fundamental of human references. People understand where they are, or where they are looking. Location and time are some of the most import grounding references that are common to human representation of events. As a resolute geo location becomes one of the key references for any SA system. To increases the utility of the SA system geo location needs to be able to locate the different aspect of an operational situation in way that will accommodate there use by a wide range of different users. In the case of more modern systems with many different inputs, each source of data may have separate and different geo-location data and reference systems. It then becomes very important to insure that all the data in the system in properly referenced to the same locations and systems.

As a result we generate the following requirements:

1. The SA system must be able to determine what geo-location to reference all data to.
2. The SA system must be able to accept data reference to several different geo-locations system.
3. The SA system must be able to overlay and register different geo-location systems and cross reference all the data within the system to the master geo locations and translate geo-locations to other geo-locations systems that have been introduced into the system.

3.0 iSpatial Solution

In order to best meet the requirements for a robust SA tool we need to build a flexible tool that is responsive and adaptable over a wide range of applications and uses. This tool is called iSpatial.

iSpatial can work with a variety of geospatial interfaces and prefers to leverage Google Earth software due to the fact that many users already are familiar with how you interact with that tool.

The simplicity of iSpatial is what allows customers to rapidly adapt it for use with new sensor feeds and missions. Customers can utilize Oracle, MySQL, or other data stores types for managing their information and conducting automated analysis (target destination projection based on heading/speed, target intent based on various mathematical calculations of previous event activity, disambiguation from standard friendly/ neutral traffic and enemy traffic, etc). The sensor facing side of the data store uses open standards for rapid ingestion of a variety of data feeds. The user facing side of the data store uses standard web service protocols to recreate what is happening in the real world on a spatial and temporal globe for situational awareness in near-real-time. Leveraging Simple Object Access Protocol (SOAP) and Representation State Transfer (REST) styles of software architecture, iSpatial maintains up to date technology to give users the smoothest interface to their sensors.

The UDOP renders many layers of content pertinent to disaster relief including geotagged surveys of places of interest. In this case camps for internally displaced people (IDPs) were polled for their population of people and families to plan for aid and resource distribution. These surveys can exist either as a static layers representing information at a point in time or as dynamic layers in which the embedded data is updated as it changes at the source ensuring that the viewer is always seeing the most up to date data. Figure 3 shows what the display will look like.

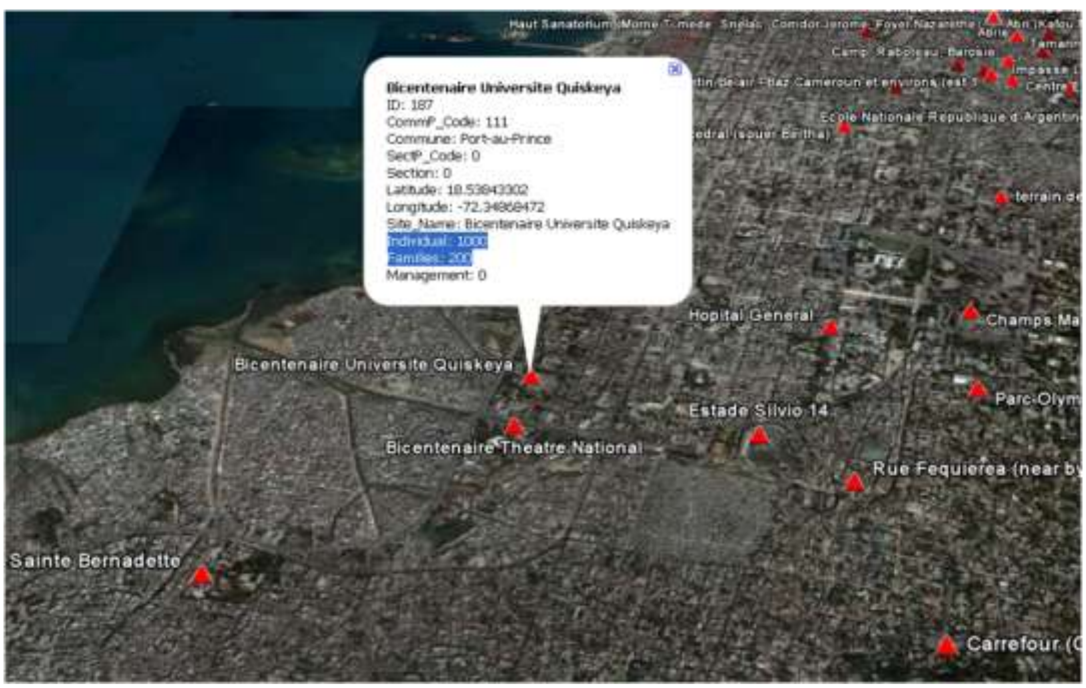


Figure 3 Layers of Content

3.1 Approach

In the world of Government, Commercial, and Private Activities there is a change occurring. We have moved through various phases of information management systems and what we expect from them. As technology continues to evolve the bar is set higher and higher for visualization of data. Everyone wants their data presented in a more aesthetically pleasing way, so they can assimilate it more rapidly. Also, as our data stores swell with ever increasing amounts of multi-media the demand to find and fuse this data increases. A shift is occurring that is similar to what we experienced when computing evolved from a specialized function that occurred in laboratories or server rooms and ended up in everyone’s desktop with the personal computer. We are entering an age of simple geographic information systems for personal, business, and government use. A generation that grew up building cities, managing armies, and organizing railroads and highways across the nation all through games that geospatially displayed ALL of the pertinent data on their enterprises is demanding more out of the old world GIS systems of the past. GIS as a discipline is still needed more than ever, but it is rapidly being dwarfed by the SGIS (Simple Geographic Information Systems) concept where any data can be displayed geospatially. With SGIS, any user anywhere can create data with a spatial context through simple tools like Google Earth.

iSpatial was developed specifically to meet the SGIS world. It is a bridge that was built to leverage the massive amounts of previously constructed GIS data and expose them in new and simple ways to the broader audience. It was designed to connect to multiple disparate data stores and fuse the data held therein spatially for any users that had access to it. It was architected to operate in any web browser with an extremely lightweight footprint so a laptop with a cellular network connection or other device could leverage its features.

In building a specific representation we can use SOUTHCOM as an example. The SOUTHCOM 3D UDOP can be roughly divided into three parts: the globe, the features built into it with iSpatial, and the content added by SOUTHCOM and the user community. The globe is made of customized imagery of Haiti’s entire area that was updated routinely after the earthquake and held up to 20cm resolution. The features were built in by TST that allow users to enter, view, analyze, and collaborate in different ways. Content is shown in the panel on the left in KML/KMZ format allowing users to view data uploaded to the UDOP or linked directly from other sources and databases (see Figure 4 below)

Figure 4 SOUTHCOM 3D UDOP

3.2 Implementation

iSpatial is an event management, "situational awareness" framework. The iSpatial framework allows organizations to rapidly develop and deploy capabilities on an existing system that is currently in operational use and has a proven track record of success. It has a spatial and temporal component that function as a canvass to develop modular tools that interface with a variety of sensors. In addition, the iSpatial framework currently includes capabilities allowing the user to provide pre-operational planning for forces deployed or security details world-wide, real-time operational support by providing information on incidents within a geo-location, and post-operational analysis by displaying the events and possible reactions to the presence of the forces or security details. Some current automated sensor feeds supported are streaming video, imagery, spatial/temporal target tracking (cellular, satellite, and radio transmission), and audio.

In practice a wide range of data can be linked and added to different layers of the systems and display. By placing and viewing content from disparate sources in a three dimensional space, users can leverage the knowledge of specialized people and organizations by viewing their content all in one place. For example users can cross reference LiDAR, hydrographic analysis of flood plains, and medical station surveys to produce a more complete picture of conditions (Figure 5 below).

Figure 5 Multi layers in a display

The UDOP's ability to show content and terrain in three dimensions is important when it comes to showing all of a layer's utility in these cases of crowd-sources imagery and overlapping icons. Figure 6 shows how this capability is used in practical displays.

Figure 6 3-D Content in multi layer crowd-source imagery

4.0 Success in Haiti

The evolution of Geographic Information System (GIS) technology has resulted in many organizations incorporating geospatial data into their information infrastructure. Integration and amalgamation of this valuable resource data highlights the necessity for adequate information sharing and distribution capabilities throughout the spatial technology community. A pivotal demonstration of this need for spatial data sharing arose on January 12, 2010, in the aftermath of the Haiti earthquake. As aid organizations and governments of the world rushed to provide support, challenges quickly surfaced in attempts to coordinate the collection of massive amounts of geographic information among a broad, disparate group. United States Southern Command (USSOUTHCOM) recognized the gap in capability that existed and operationalized elements of their Joint Intelligence and Operations Center – Information Technology (JIOC-IT) prototype system that were mature enough for use. Application of the enterprise geospatial framework, iSpatial®, provided a timely and publicly available solution. Serving as a framework for interactions with the Google Earth® Browser Plug-in application programming interface (API), the software interface provides an open platform for integration of dynamic data and development of interactive applications. The rapid fielding of a capability referred to as a User Defined Operational Picture (UDOP) provided over 2,000 users (figure 7) a common location to create, add, and edit spatial data. The breadth of data sources and content producers contributing to and making use of the UDOP accurately reflected the global community supporting the relief effort. The combination of participatory geospatial content, the collaborative nature of the UDOP, and the ability to integrate mobile applications as direct content producers provided new insights, as we look at building the future of our world in a geospatial virtual environment.

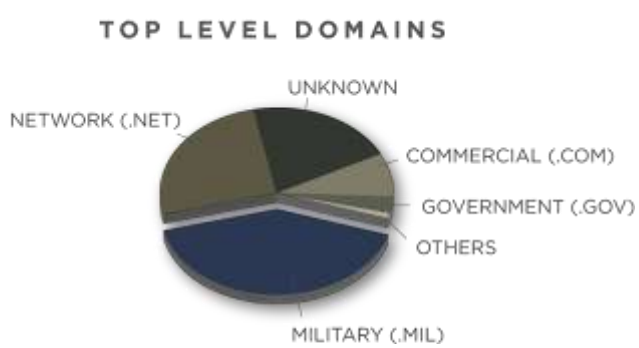


Figure 7 - With over 2,000 account users the 3D UDOP was used by people involved in Haiti relief from a range of backgrounds. This graphic does not account for the myriad users who accessed the UDOP through the View Only feature.

4.1 Users

SOUTHCOM deployed mobile phone applications (Figure 8) that essentially made every person with the applications a collector. Android G1 phones loaded with the mobile application, which embeds 3.2 megapixel photographs not only with a geolocation, but also with the camera's heading at the time of the picture. Combined with Web connectivity and server space, military personnel in Haiti had the ability to provide all UDOP users with sharp, geospecific imagery that updated to a dynamic UDOP layer in near-real time. On the UDOP the image appears as an upright window that can be zoomed in on. Phone carriers can effectively build a room where the walls make up a 360 degree point of view.

Figure 8 Hand Held Applications

The UDOP effort stressed the integration of *different* file formats. Viewing icons on a map is what first occurs when organizations look to design spatial visualization tools, but various types of imagery, documents, and databases can be integrated as well. Where the UDOP mash-up becomes uniquely valuable is in formatting data that was not intended to be viewed geospatially. The UDOP is capable of searching different database formats for data that contains geocoordinates or place names. The results can be converting to an icon on a user's Google Earth browser Plug-in. A link to the data can be established to open the original file for viewing. Flat maps can be georectified to overlay onto the 3D Globe. Imagery can be hovering in the location and direction it was originally taken and the same can be done with videos. Objects that are mobile can be overlaid and played in the time sequence that it happened, while activating any formatted reports made on the move as well. This adds some structure to budding mobile phone collection capabilities. The UDOP can place the fruits of many collectors' labor in one interface, in a context that everyone can understand, geographic space.

Different users can use existing maps and other content in the form and format they are accustomed with, while sharing the data with other users. Figures 9 and 10 show how data from the UN can be ingested into the system easily and how existing maps can be used even though they were never designed to be input into this kind of system.

Figure 9 Users from relief organizations need not leave their existing practices behind as their content may be viewed on the UDOP without having to conform their information systems to a new practice. In this case the UN Joint Logistics Command can view their professionally created products while layering content from the rest of the community on top at will.

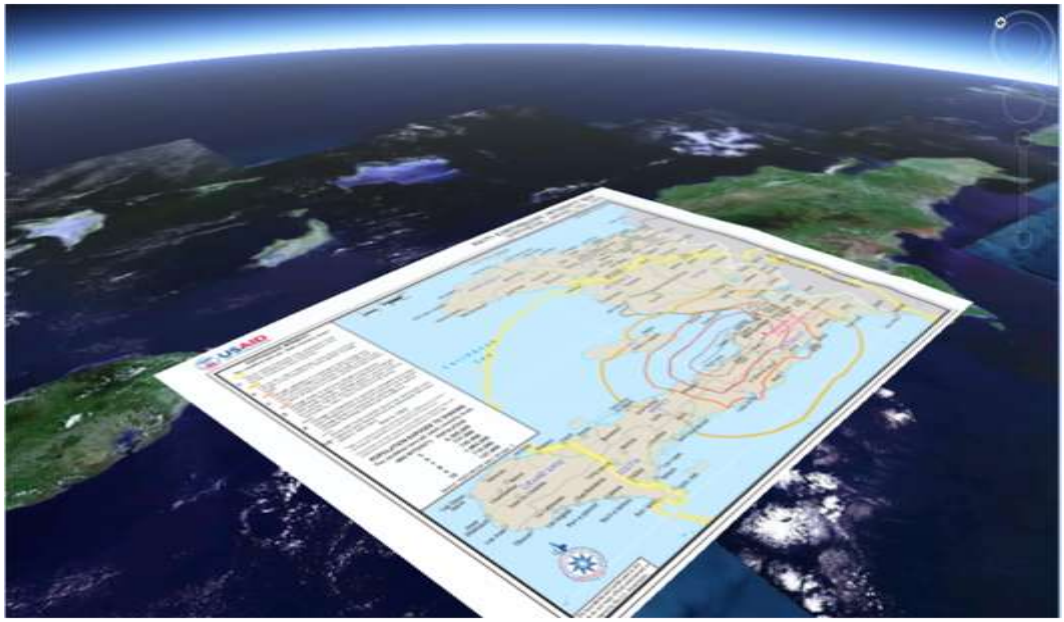


Figure 10 The 3D UDOP can render finished geospatial products like maps, that may not have been intend to be viewed in three dimensions by being uploaded as a ground overlay. This feature allows the user community to share their professionally produced content in a collaborative venue.

4.2 Rapid Capability Standup

When SOUTHCOM looked at building a UDOP capability, they took into account that the Department of Defense (DoD) and The Department of State (DoS) had made investments in Google Earth geospatial solutions. They were also aware that the Department of Homeland Security (DHS) has a similar project called Virtual USA, which is in its nascent phases. The common standards and openness of the Google Earth browser API, and its associated data ingestion and application development APIs with the iSpatial framework allow for new levels of integration that were previously unavailable. In support of a whole-of-government approach among these organizations they are pursuing a collaborative effort that exposes DoD geospatial data at the proper classification level for the mission partners with which they engage. One of the key lessons learned from Operation UNIFIED RESPONSE in Haiti was that DoD –and the global community collectively— a user-defined operating picture that allows users to upload data, create data, and dynamically scale with a near infinite amount of users. With the browser-based Google Earth plug-in and the iSpatial framework, SOUTHCOM now has a robust, highly-accessible solution for exposing and sharing data throughout the Web. The Web-based tool sets provided by allow users such as SOUTHCOM a degree of flexibility as they integrate the tools they need, allowing each department to customize their view to their mission while still sharing the underlying data. SOUTHCOM's goal was that the content created by various departments would be beneficial to everyone as a virtual world is built out with key operations, intelligence and training data shared among all participants.

A key aspect of the deployment of the systems in Haiti was the training. Because the SA tools were developed based on a simple visually based architecture and used well understand interfaces (Google Earth plug-in) the training was minimal and the different users were able to start using the systems and contributing to the evolving SA picture rapidly. Figures 11-13 shows some of the training in Haiti.

SOUTHCOM 3D UDOP and Port au Prince Training Trip Pictures

Figure 11 TST trained MINUSTAH and OCHA GIS specialists in UDOP operation on behalf of SOUTHCOM.

Figure 12 TST sent training personnel to Port au Prince to directly engage Centre National de l'Information Géo Spatiale (CNIGS) the Haitian geospatial organization that was severely damaged by the earthquake.

Figure 13 The UDOP was personally demonstrated to Mr. Helliot Amilcar, the Deputy Director of the Civil Protection Agency who sees great value in it as a coordination tool and for strategic communication. He was chiefly interested in its user-friendliness and ability to involve a large community in adding and viewing population-centric data.

4.3 Applications

Immediately following the earthquake, the chaos in Haiti was the result of the death of approximately 220,000 people, paired with the dire shortage of basic subsistence needs, such as food, water, and medical care and supplies, for the approximate 300,000 injured people and over one million homeless and displaced people. The initial response to the earthquake was one of urgent crisis action planning by military components, federal agencies, state/local emergency response personnel, non-governmental relief organizations, and commercial industry members from across the globe. Thousands of people and massive quantities of supplies were rushed towards the small, densely populated, affected area surrounding the capital of Port-au-Prince. The international response was overwhelming, but data identified as a crucial component necessary to enhancing communication and coordination logistics was in critical need of improvement. The inability to coordinate movement of personnel and aid within Haiti resulted in significant delays in the transport and delivery of much needed supplies and personnel. Many of the participatory organizations possessed data pertinent to the relief efforts, although a viable environment for collaboration did not exist. Leveraging participatory input and widely-available data and tools was imperative to a successful spatial collaboration site.

United States military efforts were initially directed and overseen from the SOUTHCOM headquarters operating in Miami, Florida, coordinating approximately 10,000 military personnel dispatched to Haiti. SOUTHCOM leaders had information of the combined relief efforts as related to their individual directorate's efforts, given the primacy of the situation, but struggled to obtain a comprehensive perspective of all other government and non-government activity in Haiti. SOUTHCOM was focused prior to this disaster on humanitarian operations throughout Central and South America, but the scope of the disaster in Haiti far exceeded anything with which they had previously dealt. Collaboration among relief efforts was essential because the response consisted of multiple nations, governmental, and non-governmental organizations. SOUTHCOM had great responsibility within the U.S. military, but ultimately was charged with providing logistics in support of the United States Agency for International Development (USAID) and the DoS; such a task could be optimized by precise collaboration among all participants. SOUTHCOM’s leadership role was even more challenging due to its geographic distance from Haiti and its role as one organization within a larger patchwork of organizations.

In many cases the different applications were deployed to different users using existing cell phone IT infrastructure (see Figure 14). This allowed anyone with a cell phone to become a data collection node.

Figure 14 Disaster Relief also brough images and text to the UDOP globe and community through Android phones.

Using disaster relief agencies’ data the system puts critical relief layers in an iPhone user’s hands while allowing them to add geospecific images and messages to the picture (Figure 15).

Figure 15 Disaster Relief and GEOCAM allow Smartphone users to upload images to the UDOP in real time providing immediate ground-truth analysis oriented in the direction the collector was facing. This on-scene information can be viewed in a user-defined presentation along with the rest of the UDOP's static and dynamic content.

4.4 Effects

The way that the UDOP filled the pre-existing gap at a COCOM level for sharing intelligence with non-traditional partners was undeniably one of the stand-out features. Thousands of users from partner nations, non-government organizations, and local and state first responders had one location to access and share relevant intelligence. The UDOP allowed users to represent the human element of what was occurring on the ground in Haiti. From geo-tagged snapshots of damaged infastructure on smart phones to creation of adaptive spot reporting layers, the UDOP flexed to meet a variety of Human Intelligence (HUMINT) and Counter Intelligence (CI) as well as other operations needs. The future promises to bring new challenges as the limits of how much information can be fused in one Google Earth browser Plug-in are pushed. The door is open, though, to a variety of potential capabilities and it will be exciting to see further experiments with attaching the right functionality to a spatial representation of data. The unclassified capture of non-traditional intelligence is an area that demands focus and the door has only been cracked on all of the different data that can be aggregated in one common interface. In the UDOP project with SOUTHCOM, much of the innovation came from the actual relief coordinators that had a need for the tool. Initially they pushed the envelope and expanded their comfort zone to embrace an inclusive collaborative environment. They did not stop there though; new users leveraged that as a starting point and came up with even more innovative ideas as the capability rapidly went through first, second and third generations of improvement. The second and third generation ideas would not have been as prevalent if users were not interacting with the initial capability. The UDOP for Haiti showed us that if users are intellectually involved in pushing the technical envelope on a capability, they have a greater interest in it. Also, having a responsive design team that can integrate capabilities in days is imperative to retain user buy-in. The humanitarian community benefits from this rapid spiraling method of development as tools are tailored to their biggest challenges. As the technical capabilities for sharing data increase over time, new ideas will be formed from users as they reset their understanding of what the high water mark is for inclusive sharing of spatial capabilities. The end result being that the mission of delivering aid (figure 16 below) was supported and enhanced, organizations that in many cased do not work together leaned to work together better and new methods, and procedures were developed which will aid future missions, both military, and humanitarian.

Figure 16 Delivery of the Aid

5.0 Future Applications

One of the stand-out features of UDOP is the way that it takes massive amounts of data and brings them together. This data can be stored in many different ways. An objective of work done with tracking activity is to collect the data and analyze more effective ways to accomplish the same objective. Additionally, red force information can be collected and fused with blue force data and played over time in order to see how the action/reaction paradigm plays out. Providing users of operations data with a visualization tool that allows them to see all of the different factors that impact the outcome of their decisions encourages them to fuse data through this tool.

The simplicity of iSpatial is what allows customers to rapidly adapt it for use with new sensor feeds and missions. Customers can utilize Oracle, MySQL, or other data stores types for managing their information and conducting automated analysis (target destination projection based on heading/speed, target intent based on various mathematical calculations of previous event activity, disambiguation from standard friendly/ neutral traffic and enemy traffic, etc). The sensor facing side of the data store uses open standards for rapid ingestion of a variety of data feeds. The user facing side of the data store uses standard web service protocols to recreate what is happening in the real world on a spatial and temporal globe for situational awareness in near-real-time. Leveraging Simple Object Access Protocol (SOAP) and Representation State Transfer (REST) styles of software architecture, iSpatial maintains up to date technology to give users the smoothest interface to their sensors.

5.1 Asset Tracking

iSpatial can be used as an event management, "personnel tracking" and "situational awareness" framework. The iSpatial Framework currently includes capabilities allowing a user to provide pre-operational planning for forces deployed or security details world-wide. Through a robust ingestion system iSpatial can pull data feeds in near-real-time and display them over Google Earth in a web browser. iSpatial is designed to ingest location data that is exposed in US GPS, RFID, and Cellular standard data formats. It organizes heading, location, time, speed, and other information relevant to a vehicle, crate, aircraft, boat, or virtually any entity that an organization would like to track. Different US Government organizations such as the Bureau of Diplomatic Security for the US Department of State have leveraged this capability throughout the world in their high threat areas of operations. Requirements from users in the field have rapidly been spiraled through GOTS development efforts to create modules build on iSpatial that bring dynamic new information management capabilities to users. These users range from worldwide operations center battle captains to tactical operations units in small huts in remote areas of the world.

The modules built to work on iSpatial include real-time operational support capabilities that provide information on incidents within a geo-location and post-operational analysis by displaying the events and possible reactions to the presence of the forces or security details. The asset tracking modules show the breadth of what can be done with iSpatial when it is used for a specific purpose and a user group invests in developing applications to interact with their data in a web environment. Mission planners have tools to develop different routes and analyze the threats along those routes, or within specific corridors that they define around the route. They also can analyze terrain and weather affects on their operations as they evaluate various courses of action for conducting their mission at different times of the day, seasons, or weather.

As missions are executed the iSpatial software provides real-time views of where assets are at and has the ability to monitor where assets are planned to be. If there is an unscheduled deviation from an existing Air Tasking Order or mission plan a user is alerted to the change and their geospatial view locks in on the asset that is no longer following its scheduled course. This type of alerting is available as well to develop spatial fencing within the Google Earth display that creates “no-fly/drive-zones” as well as “safes zones”. Assets can be assigned to safe zones and users are alerted if they leave those areas. Conversely, if an asset enters a restricted zone the user can be alerted as well.

Various US organizations have realized leap-ahead capabilities by leveraging iSpatial and rapidly developing GOTS modules on top of it. Additionally, they have shared their modules with one another to support an economy of scale that allows a group of organizations to accomplish more collectively than they ever could individually. The asset tracking components of iSpatial are an exemplar of how the framework was designed to be used for a group of users.

5.2 Analysis Support

iSpatial has an interesting role in analysis. iSpatial takes an agnostic role with data that opens the door for a variety of ways to conduct analysis. It views data in two different categories. One category focuses on traditional data stores and information that can be fused for better decision making. The other category focuses on a new type of data referred to as user based models. The first category we will address is how iSpatial supports analysis of data from traditional data stores.

There are four primary ways that iSpatial supports analytics on traditional data.

1. Web services
    a. iSpatial acts as a canvass for a user to define boundaries within a geospatial environment and then passes those boundaries to other GIS tools to request analysis. A simple example of this would be a SOUTHCOM UDOP user drawing a polygon around the town of Port au Prince in Haiti and clicking on a population analytics button. Because iSpatial has previously been connected with NGA web service surveys that are published for use it can send the geospatial boundaries that the user selected and broker the data exchange to provide the approximate population amount for the area indicated according to its records. iSpatial is designed to promote data flowing in and out of its display modules. iSpatial deployments are conducted with an understanding that there will be GIS capabilities outside of iSpatial that have significant value to add to an end user in one common view, so the inclusion of GIS web services is a fundamental element of the analytics process it provides.
2. Connecting to data stores with existing data analytics
    a. iSpatial is designed to connect to existing data stores as often as possible to leverage the investment that an organization has put into their data management systems. It extends the value of those systems by visualizing the data over high quality maps or imagery provided by Google Earth or other mapping and imagery products. When native data stores are connected to iSpatial their existing data and

any analytics is persisted for exposure to an end user. Additionally, iSpatial can broker requests for analytics on the native data store and even support the addition of new analytic algorithms that are introduced to the native data stores.

3. Locally storing location based data in conjunction with threat, terrain, and atmospheric data
    a. Due to the need for data to be created on the fly or in an environment that is geospatially displaying fused data from different providers, iSpatial has a data store and index for information. It is important to note that this data store is open and commonly accepted in the geospatial community as one of the most advanced methods for storing data that contains geospatial context. The data store is PostgreSQL and a product of the open source software community, so it limits any costs that an end customer might incur when fielding iSpatial. Also, some operations data is so vast and requires instantaneous response times that indexing it in PostgreSQL provides users maximum efficiency in viewing this information. The data stored in the PostgreSQL index combined with various analytic algorithms that are part of iSpatial makes up a robust analytic capability.
4. Locally storing intelligence and operations data with a geospatial context
    a. The final way to conduct analytics is a variation of the third where the PostgreSQL data store is used to analyze geospatial information. Various intelligence and operations reporting that has geospatial data can be indexed to display through iSpatial. This is important if an IED is found on a route that is planned for traversing or if a user is trying to analyze the probability of encountering a riot, debris in the road, or other obstacles to traveling unhindered to their end destination.

There are no limits to the domains which can be visualized and the types of data and analysis which can be linked to the geospatially. As a result iSpatial is an ideal tool and platform for almost any complex real world analysis. Figure 17 shows how the system can be used in an off-shore oil spill.

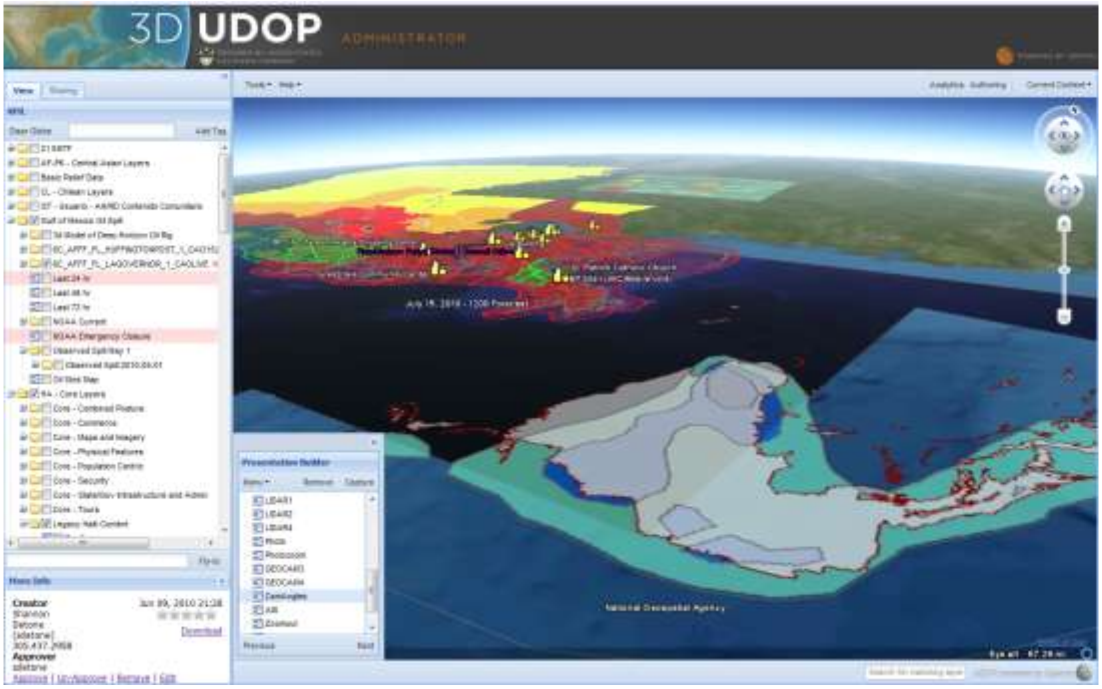


Figure 17 The UDOP was used to view the BP Oil Spill from various sources of content including NGO and State provide information that updated daily showing the spread of oil and actions taken to mitigate its effects.

5.3 New Domains (Cyber)

iSpatial has been integrated in very unique ways by US Government organizations to leverage an economy of scale with a Whole of Government approach to simple geo web enablement of data. The core technical concepts that have been successful thus far can be benchmarked on as we prepare for new and emerging threats. The cyber domain is an excellent example of how iSpatial could be applied in new ways. It introduces a variety of challenges that require new ways of looking at data and analyzing it.

Visualizing cyber data geospatially is something that will be a requirement as we conduct defense operations in that domain. Developing clear situational awareness at an enterprise level on what is occurring within threats to the holistic enterprise of our IT resources is critical. Focusing this geospatially is important because of the way we would prepare to defend against threats as well as how we would respond to these threats. The physics of our critical IT infrastructure, as well as threats, can be visualized in a geospatially relevant manner. Additionally, kinetic factors outside of the cyber domain that might influence a decision maker’s understanding of the situation could be fused into a geospatial display to add clarity and context. Leveraging geospatial visualization as a capability to help defend the cyber domain would allow for attack preparedness, current operations display of real-time activities as they unfold, and post attack analysis on what occurred and how blue and red forces reacted. Also, attack preparedness could include features like simulation and predictive analysis in order to develop “what if” scenarios and prepare Operations Plans on how to respond.

Due to the unique nature of the cyber domain it is important to emphasize visualization methods that extend beyond just geospatial. While iSpatial is designed for geospatial awareness it also adheres to a technical architecture that uses common standards, is powerful, highly scalable, browser based for collaborative activities, and easy for users to manipulate. Preparing for and understanding the defense of US cyber infrastructure requires the ability to visualize data in a way that supports nodal analysis. Entities and relationships are necessary to understand our data centers, networks, and software. Traditionally, this is depicted through 2D diagrams that show entities (servers, switches, firewalls, software, and network components) as well as the relationships between those entities. A relationship could be as trivial as a strand of fiber between a switch and a server or as complex as a wireless terrestrial link between satellites and ground receivers. Understanding this environment and developing situational awareness to defend against cyber threats requires an ability to depict this and update it instantaneously. Software used as sensors to detect threats in the cyber world needs to be tied to common operating pictures (COP) that are designed for the cyber domain.

There are a variety of ways that iSpatial can support visualization of the common operating picture in the cyber domain. Some key requirements for this cyber COP would include instantaneous sensor updates, ability to show the same data geospatially as well as in a network view, massive scalability to show trends of an attack across tens of thousands of IP addresses, and the capability to go from a high level strategic view down into a tactical perspective within seconds. All of the same features geospatial situational awareness provides such as attack preparedness, real-time operations updates, post attack analysis etc would be required through this network view.

The potential to leverage the iSpatial technology for something like cyber domain situational awareness is possible because of the fundamental technologies it leverages and the technical tenets it was designed from. Having the ability to harness the powerful 3D engine in a web browser to display tens of thousands of points and links between points provides foundational elements for a virtually endless amount of features. The adherence to common web and data standards throughout the iSpatial model provides an organized framework to build upon that offers geospatial and networked views of data. The scalability of the technology in Google Earth is evident when you see hundreds of thousands of layers of data in the worldwide web community displayed through this software. Additionally, the ability for hundreds of thousands of users to interact with Google Earth through a web browser provides rock solid evidence that this technical foundation is one that can be scaled for cyber domain defense.

6.0 Theoretical / Research

There is a long history of the development of Situational Awareness tools. This development has been supported by a range of different research and systems. Going back to per-computer days, situational awareness tools consisted of maps with units laded on them and messengers sending and receiving information to the field. Today Situational Awareness (SA) systems are some of the most complex command and control systems anywhere in the world. However they still have the same basic components. These components include the sender/observer of the information, the receiver of the information, the method for transmission of the information (runner, or phone, or satellite link), information itself, and the method/apparatus for displaying the situation.

Significant development and advancements are continuing to be made in these different components as well as in underlying technologies (including handheld computers and cell phones) which will continue to drive the advancement of SA tools. Some these areas of advance research are address below.

Man-Machine interface

A **user interface** is the system by which people (users) interact with a machine. The user interface includes hardware (physical) and software (logical) components. User interfaces exist for various systems, and provide a means of:

- Input, allowing the users to manipulate a system, and/or
- Output, allowing the system to indicate the effects of the users' manipulation.

Generally, the goal of human-machine interaction engineering is to produce a user interface which makes it easy, efficient, and enjoyable to operate a machine in the way which produces the desired result. This generally means that the operator needs to provide minimal input to achieve the desired output, and also that the machine minimizes undesired outputs to the human.

In the case of SA tools there are several different man machine interfaces that have to be addressed in the development and improvement of the system. First are the different input systems and devices, second is the displays to the information consumers, and finally in support of the many different, human analysis that need to process and reduce the data before it can be displayed or pasted to other systems or analysis'.

Display theory

SA systems today have the extremely complex task of presenting to data, images and information about a wide range of characteristics of a situation. The human operators of any given SA tool are limited both visually and cognitively in how much information they can input and process. These limits are affected continuously by other tasks and by stress on the users. In order to ensure that the users of the SA systems can make effective informed decisions based on what is presented to them, the SA systems has to continuously display the information that they need at the appropriate time to make the decision.

Display theory as studied in cognitive sociology and human factors engineering examines the needs of the human operator and the different technologies and methods of presenting them the right information in the right (expected) format and the right time. Military aviation starting during the Second World War has produced a great deal of practical research on this problem. With the advent of SA technologies being available to a much wider audience of users and containing more and more different types of data and images additional research is needed to insure that display are developed and software designed to present the different data and information in way that prove the most useful to the large groups of users.

Information Arrogation

Information arrogation is technology of considerable concern to many civil liberties and privacy advocates. As more and more information become available about a single or related event, location, person or organization the different information can be arrogated to generate both more information and to perform analysis and make inferences about the specific event, location, person, etc. The field of data and information arrogation is in its infancy. As this area of research grows and better algorithms are developed to use limited separately collected data to characterize locations, event and organization the field of situational awareness will benefit greatly by being able to use the aggregated data and representative models for the different locations and events to present complex situations more clearly and concisely to commanders and operators in the field.

Data sharing technology, vs. data sharing requirements

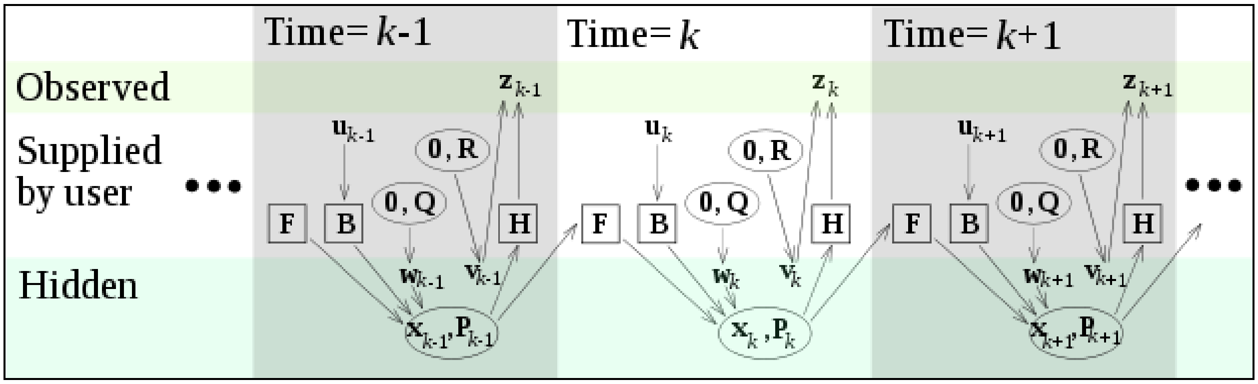
One of the highest priories of any new data system for the DoD or other U.S. government organization is the ability to share data. This requirement has been driven by past events and the inability of some organizations (particularly the intelligence community) to share data. However, how we share data and what tools we use to share data are the complex and difficult part of the equation.   In principle all data that is collected, stored, analysis and displayed in a collaborative environment like common domain tools would be shared. Clearly not all of the collected by different intelligence source can be shared. In order to sort out the different issues and requirement for sharing as much data as possible will require not only new technology but the development of robust policy. Policy research and development will need to be much more flexible in order to accommodate the interaction with a wide range of organizations that will contribute content and need data, images, and information shared with them. Also in the future policy will need to allow for much faster access and approval of data sharing to new groups. Privacy and data security issues will need both technology and policy solution as new generations of systems capture and analysis images and data (movement, cell phone and computer use, and transactions) of people conducting there daily lives. As the networks of inputs and uses grow there will also be the possibility of major new Cyber security threats to be dealt with.

Data and source reliability

The most apparent information in a situational awareness tool are the images that are presented. Although the images in an operational picture and display are the most eye-catching, often the underlying data contents more information and is of greater importance to the decision making. In first generation situational awareness tools the different data and data sources have been considered essentially equally valid, reliable, and accurate. The only major structural variation among data sources in first generation systems has been that some of the data and data source have been prohibited from use and access because of sensitivity of the sources (classification issues). In the next generation of SA tools will need to have a wide range of metrics for data reliability which will allow us to use data more effectively and solicit data when the available data is unreliable. Muti-dimensional data sources present a tremendous opportunity to use overlapping data to fill in the blanks needed for decision support and analyses.

Kanman Filter theory

One of the most robust methods for combining data and evaluating the reliability and accuracy of data from multiple sources is Kanman Filter theory. Kanman filter theory is a mathematical construct that allow for estimating the true value (state) of a system from many different inputs that have varying levels of reliability. Kanman filter systems were originally develop to support real time navigation system which determined location, direction and speed to high degree of accuracy needed for nation defense. As situational awareness tools continue to develop they have the issue of receiving data form a large number of different sources. In many cases these different sources produce overlapping and contradictory information about the current state of affairs. Kanman filter theory allows for a reliable means of combining and reconciling many different sources of data to create a highly accurate model.



The Kalman filter model assumes the true state at time k is evolved from the state at $(k-1)$.

Where:

$\mathbf{F}_k$ is the state transition model which is applied to the previous state $\mathbf{x}_{k-1}$;

$\mathbf{B}_k$ is the control-input model which is applied to the control vector $\mathbf{u}_k$;

$\mathbf{w}_k$ is the process noise which is assumed to be drawn from a zero mean multivariate normal distribution with covariance $\mathbf{Q}_k$.

At time k an observation (or measurement) $\mathbf{z}_k$ of the true state $\mathbf{x}_k$ is made according to

where $\mathbf{H}_k$ is the observation model which maps the true state space into the observed space and $\mathbf{v}_k$ is the observation noise which is assumed to be zero mean Gaussian white noise with covariance $\mathbf{R}_k$.

The initial state, and the noise vectors at each step $\{\mathbf{x}_0, \mathbf{w}_1, \ldots, \mathbf{w}_k, \mathbf{v}_1 \ldots \mathbf{v}_k\}$ are all assumed to be mutually independent

<u>Artificial Intelligence (AI) Systems Applications</u>

As we have seen from the current applications of analysis systems and programs there is a need for analysis of the data which is compiled as a result of the SA tool. One of the strongest requirements for any commander, whether he is a general on the battle field, or a CEO planning the distribution of a new product is for predictive analysis tools. The better his ability to see into the future the more successful he will be in his command. Traditionally predictive analysis tools have been one of the most important areas of research for AI systems. The enormous amount of data, images, and analysis which is being produced can easily overwhelm any human operator. The use of AI systems will in the near future be able to reduce this data and provide operators and commanders better information to may decisions. AI systems, particularly Neural Networks have the advantage over other analysis and data reduction algorithms in that they can learn on the fly (updating in real time) if they are designed and implemented correctly. Predictive analysis systems using AI will be a key part of future advancements in situation awareness tools.

7.0 Conclusions

As we have seen in this paper the uses of SA tools are critical to our ability to manage complex systems and situations. The need to present different data, images and information in a common format and common view goes beyond the need to for all actors in an ecosystem to contribute information and be able to access information about the different things going on within the ecosystem. Although this is critical for coordination of activities and effective command and control, it is even more important that there are commonly understood ways to reference and organize data, images and information. The use of time and geo-location as the primary reference and indexing method will help to standardize many different sources of different classes of data, images and information.

The demand of operations other than war drastically increases the need for a common operating picture and also increases the inputs and interactions that most be part of the system. As more and more international organizations (including military forces) are present and / or involved in working together for the common good the demand for common SA tools will continue to increase. Geo-Location systems (like Google Earth) have created an ideal base for building an operational picture. Open Architecture based systems and interfaces allow for rapid integration and prototyping and the ability to do decentralized development of applications.

The common operating picture infrastructure allow for powerful analytic application using existing data flows. These different applications will continue to grow in power and complexity much like other applications with open architecture systems, limited only by the requirements of the user population.

At the request of Southern Command, Thermopylae Sciences + Technology delivered and supported the iSpatial geospatial visualization analysis framework products and capabilities to the coalition of agencies in Haiti and supporting from beyond The iSpatial platform was instrumental in coordinating the response following the Haiti Earthquake through a series capabilities built on top of it called a User Defined Operating Picture (UDOP). In the future the iSpatial tool and development environment will be enhanced to include additional Domains including cyber security, and other current and predicted threats, enhancements to visualization across different domains, and additional intelligent systems (AI) and predictive tools to enhance planning and consequence analysis. The operations in response to the Haiti earthquake have demonstrated the tremendous value of this technology to operational commander and other actors and organizations within the theater of operations.

We have already seen that this technology will be the critical enabler for operations for the US military as well as other forces and key operations supported by the militaries of the world's nations and by other government and non-government organizations. The success of the effort in Haiti also demonstrates how important the ability to share both information about a situation is with many different collaborators is but also the ability to accept input for a wide range of different sources in real-time. By creating an infrastructure capable of supporting contribution from all actors in a given area we have seen the value of open architecture to support common operating pictures.

One if the most complex, yet important aspects of the future use of these systems will be the introduction and visual representation of new forms of data, images and information related to different dimension of SA and current situation (dimensions for SA) There are a number of different possible dimensions of a situation that commanders, operators and analysis have interested in that are not currently commonly used in or displayed by SA tools. One for the most important dimensions (aspects) of a situation is that of threat. Traditional military threats have been shown indirectly by the disposition of enemy forces, however in today's world this is not a totally affective means of displaying threat. Cyber security threats are a perfect example of threats that cannot be easily displayed in this manner.

Situational Awareness tools are becoming the front end of the system presenting to users and decision makers, and at the same time back-end systems for high level support systems. The use of SA displays to communicate information from these support systems (analysis programs) will add additional complexity to the visualization of SA systems and most be carefully studied as they are integrated.

Ongoing research in this field will yield significant and useful breakthroughs include the continuing development of advanced visualization methods, decision aids (many of which may involve Artificial Intelligence) and additional analytic capabilities of the large amount of data and information organized around SA tools and systems.