Geospatial Informatics Applications for Disaster Management

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ABSTRACT

Geospatial Informatics and its application to terrain understanding and situational awareness with particular focus on disaster management are addressed in this paper. The opportunities for information systems leveraging geospatial and other data sources are presented. Remote sensing imaging and non-imaging sources of information are explored. Coordination and sharing of in information is explored to improve the ability of multiple organizations to more effectively manage and respond to disasters and infrastructure condition assessment issues. These include 3-D visualization, thermal infrared imagery, high resolution satellite imagery and the use of digital aerial imagery. Several example applications are used including an oil spill in Virginia, water quality assessment in New England, pipeline assessment in Canada and automated bridge damage assessment in California.

Keywords: Disaster management, Geospatial Informatics, Information systems, infrastructure assessment, Digital imagery, Data management, Infrared remote sensing, GIS mapping, Global Positioning System

1. INTRODUCTION

Infrastructure managers at all levels face unprecedented challenges today. Increasing demands are being placed on agencies to preserve the existing infrastructure system and to take on new missions of improved system safety and security management. A variety of advanced technologies are available to enhance planning, designing, managing, operating, and maintaining all aspects of the nations public and private facilities. The national transportation system is one example of a major part of our infrastructure system and a critical asset for national growth and development. Aerial and satellite remote sensing represents one area of rapid development that can be leveraged to address these challenges. These technologies have significant and unique potential for application to a number of cross cutting transportation security and infrastructure condition assessment issues.

2. INFORMATION SYSTEM CONSIDERATIONS FOR EMERGENCY MANAGEMENT

It is clear that despite excellent efforts by many groups the approach to providing information for disaster management is not often effectively utilizing a wealth of data that resides, with various organizations. This existing information and technology could provide disaster mangers important information products that could save lives, reduce damage to property, and lessen the environmental impacts of disasters. The current situation is characterized by numerous shortcomings that inhibit optimal decision making for disaster management. The inability to access information and the lack of standardization, coordination, and communication are all obstacles that need to be overcome.

2.1 Information Management Goals

Considerable effort has been expended throughout the Disaster Management community to articulate issues and to characterize the dynamics and the inter-relationships that needs to be accommodated in a viable information management strategy. An important guide for this effort is found in the recommendations made by the Board On Natural Disasters (BOND) in their report to the National Research Council. The BOND's primary goals as articulated in its charter were to:

1. Improve decision making for emergencies through better access to quality data and information

2. Identify users and their needs

3. Provide information products specifically designed to meet users' need

4. Promote efficiency and cost effectiveness

5. Stimulate and facilitate mitigation

These are important components in any workable framework for comprehensive disaster management. However, the focus here is directed towards derived products, procedure and protocol. It is important that the process develops baseline products and implement solutions that reflect the complex fabric of the disaster management community. This work is done at a lower, more formative level in the information management life cycle and in fact forms the basis for the production of the products referred to by the BOND. As noted above the assessment process will work to identify the constituent components associated with specific disaster events and scenarios. The constituent components will then become the basis for technology specifications and the delivery of capabilities that encompass the products identified by the BOND.

2.2 Data Management Considerations

This section provides assumptions based on information and conclusions that have emerged from recent studies in disaster management community itself. These assumptions certainly do not constitute and exhaustive set of parameters. Rather, they provide a point of departure and a set of "operating hypotheses" that can be used to help frame discussion and consideration of needs and requirements. Available Information and capacity is not uniform, consistent and standardized for disaster managers. Large cities may have invested millions of dollars in their information systems, while smaller municipalities may be operating with one personal computer. Disasters will constantly crosscut established boundaries. A fundamental problem in dealing with disasters is that they do not respect boundaries that include organizational, political, geographic, professional, topical, or sociological consideration.[2]

Disasters will often overwhelm mechanisms for coordination and communication. In addition, the mechanisms to bring data and information to decision makers are uncoordinated. Information is often produced from disparate sources and transmitted in whatever format the provider prefers, requiring significant effort to compile it into a form that provides a coherent picture or even thwarting integration altogether. Data standards are often inconsistent, and, even more dangerous; users are sometimes unaware of the limitations and uncertainties in data or are presented with conflicting interpretations of data without the means to assess the reliability of the sources. All of these issues reduce the efficacy of the decision-making process. The problem is compounded because information delivery systems in many cases become overloaded during crises. For instance, in 1996 a moderate (magnitude 4.7) earthquake in San Jose, California, led to more than a million attempted hits in less than one day on the U.S. Geological Survey's World Wide Web earthquake information server. Most of those attempts were unsuccessful, including those by emergency managers trying to access data and information to aid in the formulation of a response plan.

2.3 Information Management Process Issues

Disaster management is an exercise in logistics and information processing and distribution. To effectively undertake these tasks requires a good understanding of disaster information requirements and the characteristics associated with disaster events knowing that each event is uniquely different. Disasters come in different sizes, have different behavior and can be categorized on the basis of their impact on natural resources, agriculture, communities etc. They can also be discriminated and classified along a number of dimensions including impact, severity, duration, geographic setting and advance warning (NAPA 1998). In order to develop the Information Technology architecture for case scenarios application it is essential to understand the disaster event from the perspective of those responsible for assimilating the data. The effective use of this information for producing operational plans to deal with the disaster event and its aftermath is critical.

2.3.1 Consideration of Infrastructure Information Phase Management

For instance, it is important to appreciate that the four basic phases of disaster management may actually manifest themselves in different ways depending on the nature of the disaster. The mitigation phase is essentially a continuous process of preparation, analysis of performance and subsequent modification and refinement. As a result it will likely exhibit the smallest amount of variance. However, the other phases (preparedness, response and recovery) will likely have significantly different attributes depending on the nature of the event. For example consider the difference in the preparedness phase that would be associated with major seasonal flooding along the Mississippi or the Missouri Rivers, the Chaparral fires along the Pacific Coast, a Tsunami that impacts much of the Pacific Rim and an earthquake such as Northridge or Loma Prieta. In each case the geographic coverage and the amount of time for planning and staging is very different. As a result, many of the other systemic aspects of the disaster management initiative will be different as well.

An event warning which impacts the manner in which the preparedness phase is managed also has implications and consequences for the recovery phase (e.g. In the case of the Loma Prieta earthquake the emergency response resources were directed to the bay area despite the fact that Santa Cruz and Watsonville had more significant damage). Partially as a result of this California is building the Tri-Net seismic sensing network to measure shake and model damage in order to make more informed decisions regarding staging recovery resources.

2.3.2 Infrastructure Disaster Management Communities

The disaster management is extremely heterogeneous. In order to develop effective systemic solutions to the needs of this community any framework must address the need to effectively and efficiently share information across institutional boundaries within and between the groups that make up this community. In essence an interface must be specified at each boundary that separates levels in an agency or at the juncture between different agencies or between different sectors. These interfaces each have at least three components: 1) technical, 2) institutional and 3) institutional administrative. The importance of these interfaces is also proportional to the difficulty of implementing them in an automated context. For instance, the lightest weight interfaces should be between levels within the same entity within a single sector. In contrast the heaviest interfaces would be those that attempt to span sectors.[4]

A number of these communities have made significant institutional investments in the construction of foundation data products that feed modeling, analysis and decision support in a range of contexts. Not surprisingly the situation in the disaster management community in regard to data parallels spatial data issues across the federal government and throughout state and local government and the private sector. The BOND also addressed the issue of data sharing by the disaster management community. Their findings recognized that despite the importance of significant databases, their utility is impaired by a host of problems deriving from incompatible formats, inconsistent geographic reference systems, conflicting standards, and other human-caused factors. Many of these problems could be resolved and the value and utility of the databases for disaster decision making greatly enhanced through improved organizational and technological coordination with only an incremental increase in cost. This is clearly in the public interest to accomplish this.

Disaster management scales for international agencies and governments to the individual.

However, a very significant level of responsibility is vested at the local level. For instance, it is the on the ground officials, many of whom are local, that ultimately play the role of first responders (e.g. police, fire, medical and public works) and who also manage many of the recovery operations. To be effective in this context protocols must define communications, database structure, data formatting, hardware and software requirements, networking, quality control, and other issues needed to assure the linkage will improve decision making before, during, and after emergencies through improved access to quality information. In addition, such a linkage will provide information products that are specifically designed to meet the needs of users

2.3.3 Common Characteristics of Disasters

Disaster management is not a linear process that can be documented easily in a flow chart with a readily apparent beginning and absolute end point. Rather, it is a cyclical process of approximation, response and re-calibration that involves many different actors whose roles in relation to one another are likely to change based on circumstances and the stage in the process. The one constant evident in the process is the chaos that drives the system. Another absolute is that the effective, efficient application of information technologies and products has the capacity to improve the system in a number of ways that will combine to save lives, mitigate overall damage, conserve resources and ameliorate human suffering.

To develop effective architectures and technologies that meet the needs of the disaster management community there must be a precise understanding of the disaster management life-cycle (Mitigation, Preparedness, Response and Recovery), the Information Communities that combine to define the disaster management community and the information processing requirements associated with the cycle of data development, dissemination, analysis and review. In addition, and perhaps more importantly, there must be a precise understanding of the dynamics between these components and the "interfaces" that these dynamics imply. Only with such an understanding can we effectively model the process and derive technology solutions that map well into the business model of disaster management.

2.3.4 Data and Information Processing Requirements

Data needs, the characteristics of data and the ability of data to contribute to analysis, response and recovery is well understood. The basic attributes of information that are considered most important by this community include:

1. Timeliness: delivery of data and information in time to drive decision-making
2. Consistency: delivery of data and information in a consistent, uniform manner
3. Understandability: delivery of data and information in a manner that is appropriate and understandable to the target community
4. Accuracy: precision in measurement and observation
5. Flexibility: adaptability to multiple situations

These information attributes have evolved over time within the disaster management community representing the viewpoint of a range of providers, users and consumers scaled from the local to national level. In this regard the communities involved transcend boundaries between recognized sectors at each of these levels (private, public, not-for-profit, NGO etc.).

3. GEOSPATIAL INFORMATICS SYSTEM APPLICATIONS

Today's powerful geospatial tools, especially remote sensing, positioning, navigation, and timing (PNT), and geographic information systems (GIS), can assist the characterization of a disaster situation. Remote sensing technologies, together with other geospatial technologies such as GIS and PNT systems, have a significant role to play in the improvement of disaster management and critical infrastructure condition assessment. Remote sensing from space combines a broad synoptic view with the ability to detect changes in surface features quickly and routinely. Remote sensing from aircraft provides the ability to examine areas in great detail from below the clouds, and ground-based systems make possible the close-in observation of events in real time. Each of these spheres of remote sensing technology hold benefits and drawbacks for use in transportation, and in particular, for the security of the Nation's complex transportation networks.

Examples of the use of remotely sensed data to support disaster management include the ability to:

1. Develop accurate digital terrain models and 3-D surface features as a means for modeling landforms along rights-of-way;
2. Visualize terrain from different perspectives, with the potential for developing threat cones and view sheds;
3. Classify vegetation types along transportation lifelines as a possible deterrent to concealment;
4. Detect, classify, and analyze temporal and spatial changes in surface features;
5. Identify facilities where topography or identifiable hazards (e.g., nuclear, chemical, fuel facilities), place communities at risk;
6. Analyze environmental factors quickly and effectively;
7. Merge real-time sensor output (video, bio-chemical sensors) with archived geospatial data;
8. Identify, characterize, and analyze a wide variety of risks to transportation networks through a gradual program of gathering image intelligence along rights-of-way;
9. Create detailed maps of an area that has suffered attack to assist in response.

For example, current policies governing the collection, use, and sharing of critical geospatial information inhibit the most efficient use of these data in developing mitigation procedures and in responding to terrorist threats and actions. On the one hand, the potential for misuse of critical information has caused federal and state agencies to restrict access to information by removing it from the Internet and other public venues. On the other, combating the threat of terrorism and responding to future attacks will require more effective sharing and use of geospatial data and information. It will also necessitate within the geospatial community continued improvement of analytical geospatial methods and software directed at improving transportation security.

Accordingly, the nation needs new institutional policies to support coordinated efforts in support of improved transportation security and coordinated emergency response. The need for interoperability of communications systems is widely understood; the need for interoperability of geospatial information is less well understood. Workshop participants recognized that meaningful progress toward preparing the nation to prevent and respond to attacks on elements of the nation's transportation networks required the coordinated effort of agencies across the federal government, among federal, state and local governments, as well as among government and private sector geospatial data providers and analysts. For example, it is little recognized by the general public that in addition to destroying two large buildings and killing nearly 3000 people, the attacks on the World Trade Center severely affected New York's transportation lifelines, making rapid response by emergency workers especially difficult. Throughout the cleanup process, transportation routings changed daily and even hourly, making timely map updates necessary. Although the agencies and individuals who responded to the challenges of saving lives and cleaning up after the attacks accomplished wonders despite having no advanced warning and working in extremely dangerous conditions, the lack of established coordination plans slowed their efforts. In effect the teams "made do" with what they could cobble together in terms of base data and imagery acquired by daily aircraft over flights, which commenced on September 14, three full days after the attacks. Fortunately, thanks to the many individuals and organizations willing to help, they were eventually able to provide coordinated mapping, GPS, and imagery information in a rapid fashion. This coordination was more a reflection of individuals committed to dealing with a massive problem, than the result of prior planning by the responsible local, state, or federal agencies. These organizations could have put teams in place and worked more quickly and effectively if institutional policies of their various agencies had encouraged the sharing of information and responsibility for response.

The geospatial data and information developed for other uses can also support improvements in transportation security. One of the strengths of a geospatial information systems approach is that one comprehensive database for a region can support many different applications. For example, as several workshop participants noted, much of the information developed by state and local communities to support infrastructure planning can be used to mitigate the threat of terrorist attacks or to enhance the speed and effectiveness of emergency response teams in case of attack or natural disaster. However, to be fully useful in combating potential terrorist threats, the structure and content of geospatial databases, including remotely sensed imagery, will have to be reviewed for their applicability in improving transportation security. In some cases, the existing framework and transportation databases will need to be enhanced.

The need to improve critical infrastructure protection has created new requirements for remote sensing and GIS analysis. In order to reap the benefits of data and information from non-transportation sources, it will be necessary to develop analytical software designed especially for the security mission. Such software and methods need to be widely available to provide comparable analytical capabilities across the United States. New analytical methods in RS/GIS specifically devoted to the support of critical infrastructure protection could greatly strengthen the nation's ability to improve transportation security. Particular attention should be given to a significant, but limited number of critical transportation assets (e.g., pipelines, bridges, ports, inter-modal facilities), rather than attempting to develop functionalities that encompass everything.

Some remote sensing methods that have been developed for military applications may be transferable to civilian security use. However, civilian measures must consider economic, social, and legal aspects that are be less relevant in a purely military situation. The measures must be designed for high reliability. Needs include:

1. New methodologies and research to identify assess and monitor high value, highly vulnerable transportation facilities across the United States;

2. New methods of analysis and use of sensor and imagery assets to assess vulnerabilities, monitor assets, and aid in post-event recovery. For example, sensitive non-imaging sensors that can detect chemical, explosive, or radioactive plumes could help in monitoring container cargo ships from aircraft or bridges under which all ships in a port must pass.

Geospatial Informatics technologies could be a major asset in identifying and mitigating emergency response weaknesses and improving disaster management throughout the United States. In particular, there is a lack of suitably interoperable technical standards, both for data sharing and for the operation of hardware and software. Although the Federal Geographic Data Committee (FGDC) has established federal standards for preparing and sharing geographic data, which have done much to improve interoperability of geospatial databases on the federal level, much more needs to be done on the state and local level to reap the benefits in times of crisis. State and local databases often lack sufficient interoperability in emergency situations, whether caused by natural disasters, human error, or deliberately by terrorists. Yet, most emergency situations will involve state and local agencies and jurisdictions. The FGDC has recommended several actions that, if accomplished, would sharply improve the response to disasters.

3. VIRGINIA OIL SPILL APPLICATION

Oil spills can seriously affect surface resources, animals and organisms that are part of the food chain that includes human food resources. Spilled oil can harm the environment in several ways, including the physical damages that directly impact animals and their habitats (such as coating birds or mammals with a layer of oil), and the toxicity of the oil itself, which can poison exposed organisms. The severity of the impact will depend on the physical properties of the petroleum-based oil, characteristics of the soil and/or the natural actions of the receiving waters on the oil.

Experts in the remote sensing technology have been trying for several years to use this new technology for the detection of oil spills or oil impacted soil and water. In part, because of the pressure impose by environmentalist, communities and regulatory agencies to look more efficient and faster ways to detect accidents. The use of airborne hyper-spectral technology for the purpose of doing research in this area had increase in the last couple of years, in part because of the flexibility that the airborne remote sensing can provide to the private industry. Among the companies that had sponsored this type of research are Exxon-Mobil, Shell, Chevron-Texaco, and several geo spatial companies. Aircraft surveys have the advantage of having a very high spatial resolution, and high spectral resolution. The only downsize for the use of aircraft is the higher cost compared to the satellite data. With the aircraft you can obtain hundreds of Km2 of information in a single day. This technology has also been tried for the detection of petroleum and possible drilling areas for the extraction of petroleum. Before we can apply this technology worldwide for the detection of oil spills, the spectral libraries of the different oils and combinations of it with different soils and water need to be developed. This is a mayor challenge in this technology since a large insitu database needs to be acquired.

The Piney Point oil pipeline failed on the morning of April 7, 2000, near the PEPCO (Potomac Electric Power Company) generating station in southeastern Prince George's County, Maryland, but the pipe fracture and oil spill were not discovered and addressed until the late afternoon. In the interim, over 140,000 gallons of fuel oil were released into the surrounding marsh, Swanson Creek and, subsequently, the Patuxent River. No injuries were caused by the accident; cost of the environmental response and clean-up operations totaled about $70 million. The rupture occurred at a wrinkle in a section of pipe that had been installed during construction of the pipeline in 1971-2. Longstanding regulations prohibit the use of pipe containing bends with wrinkles in new pipeline construction. However, pipe wrinkles that were not discovered during the construction phase or that formed sometime after installations are still found periodically in pipelines.

3.1. Hyperspectral Sensor

The sensor used for the study of the Patuxent oil spill is the Airborne Imaging Spectroradiometer for Applications (AISA) sensor system. AISA hyper-spectral imaging sensor can measure up to 55 spectral bands of information; has an airborne DGPS (Differential Global Positioning System - to measure aircraft position); and an INS (Integrated Navigation System - to combine the DGPS and an IMU (Inertial Measurement Unit) - to measure aircraft attitude.

AISA is a solid-state, push-broom instrument of small size, which makes it perfect for use in aircrafts. The instrument can be mounted on a plate that is compatible with a standard aerial camera mount, and has the flexibility of selecting the sensor's spatial and spectral resolution characteristics. AISA is capable of collecting data within a spectral range of **430** to **900** nm, and up to 286 spectral channels within this range. Current operational collection configurations for the AISA hyperspectral sensor covers a range from 10 to 70 spectral bands, this will depend on the aircraft speed, altitude, and the specific mission goals. Table two shows the spectral and spatial resolutions achievable when holding ground speed constant, in this case 120 Kts.

3.2 Imagery Analysis

The AISA sensor was used to study the oil spill in the Patuxent River and the data acquired was later retrieved using the ENVI software. The sensor obtained the data using 25 bands from around the 400nm to 800nm. The reason to only study this area of the spectrum is because of the reflectance characteristics of water in this area. The image was analyzed using two different classifications: unsupervised and supervised.

The unsupervised classification image clearly identifies the wetlands but seems to mix the oil-water pixels. Pink area is supposed to represent the areas affected with oil but there are certain areas that show up in pink that are not related with the mix oil-water. Light blue is supposed to represent more pure water, but it covers areas that are known to be affected by oil. The unsupervised image was acquired using the Isodata method.

The supervised classification image was done using the maximum likelihood method. Nine areas were chosen through the images to be able to distinguish between vegetation, wetlands and the different concentration of oil in water. The pixels chosen for each class were let grow (looking for surrounding similar pixels) using the “grow” tab of the Region of Interest in ENVI. The reason to select different areas with water is because of the variation of concentration of oil, which can affect the correct classification of an area affected or not affected with oil. Is clear how similar the signatures are that affect the ability of the software to distinguish them.

The use of hyper-spectral imagery to detect oil spills in water and soil has a lot of advantages in the field. It can be use to monitor oil facilities and therefore prevent worst scenarios when a leak in the facility is found. Also can be use to help planning the cleanup of the area, by quickly identifying the affected areas and possible path of the spill to be one step ahead. The identification of oil in the image using the different software packages available needs to be done through a proficient person, someone that has experience in the field of remote sensing and has some background on the behavior of hydrocarbons. Still this area needs more research since there are hundreds of different hydrocarbons products, and several different type of crude oil around the world. Which can affect the signature of the soil/water of study. In this specific study (oil in water) since the signature can be easily misidentify as water, hyper-spectral imagery can help to obtain a more detail spectrum to be able to separate between pure water and oil-water. In the study there were certain water areas that might be not correctly identify, but this can be more related on the lack of the experience of the analyst and not in the ineffective use of hyper-spectral imagery.

4. SEARCH AND RESCUE OPERATIONS

Search and Rescue (SAR) is one of the many applications that can benefit from remote sensing. Real-time data, collected over wide areas, reduce the uncertainty which is always present in maritime emergencies. Specifically, improvements in trajectory prediction, target detection, and survival estimation can be expected through the availability of remotely sensed data.

4.1 Trajectory Prediction

The key parameters in predicting the trajectory of a SAR object are mean wind speed, mean surface current (depth = 0.75 meters), the variability of the above two velocity vectors, the above/below water profile of the target, and the last known position of the target.

These parameters are used by Canadian search planners to calculate a datum and minimax search area in accordance with the procedures described in the National SAR Manual. The Canadian Search and Rescue Planning program (CANSARP) performs the same calculations in addition to calculating the related "arc-of-probability". Essentially, the trajectory and its uncertainty is calculated by summing the drift vectors to produce a datum, and summing the variances to produce a search area with a known probability of containing the target. See figure 8 for an example of a CANSARP produced search area.

Both the Canadian and United States Coast Guards have evaluated the accuracy of search areas produced using the above methods. All the studies have noted a significant improvement with the input of real-time, in-situ data.

For SAR operations the data must be available within 4 hours of the incident occurring to be useful for trajectory predictions. In practice this means a continuous availability of data since there can be a considerable time lag between an event occurring and the time that the SAR system is notified. The resolution required depends upon the how easily the target can be seen by units in the area. Survival craft, which are highly visible, require lower resolution than persons floating in the water. Unfortunately, no studies have been conducted to date which quantify the resolution required for SAR operations. The existing wind model from the Canadian Meteorological center in Dorval supplies a 2 degree by 2 degree grid south of 60 N and a 2 degree (lat) by 4 degree (long) grid for the arctic. The tidal models are given in rectangular grids with a resolution which varies from 1.7 km squares to 21.3 km squares.

Remote sensing can help determine the wind and surface current velocities required to predict the trajectory of a SAR target. Remote sensing can also give clues to estimate the variability in the wind and surface currents. For trajectory prediction, the SAR needs are essentially the same as applied physical oceanography and meteorology. A multiple sensor approach will likely be required, with the results blended by a numerical model. Seaconsult Marine Research Limited recommended the blending of real data into models for oil spill operations after trials on the west coast using ground based HF radar to detect surface currents.

The Canadian Meteorological Centre has also conducted an evaluation of the use of ERS-1 derived winds for search and rescue purposes. They noted an improvement in their wind product, and recommended the use of satellite derived winds for SAR

Optical sensors can be useful in indicating boundaries in the sea current such as fronts and eddies. The detection of these features could influence DMB deployment strategies and the selection of the most appropriate numerical models. For example, two sea current grids are available for use on the Grand Banks of Newfoundland, one assumes a greater influence of the Labrador current that the other. Being able to infer the position of the Labrador current relative to the search area would assist search planners in selecting the most appropriate grid. Unfortunately, SAR incidents generally occur during bad weather. Experience has shown that storms mask the sea surface from optical sensors.

The ASA/MARTEC study produced the following expected benefits table (table 3) for various remote sensing devices. For the purposes of our study, we asked ASA/MARTEC to include drifting buoys as a remote sensing device.

4.2 Target Detection

SAR targets are relatively small. A four person liferaft is approximately 5 feet in diameters, and has a radar cross-section of 1 m^2. A person floating in the water has a much smaller size. Remote sensing techcniques are unlikely to detect the presence of the target. One exception are those sensors which can detect electronic emissions from survivors. The COSPAS/SARSAT system (a version of system ARGOS) is one such space system used exclusively for SAR. Since these types of sensors are normally classed as communication sensors, they will not be dwelt upon further.

The immediate impact of remote sensing upon detection will be to assist search planners determining the optimum deployment of resources by providing environmental information which is used to estimate the performance of detection sensors.

The instantaneous probability of detection was first described by B.O. Koopman in Search and Screening as the *inverse cube law*:

$$\gamma = \frac{kh}{r^3}$$

where: represents the instantaneous probability of detection

k represents the cumulative effect of environmental and physical factors upon detection

h represents the height of the observer

r^3 represents the cube of the range between the observer and the target.

Studies conducted by the Transportation Development Centre, the Canadian Coast Guard and the United States Coast Guard have investigated which environmental factors impart a significant influence upon the "k" factor in the inverse cube law. The environmental factors deemed to have a significant influence on visual detection from a study conducted in 1990 were:

Ship motion is also believed to have a significant impact upon detection performance. The key factors in estimating ship motion are wave height, sea spectra, wave direction, stability factors such as distribution of weights on a vessel and the ship's hull form, and ship's motion relative to the waves. A study, managed by the Transportation Development Centre, is being conducted to evaluate the impact of ship's motion on vigilance and detection.

4.3 Conclusion

The search and rescue community requires real-time data for operational purposes. Evaluations of the utility of climatological data for SAR planning has highlighted the importance of real-time data The ASA/MARTEC report determined that "indirect remote sensing methods have a potential for usefulness in the long term, when problems with data availability and costs for real time S&R operations are resolved".

Recent experience with computerized search planning, has also revealed the limitations of using raw unprocessed data for operations. Controllers rely upon being given the best information available to run the trajectory and effort allocation models. Once they have an output, then their abilities in crisis management can be utilized to its fullest extent.

The new data available through remote sensing will most likely be introduced into the RCCs through other models. For example, the sensors that can detect ocean circulation would feed oceanographic models, which would -in turn - feed velocity vectors to the rescue centre. In this way, the controllers benefit from the new technology without being overwhelmed by technical details. That is not to say that they should be completely unaware of how the velocity vector fields are produced, and the importance of remotely sensed data. Controllers should be, and are to a limited extent, taught the basic principles of remote sensing and its impact upon search planning. The Canadian Coast Guard College has inserted a section of remote sensing into the Fundamental Marine SAR Course which is delivered to Canadian Coast Guard ship's officers and Canadian Airforce pilots. The fundamental course is also delivered to RCC controllers from around the world, exposing remote sensing applications in SAR to a very wide audience.

Both the United States Coast Guard and the Canadian Coast Guard have recognized the potential importance of remote sensing to search and rescue operations. Under the terms of a Joint Research Project Agreement, both Coast Guards have agreed to investigate the use of satellite based remote sensing in SAR. Activities to date have included studies of AVHRR and RADARSAT. The Canadian Coast Guard is also commencing a study with the Canadian Centre for Remote Sensing to examine the effect of a wide range of satellite sensors on the trajectories of SAR targets.

5. DROUGHT IMPACT ANALYSIS

Drought, a prolonged period of abnormally dry weather that depletes water resources, has far reaching consequences. Many municipalities in the southern Canadian Prairies were declared disaster areas this past summer due to devastating drought conditions. Earth observation images can help assess the severity and extent, as well as possible long-term impacts of drought conditions.

Figures 6 and 7 graphically demonstrate the impact of drought conditions in an area near Wainwright, Alberta. Both images are false colour composites that resemble colour infrared photographs in which growing vegetation shows up in varying hues and intensities of red. Each image is a combination of three bands from Landsat-7 Thematic Mapper. By combining spectral bands in different orders, the extraction of certain characteristics of the Earth's surface becomes possible.

The most obvious difference between the two images is the distinct difference in their overall color. The bright red of the 2001 image indicates healthy vegetation and crops representing a biomass content (vegetation density) somewhat less abundant than in a normal year. The greenish appearance of the fields in the 2002 image is characteristic of vegetation with low chlorophyll content (no infrared reflectance) and thus smaller biomass levels. In other words, the condition of the crops in this area in early July 2002 is quite poor relative to the same time period in 2001. The different shades of red in the 2001 image are characteristic of the type and health of crops that were grown. In the 2002 image, healthy vegetation is limited to areas where plants have access to water, such as along river and creek beds, around potholes and dugouts, and in marshy areas. Even native vegetation and treed areas appear under stress in comparison to the 2001 image.

Another indicator of drought conditions evident in these images is the condition of the water bodies, which appear as various shades of blue on both images. Many of the small and shallow lakes, potholes and dugouts visible in the 2001 image appear dry with fringes of vegetation growing around them in the 2002 image.

To encourage student research on the topic of drought and its impact in Western Canada, scientists at the Canada Centre for Remote Sensing, Natural Resources Canada, are assembling a geocoded set of images of the Wainwright area. Students will be able to compare Landsat images acquired in early July 1999, 2001, and 2002. Links to other sources of data, such as precipitation and crop yield, will be provided as well as a class exercise introducing methods used to interpret images and other spatial data.

6. CONCLUSIONS

It is clear that despite excellent efforts by many groups the approach to providing information for infrastructure condition assessment in emergencies is not effectively utilizing a wealth of data that resides, with various organizations. This existing information and technology could provide mangers important decision support products that could save lives, reduce damage to property, and lessen environmental impacts. The current situation is characterized by numerous shortcomings that inhibit optimal decision making for emergency management. The inability to access information and the lack of standardization, coordination, and communication are all obstacles that need to be overcome. In addition there are tools in the geospatial information area that could contribute immensely to infrastructure management in emergencies and in more routine operational situations. One of the ways to accomplish these aims is to make more effective and timely use of aerial and satellite surveillance and monitoring technologies. The challenge is how to adapt the existing capabilities of image-derived intelligence in the short-term to fit new operating circumstances, and what new ways of doing business will we need in the long-term to develop an infrastructure that is resilient to various forms of attack.

Advances in Information systems, satellites imaging systems and improved software technologies have led to opportunities for a new information products that were not possible before. For example, with the higher resolution imagery change detection for building damage assessment can be conducted rapidly and accurately with these new

The strength of any paradigm shift is realized if new questions can be answered along with traditional ones. Using remote sensing technologies combined with information sharing will address many, if not most, traditional safety, hazards, and disaster issues facing infrastructure managers, as well as provide for those raised by deliberate acts of aggression. Despite technological advance, disaster risk continues to grow. Infrastructure emergency managers and others continue to be called on to make decisions during disaster events, as well as in the pre-and-post disaster phases, with incomplete information. In order to make optimal decisions to reduce the loss of life and property, stakeholders uniformly must be able to obtain the needed information in a format that is appropriate for their capabilities. There is also the need for parties at great distances from each other to be able to share information in a seamless fashion that also allows the shared information to be interactive with local data and be used to create new integrated products tailored to the situation.

level of information products from remote sensed data. The integration of these new products into existing disaster response systems can provide a wide range of analysis tools and sources. In the area of spectral sensing new hyper-spectral sensing systems will allow detection and identification of specific surface materials, air and surface pollutants and ground vegetation types. All of these information products can be useful in the response, recovery, and rehabilitation phases of infrastructure management preparedness.

data sources. Transportation infrastructure and system wide situational awareness over a broad area could also be addressed using remote sensing data

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Altitude	Spatial Resolution	Spectral Bands
1000 m **(3280 ft)**	1 meter	20
1500 m **(4920 ft)**	1.5 meter	26
2000 m **(6560 ft)**	2 meter	34
2500 m **(8200 ft)**	2.5 meter	55
3000 m **(9840 ft)**	3 meter	58
4000 m **(13120 ft)**	4 meter	70

Table 1. Altitude and Spatial Resolution Relationship

Band number	Spectral band	Colour in composite	Characteristics that can be interpreted from this spectral band
2	0.52 - 0.60 μm green light	Blue	green vegetation mapping (measures reflectance peak); cultural/urban feature identification.
3	0.63 - 0.69 μm red light	Green	vegetated vs. non-vegetated and plant species discrimination (plant chlorophyll absorption); cultural/urban feature identification.
4	0.76 - 0.90 μm near infrared	Red	identification of plant/vegetation types, health, and biomass content; water body delineation; soil moisture.

Table 2. Spectral band frequency, color code and band number relationship

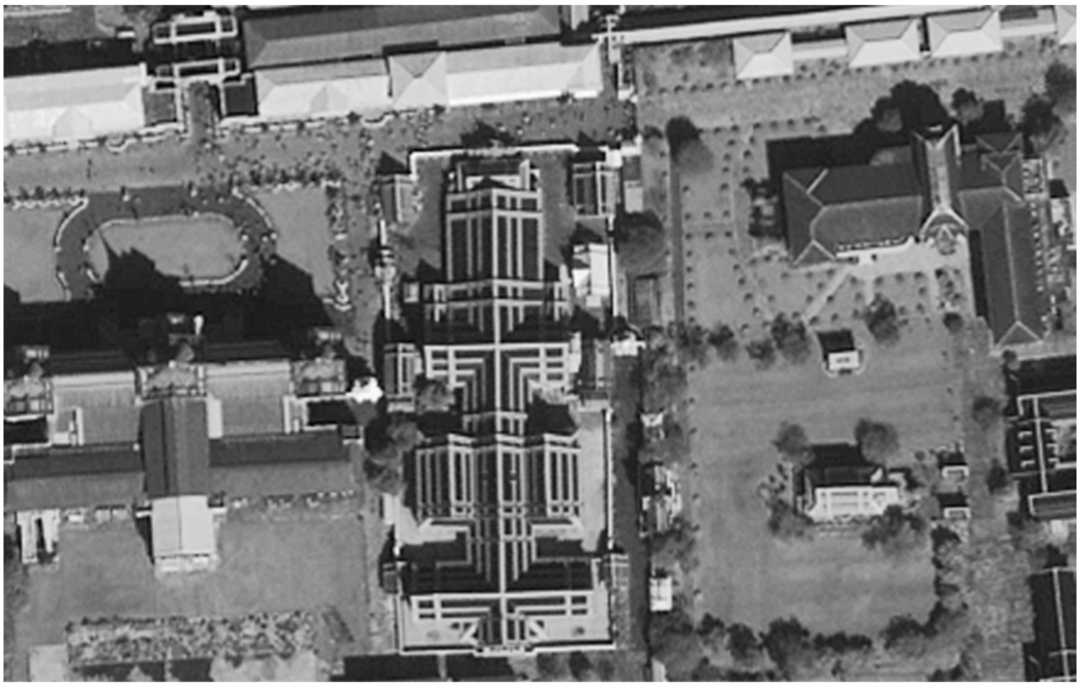

Figure 1: Digital Globe Satellite image of the Royal Palace in Thailand at 61 cm spatial resolution

Figure 2: Hyperspectral image of the oil spill area

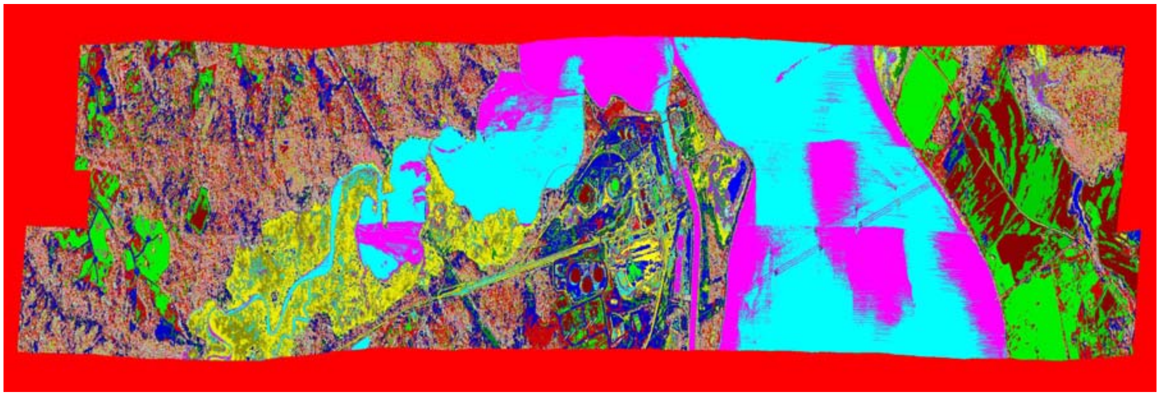

Figure 3: Unsupervised classification of the image data with ENVI (Isodata)

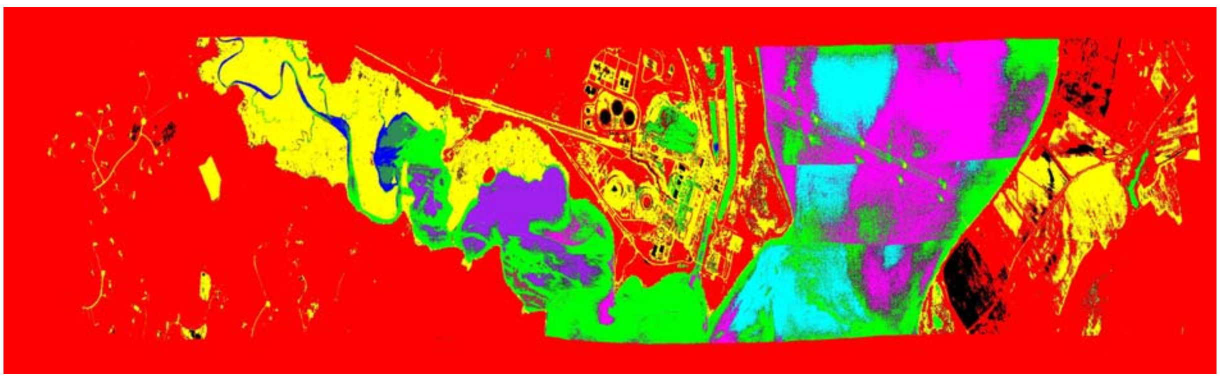

Figure 4: Supervised classification of image data (Maximum likelihood)

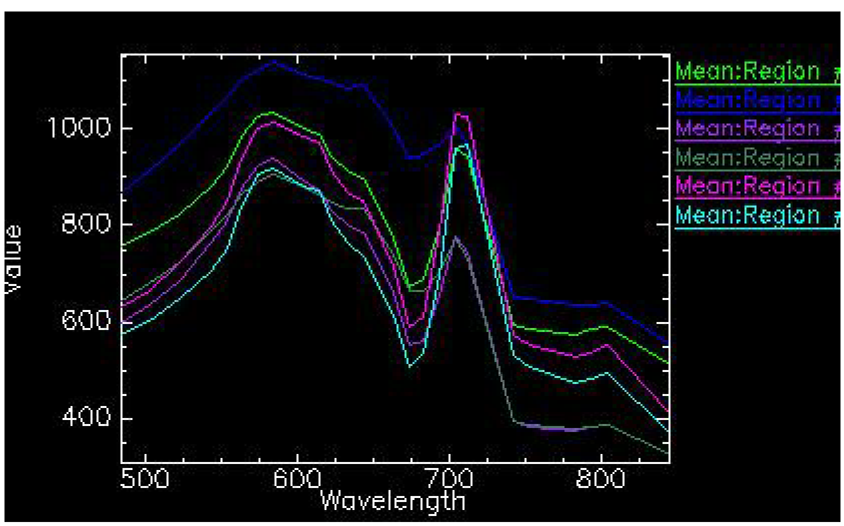

Figure 5. Mean spectral signatures of water affected by oil

Figure 6: Near Wainwright, Alberta, July 2001.
Landsat-7 Thematic Mapper
Red = NIR (Band 4), Green = Red (Band 3), Blue = Green (Band 2)

Figure 7: Near Wainwright, Alberta July 2002.
Landsat-7 Thematic Mapper
Red = NIR (Band 4), Green = Red (Band 3), Blue = Green (Band 2)

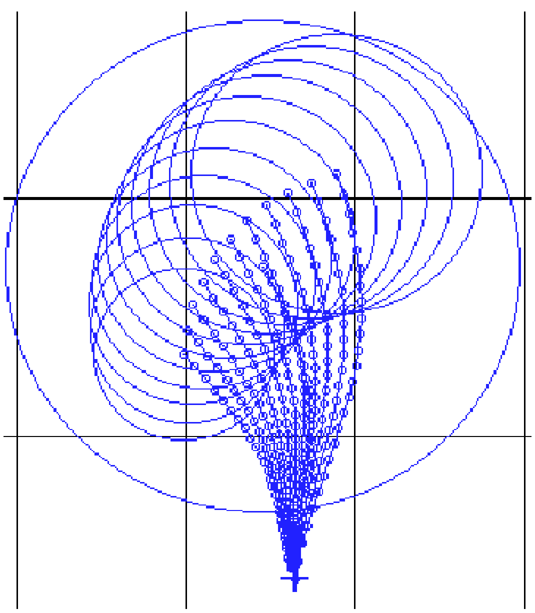

Figure 8: Search and Rescue Direction and Probability search pattern

Remote Sensing Technique	Rank
Drifting Buoys - GPS	1
Electromagnetic Current Meters	2
Drifting buoys - Mini-TODs/ARGOS	3
Drifting Buoys - Loran C	4
Radio Waves (CODAR)	5
Drifting Buoys - TODs/ARGOS	6
Drifting Buoys MTS	7
Coastal Water Level Measurements	8
Wave Fields - SAR	9
Surface Features - SAR	10
Wave Fields - Altimeters	10
Surface Features - Infrared sensors	11
Surface Features - Optical sensors	12
Surface Winds - scatterometer radar	12
Surface Features - passive microwave radiometry	12
Airborne SAR	N/A
Surface Winds - Lidar sensors	N/A

Table 3: Ranking of Location System Effectiveness for Search and Rescue

visibility (surface)	**cloud cover**	**sea surface texture (white caps)**
wave height	**wind speed**	**precipitation**

Table 4: Environmental factors of high importance for search and rescue

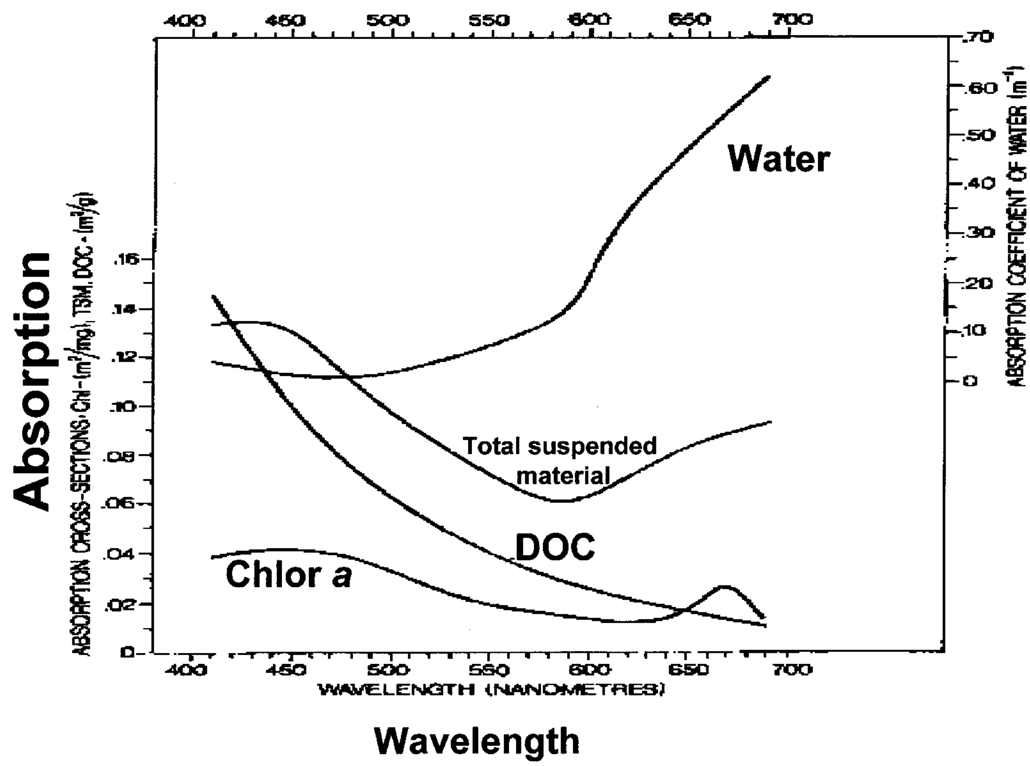

Figure 9: Absorption vs. Wavelength for typical Water Quality Parameters

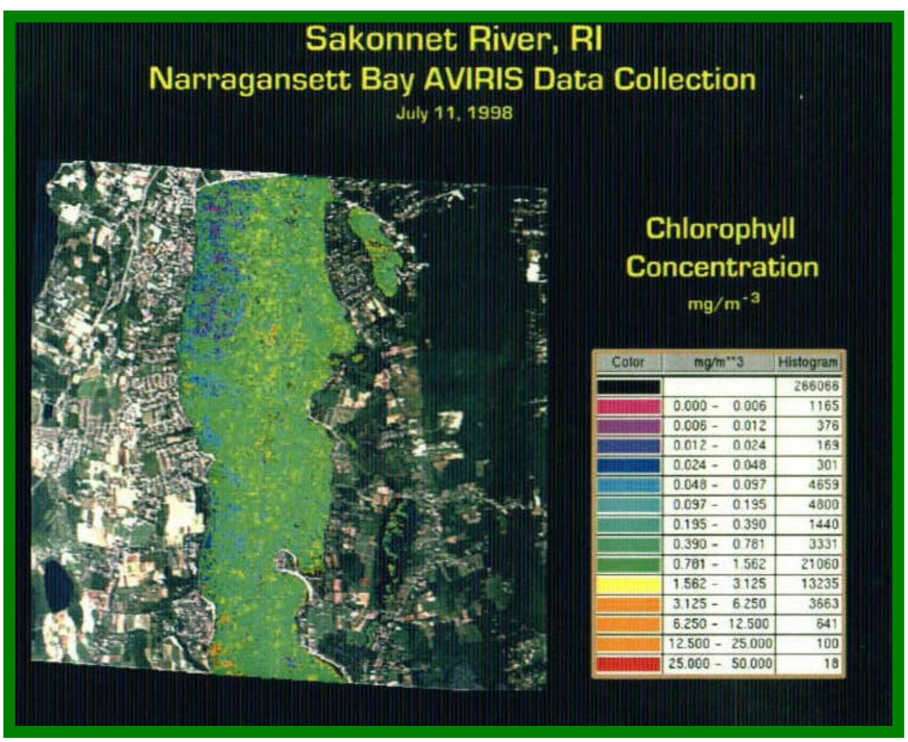

Figure 10: AVIRIS Image showing Chlorophyll concentration

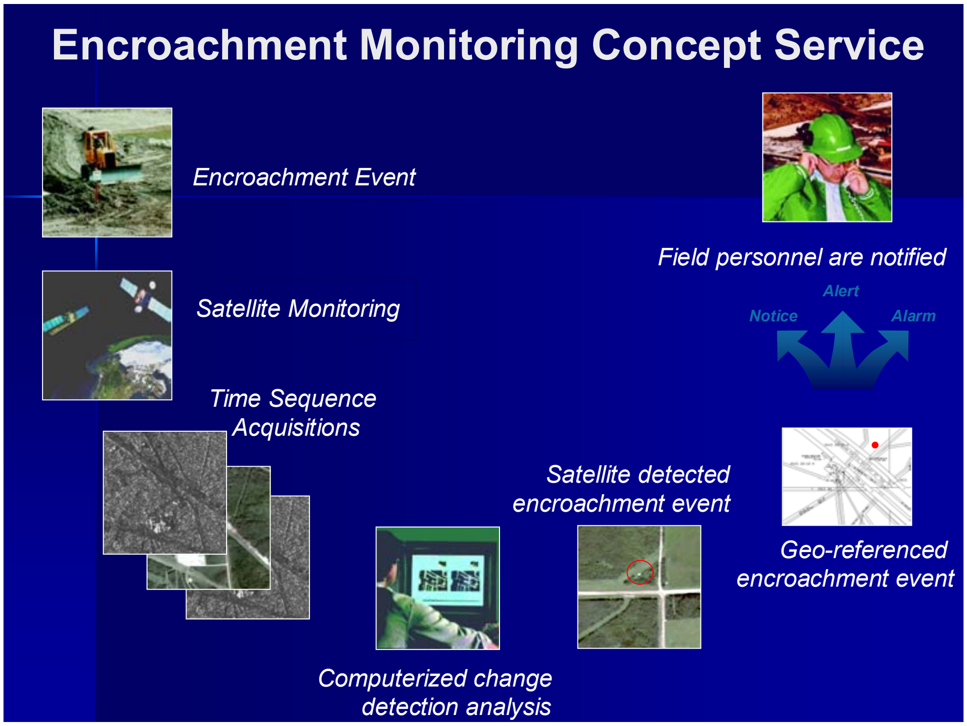

Figure 11: Pipeline Encroachment Monitoring Concept

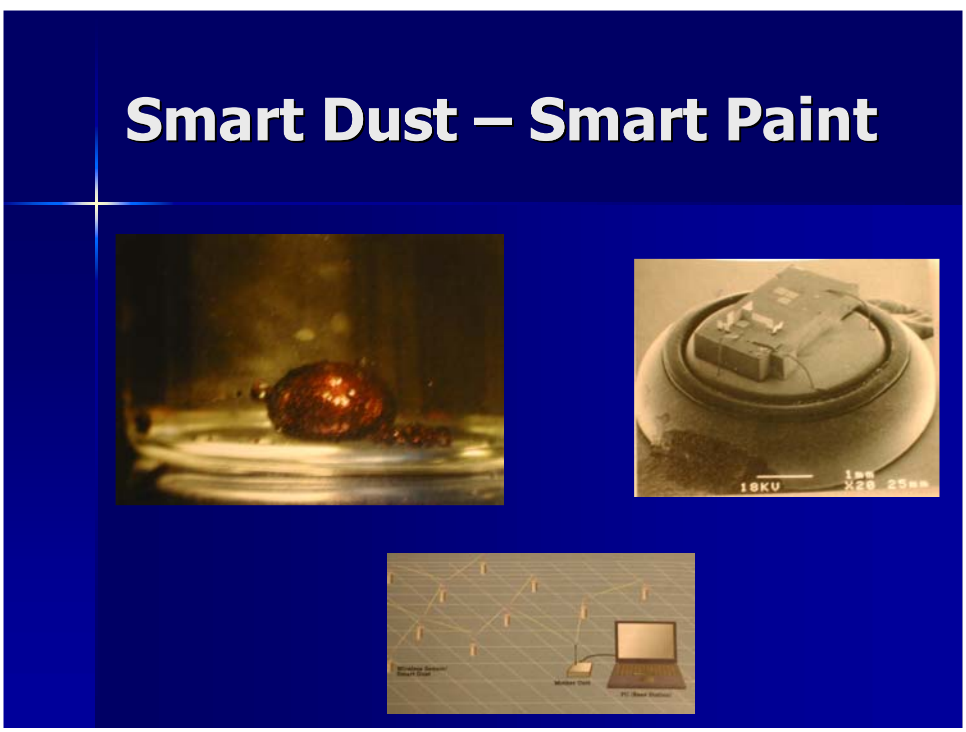

Figure 12: Applications of smart dust and smart paint for situational awareness