Multi-Purpose Sensing Technologies – Constructing an Integrated Spill Response Network

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Abstract

Oil on water events are an inevitable consequence of the transportation of petrochemicals across rivers, seas and oceans. Efficient and effective reaction to oil spills requires early detection and a coordinated, multi-tiered response. Recent developments in technologies have made the gathering and sharing of information from multi-purposed monitoring stations efficient tools in collecting and sharing real-time situational monitoring and spill response management.

Spills do not always occur in readily accessible areas and may be the result of illicit releases. Remote detection capability and access to continuously updated information are fundamental in reducing environmental impacts of spills and maintaining the license of operators legitimately struck by disaster. Remote sensing technologies have a role to play in identification, remediation, association and resolution of oil spill incidents.

Coastal Surveillance Systems are easily adapted to include capabilities of detecting oil on water and identifying vessels in the area prior to the spill event. Wave and current monitoring systems can aid in the prediction of spill origins and where the oil will be at the time clean up resources arrive on site. All of these capabilities are available on single technology platforms which can be integrated with existing assets and complementary technologies to create real time reporting and management systems.

This paper will discuss the various tools and methods available for vessel detection, oil spill detection, and, wave and current monitoring in remote areas, and the interactive roll these items have with each other. Methods of transferring this data from remote areas to command and control centers will be discussed.

1. Introduction

Petroleum and petroleum based products play an important and major role in today’s society. There are anywhere from ten to fifteen transfers involved when moving oil from the well to the final consumer. Oil spills can occur during the oil transportation or storage, and spills can occur in water, ice or on land. Marine oil spills can be highly destructive since winds, waves and currents can scatter an oil spill over an even wider area within a few hours on the open sea. (Jha, Levy and Gao, 2008)

Oil spills will happen and will continue to happen, the best we can do is collect and analyze data, invest in R&D to improve existing response technologies and to develop new technologies, and then expend resources to clean up the spill in the most efficient and effective way possible.

Oil Spill and Target Detection

Systems relying on radar as the input sensor are composed of a data acquisition or radar capture card and a processing unit which collects and processes the radar data in real time. Information from the sea surface is extracted, and with a use of various algorithms, the processing unit can provide information about oil slicks, waves, currents, vessel tracks and water depth.

Radar works during night time just as well as during day time. Detection range is dependent upon factors including the radar transmit power and the height of the antenna above the water surface.

To maximize the sensitivity of the system and the resolution of the captured radar image, a short pulse radar with fast turning, vertically polarized antenna should be used. Vertically polarized radar antennae enhance the visibility of sea clutter compared to standard horizontally polarized radar antennae. This enhancement improves the visibility and detectability of oil on water. Early detection and fast recovery are key elements in the preservation of the environment and trials and tests have shown systems to be capable of detection quantities as small as 5 liters.

An oil slick will drift with the wind and the currents. Wave and current radar monitoring systems provide a means for measurement of directional ocean wave spectra and ocean currents over a broad area of ocean surface based on analyzing the radar data returns off of the ocean surface. Like oil spill detection, operating the radar in short pulse provides optimal resolution, accuracy and performance. Wave direction and height, and ocean current direction and speed data can be uploaded to prediction algorithms that will predict where oil will move in real-time.

When an oil spill has been identified, current and wave height information can be used for operational decision making during clean up equipment deployment.

2. Platforms and Sensors for Oil Spill Detection

There are numerous platforms available that can have a detection sensor attached or connected to it. The following is a review of the most common detection sensors and platforms they can reside upon.

Satellite

The latest generation satellites have multi-mode imaging capabilities and operate within the visible light spectrum and the infrared spectrum, and often are equipped with Synthetic Aperture Radar (SAR).

The visible spectrum data can provide a good base map, but the refresh rate for images is usually too slow for rapidly changing oil spills. It can be difficult to discriminate oil from the background due to similar reflection patterns from sun glare and wind sheen. Satellites operating in the visible spectrum cannot operate at night as they are passive sensors and require light from the surrounding environment.

Oil on the water's surface absorbs greater amounts of solar radiation, thus appearing warmer during the daytime. At night oil loses energy more quickly than water, thus appearing cooler than water. The infrared spectrum cannot usually detect oil emulsions and the shoreline and seaweed can appear similar to oil, leading to false positive results.

SAR detects oil dampening of surface capillary waves and operates in both day and night equally well. It also can be operated over a large area, making it a good first detection tool.

Satellite radar imagery is not generally impacted by weather and can cover a wide area with less resolution or a small area with high resolution. However, the lack of continued coverage in a given area, the slow revisit time causing latency between image capture, interpretation, transmission and the cost of images, may prove the data to be limited in effectiveness in real time or near real time operations such as an oil spill cleanup. A vessel's oil spill radar provides 24/7 local surveillance capability and compliments broad area satellite surveillance.

Aircraft

For oil spill detection surveillance flights, there may be fixed wing or rotary wing aircraft available. Deployment times and operational range can vary, limiting time on station. Aircraft cannot stay on-station for the extended periods experienced during clean-up operations and the flights are generally weather dependent and daylight limited. Within the aircraft, multiple sensor packages are available, camera imagery along with Synthetic Aperture Radar (SAR) and Side Looking Airborne Radar (SLAR), with SLAR performing well for long range detection. Any possible areas of interest detected by SLAR can then be inspected for confirmation more closely with sensors such as vessel based radar and infrared cameras that are in the operational area.

Aerostat

Aerostats are available in a wide range of sizes and can be matched to a specific need or area of operation. They can be deployed from a barge, vessel or shoreline. In the past few years there has been improvement in the deployment containers, so aerostats can now be launched virtually from anywhere a container can be placed.

There are sensor package limitations, except with the largest of aerostats. Examples of larger aerostat payloads would be: radar, multi-spectral camera, high definition video and photographic equipment, infrared camera, radio transceiver and communications repeaters. Aerostats can be difficult to deploy under harsh weather and have wind and temperature limitations. As they are tethered, there is a range limitation to the area they can monitor as they do fall under deployed height restrictions, usually 500 feet or less.

Unmanned Aerial Vehicle (UAV)

Like aerostats, UAV's are available in a wide range of sizes and cost. Their operational range of coverage can be wide and persistent surveillance is possible. Depending on the size of the UAV, multiple sensor packages are possible, for example, camera, IR/UV sensor and radar.

The UAV's have limitations and are particularly difficult to deploy under high wind and low temperature conditions. There are also regulatory issues for flight deployment.

Vessel

An ocean going vessel is ideal for extended deployment times and operating in a wide range of sea and weather conditions. Radar is a common sensor on all vessels and platforms, and is usually accompanied by other sensors, that, in conjunction, can provide real-time oil spill tracking and management. The advantage of a radar based oil spill detection system are that they can be connected to the already existing navigational X-band radar on the vessel.

Operational training is straightforward and the radar provides good detection across a range of light, weather and sea-states. There are no deployment issues once installed and the vessel is the optimal clean-up platform. Combined with the use of a vertically polarized (V-Pol) antenna the radar can provide even better detection in low sea-states, which is a limiting factor for all x-band radar oil spill radars. In calmer weather, a vertical polarized antenna is superior for oil spill detection, as surface echoes are significantly stronger in the vertical plane than in the horizontal plane utilized in common X-Band radars.

Oil spill detection radars are range limited to approximately 4 nautical miles or less. This is due to the fact that the detection of oil requires the radar to be capable of 'seeing' oil's dampening effect on the capillary waves that are present on the water surface. These capillary waves can only be detected and discriminated out to approximately 4 nautical miles by any X-Band radar – this is a physical limitation of the radar because of the low grazing angle of a radar deployed to a vessel. Radar based oil spill detection systems are also subject to false positive alarms received from algae or plankton on the surface of the water as well as calm or flat water areas.

Fixed Site

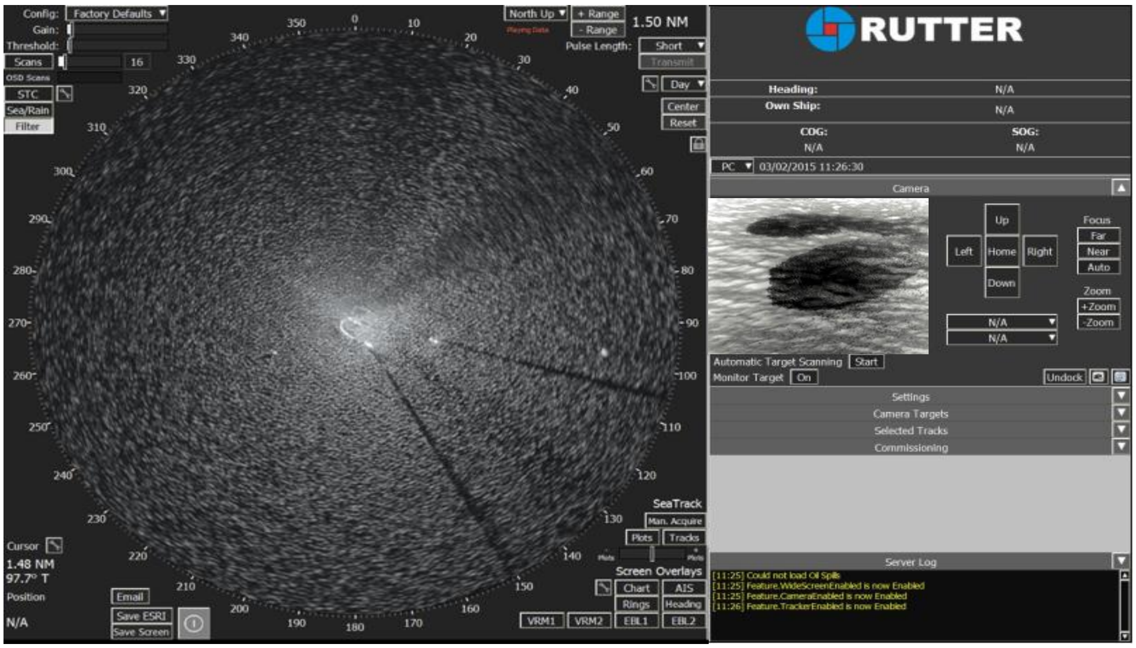
Fixed radar sites are excellent around areas with high risk of oil spills, for example, refineries, transshipment and bunkering facilities, and drilling platforms. X-Band radar based oil spill detection is a very effective first tool to identify even small spills and to alert oil spill responders to the pollution. The radar will provide continuous monitoring, and when coupled with other solutions like infrared and daylight cameras along with wave and surface current monitoring technologies they form the basis of a spill management system. Infrared cameras help verify the spill detected by the radar system. Wave and surface current monitoring will allow prediction of the path of the spill and assist with the optimum use of the cleanup measures available.

Radars cover large areas automatically, with no persistent monitoring by an operator necessary. The system will alarm when oil spills are detected, alerting the operator of the alarm condition. The system give the operators vital information about the scope of the spill. This allows the selection of the necessary resources to contain and clean up the spill. The distribution of the measured and calculated spill information to response and management systems both offshore and onshore further assists with the clean-up.

Infrared Camera

Infrared energy is one part of the electromagnetic spectrum, and all object surfaces emit a certain amount of radiation as a function of their temperatures. Generally speaking, the higher the temperature of an object or surface, the more infrared radiation is emitted. An infrared camera can detect this radiation in a way similar to the way an ordinary camera detects visible light. It works even in total darkness because the ambient light level does not matter. Oil on the surface of the water will emit a signature different than the water it sits upon, this energy can be detected by an infrared camera.

Integrating an infrared camera with a radar sensor can provide an easy method for target identification. The radar graphical user interface may also be used to control the camera, and can provide full manual controls and an embedded video window.



Screenshot of Radar detecting Oil and Infrared Camera view used to visually identify

The radar graphical user interface can be used to set up guard zones that will detect an oil spill developing within that zone. The infrared camera can then be slewed or panned to that area or target, either by manual operator control, or automatically by the detection software.

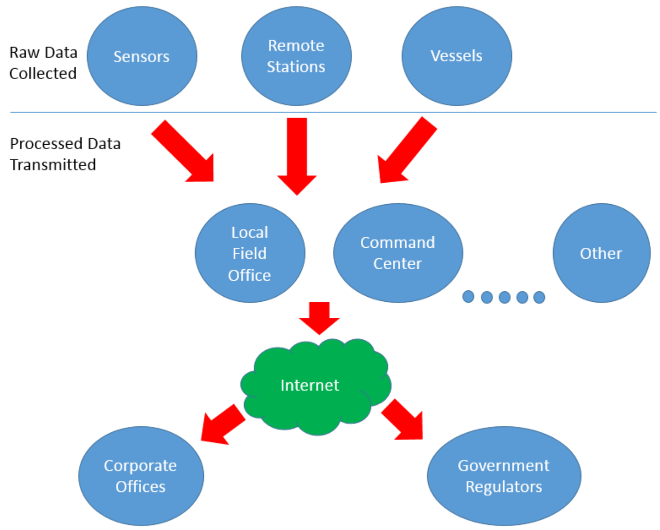
<u>Laser Fluorosensor</u>

A typical laser fluorosensor operates by emitting radiation at a wavelength that will be easily absorbed by the intended target, such as oil. The energy absorbed by the target is then emitted at another wavelength of radiation, which is then detected by a spectrometer linked to the laser.

Laser fluorosensors are active sensors and can be employed around the clock, in daylight or in total darkness, but are not successful in rough weather conditions.

3. Collecting, Analyzing and Distributing the Data

Remote sensing is essential for directing the oil spill recovery organizations to the recoverable parts of an oil spill. Consistent and reliable data acquisition is recognized as essential to efficient operations and asset management.



Typical Data Distribution Based Network

In areas where a constant power source and network connectivity with sufficient bandwidth are available, getting data back to a command and control center should not pose an issue.

With the availability of lower cost high bandwidth transmission methods, remote monitoring is becoming more and more available to the end user. The data collected can be delivered and integrated in a Geographical Information System (GIS) or Vessel Traffic Management System, transmitted to an aircraft or projected on a webserver.

<u>**Data Monitoring and Collection Systems**</u>

As described above, remote sensing, primarily from aircraft or satellites, is used today for monitoring large areas of open water, and to provide a long range view at a low data refresh rate. For drilling platforms, multi-purpose support vessels are always on standby. From the platform and in the immediate vicinity of these vessels, the most common sensors utilized are primarily X-Band radar and cameras, both infrared and daylight cameras. Sensors should be operational in day and night in order to constitute an effective oil spill detection system. Oil spill monitoring may be needed at any time and sensors should have the capability to operate during the night. These are real-time technologies, and provide a near-to-intermediate range view. Fixed wing aircraft, helicopters and aerostats are also deployed as a supplement. UAV's fitted with IR and video cameras have also demonstrated to be effective and are becoming more and more commercially and economically available.

Data aggregation can be applied to multiple remote sites, or a number of oil spill response vessels or radar sites along a coastline and the summary data can be transmitted to regional or central command and control offices and monitored from one master location. Often sensors that collect large amounts of raw data store that data at the local site, only sending the processed results to the command and control center to avoid bandwidth limitations.

SMARTBLUE Remote Surveillance Cabin (Photo courtesy of Raytheon Anschütz)

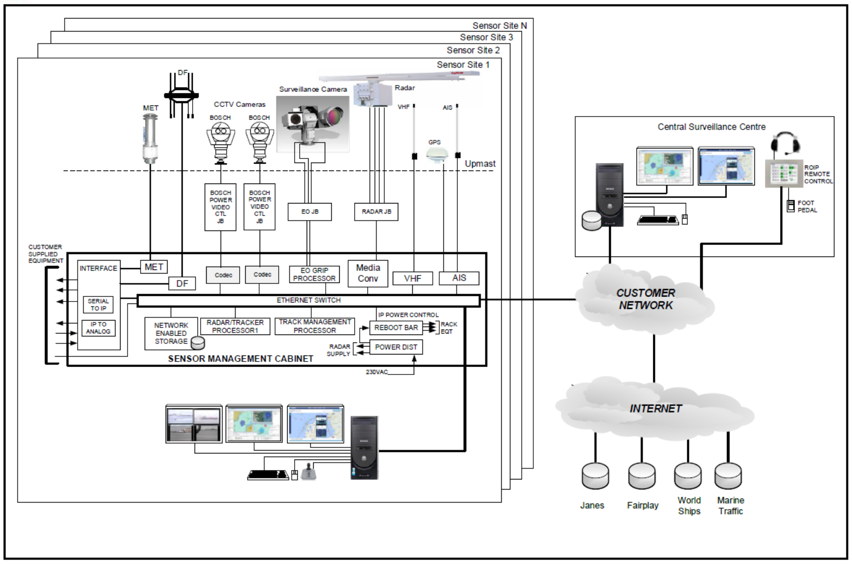
Command and Control

Remote sensing information provides the input to the common operating picture used by operational personnel to help make cleanup decisions. Seamless integration of oil spill and surveillance targets and tracks from different sources i.e. radar, AIS, infrared and daylight cameras into one consistent operational image provides a powerful and clear overview of the area.

A command and control center is typically a secure room that operates as an agency's combined dispatch center, surveillance monitoring center, emergency coordination office and alarm monitoring center.

During oil spill response operations, the challenge is to quickly gain a situational overview and maintain it through the stages of the operation. Decisions are to be made, resources are to be managed, all to ensure safe and efficient operation and minimize damage to the environment.

The diversity of available and required personnel, decision makers, resources and geographical locations, create a set of challenges which must be overcome to reach the common goal of no harm to personnel, equipment and the environment.



Typical Network Architecture (Drawing Courtesy of Raytheon Anschütz)

In the above example an internet connection is shown displaying inputs from various commercially available databases. It could also be used as a portal for in-the-field personnel using smart devices and tablets. There is a move in the industry towards data aggregation and open standards (GML for example) for sensors to feed into central systems.

4. Conclusion

Remote sensing and satellite data are effective tools for oil spill detection. Radar is a very important sensor as a source of real time data that local operators and authorities can quickly and directly use. Advantages and disadvantages of using satellite sensors versus airborne and radar sensors have been discussed. Recent advances in satellite remote sensing have made them more useful for oil spill detection. No single sensor has capability to provide all the information needed for oil spill detection and surveillance.

Sharing and access to the data is vital to the operational cleanup assets and to ensure a quick and efficient clean up. When a spill occurs, it is vital that all and neighboring affected areas or regions be able to share data. Data must be made available in a standard format to be shared.

Having access to as much sensor information as possible allows better prediction of oil movement and certainly leads to a quicker and more efficient cleanup. Real time oil spill remote sensing information can help mitigate the potentially disastrous effects of oil spills on the marine environment.

5. References

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