CALIFORNIA
DEPARTMENT OF FISH AND WILDLIFE
OFFICE OF SPILL PREVENTION AND RESPONSE

REPORT ON BEST ACHIEVABLE TECHNOLOGY *REMOTE SENSING*

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Table of Contents

EXECUTIVE SUMMARY

Remote sensing is an important tool for open-water, near shore, and shoreline spill response. Current technology is capable of providing real-time and accurate spatial mapping of spilled oil (necessary for locating and positioning recovery equipment) and applying alternative response technologies, such as in-situ burning or chemical dispersants. It also provides data on surface current direction, necessary for projecting oil slick movement and qualitative information on oil slick thickness. Remote-sensing technology is capable of offering 24-hour, all-weather slick position information, which could significantly improve the mechanical recovery of spilled oil by extending cleanup operations beyond nightfall. Platforms for remote sensing apparatus include helicopters, fixed-wing aircraft, drone aircraft, satellite, lighter than air balloons, and ground-based stations.

This report is an overview of traditional remote-sensing tools that could be deployed in response to an oil spill in California. Also included is a section on data management during an oil spill response, utilizing Geographic Information Systems (GIS) technology and data dissemination via a Common Operational Picture (COP). The report concludes with practical recommendations based on real world experience at several smaller oil spills in California and at the 2010 *Deepwater Horizon* (MC–252) oil spill response in the Gulf of Mexico. The Appendix is a table listing remote-sensing systems used at the *Deepwater Horizon* (MC-252) response, including their practical usefulness and limitations.

INTRODUCTION

Satellite and aerial imaging is being utilized throughout the world for maritime surveillance and to aid in oil spill detection, response, and monitoring. Until recently, the European Union (EU) has led the development of remote sensing applications for oil spill detection and response. The Bonn Agreement[1] of 1969 is the mechanism by which the North Sea States and the European community work together to carry out surveillance as an aid to detecting and combating pollution at sea. The experience gained through the Bonn Agreement over the past thirty-six years has been codified in the Bonn Agreement Counter-Pollution Manual.[2] In the last several years Canada has instituted a national program of satellite monitoring of the shipping lanes with their Integrated Satellite Tracking of Polluters (I-STOP)[3] project and the National Aerial Surveillance Program (NASP).[4] Both the European North Sea and Canadian operational programs analyze incoming Synthetic Aperture Radar (SAR) satellite imagery for signs of

[1] http://www.bonnagreement.org
[2] http://www.bonnagreement.org/manuals
[3] http://www.ec.gc.ca/glaces-ice/default.asp?lang=En&n=40897129-1
[4] http://www.tc.gc.ca/eng/marinesafety/oep-ers-nasp-2195.htm

potential pollution (oil slicks). If seen, dedicated aircraft are dispatched for oil slick detection and mapping. The aircraft use Side Looking Airborne Radar (SLAR) or a combination of Ultra Violet (UV) and Thermal Infrared (TIR) imaging systems to help positively identify oil signatures on the sea surface. No such operational programs currently exist in the US.

SECTION I: REMOTE SENSING AND SENSOR TYPES

The electromagnetic (EM) spectrum is a continuum of energy divided into discrete energy bands. Remote sensing technologies presently employed by the oil spill response community utilize the UV, Visible, TIR, and Microwave energy bands (Fig. 1).

There are two types of remote sensing systems, passive and active. Passive remote sensing systems record energy naturally radiated or reflected from an object. Generally speaking a passive sensor needs a relatively clear sky and daylight conditions, the exception being a thermal camera which can measure temperature regardless of daylight conditions but is hampered by clouds or fog. An active remote sensing system supplies its own source of energy which is directed at the subject in order to measure energy returned. An active system can operate independently of daylight or weather conditions.

Over the past two decades, many technology review articles have been published concerning the use of remote sensing for oil spill detection and response in the marine environment (e.g. Fingas and Brown 1997, Lehr 2010, Leifer et al 2012). American Society for Testing and Materials International (2008) has published an airborne remote-sensing guide for detecting oil on water, and most recently, the American Petroleum Institute (API) published a planning guide for remote-sensing support for oil spill response (API, 2013).

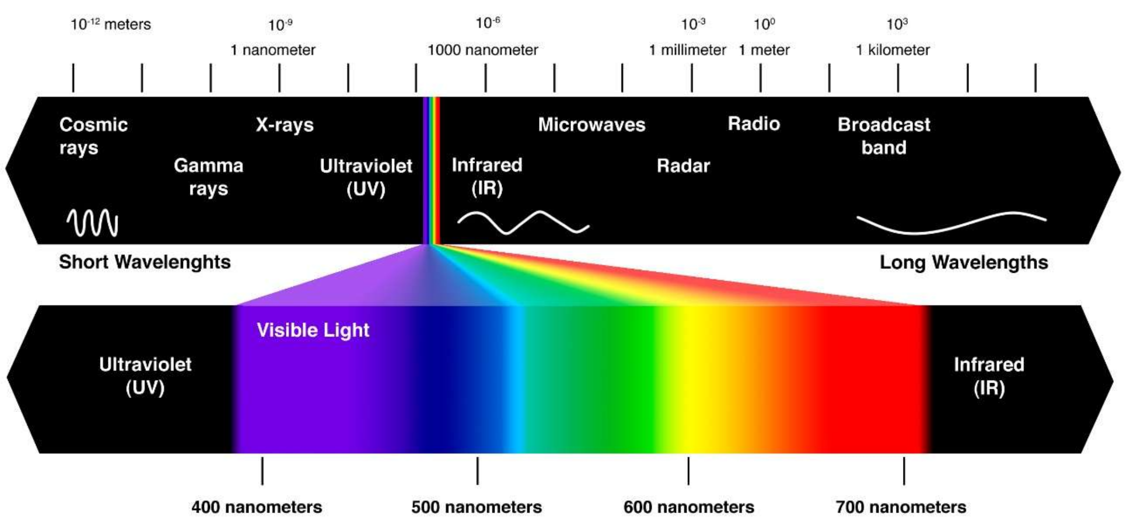

Figure 1. The electromagnetic spectrum and energy bands contained within.

VISUAL OBSERVATION – THE BONN AGREEMENT OIL APPEARANCE CODE

Visual observation of floating oil from the air is the simplest method of locating an oil spill. However, obtaining useful results requires a trained observer to characterize the oil and to describe what is seen in standard terms. The color of an oil film depends on the way light waves of different lengths are reflected off the oil surface, transmitted through the oil (and reflected off the water surface below the oil), and absorbed by the oil. The observed color is the result of a combination of these factors; it is also dependent on the type of oil spilled. Since the color of the oil is dependent on so many variables, appearance cannot be characterized purely in terms of color; therefore, an 'appearance code,' using terms independent of specific color names, has been developed. The European response community has produced its own set of standards, the most widely disseminated being those connected with the Bonn Agreement. The Bonn Agreement Oil Appearance Code (BAOAC) is based upon previously published scientific papers, small-scale laboratory experiments, outdoor experiments, and field trials (Bonn Agreement, 2009, Figure 2). Visual estimation of oil film thickness distribution is highly subjective and, if not done by specially trained and experienced personnel, tends to be inaccurate (Svejkovsky et al, 2012).

BAOAC Code	NOAA Code	Description	Layer Thickness Interval (inches)	Concentration (bbl./acre)
1	S	Sheen (silvery/grey)	$1.6x10^{-6}$–$1.2x10^{-5}$	$1x10^{-3}$-$7.8x10^{-3}$
2	R	Rainbow	$1.2x10^{-5}$–$2x10^{-4}$	$7.8x10^{-3}$-$1.28x10^{-1}$
3	M	Metallic	$2x10^{-4}$–$2x10^{-3}$	$1.28x10^{-1}$-1.28
4	T	Transitional Dark (or True) Color	$2x10^{-3}$–$8x10^{-3}$	1.28-5.1
5	D	Dark (or True) Color	$>8x10^{-3}$	>5.1
	E	Emulsified	Thickness range is very similar to dark oil	

Figure 2. Rough values for slick thickness and oil concentrations can be derived. Thickness and volume estimates from aircraft observations have a high uncertainty due to many variables.

OPTICAL SENSORS

Optical sensors are passive imaging devices sensitive in the UV, visible, and near-infrared (NIR). NIR is the portion of the TIR spectral region closest to the visible range. These sensors exploit differences in reflectance as the primary mechanism for detecting oil on water.

Photography and Videography

Traditional optical techniques rely on still photography and video cameras. These tools do provide economical means to visualize oil spills; however, standard photography and videography technology do not work at night or when cloud cover or fog is present.

Ultra Violet Sensors

Passive UV sensors operate by capturing ultraviolet energy reflected from an oil slick on the ocean surface. The reflectivity of oil in the UV spectrum is considerably different than water, thus oil is easily detected on water. The thinner the oil slick, the higher the ultraviolet signature; therefore, the sensor is best used to map the outer edge of an oil slick where sheen normally occurs. The UV sensor is best used in conjunction with a TIR sensor to fully document the extent and state of an oil slick. UV sensors are subject to interference by wind, sun glint, and kelp and other biogenic material. Further, UV sensors do not function at night or in cloudy or foggy weather.

Thermal Infra-Red Sensors

TIR sensors function by discriminating temperature differentials between objects, such as oil and their background. TIR sensors not only provide information on the location of oil on water but can also provide qualitative information on oil thickness. This is accomplished through the differential TIR color signature between varying thicknesses of spilled oil (Svejkovsky and Muskat 2009). The advantage of the TIR sensor is that it can be operated during both the day and night. The sensor cannot, however, be used through a cloud cover, as water vapor in the clouds absorbs the signal.

Multispectral Sensors

Multispectral (MS) refers to passive sensors that measure reflected and/or emitted radiation in the UV, visible, and TIR wavelengths. While human vision is limited to visible light, multispectral sensors, or imagers, can collect data over a wider range of the EM spectrum and record the energy of a discrete number (4-50) of spectral bands. MS sensors usually cover the visible portion of the EM spectrum, in addition to the NIR. Frequently, an MS based remote-sensing platform will have a variety of different sensors onboard and can therefore collect data across the EM spectrum from the visible to the TIR range (API 2013).

Ocean Imaging Corp.'s "Tactical Rapid Airborne Classification System"

A mobile system that combines MS and TIR sensors, initially funded and conceptualized by the OSPR Scientific Study and Evaluation Program (SSEP), was designed from inception as a portable and affordable system for oil film detection and thickness determination (Svejkovsky et al. 2012). It can be mounted in an aircraft of opportunity.[5] Concurrent funding from the Federal

[5] https://nrm.dfg.ca.gov/FileHandler.ashx?DocumentID=20125&inline=true
https://nrm.dfg.ca.gov/FileHandler.ashx?DocumentID=65703&inline=true

Government, then later support from the oil and gas industry, expanded the operational capabilities of the Tactical Rapid Airborne Classification System (TRACS).[6] While in-flight, the TRACS system mosaics the acquired images, runs custom image processing algorithms to interpret the imagery, and creates an output file in GIS file format. The resulting GIS formatted data files can be sent electronically directly to responder vessels and to the Situation Unit in the Incident Command Post (ICP) for direct import into the COP and dissemination across the broader response.

Field and experimental validation results confirm that the combination of MS and TIR imagery enables characterization of oil thickness of up to 2 mm (Svejkovsky and Muskat, 2009).

During the *Deepwater Horizon* response, repeat coverage with the TRACS system was also used to provide situational awareness with respect to vessels in the spill area, verify the effectiveness of sub-surface dispersant application, assess the impact of aerial dispersant application, and map beached oil.

IN-SITU SENSOR – FLUORESCENCE DETECTION – "SLICK SLEUTH" (InterOcean Systems)

The "Slick Sleuth™[7]" Oil Spill Detector and Alarm is a UV/fluorometry-type optical sensor. The Slick Sleuth line of oil spill detectors are used in a wide variety of industrial and environmental applications for remotely detecting oil spills in real-time. The highly sensitive sensor detects small (micron-level) amounts of oil on calm water, moving water surfaces (outfalls, streams, harbors, offshore), as well as on solid/dry surfaces. The detectors can be mounted downward looking on bridge piers, buoys, or offshore production facilities to survey a specific target area. Any oil present in the target area will fluoresce and subsequently emit light of its characteristic wavelengths. When oil is detected an either audible or electronic alarm is sent.

MICROWAVE SENSORS

Imaging Radar is an active remote sensing system that measures surface roughness. This technology provides its own source of illumination in the form of microwave energy and can "see" in darkness and through clouds and fog. There are two basic types of imaging radar systems used in oil spill response: SLAR and satellite-based SAR. SLAR is an image-producing system that derives its name from the fact that the radar beam is transmitted from the side of the aircraft during data acquisition. In both systems, a pulse of energy is directed to the surface at an oblique angle. At the Earth's surface, the energy in the radar pulse

[6] https://www.bsee.gov/sites/bsee.gov/files/osrr-oil-spill-response-research//544aa.pdf
https://www.bsee.gov/sites/bsee.gov/files/osrr-oil-spill-response-research//594aa.pdf
https://www.bsee.gov/sites/bsee.gov/files/osrr-oil-spill-response-research//658aa.pdf
[7] http://www.slicksleuth.com/

is scattered in all directions, with some reflected back toward the radar antenna (backscatter). A surfactant film on the ocean surface will have a dampening effect on wind-generated water surface capillary (ripple) waves; the smooth ocean surface reflects the microwave energy away from the radar antenna, thusly exhibiting a "dark" signature on the resulting radar image. The major shortcoming of imaging radar is that it does not discriminate between sheen and thick oil. The sensor is therefore a useful tool for determining the overall footprint of the oil slick and modeling the trajectory of an oil spill but provides little information on the thickness and amount of oil present, an important data requirement for spill response and cleanup activities. However, recent research has shown that it is possible to characterize areas of thicker emulsified oil within an oil slick using SAR[8] (Garcia et al, 2013).

Other limitations of imaging radar include: 1) at surface wind speeds below 5 knots capillary waves are not present (dead calm) and above 20 knots the ocean surface is too rough for the dampening effect to occur; and 2) a number of natural conditions including wind shadows, kelp beds, plankton blooms, natural organic material, and fresh water fronts will lead to false positive signals.

The most readily available SAR is satellite-based, thus acquiring imagery is dependent on the location of the satellite. MDA Geospatial Services has two operating commercial SAR satellites: RADARSAT-1 and RADARSAT-2. MDA Geospatial Services is the only SAR vendor geared for real-time delivery of SAR imagery for maritime domain awareness.[9] NASA's Jet Propulsion Laboratory (JPL) has a SAR system that uses a Gulf Airstream jet aircraft as its deployment platform, and an Uninhabited Aerial Vehicle (UAVSAR).[10] However, JPL is not geared for rapid deployment nor real-time processing. SLAR is based on an aircraft platform and is therefore a much more flexible system for imaging. Transport Canada has an oil spill response SLAR mounted on a dedicated DeHavilland Dash-8 pollution surveillance aircraft, based in Vancouver, BC.[11] This Canadian Government equipment may be accessed through the Pacific States -- British Columbia Oil Spill Task Force Mutual Aid Agreement.

High Frequency Radar

High Frequency Radar (HFR) technology is used for measuring ocean surface current velocity fields near the coast. These coastal based radar installations measure the speed and direction of the near surface currents hourly. Use of HFR to provide ocean surface current estimates for oil spill modeling can be a powerful tool as it is synoptic and operational in real time and extends over large spatial areas. HFR data is often used to help forecast where the oil or other materials will flow.

[8] http://www.jpl.nasa.gov/news/news.php?release=2012-337
[9] http://mdacorporation.com/geospatial/international/satellites
[10] http://www.jpl.nasa.gov/missions/uninhabited-aerial-vehicle-synthetic-aperture-radar-uavsar/
[11] http://www.casr.ca/bg-air-national-aerial-surveillance-program.htm

HFR has proven to be an effective tool for spill response in California. California voters through a ballot initiative in 2002 passed Prop 40, a $2.6 billion bond act that provided funds for a variety of programs related to water quality, coastal resources, and historical/cultural programs. In 2005, the California Coastal Conservancy and the State Water Resources Control Board invested $21 million from voter-approved Propositions 40 and 50 funds to build the infrastructure to map ocean surface currents. Fifty-four land-based stations now span the California coastline, providing anyone with access to the internet the ability to track past and near real-time movement of California's coastal waters, including any floating pollutants, free of charge.[12] Unfortunately long term funding for the HFR network has not been identified.

LASER FLUOROSENSOR

The laser fluorosensor is an active UV sensor that utilizes a narrow-band UV laser for stimulating fluorescent emission from spilled oil on water. The sensor works by using a laser to irradiate the sea surface. When the laser strikes oil, a characteristic visible spectrum is recorded by the sensor. The laser fluorosensor has the ability to detect and characterize different types of fresh and weathered oil. Due to the mechanics of the system, it needs to be flown at low altitude resulting in a thin line of data along the laser track. A recently developed scanning laser fluorosensor extends the line of measurement into an image path of up to 200 meters (Brown and Fingus, 2003). Because of its size and weight, the laser fluorosensor must be flown in a large aircraft such as a DC-3. In January of 2011 Environment Canada decommissioned the only such system based in North America.[13]

The U.S. Coast Guard has tested three different laser fluorosensor systems. They found that, while the three systems could successfully detect light refined oil, they were not so successful in detecting the low gravity crude oil produced from California's Monterey Formation (Fant and Hensen, 2006). Laser fluorometry has not yet been successfully utilized for operational support during an actual oil spill.

DRONES, BALLOONS, AND OTHER REMOTE SENSING PLATFORMS

Drone aircraft, also known as an Unmanned Aerial Vehicles, Uninhabited Aerial Vehicles (UAV), or Unmanned Aircraft Systems (UAS), are currently being evaluated for oil spill response. AeroVironment Corp. markets the "Puma" UAS platform that currently is being evaluated by both NOAA and Chevron Shipping Company as a reconnaissance tool for the Shoreline Cleanup and Assessment Technique and Natural Resource Damage Assessment processes. When

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[12] http://www.cencoos.org/data/hfradar

[13] http://www.thestar.com/news/canada/2011/01/12/environment_canada_mothballs_cuttingedge_technology.html

outfitted with a conventional video camera and a TIR imager (7.5 μm to 14 μm), drone aircraft have the potential to deliver information quickly and economically for areas otherwise difficult to access. The quieter nature of small drone aircraft makes this an attractive tool for reconnaissance near biological sensitive areas, such as shorebird roosting sites or pinniped haul out sites. It is noted that flying a UAS still requires special permission from the Federal Aviation Administration (FAA). As of this writing, Vandenberg Air Force Base airspace is the only airspace open (to NOAA) for drone-based remote sensing experimentation.

An Oil Spill Response Organization, Marine Services Response Corporation (MSRC), has an Aerostat (balloon based) sensor platform based in Richmond, CA. Aerostats can be deployed from MSRC's Responder Class vessels or other strategically placed marine or land-based platforms. The Aerostat can be tethered up to 500 feet in accordance with FAA rules and without special permits under most circumstances. It carries a payload consisting of an HD camera for visual images, a TIR camera for oil classification and night viewing, and an Automatic Identification System (AIS) repeater. The primary benefits of the Aerostat includes: 1) unmanned operation; 2) the ability to be used under cloud cover; 3) the ability to be used at night, and perhaps most importantly; 4) the ability to provide locational data to track oil as it migrates and moves.

Remote sensing systems based on ship masts are employed by both MSRC and Clean Seas as tactical tools to aid on-water recovery. MSRC employs the Rutter Sigma S-6 X-Band Oil Detection System. MSRC and Clean Seas both use the FLIR M-625L Infrared camera.

SECTION II: DATA MANAGEMENT WITH GIS

Computing technology has advanced to the point where it is now standard practice to employ complex GIS information in the ICP. Simultaneously, field data collection has been migrating to mobile computing applications which output GIS files that are quickly displayed for real-time situational awareness. From the initial emergency response, through clean-up and sign-off, much data with a spatial component is generated and many disparate data sets are collected. More efficient data integration, management, and visual analysis affords Incident Commanders and Section Chiefs the ability to make informed and timely planning, operational, and strategic decisions during a spill response.

Traditionally, GIS maps were created from field sketches, field notes, and verbal reports. Processing of this data by the GIS Unit in the ICP was very time consuming and prone to error. OSPR's preliminary efforts to streamline and automate field data collection utilized Global Positioning System receivers to record waypoints and track lines. Since then, more elegant electronic field data collection applications for "Wildlife Recovery and Transport", "Resources at Risk" overflights, and the "Shoreline Cleanup and Assessment Technique" have been developed and installed on iPhones and iPads. Other recent advancements allow for real-time aerial remote sensing of the ocean surface for slick detection, and detailed mapping of the slick properties. Also, real-time visualization of near-shore ocean surface current fields is obtained using HFR.

Once data are incorporated into the GIS, a web-based COP is utilized for overall situational awareness and dissemination of relevant geospatial data. During the *Deepwater Horizon* response, NOAA introduced the Environmental Response Management Application® (ERMA), a web-based GIS tool that assists both emergency responders and environmental resource managers in dealing with incidents that may adversely impact the environment. ERMA integrates and synthesizes various real-time and static datasets into a single interactive map, providing fast visualization of the situation and improving communication and coordination among responders and environmental stakeholders. OSPR has worked closely with NOAA to develop, enhance and deploy “Southwest ERMA” as California’s COP of choice for web-based data dissemination and incident situational awareness.

At the Houma, Louisiana ICP during the *Deepwater Horizon* response, many responders were from outside of the region and unfamiliar with the local geography. Area base maps with a standardized coast line and place names were not readily available causing added and unnecessary confusion. As a lesson learned, OSPR and NOAA have since pre-loaded Southwest ERMA with pertinent base maps, charts and spill response planning data from the six California Area Contingency Plans (ACPs). These data are freely available to the general public without requiring any user login credentials.

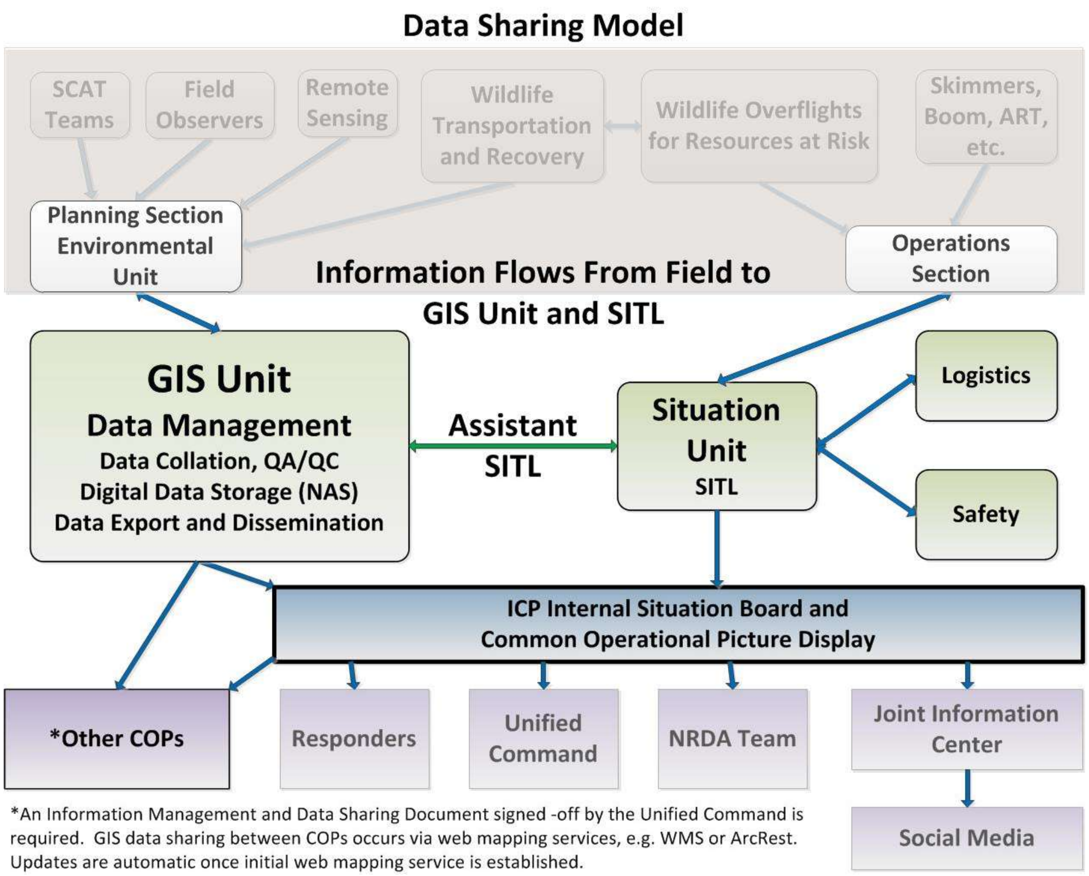

Figure 3. This figure diagrams the flow of information from the field through the ICP.

SECTION III: NATIONAL INTEGRATED OCEAN OBSERVING SYSTEM (IOOS)

The national Integrated Ocean Observing System (IOOS) is a comprehensive system for obtaining ocean information and making it available to those relying on it for both safe navigation and oil spill response. The Integrated Coastal Ocean and Observation Act was signed into law by President Obama in March 2009. This law established NOAA as the authorizing body of IOOS, a partnership between 17 federal agencies and 11 Regional Associations for Coastal Ocean Observing (RAs). In California, two RAs, the Central and Northern California Ocean Observing System (CeNCOOS) and the Southern California Coastal Ocean Observing System (SCCOOS), represent California's coast for the national IOOS. Combined, partners of these two RAs include over 100 state and federal agencies, non-profit programs, industries, and research institutions.

Ocean Observing Systems can provide and package information on sea state conditions (e.g. surface current speed and direction, wave dynamics, tides, subsurface current speed and direction, wind, temperature, and salinity), as well as ship tracking through AIS.

SECTION IV: RECOMMENDATIONS

For a moderate (Tier 2) spill response in California, the recommended remote sensing technology is an airborne integrated multispectral/thermal TIR sensor package such as the TRACS system (described above). This system has been used operationally and successfully for response and evaluating oil spill damages for marine and inland spills in California (e.g. Suisun Marsh - Kinder-Morgan Pipeline, Kern County - Chevron well blowout, and the San Francisco Bay Area - *Cosco Busan*).

For a large scale (Tier 3) spill response in California, an excellent resource to complement the TRACS system for very large area overflight reconnaissance would be the specially equipped Dash-8 pollution surveillance aircraft operated by Transport Canada based in Vancouver, BC[14] and used extensively during the *Deepwater Horizon* response. This Canadian Government equipment may be accessed through the Pacific States British Columbia Oil Spill Task Force Mutual Aid Agreement. Another resource for synoptic coverage is MDA's[15] RADARSAT (SAR) satellites. MDA can deliver interpreted SAR images in real-time (within 1 ½ hrs. after acquisition) and also has contracts with other satellite companies and can therefore provide high resolution imagery from optical satellites (e.g. QuickBird, IKONOS, WorldView 1&2, etc.).

Finally, the California Ocean Currents Monitoring Program (COCMP) HFR network, a state-wide coastal current monitoring network, has proven to be valuable for tracking local ocean surface current fields and for verifying the predictive model for the oil slick trajectory (e.g. NOAA's GNOME or ASA's OilMap). It is of ongoing concern for the oil spill response community that this program remains underfunded, and could become unavailable as a resource in the future.

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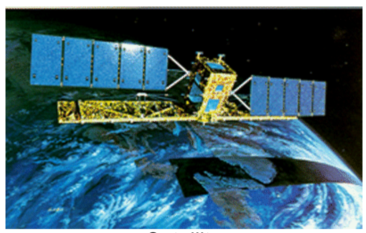
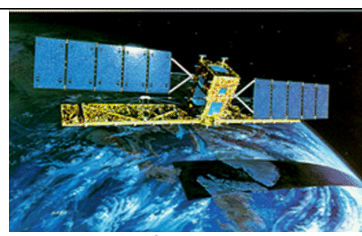
[14] http://www.tc.gc.ca/eng/marinesafety/oep-ers-nasp-2195.htm
[15] http://gs.mdacorporation.com/SatelliteData/SatelliteData.aspx

Appendix

REMOTE SENSING SYSTEMS USED AT THE *DEEPWATER HORIZON* (MC-252) RESPONSE

Vendor	*Tool*	*Platform*	*Applications*	*Time Frame for Delivery*	*Limitations*
Transport Canada MART Pacific, Vancouver	Side Looking Airborne Radar - SLAR Still Photography	 de Havilland Dash-8	**Maps detailed outline of Slick** Oblique Photographs Measures ocean surface roughness.	Two hours after mission completion Fly in the morning, data ready for evening data integration meeting	Potential for false positive due to natural phenomena, dead calm, sea grass, sediment load, etc. Cannot determine oil slick thickness or weathering state
Iceland Coast Guard	Side Looking Airborne Radar - SLAR	 de Havilland Dash-8	**Maps detailed outline of Slick** Measures ocean surface roughness.	Two hours after mission completion Fly in the morning, data ready for evening data integration meeting	Potential for false positive due to natural phenomena, dead calm, sea grass, sediment load, etc. Cannot determine oil slick thickness or weathering state
Ocean Imaging Corp.	Digital Multispectral Camera Thermal Imager Oblique still photography	 NOAA Twin Otter	**Maps oil slick thickness for recoverable vs. non-recoverable oil.** Provides detailed thickness values, sheen through fresh oil and emulsion. Provides geo-referenced data in GIS format in near real time. High detail mapping of slick thickness values. Best for detailed mapping of multiple select targets.	Immediate quick look classification for recoverable oil delivered via email. Detailed image classification in 2-3 hours	Small footprint covers tens of square miles.
U.S. Customs and Border Patrol	Forward Looking Thermal-IR	 Cheyenne PA-42	**Oblique video and still images.** Measures ocean surface temperatures	Within several hours of touchdown	Images and video can be confusing and difficult to interpret unless you are within a known area of oiling.

Icaros, Inc.	Digital Photography	 Light Aircraft	**Digital still frame photography.** Provides geo-referenced data in GIS format	Within several hours of mission completion	Individual frames have large contrast difference from edge to edge.
Airborne Data Systems	ADS Spectra-View	 Piper Navajo	**High resolution multispectral imagery for detection of thick patches of oil**. Provides geo-referenced data in GIS format.	Within several hours of mission completion	Individual frames have large contrast difference from edge to edge. Imagery requires interpretation. More subtle oil features may go undetected.
MDA Geospatial Services	Synthetic Aperture Radar Satellites. RADARSAT 1 and 2	 Satellite	**Synoptic view of entire slick.** Measures ocean surface roughness.	Daily image	Potential for false positive due to natural phenomena such as dead calm, sea grass, sediment load, etc. Cannot determine oil slick thickness or weathering state. Polar orbit, image acquisition dependent on location of satellite.
NASA	Terra and Aqua Satellites. MODIS Multispectral Sensor	 Satellite	**Synoptic view of entire slick.** Multispectral image	Daily image	Cannot determine oil slick thickness or weathering state. Polar orbit, image acquisition dependent on location of satellite.

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