# Adding a Multispectral Aerial System To the Oil Spill Response Arsenal

## *California Finds Benefits in Using Aerial Remote Sensing To Assess the Thick Patches of Oil Amid the Sheens*


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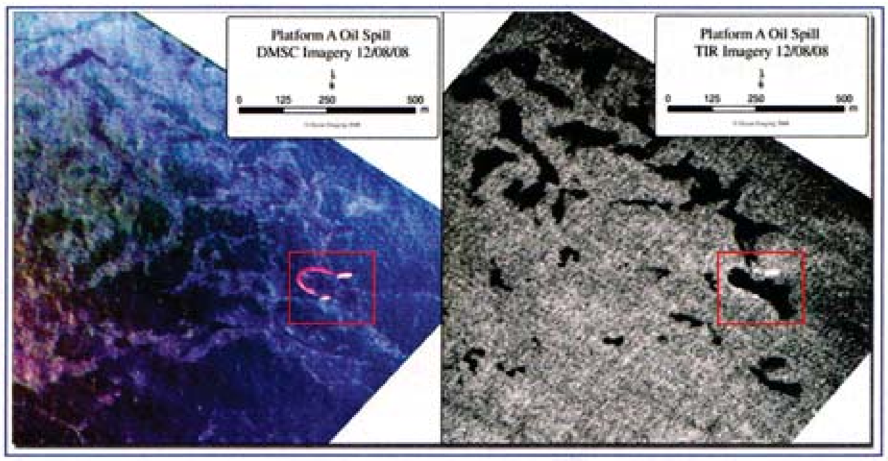



***Multispectral (left) and IR (right) images of portions of an oil spill from a Santa Barbara Channel offshore oil platform. Within the highlighted square are two vessels encircling a patch of recoverable oil with a boom.***

Accurate knowledge of the spatial extents and thickness distributions of an at-sea oil spill is of utmost importance for efficient response. It is obvious that there is a need to know the location of the spilled oil. Just as important, however, is knowledge of the oil film's thickness variations. This is because most petroleum products spread rapidly on the water surface when released into the ocean, with the majority of the affected area becoming covered by very thin sheens.

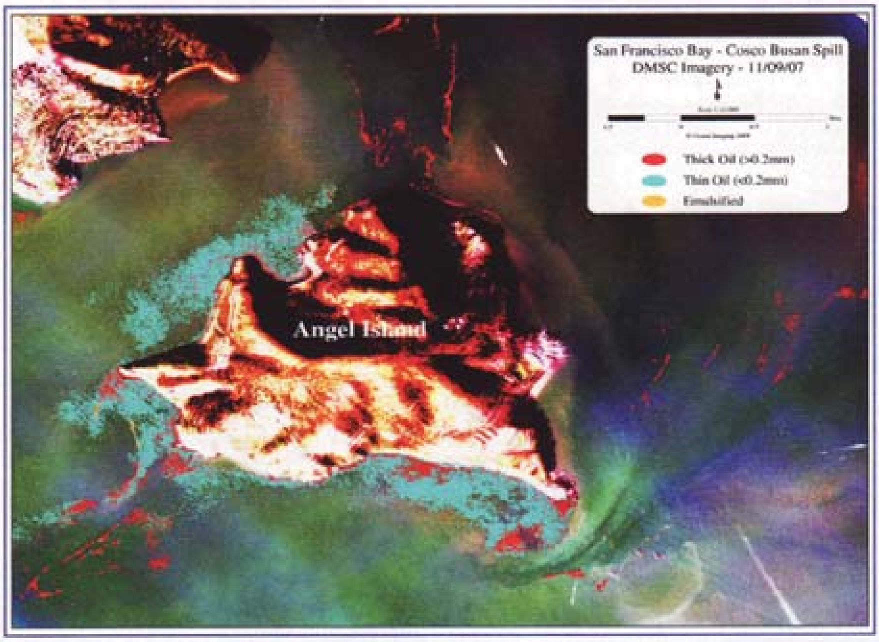
Although the sheens may ultimately affect very large regions, the total amount of oil they contain is small compared with areas covered by thicker oil accumulations. Therefore, in an efficient spill response, available recovery resources such as booms and skimmers must be directed to the thicker portions of the oil slick. In most parts of the world, the necessary recognizance presently relies on visual observations from a low-flying helicopter or aircraft and does not employ sophisticated imaging technologies.

The thickness estimations (sometimes supplemented by drawings or oblique digital photographs) rely on established relationships between the thickness of an oil film and its color appearance.

The methodology suffers from three main complications, however. First, any verbal, graphic or oblique photographic documentation is usually based only on approximate geolocation information obtained through the aircraft's global positioning system. Even if it is later reformatted and input into a computerized geographic information system (GIS), the data can contain a great degree of positional error. Second, visual estimation of oil film thickness distribution is highly subjective and, if not done by specially trained and experienced personnel, tends to be inaccurate. Third, comprehensive visual assessments are impossible at night.

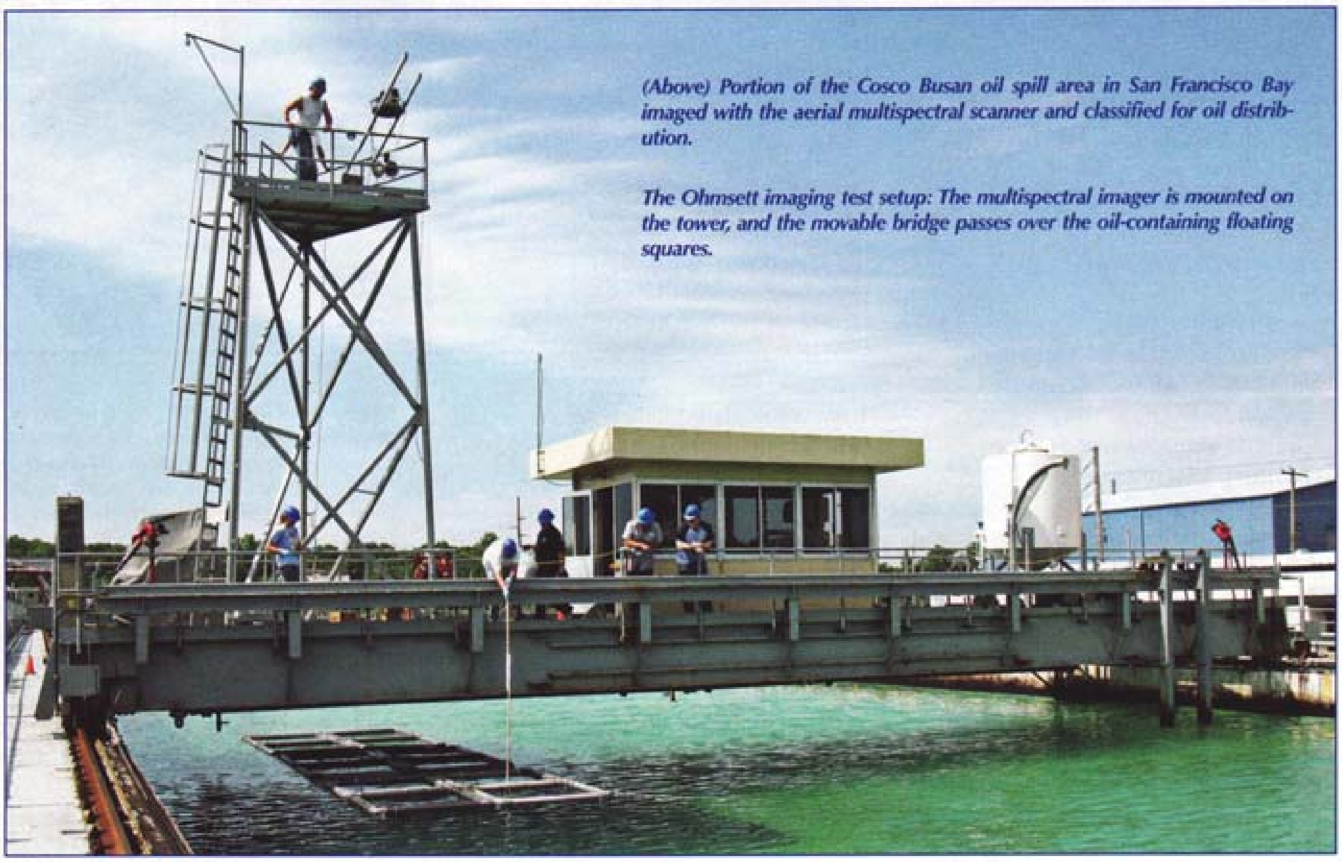
In the past decade, oil spill recognizance and response aircraft in the European Union have been increasingly utilizing remote sensing instruments to aid their operations, most notably side-looking airborne radar and ultraviolet (UV) and thermal infrared (IR) cameras. Currently, such technologies are not being utilized in the United States during oil spill responses, however.

In 2005, the Minerals Management Service (MMS) funded work by Solana Beach, California-based Ocean Imaging Corp. (OI) to develop an aerial oil thickness mapping sensor. The objective was to devise a portable, rapidly deployable imaging and mapping system that could replace visual surveys with a digitally disseminable map of high spatial resolution and accuracy. OI's initial research, done in collaboration with the California Department of Fish and Game's Office of Spill Prevention and Response (OSPR), indicated that oil slick signa-




Norwegian coast, but no such releases have been permitted around North America.

However, natural oil seeps do occur in several regions near U.S. shores, and they offer a relatively steady supply of crude oil slicks for study. The initial development work for the OSPR and MMS-sponsored projects was done over natural seeps that exist in the Santa Barbara Channel in California. OI owns a four-band aerial digital imager, the Digital Multi-Spectral Camera MK2 manufactured by SpecTerra Services Ltd. (Leederville, Australia). This sensor was flown over the seep signatures while ship-based thickness measurements were simultaneously gathered throughout each oil slick target. Continuous reflectance spectra were also obtained over films of various



*(Above) Portion of the Cosco Busan oil spill area in San Francisco Bay imaged with the aerial multispectral scanner and classified for oil distribution.*

*The Ohmsett imaging test setup: The multispectral imager is mounted on the tower, and the movable bridge passes over the oil-containing floating squares.*

tures at sea could be accurately identified and isolated from potential false targets using a combination of several wavelengths within the UV and visible range. For mapping the oil's thickness, the system was to rely on the same color change principles established for traditional visual surveys.

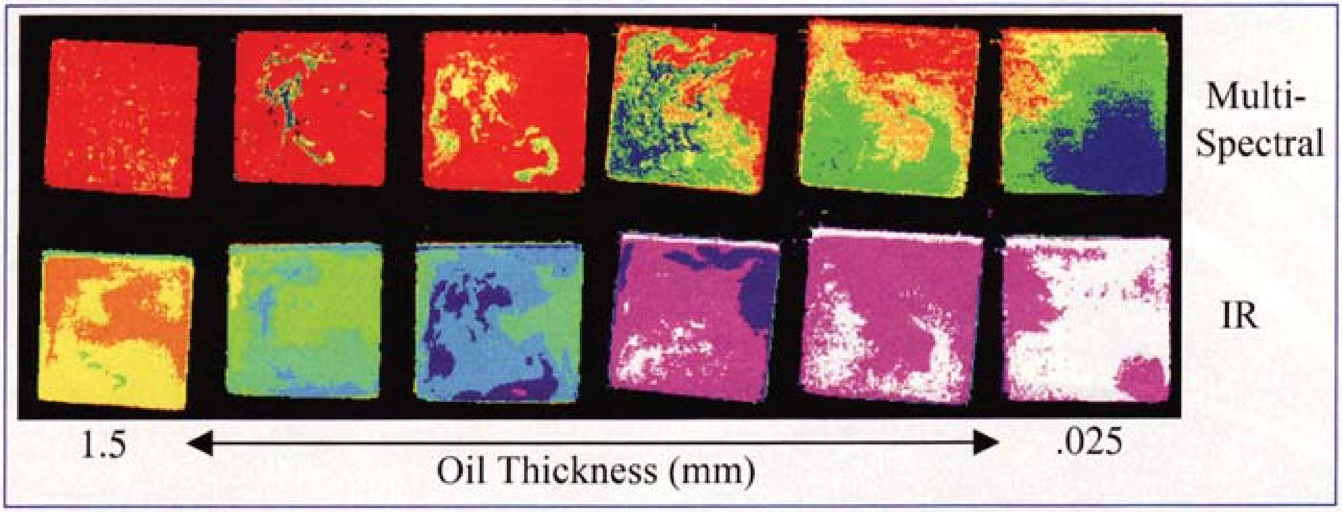
### Locating Research Opportunities

Successful oil spill remote sensing research requires the study of oil-on-water signatures in real-world conditions, including variable background water color, wave effects and sun angle differences.

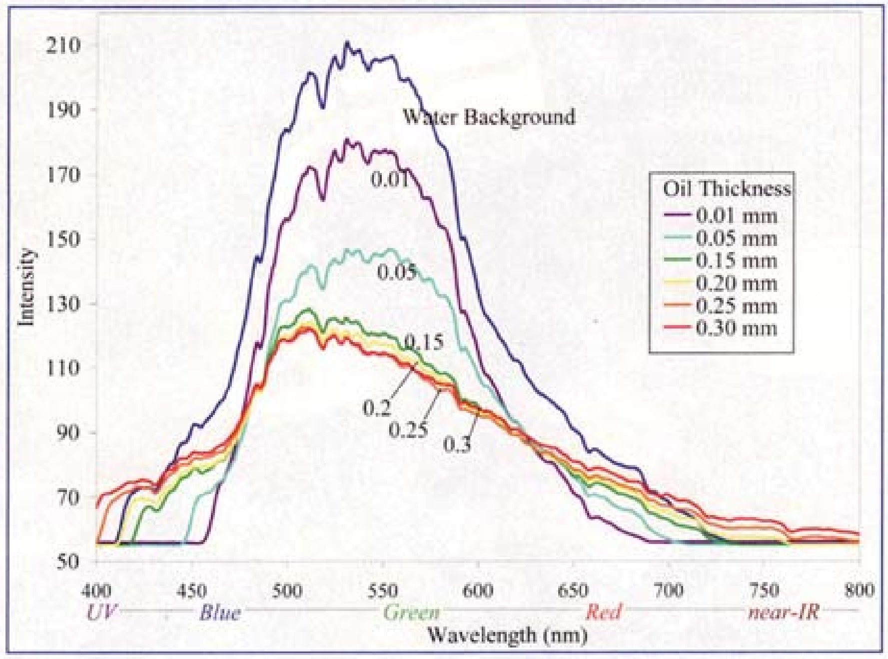
Actual spills occur relatively infrequently, therefore not providing enough opportunity for experimentation, and intentionally releasing petroleum products in U.S. waters is illegal. For several years a large-scale experimental oil release has been conducted annually several hundred kilometers off the Norwegian coast, but no such releases have been permitted around North America.

thicknesses and provided data for choosing imaging wavelength combinations that maximize the color reflectance changes related to increasing oil thickness.

The developed oil-mapping algorithm incorporates two steps: First, a neural network algorithm is used to isolate all of the oil-covered areas (regardless of thickness). Next, a fuzzy logic algorithm utilizes ratios between the four sensor channels to bin the image's




*(Above) Image classification results from a crude oil sequence in the Ohmsett tank. The visible multispectral system loses thickness detection sensitivity with increasing oil film thickness, while the IR sensor component capability increases.*




*(Right) Reflectance spectra of progressively thicker Alaska North Slope crude oil films over a deepwater background. Note the changes in the green-red parts of the spectrum with increasing oil thickness.*

oil-containing pixels into a number of thickness classes.

Experiments over the Santa Barbara Channel seeps also revealed that the multispectral system can readily distinguish between unemulsified and emulsified oil. This capability is important, because some response strategies, such as the application of oil dispersant chemicals, are ineffective on oil emulsions. Therefore, information on the floating oil's weathering state improves decision-making related to applicable response strategies.

## Adding a Thermal Infrared Camera

Utilizing UV and visible multispectral data for oil mapping has several important limitations.

First, as with the case of visual oil thickness estimations, crude and intermediate fuel oil (IFO) films thicker than approximately 0.1 to 0.2 millimeters no longer allow ambient light to fully penetrate the film and thus exhibit a constant near-black or very dark reflectance signature. A UV-visible wavelength imaging system can still accurately detect and map the spatial extents of such films but can no longer be used to estimate their actual thickness. It should be noted that while 0.1 millimeter may seem like a uselessly thin upper measurement limit, many oil spills are commonly composed of films within that range.

Second, the images can only be acquired during daylight, and the system thus offers no nighttime mapping capability. Again, this is also applicable to visual surveys.

Third, refined petroleum products, such as gasoline, diesel, jet fuel and lubricant oils, tend to have no distinct color reflectance signature at thicknesses typically encountered at sea, making their detection with visible wavelengths impossible (they do reflect in the UV and IR).

To counteract these deficits, a thermal IR camera was added to the mapping system in the second phase of the development project. IR image analysis of oil slicks is somewhat more complex than in the visible wavelength bands. Sheens generally cannot be identified, but thin films may appear cooler than surrounding water during both day and night, because petroleum substances have lower emissivity than water. Thicker films tend to trap solar heat input and thus appear warmer than water during the day. After sundown they revert to appearing cooler due to the emissivity difference.

## Test Tank Tryout

The developed algorithms were refined and validated at MMS' Ohmsett facility in Leonardo, New Jersey, in May 2006 and June 2008. Ohmsett's large test tank, which includes a wave generator, provides a unique opportunity to conduct highly controlled tests approximating at-sea conditions. Premeasured amounts of various petroleum products were spread within floating containment squares, creating oil films of known thicknesses. These were then imaged with various cameras mounted on the tower of a movable bridge as it traveled over the sample squares.

The Ohmsett tank was especially useful in acquiring diurnal time series data with the IR imager, which allowed precise observations of the oils' thermal signature changes from day to night. The Ohmsett work resulted in cross-calibration of the multispectral and IR imagery, resulting in extending the system's thickness measurement range to several millimeters and establishing nighttime mapping capability. The Ohmsett tests also allowed imaging of relatively thick oil films, which could not be found in the Santa Barbara Channel, where the thickest unemulsified films tend to be in the 0.1 to 0.3-millimeter range.

Under operational conditions, a remote-sensing-based oil spill mapping system is only valuable if the processed data can be delivered to the National Response Team's unified command and field response crews in a timely fashion. Working with OSPR, OI developed a Web-based GIS server to which the oil distribution/thickness maps can be delivered in near-real time. It is even possible to send the data directly from the aircraft in-flight using wireless networks. The server allows interactive access to the maps by different groups and agencies involved in the response. It also allows layering of other important information over the remotely sensed imagery, such as environmental sensitivity data, a coastline photo archive, shipping lane boundaries and bathymetric charts.

### Experience in the Field

While the aerial mapping system was still under development, the M/V *Cosco Busan* struck a bridge in San Francisco Bay off California and leaked about 53,500 gallons of IFO bunker fuel on November 7, 2007. A major response effort was mounted, but it was initially hampered by fog that covered the accident region and by the strong tidal currents that quickly spread the oil into other parts of the bay. Traditional visual surveillance flights were conducted each day by NOAA, and maps based on these flights were distributed to the response agencies.

On November 9, OSPR authorized OI to conduct a test flight over a portion of the oil-impacted region with the aerial mapping system. The processed imagery showed that most of the spilled oil existed in the form of either sheens or long, narrow streamers of relatively thick and recoverable oil, aligned with rapidly changing current shear zones. The multispectral GIS map allowed rapid and accurate pinpointing of the location of each recoverable streamer—an advantage not available from the visual survey map product, which outlined only general areas of sheen with patches of brown oil.

Then, in December 2008, the aerial mapping system was first utilized in true operational mode during the response to an offshore platform spill in the Santa Barbara Channel. Imaging was done during oil recovery operations to guide the recovery effort and again two days later to verify no more recoverable oil existed and response operations could be suspended.

In each case, the processed maps were posted on the GIS server within 35 minutes of data acquisition. The IR images provided the fastest and clearest means to rapidly locate patches of recoverable oil.

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### Conclusions

From experience gained during the system's use in these two events, it's clear that the operational utilization of remote sensing during oil spills provides three primary, yet separate, functions.

First, the system allows for the rapid acquisition of spatial extent and thickness information that is needed to efficiently manage response and oil recovery. For this stage, spatially detailed and accurate information on where the thickest oil accumulations are located is more important than very detailed measurement of variations in the oil's thickness. The developed system appears to accomplish this well.

Secondly, the system provided thickness analysis of image data over the entire spill to derive general parameters, such as an estimate of total volume spilled. This can usually be done with less of a time constraint. The developed system has limitations, since its algorithm bins the oil-contaminated pixels into oil thickness classes. This results in a total volume range rather than a single number. To date, validation tests show that a ±29 percent range generally achieves the 95 percent confidence interval. While this may appear quite broad to some, it is a significant improvement over most existing capabilities.

The third primary function of the system is to record the spatial distribution of the spill over time, document contact with biological resources, such as eel grass or kelp beds, and serve as input for the post-response cooperative natural resource damage assessment. ■

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