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Standard Guide for Selection of Airborne Remote Sensing Systems for Detection and Monitoring of Oil on Water[1]

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1. Scope

1.1 This guide provides information and criteria for selection of remote sensing systems for the detection and monitoring of oil on water.

1.2 This guide applies to the remote sensing of oil-on-water involving a variety of sensing devices used alone or in combination. The sensors may be mounted on vessels, in helicopters, fixed-wing aircraft, unmanned aerial vehicles (UAVs), drones, or aerostats. Excluded are situations where the aircraft are used solely as a telemetry or visual observation platform and exo-atmosphere or satellite systems.

1.3 The context of sensor use is addressed to the extent it has a bearing on their selection and utility for certain missions or objectives.

1.4 This guide is generally applicable for all types of crude oils and most petroleum products, under a variety of marine or fresh water situations.

1.5 Many sensors exhibit limitations with respect to discriminating the target substances under certain states of weathering, lighting, wind and sea, or in certain settings.

1.6 This guide gives information for evaluating the capability of a remote surveillance technology to locate, determine the areal extent, as well as measure or approximate characteristics of oil spilled upon water.

1.7 The values stated in SI units are to be regarded as standard. No other units of measurement are included in this standard.

1.8 Remote sensing of oil-on-water involves a number of safety issues associated with the modification of aircraft and their operation, particularly at low altitudes. Also, in some instances, hazardous materials or conditions (for example, certain gases, high voltages, etc.) can be involved. *This standard does not purport to address all of the safety concerns, if any, associated with its use. It is the responsibility of the user of this standard to establish appropriate safety, health, and environmental practices and determine the applicability of regulatory limitations prior to use.*

1.9 *This international standard was developed in accordance with internationally recognized principles on standardization established in the Decision on Principles for the Development of International Standards, Guides and Recommendations issued by the World Trade Organization Technical Barriers to Trade (TBT) Committee.*

2. Significance and Use

2.1 The contributions that an effective remote sensing system can make are:

2.1.1 Provide a strategic picture of the overall spill,

2.1.2 Assist in detection of slicks when they are not visible by persons operating at, or near, the water's surface or at night,

2.1.3 Provide location of slicks containing the most oil,

2.1.4 Provide input for the operational deployment of equipment,

2.1.5 Extend the hours of clean-up operations to include darkness and poor visibility,

2.1.6 Identify oceanographic and geographic features toward which the oil may migrate,

2.1.7 Locate unreported oil-on-water,

2.1.8 Collect evidence linking oil-on-water to its source,

2.1.9 Help reduce the time and effort for long range planning,

2.1.10 A log, or time history, of the spill can be compiled from successive data runs, and

2.1.11 A source of initial input for predictive models and for "truthing" or updating them over time.

3. Remote Sensing Equipment Capabilities and Limitations

3.1 The capability of remote sensing equipment is, in large measure, determined by the physical and chemical properties of the atmosphere, the water, and the target oil. There may be variations in the degree of sophistication, sensitivity, and spatial resolution of sensors using the same portion of the electromagnetic spectrum and detector technology. Sensors within a given class tend to have the same general capabilities and typically suffer from the same limitations.

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3.2 Combinations of sensors offer broader spectral coverage which, in turn, permit better probability of detection, better discrimination, and effective operation over a broader range of weather and lighting conditions. Certain combinations, or sensor suites, are well-documented, and their use is particularly suited to oil spill response missions.

3.3 The performance of virtually all sensors can be enhanced by a variety of real-time, near real-time or post processing techniques applied to the acquired data or imagery. Furthermore, image or data fusion can greatly enhance the utility of the remote sensing output or product. Similarly, there exists a variety of technological considerations and organizational ramifications that relate to the delivery of the remote sensing information to the user.

3.4 Certain parameters need to be identified and quantified to provide an oil spill response decision-maker with all of the information needed to best respond to a spill. These are:

3.4.1 Location—of the approximate center and edges of the spill,

3.4.2 Geometry—source or origin, total area, orientation and lengths of major and minor axes, fragmentation, and distribution,

3.4.3 Physical conditions—oil appearance, entrained debris,

3.4.4 Environmental conditions—wave height and direction; water temperature; position of oceanic fronts, convergence and divergence zones,

3.4.5 Proximity of threatened resources, and

3.4.6 Location of response equipment.

3.4.7 Thickness or relative thickness of the slick.

3.5 Remote sensing can contribute to all of the above data needs. Depending on the spill situation and the employment of remote sensing, some of this information may already be available, or can be determined more cost-effectively by other means. For example, in a response mode, or tactical employment of remote sensing, it is likely that the source, general location and type of oil have been reported well in advance of the launch of the remote sensing platform. In a regulatory or patrol context, this information may not be available. The spill situation influences the priorities among the elements of information and, thereby, influences the selection priorities for sensors.

3.6 A responder may require the data on an oil spill, 24 hours per day, independent of the prevailing weather.

3.7 Information from remote sensing is required in a timely manner. Strategic or enforcement information, such as the overall extent and location of a spill, should be available preferably within two to four hours from information gathering to presentation.

3.8 Tactical information, such as steering information for response vessels, should be available in as little as five minutes from detection to communication. The acceptable data delivery time is a function of the dynamics of the slick, proximity to critical areas, and the availability of clean-up resources.

3.9 Thermal imaging may provide relative thickness information useful to oil spill countermeasures, that is information that the slick is thicker than sheen.

3.10 The passive microwave sensor is currently available to give information on oil thickness.

3.11 Table 1 lists sensors based upon their mode of operation. Summary information on their advantages and disadvantages is presented.

3.12 Table 2 presents a summary of key attributes which generally influence the selection of remote sensing instrumentation.

3.13 Table 3 addresses the mission specific aspects of sensor selection.

4. Summary

4.1 The information presented in this guide should be considered a starting point for sensor selection. In addition to the context of use and the attributes of the various types of sensors, the system planner will have to give due consideration to the capabilities of the aircraft and the information needs of the users before finalizing the system design. Both sensor technology, and image and data analysis capabilities are evolving rapidly. Some equipment is not commercially-available and requires assembly and in some cases requires development. Up to two years lead time may be required for some equipment.

TABLE 1 Sensor Characteristics

Sensor/ Band	Principal of Operation	Positive Features	Limitations
Visual	Operate in, and near, the (human) visible spectrum (400 to 750 nm). Using photographic films, scanners with one or more narrow band detectors or charge coupled devices (CCD) to capture an image.	Equipment is widely available, generally inexpensive, light and easily accommodated on most any aerial platform. Imagery is in every-day use and the layman can easily relate to its content. This characteristic makes the imagery an excellent base for recording and presenting other data.	Oil is generally perceptible over the entire visible spectrum, but not uniquely so. As such, instances of not being able to discriminate the oil from its background, or differentiate it from other substances or phenomena in or on the water's surface, lead to frequent non-detects and false positives. Night vision cameras may extend the operational window, but visual technologies are limited by available light.
Infrared	While the infrared (IR) spectrum ranges from 750 nm to 1 mm, the bulk of the available remote sensing systems operate in the thermal or mid-IR, 3 µm (3000 nm) to 30 µm (30 000 nm). Within this range there are two predominant sub-groups operating at 3 to 5 µm and 8 to 12 or 14 µm. The latter range offers the most useful data for oil spills.	Fresh oil shows a contrast to open water in the thermal infrared. This characteristic is not unique to hydrocarbons. Slicks thicker than about 20 to 70 µm[A] can be seen. Newer IR cameras have excellent thermal discrimination, fairly good resolution, are light-weight, have modest power demands, and typically have both digital and video outputs.	Sheen may not be detectable. Other heterogeneities such as high seaweed or debris content, oil in or on ice, oil on beaches, etc. may render the oil undetectable in the IR.
Ultraviolet	Oil is highly reflective in the ultraviolet (UV–200 to 400 nm).	Very thin (<10 nm) layers of oil can be detected in the UV.[B] Thus, even sheen, a common regulatory definition of oil pollution, can be delineated. UV cameras have fairly good resolution, are light-weight and have minimal power demands.	High UV reflectance is not unique to oil. Sun glint, biogenic and other materials and phenomena can yield strong returns in the UV. This technology is limited to available light situations, and is best used in combination with other sensors, typically IR.
Radar	Oil has a damping effect on high frequency, low amplitude (1 to 10 cm) capillary waves. These waves, yielding a "rougher" surface, return considerably more radar energy to the receiver than calm water, in the absence of oil. As such, under the proper conditions, oil can appear as a low return, dark area in a larger, bright field of un-oiled waves. Specially tuned Side Looking Airborne Radar (SLAR) and Synthetic Aperture Radar (SAR) are two types suited to oil detection. Ship-borne radars can be optimized to detect oil slicks.	Radar has some unique advantages over other oil spill sensors: it can operate day or night; it can operate in times of reduced visibility; it can operate at higher, safer and more fuel-efficient altitudes. Typical ranges are 10 to 50 km. Ship-mounted radars have a range of typically 25 km.	Oil is not the only source of calms. Other, naturally occurring substances and phenomena can give rise to smooth water.[C] If the prevailing wind is less than about 1.5 m/s, there will not be enough "roughness" in oiled water to create the necessary roughness contrast. Likewise, above about 6 m/s the calming effect of, at least thin, oil begins to diminish.[D] The potential for false positives is high. Airborne radar equipment is expensive and it requires fairly extensive modifications to an aircraft, thus adding to both the acquisition and the operational costs.
Microwave Radiometer	Oil is a stronger emitter of microwave radiation than water (emissivity factor of 0.8 versus 0.4, respectively).[E] Therefore it shows up as a bright area against a darker background.	The passive microwave radiometer has been demonstrated to detect oil on water even under low visibility conditions.	The technology is subject to the same limitations as radar. This is an evolving technique requiring additional development and demonstration before a commercial unit is marketable. Current units are installed in dedicated aircraft and this trend is likely to continue in the near term.
Fluoro-sensors	Oil targeted or illuminated with UV light will adsorb this energy and re-emit, or fluoresce, in the visible band. Other materials fluoresce as well, but there is enough spectral uniqueness to oil to render it readily discernable. In fact it is possible that various generic types of oil and petroleum products can be differentiated.The coherent light from a laser permits the delivery of more energy from greater distances making an airborne fluorosensors feasible.	The laser fluorosensor permits the positive identification of oil and even permits some discrimination between types of oil. It appears to be the only sensor available today that permits the detection of oil against complex backgrounds as is the case with oil on beaches and in, or with, the ice.	Laser fluorosensors are fairly bulky and require significant modifications to relatively large, dedicated aircraft. Laser fluorosensors require flights as low as 1000 feet (300 m) to provide sufficient illumination by the laser. Non-scanning instruments provide only a narrow footprint of data.

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[B] Fingas, M. F. and Brown, C., "Review of Oil Spill Remote Sensing" Marine Pollution Bulletin, (83), 1, pp. 9–23, 2014.
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