THE VALUE OF AIRBORNE SENSORS IN OIL SPILL RECOVERY OPERATIONS–A CASE STUDY FROM AN OFFSHORE OIL SPILL IN THE NORWEGIAN SEA

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INTRODUCTION

Various factors influence the success of oil spill recovery operations. Parameters such as weather conditions, oil properties, shoreline substrate types, infrastructure, types of equipment, organization of the response, pre-planned procedures, and exercises can all affect the outcome of a clean-up operation. The number of factors affecting the outcome of a recovery operation tends to increase with the complexity of the operation. However, even for less complex operations like recovery of oil at sea that do not involve beach cleaning and restoration, several aspects may have an impact on the success of the operation.

In 2003, there was an acute oil spill from a sub sea installation in the Norwegian Sea. The decision makers made a significant effort in using aerial surveillance and monitoring of the oil slicks as tools for increasing the effectiveness of the operation. Both monitoring in close vicinity to the oil recovery systems and large scale surveillance were introduced. This paper addresses the importance of cooperation between aerial monitoring and mechanical oil recovery at sea relative to the efficiency of the oil recovery operations.

THE CASE/INCIDENT

One day in early spring 2003, just before midnight, the operator of an oil production platform in the Norwegian Sea received indications of oil on the sea surface. Necessary routine measures were taken, and a helicopter with infrared (IR) camera was sent out to investigate if there actually was oil spilled in the vicinity of the platform. The pilots observed oil on the water and reported their findings back to the platform. Because of poor light conditions at night, the pre-installed infrared camera was used to detect and quantify the geographical area covered by oil. A NOFO system, consisting of an Oil Recovery (OR) vessel and towboat, was mobilized and directed towards the platform. At the break of dawn the NOFO system reached the oil spill. Oil was evenly distributed throughout the area and the OR vessel employed a heavy offshore booms to collect the oil. As the oil piled up in the back of the boom, skimming of oil from the sea surface to the tanks on board the OR vessel was initiated.

An airplane designed for surveillance of oil pollution at sea was also mobilized to survey a larger area for oil that might have drifted away from the spill site. The information from the airplane was quickly sent to the emergency response leaders so a decision could be made with regards to the overall strategy for the operations. Based on this decision, a second NOFO system was mobilized for oil spill recovery.

During the following days, the surveillance airplane provided emergency response leaders ongoing updates of the overall field situation, enabling them to re-direct the two NOFO systems to the areas containing the most oil. The helicopter transmitted live IR images to the bridge on one of the OR vessels for real time guidance on a small geographical scale. Even within the oil slicks, the thickness and volumes of oil varied greatly, and real time guidance of the oil recovery systems on such a small scale was extremely beneficial.

After 7 days, expert personnel on board the surveillance plane, the authorities, and the operator (oil company), concluded that there was no more collectable oil left on the sea surface. As a result, the oil recovery operations ended and the OR vessels headed for port to unload their cargo.

TECHNICAL RESOURCES

NOFO system

The two oil recovery vessels employed in this operation were both equipped according to the NOFO and OR standards. The OR standard is a Det Norske Veritas (DNV) classification for handling of oil in oil recovery operations. The NOFO standard specifies the requirements for preparation of a ship for the installation of NOFO equipment and includes a supply vessel (OR), a towboat, 400 meters of RoBoom 3500 ocean boom and a Transrec 350 skimmer. The skimmer heads used for this operations were FRAMO HiWax skimmers designed for high viscous oils, but a traditional weir skimmer can also be used as part of the standard NOFO system. Figure 1 presents a NOFO system.

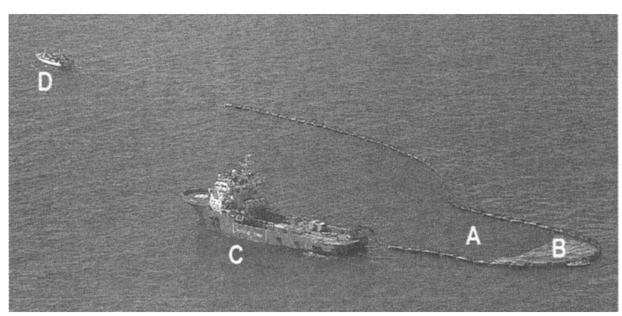

FIGURE 1: A NOFO SYSTEM; A-OIL AGGREGATING AREA, B- OIL COLLECTED IN THE BOOM, C-OIL RECOVERY VESSEL, D- TOWBOAT.

Helicopter with IR camera and down link

The helicopter on the platform was equipped with an IR camera. With the right setting, such a camera can detect oil on the sea surface and it has the ability to differentiate between areas with high and low film thickness. The down link system consists of a transmitter unit (sending on 2.54 GHz) and a receiver. The transmitter is placed on the helicopter while the receiver is placed on the bridge of the ship. The IR camera transmits live images from the helicopter to the oil recovery vessel. A stable link is obtained within a radius of 30 nautical miles (nm) (55 km).

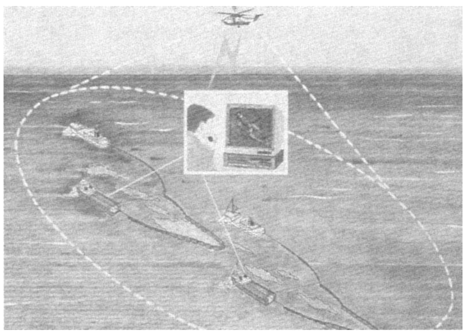

FIGURE 2: THE IR SYSTEM. THE TRANSMITTER ON BOARD THE HELICOPTER IS TRANSMITTING IR IMAGES TO THE RECEIVERS ON THE BRIDGE OF TWO OR-VESSELS. PERSONNEL ON BOARD THE SHIPS GET AN OVERVIEW OF THE LOCAL SPILL SITUATION.

Surveillance airplane (LN-SFT)

The surveillance airplane LN-SFT is used throughout the Norwegian continental shelf by Norwegian Coastal Administration (NCA) to detect oil pollution at sea. This is a propeller plane which, because of its relatively low speed (compared with jet planes), can make tight turns and make close-up observations. The plane is equipped with a range of sensors, such as ultraviolet (UV) scanner, forward looking infrared (FLIR) camera, and side looking airborne radar (SLAR). It also has a geographical information system (GIS) for mapping of flight routes and location, and for mapping the spreading of the oil slicks.

OIL VOLUME ESTIMATES

During the operation in 2003, the following main observations were used for oil volume estimates:

1) IR-video recorded by the SAR helicopter on Day 1
2) Observations by the surveillance airplane on Day 3
3) Observations by the surveillance airplane on Day 4
4) Observations by the surveillance airplane on Day 5

The observations made by the surveillance airplane on Days 3-5 provided information on the total area of the oil slicks. The film thickness varied significantly throughout the slick. Even expert personnel, conducting measurements and collecting samples in the field, concluded that it was nearly impossible to estimate an average film thickness. The field experts were only able to ascertain that the film thickness had to be less than 1mm. During the first few days, the crew from the surveillance airplane were not able to quantify the film thickness due to damaged equipment on board the plane. The surveillance airplane crew also had difficulty estimating the area covered with emulsified oil. This uncertainty was mainly due to the patchy distribution of emulsion, the thin oil film, and patches of clean water surface within the slick area. Because of the high degree of uncertainty, it was decided not to base the estimated total volume of oil from the observations on these three days (days 3, 4 & 5).

The observations made from the SAR helicopter on day 1 were documented on IR-video and photo images. This documentation, together with verbal communication with the helicopter crew formed the basis for the estimated total oil volume. These observations contained information on the slick at an early phase and are much more consistent in terms of area and thickness of oil slick than the subsequent observations.

On Day 4, measurements and samples of oil were taken in the field. Film thicknesses of 3-4 mm were found in some patches of emulsion. These were, however, the thickest parts of the emulsion, and were not representative for the entire slick area.

Another important parameter measured in the field was the water/oil ratio in the emulsion. The field crew found that the emulsion contained approximately 67% water. The specific measurements were made 3 days after the spill, and parameters used in the calculation were based on predictions from weathering analyses 6 hours after the spill which estimated an evaporation loss of 30% and a water content of 15%.

Volume estimates based on an IR-video recorded by the SAR helicopter on Day 1 at 00:41

From the IR video, an estimate of the slick area was made with the aid of GIS (Geographical Information System) applications. The geographical positions of the offshore installations were known, and were valuable parameters when mapping the oil slick with GIS tools. The total oil slick was estimated to be approx. 6 km", including oil with a film thicknesses above 5μm (as detected by the IR camera). All film thicknesses below 5μm are known as rainbow and sheen, involving very small volumes.

The entire oil slick was IR-black, no IR-white was observed. This IR color indicates that the film thickness was within the range of 5 to 200 microns. Furthermore, large parts of the slick were observed to have "discontinuous true oil color", indicating a film thickness of at least 50 microns, according to the revised Bonn Agreement Oil Appearance Code (BAOAC). Overall, the film thickness was estimated to be in the range of 50–200 microns, although not likely at the high end of the scale since no IR-white was observed.

Based on the Bonn Agreement Oil Appearance Code (BAOAC) and available information, half the oil slick (3 km") was defined as "discontinuous true oil color" and the other half (3 km") as "metallic".

Visual observations of oil provide only information about ranges of thickness. Table 1 also reflects oil fate and effect values such as evaporation and emulsion in the calculation of volume.

When taking specific information for the sub sea installation into consideration, the official figure for the initial release was somewhere in the range of 300–800 m" oil.

Observations made by the surveillance airplane on Day 3

On day 3, an oil slick 29 km long and 25 km wide, was observed approximately 35nm (65 km) east of the discharge point, with a total slick area estimated at 360 km". It was further estimated that 5% of the total slick area was covered by emulsion.

Observations made by the surveillance airplane on Day 4

An oil slick 37 km in length and with an average width of 10 km was observed approximately 23 nm (42 km) east of the discharge point, with a total slick area estimated at 370 km". Again, 5% of the total slick area was covered by emulsion.

Table 1

BAOAC code	Oil volume on surface (m")	Oil without water	Fresh oil (incl. evaporation)
Discontinuous true oil color (3km")	150-600	128-510	183-729
Metallic (5-50) (3km")	15-150	15-150	21-214
Total			204-943

Observations made by the surveillance airplane on Day 5,

Two oil slicks were observed:

1) Approximately 4 nm (7 km) north east of the discharge point, total slick area 27 km". It was estimated that 3% of the total slick area was covered by emulsion.
2) Approx. 25 nm (46 km) north east of the discharge point, area 224 km". Again, 3% of the total slick area was covered by emulsion.

IMPORTANCE OF AIRBORNE IR INFORMATION

The main goal for NOFO systems is to locate and recover as much oil as possible. For this purpose, they need detailed information on the whereabouts of the oil and specifically where the thickest parts of the oil slick are located. During darkness, visual observation of oil films is nearly impossible. Even in daylight, good visual information may be hard to obtain due to low observation angle from the ship. Overall, the possibility of detecting oil varies greatly with weather conditions. Counterlight, the amount and color of clouds, and particles in the atmosphere (rain, snow, fog) all impose different interpretation of visual information.

The NOFO systems include large booms, causing both general maneuvering operations and relocation of the systems to take time. Thus, for the NOFO systems to be the most effective, the positioning according to oil drift and the specific whereabouts of the thickest parts of the oil slick need to be well founded. The IR imaging plays a crucial role in determining relative thickness within oil slicks. Having IR information available in real time on the bridge of the OR vessel enables the On-Scene-Commander to set up the NOFO systems in a proper manner and in time to ensure efficient uptake of surfaced oil.

This case study clearly demonstrates the benefits of using airborne IR cameras for mechanical oil recovery at sea on three levels. The first level involves the ability to identify oil slicks on the sea surface, the second level involves directing the oil combating systems to the areas containing most oil, and the third level involves providing detailed information on relative thickness for each oil slick, collectively giving decision makers necessary information to combat the oil in the most efficient way.

EFFECTIVENESS OF RECOVERY OPERATIONS

Technical investigations indicate that oil was released over a period of approximately five hours. While the release initially was estimated at 100 m^3, subsequent calculations updated this estimate to between 500 and 800 m^3.

Measurement of oil volumes in the collection tank onboard the OR vessel showed recovery of 180 m^3 oil at the completion of the oil recovery operation. Mass balance calculations indicated that an equivalent fraction of the release had evaporated. No estimate was available on the fraction of oil dissipated or dissolved in the water.

Effectiveness of the recovery operation is in the present context defined as the fraction of available oil recovered. Oil that has evaporated or dissolved/dissipated in the water is not included.

Selecting the lower end of the range of the release estimate, the effectiveness of the operation is close to 60 %. The corresponding value when selecting the higher end of the range is 30 %.

Given the relatively long release period and the low film thickness in the slicks, a recovery efficiency of 30–60 % is considered very satisfactory. Active use of the surveillance aircraft was a key factor in achieving these results.

R&D ON SLICK DETECTION

Increased efficiency in reduced light and visibility

Limited operational light in the winter season is one of the major challenges for oil spill response, particularly during the winter in the northern areas of Norway. On this basis, NOFO initiated a project in 2003 to evaluate the potential for increased effectiveness of oil recovery in reduced light and visibility.

In this project, a number of technologies and approaches were evaluated, including:

- Infrared video and infrared scanners
- Micro Wave Radiometer (MWR) and Laser Fluoro Sensor (LFS)
- Satellite based radar (Synthetic Aperture Radar–SAR)
- Airborne radar (Side Looking Airborne Radar–SLAR)
- Traditional maritime radar with post processing of data
- Low light cameras and light sources outside visible spectrum
- Drift models, Metocean buoys and sonars

Based on the conclusions from this project, NOFO has embarked on a project to develop and implement a ship based radar system for detection of oil spills. This project focuses on preprocessing of the radar images and is the first step toward the goal of achieving an oil spill response that is independent of light and visibility.

In October 2004, both the radar system and the FLIR and downlink system were tested in a field experiment off the coast of western Norway. In this experiment, a limited amount of oil was released to the sea. The initial results were promising as the IR system was able to detect oil films of very low thickness.

SATELLITE

To evaluate the applicability of satellite data in detection of oil spills, NOFO has initiated a project involving regular downloads and interpretation of images from the satellites Radarsat-1 and Envisat. Over a period of one year, this information will be evaluated on the basis of applicability and cost effectiveness.