REMOTE SENSING

25.1 INTRODUCTION

.1 Remote sensing in general is the detection and identification of phenomena at a distance from the object of interest using human capabilities or special sensors. Modern remote sensing instruments are normally based on optical, electronic or, sometimes, chemical techniques. During the last decades, considerable steps forward have been achieved in the development of new sensors but also in the improvement of existing sensors and their application.

.2 When dealing with oil or chemicals spilled at sea, it is essential to be able to "find" the slick and to identify the type of substance and to estimate the volume. Bearing in mind that slicks are often difficult to see due to thin layers or absence of colours the application of electronic remote sensing techniques is of great value. Observers in spotter planes will have a better chance of finding slicks from the altitude they fly at, but even trained observers need reasonable light conditions. The conditions required are not always available. All Contracting Parties have access to remote sensing facilities and have established an aerial surveillance organisation.

.3 Details of aircraft and sensors installed available to respective Contracting Parties are listed in the Aerial Surveillance Handbook. This chapter provides a summary of the different types of sensors including a brief description of the application.

.4 This annex deals with the remote sensing of surface slicks. It should be pointed out that the use of ship-based equipment such as side-scan-sonar to detect sunken objects or optics for the observation of sunken pollutants falls equally under the heading of this chapter and is just as relevant to the scope of the Bonn Agreement. However, it is not dealt with here.

25.2 SENSORS - GENERAL REQUIREMENTS

.1 To be of use in dealing with (oil) pollution incidents, remote sensing instruments have to provide the capability to give a clear and unambiguous indication of the pollution on the sea surface from a reasonable distance under normal conditions. In addition it is desirable to have means to identify the type of pollution and the source the pollution originates from as well as a means of estimating the volume. In this respect it is mentioned here that for estimations of oil pollution the observers in Bonn Agreement member states also make use of the Bonn Agreement Pollution Observation Log (BAPOL). The procedure to quantify a detected slick is described in the Aerial Surveillance Handbook.

.2 For airborne application, the equipment should fit into the selected type of aircraft being compatible with the aircraft power supplies. It is recommended that all sensors are integrated into one operating system and signals are real-time presented on a display as well as recorded on tape or disc, including data annotation. The recorded data can thus be analysed in a ground processing station if required.

.3 Sensors fall into broad categories according to their mode of operation. Active sensors emit a signal, and measure some feature of the interaction of the signal and the target - usually by analysing the return echo. Radar systems and Laser Fluorimetry are examples of active sensors used for pollution detection. Passive sensors do not emit a signal, but rely instead on emissions from the target - usually the reflection or transmission of ambient electromagnetic radiation. Ultra violet and Infra red line scanners as well as passive microwave radiometers are examples of these types of sensors.

.4 In general, active scanners can operate at any time of day and to some extent can penetrate clouds. Passive sensors will only be functional when there is sufficient ambient radiation, and this usually means during daytime.

25.3 SIDE LOOKING AIRBORNE RADAR (SLAR)

.1 The SLAR is an active sensor that measures the roughness of the sea surface. Microwaves in the region of three centimetres are transmitted in pulses and the reflection from the surface is used to build up a radar picture on both sides of the aircraft. Capillary waves on the sea surface will give a strong echo and unusually smooth areas such as those caused by a pollution affecting the surface tension resulting in a dampening of the capillary waves, will show up against the surrounding clear water.

.2 SLAR is the most common device in use at present. Under normal conditions, between wind forces 1 to 7 Beaufort, the system will cover an area of up to 25 kilometres on one side of the aircraft. When flying undisturbed at an altitude along a straight track the image will cover a total area of 50 kilometres (both sides of the aircraft) although there will be a gap directly under the aircraft corresponding to 1.5 times the altitude. Within the area covered, the presence of even thin layers of surface pollution can be detected. The spatial resolution of SLAR lies around 20 metres on average, which means that two objects at the same distance from the antenna should have a separation of at least 20 metres to be detected as two objects. For oil detection the polarisation of the system is Vertical and for ice detection often Horizontal polarisation is used.

.3 The main disadvantage of the SLAR, that counts for all radar systems, is that it responds to any phenomena that suppresses capillary waves. For example certain current patterns, ice and surface slicks associated with biological activity can all produce false targets. Conclusively it is emphasised that though SLAR is the primary long range detection sensor the only information obtained is an indication that “something” is floating at the surface probably requiring further investigation.

25.4 SYNTHETIC APERTURE RADAR (SAR)

.1 With respect to the subject, detection of surface pollution, the SAR is similar to the SLAR. From a technical point of view there are some important differences. Where the SLAR uses a fixed antenna length, the SAR system can define the antenna length by sampling echoes over a period of time. The mechanical part of the antenna is very small. The advantage of the SAR is its improved spatial resolution that remains the same over the entire area covered. For special applications multi-polarised SAR can be delivered. Improved resolution is strongly related with the cost involved. Resolution down to one metre is possible, but at relatively high costs.

.2 At this stage of development SAR is used in satellites and in special projects such as terrain height mapping. Operational use of SAR in aircraft with the objective of detecting oil is not yet common. As developments continue and bearing in mind the likelihood of lower costs, it might be worthwhile considering a SAR, especially in cases where multi tasking is applicable to the surveillance system.

25.5 ULTRAVIOLET LINE SCANNER OR CAMERA (UV)

Surface pollution, especially oil, is a good reflector of the ultraviolet component of sunlight. An ultraviolet scanner or camera is a passive device detecting reflected ultraviolet with a wavelength of about 0.3 micrometers. The sensor is mounted vertically in the belly of the aircraft and can build up a continuous image of an entire slick, even the extremely thin areas, as the aircraft passes over the slick. It cannot distinguish between types of pollution or different layer thickness.

25.6 INFRARED LINE SCANNER (IR-LS)

.1 The IR-ls is very similar in operation to the UV-ls and the two are very often combined in a UV-IR line scanner. The sensor detects infrared radiation with a wavelength in the band of 8-12 micrometers emitted from the oil. These layers of oil radiate more slowly than the surrounding clear sea and shows up as variations in grey levels (or in defined colours). Thicker layers (greater than about 0.5 millimetres) will absorb sunlight more rapidly than the surrounding sea and show white on the display.

.2 The InfraRed sensor provides the capability within limits to obtain information on the relative layer thickness of oil slicks on the water surface. The sensor does not penetrate the water. It is not as sensitive to oil as the UV and so comparison of the outputs from the two sensors, especially when presented real time parallel to each other on the display, will show the thicker parts of the slick. This information is essential when combating activities are executed, as the combating vessels should concentrate on these thicker parts. It is obvious that other temperature-related effects, such as cooling water discharges, can mislead the IR sensor.

25.7 MICROWAVE RADIOMETER (MWR)

The passive sensor MWR is rather similar to the UV/IR-ls. It detects microwave radiation with wavelengths between 0.3 and 3 centimetres. Oil appears always to be at higher temperatures than seawater in the microwave region and the temperature depends on the thickness of the oil layer. The relationship is not a simple one, but by careful selection of operating wavelengths and careful analysis of the results the system provides the capability of a relatively accurate account of the volume of oil in the slick. A minimum layer thickness of 0.1 millimetre of oil is required to make proper use of the system. Recognizing that operational discharges according the MARPOL regulations or even much higher will not result in layer thickness over 0.1 mm.

25.8 LASER FLUORESENSOR (LFS)

This is an active sensor emitting an intense beam of coherent light, generated by a laser, to the sea surface immediately below the aircraft. The receiving apparatus is designed not to respond to the direct reflection of the beam, but to detect and to analyse the fluorescence of the pollution resulting from the laser strike. Currently laser is being operationally tested in Germany and indications are that it can provide information on the type of pollution. The experience is limited so far.

25.9 THERMAL IMAGER

Related to video cameras, but designed to operate in the infra-red region, imagers will generally not give such precise description of the surface slick as an IR-ls. However, they have the advantage of providing a real-time image of the entire slick, unlike a line scanner that builds the image up line by line as the aircraft passes overhead.

25.10 LOW-LIGHT LEVEL TELEVISION CAMERA (LLLTV)

The LLLTV can be filtered to operate in the ultraviolet region and so provide an ultraviolet analogue to the thermal imager. When used in the visible region, LLLTV can provide the possibility of imaging ship’s names or other identifying features in near darkness.

25.11 IDENTIFICATION CAMERA (IC)

Detection of discharging ships during hours of darkness is possible by the applications provided by the SLAR or SAR. Identification of the ship is a necessity with respect to gathering evidence. The identification camera is a sensor consisting of an Intensified CCD chip in a camera. The combination of the camera and an infrared flash provides the tool. A snapshot taken can be processed by frame grabbing software resulting in the ship’s name. Using the sensor is preferable to pointing a strong light at the ship since this is considered to be an act of hostility.

25.12 PHOTOGRAPHIC CAMERA (PHOTO)

Conventional photography provides a valuable, simple and readily understood record of the scene of an incident or operational discharge. When vertically mounted in the aircraft the camera contributes to the evidence to an official statement. Oblique photography in general satisfies the public and the Courts as part of the evidence rather than the more complex imagery from the other sensors. It is recommended that cameras are an integrated part of the remote sensing system and that on the photographs data-annotation is printed.

25.13 VIDEO CAMERA (VC)

Much the same applies to video recordings as to photography. The advantage of video is that it provides a more instant record and of course a moving picture. After landing the crew can immediately present an overview of the situation at sea, provided required equipment is available.

25.14 FURTHER DEVELOPMENTS AND IMPROVEMENTS

.1 Sensor manufacturers presumably will continue, in some cases at the request of the user, to develop new sensors or improve the existing ones. Proposals are expected in near future, in particular on the difficulties encountered by the operational users concerning the discrimination between substance discharged and capabilities to estimate volumes.

.2 Worth mentioning is the application of spectral imaging scanners. Remote sensing for the purpose of the detection of oil slicks, in some countries, is slowly shifting towards earth observation in the broadest sense. The objective is to make more efficient use of the available means (aircraft) and also to fill gaps in the existing sensor package.

.3 In general it is recommended to closely follow the market and study the new sensors or improvements. Digital photo cameras, improved navigation (dGPS), airborne AIS and others can be very useful tools for the Bonn Agreement members.

25.15 SYSTEMS

.1 As already stated, sensor operation can be most effective when handled through one integrated sensor system. A one-man operating system provides the capability to switch on/off the sensors and to route the data to storage and presentation. The operator selects all sensors required and, depending on the data presentation needed to identify the pollution, combines the data from different sensors. Navigational data obtained from the aircraft system is used as input into the operating system and superimposed on the sensor data.

.2 Data handling, for presentation and storage, is important so that the raw data can be processed in a ground processing station after landing. Storage on retractable hard disc, floppy disc, or tape are possibilities. Images as presented on the display to the operator can also be stored on video tape for quick presentation to authorities.

.3 In addition, as a result of data handling in a digitised form it is possible to transmit the data directly to a ground station. Some systems allow for the direct transmission of imagery from an aircraft using either fast but short-range VHF or slower but long-range HF radio. Recognising that when a ship is caught “red-handed” and is bound for a port in the coastal state the advantage of a down link system can be that images or photos are directly sent to the Port State Control authorities.

25.16 PLATFORMS

.1 World wide, most experience with remote sensing has been obtained using small fixed-wing aircraft. Selecting a type of aircraft for remote sensing operations depends on a list of aspects based on the objectives to be met once having the tool: the size and weight of the instruments to be installed, the area to be covered and the endurance. Selection of the sensor package also depends on the tasks to be fulfilled. Search-and-Rescue normally requires a homing device; border patrol may be difficult without a 360 radar. The standard package for pollution patrol flights consists of SLAR, UV/IR-ls, photo-cameras and can be extended with a MWR and/or LSF. If operation during darkness is an option an Identification camera is useful.

.2 A number of different types of aircraft are in use by the Bonn Agreement Contracting Parties and can be visited during Bonn Agreement exercises; the aircraft are described in the Aerial Surveillance Handbook.

.3. Attempts have been made to use special sensors, such as cameras and thermal imagers, on board vessels. Mounted on the masts sometimes images can be obtained. However, in general it is found that the platforms are not stable and even when mounted in high masts still too low for good use.

.4 In the event of an actual combat operation captive balloons, lifted from a vessels deck, are useful tools. Mounted on a platform hanging under the balloon, a video camera and preferably an IR-camera provides details on the oil slick to be combated directly to the master of the vessel. The imagery assists the master to manoeuvre his ship towards and into the oil slick (thicker parts).

25.17 SATELLITES

.1 The detection of oil and other harmful substance discharges by means of remote sensing systems in aircraft has been described in previous paragraphs. Relatively new is remote sensing by means of satellites. The synthetic aperture radar (SAR) on board the satellites, as installed in the ENVISAT, the ERS-2 and the Radarsat, proved in various international test programmes to be able to detect water surface phenomena even as small as 200 m², from an altitude of 900 km. The Low Resolution SAR images (100 metre) are considered to be comparable to SLAR with regard to detectability.

.2 Although the satellite SAR does not discriminate the type of pollution, it provides an indication of a possible pollution as well as a clear indication of the location and the dimensions. It is reiterated that the satellite cannot (yet) identify the pollution nor the possible polluter and in that respect has the same qualification as the airborne SLAR or SAR. The detected spot has to be verified. Other disadvantages compared to airborne surveillance are the inflexibility of the system as a result of fixed orbit and the repeating cycle. On the other hand, satellite recordings are independent of weather conditions that are limiting aircraft (like fog or freezing rain). Also the width of the radar coverage path is an advantage; 100 kilometres in case of the ERS-2, up to 500 kilometres of Radarsat.

.3 Satellite data, if received in near real time (minimum within 1 hours after the satellite pass), is useful as an early warning system in case of combatable spills. The use of near real-time satellite data requires a user community with the capability to verify possible surface pollution (oil slicks) by an aircraft. The combined use of satellite and aerial surveillance may provide a cost-effective solution for countries with certain geographical and climatological conditions.

.4 In order to take advantage of the availability of satellite SAR images it is recommended to prepare an inventory of the orbits of the satellite and the area covered. The covered area can then be incorporated into the aircraft routing. Furthermore the acquisition schedule of the satellite can be used to adjust the flight program of a remote sensing aircraft or even reduce the number of flights by having the aircraft on stand-by if the satellite covers the area of interest. On receipt of the imagery obtained from satellite the aircraft may be diverted to check possible pollution or, on occasions when no pollution has been detected the aircraft may focus on areas not covered by satellite.

.5 It is emphasised that satellite SAR can easily provide an overview of possible floating pollution over relatively large sea areas. An early warning system requires follow-up by airborne surveillance at least to verify by human eye the existence of the detected slick. In many studies a general conclusion is that satellite SAR contributes valuable information but will not replace aerial surveillance.

.6 To follow the latest developments on satellite surveillance, the EC has established a European Group of Experts on Satellite Monitoring and Assessment of Sea-Based Oil Pollution (EGEMP). The Secretariat of EGEMP is managed by EC-JRC. More information is available on http://EGEMP.JRC.IT.

25.18 MAJOR POLLUTION INCIDENT

.1 When dealing with an oil spillage, the initial function of the remote sensing aircraft will be to build up a picture of the extent of the pollution, and to identify the areas of most concern. The aircraft should run across the affected area using SLAR/SAR at an altitude that provides the best overall image of the slick(s).

.2 The preliminary investigation can then be supplemented by scanning the larger or more threatening parts of the slick(s) using close range sensors, such as infrared, ultraviolet, microwave radiometry and laser. Photographs or video should be taken whenever possible, including some of the casualty causing the pollution. Monitoring the spreading and weathering of the slicks should be continued at regular intervals.

.3. Another role of the remote sensing aircraft is to direct and guide recovery vessels or spraying aircraft. This will require extended periods in the area identifying relatively thicker parts or more threatening patches of oil.

.4 It is particularly important during an incident that the crew of the reconnaissance aircraft reports to the control centre at regular intervals, both to relay the current situation and to check for a change in instructions - the first stages of an incident are always particularly fluid. Regular returns to base will be necessary to provide the hard-copy imagery for the on-scene and overall commanders, unless direct down-link facilities are available to transmit imagery from the aircraft to surface vessels and offices.

25.19 ROUTINE PATROLS

.1 The primary objective in routine patrolling is to detect combatable oil slicks at an early stage, to encounter ships and platforms in the act of discharging oil illegally, and to gather sufficient evidence for a prosecution. Contracting Parties have agreed a co-operative approach to aerial surveillance, and this is set out in Chapter 4 of this manual.

.2 Prior planning of the pattern of surveillance is important. Baseline information from earlier surveillance or from ad-hoc observations will indicate those areas in which most effort should be concentrated. Statistical techniques can be used to relate surveillance intensity to the probability of intercepting an illegal discharge - this will indicate the level of effort necessary and allow conclusions to be drawn about the incidence of MARPOL contravention.

.3 During a mission the crew will maintain the BONN AGREEMENT POLLUTION OBSERVATION LOG, noting all relevant information on mystery slicks and actual polluters observed. A separate form will be used for reporting polluting vessels according IMO regulations.

.4 Possible offenders should be imaged and photographed using the techniques set out in sections 25.10-25.13. It is important that the photographs and imagery show that the vessel is the only possible source of the oil. The vessel's name should be photographed, if possible in a way that identifies it unambiguously as the offender, and recorded in the log. Communication should be established to invite the person on the bridge to provide information on last port of call and destination as well as to explain the discharge observed.

.5 On return to base, if not directly from the air, the evidence from the offence should be treated as evidence to court and all precautions required by the law of the land should be applied in securing it and transferring it to the competent authorities. For each routine mission, the logs should be taken for interpretation and statistical analysis and the results recorded in a database for use in periodic reports and future planning.