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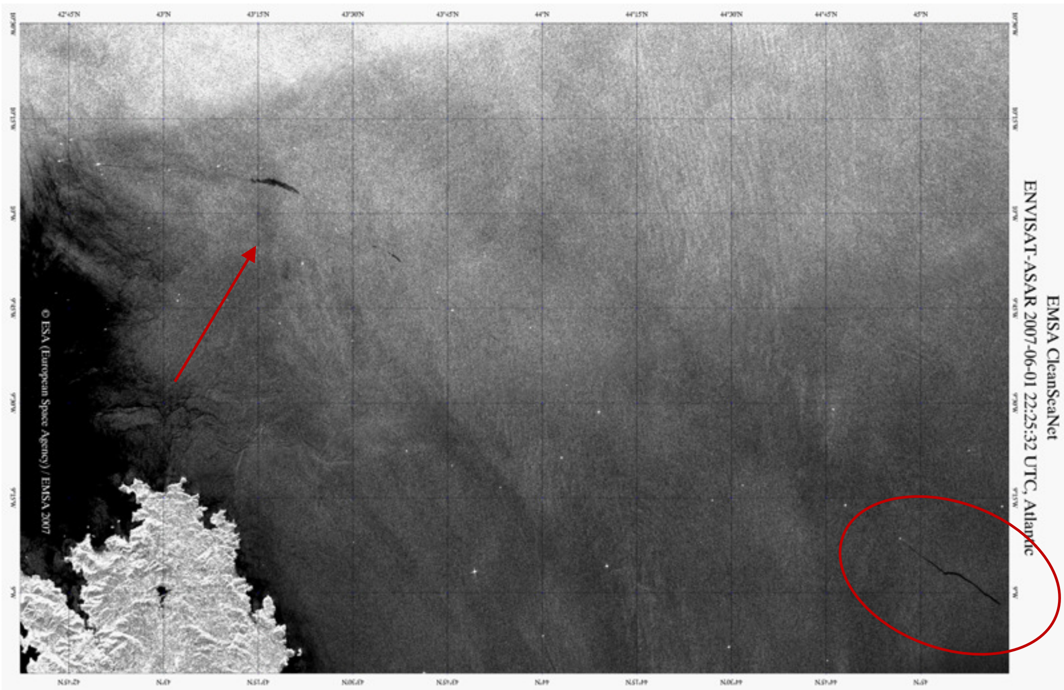

CleanSeaNet

Surveillance of sea-based oil spills by radar satellite images

Bachelor of Science Thesis in Shipping and Marine Technology

ANA PAULA ROBALO DA SILVA RODRIGUES

Department of Shipping and Marine Technology
Bachelor's Degree in Nautical Science
CHALMERS University of Technology
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Department of Shipping and Marine Technology

Chalmers University of Technology

SE-412 96 Gothenburg

Sweden

Telephone + 46 (0)31-772 1000

Figure 1 (cover):

Oil spill off the north-west coast of Spain (© European Space Agency / EMSA 2007)

This image, taken by ENVISAT-ASAR on 1 June 2007 off the coast north-west Spain, shows 2 large oil spills. The 1st one, in the bottom right of the image has very distinct linear dark features with sharp edges and uniform backscattered signal area with a potential polluter vessel connected to it (visible as a bright white spot). The 2nd one, in the left top corner, has diffuse shape but high contrast typical of a spill that has been discharged several hours ago (source: EMSA 2009a).

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Preface

This report constitutes my Bachelor of Science thesis for Nautical Studies at Chalmers University of Technology in Gothenburg, Sweden.

The European Maritime Safety Agency (EMSA) is a relatively new organization. In spite of its significance in what concerns European maritime operations and standards I can not recall having heard any reference to it during my three years at school. I chose this subject because it provided an opportunity to bridge that gap and to promote EMSA.

I first learned about EMSA's recently developed CleanSeaNet service when preparing a lecture about the International Convention for the Prevention of Pollution from Ships (MARPOL 73/78), and quickly became more interested about it: how does it work?, how useful is it?, how interesting is it for Sweden?

My expectations with this thesis were to reach a deeper understanding of EMSA and its activities, in particular of their CleanSeaNet service, explore how relevant it is for Sweden, and be able to convey this knowledge to others in an approachable way.

I would like to thank those who have been helpful during the course of my work for their guidance, in particular my supervisor Mikael Hägg, my teachers Göran Johansson and Göran Lindholm, and to my school colleagues Simon Häggbom and Abram Fryxelius for their tips.

Abstract

THIS IS A BACHELOR OF SCIENCE DEGREE THESIS about the European Maritime Safety Agency's CleanSeaNet satellite service, with focus on its operational effort to prevent illegal oil discharges, to understand its purpose and concept, as well as its significance to Sweden.

A brief introduction to the European Maritime Safety Agency opens the report, followed by an analysis of the CleanSeaNet and its relevance for Sweden.
Central problems dealt with in the report are:

- What is CleanSeaNet? Why is CleanSeaNet needed? How does CleanSeaNet monitor oil spills?
- How useful is CleanSeaNet service for Sweden? What are the advantages/disadvantages? How could Sweden contribute to CleanSeaNet?

A case study methodology was conducted, in which relevant and reliable literature was reviewed, and interviews where carefully selected and carried out. The resulting data was analyzed and formed a platform for the subsequent discussion and conclusion of this report.

Results show that CleanSeaNet was established from the need to put a stop on oil pollution in European waters, and of evidence that could document illicit oil discharges. CleanSeaNet's satellite surveillance and alerts of possible oil spills in less than 30 minutes are particularly useful for combating illegal oil discharges at sea when combined with other methods such as aerial surveillance, AIS/LRIT information and oil drift models. Results show that the Swedish Coast Guard was already experienced with satellite surveillance when CleanSeaNet was integrated in their surveillance routines.

CleanSeaNet is a positive and reliable service, with ambitious targets. The 2nd generation CleanSeaNet promises important improvements, such as the integration of CleanSeaNet information with AIS/LRIT information.

Gothenburg, the 9th of December, 2009
Ana Paula Rodrigues

Sammanfattning

DETTA ÄR EN KANDIDATUPPSATS som handlar om satellittjänsten CleanSeaNet som European Maritime Safety Agency driver, med fokus på dess operationella ansträngningar att förhindra illegala oljeutsläpp, dess syfte och arbetssätt, samt dess betydelse för Sverige.

Rapporten inleds med en kort introduktion av European Maritime Safety Agency och därefter följer en analys av CleanSeaNet och dess relevans för Sverige.
De huvudsakliga problem som behandlas i denna rapport är:

- Varför behöver vi CleanSeaNet? Hur kan CleanSeaNet övervaka oljespill?
- Hur användbar kan tjänsten CleanSeaNet vara för Sverige? Vilka är för- respektive nackdelarna? Hur skulle Sverige kunna förbättra CleanSeaNet?

Arbetet utfördes som en fallstudie. Relevant och pålitlig litteratur studerades, och noggrant valda och insiktsfulla intervjuer genomfördes. Den resulterande informationen analyserades och anlade grunden för diskussionen och slutsatsen i denna rapport.

Resultaten visar att CleanSeaNet etablerades på grund av behovet att sätta stopp för miljöförstöring genom oljespill i europeiska farvatten och för att samla bevismaterial vid olagliga oljeutsläpp. Den sattelitbevakning som CleanSeaNet erbjuder tillsammans med larm för eventuella oljespill inom 30 minuter är särskilt användbar vid bekämpning av olagliga oljeutsläpp till sjöss, när den kombineras med andra metoder såsom flygbevakning, AIS/LRIT information och avdriftsmodeller för olja. Resultaten visar att Svenska Kustbevakningen redan var erfarna vad gäller sattelitbevakning när CleanSeaNet integrerades i deras bevakningsrutiner.

CleanSeaNet är en positiv och pålitlig tjänst och med en ambitiös målsättning. Andra generationens CleanSeaNet lovar redan viktiga förbättringar, såsom integration av information från både CleanSeaNet och AIS/LRIT.

Göteborg, 9 december 2009
Ana Paula Rodrigues

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List of acronyms and definitions

Acceding Countries	Turkey, Albania, Croatia, the former Yugoslav Republic of Macedonia, Bosnia and Herzegovina, Montenegro, Serbia and Kosovo. http://ec.europa.eu/enlargement/countries/index_en.htm
Agency	The European Maritime Safety Agency. Also referred to by the acronym EMSA. http://emsa.europa.eu/
AIS	Automatic identification system. A transponder designed to be capable of providing information about the ship to other ships and to coastal authorities automatically. http://imo.org/Safety/mainframe.asp?topic_id=754
ASAR	Advanced SAR (onboard the ENVISAT satellite) "ASAR: An Advanced Synthetic Aperture Radar (ASAR), operating at C-band, ASAR ensures continuity with the image mode (SAR) and the wave mode of the ERS-1/2 AMI" (ESA 2009).
CleanSeaNet	A service from EMSA aimed to reduce maritime pollution. http://cleanseanet.emsa.europa.eu/
Copenhagen Agreement	An agreement drawn in 1993 by the Nordic countries (Norway, Iceland, Sweden, Finland and Denmark) for the Cooperation concerning Pollution Control of the Sea after Contamination by Oil or other Harmful Substances. www.copenhagenagreement.org
CSA	Canadian Space Agency. http://www.asc-csa.gc.ca
CTG MPPR	Consultative Technical Group for Marine Pollution Preparedness and Response at EMSA. http://emsa.europa.eu/
EEZ	Exclusive Economic Zone.
EFTA	European Free Trade Association: Iceland, Liechtenstein, Norway and Switzerland.
EMCIP database	European Marine Casualty Information Platform. A database being developed by EMSA with statistics and data analysis related to marine casualties. http://emsa.europa.eu/end185d007d003d002d008.html
EMPOLLEX	Marine Pollution Expert Exchange Program. EMSA's network designed to stimulate international cooperation on training and information sharing to help tackle large oil pollution incidents. http://www.emsa.europa.eu/empollex/

EMSA	European Maritime Safety Agency. Also referred to as “the Agency”. http://www.emsa.europa.eu/
ENVISAT	Environment Satellite (ESA). http://envisat.esa.int/pub/ESA_DOC/ENVISAT/ASAR/asar.ProductHandbook.2_2.pdf
EQUASIS database	A database created by EMSA centralizing information on the world’s merchant fleet about Port State Control inspections, class and P&I cover. http://emsa.europa.eu/end185d012d004.html
ERS-2	European Remote Sensing satellite nr. 2. http://envisat.esa.int/pub/ESA_DOC/ENVISAT/ASAR/asar.ProductHandbook.2_2.pdf, 07
ESA	European Space Agency. http://www.esa.int/esaCP/index.html
EU	European Union.
EuroGOOS	European Global Ocean Observing System. This association of agencies, based in Sweden, develops the operational oceanography in the European Sea areas and adjacent oceans. www.eurogoos.org
HELCOM	Helsinki Commission - the governing body of the "Convention on the Protection of the Marine Environment of the Baltic Sea Area" - more usually known as the Helsinki Convention. http://www.helcom.fi/helcom/en_GB/aboutus/
HNS	Hazard and Noxious Substances. http://emsa.europa.eu/
IMO	International Maritime Organization.
IVL	IVL Svenska Miljöinstitutet/IVL Swedish Environmental Research Institute. http://www.oljejour.ivl.se
KSAT	Kongsberg Satellite Services. A Norwegian commercial satellite center. www.ksat.no
LRIT	Long Range Identification and Tracking.
MARED	Marine Equipment performance and testing standards database. www.emsa.europa.eu
MAR-ICE	EMSA’s information network used in Marine Chemical Emergencies. https://extranet.emsa.europa.eu/index.php?option=com_content&task=view&id=89&Itemid=145

MARPOL73/78	The amended International Convention for the Prevention of Pollution from Ships, 1973 and its 1978 Protocol. www.imo.org
MS	Member States of the European Union.
MSS	Maritime Support Services.
PSC	Port State Control.
Radar	Radio detection and ranging.
RADARSAT 1/2	Advanced Earth observation satellites equipped with SAR/ASAR(Radarsat2), operating at C-band. Developed in Canada and launched in 1995/2003 by the Canadian Space Agency. http://envisat.esa.int/pub/ESA_DOC/ENVISAT/ASAR/asar.ProductHandbook.2_2.pdf,
Remote sensing	The detection and identification of phenomena at a distance from the object of interest using human capabilities or special sensors. http://earthobservatory.nasa.gov/Features/RemoteSensing/
SafeSeaNet	A service from EMSA related to vessel traffic and reporting. https://extranet.emsa.europa.eu/index.php?option=com_content&task=view&id=96&Itemid=162
SAR	Synthetic aperture radar (onboard the European Remote Sensing satellite (ERS-2) "SAR: Synthetic Aperture Radar wave mode provides two-dimensional spectra of ocean surface waves. In image mode the SAR provides high resolution two-dimensional images with a spatial resolution of 26 m in range (across track) and between 6 and 30 m in azimuth (along track). Image data is acquired for a maximum duration of approximately ten minutes per orbit." (ESA 2009).
SeaTrackWeb	The official HELCOM oil drift forecasting system. http://seatrack.smhi.se/seatrack/
SMHI	Swedish Meteorological and Hydrographic Institute. www.smhi.se
STCW	Standards of Training, Certification and Watchkeeping. www.emsa.europa.eu
STCW database	Standards of Training, Certification and Watchkeeping. A database being developed by EMSA to centralize information on seafarers employed on EU registered vessels (certificates, endorsements, etc…) and on the institutions where they are educated. http://emsa.europa.eu/end185d007d001d002.html

STIRES	SafeSeaNet Tracking Information Relay and Exchange System https://extranet.emsa.europa.eu/index.php?option=com_content&task=view&id=94&Itemid=161
STMID database	Shore-based Traffic Monitoring Infrastructure database. A database being developed by EMSA in order to centralize information on the European traffic monitoring infrastructure (VTS, AIS, SAR). https://extranet.emsa.europa.eu/index.php?option=com_content&task=view&id=82&Itemid=136
THETIS System	The Hybrid European Targeting and Inspection System. An information system being developed by EMSA to support a new Port State Control regime. https://extranet.emsa.europa.eu/index.php?option=com_content&task=view&id=55&Itemid=169
VTS	Vessel Traffic Services.

PART I – INTRODUCTION

1 Background

This study is about the European Maritime Safety Agency's (EMSA) CleanSeaNet service, with focus on its operational effort to prevent illegal oil discharges. It aims to understand its purpose and concept.

The report opens with an introduction to EMSA, followed by an analysis of CleanSeaNet service and its relevance for the surveillance of sea-based oil spills in Sweden.

This study was compiled for students as the main reader group.

2 Purpose and scope

The purpose of this work is to explore the origin and concept of EMSA's CleanSeaNet service and describe it in depth, in an understandable way. In addition, investigate the Swedish perspective on CleanSeaNet.

3 Approach to the problem

Problems/Questions raised:

• Why does Europe need the oil-spill monitoring service CleanSeaNet? What is its concept? How is does it work? How useful is CleanSeaNet?

• Is it integrated in Sweden's actual sea-based oil spills monitoring system? How useful is CleanSeaNet service for Sweden? What are the advantages/disadvantages? How could Sweden improve CleanSeaNet?

4 Method

This thesis follows the *case study* research method, as it seems to be more adequate to the *explorative* purpose of the study than action research, experiment or survey would be. Based primarily on *qualitative data*, it consists of a thorough study of a subject, where little or no influence is exerted on it. The *flexible design* of this method permits to adapt to changing circumstances as the study progresses. (Höst et al. 2006) Information sources include literature study, visits to EMSA, EDISOFT and the Swedish Coast Guard, and interviews. The findings gathered in the research process will then be analyzed and related to previously studied subjects in the Nautical Sciences Program, such as Environment, Oceanography, Meteorology, Instrumentation and Radio Communication. Finally, the subsequent results and conclusions are to be summarized and presented to the reader in a clear way.

A detailed description of the methodology applied to this study is given in *Part III – Methodology*.

5 Delimitations

Economical and legal aspects of CleanSeaNet are beyond the scope of this report, as it focuses on the operational aspect only. These constraints are set due to the time limit of 400 hours for the production of this study, but they will not affect the understanding of the CleanSeaNet's concept.

PART II – THEORY

This section introduces the context of EMSA and CleanSeaNet, presents background information on oil and a familiarization about remote sensing equipment used in surveillance of ship-sourced oil spills.

It was prepared based mostly on *official* information from *selected* leaflets, brochures and electronic information by EMSA, *scientific* information presented in IVL Swedish Environmental Research Institute's home page and on an *interview* with EDISOFT during a recent *visit* to their bureau in Lisbon.

This section is intended to be a concise introduction, presenting just what is essential to understand the contents that follow in *Part IV – Results*.

1 A brief description of the European Maritime Safety Agency (EMSA)

The European Maritime Safety Agency is the founder of the CleanSeaNet satellite service. For this reason, and in order to place CleanSeaNet in context, this opening section will provide an introduction about EMSA and its activities.

EMSA was established in 27 June 2002 by the European Parliament and the Council, through Regulation (EC) No 1406/2002 (EU 2002), to address growing concerns about maritime safety and pollution in Europe, where shipping represents a very large slice of its transport sector. In fact, more than 90% of the traded goods are brought into/taken out from Europe by sea (EMSA 2009d). As maritime traffic in Europe increased, so did the risk it represented to the European marine environment.

Realizing this, Member States gradually recognized that there was a need to start acting *in coordination*, if they wanted to see these risks *effectively* reduced. The oil spill caused by the tanker Erika, off France's North coast in December 1999, catalyzed the process that led to the foundation of EMSA.

In November 2002, shortly after EMSA's creation, another large oil spill, off the Galician coast, reinforced the need for such an Agency. The Member States, through the work of EMSA, expect to achieve a coordinated integration of their efforts in matters of maritime safety, increased efficiency of maritime legislation, the harmonisation across the EU of methodologies, procedures, information and standards, and the establishment of a joint action plan for responding to shipping disasters in European waters. According to article 1 of the founding regulation referred above, the objectives of EMSA are to

> *[...] ensure a high, uniform and effective level of maritime safety and prevention of pollution by ships within the Community,*

by means of

1. providing **technical and scientific assistance** in the field of maritime safety and prevention of pollution by ships, and
2. **monitoring** the implementation of some EU legislation, and **assessing** if these regulations are efficient.

An overview of activities is presented by EMSA (2009d), in which their actions are divided into two branches:

1. **implementation** activities, and
2. **operational** activities.

Implementation activities consist of: visits/inspections to assess if legislation is being implemented, monitor the efficiency of the legislation, provide technical assistance in making of or amending maritime legislation, provide training and information to Member States' (MS) officials on EU maritime regulation requirements and on EMSA's activities, produce statistics and identify possible trends in the maritime fields.

Operational activities are of a more practical nature and consist of: providing technical assistance on the tackling of deliberate or accidental pollution by ships in European waters, develop plans and programs to respond to spills, establish a network with vessels that can be mobilized quickly in case of a large oil spill in European waters, the active support of the exchange of vessel traffic information between Member States, development of a satellite based monitoring service to monitor traffic movement and oil spills in European waters.

Such branching into two main lines of action reflects the objectives to be met by EMSA:

- On one hand EMSA works closely with the Member States and, on the other, with the European Commission. EMSA provides the Member States with training, practical solutions and **technical assistance** they may need for the understanding and efficient compliance of regulations set out by the European Commission;

- On the other hand, EMSA carries out **inspections** in the Member States, to **monitor** if regulations are in fact being implemented, and to **assess** if the legislation is efficient for what it was intended for in the first place. The resulting findings are then reported to the European Commission, who evaluates if there is a need for updating and/or for developing new legislation in the field of maritime safety and prevention of pollution by ships.

A dynamic interaction between EMSA, the Member States and the European Commission is thus established.

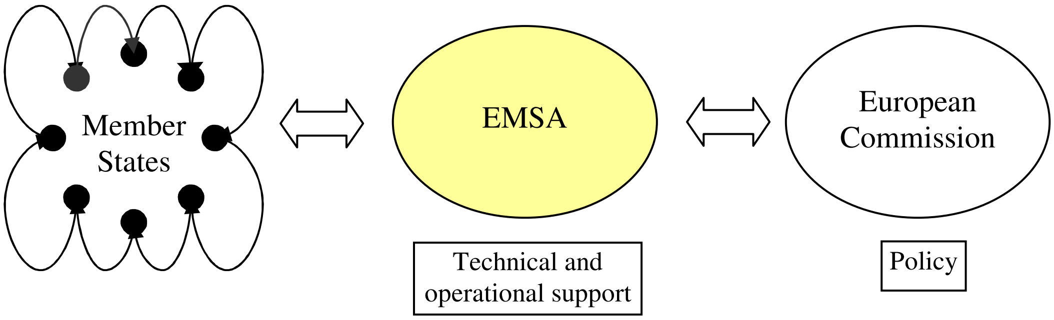

Figure 2. *The relation between the Member States, the European Commission and EMSA.*

This places EMSA on a central point of the resulting network, as shown in Figure 2. Such a position facilitates another task attributed to EMSA by article 5 of its founding regulation: to promote and develop the "co-operation between the Member States and [...] disseminate best practices in the Community" (EU 2002).

Figure 3 summarizes the activities carried out by EMSA, their respective working groups and important databases/information systems developed/under development (EMSA 2009d).

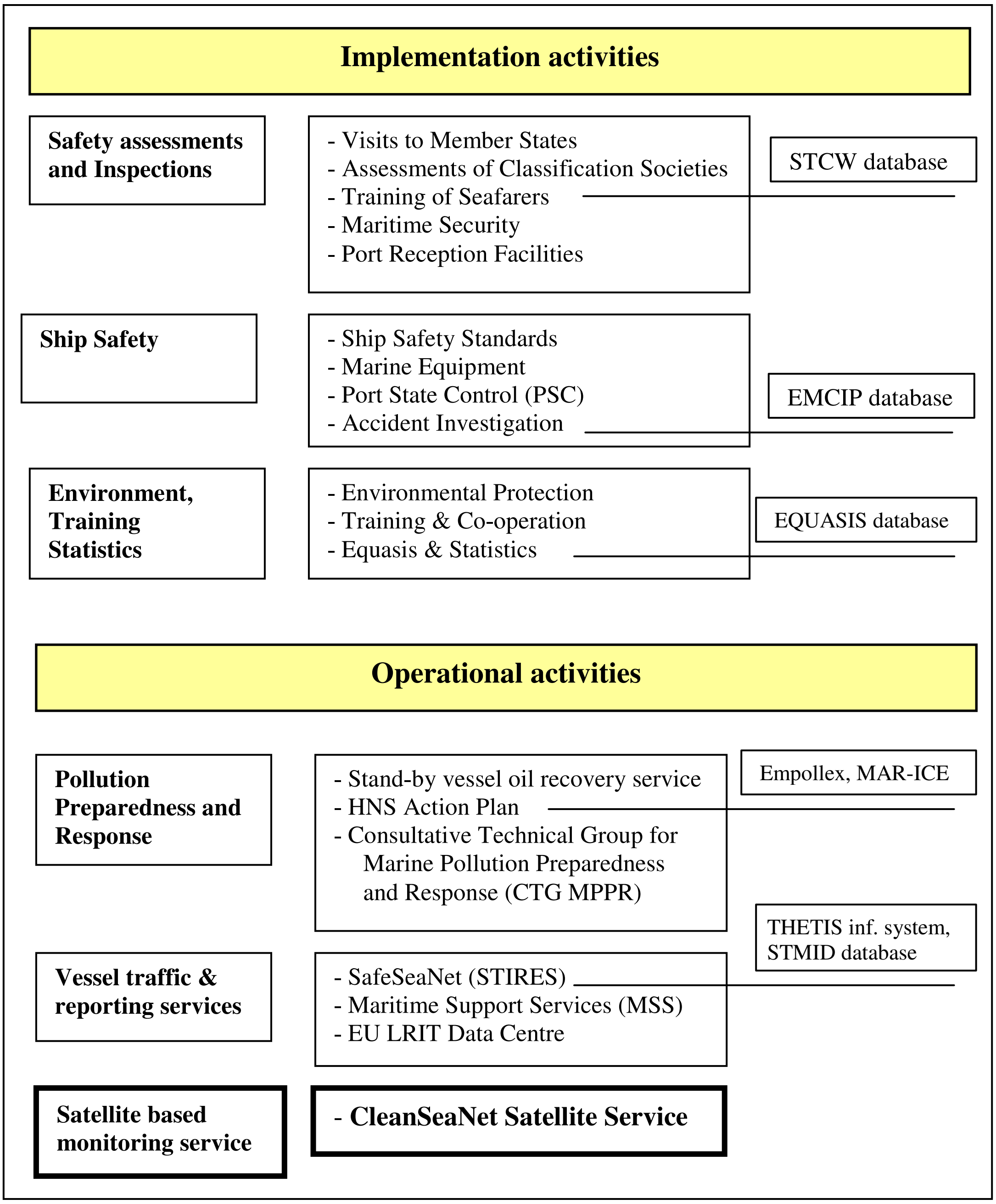

Figure 3. *An overview of EMSA's activities (EMSA 2009d).*

The object of this study is the operational activity **CleanSeaNet satellite service**, highlighted at the bottom. An opening introduction about this service is given in the next section.

2 An introduction to the CleanSeaNet service

The CleanSeaNet satellite service started in April 2007 and is available to all EU Member States, EFTA States[1], Acceding Countries[2] and the European Commission, designated hereby by users or Member States in this report.

Integrated in EMSA's operational activities, its particular role is to assist the Member States in tracing illegal discharges in European waters and to contribute with satellite images in the event of a large accidental oil spill (EMSA 2009d).

This service was created and developed by EMSA to meet the specific requirement set out to the Agency by the European Commission's directive 2005/35/EC on ship-sourced pollution, in particular article 10:

> *[...] work with the Member States in developing technical solutions and providing technical assistance in relation to the implementation of this directive, in actions such as tracing discharges by satellite monitoring and surveillance.*

Simultaneously, through the same Directive, the European Commission introduces important regulations on penalties for ship-sourced discharges of polluting substances.

A relevant issue to the creation of CleanSeaNet derives from these regulations on the penalties: there must be evidence of the infringement before being able to apply any penalty. Firstly, it is necessary to prove the existence of an infringement, i.e., that the suspected oil spill is in fact an oil spill. Secondly, it is necessary to prove that a specific ship, which navigates or has navigated in the area of the spill, is unambiguously linked to the particular oil discharge. The former requires verification and confirmation of the oil slick. The latter requires sampling to confirm the link

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[1] European Free Trade Association: Iceland, Liechtenstein, Norway and Switzerland (EFTA 2009).
[2] Acceding countries: Turkey, Albania, Croatia, the former Yugoslav Republic of Macedonia, Bosnia and Herzegovina, Montenegro, Serbia and Kosovo (European Commission Enlargement 2009).

‘ship—oil spill’. Both tasks are of the responsibility of the Member States.

What is the role of EMSA in this process? EMSA, through its CleanSeaNet service, alerts the relevant Member State of possible oil discharges detected in the area of its responsibility. It also supplies the Member States, through another service, called SafeSeaNet, results on vessel tracking that enables the Member State to contact the vessel and collect samples for proving an eventual infringement.

Detection, rapid (near real-time) delivery of warnings, oil drift models and vessel traffic information are essential parameters in such process. This is what CleanSeaNet does for the Member States. It is a technical solution created by EMSA to assist Member States combating illegal discharges by ships in European waters (EMSA 2009d).

However, if this legislation is to have the intended dissuasive effect, the risk of being caught must be obvious. This requires a rapid and consistent response from the Member States to the CleanSeaNet warnings and, in the case of confirmed spills, that samples are taken and investigated, consistently.

According to EMSA (2009d), the four key actions of CleanSeaNet service are:

- **detection** of possible oil spills using satellite surveillance and monitoring,
- **rapid alerts** (near real-time) of the detected possible oil spills,
- **assistance** in tracing oil-spill discharges, with the help of oil drift models which take into consideration meteorological conditions and currents, and
- **assistance** in tracking the movement of vessels in the area of the suspected oil spill.

CleanSeaNet’s four key actions are illustrated in Figure 4. The box next to each of them indicates the tool needed for the particular task:

- Analyzed satellite radar images,

- vessel tracking information from Automatic Identification Systems (AIS), Vessel Traffic Services (VTS) and Long Range Identification and Tracking (LRIT), and
- Oil drift models.

Based on EMSA (EMSA 2009d), with the exception of analysed satellite images, none of these tools are included in the service of CleanSeaNet i.e. they are the responsibility of the Member States. However, AIS/VTS/LRIT information and oil drift models are available through EMSA, and CleanSeaNet assists the Member States with these, on an on-request basis.

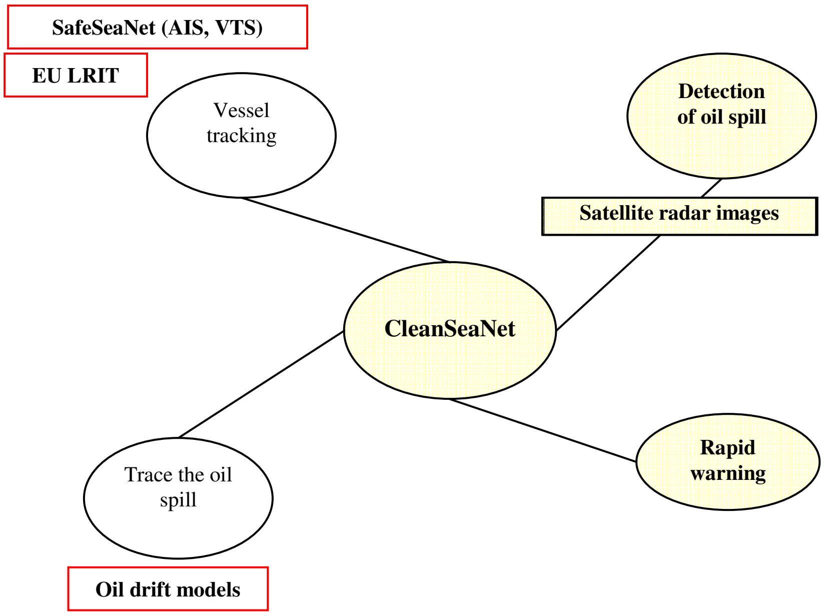

Figure 4. *CleanSeaNet relation to other activities in EMSA.*

The "2nd generation CleanSeaNet" (EMSA 2009c) was announced earlier this year and it will include improvements of the system, such as:

- Links to external oil spill drift models that allow visualizing a superimposition of forecasting/hindcastings with vessel tracking information;
- Estimation of the possible source of pollution improved, by integrating AIS/LRIT information and automatic vessel detection in the satellite imagery;

CleanSeaNet service provides its users a dedicated homepage, http://cleanseanet.emsa.europa.eu/ and a CleanSeaNet Web browser. Access to the last one is restricted.

3 Facts on oil

Time is an essential parameter for the detection of an oil discharge, tracking it to a particular vessel and for the collection of samples and, thus, of evidence. To understand this, a short study must be made on the general properties of oil and of what happens to oil once it is discharged into the sea.

Oils can be divided into four different types, based on their characteristics:

A. very light oils (such as gasoline, jet fuels);
B. light oils (diesel);
C. medium oils (such as lubricants and light crude oils);
D. heavy fuel oils (asphalt, heavier crude oils);

What happens to oil during and after its discharge into the sea depends largely on the type of oil, but also on the amount discharged, weather conditions, currents, and temperature (sea/air). As soon as oil is discharged and comes into contact with the sea water, different chemical, physical and biological processes start acting on it (oil weathering). These are illustrated in Figure 5.

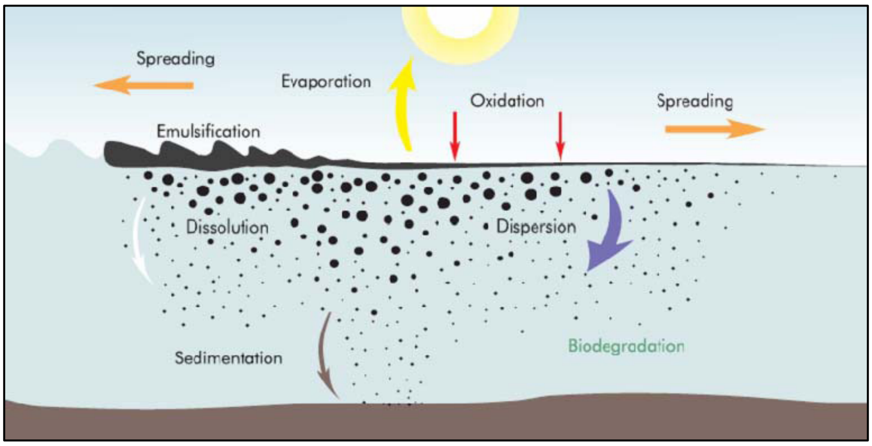

Figure 5. *Oil weathering (NORDEN 2007).*

According to IVL (2009), the detection of illegal oil discharges is somehow still difficult because chemical dispersants are being added to oil when discharging them into the sea. The oil is broken into small particles which more or less readily mix into the water (oil-in-water dispersion), and gradually disappears from the surface. This is an important aspect in satellite surveillance of oil spills because when oil disappears from the surface it can no longer be detected by the satellite radar. However, this does not mean that the oil spill is gone! Section 5.1 below will explain more how these satellite radars work.

Table 1 below summarizes the processes which are most relevant to understand the CleanSeaNet concept and that of the surveillance of oil spills.

Table 1. *Oil weathering. Adapted from IVL (2009).*

Evaporation	*Depends on type of oil, sea water temperature and wind. Fastest evaporation occurs with the lighter oils (0-48h), especially within the first hours after discharge into sea, in warmer waters and in windy conditions; evaporation subsides after 48 hours.*
Spreading (oil film)	*Light oils spread faster than heavier, denser ones, forming a large and thin oil film that is easily destroyed by wind and waves.*
Dispersion (oil-in-water)	*Depends on waves, type of oil and salinity. It does not occur in calm water. Fastest dispersion occurs with lighter oils, in rougher seas and in waters with higher salinity.*
Emulsification (water-in-oil)[3]	*Oil emulsifications are stable, very slow to evaporate, can stay afloat for several months; the volume of oil is expanded. Medium oils are more prone to emulsification that lighter ones.*
Biodegradation[4]	*Decomposition is faster for dispersed oils, i.e. lighter oils, and takes much longer time for heavier oils.*

Based on above information, and in what concerns time, it is apparent that discharges of medium and heavier oils can be detected even if a relatively long period of time has elapsed since its discharge into the sea. The reason for this is that, due to slow emulsification, they stay afloat for a relatively long period of time. In contrast, thin oil films formed from discharges of light and some medium oils (such as diesel) evaporate and dissolve faster, and therefore become hard to detect or may go even unnoticed, if too long time has elapsed since its discharge into sea, particularly

[3] Emulsification: water droplets mix into oil, resulting in a chemically and physically stable oily mixture.
[4] Biodegradation: decomposition of oil by microorganisms.

in rougher seas and in wind conditions. In other words, the oil discharge evaporates and dissolves until it finally disappears from the surface of the sea and is no longer detectable by the satellite SAR.

In conclusion, the longer the time elapsed since oil was discharged into sea, the smaller is the probability to detect it, let alone to link it to a particular vessel and collect samples.
These considerations justify the urgency of detecting oil discharges early. This is why, on one hand, one of CleanSeaNet's most important tasks is to deliver warnings of possible oil spills to the concerned Member State *in near-real time,* and, on the other hand, that the concerned Member State ensures a *rapid and consistent verification* of the oil spill warnings received from the CleanSeaNet.

4 Oil spill drift models

Oil drift models are used to simulate the trajectory of an oil spill continuously as a function of time, based on parameters such as current and winds. They are a valuable tool for CleanSeaNet service and Member States alike once an oil spill, accidental or deliberate, is detected or reported.

In general, oil drift models are used in two different ways, depending on the purpose:

1. in forecasting: the drift trajectory of a particular oil spill is simulated from the moment it was detected and *forward*.
2. in hindcasting: the drift trajectory the oil discharge is simulated from the moment it was detected and *backward*.

Forecasting gives an indication of what track the oil spill will follow, the status of the oil, and where and when the oil will reach shore. Thus, forecasting is used to plan an oil spill recovery operation, e.g. by a Coast Guard, and reduce its impact on the environment.

The second type traces the discharge *back* to an area within which the oil was probably discharged and indicates an approximate time at which it happened. This is useful for finding the source of an illicit discharge.

Figure 6 illustrates the basic principle and key elements of oil drift models. The data input is done by an operator when an oil spill is detected: information on the type of oil (light, medium or heavy oil), wind and waves. Forecasts on wind, waves and current are, in general, obtained from weather and oceanographic databases. The results generated are forecasts (hindcasts, if backward) and include estimates of, for example, how much will be left of the oil, how much has evaporated and/or dispersed after a certain time has elapsed since the oil spill was detected.

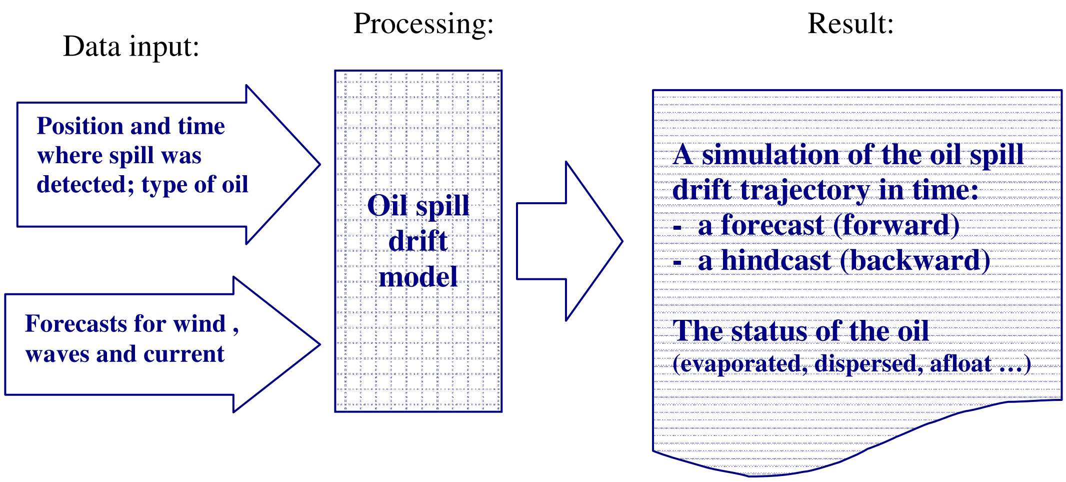

Figure 6. *The principle of oil spill drift models, based on SMHI (2005).*

Oil spill drift models can be 2D or 3D. According to SMHI (2005), 3D models are more reliable than 2D because, when performing the calculations, the 3D models takes into consideration not only the effects of wind, waves and current on the horizontal movement of the oil, but also on the vertical one, such as evaporation, dispersion and emulsification in different degrees depending on the type of oil. Based on this, it can be assumed that the trajectory projected by a 3D oil drift model is, to some degree, more accurate then one by a 2D, thus having a higher degree of certainty.

5 Remote sensing

Remote sensing is the science of "of identifying, observing, and measuring an object without coming into direct contact with it" (NASA 2009). Radars and cameras are, in this context, **sensors** and, as such, examples of remote sensing applications. They measure **electromagnetic waves** reflected by a distant object. The information about the object is presented graphically and is called an **image.**

Remote sensing equipment, such as synthetic aperture radars (SAR) or a simple digital camera, are used for the purpose of **detecting and monitoring oil slicks**. They are installed on **satellites** or on **aerial surveillance aircraft**. It is important to be aware that they have different properties and limitations.

This section will give essential background information about the satellites used by CleanSeaNet service, the sensor that they carry and those installed onboard the Swedish Coast Guard aircraft and it is based on information from KSAT (2003) and on Chapter 25 of the Counter Pollution Manual (Bonn Agreement 2009), unless stated otherwise.

5.1 Satellite surveillance

The Canadian Radarsat 1 and 2, the European ERS-2 and Envisat are the satellites used currently by CleanSeaNet service (EMSA 2007). They are equipped with synthetic aperture radar.

These satellites follow a polar orbit (EMSA 2007) at an altitude of about 800km, take only 100 minutes to complete one circle around the Earth, and do this 14 times a day. The area covered by each image is determined by the angle of the radar in relation to the surface of the Earth, and ranges from only a 45km wide area to 500km wide. According to Journel (2008), CleanSeaNet's images cover an area of 400km x 400km (Envisat) or 300km x 300km (Radarsats and ERS-2).

SAR works by detecting **changes on the sea surface**, such as an oil film. Pulses are transmitted by this sensor and received as echoes reflected by the surface: those reflected by the water (waves) are white on a SAR image, whereas echoes reflected away by the oil spill (smooth surface) are black (KSAT 2009). Synthetic aperture is a technique in which, the small antenna of SAR radar is virtually extended, and behave as being much longer than it actually is. According to Mr. Pereira[5], this technique allows improving the image resolution.

There are two types of sensors: the active or the passive.

Active sensors emit a pulse and receive the echo reflected by an object and analyze it. Radars are active sensors.

Passive sensors do not transmit any pulses. Instead, they work by measuring reflected radiation emitted by an object. Cameras, ultraviolet or infrared scanners or microwave radiometers are active sensors. As it depends on emitted radiation, this type of sensor operates during daytime only.

The SAR, being an active sensor, has the enormous advantage that it can detect slicks not only during the **day** but also during the **night**, as well as through **all kinds of weather**.

5.2 Aerial surveillance

Aerial surveillance aircraft are equipped with remote sensing equipment because oil spills are often difficult to be detected visually, even from an altitude and by trained observers.

The most common remote sensing equipment installed in the aircraft are the side looking airborne radar (SLAR), the ultraviolet/infrared scanner (UV/IR), a microwave radiometer (MWR), the laser fluoresensor (LSF), a low light level TV camera (LLLTV), identification camera (IC), photo and video camera (VC). With the exception of SLAR and LSF, they are all passive sensors.

[5] Mr. Ricardo Pereira, CleanSeaNet Operations Manager at EDISOFT, interviewed on 21.October.2009.

Some of their properties are summarized below, based on information from the "**Bonn Agreement Counter Pollution Manual**" (Bonn Agreement 2009, Chapter 25):

SLAR: this sensor has the same properties as SAR, and similar limitations. The trajectory of the aircraft is more flexible than that of a satellite, though. However, since it is installed on an aircraft the coverage of the images is significantly smaller.

UV: detects the ultraviolet radiation of the oil, giving an indication of a spill. Disadvantage: can not differentiate oils or thicknesses of an oil layer. Used often in combination with IR for best results.

IR: detects the infrared radiation emitted specifically from oil (wavelength 8-12 micrometer), shown as white on an IR image. Useful for tracing polluter vessels (trails), and to estimate oil layer thickness for assessing the approximate volume of the spill.

MWR: compares the microwave radiation emitted by the water and that emitted by the oil. Useful for detecting oil spills and determine the thickness of the oil film. Disadvantage: method has limited use if the oil spill is less than 01.mm thick.

LSF: emits a laser beam, and detects the fluorescence emitted when it hits an oil spill.

LLLTV (used with SLAR): it is not used for detecting oil spills but to provide a real-time image of a detected oil spill or of the polluter vessel, in darkness. Advantage: gathers evidence at night.

IC camera (advantageous to be used with SLAR): an infrared flash provides a "picture" with the identification of the polluting ship at night, for evidence. Advantage: gathers evidence at night.

Photo and VC: a conventional photo camera and video recorder. Used to document the discharge and the identification of the polluting ship, for evidence.

PART III – METHODOLOGY

This section presents the different methods used to conduct this study, discusses the main aspects of the sources of information chosen and defines how the analysis of such data was carried out.

1 Research method

The *case study* method was the elected research method for this work. It consists of a thorough study of a subject, where little or no influence is exerted on it. This method appeared to suit the study's *descriptive* intention better than action research, experiment or survey would do. It also fitted its *explorative* purpose.

Unexpected ideas may emerge as the work unfurls, e.g. due to scheduled interviews and visits. Therefore, a rigid method was undesirable. According to Höst et al. (2006), the *flexible* character of this method allows adjusting to the situations as they develop, which constitutes yet another good reason to apply it.

2 The three phases of this study

This document is the result of a study that followed three phases, the names of which reflect the purpose at each stage of the work:

phase 1. getting ideas
phase 2. building knowledge
phase 3. integration and consolidation

Phase 1 consisted in data collection, mainly from literature, visits and interviews. It was characterized by a relative lack of structure of both information and ideas. In the following phase the information and ideas were categorized and started to form a structure. At this stage, analysis of documents was often interwoven with information that materialized in a visit later on, in an iterative process. Knowledge about the different parts that integrate CleanSeaNet service started to build up, but was still fragmented at this point. Finally, the last phase was one in which the knowledge consolidated.

3 Data collection method

This document was based primarily on *qualitative data,* collected first through literature research and shortly thereafter through a pertinent choice of visits and interviews. According to Höst et al. (2006), observation could also be used to gather information. However, for this particular case, in which the subject of the study involves satellite radars, observation as a means of gathering reliable information was not appropriate and therefore was not used. This has not compromised the quality of the study: literature from EMSA about the CleanSeaNet service is reliable and was abundantly available; visits and interviews provided complementary, up-to-date information and helped to verify the correct understanding of the literature.

The purpose of the data collection was:

a. to identify the main components of the CleanSeaNet service and its associated elements in Sweden, and
b. to understand each component in detail.

3.1 Primary sources of information

a. visits
b. interviews

The decision to include visits and interviews in this study was taken at quite an early stage of the process. As the literature was studied it gradually revealed the different components of CleanSeaNet and the activities of the Swedish Coast Guard regarding monitoring of oil spills along the Swedish coast. It became apparent that some visits and interviews were indeed needed. Not only for receiving *up-to-date and direct* information, complementary to books, as advised by Paulsson & Björklund (2003), but also for *clarifying* any doubts, *detect* and *correct* any possible misunderstandings and develop a deeper knowledge about the subject.

The selection and planning of the visits and interviews had to take into account the time and economical resources available for this work, and ponder these against the relevance of such visit to the value of the final report.

As a result, the following visits/interviews were selected according to these criteria:

1. Swedish Coast Guard: for its relevance to the monitoring of sea-based oil spills along the Swedish coast and because its location (Gothenburg) implied virtually no travelling costs;
2. EMSA and EDISOFT: implied higher travelling costs but because both are based in the same location (Lisbon) and had the courtesy of scheduling the visits for the same week, these interviews would yield a good cost/time-value ratio. The interview to EMSA focused on CleanSeaNet, whereas the visit to EDISOFT focused on the analysis of satellite radar images;

The interviews were carried out during the visits and by e-mail. Preparations included literature study to familiarize with the subjects, mainly with material from EMSA (brochures), web pages about satellite imaging, such as those of the European Space Agency (ESA) and Kongsberg Satellite Services (KSAT), and about the Swedish Coast Guard, from their official website.
Questions were prepared in advance, but as the interviews had an open character these were mainly used as a guideline for the conversation. The conversations were not recorded, but memorized and summarized shortly after.
Prior to using this information on the subject, and in order to make sure that it had been well understood, selected interviewees were asked to read the summary of the interview and verify the accuracy of its contents. In order that this information could also be accessed by the reader, those summaries which were verified and returned by the interviewee within the deadline of this report were included as Appendices, with express consent of the interviewee.

3.2 Secondary sources of information

Scientifically produced, verified or other reliable sources of information are the preferred choices of literature, whether in the printed form or electronic-based, to render reliability to this report.

Literature research keywords included:

EMSA, CleanSeaNet, KSAT, remote sensing, satellite radar imagery, EDISOFT, European Space Agency (ESA), Swedish Coast Guard, Seatrack Web, SJÖBASIS, Helsinki Commission (HELCOM), Bonn Agreement and IVL Swedish Environmental Research Institute (IVL).

Data sources included:

- Information presented in the website of the European Maritime Safety Agency, their official presentations and brochures.
- Information on the webpage of the European Space Agency;
- Documents from Kongsberg Satellite Services on their website;
- Material on the web pages of Swedish Meteorological and Hydrographic Institute (SMHI), Swedish Coast Guard and IVL Swedish Environmental Research Institute (IVL).

Knowledge obtained in previous lectures of the Nautical Studies constituted also a source of information, although indirect, in the sense that it constituted an ‘invisible’ but essential background to understand some of the literature and key aspects of this study. Such is the case with the lectures in Meteorology and Oceanography, to understand e.g. the difficulty in analyzing satellite radar images and its relation to winds and currents, and the need for oil drift models; lectures in Environment, that helped understand the urgency to detect possible oil spills in as near-real time as possible and its relation to the evaporation and dispersion time-scales of different oils; finally, lectures in Instrumentation and Radio Communication, that provided the background needed to understand the literature about satellite radars and other remote sensing equipment.

4 Data analysis method

Analysis of data has its starting point on the information gathered, as recommended by Paulsson & Björklund (2003), and follows a structure presented below:

a. sort the information collected,
b. identify and characterize each part that integrates CleanSeaNet,
c. find the functional relationship between these parts and CleanSeaNet, and
d. build a platform with this knowledge, from which to study how they integrate with CleanSeaNet to form an operational system.

Figure 7 below illustrates the structure of the analysis process.

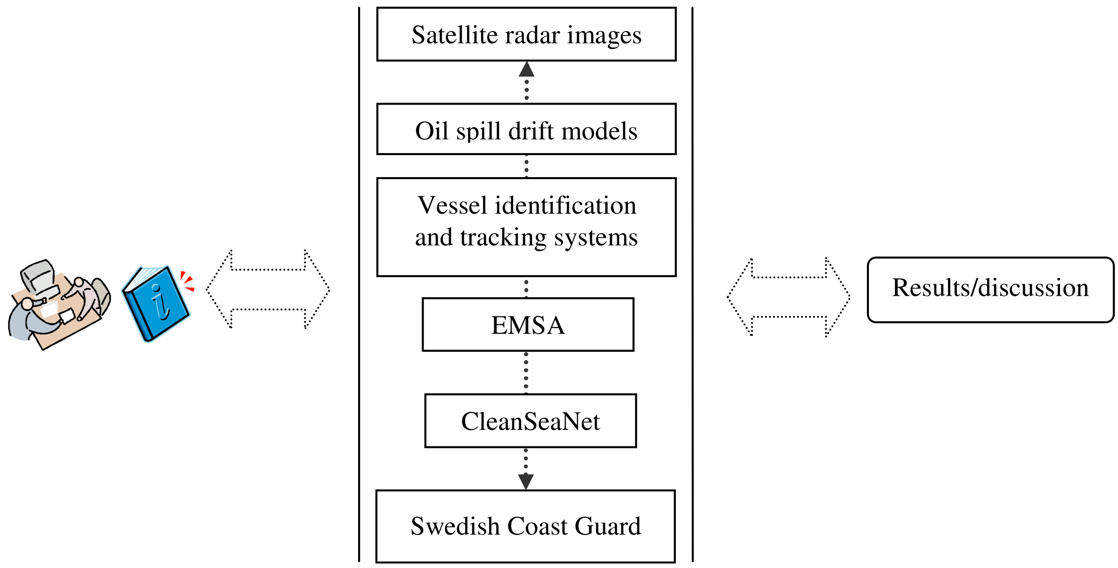

Figure 7. *Structure of the analysis process.*

Finally, the results and conclusions are to be summarized and presented in a clear way.

Presentation follows the Harvard reference system as described in "Citing and referencing in the Harvard style", by Thames Valley

University (2008), the layout suggestions as explained in “Chalmers skrivregler and typografiska råd”, by Chalmers tekniska högskola (1998), and the guidelines presented in "Writing guidelines for reports, BSc theses, and MSc theses at Chalmers University of Technology”, also by Chalmers tekniska högskola (2009).

PART IV – RESULTS

The result of an analysis of the information gathered through interviews and literature is described in this section. It is intended to answer the questions proposed in this study.

It is divided in two sections. The first focuses on CleanSeaNet itself, defining and describing each part that integrates it, how it functions and analyzing its usefulness. The second section shows the results about the usefulness and integration of CleanSeaNet in Sweden.

1 CleanSeaNet

1.1 What is it?

CleanSeaNet is an oil spill monitoring service provided by EMSA for the detection of potential discharges of oil from ships. It provides:

- a regular service of satellite imagery and alerts of possible oil spills, in near-real time i.e. in less than 30 minutes from the satellite overpass;
- Support in the event of an accidental spill;

The geographical scope of CleanSeaNet is the European seas and coastal areas.

The users of CleanSeaNet are the European Member States and EFTA States.

The purpose with this service is to help its users locate deliberate oil discharges in their waters at an early stage.

Once verified and confirmed, a rapid warning allows the tracking of the polluter vessel and the gathering of evidence needed for the courts, with the dissuading effect intended with CleanSeaNet.

In case of an accident from which an oil spill results, the CleanSeaNet service can also provide satellite images that help guiding national oil pollution response teams to contain the spill and minimize its impact on the environment.

To summarize, CleanSeaNet is a service that assists in the prevention of pollution by oil of the marine environment and, in particular, in the work engaged to discourage illegal oil discharges in Europe.

CleanSeaNet's components are Earth observation satellites equipped with SAR sensors, ground antennas that download the images, service providers who analyses the images, the CleanSeaNet Web Browser, and the final user, i.e. the Member States' Coast Guards.

Unlike aircrafts, satellites operate continuously, regardless of weather conditions, and images cover **large areas**. The SAR, being an active sensor, has the enormous advantage that it can detect slicks not only during the **day** but also during the **night**, as well as through **all kinds of weather**. These advantages are the main reasons why satellites equipped with SAR are used for the purpose of surveillance of oil slicks (EMSA 2007). However, it is important to be aware of the limitations:

- oil slicks can not be detected in winds below 2 knots or above 27 knots. The reason for this is that in virtually windless days, the sea is as **smooth** as oil, thus the sensor can not detect a change on the water surface. On windy days the sea is rougher, causing the oil and water to **mix**, and again, the sensor can not detect the difference either.

- the SAR image does not differentiate between an oil spill and another source of surface change, such as an algae bloom. This is in the origin of **false oil spills**. SAR images can only be used as an indication that something other than water is floating and, as such, detected "slicks" are to be regarded always as only **possible** slicks until they are verified and confirmed (or discarded).

- the satellite trajectory (orbit) is fixed and repeated. This makes this system inflexible compared to aircraft surveillance.

As SARs can not differentiate echoes of an oil spill from echoes of an oil slick look-alike, these images need to be analyzed before they can be used for surveillance purposes. EMSA contracted in 2007 three service providers to carry out this task:

- EDISOFT, a Portuguese company based in Lisbon;
- Kongsberg Satellite Services (KSAT), a Norwegian company based in Tromsø;
- Telespazio, an Italian company based in Rome.

Their antennas are placed in such locations that, in between them, the area of coverage of the system encompasses all European waters. EDISOFT has one antenna, in Azores, which downloads satellite images from the Atlantic coast; KSAT has three: Tromsø, Svalbard and Grimstad. They download images of Northern Europe. Telespazio also has three antennas: one in Fucino, one in Benevento and one other in Matera. These cover the Mediterranean.

Operators at EDISOFT, KSAT and Telespazio receive the downloaded images from their associated ground stations and have the responsibility to interpret and analyze them before sending them to CleanSeaNet and the Member States (Journel 2008). Figure 8 on next page illustrates the concept of CleanSeaNet.

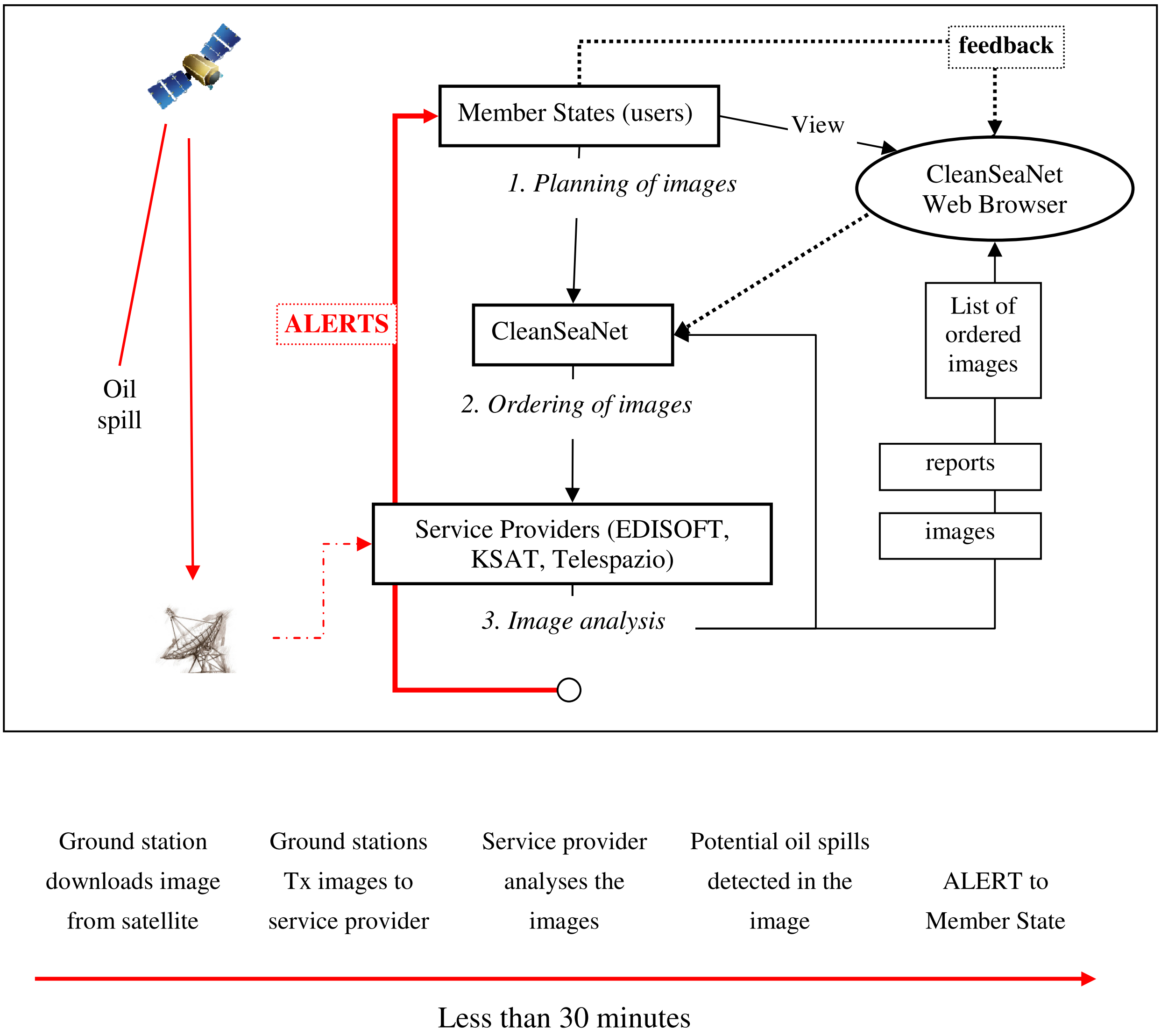

Figure 8. *The downloaded image is analyzed and sent to CleanSeaNet in less than 30 minutes.*

An important distinction to bear in mind is that **CleanSeaNet's detections are not of oil spills but of possible oil spills**. 'Look alikes' are an important aspect of satellite surveillance because they are the main source of false oil spills. Some phenomena affect the interpretation of satellite images. Wind effects on the water surface, currents and algae blooms are only a few examples. The problem with these phenomena is that they reflect radar pulses in a similar way as oil slicks do and resemble oil spills on the satellite images. Therefore they are designated by 'look-alikes'.

The analysis work, performed on satellite SAR images by EDISOFT, KSAT and Telespazio teams, aims to answer the question *"what is the likelihood that a dark trail shown on the image is an oil spill?"* It is the operator's task to **analyze** each image in order to identify and eliminate as many **'look alikes'** as possible, if not all, thus reducing the number of false oil spills.

In doing so, the operator is supported by scientific and technological tools such as, for example, algorithms, external oceanographic databases and meteorological services. According to Mr. Pereira, the operator correlates information about local sea current or upwelling patterns, wind and wave direction with the image of the oil slick and assesses how they match. Vessels are visible in the radar images as well, as white dots. The likelihood of a black trace on a satellite radar image being a potential oil spill other than a 'look-alike' may be increased if the image shows vessels in the near vicinity. The operator takes also this into account when analyzing the images. When the images are finally interpreted the results are expressed in terms of probability: dark trails with a high probability of being an oil slick are labelled "High" (symbolized by a red drop), dark trails that have some probability of being an oil slick are labelled "Medium" (symbolized by a yellow drop), and those with low probability are labelled "Low" (symbolized by a grey drop).

The analysis process of satellite images is not an easy task and operators receive specialized training for this. In addition to the above described **qualitative assessment**, analysis has also to be done rapidly so that the Member State can receive it **in near-real time**, i.e., less than 30 minutes from the satellite overpass.

What information is given to CleanSeaNet and the users once the analysis is complete?
- an alert of a possible oil slick in case it is detected on the image;
- report of the images, indicating up to three levels of confidence;
- analyzed satellite images;
- information about winds and waves;
- eventually, an indication of a possible polluter;

To facilitate the exchange of information, an interface called **CleanSeaNet Web Browser** was created. Access to the

CleanSeaNet Web Browser is restricted to the Member States, CleanSeaNet operators and the Service Providers and contains the following information: list of images ordered, potential oil spill reports and potential oil spill images from the Service providers, and feedback from eventual verification flights (feedback information is entered by the Member States) (Journel 2008). See Figure 9 below.

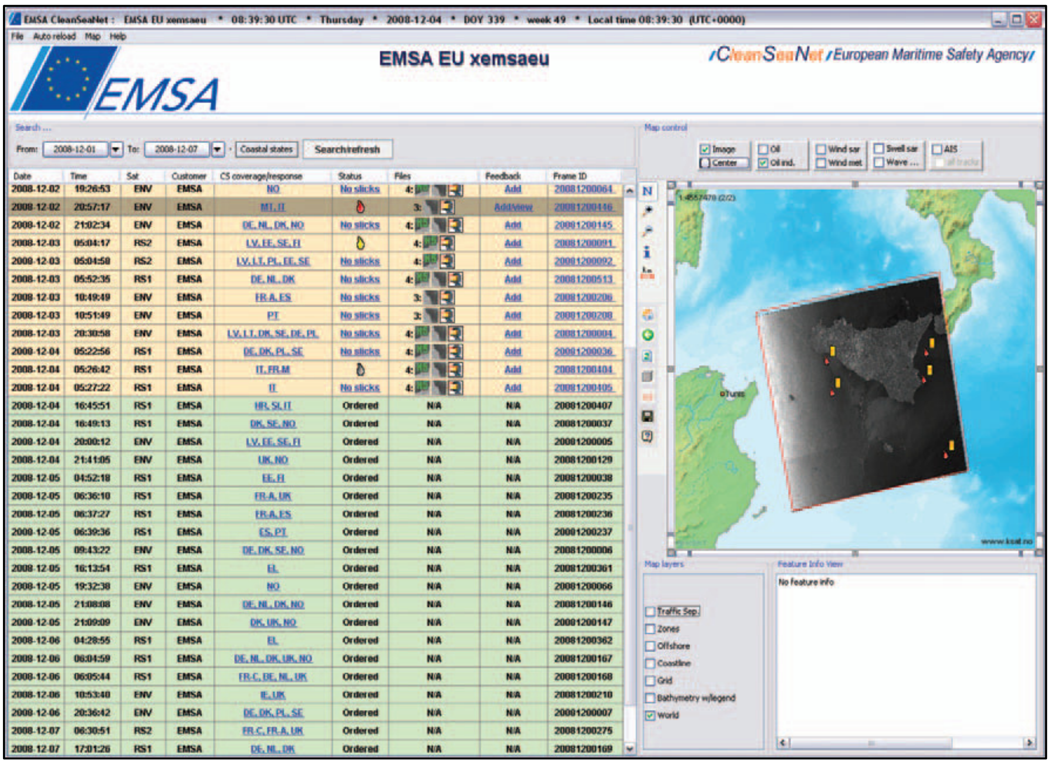

Figure 9. *The CleanSeaNet Web browser (EMSA 2009b).*

Once the alert arrives to the Member State concerned, it is up to the Member State to activate a follow-up, i.e., **verification** of the alert. If the verification confirms that there is in fact an oil slick, the next step is to identify and track the vessel. As this information is not given with CleanSeaNet service, the Member State has to consult their national AIS or, alternatively, can consult EMSA's SafeSeaNet service.

The <u>"2nd generation CleanSeaNet",</u> announced by EMSA earlier this year (EMSA 2009c), will bring important improvements to CleanSeanet, such as less false oil spills, more satellites, as well as:

- Links to external oil spill drift models that allow visualizing a superimposition of forecasting/hindcastings with vessel tracking information;
- Estimation of the possible source of pollution improved, by integrating AIS/LRIT information and automatic vessel detection in the satellite imagery;

SafeSeaNet is an information system in which up-to-date information of vessel traffic in Europe is gathered in a single server, in order to facilitate the exchange of such information between different interests, for monitoring purposes. It is used today by EU Member States, Norway and Iceland. As with CleanSeaNet, access is restricted.

SafeSeaNet was established by the European Commission in 2004 because the exchange of important vessel traffic information between different parties, e.g. port authorities, VTS and search and rescue organizations, proved to be difficult and inefficient.

According to EMSA's SafeSeaNet leaflet, the information provided on the location of ships and their cargoes in European Waters is accurate and up-to-date. Furthermore, the system is also described as reliable because EMSA's **Maritime Support Service** (**MSS**) work to guarantee that this server is always operative and to monitor the quality of information, 24 hours a day and 365 days a year.

The Member States can access the SafeSeaNet and search for, or be the provider of, information in this system. VTSs and Coast Guards are among those who usually consult SafeSeaNet looking for information. This can be, for example, identification of a possible oil polluter vessel located in a specific area on the European coast. Ship agents and masters, on the other hand, often access SafeSeaNet in order to input information such as, for example, that required in Mandatory Reports.

Different types of information are available on SafeSeaNet (EMSA, SafeSeaNet leaflet), but the most relevant for CleanSeaNet users is perhaps the Ship Notification. Users consult it to obtain up-to-date AIS information on a particular ship, searching by name, call sign or by area. When STIRES, the new module in SafeSeaNet, becomes operational the users will also be able to track the movement of vessels along the entire EU coast with AIS, in real-time (EMSA, SafeSeaNet leaflet).

The restriction of AIS, imposed by the VHF range limitation to about 50nm, is perhaps the only drawback. However, since oil spills closer to the coast are more threatening than those on the open-seas and, bearing in mind that most traffic is in coastal or near-costal waters, such limitation is perhaps not the most significant for this matter.

In any case, according to EMSA's information given on STIRES homepage (2008), SafeSeaNet is also preparing to provide ship identification on a global basis, through the recently developed Long Range Identification and Tracking (LRIT) data centre, in order to complement the currently available, of more regional character, AIS information. Contrary to AIS, the LRIT does not have such type of range limitations because it is satellite-based, and as such can be used to advantage as a complement to AIS (EMSA, SafeSeaNet leaflet).

The importance of associating AIS information to CleanSeaNet alerts has to do with the need of collecting evidence of an illegal discharge to support a legal case. An oil spill alert is of little use if it is not verified by an aircraft or vessel in order to be confirmed. However, confirmation alone does not suffice. An unambiguous identification of a suspect polluter is also necessary and AIS role is not make it possible to identify a possible polluter. The example below illustrates the identification problem and helps understand its significance in the context of surveillance of illegal oil discharges.

Suppose a potential oil spill is detected on a satellite image, along with a vessel in its vicinity. Within 30 minutes the image and oil spill alert is sent to the Member Sate concerned. Suppose also that an aircraft is sent to the spot and confirms the oil spill but, the vessel is already gone. If there is no AIS information available for that vessel, it will not be possible to identify her, let alone be able to gather evidence for an eventual prosecution. Consequently, one can conclude that, in such cases, the CleanSeaNet image and alert, as well as the subsequent verification flight, will have little value for the overall purpose of combating illegal oil discharges.

If, on the other hand, AIS information is available on a situation as the one described above, the unequivocal identification of the polluter vessel becomes significantly simpler.

In the first place, the suspect polluter vessel on the image can be identified, by superimposing existing AIS information onto the satellite image. Secondly, it is possible to reconstruct the trajectory of the vessel and superimpose it onto an oil drift hindcast, in which the starting points are the time and position of the vessel in the satellite image and the time and position of the oil slick on the satellite image, respectively. The reconstruction of the vessel's backtrack is based on continuous AIS information, whereas the hindcast for the oil drift is based on numerical models taking into consideration the wind, waves, type of oil and approximate volume. The end point of such reconstruction is the point and time at which these two trajectories – vessel's trajectory and oil slick trajectory – finally meet. This way, and because AIS information was available, the suspect vessel could not only be identified, but also preliminarily linked to the oil slick shown in the satellite image.

The example serves only to illustrate the principle, but in reality there are innumerous variations to the situation described in the example. The importance of AIS for the identification of suspect polluter vessels and the possibility it gives to track of vessels by superimposition with layers of other information, such as satellite images and oil drifts models, is undeniable, supported on the example given in Figure 10 below.

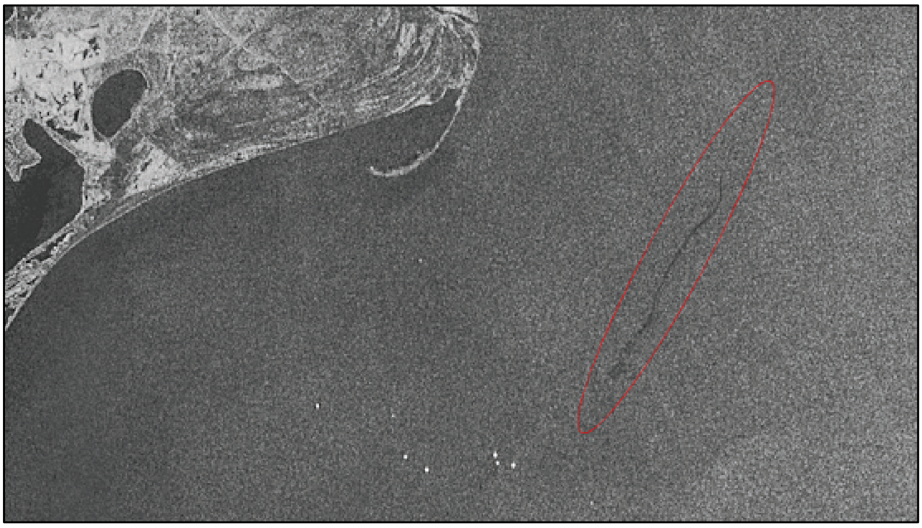

Figure 10. *"On this 3 November 2008 ENVISAT image, a 20 km long oil slick in Romanian waters was reported by CleanSeaNet. The potential polluter was identified by Romanian authorities by using vessel traffic information system and fined as the result of a Port State Control inspection in Galati" (EMSA 2009b).*

The use of **oil drift models** by CleanSeaNet, particularly of hindcastings associated to vessel traffic information, have an obvious role in the documentation of illegal operational discharges. As described in SMHI User's Manual (2009), with the help of AIS, for example, it is possible to search for a polluter that has been on the backtracked area at the time of the spill. Or, alternatively, correlate the trajectory presented in the model with the route of a suspect ship. This information, together with satellite imagery and oil samples collected onboard the suspect vessels, may lead to the evidence needed by the authorities for a legal case.

EMSA does not yet offer this function integrated in CleanSeaNet service. It is up to each Member State to decide and choose on which model.

A number of spill drift models have been developed and are used by different Members States in Europe. These include, for example, the OD3D (Norway) and MUMM (Belgium), for spills in the NE Atlantic and Nordic Seas, MOTHY (France), which provides a global coverage and the MEDSLICK (Italy, Greece) for oil spills in the Mediterranean Sea (EuroGOOS 2007). The Swedish Coast Guard uses the oil drift forecasting model Seatrack Web 2.0.

1.2 Why do we need it?

There are three important aspects to take into consideration regarding the monitoring of oil discharges. They have to do with the transportation of oil by sea, namely:

- the identification of the maritime routes in which the traffic is more intense and constant,
- identification of the areas whose ecosystems are extremely vulnerable to marine pollution, particularly to oil, and
- time elapsed from the moment of the discharge until the vessel is tracked.

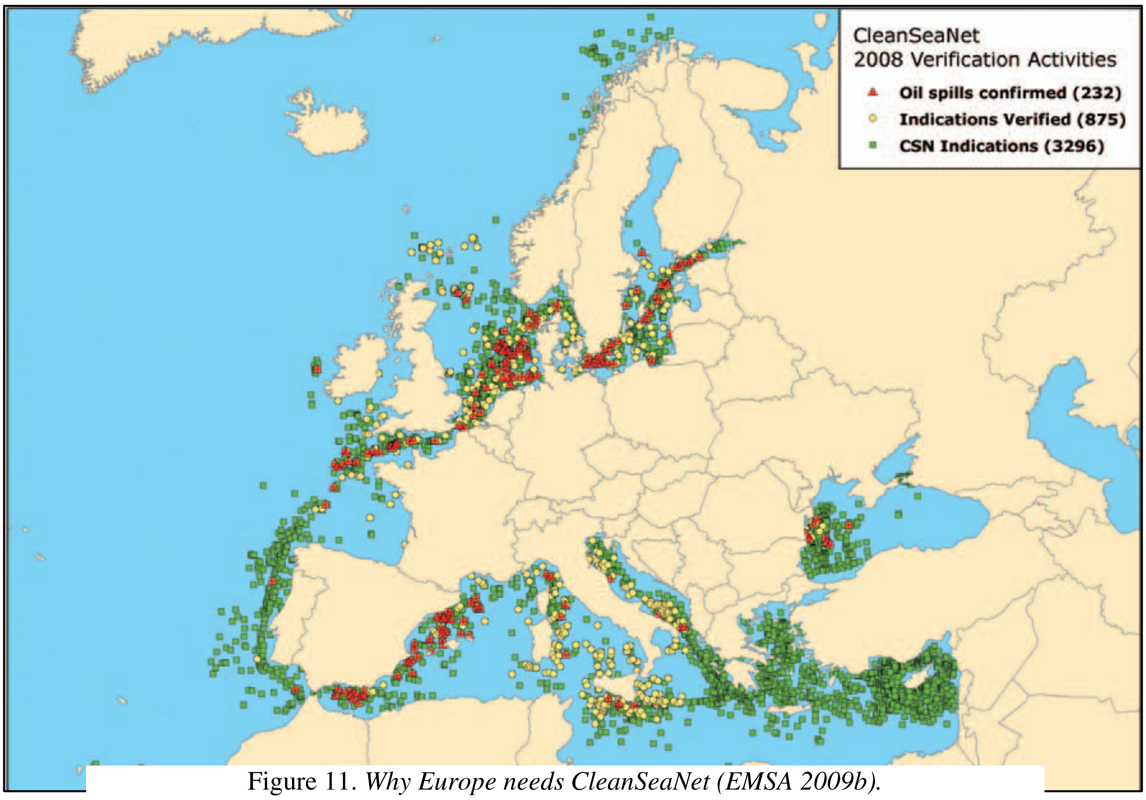

Figure 11. *Why Europe needs CleanSeaNet (EMSA 2009b).*

The importance of the first aspect is illustrated in Figure 11. Higher traffic density is relevant because it indicates areas with a higher risk of oil discharges and, therefore, where the probability of oil discharges is considerably higher. This consideration is useful when Member States manage their surveillance resources and have to establish priorities, e.g. when a Coast Guard plans their flights for aerial surveillance or when satellite images have to be ordered to EMSA.

The second one is relevant because it indicates that oil discharges in these areas will have a great local impact and, therefore, also need to be monitored, regardless of the traffic intensity.

The International Maritime Organization (IMO) has designated particularly vulnerable areas by "**Special areas**" and "**Particular Sensitive Sea Areas**" (**PSSA**). Through its well-known publication MARPOL 73/78 (IMO 2002), in particular the "Annex I – Prevention of Pollution by Oil", introduced strict measures aiming at reducing discharges of oil to the sea. Among them is the introduction of "special areas", where discharge of oil mixtures, such as bilge water from cargo spaces, into sea is completely banned. "Special areas" in Europe: the Mediterranean Sea, Black Sea, NW European Waters and the Baltic Sea; Segregated ballast water tanks were also introduced in this regulation: sea water used for ballast on the unloaded voyage shall be free from contamination by oil.

In addition, IMO, through its Resolution A.982(24) (IMO 2005), adopted guidelines to help protect designated PSSA, in which vessel traffic may be restricted, MARPOL73/78 measures are stricter (oil tankers), and in which Vessel Traffic Services (VTS) is established. PSSA in Europe: the Wadden Sea (Denmark, Germany, Netherlands), Canary Islands (Spain) and the Baltic Sea area (Denmark, Estonia, Finland, Germany, Latvia, Lithuania, Poland and Sweden).

The Baltic Sea is both a designated "special area" and a "PSSA". As such, discharges of oil and oily wastes are illegal and constitute an offence.

CleanSeaNet service was created to meet the needs of its users regarding oil pollution in their national waters and the protection their marine environment. Such need came in the wake of the increase of maritime traffic in Europe in the past decades, and the inherent risk of accidental or operational oil slicks associated with it. Recognizing such risks, and concerned about the marine environment, important legislation that forbid oil discharges into the sea have been introduced in many countries. Yet, statistics show that operational discharges in Europe are still a frequent practice (see figure 11).

In the light of these facts, one can only conclude that if the legislation is to have the desired deterrent effect, it needs to be reinforced. In other words, the slick must be detected, the polluter caught, the infraction proven and taken to court, and a heavy penalty applied to the polluter. This raises other questions:

What evidence needs to be collected? How can the polluter be tracked and identified? How can oil slicks be detected?

Oil samples, taken from both the oil slick and from a suspect polluter vessel, as well as images connecting that vessel to that oil slick, constitute evidence for a legal case.

Tracking a vessel, for posterior identification, having the coordinates of the oil slick as the starting point, is done with the help of oil drift models and information from vessel identification systems.

The role of surveillance in this process is to detect illegal oil discharges as soon as possible, preferably while the discharge is being carried out.

According to Mr. Pereira, the time factor is important for simplifying the identification of the polluting vessel and to eventually track the vessel.

On the other hand, for KSAT (2009), the time factor is also important for trying to catch the polluting vessel whilst still within the EEZ.

CleanSeaNet service was created in this context, in order to provide its users the necessary satellite imagery for such surveillance, as well as alerts of oil spills in near-real time.

According to KSAT (2009), the satellite imagery that Member States get through CleanSeaNet is needed for optimizing “the use of coastguard vessels and surveillance aircrafts, producing a more effective, also cost effective, surveillance plan".

The time factor is also important in the event of an accidental spill. An early warning of a spill helps to control and combat its potential environmental impact while it still is in the beginning. In addition, surveillance can also be used to monitor the progress of an oil spill, deliberate or accidental, and CleanSeaNet services provides satellite images requested for this purpose as well. These, used in conjunction with oil drift models, have an important role in guiding response teams for the containment of a spill and in cleaning operations.

1.3 How does it work?

The CleanSeaNet service starts with the planning, ordering and acquisition of satellite images. The ordering and acquisition of images is done at EMSA CleanSeaNet. A description of how this is done is given below, based on an interview with Mr. Lourenço[6]. CleanSeaNet receives a catalogue of all the images that will be available as satellites move along the orbits. Their orbits are fixed and repeated. Images covering Member States' coasts, adjacent water surfaces and seas are selected from the catalogue, while those irrelevant (mountain areas, no water surface...) are discarded. This preliminary selection of images is then sent to all the users, who are requested to chose and order the images they would like to receive, and for which specific dates. The planning of the images is done on a monthly basis and usually some months ahead. As an example, at the time of this interview images were being planned for February. According to Mr. Lourenço, it is up to each Member State to decide how many images are needed, which areas to cover and on which dates. It is important to bear in mind that these satellite images do not indicate oils spills but *potential* oil spills and, as such, and that there is no other way to know if it is in fact an oil spill or not other than through verification, normally by aerial means. Therefore, the selection is usually made in conjunction and coordinated with the aerial surveillance planning. It is important to refer, though, that it is entirely up to the Member Sates to decide if the oil spill is to be verified or not.

[6] Mr. Pedro Lourenço, Project Officer CleanSeaNet Satellite based Monitoring Services at EMSA, interview at EMSA on 23.October.2009.

However, in order to take the most advantage out of CleanSeaNet service, the areas and dates chosen for the images are those in which there will be at least one aircraft available to perform a verification flight.

Once the Member State has decided on the images, a list of the selection is sent to CleanSeaNet, who then orders these images to the service providers (EDISOFT, KSAT and Telespazio) and updates the planning in the CleanSeaNet Web browser.

When the satellite passes over one of stations, the images requested are downloaded and analyzed. This image analysis is qualitative, and has to do with trying to pin-point the 'look-alikes' in the image and discard them, as an attempt to reduce as much as possible the number of false oils spills. The remaining trails in the image are, thus, potential oil spills, categorized according to the likelihood of being an oil spill: "High" (indicated by a red drop), "Medium" (a yellow drop) or "Low" (a grey drop). This is not an easy task and has in addition to be done as quickly as possible: the images must reach the Member State that requested them in less than 30 minutes, i.e. near-real time, which is the time guaranteed by CleanSeaNet service.

This raises another question: why 30 minutes?

To understand the reason for this, one should take into consideration that when a Coastal State receives an image with an indication of a probable oil spill, it may take some time before an aircraft reaches the oil spill. Thus, the faster the oil spill warning is received the higher is the chance of catching a polluter 'red handed'. In addition, it is also known that the time factor is one of the important parameters in oil weathering. If a long period of time elapses from the moment when oil is discharged, until it is detected and finally verified, the oil film may have been already destroyed or fragmented, depending on the weather conditions, amount of oil and, not least, the type of oil discharged. Diesel, for example, starts to evaporate relatively fast after being discharged. The degradation of oil may compromise, to a varying extent, the securing of evidence and tracking the source of the pollution. On the other hand, the time factor is also important in case an oil spill is such that it constitutes an immediate threat to a coast or ecosystem. In this sense, a rapid warning permits the verification and subsequent deployment of response teams that combat oil pollution accidents, at an early stage, thus improving the chances to reduce the impact on the environment.

Recognising the significance of early detections, CleanSeaNet has been making continuous efforts to deliver the images ideally as fast as possible and was able to reduce the delivery time down to less than 30 minutes, i.e. near-real time.

Once the images are analysed, the service provider (EDISOFT, KSAT or Telespazio) sends them to both to CleanSeaNet and to the Member States (CleanSeaNet Web Browser, phone, mail) (Journel 2008). If a potential oil spill is detected in any of the images, the service provider sends as well an oil spill alert directly to the Member State concerned. Having received from CleanSeaNet the images and alerts for potential oil spills, it is then up to the Member State to verify it and follow up. According to the user conditions of CleanSeaNet, Member States are invited to verify and follow up oil spill alerts, and leave a feedback on the subsequent results on CleanSeaNet Web Browser. Such feedbacks play an important role in CleanSeaNet because statistics based on them help to measure the quality of this service (false oil spills, delivery time of the images) and permits identify areas that may need improvement. In other words, it closes the CleanSeaNet service loop.

In addition to providing support to Member States regarding routine oil spill surveillance of oil spills, CleanSeaNet service is extended to assist Member States in the event of an accidental oil spill in their national waters. This assistance is usually given in the form of additional emergency satellite imagery of such oil spill.

1.4 How useful is it?

CleanSeaNet service satellite service brings significant advantages to its users, some of which have been mentioned before:

a. the early oil spill warning permits, on one hand, engage response teams to fight an oil spill an early stage and, on the other hand, to track the polluter vessel and the gathering of evidence needed for the courts in the case of a deliberate oil discharge.

b. satellite surveillance covers much larger areas than those covered by aircraft on aerial surveillance.

c. unlike aircraft for aerial surveillance, satellites are operational in all weather conditions.

d. the satellites used are equipped with synthetic aperture radar (SAR). Images are produced in both daytime and night time conditions and, unlike equipment fitted in the aircraft, SAR can "see" through cloud as well.

e. CleanSeaNet acquires satellite images on a large scale, lowering the cost per unit. The unit price of an image is otherwise significantly higher and constitutes an economical load when having to be obtained outside the scope of CleanSeaNet. The images provided by CleanSeaNet services are free of charge for their users.

However, satellite surveillance still faces some technical challenges:

a. many 'look-alikes' give too many false oil spills. This implies extra costs on verification flights and may constitute a factor of dissuasion to use CleanSeaNet by a Member State.

b. satellite radar SAR can not detect oil spills in calm winds (less than 2 m/s) or in winds stronger than 15 m/s.

b. all ‘oil spills’ are only possible oil spills, with three different levels of probability, which implies they require verification always (more costs!)..

c. inflexibility resulting from its orbital and cyclical route, compared with the relative flexible flight trajectories possible with aircrafts of aerial surveillance.

Since satellites cover a much larger area than aircrafts and are not affected by weather conditions, CleanSeaNet satellites services can be used as to supplement regular oil spill surveillance flights, a solution particularly advantageous when the use of aircraft is for some reason limited or when larger areas need to be covered.

In addition, CleanSeaNet’s satellite images and the early alert of a possible oil slick represent an added-value to existing surveillance programs, in the sense that it constitutes an additional channel to receive information about possible oil spills. In a possible scenario of integrating CleanSeaNet to an existing surveillance program the amount of flight hours dedicated to routine oil spill patrolling would not be reduced but topped up with CleanSeaNet service information. In practical terms this would mean that routine surveillance flights would be carried out as planned and in the event of a possible oil spill being detected by the satellites this could be verified as well in addition.

In what concerns vessel identification and tracking, when **STIRES**, the new module in SafeSeaNet, becomes operational, the users will then also be able to track the movement of vessels along the entire EU coast with AIS, in real-time (EMSA, SafeSeaNet leaflet).

In addition, EMSA is also preparing to provide ship identification on a global basis, through the recently developed LRIT data centre, in order to complement the currently available, of more regional character, AIS information. Contrary to AIS, the LRIT does not have such type of range limitations because it is satellite-based, and as such can be used to advantage as a complement to AIS (EMSA, SafeSeaNet leaflet).

It has been shown that EU Member States are using CleanSeaNet services. Since it started in 2007, the number of images EU

Member States received from CleanSeaNet service increased from 1288 images in 2007 to 1767 images in 2008 (HELCOM 2009e).

In what concerns the number of oil spill indications and confirmed oil spills for Europe, they are as follows:

Table 2. *Statistics 2007-2008 EU Member States (EMSA 2009e).*

Year	Images received by EU Member States	Oil spill indications	Verified possible oil spills	Oil spills confirmed
In 2007	1288	1759	-	-
In 2008	1767	2712	689	202

It is shown that only 25% of the oil indications have been verified. Of these, about 30% were confirmed.

2 CleanSeaNet in Sweden

2.1 Context – how is oil spill surveillance done?

Sweden has a relatively long coast, and an Exclusive Economic Zone (EEZ) of about 70 000 km^2. This EEZ is crossed, to South and East, by an increasing number of oil tankers, in transit from and to the Gulf of Finland (Bonn Agreement 2009).

Traffic routes in the Baltic Sea are among the busiest ones in Europe. At the same time, the Baltic Sea is both a designated "special area" and "PSSA". It is a relatively closed water basin, with a somewhat restricted flow and areas of sensitive ecosystems. Large oil spills, or large amounts of illegal discharges, would have a significant impact.

For these reasons, the Baltic Sea needs strict marine environment protection and the safe transit of oil tankers. The discharge of any oil in the Baltic Sea is forbidden in the Baltic Sea, through the incorporation of IMO guidelines (IMO 2002) and (IMO 2005) into national regulations of the countries bordering the Baltic Sea, and constitutes an offence.

Yet, keeping it oil free is still a challenge: according to SMHI (2005, p.2) most of the ship-sourced oil discharges in the Baltic Sea results from illegal discharges of oily waste and contaminated water from their engine rooms and cargo holds. SMHI reports in the same text that “aircraft for aerial surveillance detects about 400 illegal oil discharges a year [...] traffic is expected to increase [...] oil transportation is also expected to rise”.

It is the task of the Swedish Coast Guard to safeguard this marine environment and maintain the safety at sea. Due to the complexity and extension of the problem, these are not easy assignments, nor are the targets ones fast to reach. Recognizing this, the Swedish Coast Guard solved the problem quite well by following a strategy that can best be described in two words: one based on **co-operation** and on **surveillance.** These will be explained further below, after a short presentation about the Swedish Coast Guard.

The Swedish Coast Guard has its Headquarters in Karlskrona and is constituted by 26 coastal stations, a flight division, located at Skavsta, and four regional command centres located at Härnösand, Stockholm, Karlskrona and Gothenburg (Swedish Coast Guard 2009a).

Its activities for protecting the marine environment along its coast includes responding to oil spill alerts and carry out aerial surveillance to detect/monitor oil discharges, and collect oil samples in case of a spill. Swedish Coast Guard vessels and aircraft, and CleanSeaNet’s satellite images are used for this purpose.

The Swedish Coast Guard’s aerial surveillance routines, oil sampling procedures and reporting standards are influenced by the recommendations in the **Helsinki Convention**[7] (HELCOM 2008) and those in the Helsinki Commission’s **Response Manual Vol.1**

[7] The Helsinki Convention: The Convention on the Protection of the Marine Environment of the Baltic Sea Area, 1992, entered into force on 17 January 2000 (Helsinki Commission 2008).

(HELCOM 2001) and The Bonn Agreement (Bonn Agreement 2007 and 2009).

Their fleet of aircraft and vessels have been modernized recently. The aerial surveillance is carried out every day, both day and night, along the Swedish coast, by aircraft equipped with remote sensing equipment (Swedish Coast Guard 2009a):

- three new Dash-8 Q-300 (KBV 501, KBV 502 and KBV 503) replaced in 2008 the older CASA 212 aircraft;
- aircraft are equipped with AIS, to identify possible polluter vessels while airborne. In addition, according to Dreier (2005), the Swedish Coast Guard's aircrafts have also the ability to extend the coverage of the AIS coast station network.
- remote sensing equipment installed in these aircrafts: SLAR, IR/UV, IC video camera, video camera and photo camera.

In addition, according to the Swedish Coast Guard (2009a), three new large multipurpose vessels will be delivered in 2009-2010 (KBV 001, 002 and 003) for dealing with spills of large volumes of oil, as well as four new combination ships to replace older environmental protection vessels.

According to the Swedish Coastguard (2009a), actions of co-operation and of aerial surveillance were stimulated and established both **nationally** and **internationally**, with the purpose of protecting the environment and promote the safety at sea, in particular of the Baltic Sea area.

On the national level, the Swedish Coast Guard joined other national authorities in the development of **SJÖBASIS** and collaborated closely with SMHI on the development of the oil drift model **Seatrack Web**. Both are today essential tools to complement the work done by surveillance.

Seatrack Web is an oil drift model developed by SMHI and the Royal Danish Administration of Navigation and Hydrography. It is the official oil drift forecasting system of HELCOM and the one adopted by the Swedish Coast Guard. It is used to help respond to and minimize the impact of oil pollution incidents but also to assist in finding the polluter and collect evidence for prosecution.

Based on information in the User's Manual (SMHI 2009), this 3D drift model covers the Baltic Sea, the Sounds, Kattegat, Skagerrak and part of the North Sea. It is intended mainly for oil recovery purposes but also does hindcasts. Seatrack Web forecasts are made daily for up to five days, and hindcasting for up to ten days back. Wind forecasts inputted in the calculations are retrieved from the HIRLAM weather model, whereas those about the current and waves in the Baltic Sea are taken from the oceanographic 3D model HIROMB. Results are shown in tables and in graphics (trajectory and times). AIS information, as well as of satellite detections of oil spills, are available in the Seatrack Web. They are integrated with the results, and correlated with the trajectory of the oil spill, thus increasing the possibility of identifying the polluter.

Seatrack Web oil drift model is reliable and accurate. SMHI (2005) quotes the view of Thomas Fagö[8], from a user's perspective, about this model: "the system has been used on several occasions and has always been found very reliable and accurate."

The Swedish Coast Guard, in close cooperation with national authorities, including the Swedish Armed Forces and SMHI, developed SJÖBASIS information system with the purpose of centralizing and presenting maritime related information in one single place so that users can obtain the information needed by acceding one system only, thus more efficiently. Information is available online 24 hours a day/365 days a year and access is restricted.

SJÖBASIS is consulted when it is necessary find the identification of a vessel or be able to track a suspect polluting vessel.

The range of information provided by SJÖBASIS is quite wide and originates from reliable sources, such as the Swedish Armed Forces, Police, Customs and VTS, to name only a few.

[8] Thomas Fagö, Response Director of the Swedish Coast Guard HQ.

What information in SJÖBASIS is interesting for the purpose of surveillance of operational oil discharges at sea? Based of Dreier (2005):

- Information from the Swedish AIS coast station network, covering the Swedish coast;
- Vessel traffic information from the Swedish Armed Forces (coastal radar stations, cameras and AIS/radar);
- Information from the HELCOM AIS, which covers the Baltic Sea, Kattegat and Skagerrak;

The information given about a vessel includes (Dreier 2005): position, heading, course and speed over ground, MMSI, call sign, type of vessel, status (anchored, underway...), ETA/ETD, data source and an indication of the quality of this information. This is valuable information for those involved in the surveillance of oil discharges and receiving CleanSeaNet alerts.

AIS/radar/cameras information are shown in real-time, but can also be replayed later on. Based on (Dreier 2005), this suggests that, both types of information are useful, in different ways. The AIS information in real time is interesting for a confirmed CleanSeaNet early oil spill alert if the satellite image indicates that a suspect polluter vessel is very close to the oil spill. A quick glance to this real-time information gives the identification of the possible polluter directly and simplifies the subsequent process of gathering evidence onboard. The replayable AIS information, on the other hand, can be used in conjunction with the Seatrack oil drift model, when there is no suspect polluter vessel in the immediate vicinity of a confirmed CleanSeaNet oil spill alert. In such cases stored AIS information can be visualized backwards in association with an oil drift hindcast and possible polluters can be identified through AIS information when the tracks of both meet. In this case, the subsequent process of control and collecting evidence is possible, though perhaps not as simple as in the former example.

Other information useful for oil spill surveillance integrated in the SJÖBASIS include the Seatrack oil drift model, SMHI weather information and the register of ships (Swedish Maritime Administration) and electronic charts (Dreier 2005). An example of how they can be used in conjunction with a confirmed CleanSeaNet oil spill alert is when AIS information and a Seatrack hindcast are shown on superimposed layers over an electronic chart of the area of the spill.

This commitment to protect the environment was extended to the international plan. Agreements of cooperation with other countries were established with the purpose of harmonizing procedures, so that, through **coherency and cohesion** of efforts the prevention of ship-sourced oil pollution could be achieved on a larger scale, and more efficiently, a more powerful deterrent effect over potential polluters. In this context, **three agreements** were established:

- the **Bonn Agreement**, between countries adjacent to the North Sea area (Bonn Agreement 1983);
- the **Copenhagen Agreement**[9], between the Nordic countries (Copenhagen Agreement 2008);
- The **Helsinki Convention**, between countries adjacent to the Baltic Sea area (HELCOM 2008);

The Helsinki Convention and the work of HELCOM merged and coordinated the efforts of Sweden and of the other Baltic countries, forming a coherent and coordinated force for protecting the Baltic Sea area (HELCOM 2008): joint surveillance flight and exchange of information were agreed between the HELCOM countries. Areas of dense traffic were consistently and continuously under aerial surveillance.

Another example of international cooperation is the project with Kongsberg Satellite Services, referred by Mr. Nilsson (Nilsson 2009), in which satellite radar images supplied by KSAT were used for the surveillance of oil pollution along the Swedish coast. After an experimental test period, the project was extended to Finland, Poland and other Baltic countries, who also started to use KSAT's satellite radar images in conjunction with the aerial surveillance of oil spills.

Today these images are supplied to Sweden by EMSA CleanSeaNet service instead. In the Baltic Sea area, as a result of the consistent

[9] Copenhagen Agreement was drawn in 1993 by the Nordic countries (Norway, Iceland, Sweden, Finland and Denmark) for the Cooperation concerning Pollution Control of the Sea after Contamination by Oil or other Harmful Substances.

and harmonized work through HELCOM, there seems to be a raised awareness against oil discharges. HELCOM statistics for 2007 show less medium and large spills, the majority of the spills is now $<1m^2$ i.e. almost negligible. In 2008, according to Swedish Coast Guard (2009a), 36 000 liters of oil was spilled around the coast of Sweden, which represents an increase of 10 000 liters compared to 2007. However, 25 000 liters came from one single oil spill in a port in the northern region.

The recommendations in such agreements shape the way how the Swedish Coast Guard plan and carry out their routines. A short selection from the **Counter Pollution Manual** on routine aerial surveillance (Bonn Agreement 2009, Chapter 25) illustrates this:

1^{st}. Under one of the planned routine flights the aircraft crew detects a possible oil spill, or receives a CleanSeaNet alert of a possible oil spill through satellite communication equipment onboard the aircraft.

2^{nd}.When planning the flights, their frequency and surveillance are to be based on traffic intensity, where the probability of oil discharges is higher.

3^{rd}. The oil spill and the polluting vessel should be documented, as a source of evidence, with all the remote sensing equipment installed onboard. Imagery should show that the vessel is the only possible source of the oil spill. Photograph the vessel's name (use IC camera if this occurs at night), showing the vessel as the clear offender.

4^{th}.The oil spill situation is reported to the authorities, from the aircraft, or after landing.

5^{th}.The observation/report logs and documentation collected, along with sampling of the spill and sampling onboard the polluter vessel, is used for prosecution and also to produce statistics and for future flight planning.

Two aspects need to be taken into account regarding the monitoring of oil discharges. One is the identification of the maritime routes in which the traffic is more intense and constant. The other is the identification of the areas whose ecosystems are extremely vulnerable to marine pollution, in particular oil.

These considerations are useful when, for example, the Swedish Coast Guard of the Member States has to plan their routine aerial surveillance flights or when satellite images have to be ordered to EMSA.

2.2 What can CleanSeaNet contribute for Sweden?

It was shown in section 2.1 that the Baltic Sea Area has dense maritime traffic. HELCOM statistics illustrated in Figure 12 shows shipping routes where traffic is more intense.

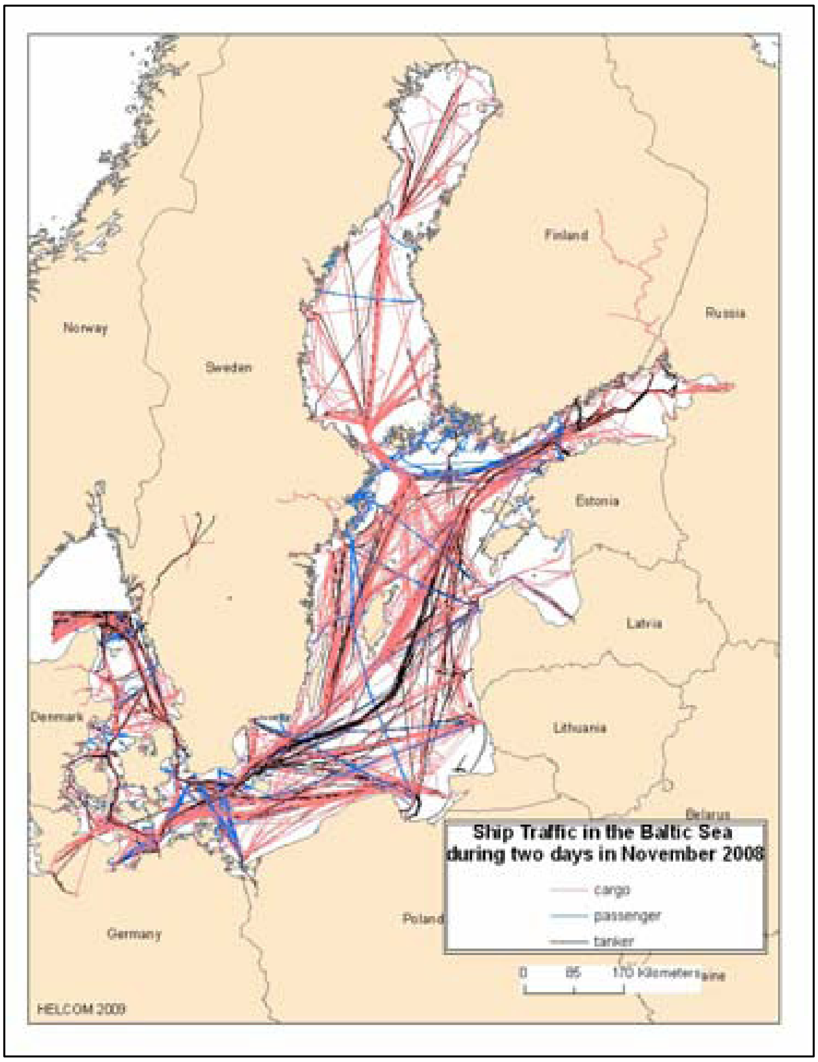

Figure 12. *Traffic in the Baltic Sea is intense (HELCOM 2009).*

Denser maritime traffic implies a higher probability of oil being discharged at sea. This is confirmed by HELCOM statistics for 2007, shown in Figure 13, in which observed illegal oil discharges form a trail that coincides with the main shipping routes in the Baltic Sea area.

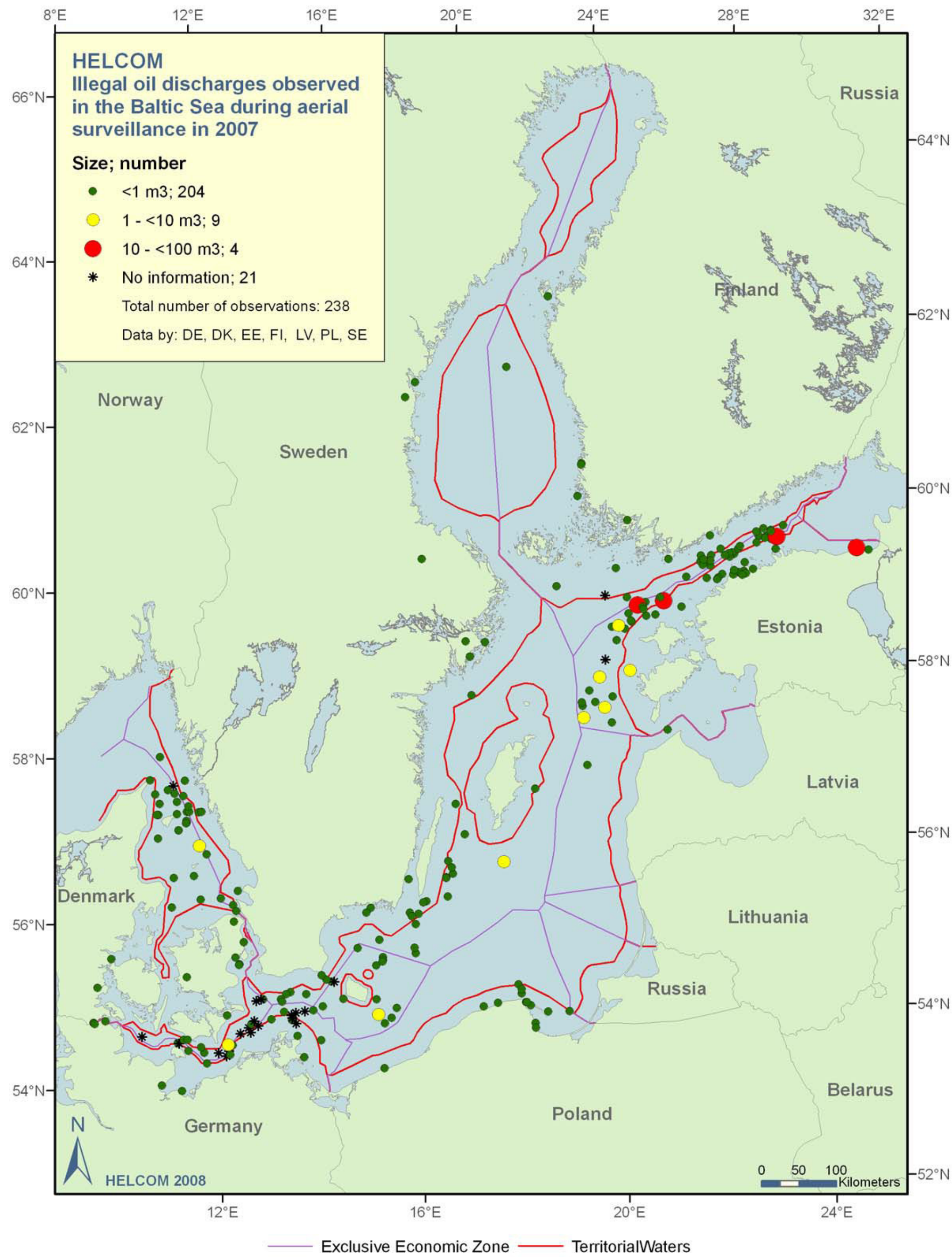

Figure 13. *Oil discharges in the Baltic Sea area 2007 (HELCOM 2007).*

In addition, Figure 13 shows that oil spills still occur along the Swedish Coast and in the Baltic Sea area, in spite of being a sensitive area and a PSSA, protected by strict regulations which forbid oil discharges. A total of 238 oil spills were observed in 2007.

This reinforces the need for surveillance so that suspect vessels can be detected, identified and linked to the oil discharge in order to invert the trend and reduce or eliminate the illegal oil discharges in the Baltic Sea.

It was also shown that surveillance of the Swedish waters is carried out by the Swedish Coast Guard, with aircraft equipped with remote sensing instruments, and supported by their vessels.

Mr. Ulf Nilsson (2009) considers that CleanSeaNet service has been useful to the surveillance of ship-based oil pollution in Swedish national waters in the sense that the oil spill alerts and satellite images **complement** aerial surveillance actions of the Swedish Coast Guard. It constitutes a source of information that complements the continuous and regular aerial surveillance operations. This aspect plays an important role when planning for an optimal use of resources at the Swedish Coast Guard.

According to Mr. Yngve De Bourg (2009, auth. transl.), CleanSeaNet service acts also as an **“alarm bell”** for alerting the Swedish Coast Guard for a necessary verification and response action to a possible oil spill. Aircraft can not cover a large area. Oil spills that occur outside the aircraft range and that would otherwise be unnoticed may be spotted by satellite imagery, which covers a larger area.

Statistics from EMSA for 2008 show that Sweden uses CleanSeaNet on a regular basis for the surveillance of oil spills (EMSA 2009e):

Table 3. *CleanSeaNet statistics 2007-2008 Sweden (EMSA 2009e).*

Year	Images received by Sweden	Oil spill indications	Verified possible oil spills	Oil spills confirmed
In 2007	258	99	-	-
In 2008	246	133	55	13

Table 3 shows also that the Swedish Coast Guard verified in 2008 41% of the oil spill alarms received from CleanSeaNet services. Of these, 24% were confirmed oil spills. According to Mr. Yngve De Bourg (2009, auth. transl.), results from the verification flights performed by the Swedish Coast Guard are reported continuously to the CSN Web Browser (feedback). In the event of a confirmed oil spill, the relevant satellite images are used as a source of evidence. Mr. De Bourg (2009, auth. transl.) confirms that some vessels have been caught this way, from which one may infer that this service is useful.

The Swedish Coast Guard uses the oil drift model Seatrack web and the information system SJÖBASIS to complement the information in the satellite images received from CleanSeaNet service.

2.3 How could Sweden contribute to CleanSeaNet?

The Swedish Coast Guard had an active role in the development of SJÖBASIS and of Seatrack Web. As a result, it is familiar with the challenges of integrating information from different sources into one single database, and knows what information needs to be overlapped and used in conjunction with satellite images and aerial surveillance.

In addition, the Swedish Coast Guard is skilled with the use of satellite images for the surveillance of oil spills, based on several years work with KSAT project.

Moreover, the Swedish Coast Guard is experienced in working in close cooperation with other organizations, such as HELCOM and Bonn Agreement, for the purpose of intensifying and harmonizing oil spill surveillance routines and procedures in the Baltic Sea area.

In conclusion, the Swedish Coast Guard's know-how and experience on the surveillance of oil spills could be used to the advantage of EMSA on the development of CleanSeaNet service, e.g. on the integration of vessel tracking information and oil drift models into the CleanSeaNet service.

PART V – DISCUSSION

CleanSeaNet is a relatively new service available to the European Member States. It is operational 24 hours a day and 365 days a year. The delivery time of images has been reduced to less than 30 minutes, which constitutes an advantage of the service. However, levels of confidence of the oil spill alerts are relatively low.

On one hand, the verification rate is low: there were 2712 oil spill indications from CleanSeaNet during 2008 and of these only 25% have been verified or reported to have been verified. This raises some questions: why is the verification rate low? Have all the verification activities been reported to CleanSeaNet Web browser? It would be interesting to study which selecting criteria is followed by each Member State when deciding which oil spill alerts are to be verified, and what factors affect verification activities.

On the other hand, only about 30% of the verified potential oil spills are confirmed oil spills. It would be interesting to determine the costs involved with the verification of all the false oil spill indications and analyze how these weigh against the benefits of CleanSeaNet satellite surveillance service.

In addition, it is clear that fast delivery times of oil spill alerts increases the chances of detecting and tracking a polluting vessel. However, the confidence level of the alert is equally important. This raises further questions: could image analysis technique be improved in order to reduce false oil spills? Alternatively, are there any technological solutions available which could be used in conjunction with the satellite SAR, increasing the confidence level to 100%?

In what concerns obtaining ancillary data, such as AIS and oil drift analysis, Member States need, at the moment, to access three or four different sources to accede this information: the CleanSeaNet service, for satellite images, the SafeSeaNet, for AIS information and national weather/oceanographic centres, for weather information and oil drift forecasts/hindcasts. It would be more practical to have all this information accessible from one single system, with the possibility to combine different data in overlapping layers, e.g. oil drift hindcast and AIS backtracking.

In this context, it was interesting to read the announcement of the 2nd generation CleanSeaNet, which will present AIS/LRIT information integrated in CleanSeaNet's satellite images.

In what concerns oil spills, it is unfortunately a fact that they still occur with some frequency in Europe, in particular along routes of denser traffic, despite strict regulations against it. This motivates the fact that most EU Member States are ordering images from CleanSeaNet service. However, an analysis of the impact these services might be having on the reduction of oil spills in European waters is premature, since the service has been available only since 2007.

It was interesting to notice that although oil spills still occur relatively frequently in Swedish national waters and the rest of the Baltic Sea area, they are becoming very small in terms of volume. In fact, HELCOM statistics have shown that operational discharges have become nearly negligible in terms of volume of oil spilled: of the 238 oil spills observed in the Baltic Sea area in 2007, 90% were less than $1m^3$. CleanSeaNet service started only in 2007 and therefore eventual effects of this service in the Baltic Sea area are not visible in the 2007 HELCOM statistics shown above. In the case of Sweden, the reduction is a result of the Swedish government's public commitment, some years back, to completely eliminate the discharges of oil in national waters by the year 2010, providing the Swedish Coast Guard and other organizations with the necessary means to achieve this goal. Thus, it was possible to develop SJÖBASIS, to integrate satellite imagery with KSAT, renew the aircraft fleet and order modern vessels to be used in the surveillance of oil spills. This long term commitment to reduce the illegal oil discharges in Swedish waters and in the Baltic Sea area, as well as the coordination of efforts through HELCOM and Bonn Agreement, has had the effect of reducing the amount of illegal oil discharges in Sweden and the rest of the Baltic Sea area.

PART VI – CONCLUSION

CleanSeaNet service is a relatively new service provided by EMSA to help the EU Member States locate oil discharges and detect suspect polluting vessels, in order to reduce oil spills in European waters. For this purpose CleanSeaNet provides the Member States with satellite images for routine surveillance activities against illegal oil discharges and near-real time alerts whenever a potential oil spill is detected on a satellite image. In addition, CleanSeaNet can provide the Member States with emergency satellite images in the event of an oil spill accident.

CleanSeaNet is needed by the European Member States because oil spills still occur in European waters, in spite of strict regulations that forbid it. In addition, CleanSeaNet's fast service shortens the time elapsed from the moment the oil was discharged until the polluting vessel is tracked, thus simplifying the gathering of evidence needed for a legal case against the polluter.

CleanSeaNet service delivers satellite images and oil spill alerts to the Member States. SAR sensors onboard satellites register images, which are downloaded to a ground station of a service provider (KSAT, EDISOFT or Telespazio). The task of the service providers is to process and analyze these satellite images, taking into account factors like currents and winds, and to discard false oil slicks, in less than 30 minutes. Potential oil spills are marked with one of the three different confidence levels indicators and sent to the EU Member State and to the CleanSeaNet browser. It is then up to the Member State to verify the possible oil spill and leave a feedback in the CleanSeaNet Web browser.

CleanSeaNet has been used by the Member States. In 2007 the Member States received a total of 1288 analyzed satellite images. In 2008 this was increased to 1767. In 2008 there were 2712 indications of possible oil spills. 25% of these were verified, of which about 30% were confirmed oil slicks.

Fast delivery of oil spill alerts (near-real time) is among the advantages of CleanSeaNet. However, the relatively high number of false oil spills is a disadvantage of the service.
In addition, it is desirable to integrate AIS/LRIT information in CleanSeaNet services. EMSA announced that the 2nd generation CleanSeaNet will have this information included in the satellite imagery.

In the particular case of Sweden, CleanSeaNet has been integrated in the Swedish Coast Guard's surveillance of oil spills activities, not only as a source of alert for possible oil spills but also as a complement to their operational routines. Sweden received from CleanSeaNet 258 satellite images in 2007 and 246 in 2008. 41% were verified in 2008, of which 24% were confirmed oil spills.

The Swedish Coast Guard has a long experience in using satellite images for the purpose of surveillance of oil spills. Due to their role on the development of SJÖBASIS and Seatrack Web, the Swedish Coast Guard has also gained valuable know-how on integrating vessel traffic information with oil drift analysis. Such experience and know-how could be useful to help improve further the CleanSeaNet service.

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Personal Communications

Mr. Ulf Nilsson - Regional Inspector Swedish Coast Guard West Region, interview on 14.10.2009, at the Swedish Coast Guard in Göteborg, Sweden and subsequent contacts.

Mr. Yngve De Bourg - Swedish Coast Guard HQ, Flight Command, Karlskrona, Sweden, interview by e-mails exchanged on the 3 & 18.12.2009.

APPENDIX A

Verified summary of the visit to the Swedish Coast Guard and interview to Mr. Ulf Nilsson, Regional Inspector Swedish Coast Guard West Region, in Göteborg, 14.10.2009, and subsequent contacts.

How is CleanSeaNet used in the surveillance of oil spills in Sweden?

CleanSeaNet service is used as a complement to the surveillance of oil spills carried out by the Swedish Coast Guard, in the sense that it provides analyzed satellite SAR images and possible oil spill alerts in less than 30 minutes. Our aircrafts/vessels verify the oil spill alert sent by CleanSeaNet. In case of being confirmed, a sample of the oil is taken with buoys or other sampling equipment. A search for information about a possible polluter vessel is carried out, in SJÖBASIS information system. It provides the AIS and radar information needed to determine the identification. In the case that it is not possible to identify immediately the vessel that discharged the oil, then a vessel tracking is done with AIS/radar information stored in the SJÖBASIS. Oil drift analysis is done on the Seatrack. Once identified and located, the Swedish Coast Guard contacts the suspect vessel and takes oil samples onboard. This is then sent for analysis. If the oil sample from the vessel matches the oil sample absorbed by the buoy then a link is established between the vessel and the slick, constituting evidence for a legal case.

How useful is CleanSeaNet?

Yes, it has been useful, as a complement to our resources with all the inherent benefits that this brings, such as the fast alerts of possible oil spills and analyzed images, and disadvantages such as false oil spill alerts.

What has changed since it was introduced?

We have not reduced the number of flight hours of our aerial surveillance with the introduction of CleanSeaNet. However, since CleanSeaNet service started, we do not need to buy satellite SAR images for oil spills surveillance like we did before. After the initial experimental phase of a satellite image project with Kongsberg Satellite Services (KSAT), under which the images had been for free, images costed then already about 12,000SEK each. Now we receive analyzed satellite images for free since CleanSeaNet service started, and delivered to us in less than 30 minutes.

We have seen a reduction on the amount of oil spilled along the Swedish coast, due to the Swedish Government's commitment to prevent pollution of the marine environment, made public some years back. The goal was to eliminate the oil pollution by 2010. An economic support package was made available for this purpose. This allowed the Swedish Coast Guard to expand its resources for combating illegal oil discharges along Swedish national waters. Besides of the project with KSAT, aerial surveillance was regularly made. In addition, the Swedish Coast Guard has been working for several years in close collaboration with other countries of the Baltic Region and, as a result, monitoring of oil spills intensified. Joint aerial surveillance missions assured that areas of more intense traffic in the Baltic Sea were being monitored continuously. We have been partners of the Helsinki Commission (HELCOM) to help fight oil pollution in the Baltic Sea, and this is reflected in our surveillance routines and its subsequent results. The aim of the Swedish Government was to eliminate totally the amount of oil illegally discharged on national waters by the year 2010. It is my opinion that the present levels are now so low that can be considered negligible, and be accepted that we have now reached that target.

Summary of subsequent contacts

The satellite image project with Kongsberg Satellite Services (e-mail 14.10.2009, translated by the author):

around 1999-2000, the Swedish Coast Guard and Kongsberg Satellite Services (KSAT) agreed to collaborate in a project to test satellite images. For this purpose, the Swedish Coast Guard received several satellite images for free, to be tested. In return KSAT was given feedback on the result of the tests. In the opinion of the Swedish Coast Guard then, the image analysis process and delivery of the images were taking too long. The Swedish Coast Guard was, at the same time, working in close cooperation with Finland, to ensure continuous aerial oil spill surveillance on areas with more intense traffic. Finland (Finnish Environment) joined also the KSAT project and the testing of satellite images continued under the condition that KSAT would improve the image analysis and speed up the delivery time. In 2002, a total of 60 images were received by Sweden and Finland from KSAT. At the same time, the joint aerial surveillance established with Finland kept areas of more dense traffic under continuous aerial surveillance. In 2003 the number of images increased to 80 (including 20 for the Impast[10] project).

In 2004: 150 images (of which, 30 were used in combination with joint aerial surveillance with Finland);

In 2005: 257 images (of which, 40 with Finland, 20 with Poland and 14 with Denmark, combined with joint surveillance with these countries).

In 2006: 360 images (of which, 40 with Finland, and 200 with Denmark, combined with joint aerial surveillance in these countries).

In 2007 EMSA became operative on the 16th April, with the delivery of its very first satellite image to a Member State (Greece). From then on, a total of about 2000-2500 images per year have been delivered to EU Member States.

[10] Impast project: project for the detection of oil discharges in combination with ship detection.

APPENDIX B

Interview to Mr. Yngve De Bourg, from the Swedish Coast Guard, e-mails exchanged on 03/18.12.2009.

Användning av SAR bilder från satellit har pågått ett antal år vid det här laget. Runt sekelskiftet pågick försöksverksamhet för att se om det kunde tillföra något, i vår ambition att bättre övervaka och reducera antalet illegala utsläpp runt våra kuster. Den av statsmakten givna målsättningen är ju att 2010 skall antalet illegala utsläpp vara försumbara. Utvecklingen har sedan lett till att satellitbilder (SAR) används dagligen i den operativa verksamheten där den utgör ett viktigt komplement och också "väckarklocka" för verifiering och respons.

1. Om integrering av CleanSeaNet i Kustbevakningens övervakningsarbetet av oljeutslapp till sjöss:

Kustbevakningen använder idag Clean Sea Net som en viktig informationskälla för miljöövervakning. Tillsammans med rutinmässig flygövervakning, som pågår i stort kontinuerligt, och sjögående enheters upptäckter och response utgör detta ett system. Med en kombination av satellitbilder, som täcker mellan 300 och 400 km i sida, och främst flygövervakning täcks stora ytor. Ett flygplan kan ju inte vara överallt samtidigt, däremot går det bra att kolla upp en indikering som erhållits från satellit. En indikation på ett eventuellt oljeutsläpp ger Vakthavande befäl i våra regioner (norra, östra, södra, västra) möjlighet att styra sina resurser och fatta beslut om hur man går vidare.

2. Hur många satellit bilder beställs för övervakning av oljeutsläpper?

Antalet bilder varierar en del från månad till månad. I Sverige har vi valt att anpassa oss till säsongsförhållanden som påverkar möjligheten att effektivt nyttja satellitresurser; under perioder med hårdare väder, iskonditioner och algblomning är det mindre värdefullt att använda den resursen. Totalt "beställer" vi ca 480 bilder under 2009. Till detta skall också läggas de bilder som grannländer beställer och som till del berör vårt intresseområde. Räknar man in dessa också så har vi tillgång till satellitinformation från mer än 500 bilder varje år.

3. Om verifiering av CSN larm om ett möjligt oljeutsläpp:

Så kallad alertmeddelanden tas omedelbart om hand av den operativa organisationen, med Vakthavande befäl i spetsen. Vanligen eftersträvar man att skicka eller omdirigera ett av våra flygplan till platsen för att snabbt kunna verifiera om det rör sig om ett otillåtet utsläpp. SAR utrustningen ombord satelliten, snarlikt vår "Side Looking Airborne Radar"(SLAR) i flygplanet, indikerar också andra saker varför en verifiering är absolut nödvändig. Det är här våra besättningars stora kunskap och erfarenhet kommer in i bilden.

4. Har några fartyg gripats följande oljeutsläpplarmer från CleaSeaNet service?

Ja det har hänt. Satellitinformationen blir då en del i en beviskedja. Det är alltid viktigt att kunna dokumentera så mycket som möjligt; foto, video, SLAR, oljeprov etc. Detta gör man från flygplan i samverkan med sjögående enheter.

5. Om feedback till CleanSeaNet Web Browser följande oljeutsläppslarmer:

Vi ger kontinuerligt feed back till CSN.

6. Vad anser ni bör förbättras i CleanSeaNet service?

På satellitsidan bör man fortsätta att utveckla algoritmer för "oil detection". Detta ligger då främst på service leverantörerna och inte så mycket på CSN. Mer info i olika valbara lager på browsern vore önskvärt, allt i avsikt att kunna fatta bra operativa beslut och underlätta bevisdelen av ett case. Det pågår för närvarande studier inför CSN 2nd generation där man bland annat kommer att kunna hitta drift modeller, olka typer av meteorologiska och oceanografiska lager av information.