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Improvement of oil spill fighting by using SAR satellite detection and e-navigation systems

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Key words: oil spill, satellite detection, e-navigation system, problem's identification, incidents

Abstract
The article presents the solution for improvement of oil spill fighting with utilization of synthetic aperture radar. The way of identification is presented as well as the treatment of obtained data in order to eliminated "looks like" objects. Such system will widely improve the oil spill fighting at a very early stage of incident.

System strategic objectives

The most important regulations for preventing pollution by oil from ships are contained in Annex I of the International Convention for the Prevention of Pollution from Ships, 1973, as modified by the Protocol of 1978 relating thereto (http://www.imo.org), The International Convention for the Safety of Life at Sea (SOLAS), 1974 also includes special requirements for tankers.

The crude oil is transported around the world by sea at any moment. The amount of oil is about 1.800 million tons per year. In most cases the oil is transported quietly and safely. But instead of measured introduced by IMO e.g. special tanker construction, the accidents with oil spill consequences still happen. Moreover, the guilty of large amount of oil spill incidents remain unfound. In effect oil is deposited on the bottom and along the coast destroying all living organisms. Very often it is too late for effective counteraction. The crucial thing in order to be able to react in time is detection in very early stage of incident [1].

Among few possibilities the satellite detection seems to be the proper one. Satellite observations offer the possibility of a frequent monitoring of wide areas. In SAR images, the brightness of the sea surface is a measure of the sea surface roughness. Smooth sea surface appears dark while the brightness increases as the sea surface becomes rougher. Oil films are very effective in damping wind-generated gravity capillary short waves on the sea surface and hence they appear dark against a brighter background in a SAR image [2]. However, there are other natural phenomena (e.g. biogenic slicks, ship wakes, low wind areas, etc.) which produce dark areas in SAR images. This class of phenomena is known as "look-alike" [3]. The figure 1 shows an example of a detected oil spill during the Event Horizon disaster. With red is marked the border of a detected oil spill.

Taking all above under consideration it seems that there is opportunity to create system responsible for detection of oil spill at very early stage of disaster.

The author proposed solution will be designed for:

– early oil pollution detection;
– evaluation of situation;
– planning antipollution action taking into account the rescue resources and other means located close to the incident area;
– contingency planning;
– analysis of situation;
– visualization in ECS/ECDIS system ashore and aboard;
– development of ECS / display applications for and integration on mobile devices (iPad, iPhone, Android tablets / smartphones etc.) (Fig. 2).

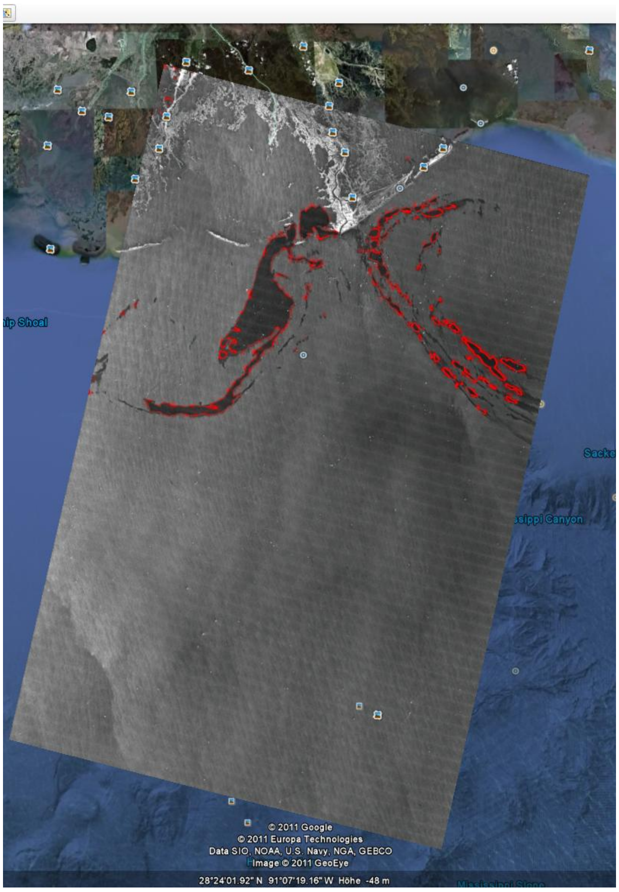

Fig. 1. Oil spill during the Event Horizon disaster within Google Earth

Scientific and technical aims of the proposed solution

Within proposed solution many other works must be performed and the following aims will be achieved:
– provision of algorithms and methodologies for decision support ensuring actions taken in case of oil spill are adequate in every stage;
– optimization of technical solutions under consideration of alternative approaches (gain compared to state of the art), complementary technologies (sensor and data fusion), and their ashore and onboard realization (sharing responsibilities) with the focus on sensor and system integrity;
– provision of sensor and data fusion based algorithms and methodologies ensuring specified integrity requirements during generation and dissemination of information used for comprehensive situation awareness;
– assumptions for visualization of navigational situation for presentation on board vessel, using criteria related to safe anti pollution operation;
– optimization of situational awareness visualization as one of problems in modern support system for aircrafts as well as vessels;
– development of optimal user interfaces for visualization on electronic chart (ECS and ECDIS);

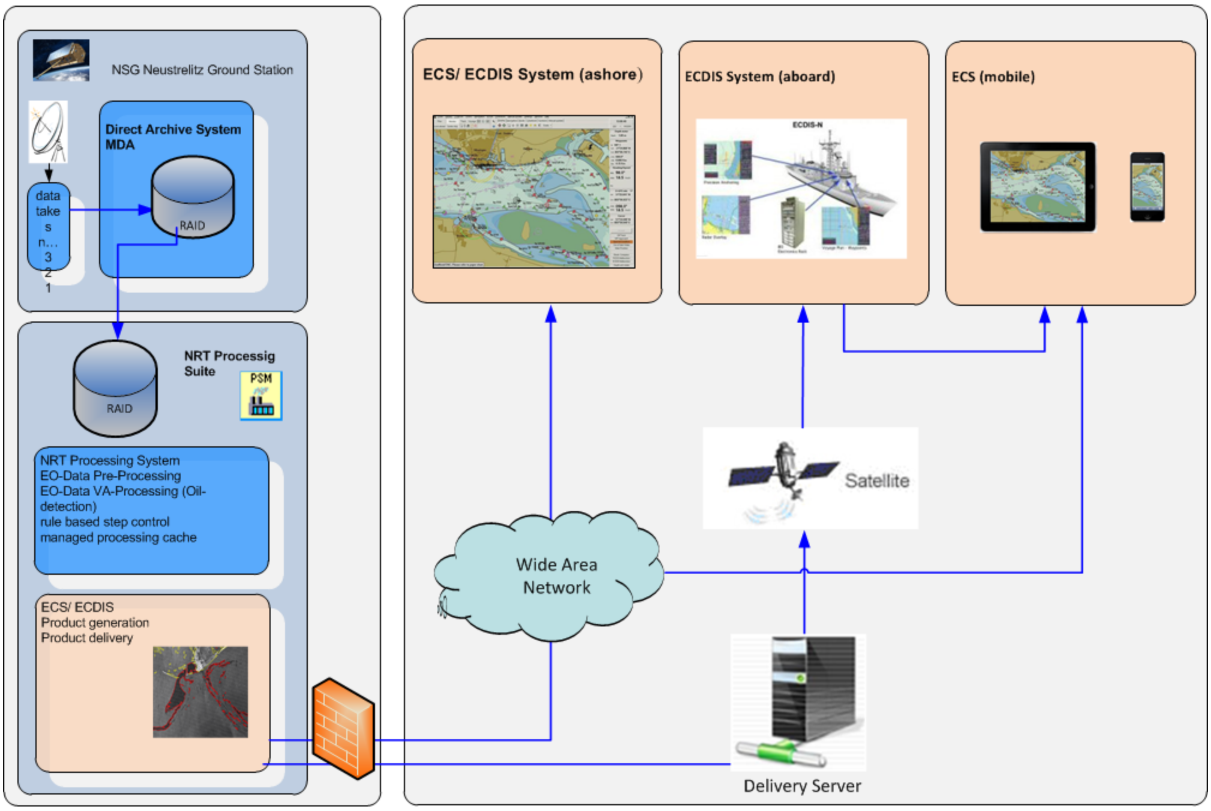

Fig. 2. Anti pollution detection system scheme

- development of optimal user interfaces for visualization on mobile devices;
- receiving current situation data on mobile devices;
- experimental and simulation based validation of technical solutions to develop and improve contingency planning in case of oil spill situations.

E-navigation and its relation with the solution

The most important challenge of IMO nowadays is to develop a framework which accommodates and builds on existing systems already furthering the concept of e-Navigation. Broadly used IALA definition of e-Navigation is as follows: "E-Navigation is the collection, integration and display of maritime information onboard and ashore by electronic means to enhance berth-to-berth navigation and related services, safety and security at sea and protection of the marine environment." At the 1st meeting of the IALA e-Navigation Committee, three fundamental elements were identified that should be in place before e-Navigation could be introduced. These are:

- electronic Navigation Chart (ENC) coverage of all navigational areas;
- robust electronic position-fixing system (with redundancy);
- standard infrastructure of communications to link ship and shore.

The most important projects in focused and related with e-Navigation are World Bank-funded Marine Electronic Highway (MEH) project in the Malacca Straits and the European Union's projects ATOMOS IV (Advanced Technology to Optimize Maritime Operational Safety – Intelligent Vessel) [4]. European Commission started working on e-Navigation in parallel with IALA funding the MarNIS (Maritime Navigation Information Services) project focused on developing e-Navigation.

ECDIS and ENC as the platform of shipborne system

ECDIS and ENC is very well defined standard. The delays in fully coverage by standard electronic charts (70% of coverage in medium and large scale charts today) and expected that coverage of all major international ports and international routes until 2012 will be at least comparable with existing paper chart coverage for those areas.

There are two types of onboard electronic chart systems, the first one is an Electronic Chart Display and Information System (ECDIS), which meets IMO / SOLAS chart carriage requirements. The second one an Electronic Chart System (ECS), which can be used to assist navigation, but does not meet IMO/SOLAS chart carriage requirements. As well as both of them can be used as stationary and mobile systems. For the cooperation with ECDIS there are two kinds of official digital charts commonly available:

- Electronic Navigational Charts (ENC);
- Raster Navigational Charts (RNC).

ENC means the database, standardized as to content, structure and format, issued for use with ECDIS on the authority of government-authorized Hydrographic Offices. The ENC contains all the chart information useful for safe navigation, and may contain supplementary information in addition to that contained in the paper, which may be considered necessary for safe navigation. Among all other available information there are that originated from satellites. At present such information is very rare in commercial systems used on the merchant vessels. In many cases data given by satellite means can give crucial information for safety of navigation, as well as environmental protection. The proposed solution focuses on the obtaining, selecting, adapting, sending and displaying additional information on the user layer in the commonly used ECDIS and ECS systems both, stationary and mobile ones [5].

Communication

The communication is most important issue of e-Navigation. Serious attempts are made to improve marine communication. The important one is MarCom (founded by Norwegian Administration) aimed towards creation of broad band marine communication networks. The interesting technique developed in the project is WiMax based and distributed mesh networks. Within the proposed solution different ways of communication will be utilized depend on the end user. In case of ashore systems, as well as mobile ones (tablest, smartphones etc.) combination of wide area network and Wireless Fidelity network will be used. For shipborne system the satellite communication will be established and utilized.

Integrated service platform

The DLR operated Ground Station at Neustrelitz is responsible for X-band data acquisition, as well as for NRT data processing and direct dissemination to users. Within proposed system the oil spill detection algorithm will be developed for TerraSAR-X/TanDEM-X SAR data. The operator complements the process of spill detection on

TerraSAR-X or TanDEM-X data. The table 1 gives an overview of TerraSAR or TanDEM-X modes used for planned oil spill monitoring in the DLR Service Chain (Table 1).

For monitoring of oil spills in near real time some dependencies have to be taken into account. With respect to the TerraSAR-X data policy only images with spatial resolution coarser than 2.5 m are available. For near real time application only single polarization data are up to now available. It is estimated that for the oil spill detection service less than 1 h including operator tasks is needed for delivering oil spill detection results to the user.

The remote sensing of oil slicks will be addressed in proposal by using single polarisation capability of TerraSAR-X. This sensor's high spatial resolution is of special importance, since the existing European oil spill detection service, EMSA's CleanSeaNet, is presently based on lower resolution images acquired by RADARSAT, CosmoSkyMed and ENVISAT satellites in conjunction with aerial and in situ observations in case of detection. Due to the recent anomaly of the Envisat satellite the revisit time for disaster monitoring will be reduced and could be improved by additional systems like TerraSAR-X and TanDEM-X. Moreover, it is expected that the incorporation of the higher spatial resolution of TerraSAR-X will offer the possibility to more accurately measure the width of discharges (being of the same dimension as the pixel size). Oil pollution at offshore platforms or due to illegal discharge from vessels, either in open sea or in coastal waters may have a severe impact on both, the flora and fauna of the polluted area (although small scale in comparison to tanker disasters). The environmental damages on the natural resources and on the economy of the area in distress are almost always uncountable. Thus, there is a need to rapidly and effectively detect and monitor such source of pollution, as well as predict oil spills drift. For this reason the solution also addresses the investigation of the possibility to measure the width of en route discharges. It should be investigated how oil spills will change

Table 1. TerraSAR-X Acquisition Modes for operational oil spill detection

	Stripmap (SM)	Spotlight (HS & SL) (NRT restriction)	ScanSAR (SC)
Swath width	30 km (single pol.) 15–30 km (dual pol.)	10 km, azimuth extend: 5 / 10 km (HS / SL)	100 km
Full performance incidence angle range	20°–45°	20°–55°	20°–45°
Azimuth resolution	3 m (single pol.) 6 m (dual pol.)	1 m / 2 m (HS, single / dual pol.) 2 m / 4 m (SL, single / dual pol.)	17 m (1 look, 4 beams)
Ground range resolution @ 150 MHz chirp BW	1.7–3.5 m (@ 45°..20°)	1.5–3.5 m (@ 55°..20°)	1.7–3.5 m (@ 45°..20°)

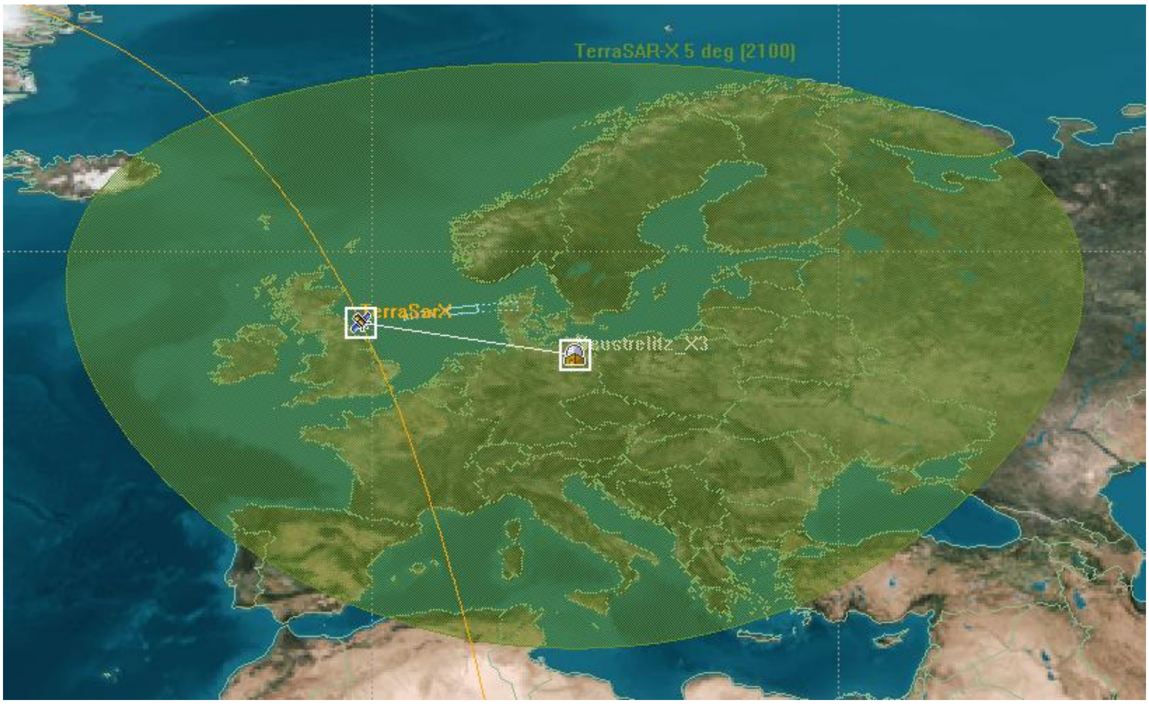

Fig. 3. Neustrelitz Horizon Mask 5 degree for TerraSAR-X

their characteristics (size, thickness, etc.) due to currents and winds.

One of the aims of the system is to analyse TerraSAR-X data in respect to its capability to improve the monitoring of oil pollution in the Baltic Sea. Improvements are envisaged regarding the algorithm performance related to near real time requirements including reduction of necessary operator interactions. Finally, the user-friendly dissemination of customised products by using new technologies will improve the availability and usage of earth observation products for oil spill fighting. It is expected that the scientific and technological achievements of this solution will be transferable to other seas (e.g. North Sea, Mediterranean) [6].

Conclusions

During the last years the possibilities and value of satellite based detection of oil spills could be impressively demonstrated. However, there are still open questions in research (algorithm development and validation), as well as in operational near real time processing and transmission of the satellite based results to the users on board vessels, ashore at e.g. coastal protection offices and further acting persons. The system is intended to close some important gaps presently still hampering the full exploitation of the available assets (SAR satellites, communication links, ECDIS, mobile systems) for oil spill fighting. Since the basic technologies are already developed at high level, the technological project risks are regarded as minor. Nevertheless, an unexpected malfunction of the TerraSAR-X satellite would cause the need to revise the remote sensing part of the proposal. However, needed SAR image data can also be acquired by a second, identically satellite TanDEM-X. It ist assumed, that the EO images needed for development and demonstration can provided by submitting a TerraSAR-X science proposal according to the innovative aim of this project.

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