Growing oil production, globalization of oil transportation and commissioning of new production fields year by year inevitably lead to increase in number of oil spills and enormous financial and natural losses. Oil spills are inevitably linked to any operations in the field of oil production and transportation. However, they vary much in scale and could be either relatively insignificant and easily accumulated by ecosystems, or catastrophic, destroying biota of entire marine areas. The physical property of oil to cover large offshore zones with thin film even on occurrence of relatively little spills causes the situation where even an insignificant spill leads to extreme disamenity. Just ten minutes after a spill of one ton of oil it covers the area of over 50 kilometers in radius, forming the so-called oil slick. Last century largest oil spills such as those of Exxon Valdis, Erika, Prestige sunk tankers irreversibly changed regional ecosystems and the corresponding damage is estimated at billions of dollars.

Dependence of world economy on oil hydrocarbons and consequently the need to transport those from supplier to customer forced the world community and individual countries to look for efficient ways of ensuring ecological safety of shipments. International agreement specifying liability of transport operators for possible spills have been signed and followed, tanker process specifications were considerably improved, coast guard and pilotage services were reinforced, international and regional oil spill response centers were formed. The efforts aimed at lowering risks of oil spills go along the way of implementing efficient pilotage monitoring systems and enhancing response teams coordination.

Significant breakthrough in ensuring transportation ecological safety was achieved on account of new technologies being developed. Presently monitoring of sea ports, transportation hubs and the busiest routes is effected with the use of information acquired through Earth surface remote sensing. Oil spillage space monitoring attained its specific importance upon appearance of radar satellites, which allow tracking an oil slick on water surface regardless of weather conditions, in particular clouds and time of the day.

As of today space monitoring programs for the busiest transportation regions have been developed and successfully functioned. Thus, European Union carries out the North Atlantic monitoring program, USA has the program for space monitoring of Prudho Bay in Alaska. Unfortunately, Russia doesn’t have a program of the kind though it needs it badly.

Russia is one of the leading power producers in the world. In June 2006 the country reached the first place for oil production, leaving Saudi Arabia behind. The major part of the produced oil is exported. Thus, in 2005, 250 million out of
the produced 455 million tons in total were shipped to foreign consumers, with 149 million tons sent by sea. From 2002 to 2005 the annual volume growth averaged 60 million tons. Industry expansion over sea shelf, growing production and high prices for energy carriers led to reinforcing the role of sea shipments and developing new transportation hubs.

For the past five years export got re-oriented from traditional pipeline to sea transportation and in future this tendency will only continue rising. Along with sea transportation growth ecological and social risks show immense increase. Active construction of sea terminals along Arctic seas coastline, in the Far East and North-West of Russia and redoubled navigation set new tasks in ensuring ecological safety of oil transportation. Urgency in finding solutions to those problems becomes a priority due to natural peculiarities of Russia: complex ice situation in the northern seas, unfavorable climatic and navigational conditions, specific vulnerability and abundance of marine ecosystems; as well as due to lack of smoothly running system of fast response to emergency situations.

Taking into account modern tendencies of oil production and transportation the objective is to develop monitoring system for the regions under the highest risk of oil spills.

**Offshore Oil Spillage Detection Technology**

Earth remote sensing data opened new opportunities for operational monitoring of onshore and offshore oil spills. Images acquired using sensors fitted in orbital platforms cover areas up to 500*500 kilometers and have resolution high enough to detect spill locations.

Radar data present the most suitable means for solving the problem of offshore oil pollution monitoring due to all-weather imagery and independence of luminosity level. It is known that on a radar image an oil slick spread over sea surface form the film and due to specific physical properties looks like a number of dark spots on the background of brighter surrounding surface.

If wind is weak, commonly between 0 and 2-3m/sec, water surface looks dark on radar images. In this case dark oil film melt into the dark ocean background and pollution detection becomes impossible.

Wind velocity between 3 and 9-11m/sec is ideal for detecting oil pollutions as oil slicks looks like dark spots on the light background of water surface. In event of stronger wind pollution detection again becomes problematic – slicks disappear from the images as they blend with top layer water.

Commonly the analysis of a radar image for the purpose of locating polluted areas starts with detection of “suspicious” zones on the particular image. This exercise is followed by differentiation between oil pollution, natural slicks of
biological nature (waste products, plankton, etc) and sea surface appearance in unfavorable imaging conditions.

On radar images oil spills are defined by the following:
- form (oil spills are usually of simple geometrical form)
- edges (smooth edge with larger gradient than that of natural slicks)
- size (too large spots normally designate natural slicks, for instance, algae or plankton colonies).
- geographic location (oil spills are mostly found in oil production areas or along oil transportation routes).

Oil spillage monitoring consists of seven major stages:
1. Data ordering and satellite programming for the area of interest through operator by the customer.
2. Satellite imagery of specified area of interest. Presently the most actively used satellites for oil spillage monitoring tasks are RADARSAT-1 and ENVISAT, which are capable of taking images of the same area of Earth surface virtually every day.
3. Receiving remote sensing data from different satellites at ground stations.
4. Preparation of radar data for further analysis including their fragmentation, geocoding and calibration. This important stage requires use of special software.
5. The next step in monitoring cycle is detecting possible oil spills using radar and multi-spectral data, location of settlements, industrial facilities and infrastructure of the fuel and energy complex (oil and gas fields, gas and oil pipelines, drilling rigs and platforms, oil terminals, ports, etc), navigation routes by their integration into GIS. This part of the analysis is done by experienced specialists using complex oil slick search and verification algorithms.
6. The fifth stage of the cycle is development of a report on the basis of complex GIS analysis regarding likelihood of oil spill presence in the area of interest.
7. The last stage is to provide the report to the customer for further decision-making.
All cycle stages above are carried out by experienced technologists and specialists and operational data processing is very important for fast response to emergency situations.

Therefore the most expedient solution to the problem of offshore monitoring as of today is the use of radar imaging data.

**Oil Spillage Operational Detection System**

ScanEx R&D Center developed complex approach to solve the problem of oil spills and leaks monitoring, which includes radar data acquisition and processing as well as detecting oil spills on water surface. The developed technology utilizes the pool of UniScan receiving stations, radar data preliminary processing software - ScanEx SAR Processor and thematic interpretation software – ScanEx Image Processor.

UniScan ground stations designed by ScanEx R&D Center presently allow receiving both optical data with 1km to 0.7m resolution and all-weather and daytime independent radar images with 100m to 8m resolution (See Table 1). All this offers an opportunity to resolve a wide range of tasks.
One UniScan™ station is capable of receiving satellite images within an area of 2.5 thousand kilometers in radius (approximately 12 million square kilometers), which provides for maximum efficiency in regular monitoring of the coverage area, without leaving the office, and saves money on ground monitoring or aerial photographic survey. UniScan™ is a full set of software applications for data storage, processing and thematic analysis rather than just data receiving hardware.

A network of regional and national Earth remote sensing centers on the basis of UniScan technology is presently functional in Russia and abroad, which confirms the idea promoted by ScanEx to establish de-centralized access to space data.

Table 1. Basic Specifications of On-board Imager Instruments

<table>
<thead>
<tr>
<th>Device</th>
<th>Satellite</th>
<th>Number of Spectral Bands</th>
<th>Spatial Resolution, m</th>
<th>Swath, km</th>
<th>Revisit period (for one satellite)</th>
</tr>
</thead>
<tbody>
<tr>
<td>MODIS</td>
<td>Terra Aqua</td>
<td>36 (visible, IR)</td>
<td>250, 500, 1000</td>
<td>2,300</td>
<td>1-2 times a day</td>
</tr>
<tr>
<td>RDSA, mode 2</td>
<td>Monitor - E</td>
<td>3 (visible, near IR)</td>
<td>40</td>
<td>160</td>
<td>Once every 9 days</td>
</tr>
<tr>
<td>RDSA, mode 1</td>
<td>Monitor - E</td>
<td>3 (visible, near IR)</td>
<td>20</td>
<td>160</td>
<td>Once every 9 days</td>
</tr>
<tr>
<td>PSA (PAN)</td>
<td>Monitor - E</td>
<td>1 (visible)</td>
<td>8</td>
<td>90</td>
<td>Once every 6 days</td>
</tr>
<tr>
<td>NRVIR MONO</td>
<td>SPOT 4</td>
<td>1 (visible)</td>
<td>10</td>
<td>60</td>
<td>Once every 1 – 4 days</td>
</tr>
<tr>
<td>NRVIR XS</td>
<td>SPOT 4</td>
<td>4 (visible, near and far IR)</td>
<td>20</td>
<td>60</td>
<td>Once every 1 – 4 days</td>
</tr>
<tr>
<td>PAN</td>
<td>IRS-P5</td>
<td>1 (visible)</td>
<td>2.5 stereo</td>
<td>30</td>
<td>Once every 5 days</td>
</tr>
<tr>
<td>LISS-3</td>
<td>IRS-P6</td>
<td>4 (visible, near and far IR)</td>
<td>23</td>
<td>140</td>
<td>Once every 24 days</td>
</tr>
<tr>
<td>AWiFS</td>
<td>IRS-P6</td>
<td>4 (visible, near and far IR)</td>
<td>55</td>
<td>740</td>
<td>Once every 5 days</td>
</tr>
<tr>
<td>LISS-4 Mono</td>
<td>IRS-P6</td>
<td>1 (visible red)</td>
<td>5.8</td>
<td>70</td>
<td>Once every 5 days</td>
</tr>
<tr>
<td>LISS-4</td>
<td>IRS-P6</td>
<td>3 (visible, near and far IR)</td>
<td>5.8</td>
<td>23</td>
<td>Once every 5 days</td>
</tr>
<tr>
<td>MX</td>
<td>near IR)</td>
<td>days</td>
<td>PAN</td>
<td>EROS A</td>
<td>1 (visible)</td>
</tr>
<tr>
<td>-----</td>
<td>----------</td>
<td>------------</td>
<td>-----</td>
<td>--------</td>
<td>-------------</td>
</tr>
<tr>
<td>PAN</td>
<td>EROS B</td>
<td>0.7</td>
<td>7.0</td>
<td></td>
<td></td>
</tr>
<tr>
<td>SAR</td>
<td>RADARSAT-1</td>
<td>1 (C-band, 5.6cm)</td>
<td>8 … 100</td>
<td>50 … 500</td>
<td>From once a day to once every 6 days</td>
</tr>
<tr>
<td>ASAR</td>
<td>ENVISAT</td>
<td>1 (C-band, 5.6cm)</td>
<td>25 … 150</td>
<td>56 … 400</td>
<td>At least once every 5 days</td>
</tr>
</tbody>
</table>

ScanEx SAR Processor (SSARP) software application is designed for processing data acquired from Canadian radar with synthesized aperture RADARSAT-1. ScanEx SAR Processor allows creating RADARSAT CEOS Level 1 (synthesized image) products from RADARSAT CEOS Level 1 (radar hologram) format files on the basis of MS Windows and Linux. This application is used on several certified RADARSAT receiving station complexes. Processed data comply with international quality standards, processing algorithms and output format structure. ScanEx R&D Center is continuously improving the algorithms to optimize data processing.

Data synthesis takes 5 to 15 minutes for one RADARSAT scene in Standard Mode. Time required for processing multi-band images (ScanSAR) is estimated at half-hour.

After synthesis radar data are interpreted in ScanEx Image Processor application developed by ScanEx R&D Center in order to locate possible oil spillage.

ScanEx Image Processor is the software application developed for processing Earth remote sensing data. Multiple functions of the application allow solving a wide range of tasks: from visualization to thematic analysis.

The application consists of the basic configuration and plug-in modules such as:
- three-dimensional modeling and visualization module;
- multispectral imagery classification and thematic interpretation module;
- digital elevation model (DEM) module;
- radar imagery processing module;
- software development kit (SDK).

The latest version of ScanEx Image Processor 2.5 executes automatic and semiautomatic detection of oil spillage on water (fig.1) as well as other functions for radar data processing:
- SAR data segmentation;
- texture analysis;
- thematic calibration of data segmentation;
- automatic vectorization of analysis results;
- oil spills detection;
- ship detection.
Simple and convenient interface allows fast and accurate locating of possible oil spill on water surface within the shortest time, up to 5 minutes for a scene 100*100 kilometers in size.

**Monitoring Oil Spills Off the Northern Caspian Shore**

Unique technique of ScanEx R&D Center based on in-house built satellite data receiving stations and specially developed software allows receiving information on presence or absence of oil spillage as well as its localizing within just a few minutes using Canadian RADARSAT and European ENVISAT satellite data. Supported by its unique technologies in 2007 ScanEx R&D Center plans to complete the project on radar monitoring of the Northern Caspian waters in near real-time mode. This pilot region wasn’t selected randomly. Oil exploration and production offshore Northern Caspian has been under way for quite a long time, busy transportation routes run across this area connecting production fields with biggest sea ports. Extreme ecological vulnerability and high biological variety are characteristics of the Caspian Sea. Oil products dumping and oil spill incidents have an extreme impact on sea-lake ecosystem and may lead to disturbing already precarious ecological balance. It should be noted that in some regions,
for instance in Kazakhstan sector, non-stop offshore pollution is occurring due to presence of more than hundred abandoned wells. This fact is supported by the results of preliminary analysis of region radar images taken by ScanEx R&D Center. Thus, for example, on the image dated September 8, 2006 (Fig. 2) one could clearly see oily spots footprint stretching to 41 kilometers. The image of October 16, 2006 (fig. 3) covering Kazakhstan part of the Caspian Sea showed high probability of offshore oil spillage presence.

Figure 2 Figure 3. The footprint of oily spots stretched to 41 kilometers along a ship route in the Caspian Sea (RADARSAT-1, September 8, 2006) © MDA, ScanEx, 2006
The project extends beyond the limits of a technological experiment and sets the objective to provide public, governmental authorities and business community with objective and operational information regarding hydrocarbon pollution of the Caspian offshore area. Hopefully the fact that independent objective information is made available regarding oil and gas industry environmental impact to the Caspian shelf will motivate the companies involved to elevate ecological standards and promptly respond to emergencies, while governmental authorities exercise efficient control and set forth an efficient policy.

The present objective of the operational monitoring of oil spills on waters has gained high importance mainly due to aggravating ecological situation offshore the Russian seas and consequently the related social and economic aspect. Earth remote sensing data played the decisive role in acquiring operational and valid information on ecological status of offshore and open water zones. Today ScanEx R&D Center has the complete cycle technology for offshore oil spills monitoring. Availability of own stations, original software and experienced specialists allow operational detection of the presence of hydrocarbons on water surface. ScanEx R&D Center is the first company in Russia launching initiative project, which is aimed at monitoring Northern Caspian waters in operational mode. The initial results proved the necessity of such monitoring and its importance for ensuring the region ecological safety. Due to their versatility applied technologies can and should be also used in other offshore oil production regions – Sakhalin, Kaliningrad district and ultimately offshore the northern seas.

Figure 3 RADARSAT image of north-western part of the Caspian Sea dated October 16, 2006. Blue arrows indicate clear water outflow from the river mouth. MDA, ScanEx, 2006.