This report provides the key recommendations from WP 2 with respect to enhancement of surface surveillance capabilities for oil spill response using both airborne and space-borne platforms. It is the final report from the steering committee. All findings and recommendations have been reviewed by the steering group and have been included by consensus. The findings from a real-world response exercise supported by current responders are provided in an Appendix.

31 March 2015

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Frontispiece. Clockwise from top left: Islander aircraft used in oil spill response (courtesy Richard Blain, Aerospace Resources); visible satellite image of the Gulf of Mexico from NASA's Terra satellite of the Gulf oil spill on May 17, 2010, from the Moderate Resolution Imaging Spectroradiometer (MODIS) Instrument (courtesy NASA); SpecTIR hyperspectral data covering 360 spectral channels from the Gulf of Mexico oil spill, 6 July 2010 (courtesy Justin Janaskie, SpecTIR); artist’s impression of NASA’s AQUA satellite, which has been operating for a decade with multiple sensors on board, including MODIS which was used to monitor the Gulf of Mexico oil spill (courtesy, NASA).
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Executive Summary

This is the final report from the Oil Spill Response Surveillance, Modelling & Visualization JIP, WP2, covering surface surveillance remote sensing methods for oil spill detection in water, building on information included in previous working group reports ([1], [2]), and providing a summary of findings and recommendations for future work. It includes the results of a real-world satellite surveillance exercise involving satellite operators with commercially available response services. The recommendations are as follows:

**Recommendation 1.** A centralised, operational oil and gas industry facility should be established for coordinating planning of satellite surveillance for OSR.

**Recommendation 2.** Regionally-based and coordinated oil spill surface surveillance and response planning, articulated through field development and emergency response plans, should be customised for the particular environmental and operational challenges of each region, and refreshed on a regular basis. These may be operated as a distinct organisation, or a virtual organisation consisting of, and managed by oil and gas operators in a region.

**Recommendation 3.** Delivery of all surface surveillance products, including oil spill analyses, should be viable within 2-3 hours of data acquisition and the products should be pre-defined for suppliers.

**Recommendation 4.** The industry should work closely with suppliers in order to ensure that suppliers are up to date in terms of industry requirements for oil spill response (e.g. research priorities, sampling requirements, Common Operating Picture recommended practice, etc.).

**Recommendation 5.** Archiving of surface surveillance data and products by operators needs to support effective post-spill access and analysis, with recognised standards for metadata, data storage and formatting.

**Recommendation 6.** All surface surveillance suppliers should comply with the Common Operating Picture recommended practice in order to support efficient exploitation of data and products within oil spill response [3].

**Recommendation 7.** The industry should support research to enhance the effectiveness of surface surveillance in oil spill response, covering innovative measurement concepts, new sensors and sensor combinations, sensor deployment strategies and configurations for oil spill response, multi-sensor data fusion and key technologies supporting remote sensing.

**Recommendation 8.** The industry should take steps to ensure that new sources of data and products, including continuity missions for current sensors, have a means to be assessed and, where and when appropriate, migrated to operational use for oil spill response.

**Recommendation 9.** Key personnel should be trained in surface surveillance on a regular basis to ensure that there is knowledgeable and up to date experience available within the industry, in response to rapid evolution in technologies.

**Recommendation 10.** It is recommended that both airborne and satellite surface surveillance should be included in exercises and all datasets be made available for cross-referencing and lessons learnt.

**Recommendation 11.** A regular horizon scan for surface surveillance technologies should be carried out, extending 5 years and refreshed every 2-3 years, to enable technologies to be identified for evaluation and potentially developed and tested for oil spill surface surveillance, provided in the form of a Technology Roadmap.
Acknowledgements

The International Oil and Gas Producers Association (IOGP) / International Petroleum Industry Environmental Conservation Association (IPIECA) Joint Industry Project on Surveillance, Modelling & Visualization (SMV JIP) Work-package 2 steering committee acknowledges the important and appreciated support and input from several individuals and organisations, as follows:

- Leadership, management and funding from the IOGP and IPIECA.
- Input from many satellite data vendors, remote sensing value-added organisations, oil spill responders and researchers, many of whom invested significant time in contributing to the workshop and responding to the questionnaire, interviews and exercises.

Acronyms

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<td>Area of Interest</td>
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<td>NOFO</td>
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Reference Documents


1. Introduction

Oil spills have the potential to threaten human health and safety, the integrity of the environment and the viability of local economies, and the oil and gas industry has a responsibility to seek out and deploy, all available technologies to both minimise the risk of spills, and to deal effectively with them if and when they occur.

The April 2010 Gulf of Mexico (Macondo) oil spill incident, and the Montara incident in Australia which preceded it, have had far-reaching consequences in prompting the re-examination by industry not only of operational aspects of offshore operations, but also of an operator’s ability to respond in the event of an oil spill incident or well blowout. In response to this, the International Association of Oil and Gas Producers (IOGP) formed the Global Industry Response Group, tasked with identifying learning opportunities both on causation and in respect of the response to the incident. Nineteen recommendations were identified and these were addressed via a three-year Joint Industry Project (JIP) funded by sixteen oil industry members. The Oil Spill Response JIP (OSR-JIP) initiated discreet projects or provides support to projects initiated by other trade associations in the nineteen subject areas resulting from the IOGP Oil Spill Response JIP project. The OSR-JIP was managed by IPIECA on behalf of IOGP in recognition of its long-standing experience with oil spill response matters.

An important element of this review covered surface surveillance, or remote sensing, using airborne and space-borne platforms, and this was organised in the form of work-package (WP) 2 “Surface Surveillance” of the IOGP joint industry project "Surveillance, Modelling & Visualization" (SMV JIP) for oil spill response (OSR), established to enhance industry practices in connection with oil spill surveillance. Airborne and satellite surveillance have been evolving rapidly in recent years, with many more platforms, a greater variety of sensors, data volume and transfer and improving operational capabilities. However, there are two challenges associated with this: the first is to work effectively with suppliers to ensure that such improvements are exploited for oil spill response and the second is to be aware of the challenges and limitations of this technology. Used judiciously, satellite remote sensing can provide wide coverage situational awareness for oil spills and ensure that costly airborne and ground-based assets can be deployed in an effective and timely manner, while airborne remote sensing can provide detailed and tactical information on the oil spill itself.

This final report provides key recommendations from WP 2.
2. Objectives of the Project

The objectives of WP2 Surface Surveillance for Oil Spill Response using Remote Sensing are to provide:

- A review of the intrinsic technical capabilities of available sensors, incorporating information from literature, workshop reports and direct from commercial vendors.
- An assessment of current and planned future capabilities of sensors and relevant platforms in terms of actual response to oil spills in different global locations, to include timeliness of response.
- Identification of technology and surveillance gaps.
- Suggestions for follow-on activities, including research, technology development and improved infrastructures, to close gaps.
- Coordination with work from the API and other JIP tasks.

3. Scope

The scope of WP 2 Surface Surveillance for Oil Spill Response using Remote Sensing can be described as follows:

- Surveillance of oil spills from satellite remote sensing only, with an emphasis on commercial suppliers.
- Focus on effective selection of, and access to, remote sensing data rather than on value-added analysis or downstream application of the data. For the latter, IOGP/PIECA SMV JIP WP 5 on GIS/Mapping and Common Operating Picture is relevant, as well as the work of the API [5].
- Detection and characterisation of oil spills and not other met-ocean parameters, except for identifying these additional parameters when they are a potential by-product of data acquisition for OSR.
- Surveillance of offshore and coastal domains; land and polar domains are addressed briefly. Surface surveillance for Arctic oil spills is addressed in [6].
- Sampling of the top 25 metres of the surface only (i.e. not covering atmospheric sampling).
- Consideration of technical and operational factors in relation to satellite data, and not commercial factors.
4. Project Activities

WP2 involved a range of sources that were aimed at identifying key requirements, challenges and opportunities in relation to effective surface surveillance for oil spill response (Figure 2), including the following:

- The expertise of the steering committee, with representation from the oil and gas industry, service providers and oil spill responders.

- Open literature which (a) reviews experiences from oil spills and (b) reviews or assesses specific remote sensing technologies for OSR.

- A workshop held in Frascati, Italy, 18-19 February 2013, with questionnaires sent prior to the workshop. The workshop was sponsored by IPIECA and hosted by the European Space Agency (ESA), and included invited presentations, vendor pitches and discussion sessions. The workshop invited the participants to specify requirements for OSR and to identify current capabilities and gaps, leading to a set of findings.

- Post-workshop questionnaires sent to satellite image suppliers (12 responses), commercial airborne platform (39 responses from 139 distributed questionnaires) and sensor suppliers (22 responses from 43). The questionnaire solicited vendor suggestions on which sensors are appropriate for OSR, the capabilities of the sensors and platforms in terms of sampling and responsiveness, and suggestions in terms of configurations and processing.

- Reports on satellite and airborne surface surveillance capabilities (respectively, [1] and [2]), incorporating analysis of results from the above sources, along with simulations of satellite surveillance capabilities, and taking into account the API report on planning guidance for remote sensing of oil spills [5].

- Coordination with WP 5, which is addressing guidelines for the Common Operating Picture [3].

- An exercise with key satellite image suppliers to validate some of the above results as well as to provide additional findings, summarised in Appendix A to this report (Section 7).
5. Recommendations

These recommendations are based on project activities and the findings of the working group, and have been reviewed by the steering committee.

5.1. Organisation and Planning

5.1.1. Global Satellite Surveillance Centre

**Recommendation 1.** A centralised, operational oil and gas industry facility should be established for coordinating planning of satellite surveillance for OSR.

The use of satellite surveillance is global in application and challenging in terms of technology and operational issues, and an effective response to an emergency may require coordination of acquisition leveraging several satellite platforms, operated by different commercial and national organisations. The International Charter Space and Major Disasters (REF) has demonstrated the value of a coordinated approach to emergency tasking and acquisition of information. There would be significant efficiencies to ensuring that satellite surveillance for oil spill response is coordinated globally, reducing costs and minimising tasking conflicts. This coordination could also reassure stakeholder populations in areas of oil and gas operations that adequate provision is in place to respond to oil spills.

Such a facility should have the following capabilities:

- The global facility would work closely with regional response organisations, where they exist, and be able to respond to an oil spill anywhere in the world, including producing oil and gas basins, exploration areas and shipping routes.

- To act as a repository for experience in satellite surveillance for oil spill response, and based on this to coordinate and advise on access to satellite data on a global basis and, where appropriate, on behalf of the industry both internally and with external organisations.

- To provide guidance to researchers, agencies and suppliers in relation to oil spill requirements for satellite data, in terms of areas of interest, standards, research priorities, etc.

- To host a multi-satellite planning capability that can be used to support oil spill response for major events with emergency data planning, ordering and data access, with built-in planning constraints, access to free data, identification of pre-planned data, and streamlined workflow, including ordering.

- To support the industry in the development of appropriate global standards, good practices and guidelines and ensure that satellite surveillance issues are appropriately reflected in the COP architecture and interfaces.
- To support training of personnel.

A possible analogue for the Global Satellite Surveillance Centre is Oil Spill Response Limited, which provides member companies “with the resources to prepare for and respond to oil spills efficiently and effectively on a global basis.”

(http://www.oilspillresponse.com/about-us/vision-mission-business-integrity)

Figure 3 Average global revisit times, in hours, from satellite-based synthetic aperture radar (SAR) from Airbus, MDA and e-GEOS satellites (from [1]).
5.1.2. Effective Regional Surface Surveillance Planning

**Recommendation 2.** Regionally-based and coordinated oil spill surface surveillance and response planning, articulated through field development and emergency response plans, should be customised for the particular environmental and operational challenges of each region, and refreshed on a regular basis. These may be operated by a distinct organisation, or a virtual organisation consisting of, and managed by, oil and gas operators in a region.

Planning of surface surveillance is optimally designed at the regional level, tailored to relevant jurisdictions, physical environments and key suppliers. Pro-active surveillance programmes provide a degree of confidence in the early detection of oil spills and may reduce the time taken to acquire satellite imagery in the event of an incident. Pro-active surveillance programmes also provide response staff with familiarity on the capabilities and limitations of the methods employed.

In some regions this capability already exists, driven by government and legislation. Examples include the Norwegian Clean Seas Association for Operating Companies (NOFO, [http://www.nofo.no/en/](http://www.nofo.no/en/)) and the European Maritime Safety Agency (EMSA, [http://www.emsa.europa.eu/](http://www.emsa.europa.eu/)). In other areas, surveillance may be the responsibility of individual oil and gas companies.

Such plans should include the following:

- Regional directories of available and suitable airborne suppliers and capabilities, including sensors (e.g. portable sensor packages linked to available platforms), identified based on regional requirements. These directories should be reviewed annually.

- All necessary permissions and contractual arrangements should be in place, to meet the requirement for effective oil spill surveillance, ideally within 24 hours, or at worst 72 hours, of an oil spill event. This should cover the provision of satellite resources as a minimum, and should extend to aircraft and portable sensors on standby for deployment.

- Routine satellite image acquisitions should be carried out for early detection of spills, regular exercises and tests, environmental baselining and development of data interpretation skills, supported through the use of free imagery, where available, and multiple operator cost sharing of imagery where possible, with support where appropriate from the central satellite surveillance facility.

- Emergency surface surveillance acquisition plans should be prepared in advance and refreshed regularly to remove all avoidable delays in ordering surveillance acquisitions in the event of an oil spill.

- Oil and gas personnel should receive training and exposure to response capabilities through pro-active surveillance and exercises, including 'real life' tasking of satellites during such exercises.
Local airborne platform availability factors (from [2]).
5.2. Delivery

5.2.1. Delivery Timings

Recommendation 3. Delivery of all surface surveillance products, including oil spill analyses, should be viable within 2-3 hours of data acquisition and the products should be pre-defined for suppliers.

Surface surveillance information is only useful if it has some relevance for current conditions. Out of date imagery and products can be more distracting than useful and hence providing clear limits on the timeliness of data is important.

In practise, opportunities should be identified to reduce the lag between acquisition of data and delivery of information of value to OSR.

With clear technical definitions in place the delivery of OSR EO products can be streamlined and fast information delivery achieved.

5.2.2. Working with Suppliers

Recommendation 4. The industry should work closely with suppliers in order to ensure that suppliers are up to date in terms of industry requirements for oil spill response (e.g. research priorities, sampling requirements, COP recommended practice, etc.).

This may be achieved through conferences, workshops and virtual resources, supported by the oil and gas industry.

If the industry plays a pro-active role in engaging with suppliers, then this creates numerous benefits, as follows:

- Industry is well placed to assess and vet suppliers in terms of their capabilities.
- Industry is able to jointly develop standards and guidelines for the use of surface surveillance in oil spill response, culminating in fit-for-purpose contractual arrangements being in place with key suppliers in readiness for possible oil spills.
- Industry is able to identify opportunities to help steer and encourage the development of new technologies.
5.2.3. Data Archiving

**Recommendation 5.** Archiving of surface surveillance data and products by operators needs to support effective post-spill access and analysis, with recognised standards for metadata, data storage and formatting.

The availability of well preserved and accessible information after the oil spill event has the following benefits:

- Training;
- “Lessons learned” analysis;
- Evidence for later internal reviews, litigation, etc.

However, it is necessary for the information to be complete (e.g. metadata fields), accurate and accessible.
5.2.4. Common Operating Picture

**Recommendation 6.** All surface surveillance suppliers should comply with the Common Operating Picture recommended practice in order to support efficient exploitation of data and products within oil spill response [3].

The COP is central to the effective exploitation of surface surveillance for oil spill response. It is defined as follows [3]:

"A Common Operating Picture (COP) is a computing platform based on Geographical Information System (GIS) technology that provides a single source of data and information for situational awareness, coordination, communication and data archival to support emergency management and response personnel and other stakeholders involved in or affected by an incident."

A COP enables data to be used effectively within an operational environment, based on interoperability and the provision of an appropriate environment with collaborative tools (Figure 5). It is essential that suppliers comply with COP guidelines and standards in order that their data is able to be effectively exploited for oil spill response. Standards and guidelines for the format and delivery of oil spill products from imagery already exist, for example in EMSA, and available standards should be taken into consideration by the IOGP Geomatics Committee in developing such compliance.

![Image of Common Operating Picture](image_url)

**Figure 5.** The Common Operating Picture will place requirements on suppliers of surface surveillance products and services (figure courtesy of Shell).

Several findings from the surveillance exercises described in Section 7 would be addressed by the deployment of a COP (e.g. findings 2, 4, 6, 8, 14 and 15).
5.3. Research and Development

5.3.1. Developing New Data Sources

**Recommendation 7.** The industry should support research to enhance the effectiveness of surface surveillance in oil spill response, covering innovative measurement concepts, new sensors and sensor combinations, sensor deployment strategies and configurations for oil spill response, multi-sensor data fusion and key technologies supporting remote sensing.

Research and development allows the industry to identify, encourage and adapt surface surveillance technologies for oil spill response.

This research may be supported through the establishment and funding of dedicated facility (or facilities) or through coordinated support of research institutions.

The following areas are identified as worthy of industry support:

- Improved characterisation of oil spills; including thickness, oil type, degree of weathering.
- A comparative assessment of the potential advantages and limitations of different sensors of satellite and airborne platforms.
- Design, development and testing of innovative measurement concepts and sensors for oil spill response, including optical (e.g. spectroscopy, to extract more detailed and robust information about oil spills), laser fluorescence and microwave (e.g. full polarisation and different frequency information from imaging radar, and its potential for reduction in false detections).
- Identification of the optimum configurations and deployment strategies for sensors (e.g. optical sensor configurations).
- Effective combination of surface surveillance observations, in terms of data fusion techniques for optimising information on oil spills from different sensors, and visualisation for effective decision-making.
- Development of supporting technologies for effective exploitation of surface surveillance in oil spill response, such as on-board processing of data and timely delivery of data and products from platforms, and cloud computing and virtual reality applications.
Recommendation 8. The industry should take steps to ensure that new sources of data and products, including continuity missions for current sensors, have a means to be assessed and, where and when appropriate, migrated to operational use for oil spill response.

The industry should take into consideration that there is a growing quantity and variety of surface surveillance data, including experimental, pre-planned and low cost sources of data, which may in some cases meet requirements of operational value for oil spill response.

Existing satellite missions have a limited life span and will be replaced with new platforms, which must be evaluated and, if suitable, integrated into surveillance and response programmes.

To determine whether the new platforms and data sources are suitable for integration, the evaluation should:

- Demonstrate the applicability and limitations of new data sources for oil spill response.
- Ensure that the data has real value to COP managers and responders through contractual mechanisms, exercises, etc. It is important that the COP does not have misleading, unvalidated or otherwise erroneous and distracting data within the COP.
- Plan and negotiate with suppliers for the use of new, genuinely useful data sources, including early technical and commercial assessment and preparation and the provision of clear industry requirements.

Figure 6. The Aeryon Labs Scout UAV in an oil spill response demonstration in Prince William Sound, Alaska, in 2011, University of Alaska Fairbanks photo courtesy of Greg Walker.
5.3.2. Training

**Recommendation 9.** Key personnel should be trained in surface surveillance on a regular basis to ensure that there is knowledgeable and up to date experience available within the industry, in response to rapid evolution in technologies.

Training is critical to maintain readiness for oil spill response, to support new personnel entering oil spill response and/or remote sensing, and to support effective communication and interaction with suppliers. Training should include, but not be limited to:

- Surface surveillance basics (sensor techniques, constraints, etc.);
- Availability of new data sources and sensors;
- Evolving standards and guidelines in the application to oil spill response;
- Status of operational issues to deployment of surface surveillance (regulations, etc.).

5.3.3. Exercises

**Recommendation 10.** It is recommended that both airborne and satellite surface surveillance should be included in exercises and all datasets be made available for cross-referencing and lessons learnt.

Historically, oil spill exercises have tended to focus on ground-based and airborne activities, but satellite technologies should be included. The following benefits will accrue from such exercises:

- Early assessment of new data sources or value-added products to OSR.
- Validation and refinement of more mature techniques and products.
- A framework for linking together researchers and operational users to provide a route for development of products and capabilities.
- A means to test and, where required, improve operational practices prior to a real emergency.
- A means of providing training, not only “in the field”, but in terms of planning, delivery and analysis.
- A way to carry out tests in less familiar environments, such as the Arctic.

Exercises should wherever possible include real acquisition and delivery of data or products, but additional simulation exercises are also useful.
5.3.4. Technology Roadmap

**Recommendation 11.** A regular horizon scan for surface surveillance technologies should be carried out, extending 5 years and refreshed every 2-3 years, to enable technologies to be identified for evaluation and potentially developed and tested for oil spill surface surveillance, provided in the form of a Technology Roadmap.

The rate of development of technologies is such that technology assessments become quickly out of date. A prime example is the development of unmanned aerial systems (UAS) and associated sensors. Such a roadmap should also take into account both technical and non-technical (e.g. regulatory) potential. Relevant technology assessments elsewhere in the industry should be leveraged (e.g. [4]).

6. Conclusions

Satellite and airborne remote sensing is now an accepted and integral component of effective OSR. Together, they provide a combination of wide coverage situational awareness and closer tactical decision-making support. Satellites are routinely available and can be used to deploy airborne assets both efficiently and safely. New business models for provision of satellite data and products are being explored, as satellite constellations (of complementary as well as similar sensors) replace the more traditional single platform missions. Both airborne platforms and sensors are developing at a rapid pace, particularly in relation to UAS, and the regulatory environment is lagging the technology in many areas. These developments point to the need to maintain awareness of technologies through a technology roadmap as well as direct involvement of the industry in supporting key areas of research that provides the opportunity for effective new technologies to be adopted by the industry.

Much enhancement in the value of surface surveillance can be derived from effective planning of its use, both at a global scale in relation to satellite imagery and at a regional scale, where local conditions can dictate the optimum types of sensors, platforms and observation strategies. Surveillance planning that is purely or mainly triggered by an oil spill will be opportunistic and therefore inefficient and inadequate. There are many features of surface surveillance planning, such as licensing, contractual arrangements and imaging plans that can be established in advance of an oil spill. The use of pro-active satellite imaging in key areas, augmented by exercises (involving airborne and satellite platforms) and training can also help to ensure surveillance readiness for oil spill response.

Finally, the adoption of a Common Operating Picture in oil spill response, which supports efficient decision making, will depend on the compliance of those providing surface surveillance products or services, and this will be an area that the industry will need to focus on.
7. Appendix A. Satellite Surveillance Exercise

7.1. Objectives

The exercises were designed to provide insight into the current procedures of providing initial satellite surveillance for oil spill response, and to complement and validate the completed questionnaires from vendors described in [1].

7.2. Scope

The scope was defined as follows:

- To carry out satellite imaging of a simulated oil spill response exercise involving no release of oil.
- To have the oil spill response exercise involving two contrasting “oil spill” locations from the point of view of satellite image acquisition.
- To involve established SAR satellite operators. The results from two are reported here: MDA and Airbus Defence and Space (Airbus DS).
- The satellite operators were asked to provide their own data, therefore satellite operators were not expected to provide third party data (e.g. any “free” cloud-free optical or third party SAR data).
- To focus on capabilities for initial surveillance of a new oil spill, rather than new updates (i.e. oil spill surveillance from a “standing start”).
- To allocate a defined period during which the “oil spills” would occur, but not to provide any advance warning to the satellite operators of the locations or timings of the two “oil spills” within the defined period.
- To have the satellite operators each provide independent deliverables for image feasibility and oil spill analyses according to their own practices, based on their own imagery, providing their standard deliverables.
- The exercises did not attempt to re-create a full oil spill response support operation by the satellite operators. The primary goal of initial surveillance precluded the usual management of imaging sequencing and prioritization that an imagery provider would do when combining different satellites in an incident response.
7.3. Exercise scenarios

The oil spill exercise was facilitated by Oil Spill Response Limited (OSRL) through their relationship with MDA (for RADARSAT-2 imagery and oil spill products), who in turn coordinated the participation of Airbus DS for TerraSAR-X and derived oil spill products. The details of the exercise scenarios are provided in Table 2.

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<tbody>
<tr>
<td><strong>Time of “spill” alert</strong></td>
<td>08.20 UTC</td>
<td>08.24 UTC</td>
</tr>
<tr>
<td><strong>Aol</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Centre</td>
<td>72.081 -58.103</td>
<td>3.914E, 5.769N, WGS84</td>
</tr>
<tr>
<td></td>
<td>(72° 4’51.72”N</td>
<td></td>
</tr>
<tr>
<td></td>
<td>6’9.87”W)</td>
<td></td>
</tr>
<tr>
<td>Extents</td>
<td>72.055 -58.156,</td>
<td></td>
</tr>
<tr>
<td></td>
<td>72.100 -58.045</td>
<td></td>
</tr>
<tr>
<td>Area</td>
<td>10.67km²</td>
<td>94.89km²</td>
</tr>
<tr>
<td>Downlink coverage</td>
<td></td>
<td></td>
</tr>
<tr>
<td>antenna</td>
<td>Direct reception or close</td>
<td>No direct reception</td>
</tr>
<tr>
<td><strong>Temporal coverage</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Mean¹</td>
<td>~4.04 hrs</td>
<td>~14.22 hrs</td>
</tr>
<tr>
<td>Max</td>
<td>~15.25 hrs</td>
<td>~59.88 hrs</td>
</tr>
<tr>
<td>Diurnal</td>
<td>Acquisitions spread through the day</td>
<td>Acquisitions grouped around 2 times per day</td>
</tr>
<tr>
<td><strong>Visibility for optical data</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>0 hrs daylight</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Mean cloud ~ 60-70%</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Visible data not available</td>
<td></td>
<td></td>
</tr>
<tr>
<td>12 hrs daylight</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Mean cloud ~70-80%</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Visible data unlikely</td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Interpretation challenges</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Open water</td>
<td>Biogenic slicks, fronts, internal waves, variable wind stress, wind shadows, upwelling, turbulent ship wakes</td>
<td></td>
</tr>
<tr>
<td>Probability of winds NOT between 3 and 10 m/s over 72 hrs</td>
<td>87%</td>
<td>46%</td>
</tr>
<tr>
<td>Sea ice</td>
<td>Median: dispersed ice</td>
<td>Ice free</td>
</tr>
<tr>
<td>Maximum: pack ice (90% ice)</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Table 2. Description of the two oil spill exercise locations (environmental figures from [1]).

The two locations were intentionally selected by the IOGP to provide contrasting scenarios in terms of the environment and the access to satellite imagery.

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¹ From [1], restricted to available satellite SAR imagery with spatial resolution <30m and incidence angle between 22° and 45°.
7.4. Results

The exercises proceeded smoothly in terms of planning and organisation with good cooperation from and between the satellite operators. The following points of consideration are pointers to areas which could be given some focus of attention based not only on the exercise outcomes but also on related inputs through WP 2.

7.4.1. Coordination

The exercises were managed by OSRL, who also provided responses to technical proposals from the satellite operators, prior to image tasking. MDA coordinated the activities of the imagery providers in the exercises. The process involved in each of the two trial activations was:

- IOGP team determined the area of interest and emergency call timing for the activation.
- OSRL activated MDA to support the emergency using standard procedures.
- MDA immediately activated Airbus DS via phone and email.
- Airbus DS provided (via MDA to OSRL) a technical proposal outlining available imagery over the area of interest.
- OSRL confirmed the preferred first-available imagery from each satellite operator.
- Each satellite operator tasked the satellite(s) and managed imagery downlink, processing, and analysis.
- Each satellite operator reported delivery directly to OSRL.

Because of the structure of the trial (i.e., measuring time to first image) and to provide full transparency, the interactions between the responder (OSRL) and the satellite operators were separate (although routed via MDA). Decisions on imagery were made without easy methods of comparing the acquisitions planned by the different suppliers. In generating spill response plans, it would be useful for planning of satellite imagery to be coordinated among satellite operators to optimise coverage and temporal sampling.

7.4.2. Planning of Imagery

The satellite operators were explicitly asked to provide imagery from TerraSAR-X and RADARSAT-2 respectively, and this reflected the scope of the exercises.
The image modes that were selected for new tasking are shown in Table 3.

<table>
<thead>
<tr>
<th>Imaging Mode</th>
<th>Spatial resol'n</th>
<th>Swath width</th>
<th>Polaris’n (selected)</th>
<th>Incidence angle</th>
<th>Acquired for:</th>
<th>Aol coverage</th>
</tr>
</thead>
<tbody>
<tr>
<td>RADARSAT-2 (MDA)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>W. Greenland</td>
<td>10.67 km²</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>W. Greenland</td>
<td>10.67 km²</td>
</tr>
<tr>
<td>ScanSAR Narrow A</td>
<td>25m (4 look)</td>
<td>300 km</td>
<td>HH</td>
<td>20.9-39.0°</td>
<td>W. Greenland</td>
<td>10.67 km²</td>
</tr>
<tr>
<td>ScanSAR Narrow B</td>
<td></td>
<td></td>
<td></td>
<td>31.3-46.0°</td>
<td>W Africa</td>
<td>94.89 km²</td>
</tr>
<tr>
<td>TerraSAR-X (Airbus DS)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>W. Greenland</td>
<td>10.67 km²</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>W. Greenland</td>
<td>10.67 km²</td>
</tr>
<tr>
<td>ScanSAR Wide</td>
<td>40m</td>
<td>200 x 270 km</td>
<td>VV</td>
<td>27.1-44.9°</td>
<td>W. Greenland</td>
<td>10.67 km²</td>
</tr>
<tr>
<td>ScanSAR</td>
<td>18.5m</td>
<td>100 x 150 km</td>
<td></td>
<td>39.9-47.0°</td>
<td>W Africa</td>
<td>94.89 km²</td>
</tr>
</tbody>
</table>

Table 3. Offered image acquisitions from the satellite operators.

The areas of interest for Greenland and West Africa covered ~11 and 95 sq km respectively. The basis for decisions on which image modes and configurations to offer to the responder was not clear and in the exercise it is not clear why, for example, the imaging modes had higher spatial resolution for the larger coverage West Africa Aoi than for the smaller coverage Greenland Aoi (by factor nearly ten). Single polarisation imagery was provided, in some cases this was HH polarisation and in some cases VV polarisation. Dual polarisation was available in some cases but not provided. In practice, the timing of imagery will often “trump” the optimum configuration in terms of selection, but there is still some lack of clarity over why particular imaging modes were offered to the responder.

**Finding 1.** It would be useful for clarity to be provided with the reason for offering particular image modes to the responder (via the image supplier technical proposals).

The satellite operators were able to check archives to determine whether existing acquisitions were available for the areas of interest, and in some cases there was availability.
7.4.3. Providing Technical Proposals to the Responder

The technical proposals were delivered to the responder so that imagery could be selected for tasking. These proposals included details on the various imaging opportunities and covered a wide range of formats and levels of detail. The information that was provided by the suppliers was useful, including maps showing the coverage with the AoI, information on time of acquisition, etc.). However, in some cases, the amount of information was much larger than was needed (e.g. detailed orbit information that has no bearing on selection of imagery). In other cases, information that would be useful was not provided (e.g. estimated time of delivery of imagery, spatial resolution).

Finding 2. It would be useful to see the specific information provided to the responder limited to relevant information (e.g. acquisition time, imaging mode, etc.), so that the responder can select imagery quickly. In addition, some new information fields would be useful including spatial resolution of the imagery and expected time of delivery.

Finding 3. It would be useful to see the information provided to the responder being specified in a consistent format to ease the selection of imagery.

Because of the goals and structure of the trial, the responder had to decide separately on acquisitions from each individual image supplier and their own satellites. In a real response situation it would be preferable if the “technical proposals” were merged into one for each satellite and sensor, as long as this did not come at the cost of a delayed technical proposal.

In some cases, the technical proposal required a set of technical options to be selected, such as polarisation selection, and then the order signed. In an emergency situation, these technical options should be pre-selected or completed automatically to streamline the process.

Finding 4. Orders based on technical proposals should be streamlined and avoid the need for manual completion of technical options. A single order for multiple satellite data would be ideal.
7.4.4. Data Acquisitions

The actual acquisition opportunities are shown in Figure 7. These show that over Greenland, there was flexibility in terms of when the imagery could be acquired, whereas over West Africa, the acquisitions were far more constrained. This reflects the contrasting latitudes of the two locations. There were very large differences in the acquisition times of the satellites, which could have had major repercussions in terms of situational awareness near the start of a spill event. This is due to a combination of coverage characteristics associated with the different satellites, but also tasking window constraints.

**Finding 5.** It is clear that data should be available from more than one supplier in order to optimise, for any particular area and time, the lead time for data acquisition. There are areas and times around the globe for which each supplier is disadvantaged in terms of their tasking schedule and/or station coverage and/or sensor coverage. Pre-programmed imaging programs, not employed in this trial, can drastically reduce the time to first image in an emergency situation versus a standard emergency call procedure.

![W of Greenland](image1.png)

![W Africa](image2.png)

Figure 7. Actual exercise acquisitions in the context of available acquisitions from MDA and Airbus DS.
7.4.5. Notifications

The satellite operators each notified the responder directly when products were available for download. These notifications were variable in the amount of information they provided. In this exercise, it was planned that there would be less integration of information from satellite operators in order to retain visibility of responses from the individual operators.

7.4.6. Image products

The image products are provided in a variety of formats, and were provided via ftp server. The products themselves have not been evaluated in terms of data quality or standards for oil spill response, as this is outside the scope of this exercise.

7.4.7. Oil spill products

The oil spill reports come in a variety of formats as indicated below. All of these contain map displays and details on specific possible oil spills with probabilities. Assessment of these independent products was outside the scope of the exercises.
Figure 8. MDA oil spill products. RADARSAT-2 images (thumbnails, top), oil spill reports for Greenland with superimposed estimated wind field (middle row, left) and West Africa (middle row, right) and detailed oil spill report of part of the Africa coast (bottom). These files accessed in GeoTIFF (imagery), Shapefile, kml (middle) and pdf (bottom) formats.
Figure 9. Oil spill report from Airbus DS for Greenland (top and middle left) and West Africa (top and middle right), with example detailed report below. The files were accessed in pdf formats.
7.4.8. Schedule

The exercises represented a good test of how quickly the satellite imagery and oil spill products could be provided to the responder. The timings are summarised in the following figure.

![Exercise Results](image)

Figure 10. Actual acquisitions from the exercises vs best and worst case timings provided by the satellite operators from [1].

Figure 10 confirms that lead times are more significant than latencies for initial surveillance of an oil spill, but the figure also shows that there are significant differences in performance both between suppliers and, to some extent, between locations.

Overall, the cumulative lead times and latencies approximate the values anticipated, with the whole process from oil spill alert to delivery of oil analysis product being between about 12 hours and 75 hours.

Some factors that influence the wide range of turnaround times are as follows:

- There is better temporal sampling and better ground station coverage over West Greenland, so Greenland has generally better turnaround times for satellite imagery. Confirmation to acquisition is longer over West Africa because of fewer imaging opportunities. Downlink latency is more variable for West Africa because the distance to downlink stations is more variable.

- In general the oil spill products were provided fairly quickly and the variability in the latency of oil spill reports was in part related to the structure of the trial requiring independent analysis by each operator rather than the more standard approach of a single analysis team utilizing all of the imagery sources to provide consistent reporting.