ARCTIC OIL SPILL RESPONSE TECHNOLOGY

JOINT INDUSTRY PROGRAMME

SUMMARY REPORT

TABLE OF CONTENTS

ABOUT THE JIP

The Arctic Oil Spill Response Technology Joint Industry Programme (JIP) was launched in 2012 to undertake specifically targeted research and technology projects identified to build on an already extensive research and experience background, to further improve Arctic spill response capabilities.

The JIP was a collaboration of nine oil and gas companies (BP, Chevron, ConocoPhillips, Eni, ExxonMobil, North Caspian Operating Company, Shell, Statoil and Total) and focused on six key areas of oil spill response: Dispersants; Environmental Effects; Trajectory Modelling; Remote Sensing; Mechanical Recovery and In-Situ Burning.

The JIP consisted of two phases: the first phase included technical assessments and state of knowledge reviews and the second phase focused on experiments and included laboratory, small and medium scale tank tests, and field research experiments, to further improve Arctic spill response capabilities and better understand the environmental issues involved in selecting and implementing the most effective response strategies.

The JIP results are publicly available to all users through the programme website. Dissemination of findings through conference papers and peer-reviewed journal articles was a primary objective from the beginning. The programme built on an already extensive research and experience background to further improve Arctic spill response capabilities. The JIP provided a vehicle for sharing knowledge among the participants and international research institutions, and disseminating information to a broad range of stakeholders.

The JIP set out to leave a lasting legacy by fostering the acceptance of new oil spill response strategies, facilitating the understanding of environmental choices associated with the different response tools and conducting significant new research that builds upon the decades of prior work.

1. CONTEXT

The oil and gas industry is committed to operating safely and responsibly and preventing spills from ever happening. Regardless of how low the risk level may be, achieving and continually improving response capabilities will always be a key priority.

The four key elements involved in addressing the challenges of working in any operational area are: Prevention; Planning; Preparedness and Response.

While incident prevention remains the cornerstone of industry's approach to risk mitigation, oil spill preparedness and response establishes the means to effectively plan and minimise the potential environmental consequences associated with any spill scenario, from small localised releases through to the unlikely large-scale events. Preparedness is important for enabling a rapid and coordinated response, using the most effective response strategies to minimise the spill impact

While ice is a characteristic year round physical feature in the central part of the Arctic Basin, many parts of the Arctic where oil and gas activities are today have no ice present at any time, for example the southern Barents Sea on the Norwegian Continental Shelf. The severity and duration of the ice environment varies substantially throughout the Arctic, depending on the time of year and location. Consequently, the choice of optimal oil spill response options in the Arctic can vary greatly depending both on the location and timing.

The oil and gas and shipping industries, together with government agencies, have developed the capability to detect, contain and clean up spills and minimise the overall impacts of a potential spill in Arctic environments through more than 90 years of Arctic operations. Over the past four decades, the oil and gas industry has developed the capability to prevent, detect, contain and clean up spills and mitigate the residual consequences in many Arctic environments. Many of these advances were achieved through collaborative research programmes such as this JIP, often with a mix of industry, academic, consulting and government partners.

This research is documented in thousands of peer reviewed papers, hundreds of studies, laboratory and basin experiments, field trials and testing conducted in the United States, Canada, Finland and Scandinavia. Recent examples include the SINTEF Oil in Ice JIP (2006-2009) and research conducted at OHMSETT – The US National Oil Spill Response Research and Renewable Energy Test Facility.

Giving responders the flexibility to apply the most effective combinations of response tools to suit the prevailing condition is the key to mounting a successful response and minimising impacts to the marine environment. The industry continues to develop technologies both as individual companies and through joint industry programmes to improve its ability to respond effectively to spills.

2. INTRODUCTION

Over the course of a five-year programme (2012 to 2017), the JIP has developed and carried out a series of advanced research and development projects, in six key areas of oil spill response: Dispersants, Environmental Effects, Trajectory Modelling, Remote Sensing, Mechanical Recovery and In Situ Burning (ISB), covering the primary response tools and support functions that together make up an integrated response system. The JIP research programme focused on priority areas where new research and technology development had the best chance of significantly advancing capabilities to respond to marine spills in the presence of ice in the near future.

As the largest and most extensive research effort ever undertaken in the field of Arctic spill response, expert technical working groups populated by experienced researchers from each of the member companies developed and steered the individual research programmes in the different focus areas. A global network of recognised experts in the different disciplines of oil spill response were contracted to carry out the work. These activities produced new information technology solutions, response systems, models and scientific data on important topics such as operability windows, toxicity and effectiveness.

JIP research involved a combination of laboratory and field experiments, modelling efforts and analysis of existing data, leading to the development of improved operational methods for response. Projects ranged across dispersant effectiveness testing, modelling the fate of dispersed oil in ice, assessing the environmental effects of an Arctic oil spill, advancing modelling trajectory capabilities in ice and mapping of oil in or under ice in daylight and darkness, assessing best options for mechanical recovery and expanding the window of opportunity for ISB response operations.

This Summary Report supports the more extensive Joint Industry Programme Synthesis Report, which provides a detailed and comprehensive description of the JIP's results as part of a continuum of historical research stretching back over four decades, and explains the strategic significance of the JIP's findings in improving Arctic response capabilities.

To access the Synthesis Report and all research reports under the JIP, visit
http://www.arcticresponsetechnology.org

3. OBJECTIVES OF THE JOINT INDUSTRY PROGRAMME

The ultimate goal of the Arctic Oil Spill Response Technology JIP was to continue to build confidence in the available response tools, to extend their capabilities with new strategies and systems and to provide a better understanding of operating windows when a given response tool is likely to be effective. Specific objectives of the JIP were to:

1. Improve capabilities in many aspects of Arctic spill response.
2. Develop the knowledge base needed to better assess the net environmental benefits of different response options.
3. Prove the viability of existing oil spill response technologies in the Arctic and determine their operating boundaries compatible with environmental conditions and the need for responder safety.
4. Develop new oil spill response technologies for the Arctic.
5. Disseminate information on best practices for Arctic response to a wide range of users (regulators, responders, indigenous peoples, informed public and responders).

To achieve these objectives, the JIP research programme focused on priority areas where new research and technology development had the best chance of significantly advancing in the near future, the capability to respond to spills in the presence of ice as well as in open water. Research topics were chosen to encompass all the key elements of an integrated offshore response system: Dispersants, Environmental Effects, Trajectory Modelling, Remote Sensing, Mechanical Recovery, and In Situ Burning (ISB). That the JIP achieved this goal is clearly evidenced by the results as summarised in this report.

4. KEY FINDINGS FROM THE PROGRAMME

The JIP research has consolidated a vast amount of existing knowledge in these six key areas to provide a robust and more accessible baseline for future regulators, users and industry representatives concerned with assessing, approving, planning, executing and providing oversight to ensure safe Arctic drilling and production programmes in the future.

The scientific research has added a significant new knowledge base to the existing peer-reviewed literature on oil spill impacts, herders and burning, dispersants, remote sensing and trajectory modelling. With this new information, these tools can more confidently take their place as response strategies alongside traditional methods such as mechanical recovery.

As a result of past efforts and now this JIP, a range of operationally proven tools is available to suit specific regional environments, seasons, drilling and production programmes. The following results demonstrate the ways in which the industry is better prepared to address the challenges of Arctic oil spill response planning, both with improved information, incremental advancements, new strategies and major advances achieved through the JIP.

Knowledge and Understanding

The JIP's scientific research has added a significant new knowledge base to the existing and extensive peer-reviewed literature on oil spill impacts on the Arctic environment, herders and burning, dispersants, remote sensing and trajectory modelling.

The JIP produced state of knowledge reports to consolidate the extensive knowledge base on these topics acquired through hundreds of past projects and covered: Dispersants, Environmental Effects, Trajectory Modelling, Remote Sensing, Mechanical Recovery, and In Situ Burning (ISB).

The JIP sponsored a highly comprehensive comparative assessment of multiple under and above ice sensors to detect oil in different situations, including beneath, among, and on top of and trapped within the ice. The knowledge gained from this programme, supported by state of knowledge reviews, led to development of an operational guide to oil in ice detection and mapping.

As a result of the JIP research incorporating sophisticated oceanic turbulence modelling and field studies, we are now better able to model the behaviour of a dispersed oil plume under ice and to better determine the conditions under which dispersant use in ice would be warranted or not.

The JIP developed a unique literature database. Three thousand five hundred studies and citations were organised according to their relevance to each element in the Net Environmental Benefit Analysis (NEBA) process. This database represents a valuable asset that regulators, scientists and industry can use to ensure that the best available scientific knowledge is applied when executing NEBA to evaluate new projects.

The JIP has consolidated data from key research projects (tests, trials, studies) covering more than 4 decades, and for the first time such data has been readily accessible and compiled in an interactive timeline.

Operational Aspects and Response Capabilities

The work conducted by the JIP has improved capabilities to prepare more effective contingency plans for drilling and production programmes and improve oil spill response operational capabilities in an actual incident involving oil and ice.

Examples include:

- Supporting the development of several improved high-resolution ice drift models that outperform earlier models, both in pack ice environments with high ice concentrations and more dispersed dynamic ice associated with Marginal Ice Zones (MIZ). These models will give more realistic trajectory modelling predictions to highlight the relevance for oil spill response operations.
- Developing, engineering and field testing several entirely new aerial response systems geared to deal rapidly with an offshore spill, and including an operational prototype of an integrated herder/burn helicopter delivery system, and a conceptual design for a long-range fixed and rotary wing ignition system. These systems have the potential to significantly extend the operating area (from tens to hundreds of kilometres) for the future use of burning as an offshore response tool, without having to rely on nearby support vessels or the availability of surface response assets such as booms.

KEY OUTCOMES OF THE JIP RESULTS ARE:

- State of knowledge reports on key oil-in-ice response topics such as remote sensing, dispersants, ISB and environmental effects synthesise critical information gained over more than 40 years.
- New data on response effectiveness in different conditions informs decision-making at all levels from planning through to response.
- The environmental effects database and literature navigator facilitates the use of NEBA by reducing the effort to identify and access the known, relevant information. This will lead to a better understanding of the potential environmental effects of selecting different response strategies.
- Better defined windows of opportunity and new data on expected response effectiveness for strategies involving dispersants, herders and burning will improve contingency planning and enable more realistic training courses, drills and exercises to maintain and develop responder skills.
- Results of the dispersant research show the relative benefits of Subsea Dispersant Injection (SSDI) in a range of water depths and wind speeds. These results will assist government and industry decision-makers in assessing whether or not to incorporate this tool as part of oil spill response plans.
- More effective remote sensing supported by trajectory modelling will help responders to better detect, track and map oiled area extent and movements.
- A practical field operations guide to remote sensing of oil in ice will help responders identify the most effective mix of sensors and platforms to suit a particular Arctic spill scenario.
- New response tools such as aerial herder/burn systems enable rapid response to remote spill locations without being dependent on marine support.
- The JIP results inform the public on many important topics involved in any discussion of Arctic oil spill response. This transfer of information is supported by public availability of reports and on line access to all of the material produced by the JIP including state-of-the-art technology reviews, technical reports, peer-reviewed papers, videos and graphics.
- The rigorous scientific process followed by the JIP should provide greater levels of confidence in Arctic oil spill response capabilities.

5. KEY PROJECT ACHIEVEMENTS

IN SITU BURNING OF OIL IN ICE

Background

The project was developed to raise the awareness of industry, regulators and the public of the significant body of knowledge that currently exists on all aspects of ISB, and to inform specialists and stakeholders interested in operational, environmental and technological details of the ISB response technique.

Key Achievements

The project reviewed and disseminated a vast body of knowledge on all aspects of in situ burning of oil slicks at sea, both in the presence of ice and in cold climate open water conditions. A series of comprehensive reports were written aimed at informing industry, regulators and users of the large body of information readily available. Three comprehensive State of Knowledge reports were developed:

- The roles, functionality, benefits and limitations of ISB as a response option in the Arctic offshore environment, including planning and operational aspects and any potential impacts on human health and the environment;
- A review of the findings of all relevant scientific studies and experiments as well as previous research efforts on the use of ISB in Arctic environments both offshore and onshore; and
- A summary of the status of regulations for use of ISB in Arctic nations.

What has been the impact of this Programme?

The compendium of research further supports that technology exists to conduct controlled ISB of oil spilled in a wide variety of ice conditions and improved confidence in its effectiveness, supporting that ISB is one of the response techniques with the highest potential for oil spill removal in the presence of ice. It provided confirmation that there is a considerable body of scientific and engineering knowledge on ISB to ensure safe and effective response in open water, broken pack ice and complete ice cover, gleaned from over 40 years of research, including large-scale field experiments and successful implementation in large spills such as the Deepwater Horizon response.

HERDERS AND IGNITION SYSTEMS

Background

A series of projects developed new herder application and ignition systems and engineering concepts to facilitate the use of ISB in offshore Arctic environments by extending offshore range and reducing response times. Two projects involved large-scale field trials and testing in Alaska and Norway where regulators and responders from both countries had the opportunity to see the value of the new herder/burn response tool first hand.

A separate project developed an engineering concept for a new palletized long-range ignition system for rapid deployment by fixed or rotary wing aircraft.

Key Achievements

Aerial Herder Delivery and Ignition Systems – Alaska

The application of two types of herders and subsequent ignition of a free-floating oil slick from a helicopter was successfully demonstrated using a large-scale on land test basin constructed in cooperation with the University of Alaska Fairbanks.

Norwegian Offshore Field Trial

The project successfully demonstrated the use of herders in offshore open water conditions. These field experiments provided a valuable opportunity to transfer herder and ISB technology to the Norwegian Coastal Administration and NOFO.

Long-range aerial ignition system

The results have extended the possibility of burning oil on ice much further offshore without having to depend on marine resources on site. Through the work of the JIP, a prototype airborne system that integrates the ability to apply herder from a helicopter and then ignite the treated slick in a single flight has been developed and tested.

The engineering study that was conducted produced a conceptual design of a palletized airborne ignition system capable of rapid installation in a suitable fixed wing airplane or helicopter. This development could enable access to remote offshore sites at higher speeds with much greater capacity and endurance than existing aerial ignition tools.

Herder fate and effects

More information and data has been gathered on herder toxicity on several primary Arctic marine species, which is important to gain the necessary approvals for use of herders in an operational scenario.

What has been the impact of this Programme?

Being able to implement an earlier response capability in remote offshore areas greatly increases the chances of protecting key environmental assets.

As a direct result of the research and engineering efforts, the JIP has developed a new integrated aerial delivery system for herding and burning slicks, expanded the application of herders to offshore open water environments, further evaluated potential herder toxicity and produced a new engineering concept for a higher capacity, longer-range aerial ignition system.

A new field trial offshore Norway in collaboration with NOFO and NCA provided additional verification that herders could contract slicks for effective ignition in open water, adding to the successful experience in a previous JIP with herders and burning in the presence of ice.

Laboratory tests with several Arctic species corroborated the view that in field applications, low volumes of herders that rapidly spread to form a monolayer on the surface should pose no significant risk to the environment in terms of their toxicity to or effects on selected organisms.

Regulators and the responders in Alaska and Norway attended the JIP's successful field trials where they witnessed demonstrations of the potential of herding and burning as a new combined response strategy for both ice covered and open water.

The conceptual design for a new long range aerial ignition system using fixed wing and rotary wing aircraft has the potential to expand the use of ISB to offshore sites previously beyond the range accessible by a helicopters carrying the Helitorch™.

The results of the programme have provided a new rapid response capability less dependent on surface support, improved effectiveness in responding to spills in remote areas, and improved confidence in the operational performance and environmental acceptability of herders.

DISPERSANTS

FATE OF DISPERSED OIL UNDER ICE

Background

The overall goal was to develop tools to support contingency planning and operational response decisions with respect to dispersant use in the presence of ice.

Key Achievements

An existing model was used to predict the resurfacing potential of a dispersed oil plume under ice with and without the addition of mechanical mixing energy. An existing model demonstrated the potential environmental benefits of SSDI in significantly reducing the percentage of oil surfacing from a subsea release and the subsequent persistence of surfaced slicks in different water depths and wind speeds.

What has been the impact of this Programme?

New data sets of expected dispersant effectiveness in ice as a function of a wide range of physical variables will help regulators, planners and responders understand how dispersants are likely to perform in different scenarios.

Modelling results showing that the use of dispersants in response to a large incident would likely result in insignificant impacts to Arctic Cod populations as an example.

Proof that oil frozen into the ice surface through the winter remains dispersible when released from the ice the following summer regardless of whether the oil already contained dispersant at the outset.

DISPERSANT TESTING UNDER REALISTIC CONDITIONS

Background

The aim of this research was to establish the operational limits of dispersants in Arctic ice covered waters and to summarise the regulatory status for dispersant use for each Arctic nation/region.

Key Achievements

Reports completed further reinforced previous research that dispersants can work in the Arctic and will, under certain conditions, be more effective in the presence of ice than in open water. Studies also confirmed that the presence of ice can increase the time window within which dispersants can be used effectively. However, with a few exceptions, where good regulatory models have been established for dispersant use, and credits are in place, there is generally an absence of national policies and procedures to pre-approve the use of dispersants and additional effort is needed to influence decision-makers about the importance and effectiveness of dispersants and thus the need for such procedures. Future policy should be informed by this work leading to appropriate pre-approval and credit.

What has been the impact of this Programme?

As a result of the JIP's efforts in this area, there is now a new understanding of the relationships between expected dispersant effectiveness in ice and a wide range of variables including oil type, dispersant type, water salinity, energy level and ice concentration. This information will lead to improved contingency plans and real time response decisions based on scientific evidence of how dispersants are likely to perform in different scenarios. It has validated relative dispersant effectiveness in ice with different energy levels over a much larger range of variables than previous research.

OIL SPILL DETECTION AND MAPPING IN LOW VISIBILITY AND ICE

Background

The JIP's work in this area aimed to expand industry's remote sensing and monitoring capabilities, for responding to spills in a wide range of scenarios (oil under, in, among and on ice). This was met by implementing three phases, each building on the results of the previous phase. These phases included: 1) two state of knowledge reports on surface and subsea sensors, 2) concurrent testing of surface, on-ice and underwater sensors under experimental conditions for two months and 3) additional testing of multi-wavelength IR and FMCW radar, as well as the creation of a unique operational Arctic remote sensing guide.

These reviews were followed by a unique test series in a large scale basin test at the CRREL facility in New Hampshire, USA. Multiple sensors mounted above and below the ice scanned oil layers beneath and trapped within the ice at different depths throughout a complete growth and decay cycle. Variables included oil film thickness, location of the oil layer within the ice sheet and situations with free oil beneath the ice or on the surface during freeze-up.

Key Achievements

The Programme further supports that there are several airborne and surface imaging systems technologies that exist today capable of, or having the potential for, effective sensing in a limited range of ice and environmental conditions that could be experienced in the Arctic.

A comprehensive test programme was developed to further evaluate and qualify the most promising sensors and platforms and recommend the most effective sensor suite for detecting oil in the ice environment under different conditions. The large-scale basin testing showed that all of the sensors were capable of detecting oil in ice under certain conditions.

A new remote sensing operational guide has been developed that synthesises the existing knowledge base on oil in ice remote sensing and provides a concise operationally-oriented tool that responders can use to select the most effective sensors and platforms for a given set of conditions. Dealing specifically with twelve different oil and ice scenarios, this is the first such guide of its kind, complementing initiatives by IPIECA and others that summarise best practices and available sensors for remote sensing in open water.

What has been the impact of this Programme?

The work has increased the understanding of capabilities and limitations of different sensors and is a major gain in assessing what is most likely to work in different situations.

The results and recommendations of the JIP remote sensing research projects facilitate the selection of the most effective remote sensing technologies to detect oil in, under, on and around ice in the event of an actual spill.

The test programmes conducted are the first proof of being able to detect encapsulated oil from below with sonar.

As a result of JIP-sponsored test programmes, response managers now have a better understanding of relative sensor capabilities, strengths and weaknesses in particular oil and ice situations when using a range of different sensors above and below the ice. Variables included oil film thickness, location of the oil layer within the ice sheet and situations with free oil beneath the ice or on the surface during freeze-up

ENVIRONMENTAL EFFECTS FROM ARCTIC OIL SPILLS AND OIL SPILL RESPONSE TECHNOLOGIES

Background

The environmental effects project aimed to improve the available knowledge base for using Net Environmental Benefit Analysis (NEBA) in oil spill response decision-making and to better understand the environmental issues involved in selecting and implementing the most effective, environmentally acceptable response strategies.

Key Achievements

In 2013 a multi-disciplinary team of experts performed a comprehensive review of the scientific study of environmental consequences of spilled oil and oil spill response byproducts in the Arctic marine environment. This review indicated that there was a significant science base for oil spill response decision-making in the Arctic already available.

This effort culminated in the online publication of a report "Environmental Effects of Spilled Oil and Response Technologies in the Arctic", based on over 960 literature references from investigations into spilled oil and oil spill response technologies in the Arctic marine environment.

From this report the JIP produced a NEBA information and support tool (web-based literature portal) that identifies and summarises crucial data for evaluating the ecological consequences of oil spill response options.

To expand areas where literature was found to be less extensive, four research projects were conducted, and included modelling studies, laboratory, and field research experiments. The field research included experiments to understand the oil weathering process and natural biodegradation of the oil under Arctic conditions and measure the sensitivity and resiliency of sea ice communities. A multidisciplinary team of experts examined the long-term fate, behaviour, persistence and biodegradation of the oil in ice together with the impacts on the microbial and plankton communities in and under ice, following different response scenarios.

What has been the impact of this Programme?

Through these activities in this area, the JIP has successfully reviewed and extended the available science base on oil spill impacts in an Arctic environment, and produced a web-based literature access tool where this information is stored and easily retrieved.

Results from laboratory and field tests, and modelling studies has improved the understanding of what happens to oil once frozen into ice, how microbiology reacts to oil in ice and what the exposure potential is of sea ice ecosystems. This information will provide valuable new data to support NEBA.

This information and the developed systems will help the response community in selecting a combination of response strategies that minimises the effects to people and the environment.

OIL SPILL TRAJECTORY MODELLING IN ICE

Background

The overall aim of this research component was to improve the ability of contingency planners and responders to predict the movement of oiled ice with greater accuracy in a range of ice conditions, including pack ice and the more dynamic conditions of the Marginal Ice Zone (MIZ).

Key Achievements

This JIP research programme advanced oil spill trajectory modelling by supporting the development of several improved higher-resolution ice drift models that outperform existing models both in pack ice environments with high ice concentrations and more dispersed dynamic ice associated with Marginal Ice Zones (MIZ).

What has been the impact of this Programme?

By requiring that the ice model outputs be provided in internationally accepted data exchange formats, the two most commonly used oil fate and behaviour models can now efficiently import the data produced by a variety of available ice models to provide more accurate predictions of oiled ice movements in a range of ice conditions.

MECHANICAL RECOVERY OF OIL IN ICE

Background

The aim of this JIP initiative was to examine results from previous research projects and operational experience with mechanical recovery in ice to identify opportunities to substantially improve mechanical recovery performance.

Key Achievements

The JIP brought together many of the leading experts in the world to study the challenge of developing new, improved mechanical systems to work in ice covered waters. Novel concepts were put forward but none demonstrated the necessary recovery improvement potential to justify further development.

What has been the impact of this Programme?

Comprehensive evaluation confirmed that the physics of oil spreading and ability of equipment to come into contact with recoverable oil, rather than recovery equipment design itself, limit efficiency of mechanical recovery in ice. The existing systems are already operating at close to their maximum attainable recovery rate in ice and substantial improvements in overall mechanical recovery rates and efficiencies cannot be readily achieved by additional equipment design. This analysis confirmed that integrating field operations with advanced support tools like real-time remote sensing could lead to greater improvements by enhancing the performance of existing recovery systems, for example making sure they are positioned in the thickest oil films to maximise encounter rates.

6. CONCLUSIONS

This JIP represents a significant achievement in the field of Arctic oil spill response research. Its diverse suite of results covers all of the different response tools and important support activities that produce an effective integrated response system. The results of this programme demonstrate that:

- There is a large body of work (over 40 years) underpinning Arctic spill response;
- Operative response options exist to suit a wide range of conditions;
- Effective oil spill response in the Arctic is possible; and
- The JIP's findings have increased response capabilities through:
    - Increasing knowledge and understanding
    - Improving operational aspects
    - Enhancing industry's planning and preparedness

- Improving decision making for responders, and
- Providing greater support for Regulators and Policy Makers.

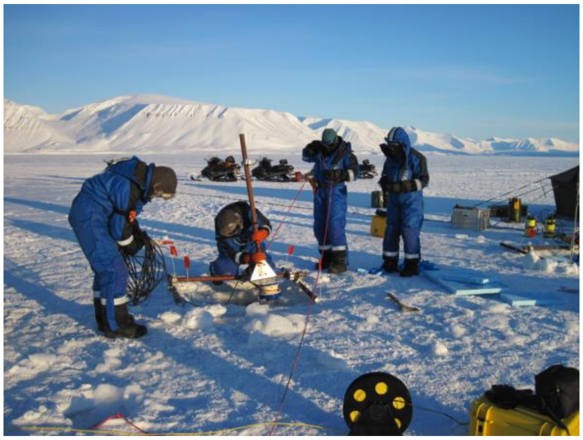
The JIP research has consolidated a vast amount of existing knowledge in the six key areas to provide a robust baseline for future regulators, users and industry representatives concerned with assessing, approving, planning, executing and providing oversight to ensure safe Arctic operations in the future.

The results of this JIP serve a broad cross section of industry, government, academic and public interests at strategic and tactical levels, from planning, through preparedness to response execution, and will enhance improved oil spill response in general, not just for Arctic operations.

Overall, the JIP has consolidated, reinforced and advanced a rigorous scientific basis to support informed decisions on the future use of dispersants and burning as primary response strategies in the Arctic. With this new information, these tools can take their place alongside traditional methods such as mechanical recovery and be considered as primary strategies in future contingency plans.

Industry now has a more robust range of operationally proven tools to suit specific regional Arctic environments, encompassing ice and open water seasons. Most importantly advances made under this JIP are underpinned by peer-reviewed science and full transparency in making the results available to a wide audience through reports, conference and journal articles.

Programmes like the JIP reflect industry's collaborative approach to Arctic oil spill research. Advancing oil spill response is a key area where the oil and gas industry works together to achieve a common goal, joining forces provides access to a much wider range of technical expertise and experience and represents a more efficient way to manage available research.



LIST OF REPORTS FROM THE PROGRAMME

Mechanical Recovery

- Summary Report

In Situ Burning (ISB)

- State of knowledge
- Technology summary and lessons from key experiments
- Status of regulation in Arctic and subarctic countries
- Research summary: herding surfactants to contract and thicken oil spills for ISB in Arctic waters
- Historical review and date of the art for oil Slick ignition for ISB
- Field research on helicopter application of chemical herders to advance ISB
- Develop and test Integrated herder/ignitor delivery system for helicopters
- Conceptual design of long range aerial ignition system
- NOFO Oil on Water 2016 field exercise – validate use of herders and burning in open water

Dispersants

- Status of regulations and outreach opportunities
- Fate of dispersed oil under ice
- Field study to collect under-ice turbulence data (Svea, Svalbard)
- Flume tank experiments
- Dispersed oil fate model
- Propeller wash turbulence mixing model
- Dispersant effectiveness testing under realistic conditions
- Modelling subsea dispersant injection
- Evaluating dispersant effectiveness boundaries
- Oil and dispersant ice core analysis
- Peer-reviewed papers on dispersant effects on fish populations
- Biodegradation of dispersants in sea water
- Development of manuscript on dispersant use

Remote Sensing

- State of knowledge Reviews: surface & subsea remote sensing
- Basin tests: above and below ice sensor comparison & modelling
- Basin tests: infrared sensor capabilities to detect oil on ice
- Basin tests: FMCW radar to assess capabilities for airborne detection of oil under ice
- Guide for oil spill detection in ice covered waters

Trajectory Modelling

- Sea ice model developments to improve oil spill forecasting
- Improved ice trajectory models and validation with drifter data
- New ice models integrated with existing oil fate and behaviour models

Environmental Effects

- Environmental effects of arctic oil spills and arctic spill response technologies
- Web-based NEBA support tool – literature database and information portal
- Unique Arctic communities (field mesocosms & laboratory studies)
    - Oil biodegradation and persistence
    - Resilience and sensitivity