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Arctic Potential: Realizing the Promise of U.S. Arctic Oil and Gas Resources
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Paper #6-10

RECENTLY PUBLISHED LISTS OF ARCTIC TECHNOLOGY/RESEARCH NEEDS

Prepared for the

Technology & Operations Subgroup

On March 27, 2015, the National Petroleum Council (NPC) in approving its report, *Arctic Potential: Realizing the Promise of U.S. Arctic Oil and Gas Resources*, also approved the making available of certain materials used in the study process, including detailed, specific subject matter papers prepared or used by the study's Technology & Operations Subgroup. These Topic Papers were working documents that were part of the analyses that led to development of the summary results presented in the report's Executive Summary and Chapters.

These Topic Papers represent the views and conclusions of the authors. The National Petroleum Council has not endorsed or approved the statements and conclusions contained in these documents, but approved the publication of these materials as part of the study process.

The NPC believes that these papers will be of interest to the readers of the report and will help them better understand the results. These materials are being made available in the interest of transparency.

The attached paper is one of 46 such working documents used in the study analyses. Appendix D of the final NPC report provides a complete list of the 46 Topic Papers. The full papers can be viewed and downloaded from the report section of the NPC website (www.npc.org).

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Topic Paper

(Prepared for the National Petroleum Council Study on Research to Facilitate Prudent Arctic Development)

6-10	**Recently Published Lists of Arctic Technology/Research Needs**
Author(s)	**Jed Hamilton (ExxonMobil)** **Peter Noble (Noble & Associates)**
Reviewers	**Neal Prescott (Fluor)** **Mitch Winkler (Shell)**
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SUMMARY

There have been several initiatives by others in the past 5 years that have sought to define the critical technology needs to facilitate Arctic hydrocarbon exploration and development. Three of the more recent initiatives are summarized herein. Together these capture the knowledge and experience of most of the industry's subject matter experts for Arctic Development. The study reported by C-CORE's Center for Arctic Resource Development was conducted at a higher level and tried to focus on a smaller set of critical research needs. The RU-NO Barents Project study developed a very comprehensive list of technology development needs within a spectrum of technology groups specific to the Barents Sea and environs. Prioritization was a part of the study within each individual technology area; however the objective was not to prioritize amongst the technology areas. Many of the technology areas equally applicable to deepwater and being driven today by Deepwater R&D. The third is a list that was compiled in March 2011 by a broad group of IOC's seeking potential key, non-competitive Arctic research and technology advancement opportunities for which there might be consensus for joint industry funding.

A review of the recommendations from these documents did not identify technology areas not already listed in the E&P chapter list from topic paper TP3.1. In most cases, the identified needs represent areas for enhancement of existing technologies to improve performance, cost or reliability vs. technology that does not exist. Key technology enhancement areas listed in the studies included Arctic well integrity and spill prevention, oil spill response, floating drilling in ice and supporting ice management operations and design and burial technology for protection of offshore pipelines subject to ice interaction. Conclusions reached from this review are as follows:

1. Identified areas / priorities are largely aligned with ongoing initiatives
2. There are strong synergies with several Deepwater challenges and technologies

I. INTRODUCTION

One of the objectives of the NPC AR report chapter on offshore Arctic exploration and development technology is to develop a prioritized list of research and/or technology enhancements that could materially facilitate prudent US Arctic development. To that end, it is instructive to review recent such lists developed by various groups as part of scoping efforts to shape and focus Arctic research programs. The renewed interest in Arctic exploration over the past 5+ years has prompted several studies of Arctic development technology needs. Three are discussed herein, and it is felt that they represent the thinking of most of industry subject matter experts. Of course, needs change as exploration plans gain sharper focus and ongoing research studies provide clearer understanding of specific technology needs. Hence, some needs identified previously may be less important or may have been fulfilled by industry technology development work over the past five years. A good example of this is the recent rapid advancement of well capping technology. It should be noted that while the studies discussed herein do a reasonable job of considering the multiple facets of "prudent development," they were motivated more by economic and efficient development than environmental or human impact concerns per se. Additionally, these studies do not in every case seek to place the stated technology enhancement need in context of what technology already exists. Hence, one cannot interpret a technology enhancement area from these previous studies as an indication that suitable technology does not already exist.

II. C-CORE CENTER FOR ARCTIC RESOURCE DEVELOPMENT (CARD) – ARCTIC DEVELOPMENT ROADMAP

CARD reviewed 21 documents from the public domain between 1992 and 2010 that listed Arctic technology development needs. The study is documented in Ref. 1. They also consulted with Arctic oil and gas development subject matter experts from 14 oil and gas and consulting companies. The CARD study defined these common technology groups and ranked them in the 3-tier pyramid diagram (below) from their report.

- Hydrocarbon Detection, Exploration and Evaluation Technologies
- Ice Management Technologies
- Bottom-founded Structure Platform Technologies
- Floating Structure Platform Technologies
- Subsea Technologies
- Hydrocarbon Export Technologies
- Transportation and Support Technologies
- Escape, Evacuation and Rescue
- Environmental Protection Technologies

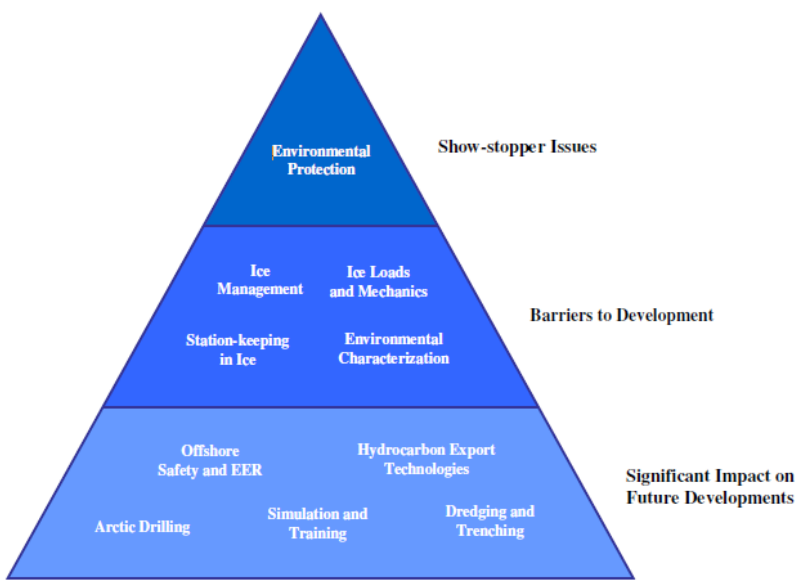

Figure 1 3-Tier technology prioritization from CARD report

Environmental protection technologies, including drill well source control and oil spill tracking and response were considered at the top-tier level due to their importance in obtaining and maintaining a license to operate. For clarity, environmental protection technologies were not identified as “show stoppers” per se, but environmental protection and safety are top priorities.

Barriers to Development (second tier) included ice management capability (for floating drilling and other floating operations requiring station keeping), ice loads and mechanics (for improved reliability and integrity of designs), Station-keeping in ice and environmental characterization. Of course, ice management and station-keeping are integrally related as are ice loads and environmental characterization.

Third tier items included offshore safety and EER (Escape, Evacuation and Rescue), hydrocarbon export technologies (including tankering and Arctic pipeline design), Arctic drilling, simulation and training, and dredging a trenching (primarily for installation of buried Arctic pipelines and facilities to achieve ice protection).

The CARD study also produced the table in Figure 2 of technologies needed for the Beaufort Sea, which is instructive.

III. RU-NO Barents Project Report

The Russian – Norwegian oil and gas industry cooperation in the High North project (RU-NO Barents Project) is a collaboration-promoting project undertaken by INTSOK in Norway. Project participation included both government and industry from Norway and Russia. According to project documents, the main objective of the RU-NO Barents Project is, through industry cooperation and knowledge of Arctic technology needs, to contribute to the growth of the Russian and Norwegian industry participation in future petroleum endeavors in the High North.   Detailed study objectives included:

- Assess common technology challenges Russia and Norway face in the development of the High North
- Analyze existing technologies, methods and best practice Russian and Norwegian industry can offer for the High North today
- Based on the above: Visualize the need for innovation and technology development the industry in the two countries needs to overcome
- Promote stronger industrial links between the two countries

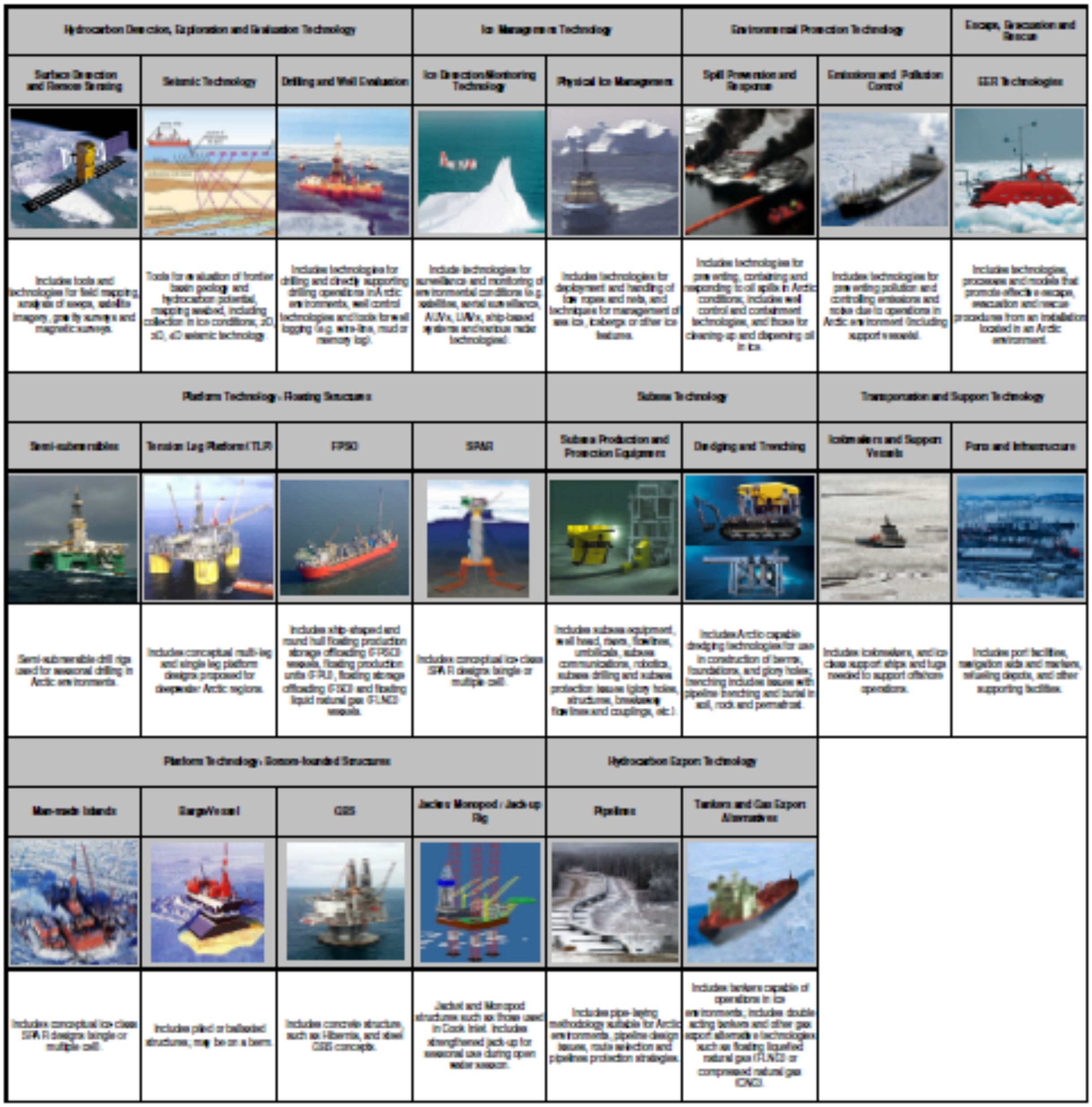

Figure 2 CARD report summary table of technologies needed for the Beaufort Sea

A. Technology Needs from RU-NO Barents Project Reports – Drilling, Well Operations and Equipment Report

The following summary table was produced by the RU-NO Barents Project team studying Drilling, Well Operations and Equipment (Ref. 2).

INTSOK Norwegian Oil and Gas Partners

Table 3: Technology Development Summary Table

Main category	Description	Timeframe	Suggested category of solution provider
Mobile Drilling Units (MODUs) and Drilling Installations	**Design basis and data** - Data should be made available publicly, and the data should be verified and agreed as established criteria - The data should be organized per area	Short Term	• Industry • Research institutions
Mobile Drilling Units (MODUs) and Drilling Installations	**Design Ice Load Models** - Correlation between model test, model test conditions and real data to be understood and standardized - Efficiency of sea ice management (ice breaking, slurryfication, etc) and predictability of such operation methods are not well defined and standardized - Efforts to establish understanding, improve predictability and efficiency of methods to be developed	Short Term	• Industry • Research institutions
Mobile Drilling Units (MODUs) and Drilling Installations	**Rules and Regulations for Operations in Arctic Offshore** - Industry understanding' of rules and regulations, including authority's approval and consent processes in various jurisdictions in the High North should be improved - As approval and consent process are now being further developed in the Northern waters, coordination between jurisdictions would improve efficiency, lateral learning and use of best practice - A "Roadmap" or comparative analysis to help industry to understand various jurisdictions should be developed	Short Term	• Industry • Authorities
Mobile Drilling Units (MODUs) and Drilling Installations	**Mooring Systems** - An efficient disconnect/reconnect system for mooring and riser needs to be developed, probably based on turret technology	Short to Medium Term	• Industry
Mobile Drilling Units (MODUs) and Drilling Installations	**Vessel design for Ice Conditions** - Vessel alternatives for a range of drilling and well operations covering water depths down to 350m, temperatures down to -30C and capable of operations in relevant sea ice conditions should be developed to meet the requirements of year round operations 'Medium Term' - For 'Long Term', MODUs to be developed for operating conditions will be more severe with temperatures down to below -40C, stronger currents and harsher environment altogether.	Medium Term Long Term	• Industry • Research institutions
Drilling and Well Operations	**Arctic Well Control** - Regulatory requirements in the Barents (Russian and Norwegian regulations) and Kara Seas (Russian regulations) to be compared - Controls to be developed to mitigate where conventional deepwater controls are ineffective in Arctic considering such factors as ice conditions, equipment operability in ice, and impacts on operating procedures and people - Enhanced preventative measures to be developed to reduce the risk (probability and consequence) of well control issues, such as BOP with dual shear rams	Short to Medium Term	• Industry • Research institutions • Authorities
Drilling and Well Operations	**High latitude surveying uncertainty and degradation of quality of data** - Technology required for accurate positioning of wellbores to be developed	Short to Medium Term	• Industry
Ice, Weather and Cold Climate Challenges	**Wellhead location and protection** - Technology solutions for protection of well heads, including BOP and x-mas tree, from iceberg interaction where appropriated should be developed	Medium Term	• Industry
Ice, Weather and Cold Climate Challenges	**Ice management systems** - Reliable and sufficient detection, forecasting and prediction systems to be established and be available in the areas of operation - Vessels and systems required to support the drilling operations to be available, certified and approved for area of operation	Medium Term	• Industry • Research institutions

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RU-NO Barents Project, Drilling Well Operations and Equipment-Report, 21. February 2014

Table 1. RU-NO Barents Project Drilling, Well and Operations Research Needs (Courtesy: INTSOK RU-NO Barents Project)

The report also makes mention of the interdependency with logistics: "Existing paradigms need to be challenged and new ways of thinking considered to impact logistics costs and requirements. For example, slimmer wells have the opportunity to reduce resupply requirements".

B. Technology needs from RU-NO Barents Project Reports -- Pipelines and Subsea Installations Report

The following are the numerous technology development needs extracted from the Pipelines and Subsea report (Ref. 3).

1. Wellhead and X-mas trees

- Improved mapping and further studies of the areas thought to be suffering from the seabed challenges; the areas affected the properties of the seabed and the perceived influence on the wells.
- Improved methodology for assessing load and fatigue impact on wellheads – short term during installation and intervention but also through a full life of field scenario. The utilization of instrumentation systems to reduce uncertainty of status should be included in this development.
- New and innovative wellhead foundation solutions (including cement technology and instrumentation for monitoring) for a seabed with changing properties.
- Evaluation of adequacy of current drilling practices for areas where the seabed may contain shallow gas and/or frozen soils.
- Establish clear requirements for the influence of seismic activities on wells and wellhead structures.
- Establish clear requirements for how to protect wellheads and X-mas trees from icebergs as well as scoring ice in shallow waters.
- Establish risk assessment methods for wellheads and X-mas trees (including well barriers) with respect to seabed conditions, ice bergs and scoring ice in shallow waters.
- Improved understanding of the consequences on the environment for wells in a deteriorating state where leakage is a possible consequence thus potentially leading to a catastrophic event.
- Further development of drilling, well and completion technology reducing the size of the well (slender well) while at the same time proving sufficient through bore in the production tubing and X-mas tree thus satisfying the various fields production requirements.

2. Manifolds and templates

- With Shtokman being a field which has been subjected to thorough studies and evaluation, it is recommended to review the material and provide a "lessons learned" for future reference.
- Development of modular and reduced weight/size solutions optimized for fast installation and potential use of ROV/AUV/submarine technology.
- Development of ROV/AUV/submarine technology for installation of modules and general surveillance and inspection of the seabed structures.
- Further development of batch installation and wet parking technology with the purpose of significantly reducing the time needed during installation.
- Development of technology to reduce dependence on heavy lift transport and installation vessels (e.g. use of buoyancy modules)
- Development of robust system solutions (contingency) for areas where damage caused by ice or denied IIMR access will reduce the availability of the Subsea Production Systems significantly. (e.g. alternative routing of fluids or well stream, redundant communication)
- Develop IIMR strategies to obtain acceptable availability in the various regions including developing CPM technology to match the requirements in the IIMR strategies.
- Further develop risk assessment methodology to cover the challenges in the region
- Develop "ice and iceberg management" philosophies for the various regions as input and guidelines for the particular future field developments.
- Further develop methods for seabed excavations with the aim of significantly reducing time and volume of discharge of silt/particles in environmentally sensitive areas.
- Further development and use of materials and lubricants which does not suffer from extreme cold temperature or large temperature cycles. Use of lightweight materials such as aluminum and GRP should be included in this scope of work as this will also reduce the weight of the equipment.

3. Subsea control systems

- Further development of hydraulic fluids to reduce content of potential toxic chemicals while still providing the necessary functionality for long and reliable operation of hydraulic systems.

- Further development of technology to eliminate discharge of hydraulic fluids to sea. The fluid could be returned to a host facility, to a catchment tank or possibly be re-injected into a reservoir together with produced water.
- Further development of electrical control systems including work on system architecture and integration of CPM technology for improved reliability and ability for seamless replacement of modules without interruption of operations.
- Further development and qualification of downhole electric valves.
- Further development of technology enabling communication, power distribution and supply of hydraulics for the longest step out distances.
- Development of technology for interfacing and operating ROV/AUV's such that these can perform tasks independently of surface located vessels. Communication technology for high capacity data transfer including visual streaming (real time) and power supply should be part of the scope.

4. Workover systems
- Development of workover and intervention philosophies for the various regions as input and guidelines for the particular future field developments and the development of the necessary technologies.
- Development of technologies which reduces the need for "tight" vessel station keeping during workover and intervention operation including improvement to GPS positioning systems
- Development of technologies which enables faster workover and intervention operation
- Development of technologies which enables faster yet safe temporary abandonment of operations and subsequent reconnection for continuation.
- Development of technologies which reduces loads on subsea structures during workover and operation. Both normal operations and accidental scenarios shall be considered.
- Development of technologies and services enabling more use of ROV/AUV/Submarines including ability to operate under ice.
- Development of technologies enabling "wet parking and storage" of spares (e.g. control modules).
- Further development of Riser Management System including incorporating ice management services
- Improvement to weather monitoring and prediction services. Of particular interest is to look more into the unpredictability of weather patterns which has the potential to interfere with workover and intervention operations. Ocean currents should also be included in this scope of work.

5. Umbilicals
- Further development of elastomeric material which does not suffer from brittleness in cold climate during storage as well as during reeling.
- Further development of methods and services for transportation, storage and installation which prevents exposure to extreme low temperature.

6. Infield flowlines and risers
- Further development of low temperature polymeric materials for insulation purposes in flow lines or risers.
- Further investigation into low temperature effects of fatigue in a "multi influenced environment".
- Development of flowline technology which eliminates the need for exact infield measurements of "as installed" locations of connection points
- Further development of weak-link and "seal off" functionality as part of flowline termination connections, including possible legislation issues.

7. Remote sources of electrical power
- Power transmission for very long distances – more than 500 km
- Subsea converters DC/AC

8. Electrochemical generators based on fuel cells

- Extend lifetime beyond 250days in continuous operation
- Improve battery capacity beyond 1MW

9. Nuclear energy sources

- Increase subsea nuclear power plants capacities above 35MW

10. Separation

- Technology improvements are needed to increase the separation efficiency and operating range (e.g. turn-down performance) of subsea separation systems. Compact separation systems also require further development in the areas of slug control and fast-acting control systems.
- Further improvements in technology will be required to facilitate the use of subsea separation systems in remote subsea fields, especially in the areas with reduced accessibility due to ice cover, e.g. technologies for:
    - Remote condition monitoring and diagnostics
    - Oil-in-water and solids-in-water measurement
    - On-line removal and disposal of sand/solids
    - Subsea leak detection
    - Autonomous subsea intervention systems with year-around, all-weather surveillance and maintenance capabilities, e.g. Autonomous Underwater Vehicles (AUV), resident ROVs, or submarine-based systems.
- Longer-term developments of subsea fluid conditioning technology (e.g. gas dehydration systems, compact electrostatic coalesces for oil de-watering) will be required to achieve export quality hydrocarbons, which could further reduce the need for topside processing facilities. This could allow, for example, direct tie-in from a subsea gas field to a gas export pipeline network, or subsea storage of stabilized oil and subsequent offloading to tanker for transport to market.

11. Pumping

- Technology development efforts for subsea pumping should be focused on increasing the rating of subsea pumps in terms of motor power, differential pressure, water depth, and casing pressure.
- Development of alternative, environmentally-friendly barrier fluids for subsea pumps can reduce environmental impact in case of accidental discharge.

12. Compression

- Dry gas compression systems require simplification/optimization to reduce the number of system components which could result in less complex, more compact design (reduced foot-print, lower weight). In addition, improving their liquid tolerance could expand their application range.
- Wet gas compression systems require scale-up to increase their unit power, flow rate, and differential pressure.
- High-pressure subsea compressors will be required for subsea gas reinjection.
- Electrical power distribution and conversion components (e.g. transformers, switch gear, variable frequency drives (VFD), uninterrupted power supply (UPS)) will require a pressure compensated, liquid filled packaging to reduce their size/weight. Liquid filling of VSD's etc is also expected to increase reliability, due to more stable environment for components (better cooling), and also less complicated cooling. The weight will not necessarily be reduced due to the weight of the oil and the limited water depth in these areas (not very thick pressure vessel walls).
- Electrical power connectors and penetrators will need further development to accommodate the requirements of long-distance, high-power transmission systems, which in the future may be featuring higher voltage (up to 145 kV) and either low-frequency AC or DC transmission technology.

- Further improvements in technologies for remote condition monitoring and diagnostics of subsea compressors will be required to facilitate the use of subsea compression systems in remote subsea fields, especially in the areas with reduced accessibility due to ice cover.

13. Flow assurance

- The existing multiphase flow simulation programs have limitations (high uncertainty/low accuracy) when modeling/predicting behavior of certain types of fluids, which, combined with the need for long-distance transport and large diameter pipelines, can introduce significant errors in the flow prediction. Specific examples are
    - Ability to predict pressure drop in pipelines transporting heavy/viscous oil, or
    - Ability to predict liquid accumulation in gas-condensate pipelines with low liquid content (especially for large-diameter pipelines).
- The lack of quality experimental data complicates the development and validation of new multiphase flow models. This type of data, both from the laboratory-scale and full-scale experiments, will be needed to calibrate/validate the flow simulation results.
- New/improved models for multiphase flow, with improved capabilities to predict flow instability, slugging, and liquid accumulation will facilitate development of remote field in the arctic.

14. Design, installation and operation of pipelines

- Establish an accurate and extended design basis covering the new environmental conditions with characteristic parameters for;
    - Sea surface ice conditions, including statistical parameters for icebergs and ice ridges where relevant.
    - Polar lows statistics.
    - Seabed ice scouring statistics.
    - Landfall and onshore sections with continuous and discontinuous permafrost.
- Develop design methodologies and analysis models for simulation of Arctic specific load conditions and phenomena such as:
    - Design methodologies for pipelines in shallow water conditions exposed to the threat of ice gouging. This typically includes the development of reliable pipe-soil-ice interaction models and corresponding pipeline design criteria to define an optimized pipeline protection cover depth based on risk principles.
    - Design methodologies for pipeline sections exposed to ground movements induced by discontinuous permafrost and pipe-soil-ice interaction effects.
- Develop design solutions for pipeline landfall sections with challenging soil and ice conditions. Case specific landfall solutions are normally needed to meet the requirements from variable sea ice conditions, coastline erosion effects, exposure to discontinuous permafrost or interaction with fresh water around river deltas.
- Develop equipment for efficient deep seabed trenching. In potential ice scouring regions the pipeline could be protected from direct ice contact by lowering the pipeline into a seabed trench. The required seabed trenching depth is typically larger than 3 m, which is outside the range of most trenching equipment currently available on the market.
- Develop pipeline concepts enabling long distance transportation of unprocessed or partly processed well fluid. This may be developed as integrated subsea processing and transport solutions.
- Develop safe and cost-efficient pipeline fabrication and installation methods meeting the challenges of harsh environmental conditions, remoteness and lack of infrastructure. This could typically cover;
    - Pipeline welding procedures at low temperature.
    - Pipeline coatings resistant to low temperatures.
    - Installation procedures reducing the consequences of polar lows.
    - Optimized transit and installation periods.

- Develop survey, maintenance and repair concepts minimizing the need for surface vessel support.
- Develop pipeline monitoring and inspection concepts giving updated information about the internal flow condition and the pipeline integrity condition, which are independent of the weather and sea surface ice conditions.

C. Other RU-NO Barents Project Reports

The RU-NO report on Logistics and Transport was passed along to the Logistics and Infrastructure chapter team. It really addressed Barents and Kara Sea logistical issues and did not have an E&P technology development focus.

The RU-NO report on floating and Fixed Installations was not complete as of the writing of this topic paper. Its issuance is anticipated for December 2014.

The RU-NO report on Environmental Protection was passed along to the Oil Spill Response chapter team. It did not have E&P technology content.

As for the other research priority studies, strong synergies were found between Deepwater and Arctic technology enhancement needs, especially in terms of well integrity and subsea facility reliability.

III. TECHNOLOGY RESEARCH OPPORTUNITIES FROM IOC COLLABORATION MEETINGS

This study (Ref. 4) consisted of several meetings in 2012 of Arctic development subject matter experts from industry IOCs with Arctic interest in which technology enhancement needs were explored and consensus was sought on potential opportunities for joint funding on key non-competitive topics (e.g., items related to improved integrity of Arctic operations such as enhanced personnel safety and improved environmental protection). Participating companies included BP, Conoco-Phillips, Shell, ExxonMobil, Chevron, Statoil and Total. The list below was developed from items nominated by the various participating companies. While consensus eventually aligned on the topic of Arctic well integrity and spill prevention, it is instructive to consider the broader list of technology areas considered of higher importance by the participants. Note that industry has been actively advancing the technology in most of these areas since the time this list was constructed.

Ice Management	• Enhanced techniques for ice management • Calculation of managed ice loads on stationary floating vessels • Numerically predictive ice management modeling – Performance prediction based on environment and fleet characteristics • Remote sensing enhancements (automation of ice edge and ice type detection from satellite imagery) • Trials to demonstrate ice management field performance
Arctic Pipelines	• Deep trenching/dredging (goal is 6 m +/- trench and fast) • Pipeline design and construction for offshore ice environment
Well Containment / Source Control	• Arctic well capping • Shallow water well capping • Ship-based well capping system • Enhanced shear and seal ram • Arctic well containment system • Same season relief well drilling

Other Topics	• Emergency handling/EER in Arctic • Minimizing environmental impacts of shipping • Marine sound reduction from stationary and moving vessels

Table 2. Multi-company listing of potential technology enhancement opportunities

Some items were nominated by a single company, but several were nominated by multiple companies as being high priority for industry technology advancement. Items that were nominated by multiple companies included:

1. Arctic well capping and containment;
2. Floating drilling rigs for operations in ice that are capable of safe, efficient disconnection and reconnection;
3. Ice management to support station-keeping for floating operations in ice;
4. Deep trenching capability for subsea pipelines.

It should be noted that these were identified as areas where future Arctic exploration and development in harsher conditions could benefit from enhancements of current technology versus areas where the current level of technology was deemed inadequate.

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