Paper #5-2

INDUSTRY NEEDS WITH RESPECT TO ICE MEASUREMENTS AND DATA COLLECTION

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)		
5-2	**Industry Needs with Respect to Ice Measurements and Data Collection**	
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SUMMARY

Objective of this technical paper is to outline the data needs of industry for design and operations.

Introduction

Offshore oil and gas activities in the North American Arctic require a sound knowledge of the ice regime as it will be needed to define: accessibility and operability in the region, the class of vessels required to operate in the region, the choice of platform for exploration and ultimately the concept selection for production and offtake strategy.

Typically, in early phases (seismic surveys and exploration drilling), the operating strategy is to avoid the ice, if possible, and to conduct operations during the open-water season. During later project phases (production and export) year-round operations require that more detail be known of the ice conditions and in particular, extreme conditions that will drive the design of concepts selected.

Preplanning and design

Ice data collection and analysis during preplanning and design will build on existing knowledge and focus on building as complete a picture as possible on the full spectrum of ice conditions. The various parameters, as described in this paper, are typically assembled into distributions and ranked, according to severity, such that light, normal, heavy and extreme conditions can be defined. Notionally, normal and heavy conditions are used to describe the range of expected operating conditions. Extreme conditions are typically defined as the limiting conditions that drive the design of vessels, structures and pipelines operating in the region of interest. Extreme conditions are often referred to in the context of annual probabilities of exceedance in the range of 10^{-2} to 10^{-4} as required to satisfy design codes (ISO 19906 for example).

Open water season
Activities such as seismic acquisition, exploratory drilling and early phase development will most often take place during the summer period when encounters with ice can be minimized.

Key Parameters:

Length of open water season
The number of days when pack ice is absent from the region or is present in concentrations less than the operational thresholds of the platform being operated.

Ice break-up date
The date on which the total pack ice concentration drops below 1/10 (or the operational threshold) and remains at that level for a period of time at a predefined operational radius around the site.

Ice freeze-up date
The date on which the pack ice concentration exceeds 1/10 (or the operational threshold) and remains at high concentrations for an extended period of time.

Ice incursions (frequency and duration)
Open water operations in the Chukchi and Beaufort Seas may be interrupted on occasion by the incursion of ice into the operating region from the nearby polar pack or residual seasonal ice. Statistics on the frequency (number per year), duration (days) and severity (total and multi-year ice concentrations and information on floe sizes, if available).

Methods and Technologies Utilized

Historic Ice Chart Archive
The U.S. National Ice Center (NIC) in conjunction with the National Snow and Ice Data Center (NSIDC) (1972 – present) and Canadian Ice Service (CIS) (1968 – present) maintain databases of digitized historical ice charts that generally serve as the basis for defining open water season. These data are also useful for quantifying long term (decadal) trends in season lengths as well as annual variability in ice conditions.

Satellite archive
Archived SAR and optical satellite data are often used to augment results from the ice chart analysis, in particular for characterizing ice conditions that may occur during ice incursions.

Local and/or accumulated knowledge
In some cases local knowledge may be called upon for better defining localized break-up processes, documenting the change in ice conditions with respect to time or identifying prior studies conducted in the region of interest that may already exist.

Occurrence of ice by type/thickness
Differentiating ice by type, in particular first year ice versus old ice, and thickness is important when “in ice” operations are expected to ensure that the operability of a system (platform, ice management fleet,

tankers, etc.) meets or exceeds the expected conditions during your planned operating window (e.g. open water only, late season operations during freeze-up or year round operations).

Key Parameters

Multi-year ice proportion

Ice thickness
Refers notionally to level ice thickness (deformed ice discussed below) and is typically defined in ice charts using terms such as: new ice (<10 cm), grey ice (10 – 15 cm), grey – white (15 – 30 cm), thin first year (30 – 70 cm), medium first year (70 – 120 cm), thick first year (>1.2 m).

Methods and Technology Utilized

Ice charts (current and historic)
Use of NIC and CIS ice chart archive to extract statistics on partial concentrations of ice by type.

Satellite archive
Satellite data is often used to augment the operational ice charts to extract additional statistics not readily available in the "egg code" descriptions on the ice chart. For example, when charts indicate "trace" amounts of multi-year ice, satellite data for the same period can be used to further characterize the occurrence.

Aerial surveillance
Aerial surveillance by trained ice observers, in support of field operations, will result in local, detailed ice charts close to the center of operations. Airborne SAR can also be collected and provides the ability to classify ice by type. EM and altimeter data may also be collected over narrow transects to provide a measure of ice thickness and infer ice type from the result. It is important to note that recently there has been a preference to move away from manned flight for safety reasons. Weather conditions will also limit the amount of flight time available.

In-situ measurements / field observations
In situ methods of ice-thickness measurement include drilling for direct measurement, photography of blocks turned during ship transit for graphic analysis and installation of thermistor chains for temperature-gradient measurement.

Freezing Degree-days (FDD)
The accumulation of FDD throughout the ice season can be used to predict thermodynamic ice growth.

Floe size distribution (by ice type)
Floe size, particularly in multi-year ice and sometimes thicker first year ice types, is an important parameter used in evaluating ice management effectiveness and ice load calculations.

Methods and Technology Utilized

Satellite archive
Resolution of archived SAR data is generally in the 100+ m. This allows for characterizing ice present in larger floes but is of limited use in characterizing sub 100 m floe sizes. Archived Landsat imagery has a resolution of 30 m.

Active satellite acquisition
High resolution SAR and optical data can be acquired to better evaluate floe sizes in the sub 100 m range.

Field observations
Aerial or ship based imaging are routinely collected by vessels operating in regions of interest.

Statistics on deformed ice

Key Parameters

Keel drafts
Maximum draft of a ridge feature and variation of draft along the length of the feature

Sail heights
Maximum and variation along length of feature

Ridge lengths
Length of deformed feature

Ridging intensity
The number of ridges encountered along a unit length or number of features in a given area.

State of consolidation
The strength of a deformed ice feature is primarily influenced by the thickness of the consolidated (refrozen) layer. In a first year feature the consolidated layer thickness will often be estimated as a multiple of the parent ice thickness (often in the range of 1.5 to 2 m). When a first year feature transitions into a second year or multiyear feature, the consolidated layer will progress through the depth of the feature until most of the void space is refrozen.

Grounded ice features
Grounded ice features present challenges to vessel traffic and pipeline design. If winter operations are required, potential for formation of grounded features and frequency at which they occur needs to be investigated. In the case of pipeline routing, grounded ice features that form above the buried pipe may impart stresses into the pipe that will need to be defined and designed to overcome. Grounded ice features that have potential to become freely floating while still intact can also present challenges.

Deformed multi-year features
Ridges and hummock fields

Methods and Technology Utilized

Satellite data acquisition.
High resolution optical imagery (low resolution data will likely miss all but extreme features (if detecting any) thus biasing the data – may be used for v. large ice islands) – ridging intensity (#/km or #/km^2 for example), ridge lengths, sail heights (based on shadow measurements), grounded ice features (from successive scenes and comparing to surround ice movement, or high sail heights suggesting rubble pile up on grounded feature), extreme ice feature (EIF) identification (EIFs are discussed later in this paper).

Aerial photography
Similar to satellites

Airborne LIDAR
Ridging intensity, sail heights

EM / GPR
Ice thickness and ridge thickness (up to ~15m). These sensors can be deployed by air, sled, snow machine. Beam width and altitude play a role in the resolution of keels.

Single point ice profiling sonar (IPS)paired with ADCP
Ridging intensity and keel drafts. Fixed mooring data is a good source of sampling of ice draft and movement at a single location. Research is also ongoing into discriminating first year ice features from multi-year ice features (Fissel et. al., 2014).

Submarine based upward looking sonar (SCICEX, declassified submarine cruises)
Provides data on keel drafts and ridging intensity along a survey transect, similar to an IPS/ADCP pairing. Data collected in a particular area is usually over a short time period and provides a "snap shot" view of the ice at one point during the season. Data collected is also limited to deeper waters (>100m) due to limitations of operating a submarine under ice cover in shallow waters. More recent advancements of AUVs have seen some data collected in this way.

Multi-beam sonar
Can produce an elevation map of the underside of the sea ice (ice canopy), giving a spatial view of the ice. Adds another dimension to understanding keel distributions (frequency and depth). May also be useful for understanding the behavior of oil under ice.

Ship transits
Ice observers logs can be used to extract ridging intensity and sail height data. Anecdotal data on the extent of consolidation may also be available.

Field surveys
Detailed topography of ridges (sails and keels), lengths, widths, extent of consolidation. These data are generally limited to the larger features.

Ice drift trajectories
Useful for a variety of engineering and planning activities: ice loading, ice management, EER, ice pressure occurrence to name a few. Data are also used in developing and validating ice drift models.

Methods and Technology Utilized

IPS/ADCP paired moorings

Satellite imagery (comparing successive scenes to track motion)

Drifter buoys

Shore based HF radar

Physical properties of ice
Field measurements are useful for tracking the progression of ice from first year to multiyear through measurement of salinity or brine volume. Relating ice strength to ice temperature and salinity is an important relationship.

Key Parameters

Salinity

Temperature

Compressive Strength

Flexural Strength

Technology / data

In-situ measurements (coring samples) of salinity, ice temperatures and other chemical biological content.

Bore-hole jacks – measure of (relative) ice strength at varying depths, temperature and salinity

Extreme ice features (EIF)
The phrase "extreme ice feature" in the Beaufort and Chukchi Seas generally refers to ice islands, ice island fragments, large multiyear hummock fields and large floebergs. They are features that will tend to govern the design of any fixed structure but the frequency at which they are observed in the region makes it difficult to fully characterize the risk they pose. It is also important to understand how a changing climate will impact the rate at which we may encounter these features in the coming decades. Ice island occurrence rates, for example, may increase during the period of deteriorating ice shelves (e.g. Ward Hunt) but may then reduce, or disappear, when ice shelf calving stabilizes or disappears.

Methods and Technology Utilized

Baseline monitoring and annual surveys
Utilizing cost effective satellite data, one can conduct annual surveys in source regions (NW coastline of Canadian Arctic Islands) and regions of interest (Beaufort and Chuckchi Seas) to build a statistically significant set of observations.

Ice gouging

Requirements for operations.

The type of operation (drilling, production, etc) and sensitivity of the operation to changing ice conditions will dictate the need for and type of "real-time" ice information to support said operations. For open water drilling the general requirement is to track potential ice incursions. The minimum ice feature size to be tracked will depend on vessel type, ice class and station keeping system. For extended season or year-round operations, the issue becomes more about detecting potentially unmanageable features. This adds the requirement for thickness and strength. The areal extent over which the real time observations are required will also depend on the operations. Typically any ice within 2-3 days drift from the facility will be monitored frequently (multiple times per day) while ice further afield will be updated on a daily basis.

Ice drift (actual and forecast)

Real time ice drift data and short-term pack ice drift forecasts (1-3 days) may be used to forecast when ice will reach an installation, or exceed specified concentration limits of the platform and may be used to delineate areas of sea ice upstream of a platform that should be managed into smaller floe sizes to reduce loads on a platform. Medium and long-term sea ice forecasts may be required when planning longer term activities and allocating resources.

Methods and Technology Utilized

Temporally spaced satellite images
With operations situated in the polar region and the increasing number of SAR satellites available and being planned for launch, it is becoming possible to acquire multiple scenes per day to track ice movement.

Aerial Surveillance
Visual or instrument based observations can provide up to date information on ice movement. This type of platform is susceptible to weather delays. With an increased emphasis on safety in industry and increased opportunities of data acquisition from satellites, manned aerial surveillance is not as favorable as it was in the past. Emerging unmanned flight technology (UAV, UAS) with smaller/lighter instrument payloads will need FAA approval for operations in civilian (Alaskan) airspace to fully exploit their capabilities for delivering safe, real-time surveillance in the field.

Drift buoys
Drift buoys can provide real time reporting of position, drift speed and direction.

Marine Surveillance
Visual observations and marine radar

Marine weather forecasts combined with up to date observed ice conditions to feed into ice drift forecast

Ice concentrations (total and partial)

Methods and Technology

Operational ice charts
Derived from: radar satellite data acquired within a few hours of chart being issued interpreted and prepared by qualified experts, local aerial reconnaissance and vessel reconnaissance

Ice thickness

Visual observations (ie – ice turning on edge as it passes along side of an icebreaker)

EM type sensors

New technologies – eg. Ice thickness radar as studied by CPC, JPL and Fugro or Newfoundland PRNL study

Ice pressure

Methods and Technology

In field observations – decreasing vessel performance, observed ridge building

Forecast models

Initiative to Standardize Data Collection: ISO 19067 – Physical environmental data for Arctic Design and Operations

The purpose of the ISO TC67 SC8 WG6 is to develop International Standard ISO 19067 "Physical environmental data for arctic (design) and operations". Reference to arctic and cold regions in this International Standard is deemed to include both the arctic and other cold regions that are subject to similar environmental conditions. The motivation behind this development is:

- Physical environmental data is one of the key premises for design and operations, in particular for areas with limited prior experience and harsh conditions.
- Current international standards (ISO 19901 and ISO 19906) do not cover arctic data.

The ISO 19067 aims to:

1. Identify all relevant data needed to ensure that arctic design and operations of the petroleum and natural gas industries in arctic and cold regions can be carried out in a safe manner.

2. Consolidate description of and requirements for collection, analysis and presentation of data for the arctic physical environment in one place.
3. Ensure that all data required for design and operations are given due consideration.
4. Ensure that all relevant data are properly collected, analysed and presented for end users.

Development and adaptation of the ISO 19067 will allow to:

- Increase safety of arctic operations.
- Simplify the process of planning, contracting and executing data collection programs and analysis.
- Align data collection programs and analysis for most efficient use of data for arctic operations.

In particular, ISO 19067:

- Will address data needed for both design and operations, i.e. for the entire project lifecycle. Operations include planning and actual execution.
- Can cover the onshore part of the scope if experts will be nominated (currently it is not the case).
- Will not repeat Regional Information as provided in ISO 19906.
- Will not repeat or improve ISO 19901-1 in the area of "non-Arctic" metocean data unless deemed necessary for Arctic applications.

The tentative table of contents of ISO 19067 is:

1. Relevant Parameters for Arctic design and operations
2. Water depth, tides and storm surges
3. Wind, Waves, Currents
4. Temperature
5. Visibility
6. Sea ice
7. Icebergs
8. Snow and ice accretion
9. Seabed considerations

10. Climate change
11. Other design and operational considerations

The following countries actively participate in the development of the ISO 19067: Norway, Canada, Russia, Netherlands, France, Italy and United Kingdom. The United States is currently not an active participant.

Target timeline for the development of the ISO 19067 is as follows:

- New Work Item Proposal: Q2 2013
- Working Draft: Q4 2014
- Committee Draft: Q2 2015
- Draft International Standard: Q4 2015
- Final Draft International Standard (for ballot): Q4 2016.