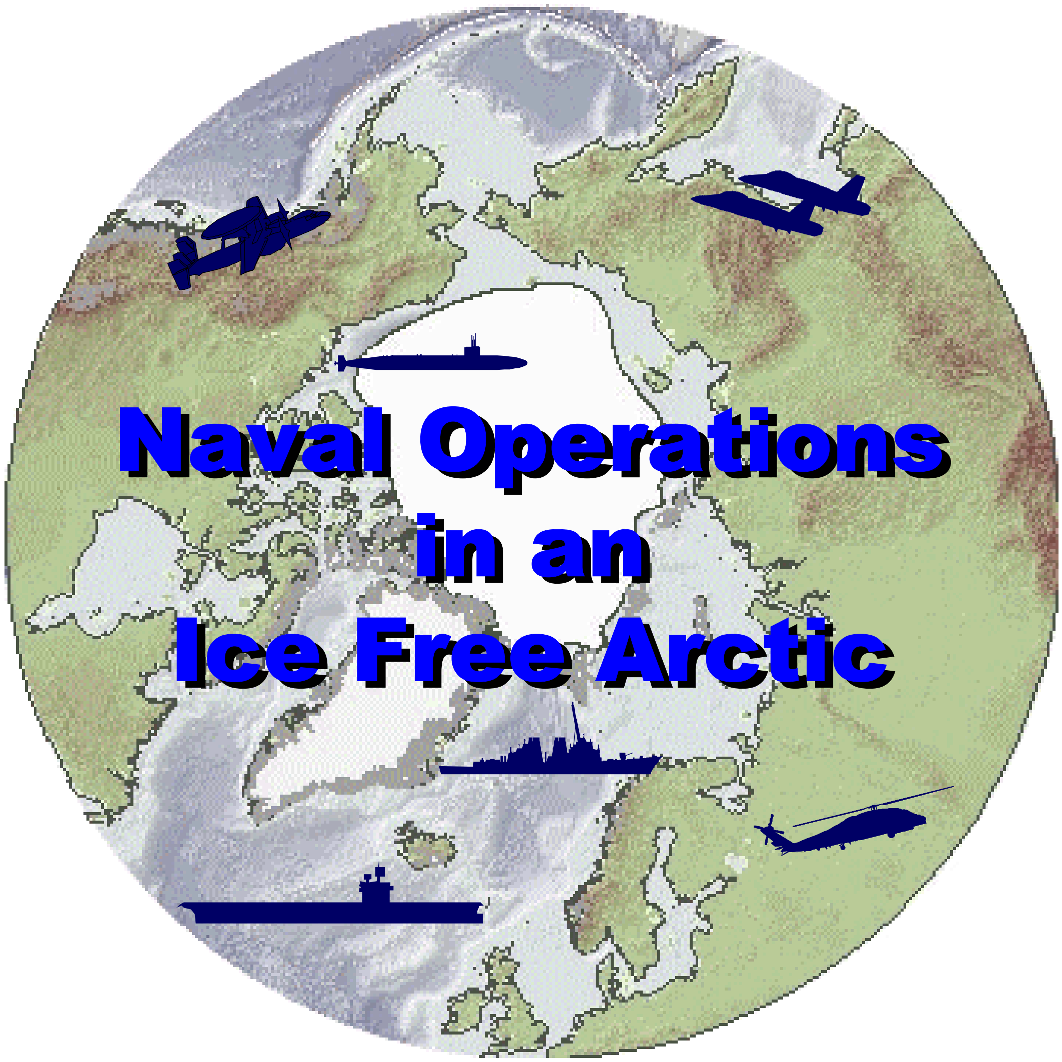

Naval Operations in an Ice-free Arctic Symposium

17-18 April 2001

<u>Final Report</u>

OFFICE OF NAVAL RESEARCH,
NAVAL ICE CENTER,
OCEANOGRAPHER OF THE NAVY,
AND THE ARCTIC RESEARCH COMMISSION

Prepared by:
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EXECUTIVE SUMMARY

On 17 and 18 April 2001 the Oceanographer of the Navy, the Office of Naval Research, the Arctic Research Commission, and the Naval Ice Center co-sponsored a symposium on Naval Operations in an ice-free Arctic. The purpose of the symposium was to evaluate potential U.S. naval operations, provide initial guidance in determining potential naval missions, and identify future naval requirements for operations in an ice-diminished Arctic.

There were fifty military and civilian participants representing the Navy staff, the fleet, program managers, U.S. Coast Guard operators, Arctic subject matter experts, Canadian military and civilian experts and officers from the Royal Navy. Their diligent efforts and willingness to share their insights concerning proposed naval operations in a challenging environment will be invaluable to the development of new concepts, strategies, policies, and programs.

Throughout the symposium, participants were required to assess potential needs against operationally driven requirements, identifying and documenting shortfalls and limitations and their impacts on operating in an ice-free Arctic (summer). Facilitator led discussions assisted in clarifying and refining identified strategies, operational impacts and required capabilities. While the conference focused on an ice-free Arctic, it should be noted that a more correct term is a navigable Arctic with ice infested waters. A summary of the salient points discussed during the symposium are addressed below:

Observed and Forecasted Arctic Change

- Submarine data reveal a 40% decrease in arctic sea ice volume. Satellite passive microwave data since the 1970s demonstrate a decrease in sea ice extent of 3% per decade. Model data suggest that a sea ice thickness decrease of 30% and an ice volume decrease between 15% and 40% by 2050.
- These trends translate into a possibility that the US Navy will be required to operate in the Arctic. The ice infested waters will restrict maneuverability and limit sensor and weapon employment. Harsh arctic conditions will cause super structure icing and limit personnel exposure times.

Overarching Issues

- The operational implications of an ice-free Arctic are neither well known nor well appreciated outside the oceanography community. Significant research and a subsequent education/awareness plan is required to inform all stakeholders including requirements officers, acquisition executives, and operators. This is essential to produce the level of naval service interest required to make informed decisions about future extended operations in the polar seas.
- No new naval missions are expected, but an increased scope of naval operations is likely in an ice-free Arctic. Ensuring access and stabilizing the global commons are the most overriding reasons for increased operations in the Arctic.

- New capabilities will be required in many aspects of air, space, surface and subsurface operations and support.

Operations

- The projected Ice-free Arctic environment will have a significant effect on the safety and effectiveness of naval operations. These effects will be most telling on fleet capability to conduct operations for extended periods of time. Although the current range of missions will likely apply, future systems must accommodate a significant modification to Required Operational Capabilities (ROC) and Projected Operational Environment (POE) for the conduct of extended polar operations. Modeling and prediction of the environment together with platform design modifications for the operating conditions will be important.
- Polar C4ISR infrastructure appears to be a limiting factor. A dedicated polar space support concept of operations is required to provide network centric warfare capability for polar operations. Ice reconnaissance should be a key component.
- Logistics support for extended operations appears to be a limiting factor. Both organic carrier on board delivery/vertical on board delivery (COD/VOD) capability and shore infrastructure must be enhanced to preserve current levels of underway replenishment (UNREP) capability and desired combat optempo.
- New sensor and weapon performance capability will be required to support both undersea warfare and strike warfare. New sensor capability will also be required to support levels of intelligence, surveillance and reconnaissance that leverage other warfare areas.
- Current environmental measurement and prediction, including Arctic weather and ice prediction, shallow water acoustic performance prediction, and dynamic ocean environmental changes is inadequate to support larger naval operations in the Arctic. A new focus on short range forecast accuracy for both weather and ice conditions is required. Reliance on Synthetic Aperature Radar (SAR) will increase and must be budgeted for purchase (OM&N).
- The Navy currently does not perform weapons testing and evaluation in the Arctic environment for either legacy or developing weapons systems.
- Current levels of cold weather/polar operations training are insufficient for the conduct of extended combat operations.
- Current charts and GPS support plans will not support extended polar operations. Both safe navigation and precision weapons delivery capability may be significantly constrained unless these shortfalls are addressed.
- Current icebreaker capability will not support extended polar operations by battlegroup sized forces. The US Navy has no ice breaking capability, and the US Coast Guard only has three polar icebreakers. Icebreakers should be considered an essential part of extended polar operations infrastructure.
- Constrained maneuvering room and rapidly changing weather conditions will require new tactics, techniques, and procedures that must be addressed in tailored polar training evaluations. Automated navigation systems certified for extreme weather and low visibility will be required.

- The expanded use of autonomous and automated vehicles will be required to provide real-time environmental data as well as other mission critical information. UAVs, USVs, and UsuVs, will play a critical role in accomplishing tasks that the environment prevents conventional manned platforms from completing.
- Aircraft maintenance will be a significant limiting factor to optempo unless the expected polar operating environment is included in design specifications for new systems, and unless enhanced diagnostics tools are available for enabling Smart Maintenance procedures. In particular, future low observable (LO) platforms could be significantly less effective unless cold weather procedures are adopted.

Strategy and Policy

- The most significant change envisioned is that forces will need to form into task groups (or forces) where the "task" defines the composition of the group. These tailored force packages would likely not look like the traditional carrier battlegroup. Additionally, traditional assets will likely be used in some non-traditional ways.
- Interoperability between allied, joint, and coalition forces must be improved in order to operate effectively in the region.
- Bilateral and multinational alliances will be essential to define all international boundaries (Economic Exclusion Zones and continental shelves) within the Arctic, resolve bilateral issues related to the United Nations Convention on Law of the Sea (UNCLOS) implementation in the Arctic, and provide forward basing capabilities and shorten logistic space and time lines.
- Potential threats that will emerge from greater access to the region must be better defined, both by country (or group such as a terrorist organization) and type.
- A concept of operations for maritime forces in the Arctic will be required, including the types of platforms and weapons systems needed for Arctic operations.
- Currently there is no single unified CINC with operational responsibility for the Arctic region. An Arctic area of national defense/naval requirements should be defined and assigned to a single CINC.

Programmatics

- Resources vs. Commitments – There may be other, more pressing challenges and commitments that will stretch forces and budgets and potentially preclude integrated operations in the Arctic.
- The Navy needs a uniformed advocate for RDT&E and S&T Arctic issues.
- The current S&T investment plan should be reviewed to ensure Future Naval Capabilities (FNCs) include technologies relevant to the ice-free Arctic.
- Arctic specific requirements should be incorporated into the formal requirements documentation system (CRDs, ORDs).
- A scrub of current Navy programs should be conducted to evaluate their relevance to future operations in an altered Arctic environment.

Conclusion

The timeline for a significantly navigable Arctic may extend decades into the future. However, the group noted that U.S. Naval operational missions in the Arctic, and related requirements, must be identified in the nearer term to ensure that the necessary operational capabilities exist when future Arctic missions do present themselves. Recognition and acknowledgement by DON/DOD of new threats presented by changes in the Arctic seascape is required to generate the necessary momentum to sustain an active interest in developing a strategic plan that includes prudent resourcing in future POM cycles to acquire the unique capabilities required to operate in the hostile environment of the Arctic.

The symposium's assessment should be considered as a preliminary evaluation of Ice-free Arctic operations. Constraints of scope, time and manpower limited this effort to a preliminary exploration. A detailed capabilities assessment is required to refine and expand on this initial work. For further information contact the Naval Ice Center. CDR Zdenka Willis, Commanding Officer or LCDR Doug Lamb, Science and Applied Technology Officer.

BACKGROUND

The Arctic ice cap is decreasing in thickness and area of coverage, a phenomena highlighted in recent news articles and a fact confirmed by an increasing body of data gathered by the National Ice Center (NIC)/Naval Ice Center (NAVICE) in Suitland, Maryland. Vessels and aircraft operating in the Arctic have reported diminished summer ice coverage and scientific models consistently suggest that seasonal sea lanes through the formerly ice-locked Arctic may appear as soon as 2015. It is postulated that summertime disappearance of the ice cap could be possible by 2050 if this trend continues. The implications for national security and by extension, the impact on naval operations, are significant.

An initial meeting was held at the NIC on 7 July 2000 with representatives from the NIC/NAVICE, the Oceanographer of the Navy (N096), Office of Naval Research (ONR), MEDEA, the Arctic Research Commission, and U.S. Coast Guard in which some of these national and strategic issues surrounding operations in an ice-free or ice-diminished Arctic was framed. Weapons system design and acquisition takes many years and the development of sound tactics, doctrine and policy take nearly as long to codify for those new systems. Because of the predicted changes to the Arctic environment in the near future, it was deemed prudent to take the first step in evaluating likely naval operations in that altered environment so that appropriate measures can be taken now to ensure that systems, operational concerns and policy concerns are addressed. From this initial meeting a recommendation to establish a forum to evaluate the naval implications of operating in an ice-free Arctic was made. The NAVICE was given the task of orchestrating such an event, and the firm of Whitney, Bradley and Brown, Inc. of Vienna, Virginia (WBB) was contracted to provide the design and facilitation. The result was the Naval Operations in an Ice-free Arctic Symposium, which was held at the Admiral Gooding Center at the Washington Navy Yard on April 17, and 18, 2001.

PURPOSE

Sponsored by the Oceanographer of the Navy, the Office of Naval Research, and the Arctic Research Commission, and hosted by the Naval Ice Center, the symposium was a first-ever attempt to bring together a diverse collection of operational representatives from the U.S. Navy and Coast Guard, as well as various members of the scientific community and Arctic subject matter experts. Canadian armed forces and research representatives, and officers from the Royal Navy also contributed their observations and ideas and added to the richness of the dialogue. The explicit purpose of the symposium as expressed by the Honorable George Newton, Chairman of the Arctic Research Commission, was to evaluate potential naval operations, provide initial guidance in determining potential naval missions, and identify future naval requirements for operations in an ice-diminished Arctic.

OBJECTIVES

Objectives of the symposium, which were used to design the event, select guest-speaker topics, tailor formal presentations and, and provide a benchmark for symposium success, are listed below:

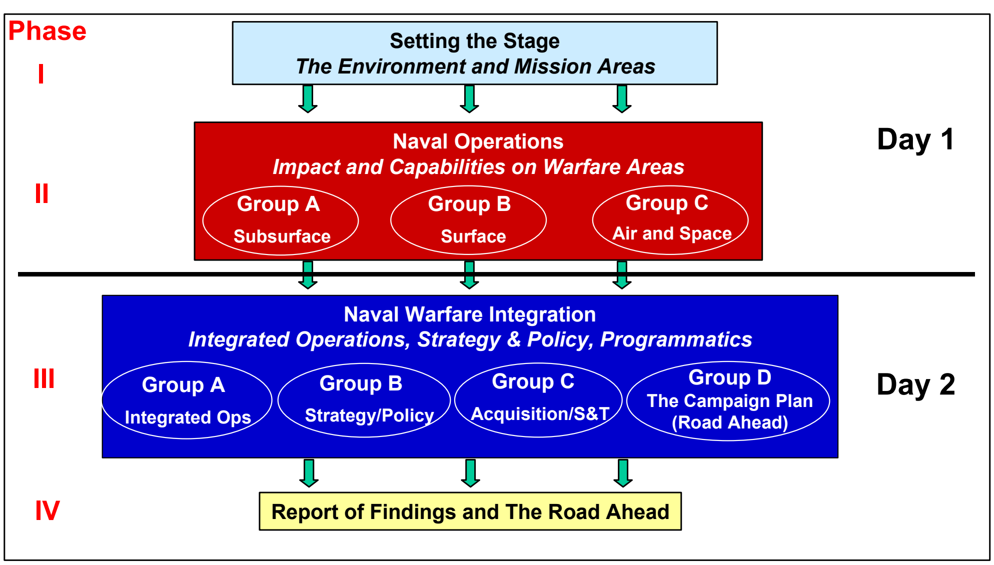
1. Identify potential requirements for future naval operations for an assumed projected retreat of the Arctic ice cover.
2. Examine potential impacts/effects on such operations and identify baseline capabilities for operating in this altered Arctic environment.
3. Explore the strategic and policy issues that could elicit a strategic (military) response due to the Arctic being ice-free during a portion of the year.
4. Establish the criteria and key elements for a continuum of heightened awareness and participation in examining operations in this altered Arctic environment.

PROCESS

The symposium involved fifty 0-5/0-6 level military and civilian participants representing the Navy staff, the Fleet, program managers, U.S. Coast Guard operators, Arctic subject matter experts, Canadian military and civilian experts and officers from the Royal Navy. Discussions were conducted at up to the SECRET releasable Canada/U.K. classification level.

Throughout the symposium, participants were required to assess their needs against operationally driven requirements, and identify and document shortfalls and limitations and their impact on operating in an ice-free Arctic. Facilitator led discussion sessions, and decision support software were used to assist in discussing, clarifying, and refining identified strategies, operational impacts and required capabilities.

The sequence of events for the symposium was as follows:

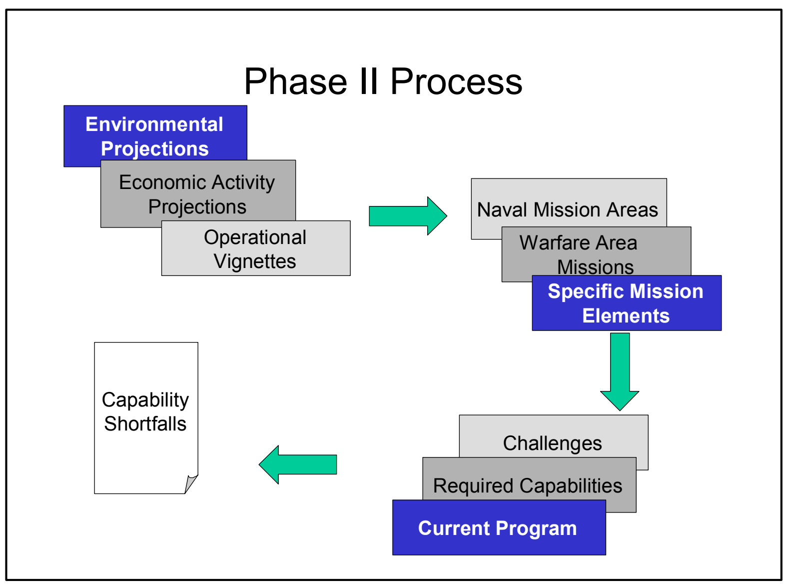


Phase I

Phase I was conducted in plenary session that began with welcoming and introductory briefings. RADM Dan Bowler, the Director of Warfare Integration and Assessment (N70) gave the keynote address. Dr. Gary Brass from the Arctic Research Commission presented a briefing that outlined the predictions for the Arctic environment in the 2015 timeframe. CAPT Jeffrey Garrett, CO of the USCGC Healy provided an operational perspective of current surface operations in the Arctic. LCDR Doug Lamb from NAVICE provided the participants with seven operational mission vignettes meant to stimulate discussion and provide a backdrop for consideration of issues in the breakout sessions that followed. These presentations established the context and framework for the remainder of the symposium.

Phase II

Participants were apportioned into one of three Interest Track Focus Groups, which were organized to ensure a blend of warfighter competencies and technical knowledge within each group appropriate to the warfare area being examined. Group A, the Aviation Group, addressed the implications of an Ice-free Arctic for selected air warfare, space and aviation support tasks, to include fixed wing, rotary wing and Unmanned Air Vehicles (UAVs). Group B, the Surface Group, emphasized issues concerning the operation of naval surface vessels in the altered Arctic environment. Group C, the Subsurface Group, focused on issues concerning the operation of submarines and undersea warfare in the altered Arctic environment. Using the information presented in Phase I, facilitators and pre-designated team leaders directed the groups through three sessions. These sessions included an examination of the operational roles and future missions likely to be undertaken in the Arctic; an identification and discussion of the unique operational challenges and threats presented in accomplishing those missions, and finally a determination of the capabilities needed to meet those challenges and current shortfalls. This phase concluded with a plenary session on the morning of day 2 in which each group briefed out their individual findings.



Phase III

Participants were re-formed into four new Interest Track Focus Groups. Group A, the Integrated Operations Group, was challenged with considering the operational implications and capabilities of operating in this new Arctic environment from a Battle

Group/Fleet presence perspective vice the platform specific viewpoint of Phase II. Group B, the Strategy and Policy Group addressed the naval strategy and policy to achieve operational presence and success in the Arctic. Group C, the Acquisition / Science & Technology Group, discussed appropriate methods for inserting some of the capabilities discussed in Phase II into the formal requirements and acquisition process. They also reviewed ideas for the integration of new technologies. Group D, the Campaign Plan Group, began to build the "Road Ahead" plan for continuing the dialogue of the symposium. This phase concluded with a plenary session in the afternoon of day 2 in which each group briefed out their individual findings.

Phase IV

The symposium concluded with a final plenary session that summarized the key initial symposium findings and reviewed options for furthering the discussion in the future.

A Control Group, consisting of NAVICE, ONR, Oceanographer of the Navy, Arctic Research Commission and WBB personnel, was responsible for the execution of the entire symposium.

PHASE I: INTRODUCTION

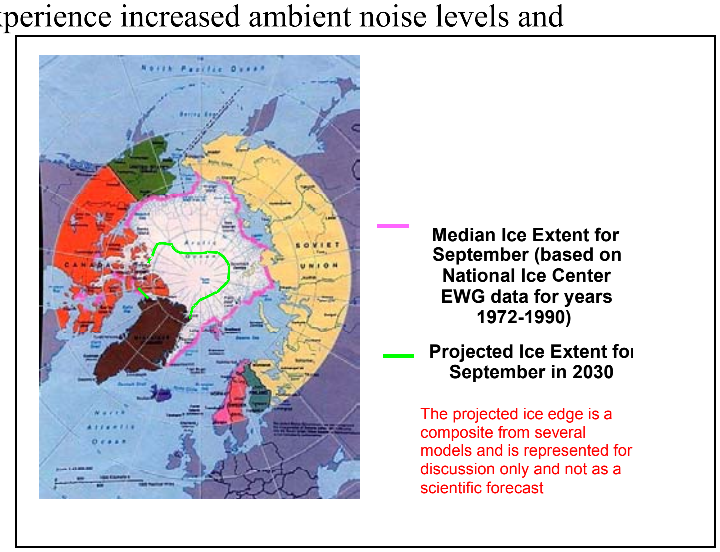
The keynote address, delivered by RADM Bowler, provided a perspective on the new OPNAV alignment and requirements process and highlighted the reasoning for the mission of the symposium. Furthermore, it challenged the participants to make their efforts count. The following synthesizes the keynote briefing:

- N7 will identify and champion the warfighting and training requirements necessary for the Navy to achieve its core competencies and meet naval and joint operational commitments.
- N70 will coordinate relevant analysis within and among the supporting warfare commands to ensure research and studies dollars are best contributing to a common capabilities-based effort. The objective is to prevent a disconnection between what the Fleet really needs and what OPNAV actually provides.

- This new process will eliminate the past process of providing a resource driven capability and replace it with one that is requirements driven. While the warfare sponsors must remain aware of resource limitations as they promote their programs, they must now plan to resource to the 100 percent validated requirement, and provide an assessment of risk should they be unable to do that.
- The work of this symposium is a part of this new process and will be on the leading edge of what N7 is trying to accomplish. The participants were challenged to identify and analyze as many of the issues associated with operating in the Arctic region as they could. This will contribute to identifying the "ground-truth" requirements for operating in the Arctic, from the tactical implications of how to operate in that harsh environment, to the kinds of ships, aircraft, submarines and other equipment to bring to the arena.
- The potential implications of an ice-diminished Arctic to the commercial shipping industry, as well as the operational implications for the military, are enormous.
- The symposium work will potentially lead to the development of the requirements for future programs that allow our forces to operate effectively in a new arena. Identifying these fundamental warfighting requirements is consistent with Chief of Naval Operations (CNO) directives. If the U.S. is to be effective in the Arctic from the start, we must begin now to identify the how, where, what, and why of Arctic and cold weather operations.

Dr. Gary Brass delivered a brief on the projected altered Arctic environment in the future. The major discussion items of this brief are contained in Appendix A. A summary of the salient points and predictions follows:

- Over the next 20 years, the volume of Arctic sea ice will further decrease approximately 40%, and the lateral extent of sea ice will be sharply reduced (at least 20%) in summer.
- Polar low-pressure systems will become more common and boundary layer forced convection will increase mixed (ice-water) precipitation. Cloudiness will increase, extending the summer cloudy regime through earlier onset and later decline. The likelihood of freezing mist and drizzle will increase, along with increased vessel and aircraft icing.
- Sonar operations in the Arctic will experience increased ambient noise levels and the surface duct will be diminished or lost. Ice keels will be shallower and less abundant and the area in which they can be expected to occur will be reduced. Active sonar detection of submarines will become more feasible.
- Within five years, the Northern Sea Route (NSR, a.k.a. the Northeast Passage) will be open to non-ice-strengthened vessels for at least two months each summer.



- Within 5-10 years, the Northwest Passage will be open to non-ice-strengthened vessels for at least one month each summer.
- Both Russia and Canada assert policies holding navigable straits in the NSR and Northwest Passage under their exclusive control. The United States differs in its interpretation of the status of these straits, with a potential for conflict.
- Within 5-10 years, the Sea of Okhotsk and the Sea of Japan could potentially remain ice-free throughout the year.

Seven operational mission vignettes were briefed to provide the stimulus for discussion and provide a backdrop for consideration of issues in the breakout sessions that followed. These vignettes, standard for all of the focus groups, spanned a large portion of today's naval roles and missions, including Freedom of Navigation (FONOPS), Carrier Battle Group (CVBG) Transit of the Northwest Passage as an opposed deployment option for Pacific conflict, disputed Economic Enforcement Zone operations (EEZ), Maritime Interception Operations (MIO), Control of Drug Trafficking, Coordinated Undersea Warfare Operations (USW), and Non-combatant Evacuation Operations (NEO). These are provided in Appendix B.

PHASE II: NAVAL OPERATIONS

AVIATION GROUP FINDINGS

General

Group membership is indicated at Appendix C. Specific group expertise included the following:

- Air wing operations (two former air wing commanders)
- Fleet operations (former fleet N3)
- Carrier operations (former CV executive officer)
- Other air capable ship operations (Canadian cutter commanding officer)
- Maritime patrol operations (VP pilot and TACCO)
- Maritime command and control (former TACAMO squadron commander)
- Helicopter operations (LAMPS pilot, HS pilot, helicopter logistics (HC) squadron commander)
- Aircraft test and evaluation (NATC helicopter test pilot)
- Oceanography (two staff oceanographers)
- Ice forecasting (Chief of Forecasting, Canadian Ice Service)
- Naval Intelligence (former NavEur N2)
- Space reconnaissance (one space agency representative)
- Several of the members were current aviation requirement officers from OPNAV (N7), providing the necessary current aviation program context for capabilities discussions (former N780D, current N780E and other aviation platform requirement officers).

Using the Phase I briefings as context, the group conducted three interactive evaluations. Space support factors were considered integral to each evaluation, but limitations in representation by Navy space warfare officers typically resulted in discussions and analysis dominated by an aviation focus.

Identifying Future Missions for Naval Aviation

The first evaluation was to identify the roles and missions likely for naval forces operating in the Ice-free Arctic in the 2015-2020 period. The group focused on factors unique to the projected Arctic environment, assuming that current projections for force structure, science and technology development and command and control initiatives currently included in the Navy program continue to fruition.

Basic Mission Areas: A full range of likely naval mission area activity was evident from the information briefings and operational vignettes with naval aviation playing key roles in the execution or support of each. Given the meteorological and operational assumptions provided, the tempo of future Arctic naval operations is expected to be significantly higher than what it is now. This finding has far reaching implications for force logistics supportability, which is projected to be air-intensive. Operations in the presence of significant ice and under the ice are indicated. Additionally, because operations may be both relatively large scale and conducted in extreme high latitudes, command and control requirements may significantly exceed those required for the present level of mostly submerged naval operations. The capacity of current space platforms to support the requisite level of command and control (C^2) activity is an important question that requires detailed examination.

The Future Threat: The assumed high level of economic and other transnational activity in the Ice-free Arctic implies increased opportunity for tension between the states contiguous to the region. These countries include Canada, Norway, Sweden, Russia, China and the United States. Potential adversarial activity was identified only for Russia, China and international criminal or terrorist elements.

Projected Mission Tasking: Based on the suppositions relating to required naval activity and potential adversary activities, a full range of aviation and space missions was indicated, including the following:

- Mine warfare
- Anti-air warfare
- Anti-surface warfare
- Amphibious operations
- Anti-submarine warfare
- Special warfare operations
- Strategic communications support
- Air and cruise missile strike operations
- Underway replenishment, including carrier on-board delivery (COD) and vertical on-board delivery (VOD) operations

- Airborne command and control, including intelligence, surveillance, reconnaissance and targeting
- In-flight refueling operations
- Support for fisheries protection and control
- Support for scientific and environmental exploration
- Search and rescue, and combat search and rescue

Key factors for mission execution: From this list, the group examined common mission elements likely to be affected by the projected environment. This inquiry included launch and recovery operations from aircraft carriers and other ships, Arctic air navigation, weapons systems employment, personnel performance, sustainment factors and command and control considerations. The group identified the following key mission elements and the challenges expected for each:

Launch and recovery:

- Effect of limited ship maneuverability during conditions of rapidly changing ice and weather conditions, given current restricted cross wind operating envelopes for both fixed wing and helicopters
- Limitations on safe aircraft handling during potentially extreme deck movement and icy deck surfaces
- Effect on shipboard recovery during rapidly changing poor visibility conditions
- Divert field availability in the expected operating areas
- Pre-launch de-icing requirements
- Optempo limitations due to current restrictive flight envelopes
- Low visibility effects on in-flight refueling ability and requirement

Navigation:

- Global Positioning Satellite (GPS) availability at high latitudes
- Visual and radar navigation effects from changing ice patterns and apparent changes in the ice encrusted beach line
- Availability and accuracy of land area charts for mission planning
- Effect of polar magnetic variation on backup navigation options (INS) for GPS-denied operations
- Suitability of present space based systems to provide accurate ice position updates to existing charts

Weapons systems employment:

- Availability and fidelity of sensor prediction models for the polar environment
- Ability to deploy sensors and weapons "through the ice"
- Air launched torpedo performance under the ice
- Tactical Land Attack Missile (TLAM) performance given potential GPS limitations and effects of predominant fog and snow conditions
- Other GPS-guided munitions accuracy given potential GPS limitations

- Effects of low visibility conditions on current EO/IR (electro optical / infra-red) terminal weapons guidance sensors
- Effect of sustained icing environment on performance of fixed wing, helo and Unmanned Air Vehicles (UAV) platforms
- Effect of sustained icing environment on performance of terminal weapons guidance apertures
- Performance of planned aircraft EO/IR sensors in low visibility and fog
- Suitability of current tactics and self-protection countermeasures during periods of extended daylight operations
- Suitability of current precision strike targeting systems during periods of extended surface obscuration
- Potential reduced aircraft survivability due to potentially lower durability of planned low observable (LO) treatments in sustained icing conditions

Personnel performance:
- Safety implications of operations during extended periods of extreme wind chill, darkness, low visibility, ship movement and ice covered decks
- Potential for increased manning to accommodate limited duration topside maintenance and handling operations during extended cold weather operations
- Adequacy of current topside work clothing for full range of nuclear, biological, chemical (NBC) protection and cold weather operations
- Adequacy of current personnel locator system to support rescue during periods of slick deck, reduced visibility and cold water operations

Sustainment:
- Suitability of current "Just in Time Delivery" concept for aircraft parts in area of poor flying weather and primitive regional support infrastructure
- Compatibility of current carrier (CV) deck multiples with limited elevator movement availability during prevailing heavy weather operations
- Effect on current reduced radar signature structures during extended operations in icing conditions
- Suitability of current reduced radar signature maintenance procedures during extended low temperature conditions
- Effect of extended low temperature conditions on key maintenance functions, e.g. flight control rigging embarked and ashore, aircraft recovery operations ashore and on the ice, and aircraft and support equipment battery performance
- Effect of restricted replenishment at sea, COD and VOD operations on projected desired optempo (fuel and weapons) and current AVCAL plans (parts)

- Effect on aircraft availability and sortie rates given anticipated decreased Mean Time Between Failure and increased Time to Repair for hydraulic systems affected by poor cold weather performance
- Suitability of current intake screens for engine maintenance during extreme icing conditions

Command and Control:

- Suitability of current C4ISR support when manned aircraft operations are restricted for extended periods by weather (could also apply to UAV)
- Suitability of present satellite reconnaissance and targeting sensors in periods of extended surface obscuration
- Suitability of present satellite constellation to support projected Network Centric Warfare (NCW) connectivity requirements
- Availability of spaced based imagery in extreme high latitudes
- Availability of present regional land-based weather stations to support short term forecasting during extended operations in conditions of rapidly changing flying weather
- Effects of Electro magnetic interference on line of sight and beyond line of sight communications system

<u>Identifying Required Operational Capabilities for Naval Aviation</u>

The next challenge for the group was to identify the operational challenges and geo-political threats the projected operating environment would pose to aviation and space operations. Both meteorological and polar latitude effects were considered. Full political and military cooperation between Canada and the United States was assumed.

After decomposing mission areas into specific missions and mission elements, the group used a facilitated groupware process to list required capabilities for naval aviation and space operations in the future Ice-free Arctic. The stimulus for this effort was a short question bank:

- *What are the capabilities needed to meet the challenges addressed in the earlier session?*
- *What changes in aviation and space platforms would these operations require?*
- *What changes in platform-specific tactics, operating procedures and support would be required?*

Although mindful of the specific nomenclature and format required by OPNAV in the requirements development process, the group was not constrained to make their input compatible with what will be required by future requirements officers who seek to adapt the symposium report to Planning, Programming, Budgeting System (PPBS) standards.

The following provides a summary of the projected aviation specific operational capabilities by mission element that will be required in the future to operate in the Arctic:

Launch and recovery:

- Automatic landing system capable of zero ceiling/zero visibility recovery for all aircraft (fixed wing, helo, UAV, UCAV) and all air-capable platforms
- Expanded cross-wind launch and recovery wind envelopes
- Special cold weather/icy surface, pitching deck aircraft handling systems
- Built in de-icing capability for flight decks and other critical path aircraft handling surfaces
- Capability for launch and recovery on the ice

Navigation:

- Navy high altitude synthetic aperture radar (SAR) capability for near real-time ice mapping
- Increased availability of polar land mass charts suitable for precision navigation and targeting support

Weapons systems and sensor employment:

- Additional in-flight de-icing capability for all aircraft platforms and sensors
- Ice penetration capability for acoustic sensors and USW weapons
- Enhanced target discrimination for under the ice weapons
- Increased options for active acoustic undersea sensors
- Low visibility sensors for helicopters
- Arctic capability for UAV and UCAV
- Validated polar RF and EO propagation models
- Terminal guidance for air launched weapons that is less dependent on EO/IR condition.

Personnel performance:

- Cold weather protective clothing for flight deck and air crew that is compatible with NBC Measures of Protection (MOP)
- Additional warming spaces to support weather deck/flight deck crew rotation
- Enhanced polar operating experience through more frequent and tailored polar training
- Enhanced adverse weather personnel location systems for search and rescue / combat search and rescue (SAR/CSAR)
- Enhanced remote maintenance troubleshooting support to permit smaller numbers of maintenance man-hours and reduce the required exposure of diagnostic and repair technician to adverse weather

Sustainment:

- Increased ice breaker support
- Increased cold-weather kit support in aviation ship AVCAL
- Improved capability for cold weather repair of LO materials

- Procedures/protective measures for reduced susceptibility to in-flight icing damage to LO materials and sensor apertures
- Expanded land based polar logistics infrastructure
- Health monitoring and failure prediction tools for Smart Maintenance of all aircraft types
- Increased fuel, weapons, parts and general stores capacity to offset likely restrictions to present UNREP capability
- Increased availability of long range, land-based tanker support
- Aircraft recovery equipment and concept of operations for emergency diverts onto the ice

Command and control:

- Long duration organic and non-organic sensors to support the battle group when flight operations are restricted
- Wideband 2-way communications systems capable of 24/7 polar operations for both C4I and tactical communications
- Organic modeling access for weather effects on space systems support
- Increased land site infrastructure to support near-term weather forecasting
- Improved ice prediction models
- C2 systems hardening for solar/auroral electromagnetic effects
- Assessment of threat systems performance in polar operating environment
- Enhanced EO/IR aircraft countermeasures systems for self-defense in extended daylight operations
- All weather sensor support for precision targeting
- Space-based synthetic aperture radar (or equivalent) for ice reconnaissance
- Assessment of national systems support availability during extended polar operations
- GPS adaptations for specifics of high latitude operations
- Validated geo-spatial models to support TLAM and other GPS guided munitions (GGMs)
- Offboard support concept of operations for low-visibility EMCON operations

Projecting Capability Shortfalls for Naval Aviation

Finally, after identifying the general operational capabilities required for accomplishing the specified missions in the projected environment, the group evaluation highlighted capabilities not supported by the current Navy program.

Aviation requirements officers provided feedback on the degree to which the current Navy program objective memorandum (POM 02/PR 03) includes the projected capabilities identified in the group's second examination. Key shortfalls include:

- Flight deck surfaces and aircraft handling equipment will not support desired polar aviation optempo
- Personnel protective clothing is not compatible with other combat MOP

- Present maintenance diagnostic and predictive tools lack the flexibility to offer the level of Smart Maintenance required for extended polar operations
- Present LO structures and maintenance procedures may not be compatible with extended combat demands in the polar environment
- Present squadron and aviation ship manpower may not be optimal for extended polar operations
- Forward logistics infrastructure is inadequate for support of extended polar operations
- Present organic logistics aircraft will have limited utility for UNREP if de-icing and anti-icing capabilities are not enhanced
- Aviation contribution to conducting Undersea Warfare will be constrained unless sensor and weapon delivery capability includes provisions for "through the ice" employment
- There is no provision for the U.S. controlled, wide-scan synthetic aperture radar capability necessary for ice reconnaissance
- Navy lacks the operational meteorological prediction capability necessary for safe naval aviation operations in the rapidly changing polar environment
- Plans for tasking, processing, exploitation and dissemination of national sensor data do not include the additional demands that would be placed on these assets in a navigable Arctic
- AVCAL requirements for polar operations must be evaluated in light of expected degradations to systems reliability
- Space based infrastructure to support Network Centric Warfare will be insufficient to support battle group operations
- Present amount of cold weather/polar operations training will be insufficient for the conduct of extended combat operations
- Polar operations will affect the current sanctuary emphasis for naval aviation employment, making aviation platforms increasingly vulnerable to hostile systems in extended daylight operations unless enhanced self-protection capability is provided
- U.S.–Canadian interoperability requires higher priority for combined force polar operations

SURFACE GROUP FINDINGS

General

Group membership is indicated at Appendix C. Specific group expertise included the following:

- Maritime Operations Planner from the Canadian Chief of Maritime Staff
- U.S. Navy OPNAV Requirements Officer
- Two current post-XO tour Surface warfare Officers
- Post-Command Surface Warfare Officer
- Head of Icebreaking Program, Canadian Coast Guard

- Chief of USCG Ice Operations Division
- Office of Naval Intelligence Analyst
- CINCPACFLT Senior Analyst
- Senior Scientists from the National Ice Center and Naval Atlantic METOC Center
- Naval Surface Warfare Center Senior Analyst

The group was tasked with providing a preliminary capability analysis for future surface operations in northern seas under significantly different meteorological conditions than those prevailing today. Based upon this analysis, future operational requirements recommendations were solicited from the group.

Using the Phase I briefings as context, the group conducted three interactive evaluations using decision support software. The objective of the first evaluation was to identify the roles and missions likely for naval forces operating in the Ice-free Arctic in the 2015-2020 period. The group focused on factors unique to the projected Arctic environment, assuming that projections for force structure, science and technology development and command and control initiatives currently included in the Navy program continue to fruition.

Next, the group identified the operational challenges and geo-political threats the projected operating environment would pose to surface operations. Both meteorological and polar latitude effects were considered. Full political and military cooperation between Canada and the United States was assumed.

Finally, the group identified the general operational capabilities required for accomplishing the specified missions in the projected environment. This evaluation included highlighting capabilities not supported by the current Navy program.

Identifying Surface Warfare Missions in an Ice-free Arctic

Basic Mission Areas: Based on the information briefings and operational vignettes, all current Naval missions have Arctic applications, in particular, ensuring access and "stabilizing the global commons." Surface operations will play a key role in the execution or support of each. Given the meteorological and operational assumptions provided, the tempo of future Arctic naval operations is expected to be significantly higher than presently. This has far reaching implications for force logistics supportability. Operations both in the presence of significant ice and under the ice are certain. Because operations may be both relatively large scale and conducted in extreme high latitudes, command and control requirements will likely exceed those necessary for the present level of mostly undersea operations. The capacity of current space platforms to support the requisite level of C^2 activity is an important question that requires detailed examination.

The Future Threat: The assumptions made relating to a high level of economic and other transnational activity in the Ice-free Arctic highlight areas of contention for the states contiguous to the region. Given the environmental constraints, major threats to surface forces will likely be from the air or undersea, with mines a particular concern.

Projected Mission Tasking: Based on the assessment of likely Arctic surface warfare missions and potential adversary operations, the following tasks were seen as the most likely to require surface support:

- Transit Escort
- Illegal Migrant Interdiction
- Ice Tracking
- Anti-Surface Warfare
- Mine Warfare
- Ballistic Missile Defense
- Air Defense
- Amphibious Operations
- Undersea Warfare
- Special Warfare Operations
- Land Attack
- Maritime Interdiction Operations
- SAR
- Fisheries Patrol
- Support for Scientific and Environmental Exploration

Key factors for mission execution: From this list, the group examined common mission elements likely to be affected by the projected environment. This inquiry included navigation, sensor employment, weapons employment, seakeeping, personnel factors, communications, underway replenishment, ship structural and engineering considerations, command and control, and tactics, techniques and procedures. The key challenges expected for each are indicated below.

Navigation:
- Lack of robust environmental prediction system for ice/ocean/atmosphere
- Inadequate charts (including bottom contour) and soundings
- Positional accuracy (differential between GPS and charted positions)
- Absence of navigation aids
- Refractive conditions
- Conversion of charts to WGS 84
- National Technical Means (NTM) satellite sensor design (Arctic use)
- Host country requirements for pilot/ice pilot/vessel escort
- Absence of celestial navigation back-up during summer months
- Ability of navigation system antennae to survive environment

Sensors:
- System survivability in environment (lubricants, etc.)
- Visibility (optical, laser, infra-red)

- Atmospheric ducting, acoustic ducting, ice noise
- Development and use of automated vehicles above and below the surface
- Phased array vs. rotating radar survivability
- Performance of USW (undersea warfare) sensors
- Availability of national space sensors in the Arctic regions
- Need for networked multi-regime sensors

Weapons:

- Warhead/seeker performance in harsh environment
- Cold weather tolerance (high moisture and icing conditions)
- GPS and topographical considerations for cruise missile employment
- Acoustic variability, including reverberation, spreading, topographic noise stripping, and ducting

Personnel:
- Safety implications of operations during extended periods of extreme wind chill, darkness, low visibility, small boat operations, ship movement and ice covered decks
- Isolation in a desolate environment (TV-DTS/Sailor phone and e-mail connectivity)
- Specialized cold weather training
- Instrument qualified ship navigation
- Medical requirements on smaller ships
- Rest and Relaxation (R&R) considerations
- Cognitive challenges associated with effects of prolonged darkness and cold

Seakeeping:
- Reserve buoyancy related to icing
- Risks associated with rapidly changing environmental conditions and shallow water (high seas/winds, icing)
- Small boat operations

Command and Control/Tactics, Techniques, Procedures:
- Suitability of current C4ISR support when manned aircraft operations are restricted for extended periods by weather (could also apply to UAVs)
- Suitability of present satellite reconnaissance and targeting sensors in periods of extended surface obscuration
- Availability of high-bit transmission satellites
- Suitability of present satellite constellation to support projected Network Centric Warfare connectivity requirements
- Availability of spaced based imagery in extreme high latitudes

- Applicability of littoral tactics in the Arctic region
- Joint operations considerations, including OPCON issues

Underway Replenishment and Logistics:

- Sea-state and exposure concerns
- Oiler availability
- Pollution regulations
- Visibility and sea-room
- Absence of shore-based infrastructure

Ship Structural and Engineering Considerations:

- Hull plate thickness, stringer separation, propeller construction, sea bay construction, and steering gear protection
- Double hull requirements
- Cold temperature effects on steel
- Rime ice build-up on topside surfaces
- Hull design considerations (ice-breaking vs. warship configuration)
- Hydraulic system temperature vulnerability
- Damage control system operability
- System shock resistance
- Cracking and loss of protective coatings and insulators

Identifying Required Surface Operations Capabilities

After identifying the mission elements and the key challenges associated with them, the group used a similar groupware process to list required capabilities for surface operations in the future Ice-free Arctic. The resultant capability requirements were developed in response to the following queries:

- *What are the capabilities needed to meet the challenges identified earlier?*
- *What changes in surface platforms would these operations require?*
- *What changes in platform-specific tactics, operating procedures and support would be required?*

Although mindful of the specific nomenclature and format required by OPNAV in the requirements development process, the group was not constrained to make their input compatible with what will be required by future requirements officers who seek to adapt the symposium report to PPBS standards.

The following provides a summary of the projected surface specific operational capabilities by mission element that will be required in the future to operate in the Arctic:

Navigation:

- Full GPS coverage including Arctic differential GPS
- More complete bathymetry

- Current and correct digital nautical charts and consistent datum
- Automatic Radar Plotting Aid (ARPA) plus radar
- NAVAID coverage (including hydrographic platforms capable of working in the Arctic environment)

Sensors:
- Increased use of automated sensors
- Radomes designed for extreme weather conditions
- Autonomous or unattended sensors for continuous data collection (e.g. through-ice acoustic buoys)
- Expanded use of networked sensors – Cooperative Engagement Capability (CEC)
- Integration of multi-spectral and multi-medium sensors for navigation
- All-weather, space-based radars (e.g. Canada RADARSAT 2 & Europe's ENVISAT)

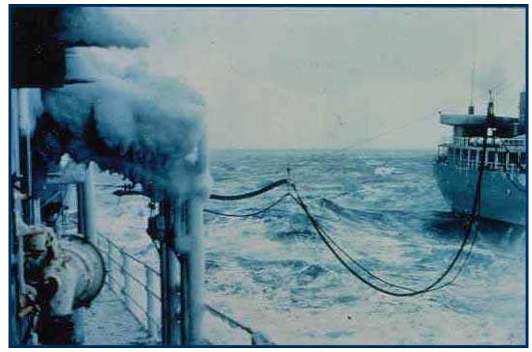
Weapons:
- Accurate topographical maps for cruise missile targeting and navigation
- Improved environmental prediction models
- Seeker/guidance improvements for Arctic operations
- Reload capability
- Development of microwave weapons (less susceptible to environmental conditions)

Seakeeping:
- Advanced ship-control systems
- Active stability control systems

Personnel:
- Cold weather protective clothing that is compatible with NBC Measures of Protection (MOP)
- Enhanced polar operating experience through more frequent and tailored polar training
- Cold weather damage control training
- Progressive watchstanding practices (e.g. Integrated Bridge System (IBS), Automatic Radar Plotting Aid (ARPA), etc.)

Command and Control/Tactics, Techniques, Procedures:
- Robust satellite communications system
- INMARSAT above 80 degrees north
- E-mail connectivity
- Large satellite bandwidth to handle increased automated data requirements associated with Network Centric Warfare
- Battle group integration of ice-breaker operations

- Revisions to tactics, techniques and procedures (TTP) related to Arctic warfare operations (including mine warfare, amphibious operations)
- Constrained waterway tactical doctrine
- PACFLT/LANTFLT Standard Operating Procedures (SOP) standardization
- Identification of Arctic peculiar intelligence needs



Underway Replenishment and Logistics:

- Ability to conduct stationary refueling
- Arctic-capable bulk fuel systems
- Internal UNREP capability (minimize exposure)

Ship Structural and Engineering Considerations:

- New Arctic ship design vs. modifications to existing platforms
- Increased JP-5 storage
- Arctic capable paints, insulators, and lubricants
- Small boat design
- Organic aviation capable of operating in that environment
- Re-engineering of cooling/feed systems (ice guards on seabays)

Projecting Capability Shortfalls for Naval Surface Forces

Surface requirements officers and subject matter experts provided feedback on the degree to which the current Navy program (POM 02/PR 03) includes the projected capabilities identified previously. Key shortfalls include:

- Inadequate charts of the Arctic region
- Navigation training
- Electronic navigation systems
- Sensor/Weapon/Communications performance testing
- Environmental monitoring and modeling (e.g. real time system performance prediction)
- Extreme cold weather design/modifications to existing and planned sensor and weapon systems
- Hull design and performance/stability monitoring systems
- Arctic capable damage control systems
- Ice-clearing systems for phased array radars
- Ice-breakers
- Wargaming in an Arctic scenario

SUBSURFACE GROUP FINDINGS

General

The fifteen members of the Subsurface Group represented various operational commands of the U.S. Submarine Force and scientific research laboratories, and included representatives of the Canadian Defense Forces and the Royal Navy. Many of the group had conducted under-ice or other Arctic-related operations. Group membership is indicated at Appendix C. Specific group expertise included the following:

- Director, Arctic Submarine Laboratory
- Chairman, Arctic Research Commission
- Head of Operations, Arctic Submarine Laboratory (ice pilot/Arctic expert)
- 7 former submarine commanding officers
- Canadian Department of National Defence Scientist
- Office of Naval Intelligence – SWORD
- HF sonar specialist
- Deputy Director, NAVOCEANO
- Manager Charting & Oceanography, CNO N23
- Unmanned underwater vehicles (UUV) requirements and programs officer
- ASN (I&E)
- Science Advisor to CNO N70

The Subsurface Group charter was to discuss the implications for submarine operations in an ice-free Arctic in the 2015-2020 timeframe and to identify any shortfalls in current submarine capabilities to conduct those operations.

Identifying Subsurface Warfare Missions in an Ice-free Arctic

After a brief introduction by each of the participants, the group first considered why U.S. submarines might be conducting operations in an ice-free Arctic region in the 2015-2020 timeframe. Using electronic brainstorming, a list of potential missions was generated and duplicate items were consolidated. These missions tended to stress the typical “war-fighting missions” that submarines have traditionally engaged in.

Projected Mission Tasking: Based on the above discussion, the group revisited their list of potential missions and expanded it to a total of twenty-three missions. The list was clarified and then prioritized based on a mission’s likelihood of being conducted. The prioritization was conducted by allowing each group member to prioritize the list independently and then using computer groupware to integrate results into a total group priority listing. Again, the group’s prioritization tended to stress more traditional submarine missions as indicated in the top five of the following missions:

- ISR
- Anti-Submarine Warfare (ASW)
- Interdiction/Protection of Sea Lines of Communication (SLOCs)

- Maintaining Arctic Expertise
- Forward Presence
- Anti-Surface Warfare (ASUW)
- Power Projection
- Testing New Hulls, Sensors & Other Systems
- Environmental Data Collection
- Strike Warfare
- Missile Defense
- Area Denial
- Special Warfare Operations
- Freedom of Navigation Operations
- Mine Warfare (includes Mining & Mine Counter Measures (MCM))
- Transfer of Forces
- UUV/UAV Operations
- Trade Sanction Enforcement
- Search & Rescue (SAR)
- Escort Duty
- Assist Civilian Law Enforcement Authorities
- Maritime Interdiction Operations (MIO)
- Non-Combatant Evacuation Operations (NEO)

<u>Projecting Capabilities and Shortfalls for Naval Subsurface Forces</u>

The group next identified and discussed the operational challenges for submarines to conduct the above missions in the Arctic in 2015-2020. The challenges were clarified and sorted into six categories: navigation, sensor employment, weapons employment, communications, submarine operability, and tactics.

The group's intended process was to discuss the capabilities needed to meet these challenges and then identify the shortfalls in existing and/or planned submarine capabilities. But because the submarine force has routinely conducted operations in the Arctic for decades, the group recognized that their *challenges*, in the majority of cases, directly equated to *submarine capability shortfalls* needed to conduct operations in the Arctic in 2015-2020. Accordingly, the group prioritized the shortfalls in each of the six categories based on importance to Arctic operations in the 2015-2020 timeframe. As a final step, the group prioritized the six shortfall categories as indicated below.

Challenges that affected submarine operations in most or all of the following categories, but those that the group did not translate to a specific capability shortfall included greater shipping densities, greater abundance of marine life (e.g., whales), currents due to freshwater runoff, low temperatures, and effects of weather (fog, waves, storm surges).

Although mindful of the specific nomenclature and format required by OPNAV in the requirements development process, the group was not constrained to make their input compatible with what will be required by future requirements officers who seek to adapt the symposium report to Program Planning and Budgeting System (PPBS) standards.

Submarine Operability Shortfalls: The group identified nineteen challenges to submarine operability, which encompassed the large area of submarine "seakeeping" and "housekeeping" issues. The list of challenges was easily translated to thirteen capability shortfalls that were then prioritized. The top five operability shortfalls are:

- Surfacing capability, including hardening, ballasting, & controlled deballasting
- Arctic ice pilot experience
- Ahead-looking sensors for ice keel and iceberg avoidance
- Environment measurement and prediction, including Arctic weather and ice prediction, shallow water acoustic performance prediction, and dynamic ocean environmental changes
- Maneuverability, including ice avoidance and quiet operations

The technique used to prioritize the shortfall areas showed no discernable difference in priority for other identified operability shortfalls including the following:

- Shallow water operations (especially in ice-covered areas)
- Lack of search and rescue (SAR) facilities
- Suitability of submarines and weapons for extended cold weather deployments
- Lack of operational documentation for the Arctic (e.g., Submarine Technical Oceanographic Reference Manual (STORMs))
- Submarine rescue in Arctic environment using external means and emergency escape capabilities
- Logistics in an austere and remote region

Submarine Weapons Employment Shortfalls: The group identified fifteen challenges to submarine weapons employment in the Arctic. These challenges easily translated to thirteen capability shortfalls that were then prioritized. The top five weapons shortfalls are:

- Lack of weapons testing and evaluations in the Arctic environment
- Surface launch capability of submarine launched missiles
- Ability to shoot missiles when ice is present overhead
- Shallow water effectiveness of torpedoes
- Environment measurement and prediction
  - Sound velocity profile (SVP)
  - Shallow water acoustic performance prediction
  - Acoustic noise prediction
  - Environmental database deficiencies

- Dynamic ocean environment changes will require continual updating of models & predictions

The technique used to prioritize the shortfall areas showed no discernable difference in priority for other identified shortfalls including the following:

- Weapon countermeasures
- Missile hatch ice clearance system
- Weapons accuracy at high latitudes
- Knowledge of ice coverage
- National sensor limitations
- Allied interoperability issues
- Weapon systems designed to operate in an icing environment

Submarine Sensor Employment Shortfalls: The group identified fifteen challenges to submarine sensor employment in the Arctic. These challenges translated to eight capability shortfalls that were then prioritized as follows:

- Ahead-looking ice-avoidance sensors for highly variable acoustic conditions
- Acoustic & environmental measurement & prediction, including both vertical and horizontal Sound Velocity Profiles (SVP), environmental databases, ambient noise measurement, and acoustic modeling
- Improved high latitude remote sensing capability (polar orbits that can see through clouds)
- More trained sensor operators for the Arctic acoustic environment
- Secure ice sonar to pick out ice keel, iceberg, bottom obstacle
- Ice-hardened sensors
- Variable depth towed array
- Ice-penetrating ESM/COMMS/NAV buoy

Submarine Navigation Shortfalls: The group discussed eleven challenges to submarine navigation in the Arctic. Nearly all of the challenges focused on the submarine's ability to obtain a fix while operating submerged in the Arctic. As a result, these challenges translated to only two capability shortfalls that were then prioritized. The two navigation shortfalls are:

- High latitude navigation system accuracy without external input
- Obtaining navigation fixes while submerged
  - This encompassed a number of challenges, including access to GPS, chart accuracy, ice-penetrating NAV buoy, Ring Laser Gyro Navigator (RLGN) versus Electro-Static Gyro Navigator (ESGN), and magnetic and gravitational anomalies

Submarine Communications Shortfalls: The group discussed nine challenges to submarine communications in the Arctic. The challenges translated to six capability shortfalls that were then prioritized as follows.

- High latitude, high speed communications

- Two-way communications from under ice
- Limited satellite communications
- Improved acoustic communications
- Improved allied interoperability
- Environment measurement and prediction and environmental database deficiencies

Submarine Tactics Shortfalls: The last category the group discussed had to do with the challenges to submarine tactics in the Arctic. Most of the challenges discussed mirrored those identified earlier for the other five categories. In fact, there was only one new challenge in this category and the group felt that it was a significant shortfall in submarine capability to perform Arctic missions in 2015-2020. That shortfall is the lack of tactical development for routine submarine operations in the Arctic.

PHASE III: NAVAL WARFARE INTEGRATION

INTEGRATED OPERATIONS GROUP FINDINGS

Introduction

The Integrated Operations group met to discuss issues related to integrated naval operations in the context of an Ice-free Arctic. Participating in the deliberations were warfighting representatives from the United States Navy, Royal Canadian Navy, Royal Navy, United States Coast Guard, and Canadian Coast Guard. Additionally, Arctic experts from the Naval Ice Center, Naval Warfare Development Command (NWDC), and the Arctic Submarine Laboratory provided valuable subject matter, environmental, and scientific expertise to the discussions.

Originally, the group was asked to consider several questions regarding the details of integrated operations. These included:

- Are there any additional missions or integrated naval operations that would be required in the Arctic in the 2015-2020 timeframe?
- What changes are required in CVBG, ARG, SAG tactics, techniques, and procedures associated with integrated operations in an Ice-free Arctic environment?
- What are the implications on OPTEMPO, logistic support, basing, etc?
- Are there any additional considerations that must be considered when planning for integrated naval operations in the Arctic environment?

Although each of the above questions were eventually addressed, the group found it more useful to approach integrated operations from the standpoint of missions, required changes to current operating procedures, and implications for current fleet operations.

Definition

The first issue encountered by the group was finding an acceptable definition for integrated operations. Traditionally (i.e. warm-water open-ocean operations), "integrated operations" comprise all of the functions of an aircraft carrier battlegroup and its support ships. Less frequently, integrated operations included the Amphibious Readiness Group and/or joint force elements.

Given the harsh environment in the Arctic region and the demands placed on units operating there, the group concluded that the traditional definition of integrated operations was inadequate. Due to the unique operating situation, integrated operations would need to include assets from every available resource capable of working in the Arctic. These would include military (including allied/coalition), Coast Guard, scientific, and commercial. The following agreed-upon definition encompasses the larger scope of integrated operations in an Ice-free Arctic:

> "Integrated Operations is two or more elements from a mixture of possibly Combined and/or Joint forces (including other national and civil elements) working towards a common objective."

Missions

Next, the group examined what, if any, new missions would require integrated operations in the region. By leveraging the assessment accomplished by the warfare specific working groups (surface, sub-surface, and aviation) the group concluded that there are no <u>unique new</u> missions. <u>How</u> those existing missions are executed however, would likely change dramatically, to include an increased emphasis on less traditional tasks. The more traditional warfare areas of air defense, undersea warfare, and strike warfare (among others) will remain important. However, missions such as Military Assistance to Civilian Communities (MACC), law enforcement, humanitarian aid, search and rescue, commercial convoy escort, scientific exploration and research, and environmental protection will gain added importance. These requirements will necessitate changes in how forces operate in an integrated fashion. The next section discusses those required changes.

Changes Required

The most significant change envisioned is that forces will necessarily form into task groups (or forces) where the "task" defines the composition of the group. These tailored force packages would likely not look like the traditional carrier battlegroup. The incorporation of both U.S. and allied icebreakers, mine counter measures vessels, and operating in the restricted waters in and around the ice will significantly alter the tactics, techniques, and procedures used by groups of ships, submarines, and aircraft.

Additionally, traditional assets will likely be used in some non-traditional ways. Submarines and aircraft will provide perhaps the best “environmental intelligence” of ice and weather conditions along the group’s intended track. For Surface Action Groups operating without an aircraft carrier or large deck amphibious ship, it will be imperative to have an organic helicopter capability to perform the same function. Ice reporting will be a new mission for helicopters and one that will be critical to the success of any group operating in the region.

Another very important change will be the expanded use of UAVs, USVs, and UUVs in the Arctic. These unmanned, relatively inexpensive vehicles can be used for a variety of missions when manned platforms would be grounded or forced to operate on the edge of the safety envelope. In addition to their usual reconnaissance role, unmanned vehicles could be used for weapons delivery platforms and as “pathfinders” to scout ice conditions.

The composition of carrier airwings will change to reflect the increased importance of rotary lift in the harsh Arctic environment. Unpredictable sea states may preclude routine alongside replenishments and force more vertical resupply. This may also be true in the case of amphibious operations where sea state may prevent landing craft operations. Airborne lift (either helicopter or tilt-rotor) will take on much of the load of transporting marines from ship to ice or shore.

Logistics and resupply will be accomplished differently than now. Longer range planning for refueling and replenishment will be required. Distances between ports with refueling capability, coupled with the unpredictability of weather that may preclude regular underway refueling, may force the fleet to develop a stationary refueling capability. Additionally, shore-based aircraft capable of resupply and able to operate in the Arctic environment will be needed to fly supplies into remote regions in the vicinity of transiting battlegroups where vertical lift can then transport the supplies to the ships. Improvement of logistical support facilities in friendly areas (e.g. Alaska, Canada, Greenland) will be important to sustained operations in the region.

Although the group tried to limit their discussions to issues at the macro level, there were some micro level details worth noting. In particular, command and control and communications considerations came to the forefront. The group consensus was that communications procedures would need to be modified for working with allied, scientific community, and commercial assets. Additionally, communications satellite coverage in the Arctic will require improvement to reduce an integrated group’s dependence on less reliable methods. Deck cycle times for aircraft undoubtedly will be affected by the severe environmental conditions. Increased reliance on instrument navigation systems like IBS and ARPA will necessitate more comprehensive training and proficiency in conducting navigation and piloting by instrument. These are just a few of the details that will need to be addressed in order to operate efficiently and safely in the Arctic. All of these considerations may cause important changes to the ROC/POE (Required Operational Capability / Projected Operational Environment) for some task force platforms.

Additional Considerations

Other issues not directly related to integrated operations will, nonetheless, have an important effect on a battlgroup's ability to conduct its mission. Devoting training time and exercises to the Arctic environment will be required to ensure that any forces participating in Arctic operations are prepared for the unique conditions encountered there. This training requirement has a testing component as well. The Navy will need to test ship and aircraft systems for their ability to operate in the Arctic setting. Increased presence in the Arctic due to the shrinking of the icecaps will strain already stretched naval resources even further. How these additional requirements are filled will effect the Navy's ability to conduct integrated operations in the region. Currently, there is no CINC with OPCON over the region. Furthermore, NATO has a standing regional planning group but no command structure in place. As operations in the area increase, the question of "who is CINCARCTIC?" will eventually become important.

Implications

After reviewing the various issues discussed above, the group concluded its work by outlining the five major implications that integrated operations in the Arctic region will have in the future.

- Resources vs. Commitments – There may be other more pressing challenges and commitments that will stretch forces and budgets and potentially preclude integrated operations in the Arctic
- Interoperability - Integrated interoperability between allied, joint, and coalition forces as well as scientific and commercial entities must be improved in order to operate effectively in the region
- Training, Exercises, and R&D – There must be increased emphasis on exercises, training, and R&D in the Arctic or, at least, sub-Arctic environment to ensure the efficacy of our forces operating there
- UUVs/UAVs/USVs – The increased use of unmanned vehicles for a variety of missions will increase the effectiveness of battlegroups while mitigating some of the risks to personnel
- Command Structure – The assignment of the Arctic to a CINC or the creation of a CINCARCTIC command organization will become increasingly important as operations in the area increase. Additionally, the inclusion of the Arctic in a detailed combined or national defense plan will also be required

STRATEGY & POLICY GROUP FINDINGS

This group consisted of twelve people, including representatives of the U.S. scientific community, U.S. Navy, U.S. Coast Guard, and Canadian Defense Forces, which met on the second morning of the symposium. The Strategy & Policy Group's charter was to (1) discuss the implications for maritime strategy and naval operational policy of an ice-free Arctic in the 2015-2020 timeframe and (2) identify potential changes that might be required in current strategy and policy.

There were several factors that made this a particularly qualified group to discuss strategy and policy issues. The group leader is a faculty member of the U.S. Naval War College Strategy & Policy Group. The senior Canadian officer on the group works for the Canadian Navy Directorate of Maritime Strategy. The group also had senior officers representing the U.S. Navy JAG and the Canada Defense JAG. Coast Guard representation included the Chief, Ice Operations Division, USCG Headquarters. Finally, the group also had appropriate representation from the naval warfare surface, subsurface, and air communities. Appendix C provides a detailed list of the Strategy & Policy Group participants.

Why Operate In the Arctic in 2015-2020?

The Strategy & Policy Group's process to achieve its charter used the Air, Surface, and Subsurface Group outputs on platform missions, challenges, capabilities, and shortfalls as a starting point for further discussion. The group had some concerns that these "platform-focused" groups had not ventured far enough "out of the box" in their consideration of potential missions in the Arctic, specifically in their prioritization of those missions. The group spent a considerable amount of time discussing "traditional" warfare areas versus more non-traditional areas of naval operations that they expected to occur in the Arctic. To better focus their discussion, they decided to identify their own reasons for why U.S. forces might operate in an ice-free Arctic and to use that information to develop their own list of prioritized potential naval missions for the Arctic in 2015-2020.

The group ultimately determined that there was only one overriding reason for increased operations in the Arctic in 2015-2020: increased access. Today, most of the Arctic is inaccessible for all or most of the year because of the ice coverage. As the icecap recedes and more of the Arctic becomes ice-free for a longer period each year, more and more vessels (and aircraft) from many nations will operate in the region. This increased accessibility to a variety of vessels will in turn require increased naval operations in the region for one of three purposes:

- Increased Economic Activity with increased associated environmental protection activities. This includes both access to the region to exploit the natural resources available and access through the region to save transit time.
- Increased Need for Law Enforcement of both domestic laws and international treaty obligations (e.g., United Nations Convention on Law of the Sea (UNCLOS), counter-drug operations, and migrant smuggling). Military forces will have unique capabilities, at least in the short term, to support civilian law enforcement authorities.
- Increased Security Needs resulting from the opportunities of potential adversaries to exploit the waters of the Arctic in ways that are counter to our national security.

National and Maritime Strategy Implications

Having identified why naval forces would operate in the Arctic in 2015-2020, the group next discussed what the implications of those operations were for U.S. national strategy. The group discussed the three goals of the ***National Security Strategy for a Global Age*** signed by the President in December 2000 and determined that these goals would not likely change as a result of changes in the Arctic region. The three goals are: (1) Enhance security with effective diplomacy and military forces ready to fight and win; (2) Bolster economic prosperity; and (3) Promote democracy abroad. The Canadian representatives from the group indicated that from their perspective, the Arctic would be an area in which economic development would be "uniquely" regulated because of its fragile environment.

The group next explored the implications of naval operations in the Arctic for the three elements of national strategy presented in the President's ***National Security Strategy for a Global Age*** and specifically the implications for maritime strategy. The group listed strategy changes they felt would be required for each element.

Shaping the Environment: The group felt very strongly that bilateral and multinational alliances would be a primary concern in shaping the environment. These alliances will be needed to define all international boundaries (Economic Exclusion Zones and continental shelves) within the Arctic, resolve bilateral issues related to United Nations Convention on the Law of the Sea (UNCLOS) implementation in the Arctic, and to provide forward basing capabilities and shorten logistic space and time lines. Issues involving commercial and military overflight of Arctic waters must also be addressed. From a military perspective, the group discussed the need to ensure interoperability with allies in the Arctic environment and the implications of greater access on implementation of our strategic deterrence policy.

Canada, in particular, has strong feelings about access to areas it considers its territorial waters and also has concerns for protecting the Arctic waters. In accordance with the provisions of UNLCOS, Canada has claimed sovereignty and jurisdiction over the Arctic Archipelago by drawing straight baselines around the outer edges of the archipelago. Under UNCLOS, all waters inward of the baseline are considered by Canada to be "internal waters". This has the practical effect of not permitting "transit passage" or "innocent passage" and requiring all vessels, aircraft and persons to comply with Canadian domestic law. The U.S. disputes this claim, particularly in regards to the status of the Northwest Passage. The U.S. claims the Northwest Passage is an "international strait" as defined under UNCLOS. This means "transit passage" is permitted and vessels, aircraft and persons do not necessarily have to comply with Canadian domestic law. The differences between Canada and the U.S. on these issues are significant and have a direct impact on the development of national and maritime strategies for naval operations in an ice-free Arctic. These differences must be resolved, probably through bilateral agreement(s).

Similarly, Russian maritime claims on the Northern Sea Route, if unresolved, could hamper operations - especially transit of forces. The group discussed the need to begin soon to work on developing and strengthening alliances for the region.

Responding to Threats and Crisis: Discussions of this element of the strategy determined there was a need to better define the potential threats that will ensue from greater access to the region in 2015-2020, both by country (or group, such as a terrorist organization) and type of threat. Additionally, a concept of operations for maritime forces in the Arctic will be required that includes the types of platforms and weapons systems needed for Arctic operations. The group also felt that the issue of commercial and military overflight needed to be addressed.

Preparing for an Uncertain Future: Discussions related to potential changes to this element of the strategy, as with “responding to threats and crisis,” emphasized the need to conduct greater analysis to identify and understand the military threats to operations in Arctic waters. Additionally, the group felt strong emphasis should be placed on relevant training and exercises for maritime forces to prepare them for operations in an Arctic climate anticipated to be continually changing. Other potential strategy changes discussed included the need to prepare for asymmetric threats, consider the impact of the “Revolution in Military Affairs (RMA)” and support greater Arctic research and development.

Naval Missions in the Arctic In 2015-2020

Using their discussion of changes to national and maritime strategy as a backdrop, the group next revisited the missions that each of the platform groups had briefed earlier that morning. The group brainstormed some additional missions and then prioritized their own list of twenty-four “most likely” naval missions. Their results were somewhat different than those briefed earlier by the Air, Surface and Subsurface Groups, and reflected the group’s strategic, rather than platform focus on potential naval missions in the Arctic. Their top five missions were:

- Law enforcement operations
- Ensure freedom of navigation
- Protection of natural resources
- Transit of forces
- Homeland defense

Rounding out the top ten missions were forward presence, intelligence, surveillance, and reconnaissance (ISR), scientific exploration, maintain/improve capability to operate in the Arctic, and uphold allied commitments. Initially, strategic deterrence had been ranked as one of the top ten missions, but after further discussion the group concluded that there was no value added to operating U.S. SSBNs in the Arctic given the current capabilities of the Trident missile system.

Naval Policy Implications

Finally, policy changes that would be required to better support Arctic operations in 2015-2020 were considered. The group identified three broad areas of potential policy change:

- Increase the emphasis on Arctic issues in our bilateral and multilateral engagement with Arctic nations. This area was a logical extension of the group's earlier discussion of the strategic need to focus heavily on bilateral and multinational alliances in the Arctic.
- Review the Unified Command Plan (UCP). Currently there is no single unified CINC with responsibility for the Arctic. An Arctic area of national defense/naval requirements should be defined and given to a single CINC.
- U.S. military and political strategy has to engage the American public to support a military presence in such an environmentally sensitive area as the Arctic. This engagement strategy should also include the native peoples of the Arctic area since changes in both the natural and political environments of the Arctic will affect their lives the most.

Critical Issues

The session concluded with a brief discussion of "critical issues" that the group identified as it explored potential implications of an ice-free Arctic for U.S. maritime strategy and policy. The group agreed that the only critical issue was that the U.S. Navy cannot "go it alone." The need for bilateral and multinational alliances for the Arctic region will be extremely important, especially with Canada and Russia.

ACQUISITION / SCIENCE & TECHNOLOGY (S&T) GROUP FINDINGS

On day two of the symposium a panel was formed to discuss the implications of the symposium findings to the Acquisition and S&T processes. Twelve symposium participants, with varied military and civilian expertise examined implications of military capability assessments in the Navy program of record. It should be noted there were relatively few participants with a practical background in actual Acquisition or S&T programming.

Methodology

The group planned to consider the following broad categories under the Acquisition and S&T heading:

- Implications for New Acquisition Programs
- RDT&E (Research, Development, Testing and Evaluation)
- S&T Plan Implications
- Effects on Program Schedules
- Requirements Process Implications
- Quadrennial Defense Review (QDR) Implications

Due to time limitations, only the first three were considered in any depth.

Implications for new acquisition programs

The group considered the following question:

"Based on the outputs of Phases II (capabilities evaluation), what are the implications for new programs and modifications to existing programs to support the projected naval operations in the Arctic in the 2015-2020 period?"

The following sub-topics were addressed to better characterize the issues for the Acquisition and S&T processes.

- Measurement and Modeling Predictions
- Requirements Documentation
- Weapons
- Communications
- Navigation
- Sensors
- Manpower
- Platform Design
- Space
- Air
- Surface
- Subsurface

Measurement and Modeling Predictions: Data collection in all forms was a topic of great interest. It was generally agreed that we must understand the environment and have the tools to predict environmental conditions in the air, on the surface and under the sea to operate in an ice-free Arctic. It was acknowledged that an "ice-free Arctic" should not be construed as a benign operating environment. As noted in day one briefings, an ice-free Arctic would give our forces greater latitude to operate, but at the same time present unique environmental challenges such as free floating ice, ice fog/mist and cold temperatures. These will remain as significant drivers when conducting operations.

Items that were of significant interest included:

- Data collection with a requirement for a tool for determining ocean temperature structure
- Development of ice/weather prediction models within a small scale area

- Acquiring an ACOUS (Arctic Climate Observations using Underwater Sound) capability for the Arctic
- Incorporating Arctic sensors into GCCS-M to ensure networking of vital information
- The need for a U.S. based Synthetic Aperature Radar (SAR)

Requirements Documentation: Discussion was wide ranging on this subject. The overriding consensus was that all future Operational Requirements Documents (ORDs) and Mission Needs Statements (MNSs) must have a section that addresses those systems that will be required to operate in the ice-free Arctic. Specifics included:

- Add Arctic operations to the DD-21 and LPD-17 MNS
- Review all planned NIMA and NSA tasking, process, exploitation and dissemination architectures
- Consider MNSs for two additional USCG icebreakers (this could be considered a requirement vice a need for a MNS)
- Ensure ORD for wide bandwidth communications includes anticipated requirement for continuous connectivity within the ice-free Arctic region

Weapons: An ice-free Arctic will offer new opportunities for science, commercial shipping and development--particularly oil and gas exploitation. The probability of a military presence and potential for hostile actions logically follows. This would include potential belligerents comprised of Non-Governmental Organizations (NGOs), terrorists and environmental activists. Weapons and weapon systems must function as designed in an ice-free Arctic environment. Highlights of the comments were:

- Need for the Mk-46 shallow water, under ice, torpedo that would be air and surface launched
- An Arctic Submarine Launched Ballistic Missile (SLBM) capability
- An Arctic Submarine Launched Cruise Missile (SLCM) capability
- Potential for Arctic capable mines
- Cold weather testing for all legacy and future weapons systems to include sea based missile systems
- Evaluation of terminal guidance sensor performance in icing intensive flight environments and in expected low visibility conditions

Communications: The subject of communications created some of the liveliest discussions of the day. It was widely recognized by all participants, both scientists and operators alike, that the Arctic will pose unique and daunting challenges to establishing and maintaining continuous and effective communications. High latitude operations are known for their challenges to maintaining communications on all of the frequency bands the military might use. As the military moves with increasing vigor towards a Network Centric Warfare architecture that inherently requires enormous amounts of bandwidth, and weapon systems that are linked forward and rearward to shooters, sensors, controllers and commanders, the need to consider and enable a robust Arctic communication capability is readily evident. Additionally, while the military will be a primary user of the communications environment, commercial uses will also balloon as the Arctic opens up. Items that were of prime importance to the group included:

- Establishment of a dedicated high latitude satellite communication capability
- Research to determine the unique requirements for communications in the northern region
- The need for a secure acoustic communications system between submarines and surface vessels
- Expanded use of unmanned platforms to relay communications data
- Requirement for an ice penetrating communications buoy

Navigation: Challenges to navigation are similarly significant and often times unique to the Arctic region. As the Arctic becomes more ice-free, significant changes in known landmarks will take place. The group felt that there would be challenges in the ability to navigate using the current standard – GPS. Among those items that were discussed and considered crucial:

- Improved, high resolution charting of the Arctic, with sufficient detail to enable passive navigation
- Improving GPS coverage in the high latitudes
- Improving non-GPS navigation methods at high latitudes
- Development of ice penetrating buoys not only for communications but also for navigational applications

Sensors: General discussion was focused on the anticipated requirement to be more able to reach out and "touch" the Arctic environment through either improved legacy sensor systems or the creation of new systems. A particularly important capability will be to know the weather, anticipate climatic changes, track ice flows, and track shipping in this "new" ocean. A major concern was the ability to navigate on the surface in free-floating ice and to be able to withstand potential minor scrapes with floating ice. Items of note included:

- High latitude SAR satellites
- Improved weather station monitoring
- Improved submarine-mounted environmental sensors
- Acquire and backfit, as required, forward looking/side scan fathometer
- Investigate sonar dome technology that would be able to withstand free floating ice encounters

Manpower: Recognizing the stressing environment that continuous operations within an ice-free Arctic will place on personnel, the group focused on two areas considered worthy of further development:

- Protective clothing, including both flight and deck hand exposure suits
- Personnel locator systems for rapid and precise location of personnel in the water

Platform Design: Development of systems that will effectively work within the ice-free Arctic will be crucial to our ability to operate. The extended operating time frames which are likely to be encountered will drive the design changes. These include:

- Structure and substructure capabilities to withstand ice accumulation
- Changes to ship habitability systems to accommodate cold temperatures
- Placement of warming stations for deck hands
- Force structure for an ice-free Arctic appears to be an additional design issue. Platform adaptations appropriate for polar operations will likely impose more significant cost and performance penalties than would be expected for operations in more benign environments. A specially configured "Arctic Squadron" (ships and aircraft) approach should be evaluated as a candidate baseline acquisition strategy.

Air: Air vehicles may require changes to operate effectively in an ice-free Arctic. Items that should be considered include:

- Developing an ice accretion model that will help predict probabilities of ice accumulation on deck and in the air
- Development of a reliable Automatic Landing System for all air vehicles on all decks. The ability of the Arctic to fall to zero visibility is well documented and is expected to worsen in a developing ice-free Arctic
- Improved in-flight deicing for air vehicles
- Ensuring all UAV/UCAV vehicles are built with operations in an ice-free Arctic in mind

Surface: As with the air model, stresses will be placed on surface vessels when operating in an ice-free Arctic. Items that should be considered include:

- Developing an ice accretion model that will help predict probabilities of ice accumulation on deck and superstructure surfaces
- Ice clearing capability for the AEGIS system
- Hull strengthening and screw protection in future design and all retrofit
- Development of a bow mounted sonar system not as susceptible to damage as the current "glass dome" design
- Development of deck non-skid material compatible with Arctic operations
- Ensure icing stability consideration is taken into account for DD21 class ships
- Procurement of a limited number of icebreaking DDG's for single ship operation in the Arctic

Subsurface: While submarines have operated under the Arctic ice cap for years, the advent of an ice-free Arctic will dramatically change the roles and operations of submarines. It can be envisioned that types and classes of submarines that have not operated in the Arctic will begin to do so. Items for consideration include:

- Hull strengthening and screw protection in ship design and retrofit
- Develop a Virginia Class submarine Arctic capability
- Develop a SSBN under ice capability

- Arctic Blow System installation on current 688I and future Virginia Class submarines

Implications for S&T

The discussion of RDT&E and S&T became rather homogeneous due to the limited time remaining. Considering the need for an energized RDT&E program in order to operate in an ice-free Arctic, the group acknowledged that the 2015 timeframe is just around the corner in terms of development and fielding of new systems. Research is the highest importance since so little is still known about long-term climatic change in the Arctic. Of particular concern was the lack of predictive models that will be vital when operating in an ice-free Arctic. In general these models do not exist, nor is there sufficient data with which to construct such models. Items of immediate concern include:

- Development and funding of Arctic research in order to create accurate predictive models
- High latitude GPS satellite system
- High latitude SAR system
- Open ocean ARGOS (Advanced Research and Global Observation Satellite) oceanographic floats are planned in the next few years. There are none planned for the Arctic and it would seem advisable to develop this program now for an ice-free Arctic.

Finally, the discussion focused on who should be the advocate for RDT&E and S&T. This is not just a military issue. An ice-free Arctic will encourage commerce and development and thus bring the civilian populace in greater concentration than ever before. The technologies that the military will require will probably have concurrent applications in the civilian world. National joint advocacy for Arctic issues will be a must to bring together diverse commercial, DoD, economic competitiveness and environmental protection interests. The Arctic Research Commission would most likely serve as an initial representative in any advocacy consideration. Across the military, major claimants should begin on a DoD scale. This will ensure a Joint representation of the issues. Within the Navy there needs to be a uniformed advocate for Arctic issues. Participants recommended that key stakeholders such as the CINCs, CNO, and N7 be briefed and consulted. There was general consensus on the need to incorporate Arctic requirements into the formal requirements documentation system (CRDs, ORDs). Additionally, a review of the current S&T investment plan to ensure Future Naval Capabilities (FNCs) include technologies relevant to the ice-free Arctic should be undertaken.

THE ROAD AHEAD

The timeline for a significantly navigable Arctic may extend decades into the future. However, the Road Ahead discussion group noted that U.S. Naval operational missions in the Arctic, and related requirements, must be identified in the nearer term to ensure that the necessary operational capabilities are resident when future Arctic missions do present themselves. Recognition and acknowledgement by DON/DOD of new threats presented by changes in the Arctic seascape are required to generate the necessary momentum to sustain an active interest in developing a strategic plan that includes prudent resourcing in future POM cycles to acquire the unique capabilities required to operate in the hostile environment of the Arctic. The Road Ahead group recommends a focus on short-term actions that will help build a momentum case inside of DON and DOD for preparing for eventual Arctic operations. The discussion group identified five major elements of an acquisition pathway that will lead to an Arctic-capable Navy:

- Climate Change Validation – Validate the eventuality of a future navigable Arctic and continue to update the climatological forecast as new information becomes available.

- Threat Assessment – Identify plausible future missions that would invite or require the Navy to operate in a navigable Arctic.

- National Maritime/Military Strategy – Incorporate Arctic Naval missions and operations into the development of National Maritime/Military Strategy.

- Requirements Assessment – Continue the early stage process of identifying the unique requirements that must be satisfied to successfully meet the operational challenges of Arctic operations.

- Acquire Capabilities – Acquire the assets required to operate in the Arctic.

Immediate actions can be undertaken to address task elements 1-3 above. Formal requirements assessment and acquisition planning are future activities contingent on further refinement of the environmental forecasts and the development of consequent Arctic centered operational missions. Additionally, the discussion group advised the development of a formal, directed communications plan intended to raise awareness of the evolving Arctic seascape and potential Naval related operational implications. The group also generated a set of more specific recommendations for immediate action:

Climate Change Validation

The Road Ahead group recognized that energizing DON interest in resourcing for operations related to future Arctic operations requires validation and ongoing refinement of the existing climatological forecasts. A significant body of literature already exists that outlines the positive probability of a navigable Arctic. The group suggests that climatological and environmental forecasts of Arctic change generated by the entire range of agencies and organizations (both U.S. and international) be compiled to establish independent scientific verification of the phenomenon. A composite set of reinforcing scientific conclusions will help validate the Arctic warming phenomenon in an unbiased fashion. The parallel forecasts made by various scientific and governmental organizations should be distilled into a technically accessible message that effectively describes the eventuality of a navigable Arctic. Updated research data should continue to be compiled by DON so that the evolving climatological profile of the Arctic can be routinely included in status briefs and reports presented to senior leadership. Current forecasts predict the window of significant navigable opportunities in the Arctic will open between the years 2020 and 2050. A more precise forecast that shifts the time window of probable occurrence to the left would present a more compelling argument to DOD/DON leadership for enhanced interest and subsequent planning activities related to the associated contingencies.

Threat Assessment and National Military Strategy

As the Arctic climate forecasts continue to mature, a parallel effort must but made to develop realistic threat and/or opportunity assessments that describe why and how the U.S. Navy would be called upon to operate in the Arctic. Naval Arctic missions could result as responses to national security challenges from hostile agents or from opportunities to exploit operational efficiencies offered by Arctic transit during peace-time. These missions and opportunities must be clearly and credibly identified. The Road Ahead discussion group recommends that the operational vignettes that provided the backdrop for discussion at the symposium be examined as a candidate set of potential Arctic missions. Selected vignettes could be augmented and refined so that they may be formally validated as feasible missions requiring U.S. Naval operations in a navigable Arctic.

Accepted missions could be then incorporated into the development of future National Maritime/Military Strategy. The Road Ahead discussion group suggests that N81 be encouraged to include validated Arctic operational scenarios in the IWARS process. Scenario wargames should also be conducted with the most plausible Arctic missions used as the situational overlay in game design. These Arctic centered wargames would reinforce mission plausibility, more fully define the operational requirements that extend beyond current capabilities, and also build awareness about a navigable Arctic inside of the operational community.

Raising Awareness

As the climatological forecasts of the Arctic are updated and made more accurate, a mechanism must be put into place to communicate the status of Arctic navigation to DON/DOD leadership and important stakeholders including other government agencies, Congress, allies, international agencies and commercial interests. Decision makers in the planning chain must be made aware of the significant probability the Arctic will become navigable within the strategic planning horizon. Additionally, the validated Arctic related threat assessments that result from climatological change must be broadly communicated to the U.S. national security apparatus.

The Road Ahead discussion group identified some key communications mechanisms and stakeholders to assist in advancing the concept of Naval operations in a future navigable Arctic. Arctic-unique requirements should be considered in the preparation of Integrated Priority List (IPL) and Component Commander Issue Papers (CCIP) published by the Unified and Component Commanders. It also suggests the development of a Navigable Arctic briefing package. The package should include visual representations that illustrate the observed changes in the Arctic seascape documented by remote sensors over the past two decades. Targeted stakeholder groups for this information package should include:

- Deputy Assistant Secretaries of the Navy (e.g., Undersea Warfare Steering Group)
- Operational Analysis Groups (OAG's) that span multiple mission areas
- Presentation at the plenary session of the Anti-Submarine Warfare Improvement Program (ASWIP)
- The Surface Warfare Development Group (SWDG)
- Navy Strategic Studies Group (NAVSSG)
- Presentation at the National Defense Industrial Association (NDIA) spring/fall symposia

The Road Ahead group also recommends the establishment of a knowledge management web based portal to share collective knowledge on relevant issues related to a changing Arctic (science, emerging threats, commerce, etc.)

Finally, the group also noted that the NAVICE office would eventually hand off oversight of the Arctic operations challenge. It recommends identifying one or more DON or Joint offices/organizations with adequate resources to take on the responsibility of managing the navigable Arctic initiative.

RECOMMENDATIONS

The efforts described above in the "Road Ahead" provide the rudiments of a campaign plan for addressing the many points raised during the symposium. Many other recommendations are found throughout this report within the individual group findings. While the conference focused on an ice-free Arctic, it should be noted that a more correct term is a navigable Artic. Further these recommendations can be applied even with the current Arctic environment.

- Realize that this symposium was a limited, initial attempt to address operational capabilities required for naval forces in the Arctic. While the results and output indicate that there are significant issues for the U.S. Navy, they are largely unfiltered. A formal methodology for addressing and evaluating these results, to include a detailed capabilities assessment, is required to refine this preliminary effort.

- OP 096 should increase both research and analysis of changing polar environmental conditions, and increase efforts to educate the warfighter on their implications. Consider polar operations as the focus in future Global War Games.
- Incorporate Arctic aspects into planned war games, Fleet Battle Experiment (FBE) or other exercises.
- N7 should incorporate Ice-free Arctic implications into a future polar mission capabilities assessment, with results incorporated into design specifications for forces expected to serve in the projected environment.
- N8 should incorporate Ice-free Arctic implications into future Integrated Warfare Architecture (IWAR) assessments and consider means for incorporating Arctic operations requirements into CRDs and ORDs.
- OPNAV should increase interaction between USN and Arctic littoral navies to leverage their Arctic operational experience.

APPENDIX A

THE ARCTIC OCEAN AND CLIMATE CHANGE: A SCENARIO FOR THE US NAVY

Preface

The United States Arctic Research Commission has asked a panel of experts to contribute their informed views of the changes to be expected in the Arctic Ocean in the mid to late Twenty First Century. The following is an edited compilation of these views produced to assist the Navy in considering the effects of climate change on their operations in and around the Arctic Ocean. Predictions are among the most hazardous activities scientists can undertake. Neither the individual contributors to this paper nor the Arctic Research Commission are prepared to assert that the scenarios discussed here are in any way guaranteed. On the other hand, they represent the honest expectations of the expert scientific community.

Summary

- The climate of the Arctic responds to short term variations on a roughly decadal scale known as the Arctic Oscillation (AO) and the North Atlantic Oscillation (NAO) which are closely coupled and may be features of the same phenomena observed in different regions. These decade long oscillations will continue to add variability to Arctic climate.

- Model studies indicate that temperatures in the Arctic region will increase by mid-century with summer temperature (Jun-Aug) increasing by 1-2 deg. C, autumn (Sep-Nov) by 7-8 deg. C, winter (Dec-Feb) by 8-9 deg. C and spring (Mar-May) by about 5 deg. C. Variations between model predictions are of the order of 1-2 deg. C in summer and 5-6 deg. C in winter.

- In the winter the entire Arctic Basin will be ice covered. Model studies suggest that summer ice extent will decrease by roughly 30% and ice volume by roughly 40%. A conservative consideration of model results suggests summer ice extent will decrease by only 15% and that ice volume will decrease by 40% leading to an increase in the relative abundance of thin, first-year ice.

- The Sea of Okhotsk and the Sea of Japan will remain ice-free throughout the year. The Russian coast and the Canadian Archipelago will be ice-free and open to navigation by non-ice-strengthened ships in summer.

- In the atmosphere, the Arctic boundary layer will be warmer and wetter. Cloudiness will increase, extending the summer cloudy regime into earlier onset and later decline. The likelihood of freezing mist and drizzle will increase as a result.

- Polar low-pressure systems will become more common and boundary layer forced convection will increase mixed phase (ice water) precipitation. Vessel and aircraft icing will be more common.

- Arctic warming will affect permafrost. The active (seasonally melted) layer will thicken and permafrost extent in the discontinuous permafrost region (along the borders of permafrost stability) will decrease. The inner and outer boundaries of the discontinuous zone will move to the North.

- Changes in timing and composition of river runoff will affect surface seawater. Increased sediment loads in spring runoff will spread out at sea affecting optical transparency.

- Soils will be drier and more susceptible to tundra fires. Local optical properties may change affecting energy balances and local weather.

- Declines in traffic on the Northern Sea Route (NSR) may continue in concert with Russian economic difficulties. But climate induced increases in trafficability in the NSR may cause increased use for Atlantic-Pacific transportation.

- Both Russia and Canada assert policies holding navigable straits in the NSR and the Northwest Passage under their exclusive control. The US differs in their interpretation of the status of these straits. As these routes become more available for international traffic, conflicts are likely to arise.

- Ships which can expect contact with even minor abundance of sea ice require increases in stiffeners and plate thickness in the affected region. Underwater installations including propellers, rudders, fin stabilizers, sea chests and especially thin skinned sonar installations must be redesigned for Arctic operations.

- Icing of ships and aircraft will require accommodation in ship/aircraft design and operation. Weapons systems will also be affected by icing conditions.

- Sonar operations in the Arctic will experience increased ambient noise levels and the surface duct will be diminished or lost. Ice keels will be shallower and less abundant and the area in which they can be expected to occur will be reduced. Active sonar detection of submarines will become more feasible.

- Russian economic levels have resulted in the reduction of the Russian Arctic's European population. Operation of the expensive and difficult logistics pipeline to Arctic communities may be further reduced leading to a return to subsistence living by native populations.

- The Russian Arctic is a storehouse of natural resources. Changing climate may spur an increase in exploitation of energy, mineral and forest resources, especially by or for the benefit of resource poor Asian nations.

- The response of marine resources to changing climate is very difficult to predict but northward migrations are likely. In particular, northward movement of Bering Sea species into the Beaufort/Chukchi Sea region north of Bering Strait is likely. Climate warming is likely to bring extensive fishing activity to the Arctic, particularly in the Barents Sea and Beaufort/Chukchi region where commercial operations have been minimal in the past. In addition, Bering Sea fishing opportunities will increase as sea ice cover begins later and ends sooner in the year.

- Ecological disruption due to climate induced separation of essential habitats can be expected with particular effects on marine mammal populations.

- The exploration, development, production and transportation of petroleum in the Arctic will expand with or without climate change as prices continue to rise due to the decreasing rate of discovery of reserves elsewhere. Climate warming and reduction in ice cover will facilitate and perhaps accelerate the process.

I. *Modeling recent and future changes in the Arctic Ocean environment*

Understanding of global and regional components of the earth's physical environment and its short-to-long term variability is one of the main requirements for realistic forecasts of weather and climate. Both global climate models and recent observations suggest that the Arctic Ocean is the region where an amplified response to global climate change might be taking place. In addition, changes in the Arctic Ocean and sea ice circulation are important to dispersion of nuclear contamination, biological productivity, and navigational forecasts.

Some models predict that the Arctic ice will significantly reduce in area and volume or possibly disappear during summer months as a result of increased greenhouse gases. The sea-ice albedo feedback is used to explain such a scenario. It implies that at warmer temperatures there will be less sea ice in the Arctic, which will allow an increased absorption of solar radiation due to decreased albedo, which will result in even warmer temperatures, and so on. The only immediate stabilizing effect (or negative feedback) comes from more rapid radiative cooling of the sea ice surface at warmer temperatures. On the other hand, other stabilizing effects are possible over longer times. For example, warmer air temperatures may lead to enhanced hydrological cycle and greater moisture convergence into the Arctic Ocean providing increased stratification in the upper ocean. Melting of large amounts of sea ice must also lead to dramatic increases in the fresh water flux out from the Arctic Ocean. The Great Salinity Anomaly of the late 1960s and 1970s is a good example of such an extreme event. An excess of fresh water exported from the Arctic into the Nordic and Labrador seas can alter or stop convection there, thus strongly affecting the formation of North Atlantic Deep Water and the global thermohaline circulation. A favorable scenario of Arctic climate change is one with a shorter-term (years to decades) natural variability superimposed on the long term warming trend due to greenhouse gas and other human-related emissions. Such a scenario is at least partly in agreement with time series of the Arctic Oscillation (AO) and the North Atlantic Oscillation (NAO), which are often used as indices of Arctic climate variability.

Over the last few decades, general circulation models (GCMs) have made significant advancements in representation of physical processes determining oceanic regimes and their variability and in use of modern high performance computers to solve complex oceanographic problems. Regional models of the Arctic Ocean have increased their spatial resolution by an order of magnitude, from the order of 100 km to 10 km, during the last decade. As a result, many important (and commonly neglected) small-scale bathymetric and geographic features have been included in such models. This allows more realistic representation of circulation and water mass and properties exchanges within the Arctic Ocean and its interactions with the global ocean. High model resolution also allows to better address new tactical requirements of operational ice prediction models, such as ice edge position, lead orientation, and sea ice thickness and concentration.

Improved regional models can successfully simulate recent regime shift in the sea ice and ocean circulation between the 1970s / 1980s and the early 1990s. Model results are in qualitative agreement with hydrographic measurements (suggesting recent changes) from the SCICEX submarine cruises and from icebreaker expeditions in the early 1990s. One of the conclusions from those models is that changes in the sea ice and ocean circulation and properties are at least partly in response to larger scale variability in the Northern Hemisphere weather patterns, such as AO or NAO. The shelf circulation and shelf-basin communication changes significantly between different regimes. The large scale drift of sea ice and its properties as well as the fresh water export from the Russian shelves and the Atlantic Water circulation within the Eurasian and Canadian Basins change in the early 1990s. Largest changes associated with this shift take place in the Eurasian and Makarov basins, over the Chukchi/Beaufort shelves and slopes and in the Canadian Archipelago. Information about spatial distribution of recent changes is crucial as it provides guidance for future field campaigns and potential future tactical operations, not available otherwise. Results from both observations and models indicate that a continuation of large scale measurements including repeated basin-wide hydrographic transects and focused process studies in the above mentioned regions should be of highest priority. This would allow evaluation of what may be an inherent cyclicity in Arctic climate and understanding and possibly more reliable predictions of future climate change in the Arctic Ocean.

II. *Climate Model Projections for the Mid-21st-Century Arctic*

The global climate models used by the Intergovernmental Panel on Climate Change (IPCC) project a stronger warming over the Arctic Ocean than over any other area of the Northern Hemisphere. However, the Arctic warming is highly seasonal, and it varies widely among the nine models used by the IPCC. Relative to the 1961-1990 baseline climatology, the central Arctic Ocean is projected to be warmer in the 2030-2060 period by 1-2 deg. C in summer (Jun-Aug), by 7-8 deg. C in autumn (Sep-Nov), by 8-9 deg. C in winter, and by approximately 5 deg. C in spring (Mar-May). The across-model standard deviation of the projected warming is nearly as large as the warming itself, ranging from 1-2 deg. C in the summer months to 5-6 deg. C in the winter months. The spatial pattern of warming over the subpolar seas and the Arctic Ocean is closely tied to the retreat of sea ice. Adjacent land areas are projected to warm more than the ocean areas in summer, but less than the ocean areas in winter.

Projected annual mean precipitation rates for 2030-2060 are generally higher than at present by about 1 cm per month, although the changes tend to be smaller in summer and larger in autumn. While there is a tendency for the largest precipitation changes to occur over the subArctic (50 deg.-70 deg. N), the spatial pattern of the projected change in precipitation is noisier than the pattern of temperature changes. The model-to-model scatter of precipitation change is even greater than the scatter of the temperature changes. Changes in evapotranspiration have yet to be evaluated.

Sea level pressure is projected to decrease by 1-2 mb over much of the Arctic. The largest projected decreases of pressure are in autumn and winter, and on the Eurasian side of the Arctic Ocean. While lower mean pressures may imply more cyclone activity, there has not yet been a systematic evaluation of daily model output to determine whether synoptic (i.e., storm) activity shows a significant increase in the climate scenarios. To our knowledge, there have been no evaluations of changes in cloudiness and radiative fluxes over the Arctic in the climate projections of global models.

Observed Climate Change in the Arctic: Records for 1961-1990 over the central Arctic Ocean, collected as part of the Russian "North Pole" drifting station program, show statistically-significant increases in temperature of 0.89 deg. C and 0.43 deg. C per decade for May and June, respectively. Temperature increases during this period are also significant for summer as a whole. A different analysis for the period 1979-1997, based on a combination of temperature data from the North Pole program, drifting buoys and land stations, reveals statistically significant trends over most of the Arctic Ocean in spring, locally exceeding 2.5 deg. C per decade. This is consistent with indications based on satellite passive microwave records of an earlier onset of spring melt over the sea ice cover and is likely also related to reductions in sea ice extent of about 3% per decade since 1979 as assessed from satellite records.

Temperature trends over the Arctic Ocean are broadly consistent those over land. Land records show pronounced warming from about 1970 onwards (mostly in winter and spring), over Siberia and Northwestern North America. The general pattern of warming is partly compensated by cooling trends over eastern Canada and the northern North Atlantic. It is important to note that in terms of 55-85 deg. N zonal averages, temperatures around 1970 were below average. Hence, what we've really seen is (in part) a recovery from anomalously cold conditions. It also appears that from 1920-1940, Arctic temperatures rose even more sharply than in the past several decades. On the other hand, the paleo-climate records suggests that today's Arctic temperatures are the highest of at least the past 400 years, possibly longer.

Since 1900, there has been a general increase in precipitation for the 55-85 deg. N latitude band, largest during autumn and winter. There have been pronounced recent increases in the past 40 years over northern Canada. Changes over the Arctic Ocean are unknown due to the paucity of data.

The general pattern of recent Arctic temperature change and (at least to some extent) changes in precipitation appear to be related to shifts in the large-scale atmospheric circulation, reflected in generally positive modes of the Arctic Oscillation (AO) and North Atlantic Oscillation (NAO). Changes in the AO and NAO are also reflected in observed decreases on sea level pressure over the central Arctic, as well as a tendency for more frequent high-latitude cyclone activity. Recent modeling experiments indicate that anthropogenic forcing may modulate the intensity and frequency of modes of variability such as the AO and NAO.

In summary, observed changes in temperature, precipitation and atmospheric circulation are broadly in accord with climate model projections. However, attribution of change is complicated by the wide scatter between projections from different models.

III. *A Scenario for Arctic Ocean Sea Ice in the Year 2050*

Predicting the future climate is risky. Climate is known to be variable on "all time scales." Trends that appear for, say, a decade may or may not persist into the next decade. Climate models make predictions based on an insufficient representation of important physics and chemistry. With this disclaimer, we construct a scenario for Arctic Ocean ice conditions in the year 2050. Our approach is this. We examined the changes predicted by four reputable global climate models. We compare these with extrapolated trends that have been observed over the last several decades. We then suggest a conservative interpretation of both types of evidence for what to expect by 2050. For both models and observations, we deal with end-of-summer minimal extent, volume and thickness which have decreased more than winter maximums.

Model evidence: Four global climate models predict reductions in ice extent and thickness in the Arctic. The models all show a continually decreasing ice cover. A middle-of-the-road estimate from models is that by 2050, ice extent will be down about 30% (to 3.5 million sq. km).

Models also predict a declining ice volume. A moderate model estimate is that by 2050, ice volume will decrease some 40% to 5400 cubic km. Models are not fully credible. When run to "predict" past observations, different models show different biases, so their projections into the future are of uncertain validity. But they all predict a diminishing ice cover.

The 4-model average decrease by 2050 is 30% in summer minimum ice extent and 40% in summer minimum ice volume.

Observational evidence: The 100-year historical record from ships and settlements going back to 1900 shows a decline in ice extent starting about 1950 and falling below pre-1950 minima after about 1975. This decline is better documented by satellites during the last 20 years. The rate of decline is about 3% per decade.

The record of submarine ice draft data shows that the ice draft at the end of summer has declined by about 40% over a time interval of about thirty-five years, or about 11% per decade. There are few data from the intervening years, so it is difficult to assess "normal" climatic variability, even over the 35 years of submarine data, much less over a longer period.

Future scenario: A conservative scenario is that by 2050 the observed trend will reduce summer minimum ice extent by 15%; this is an extrapolation of the satellite observations which are quite reliable and are not contradicted by climate model forecasts. For volume and thickness, a conservative estimate is obtained by extrapolating model forecasts that are not contradicted by sparse observations. By 2050, the end-of-summer volume can be expected to be down by about 40%, of which about 15% would be due to decreased extent and the remaining 25% would be seen in an end-of-summer thickness reduced by 25% to about 1.5 m.

What does this mean in terms of various regions of the Arctic? During winter, the central Arctic and all peripheral seas including the Greenland Sea, Bering Sea, and Gulf of St. Lawrence will continue to have significant ice cover. Extent and, in most areas, ice thickness will be reduced. The Sea of Okhotsk and Sea of Japan will be ice-free for the entire year. In late summer, the entire Russian coast will be ice-free, allowing navigation through the Barents, Kara, Laptev and East Siberian Seas along the entire Northern Sea Route. The Northwest Passage through the Canadian Archipelago and along the coast of Alaska will be ice-free and navigable every summer by non-icebreaking ships. Ice will be present all year along the eastern and northern coasts of Greenland. Ice will also remain throughout the summer within and adjacent to the northern Canadian Archipelago. Significant ice will remain in the central Arctic Ocean, though the mean thickness will be about 1.5 m, and it will be less compact.

IV. *Changes in Weather Patterns in the Arctic under Assumed Global Warming*

Recent scenarios of climate change in the Arctic produced by state-of-the-art global climate models (GCMs) suggest that the Arctic/sub-Arctic will see substantial warming over the current state. The cold season in particular in many models sees a 6-8 deg. C warming over the ocean, with a less dramatic change in terrestrial regions. Associated with many of these is the prediction of an ice-free or nearly ice-free ocean state, at least seasonally if not throughout the entire year. It is certainly plausible that the marginal ice zone will migrate considerably poleward throughout the year in a warmer climate.

A discussion of how weather (vs. the cumulative effects of weather we call climate) is difficult to predict based on a broadly defined seasonal mean state. That being the case, it *is* possible to speculate on how weather as currently understood might be impacted by changes in a background "mean" state. Given the nature of Naval operations, this discussion will focus on marine weather.

A more ice-free ocean and/or longer ice-free season would clearly lead to much greater latent and sensible surface heat fluxes into the Arctic boundary layer (BL). A warmer and moister BL would most likely produce greater BL cloudiness, perhaps extending the current observed summer cloud fractional coverage maximum on both ends of the warm season. This would result in poorer surface visibility for a greater portion of the year, and in the winter could also increase the likelihood of freezing mist and drizzle

Since the temperature of the continental Arctic away from the coastal regions will continue to be modulated largely by radiative energy loss (assuming that seasonal snow cover still pertains), the temperature differences between land and ocean will likely be more pronounced, creating more localized baroclinicity to the coastal regions in the cold season. Given the ingredients of greater baroclinicity, a BL environment with significantly enriched latent energy, and the strong planetary vorticity implicit in the high latitude setting, it seems reasonable for Arctic cyclogenesis of so-called polar lows to be more common than currently observed during much of the year.

BL-forced convection would be more likely with these systems, much of it being from mixed-phase clouds, particularly in the warm sector with higher precipitation rates and more localized precipitation. Vessel icing could be a prime concern, especially in the vicinity of cold Arctic continental air masses where over-running is likely to occur. With the likelihood of more mixed-phase precipitation through a much greater portion of the year, the threat of aircraft icing would also be greatly enhanced.

Under the ice-free ocean scenario, the equator-to-pole temperature gradient will be diminished over current values perhaps weakening the magnitude of the polar jet. However, as stated above, the increased heterogeneity of surface heating in the lower troposphere may act as more of an "anchor" to the long wave pattern producing preferred regions of cyclonic storm activity and cyclogenesis.

Finally, the current tendency of poleward-propagating extratropical cyclones to decay in cooler subArctic waters (for example as currently happens in the Aleutians/Bering Sea and the "coffin corner" of the Gulf of Alaska near Yakutat) might be diminished, causing stronger and more frequent activity in the subArctic coastal margins.

V. *The Response of Arctic Hydrological Processes to a Changing Climate*

The effects of a warming climate on the terrestrial regions of the Arctic are already apparent; some subsequent impacts to the hydrologic system are also evident. It is expected that the effects and consequences of a warming climate will become even more pronounced within the next 10 to 50 years, at first primarily through atmospheric and near-surface processes and later through geomorphological evolution and hydrological responses to permafrost degradation. These changes will affect the Naval Mission in the Arctic Basin through impacts on regional weather, oceanic circulation patterns, salinity and temperature gradients, sea ice formation, and water properties. It is difficult to quantify the long-term effects of a changing climate, but it is possible to envision many of the changes that we should expect.

The broadest impacts to the terrestrial Arctic regions will result through consequent effects of changing permafrost structure and extent. As the climate differentially warms in summer and winter, the permafrost will become warmer, and the active layer (the layer of soil above the permafrost that annually experiences freeze and thaw) will become thicker. These simple structural changes will affect every aspect of the surface water and energy balances. As the active layer thickens, there is greater storage capacity for soil moisture, and greater lags and decays are introduced into the hydrologic response times to summer precipitation events. When the frozen ground is very close to the surface, the stream and river discharge peaks are higher and the baseflow (low discharge rates that occur in rivers between storms or in winter) is lower. As the active layer thickens and the moisture storage capacity increases, the lag time of runoff also increases. This has significant impacts on large and small scales. The timing of stream runoff will change, reducing the percentage of continental runoff released during the summer and increasing the proportion of winter runoff. This is already becoming evident in Siberian Rivers. As permafrost becomes thinner and is reduced in spatial extent, the proportions of groundwater in stream runoff will increase as the proportion of surface runoff decreases increasing river alkalinity and electrical conductivity. This could impact mixing of fresh and saline waters, formation of the halocline, and seawater chemistry.

Other important impacts will occur due to changing basin geomorphology. Currently the drainage networks in Arctic watersheds are quite immature as compared to the more well-developed stream networks of temperate regions. These stream channels are essentially frozen in place because the major flood events (predominantly snowmelt) occur when the soils and streambeds are frozen solid. As the active layer becomes thicker, there will be significantly increased sediment loads delivered to the ocean. Presently, the winter ice cover on the smaller rivers and streams (<~10,000 km^2) are completely frozen from the bed to the surface when spring melt is initiated. However, in lower sections of the rivers there are places where the channel is deep enough to prevent complete winter freezing. Break-up of the rivers differs dramatically in these places where the ice is not frozen fast to the bottom. Huge ice chunks are lifted by the flowing water, chewing up channels bottoms and sides and introducing massive sediments to the spring runoff. Such increased sediment loads may affect coastal water properties with consequent impacts on sound transmission, estuary productivity, contaminant transport, and a host of other marine processes.

As the air temperatures become higher, the active layer becomes thicker. Even if precipitation increases, we have reason to believe the surface soils will become drier. The Arctic is described in many basic geography textbooks as a desert due to the low precipitation rates; however, it is a desert that frequently looks like a bog as the ice-rich permafrost near the surface prevents infiltration of surface soil moisture to deeper groundwater. If the active layer thickens to the point where a talik (an unfrozen layer above the permafrost, but below the seasonally frozen soil) forms, then soils may drain internally throughout the winter leaving the surface significantly drier. As the surface soils dry, the feedbacks to local and regional climate will change dramatically, with particular emphasis upon sensible and latent heat flux. Drier soils will also influence the rate and intensity of tundra fires, providing more positive feedback mechanisms by creating darker surfaces that absorb more solar radiation and through releasing large quantities of carbon from peat soils. This may impact recycling of precipitation, military capabilities to predict weather and may indeed increase variability of many processes and variables, including convective storms.

These changes in the hydrological regime should improve productivity of terrestrial aquatic and marine ecosystems. Increases in winter baseflow will markedly improve winter habitat in streams and rivers for freshwater and anadromous fishes. There is a possibility that these rivers could eventually support commercial fishing industries. There are numerous economic and natural barriers constraining potential marine industrial development, however if the sea ice degradation does allow civilian vessels to work in the Arctic Ocean during at least the summer months, then we should expect a fishing industry will develop. As pressure on fishing resources continues to intensify throughout the North Pacific and North Atlantic, the fishing industry may indeed “push these limits” and attempt to establish market influence sooner than natural conditions permit. Consequently, Naval and Coast Guard rescues of vessels trapped in sea ice may become routine long before sea ice degradation allows extensive civil transport of the Arctic Ocean.

VI. *Arctic Environmental Change and the Northern Sea Route*

Recent Arctic environmental changes, in particular changes in the area and thickness of sea ice, can fundamentally impact Arctic marine transportation. Longer melt seasons, thinning ice covers, and reductions in multiyear ice have key operational implications (for example, greater access and longer navigation seasons) for shipping around the Arctic basin. Notably the Northeast Passage, or the Northern Sea Route (NSR) from a more formal Russian perspective, across the north of Eurasia has experienced reductions in the sea ice cover. In addition, the administration, regulation and overall operation of Russia's NSR have undergone considerable changes during the past decade following the end of the Soviet Union. The combination of regional environmental change and new management of the NSR and Russia's Arctic fleet pose potential implications for the United States and naval operations.

The end of the USSR has brought great change to all aspects of the NSR. Total cargo tonnage along the NSR has been reduced to less than 2.0 million tons, less than a third of what it reached during the heyday of the Soviet Union. This reduction in cargo and ship traffic is primarily a consequence of changes in the industrial complex at Noril'sk. However, year-round marine operations across the Kara Sea to Dudinka (port city for Noril'sk) were maintained throughout the 1990's. This was accomplished using the capable, but aging icebreaker fleet (nuclear and non-nuclear) of Murmansk Shipping Company (MSC). In November 1998 controlling interest in MSC was acquired by the Russian oil company, Lukoil; fresh capital from Lukoil has allowed the recent buildup of a domestic Arctic tanker fleet. Comprehensive and official regulations for navigation along the NSR remain in effect; navigation control, mandatory pilotage, mandatory icebreaker escort (in Vilkitskiy, Dmitry Laptev, Sannikov and Shokalskiy straits) and rules for escort represent a considerable effort to control domestic and foreign shipping along the NSR. Recent papers have highlighted the continued differences between the US and Russia concerning the NSR. The US continues to assert that the ice-covered straits of the NSR are international and subject to the right of transit passage; Russia continues to claim the straits as internal waters. This is likely to remain a contentious political issue between the US and Russia despite future access to the Russian Arctic under more favorable climatic conditions.

A comprehensive study of the NSR - the International Northern Sea Route Programme (INSROP) - was conducted during 1993-99 and funded primarily by Norwegian and Japanese interests. Three principal partners were involved: the Ship & Ocean Foundation (Tokyo), the Central Marine and Design Institute (St. Petersburg), and the Fridtijof Nansen Institute (Oslo), the key coordinator. The project produced 167 peer-reviewed working/technical papers (involving 318 researchers at 50 institutions in 10 countries; a handful of US researchers participated) and a comprehensive reference volume. Significant Russian information on the NSR environment, Arctic ship technology, legal positions, commercial shipping, navigation regulations, and regional (Russian Arctic) economies is now available outside Russia within the INSROP reports. The proceedings of an INSROP summary conference held in Oslo 18-20 November 1999 (The Northern

Sea Route User Conference) have now been published. Included are several conclusions drawn from the conference and overall INSROP effort: the NSR's technological and environmental challenges are no longer absolute obstacles to commercial shipping; the EU and oil/gas interests are conducting pilot studies for Arctic marine routes between the Kara Sea and Europe; Russia needs to better accommodate the concerns and requirements of international shipping (NSR tariffs require considerable adjustment); and, the NSR's physical and operational infrastructure must be further developed to attract increased commercial use. Discussed during the workshop were the impacts of future reductions of sea ice along the NSR on extending the navigation seasons and future requirements for icebreaker support. One significant question remains unresolved: will future Arctic commercial ships navigate along the NSR independently (without icebreaker support) if ice conditions continue to improve?

Recent evidence from satellite observations confirms that the areal extent of Arctic sea ice has decreased approximately 3% per decade. The largest decrease derived from historical records has been recorded for summer since 1950, a key observation for seasonal shipping along the NSR and other Arctic marginal seas. The Siberian Arctic has experienced sea ice reductions during the last decades of the twentieth century. Parkinson has shown regional sea ice reductions in the NSR area for 1978-1996: a 17.6 % decrease per decade in summer for the Barents and Kara seas, and a 3.7% decrease per decade for a large Arctic Ocean area including the Chukchi, East Siberian and Laptev seas. Record summer sea ice reductions in the Russian Arctic for 1990, 1993 and 1995 have also been identified; a record sea ice retreat was observed in 1998 for the Beaufort and Chukchi seas. The area of winter fast ice in the Russian Arctic (Kara Gate to Long Strait) decreased by 11.3% for 1975-93 and there have been reductions in total and old ice areas in the East Siberian Sea during 1972-94. Johannessen has observed a 14% decrease in winter multiyear ice in the central Arctic Ocean for 1978-98 and Rothrock has calculated ice thickness reductions (40%) from submarine data across the Arctic Ocean. These significant transformations and the regional trends noted for the Siberian Arctic, if continued, portend improved conditions for Arctic navigation along the NSR.

Several implications for the US/USN are apparent with regard to the changing nature of Russia's Northern Sea Route:

- Potential greater marine access along the Russian Arctic coast for domestic and international commercial shipping;

- Continued US and Russian differences in the application of the LOS to the Arctic and NSR;

- Closer collaboration between the EU and Russia in development of Western Siberia by oil/gas interests and use of the NSR as a regional marine route (between the Kara Sea and Europe);

- Potential use of the NSR for through transit (Atlantic to Pacific and return) of hazardous wastes and other sensitive cargoes;

- Lukoil's dominant position as owner of both icebreakers and Arctic tankers, and the exclusion of other domestic & foreign competitors (for example Finnish tankers);

- The continued exclusion of US research ships from operating in the Russian Arctic for collaborative science.

VII. *Surface Ship Design Requirements for Arctic Operations*

Background: The U. S. Navy has not recently designed surface ships, other than ice breakers, to operate in the Arctic. The problems of ice damage and topside icing when surface ships were operated in high latitudes were handled on an ad hoc basis. From time to time during the design of a new class of surface ships, the issue of ice hardening has arisen. One example was during the design of the Perry (DDG-7) class guided missile frigates. While high latitude operations were envisioned, these ships were heavily cost constrained and the ice hardening characteristic was dropped from consideration during cost tradeoffs.

The Navy and Coast Guard, however, have designed icebreakers, as have commercial interests. Other commercial ships have been designed for ice hardening. Most major classification societies who govern the details of commercial ship hull design have established rules for the design of ship hulls for operations in ice. The American Bureau of Shipping (ABS) would be the relevant classification society for U. S. ship design.

The ABS rules for design and construction of ships for "navigation in ice" have evolved over a period of many years and are part of a multi-volume set entitled Rules for Building and Classing Steel Vessels. This document could provide the basis for design of a warship that was to "navigate in ice".

There is provision to tailor the hardening of the design to operate in "multi-year" or "first year" ice, in company with an ice breaker or independently, in what thickness of ice, and in the area of ice cover it might be expected to encounter.

Assumptions: The likely operation of surface warships in the Arctic considering the effects of climate change could be in an area of "first year" open ice, less than one meter thick, covering no more than 60% of the total area of operations.

Discussion: With the above assumptions, ABS Rules require strengthening of the bow and stern areas. Since current surface ships have not considered strengthening for ice operations, Future designers must carefully analyze the ABS Rules in selecting plating and stiffener configuration in the bow and stern areas. Of course, independent finite element analysis, taking into account the dynamic and static loads caused by encountering the ice, can also provide the designer with the structural design configuration.

Bow mounted sonar domes and arrays in particular would require careful attention. Propellers, rudders, fin stabilizers, and sea chests are also affected by ice operation. The effect of topside icing and a provision to de-ice must also be considered. While straightforward in a new design, modifications of existing ships could be a costly process

VIII. *CLIMATE CHANGE IN THE ARCTIC: Effects on Sonar Performance*

Background: Recent reports indicate a dramatic decrease, over the past several years, in sea ice thickness and extent in the Arctic. If this trend continues, significant areas of the Arctic Ocean may become permanently ice-free in the future. The entire area may become seasonally ice-free. The presence of sea ice has great impact on Naval operations. In particular, it affects the performance of sonars, and it makes the region a parochial submarine operating area.

Discussion - The present situation: Near-surface sound propagation paths in the central Arctic are typically upward refracted, due to a positive sound velocity gradient; such upward refraction traps acoustic energy near the surface, and results in abnormally low long-range propagation losses at low frequencies (below 50 Hz.) The presence of ice cover causes the sound propagation to be dispersive; higher frequencies suffer greater losses due to multiple reflections off the rough under side of the ice.

- Ambient noise in the Arctic can be extremely low (lower than sea state zero) in the central Arctic under solid ice cover; or extremely high in marginal ice zones, where the noise of collisions from moving ice can exceed that of wave noise in the open sea.

- Ice keels, created as sea ice is compacted by wind and currents, present large acoustic reflectors to active sonars; they can easily equal or exceed the acoustic target strength of a large submarine.

- The geographic proximity of the Arctic Ocean to North America, Europe, and Asia makes it a particularly attractive area for the stationing of strategic (ballistic missile) submarines. Transiting submarines may be detected at long range by surveillance sensors, but the ice canopy makes deployment of surveillance systems costly and difficult. Stationary submarines can take refuge near the ice, where they are virtually undetectable and invulnerable to attack; or in the marginal ice zones, where environmental noise masks their presence.

- Operation of submarines in shallow ice-covered seas is especially difficult and hazardous due to the need for the submarine to operate close to the ice where ice keels present collision hazards. Active sonar must be used continuously in such environments (contrary to the instincts of submariners) in order to assess ice hazards ahead of the ship. ASW operations, concurrent to a shallow under-ice transit, are impossible as the ship is fully engaged in navigating the ice hazards.

Probable changes due to climate change: Melting of Arctic sea ice will expose the sea surface to winds, which will significantly change both ambient noise and acoustic propagation. Wind-generated waves will make ambient noise in the central Arctic more typical of temperate oceans (i.e., increase). Wind-generated mixing of near surface water, combined with warmer air temperatures, will diminish or eliminate the surface duct, increasing low frequency propagation loss.

Disappearance of the ice canopy will also eliminate the haven now provided to stationary submarines by ice keels. Active sonar detection of submarines, both by ASW sonars and by acoustic torpedoes, will become feasible.

In summary, melting of sea ice in the Arctic will turn it into a conventional open-ocean ASW environment, with none of the advantages it now affords to an adversary strategic submarine.

In spite of the increased vulnerability to a strategic submarine positioned in the Arctic, because of its geographic location it will still be a prime location for stationing such forces. And, perhaps significantly, absence of sea ice will render the ocean both accessible to and a viable operating area for any submarine force B ice strengthened or not; nuclear or conventional.

IX. *Socio-economic Change in the Arctic*

As climate changes in the Arctic, socio-economic conditions will change as well. Additional changes are also imposed by factors external to climate change. The diminution of summer ice cover will permit a more active use of the Northern Sea Route (see above). On the other hand, recent population trends in the Russian Arctic indicate that a rapid decline in the population of European Russians is underway now and that the demand for the logistics pipeline provided to communities in the Russian Arctic by the NSR may decline. On the other hand, the Russian Arctic is a resource rich region and continued and expanding exploitation of energy, mineral and forest resources may be expected. In particular the interests of China and Japan in the abundant resources of the Russian Far East appear to be kindling renewed interest in the region in these countries. Russia has recently commenced the construction of a fleet of eleven ice capable tankers for oil transport in the Arctic.

A further consequence of changes in summer ice extent as well as changes in the oceanography of the region will be changes in fisheries. Already, commercial species are recording sightings well north of their usual ranges. Salmon have been seen in rivers near Barrow, AK, well north of their normal range. Marine mammals will respond to these changes as well. Walrus require the opportunity to haul out on ice floes near their feeding grounds. As the ice edge retreats walrus populations will be required to adapt new strategies for calving and feeding.

Among indigenous people in Alaska approximately 50% of the calories consumed come from “country” foods. The seal, walrus, whale and fish components of the subsistence harvest will change as the climate changes (as will the terrestrial component of wildfowl, caribou and moose). These changes may be accompanied by the growth of commercial harvesting in the region by fishing vessels from farther south. In the Russian Arctic, subsistence hunting and fishing at sea may well expand due to the retreat of the European population and the consequent reduction in the supply both of food staples and of the cash economy necessary for the purchase of imported food.

In addition to changes at sea, climate change will affect marine infrastructure in the coastal zone. Permafrost degradation, increases in sea level (due to thermal expansion as deep water warms and to the melting of Arctic and Antarctic glaciers) changes in river flood patterns and timing can be expected to have negative effects on port structures such as docks, bulkheads, cargo handling facilities, airports and roads in the Arctic. If resource exploitation in the Russian Arctic increases, greater demands for sea lift may occur as new and replacement facilities are required for resource acquisition, processing and transportation.

In addition to these potential changes, the search for and development of offshore petroleum resources is bound to come to the Arctic. Climate warming can only accelerate the process. The petroleum industry is already moving into deeper water in other regions. A decrease in the problems associated with drilling and producing oil offshore as sea ice extent and thickness diminishes will expand exploration and production opportunities in the Arctic. Plans are already being made for offshore drilling for oil in the US Arctic. The Russian and Canadian sectors are also strong potential sites for offshore development. These developments will bring seismic exploration ships, mobile drilling platforms of various types and offshore supply vessels into the region with the concomitant development of shore-based facilities.

X. *Acknowledgements*

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APPENDIX B

OPERATIONAL PERSPECTIVE – VIGNETTES

1. Freedom of Navigation (Right of Transit Passage): Northern Sea Route dispute between Russia and the U.S escalates. The legal status of the NSR has long been one of the most contentious political issues in US–Soviet/Russian Arctic relations. The USA claims the ice-covered straits of the route to be *international* and subject to the right of *transit passage*, while Russia claims them as *internal waters* under several lines of argument, including historic waters, closed by straight baselines. Russia asserts policies holding navigable straits in the NSR under their exclusive control. Although icebreaker escorts are no longer required, Russia charges a tariff for passage. European shipping companies lobby the EU to adopt a policy that accepts the tariffs, which are competitive with the Suez and Panama Canals for Pacific/Atlantic transit. The U.S. does not want the EU to set a precedent. The USN decides to conduct a FONOP (Freedom of Navigation Operation) through the NSR and sends a SAG consisting of one DDG, one DD, and one FFG to enter the NSR from the west. An LA Class SSN is also assigned to rendezvous with the SAG northeast of Iceland and conducts a submerged NSR transit in support of the SAG.

2. Battle Group Transit of Northwest Passage: Chinese sovereignty claims in the China Sea and repeated military exercises in the area lead to a confrontation with Taiwan and China. By the 2020 timeframe, China SSNs have the communications and navigation capabilities for blue water deployments. Naval forces normally forward deployed to Westpac have been sent to Persian Gulf due to a crisis there. The USS Stennis is deployed from San Diego, but Commander Seventh Fleet wants a Second CVBG at his disposal. The USS George Washington is preparing for a Med deployment to relieve the USS Truman in August. The decision is made to deploy the GW battle group to Westpac and extend the USS Truman or gap the Mediterranean Sea. The NW passage is ice-free in the summer and commercial shipping routinely transits. The NW passage offers the shortest route and reduces the transit from 17500 nm around Cape Horn and 11600 nm through the Panama Canal to 8700 nm. Russian SSN crosses Arctic to intercept and monitor CVBG transit. With U.S. forces tied down in Persian Gulf, China seizes the opportunity position forces on disputed islands in China Sea. Hostilities escalate. China believes that it can prevail in an engagement with the JCS BG, and positions both SSs and an SSN in the Strait of Malacca to cut off reinforcement from the west. China perceives the U.S. threat to be the GW BG and deploys an SSN to oppose the transit through Bering Strait. The USWC requires the Bering Strait to be sanitized prior to transit.

3. Protection of Shipping: Fishing becomes big industry in the Beaufort and Chukchi Seas, and tensions rise between Russian, Japanese and U.S. fishing fleets. Russia asserts a claim on the continental shelf in the Chukchi Sea including the Chukchi Cap as a historic sea and territorial waters. The U.S. and

Japan dispute Russian claims and continue to operate fishing fleets in the vicinity of Chukchi Cap. USCG aerial patrols obtain evidence of Russian vessels conducting illegal fishing inside U.S. EEZ and seize the responsible vessels. Hostile fishing activities including, cutting each nets, vessel ramming, etc. occur weekly. The single USCG Hamilton class cutter that operates north of the Bering Strait is unable to control the situation. Alaskan Senators and Representatives are demanding action from the Departments of Defense, State and Commerce. Russian Naval forces supported by air forces have moved in to protect their interests and are bullying U.S. fishing fleet, including incursions into U.S. EEZ. The USN sends two frigates and a destroyer to counter the Russian presence. A SSN is deployed for ISR and P-3s and Global Hawk UAVs from Adak, AK assist with surveillance.

4. Maritime Interdiction Operation: All source intelligence indicates that merchant shipping will be used to transport chemical warfare agents via the North West Passage on a route from China with a destination on the U.S. East Coast. US and Canadian establish MPA detachments in Adak, AK, Inuvik NW Territories and Thule, Greenland to track the vessel, but weather precludes continuous surveillance. HUMINT sources substantiate concerns that cargo may be transferred to a smaller vessel (i.e. a f/v or speedboat) in the Bering Sea or Hudson Bay as a point of entry into North America. Satellite passes are too infrequent to determine if cargo is possibly unloaded. USN coordinates with USCG and CCG to monitor possible ports. A SSN operating in the Norweigan Sea conducts an Arctic crossing to covertly intercept and track the suspect merchant vessel through the Canadian Archipelago and report on its activities.

5. Drug trafficking: Former Soviet military transports are used by organized crime activities to smuggle heroin via air routes out of Russia, across the Arctic, and into North America. JIATF North is established to maintain naval detection and monitoring assets and coast guard law enforcement assets in the Arctic. Relocatable over the horizon radar (ROTHR) sites located in Alaska and Canadian Archipelago are used in conjunction with NORAD to maintain surveillance. At least one Aegis platform is assigned continuous picket duty. USN P-3s flying out of Barrow, AK and CP-140s flying out of Inuvik, NW Territories are used for aerial intercept and tracking. A SSN conducts an ISR mission offshore of departure airfields.

6. USW Coordinated Operation: In 2030, the U.S. has an operational Ballistic Missile Defense shield over parts of Asia. A rogue nation with chemical/biological capabilities deploys a SSBN into the Arctic to close the distance to the U.S. and take advantage of hiding in the marginal ice zone. A JTAA is established in the Chukchi and Beaufort Seas. A SAG with T-AGOS support and MPA working in the JTAA provide localization assets with a subsequent handoff to a USN SSN for tracking. A DDG capable of theater ballistic missile defense (LINEBACKER) assumes picket duty in the area in the event of a successful ballistic missile launch.

7. Non-Combatant Evacuation Operation: Environmental terrorists seize a research station in the Svalbard Archipelago being used by a U.S. based multi-national corporation for mineral and oil exploration in the Arctic. The terrorists have been using explosives to destroy equipment at the station, and are threatening personnel if the corporation does not cease all activities in the Arctic Ocean. Although Svalbard is under Norwegian sovereignty, a U.S. signed international treaty prohibits military activities in the archipelago. The breakdown of hostage negotiations is followed by the execution of some of the U.S. citizens. The USS Saipan ARG and 26th MEU, which is Special Operations Capable, are conducting an exercise off Scotland. The Saipan transits to Svalbard and plans a rescue using helo inserted special forces. EO capable P-3s flying out of Tromso, Norway conduct surveillance. U.S. military actions incite protest from the Russians.

APPENDIX C

Name	Rank	Organization	Background	Day 1	Day 2
Addison, Tim	CDR	Canadian Navy	Canadian Navy Current Ops	Surf	IO
Aldinger, TY	Capt	SUBPAC	METOC	Surf	RA
Arias, Jim	Mr.	NSWC Dahlgren Division	Amphibious Ship Project Engineer	Surf	Acq
Baker, Frank	CDR	NLMOC COMP NWDC	METOC	Air	IO
Barker, Jeffrey	CDR	Naval War College	METOC	Air	S&P
Barns, Thomas	Capt	OPNAV N780E	Helo Pilot	Air	IO
Bienhoff, Paul	CDR (ret)	JHU APL	Sub Co / Arctic Research	Sub	Acq
Bodenstedt, Joseph W.	CDR	USCG HQ	Propective Chief, Ice Operations Division @ USCG Headquarters	Surf	S&P
Boulden, John	CDR	ONI-SWORD	Sub CO	Sub	S&P
Brass, Garrett W.	Dr.	US Arctic Research Commission	Arctic research	Surf	Acq
Cathcart, Blaise	LTCOL	Canadian Forces	JAG Officer	Sub	S&P
Davis-Marks Michael	CDR, RN	British Embassy	Sub CO	Sub	IO
Dorman, Merrill H.	Capt. (ret)	EG&G Technical Services Inc	Ret Sub CO, HF sonar	Sub	Acq
Falkingham, John	Mr.	Canadian Ice Service	Chief of Ice Forecast Operations	Air	RA
Fischbeck, Jeffrey A.	Capt	Arctic Submarine Laboratory	Director, Arctic Submarine Laboratory Sub CO	Sub	Acq
Furze, Peter	CDR	NAVOCEANO	METOC	Sub	S&P
Gallamore, Jay	CDR	CNO N78	Aviator	Air	S&P
Garrett, Jeffrey M.	Capt USCG	Co USCG Healy	Polar Ice Operations	Surf	IO
Garry, Joe	LCDR	OPNAV N763T	SWO	Surf	Acq
Gillard, David	Capt	OPNAV N70	METOC	Surf	RA
Gossett, Jeffrey	Mr.	Arctic Submarine Laboratory N3	Head of Operations at Arctic Submarine Laboratory	Sub	IO
Hayes, Richard	Mr.	CNO N960B	Dep. Dir., Programming & Assessment Div	Air	RA
Jackson, David	Mr.	Icebreaking Division, Canadian Coast Guard	Manages CCG icebreaking program	Surf	IO
King, Charles	LCDR	NRL Det Stennis	METOC/sub exp	Air	Acq
Lancaster, Chuck	Capt USCG	Chief, Office of Aids to Navigation USCG	Surface, CO Ice breaker	Surf	S&P
Ledbetter, Mike	Mr.	National Science Foundation		Sub	Acq

Marsh, W Clyde	RADM	OPNAV N75	Amphibs - mines		
Matt, Joseph	Mr.	OPNAV (N23)	Manager Charting & Oceanography	Sub	RA
McFadden, P. Dean	Capt.	Canadian Navy	Directorate of Maritime Strategy	Air	S&P
McKeown, Raymond	Dr.	NLMOC	METOC scientist	Surf	Acq
Medley, Richard	CDR	OPNAV N773B	Sub Co / Arctic, UUVs	Sub	RA
Mineart, Gary	CDR	NRO (AS&T/TDG)	METOC, Space Systems, Ops	Air	Acq
Morrisey, Charles	Mr.	Canadian Department of National Defence	Defense scientist	Sub	S&P
Newton,George B.	Hon.	Chair, U.S.Arctic Research Commission	Retired CAPT, USN; Sub CO	Sub	RA
Noble, Chris	Capt (sel)	SECNAV OPA	SWO	Surf	IO
Ostrander, Frank	CDR	Navy Jag, Code 10	JAG Officer	Air	S&P
Riedener, Laurens	Mr.	ONI-21	Intel	Surf	S&P
Ryan, Kenneth	CDR	CNO N78	Aviator	Air	S&P
Stewart, Paul	CDR	ASN (I&E)	METOC (SWO background)	Air	Acq
Van Woert, Michael	Dr.	National Ice Center	National Ice Center Chief Scientist	Surf	IO
Widmeyer, Ray	Dr.	OPNAV N70	Science Advisor to N70	Sub	S&P
Wilson, Walter	CAPT	OPNAV 00K	N2	Air	S&P
Winter, Peter	LCDR	OPNAV (N76)	SWO - USW rqmnts	Surf	RA
Facilitation Team:					
Connell, Doug	Capt (ret)	WBB	CAG / F-18	Air	S&T
Mack, Steve	Mr.	WBB	Facilitator		Road Ahead
Nevitt, Pat	Cdr (ret)	WBB	Facilitator / NFO	Lead	Lead
Roberts, Dana	Capt (ret)	WBB	Sub CO	Sub	Strategy & Policy
Seglem, Mark	Capt (ret)	WBB	Surface	Surf	Integrated Ops
Taylor, Robert	Capt (ret)	WBB	CAG / A-6	Air	Acq
Control Group					
Willis, Zdenka	CDR	NAVICE	METOC		RA
Lamb, Doug	LCDR	NAVICE	METOC		
Conlon, Dennis	Dr.	ONR Code 322HL	Sponsor		
Spinrad, Rick	Dr.	N096	Sponsor		

APPENDIX D

ACRONMYS

ACOUS	Arctic Climate Observations using Underwater Sound
ARG	Amphibious Readiness Group
ARGOS	Advanced Research and Global Observation Satellite
ARPA	Automatic Radar Plotting Aid
ASN	Assistant Secretary of the Navy
ASUW	Anti Surface Warfare
ASW	Anti Submarine Warfare
ASWIP	Antisubmarine Warfare Improvement Program
AVCAL	Aviation Calibration
C2	Command and Control
C4ISR	Command, Control, Communications, Computers, Intelligence, Surveillance and Reconnaissance
CCIP	Component Commander Issue Papers
CEC	Cooperative Engagement Capability
CINC	Commander in Chief
CNO	Chief of Naval Operations
CRD	Capstone Requirements Document
COD	Carrier Onboard Development
CV	Carrier
CVBG	Carrier Battlegroup
DTS	Digital Telephone System
EEZ	Economic Enforcement Zone
EMCON	Emergency Communications Conditions
ENVISAT	European Environmental Satellite
EO/IR	Electro Optical / Infra-Red
ESGN	Electro-Static Gyro Navigator
ESM	Electronic Signal Monitoring
FNC	Future Naval Capabilities
FONOPS	Freedom of Navigation Operations
GGMs	GPS Guided Munitions
GPS	Global Positioning System
IBS	Integrated Bridge System
ISR	Intelligence Surveillance and Reconnaissance
IPL	Integrated Priority List
IWARS	Integrated Warfare Architecture Assessment
LO	Low Observable
MACC	Military Assistance to Civilian Communities
METOC	Meteorological and Oceanographic
MCM	Mine Counter Measures
MIO	Maritime Interception Operations
MNS	Mission Need Statement
MOP	Measure of Performance

NATC	Naval Air Test Center
NAVAID	Navigational Aid
NAVICE	Naval Ice Center
NAVOCEANO	Naval Oceanographic Office
NAVSSG	Navy Strategic Studies Group
NBC	Nuclear, Biological, Chemical
NCW	Network Centric Warfare
NDIA	National Defense Industrial Organization
NEO	Non-combatant Evacuation Operations
NIC	National Ice Center
NIMA	National Imagery and Mapping Agency
NGO	Non-Governmental Organization
NSA	National Security Agency
NSR	Northern Sea Route
NTM	National Technical Means
NWDC	Naval Warfare Development Command
OAG	Operational Advisory Group
ONR	Office of Naval Research
OPNAV	Office of the Chief of Naval Operations
OPTEMPO	Operational Tempo
ORD	Operational Requirements Document
POE	Projected Operational Environment
POM	Program Objective Memorandum
PPBS	Program Planning and Budgeting System
QDR	Quadrennial Defense Review
RADARSAT	Radar Satellite system
RDT&E	Research, Development, Testing & Evaluation
ROC	Required Operational Capabilities
RF	Radio Frequency
RLGN	Ring Laser Gyro Navigator
RMA	Revolution in Military Affairs
SAG	Surface Action Group
SAR	Synthetic Aperture Radar
SAR/CSAR	Search and Rescue / Combat Search and Rescue
S&T	Science and Technology
SLBM	Submarine Launched Ballistic Missile
SLCM	Submarine Launched Cruise Missile
SLOC	Sea Lines of Communication
SOP	Standard Operating Procedures
STORM	Submarine Technical Oceanographic Reference Manual
SVP	Sound Velocity Profile
SWDG	Surface Warfare Development Group
TACCO	Tactical Coordinator
TACAMO	Take Charge and Move Out
TLAM	Tactical Land Attack Missile
TTP	Tactics, Techniques and Procedures

UAV	Unmanned Air Vehicle
UCAV	Unmanned Combat Air Vehicle
UCP	Unified Command Plan
UNCLOS	United Nations Convention on Law of the Sea
UNREP	Underway Replenishment
UsuV	Unmanned Underwater Vehicle
USV	Unmanned Surface Vehicle
USW	Undersea Warfare Operations
UUV	Unmanned Underwater Vehicle
VOD	Vertical Onboard Delivery
VP	Patrol plane