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Under Ice Operations

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The oceans of the world, and the myriad of mysteries they contain, have long been described as "Inner Space." For centuries man has been scratching at the surface of this inner space, and in recent years has been making progress in his understanding of it. Yet man has been denied even the surface in those parts of the oceans where there is permanent ice coverage—a cover that only the development of the true submarine has permitted a break. This new development, coupled with the cold war, has rendered the polar icecap of the Arctic Ocean an area of the utmost importance to east and west, an area that neither side can permit the other to dominate. Scientific data, operational experience and simple presence in that environment must be accrued, developed and maintained so as to understand the geographical and strategic aspects of the Arctic Ocean.

Geography

Study of the polar map at Figure 1 gives a view of the Arctic that is geographically more realistic than the more often seen mercator-type projection. The Arctic is the fourth largest of the world's oceans. It is very nearly landlocked, with the Soviet Union alone comprising over half its shores, and Canada, Alaska and Greenland providing the majority of the rest. It has numerous islands around its periphery, but its central waters are land-free with water depths of roughly 1,500-2,000 fathoms. Its two most characteristic features are its permanent icecap with its seasonal growth and diminution, and its pattern of currents determined by the combined effects of the great currents of the Pacific and Atlantic oceans, and by the rotation of the earth.

Pack Ice

There is a floating raft of ice ranging, depending on season, from its maximum in April/May to its minimum in September/October. Its thickness

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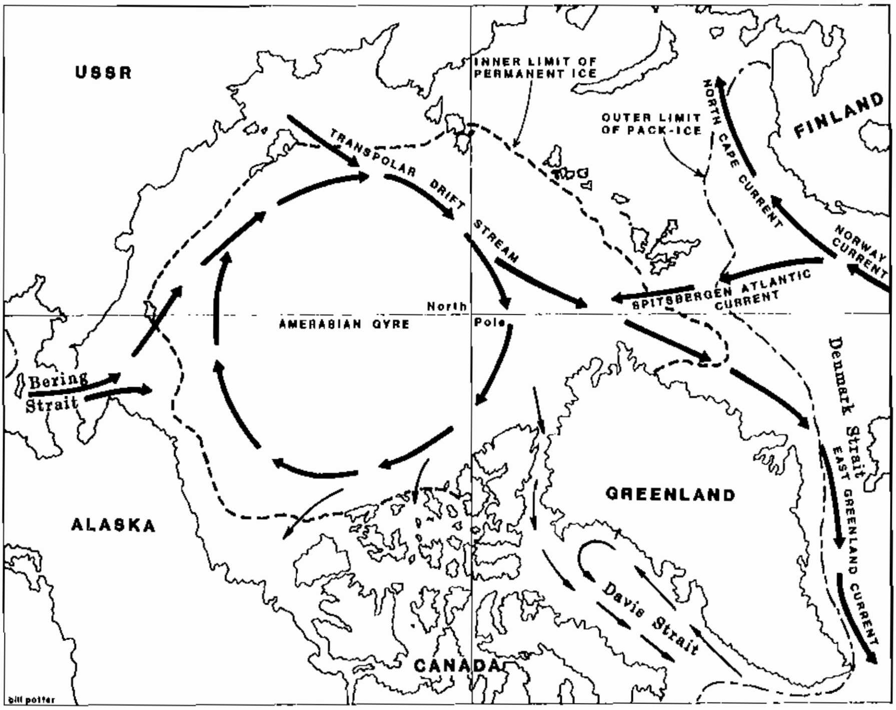

Figure 1. Polar Stereographic Map of Arctic Region, Showing Pack-ice Average Limits and Prevailing Currents

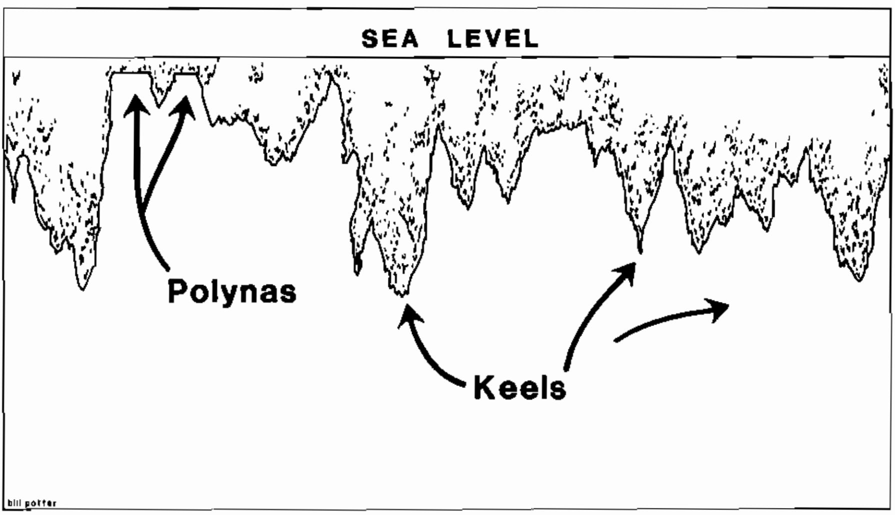

Figure 2. A Section of Under-ice Profile

Under Ice Operations 21

varies from a few inches to nearly 200 feet (independent of season) and it has a root mean square value of about 20 feet. The unevenness of its thickness is caused by the continual tearing, grinding and compression of the "raft" as it is acted upon by the currents and landmasses. In areas where a tear or fissure is located as two parts of the "raft" are drawn apart, the exposed water immediately freezes to a depth of about 10 inches, and this area of thin newly formed ice is known by its Russian name of Polyna. Polynas can be of the order of a few miles long by several hundred yards across, and are important for the submarine should it need to break surface to communicate, change its atmosphere, confirm its position or even fire missiles. In other areas, compression causes a fractured ice raft to tilt vertically before being refrozen in its new position, giving rise to "sails" above water and "keels" below. It is these keels which can reach some 200 feet in depth and which also clearly have a significance for the submarine. Figure 2 shows a typical submarine ice-profile sonar trace.

Icebergs and Ice Islands

Of strategically lesser significance than the all-pervasive pack ice, icebergs and ice islands are of interest to the submariner and scientists. The enormous glaciers of Greenland are the "calving" areas for icebergs: about 12,000 such monsters are produced annually. A typical iceberg would rise some 250 feet above water from a base some 1,200 feet below the surface and would weigh about 1.5 million tons. They are borne southwards down the Davis and Denmark Straits by the prevailing currents, and their main significance is as a danger to submarine and surface transiters. While the greatest outflow of water from the Arctic uses the Denmark Strait, the area is wide and deep enough to permit prudent circumnavigation; however, the narrow confines and shallow waters of the Davis Strait render little help to the transiter who can neither go under the berg nor round it.

Ice islands are flatter plateaus of ice shorn off the land such as the northern shore of Ellesmere Island. They can measure several miles across and stay within the Arctic Ocean, being borne round the ocean by the circular currents in the Amerasian basin. Since they do not reach warm climates, they are very long-lived and form useful bases for scientific settlements. Particularly well known is the ice-island T3 which has been occupied by US scientists for over 20 years. Soviet scientists are avid ice-island users, and indeed in recent years a Soviet occupied island was "arrested" by Canadian security forces when it penetrated the latter's territorial seas.

Strategic Considerations

Further references to the map at Figure 1 will remind the reader that the "shortest distance between East and West lies north and south," i.e., across the Arctic Ocean. The enormous extent of the Soviet littoral on that ocean also explains why the Russians have shown acute interest in the area—they have over 10,000 miles of Arctic coast.

There are however several other factors that are of strategic significance. Already mentioned, the advent of the nuclear-powered submarine has permitted exploitation of the waters under the icecap. Less obvious, though, is the fact that the Western ASW advantage over the Soviets may have had a considerable influence in forcing them to seek refuge for their missile-firing submarines closer to home. A decade ago, the short range of Soviet submarine-launched ballistic missiles (SLBMs) demanded that the firing submarines take up patrol positions in the western Atlantic. To do this, they had to transit through the chokepoints and "home waters" of Nato's northeastern flank where they were subject to detection and possible shadowing. Faced with this, enormous Soviet effort has gone into developing longer range SLBMs and submarines that are specifically designed to operate for extended periods under ice. This has effectively turned the tables on the West: deploying in the Arctic, Soviet submarines have no chokepoints to transit, and their operating areas are considerably more familiar to them than to the West; conversely, Western anti-SSBN submarines have themselves to transit the chokepoints of the Davis and Denmark Straits; the areas are great distances from the US and UK bases, and the inventory of knowledge of the operating areas is relatively poor. A similar strategic advantage in favor of Soviet ASW submarines can be assumed should the West choose the Arctic as a patrol area for its own SSBNs. Furthermore, a major contribution to Western ASW capabilities has been their highly superior air and surface assets, and the Arctic icecap effectively rules them out as nonplayers in the new arena.

Environmental Aspects

Sound-Velocity Profile (SVP). Because the icecap effectively prevents both seasonal and diurnal solar heating, and because the waters of the Arctic are well mixed by the constantly flowing currents, the SVP is essentially "all positive" (see Figure 3). Salinity variations in the upper few feet typically have a marked positive effect.

The effect of this all-positive gradient is to produce the characteristics of a deep sound-channel (DSC) with its axis at or near the surface. Figure 4 is a typical ray-path diagram. Even in open waters, the SVP follows this characteristic shape since the sun is too weak to create a temperature gradient of any significance, and because of freshly melted surface water the salinity gradient is at its maximum. Thus, sound in the Arctic can theoretically travel great distances undisturbed by thermoclines and aided by the cylindrical spreading feature of the DSC.

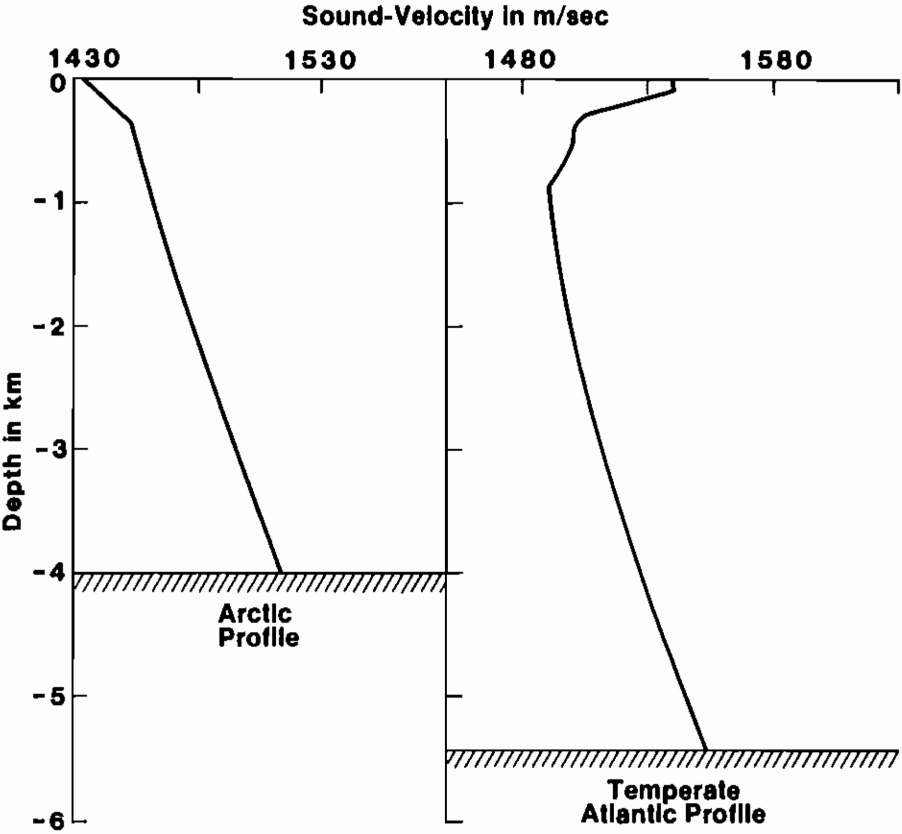

Figure 3. Sound-Velocity Profile of Central Arctic Ocean Compared with Profile of Temperate Atlantic

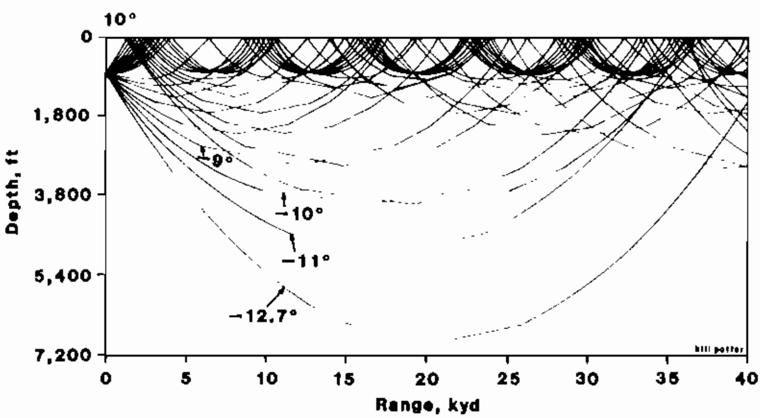

Figure 4. Arctic Ray-Path Diagram

Naval War College Review, Vol. 38 [1985], No. 4, Art. 3

Noise and Attenuation. Other characteristics of this unique area depend on the degree of ice cover. In this respect, the Arctic Ocean can be regarded as having three separate zones: that totally covered by ice; the open waters; and the transition zone between—known as the Marginal Ice Zone (MIZ). Ambient noise in the area of total coverage is generally very low: there is of course no wave noise and the water is virtually unaffected by wind. But the ice is continuously "working," producing stress and fracture noises that are significant, though of a lower level than noise associated with waves. Clearly, the more well-established the ice the quieter it will be. In the open-water zone, ambient noise is subject to all the variables of any temperate ocean. Prevailing weather, though, is generally more adverse than most other areas of the world, giving rise to a corresponding higher sonar sea state. In the MIZ, noise levels are generally very high: the constant breaking of waves upon the ice floes, and the constant movement of the floes themselves with their grinding, collision and melting noises, all contribute to a relative cacophony. The three zones are similarly affected by biological noise, with ice-covered areas being sparsely populated (essentially no sea mammals) and the open-water zone the most heavily affected. Finally, the total absence of shipping in either pack ice or MIZ, with very little in the open-water zone results in little ambient noise.

Attenuation of transmitted noise is, however, affected by the icecap. The large number of vertical surfaces of the ice keels, and the rough underside of the ice as a whole will clearly cause sound in the sea to be reflected randomly. Active transmissions will accordingly also suffer from heavy reverberations.

Thus, relative to non-Arctic acoustics, we can summarize Arctic acoustics as follows:

Transmission and Sound	-	Better, due to positive SVP and shallow depth of the sound axis. Less variable, due to more constant meteorological conditions.
Ambient Noise	-	Lower under continuous ice cover; higher in MIZ.
Attenuation	-	Higher because of under-ice irregularity, but lower because of less marine life and no shipping.

Navigation. One of the most fascinating aspects of polar operations is the challenge extended to the navigator. Position-keeping for most nuclear submarines devolves heavily upon the ships' Inertial Navigation System (SINS), and modern technology has gone a long way towards reducing to a minimum the errors inherent in the system.

Operating in its polar mode, the SINS stable platform is switched to a free gyrosystem, giving it rigidity in space on one of its axes rather than operating on a "north-up" principle. However, it remains necessary to monitor very carefully any generated errors, for which accurate fix information is highly desirable. Existing radio aids for polar latitudes are virtually useless above 80°N (Omega & Loran C), though both systems can be accessed without needing to raise a surfaced aerial. Satellite navigation is also heavily degraded because of high elevation angles achieved by the US polar-orbiting satellite system. Also, the UHF/SHF satellite navigation system depends on a surfaced antenna—this requires the location of a Polyna to break surface and thus provides the enemy the opportunity for detection.

The absence of scientific and hydrographic information of sufficient accuracy precludes bottom contour navigation. A similar paucity of geodetic and gravitational information precludes the calculation of vertical deflection forces, a prime source of error in inertial navigation systems. The difficulties of obtaining these scientific surveys under the icecap are self-evident.

Thus, there are many difficulties. Clearly these difficulties also confront the Soviets; indeed the particular requirements of SLBM navigational accuracy are more critical than the requirements of an antimissile firing SSN. Solutions do exist, and technology is already providing advanced gyroscopes that are less prone to errors, while it is also possible, for instance, to incline the orbits of navigational satellites so that they may be nsed at polar latitudes.

Command, Control, and Communications. The prime element of C^3 in submarine warfare (indeed nearly *all* naval warfare) is communications. The special features of communication in the Arctic center upon the existence of the icecap, which forms both a physical barrier to surface penetrating aerials (as for satellite navigation), and also a prohibitive hazard for any towed buoy because of the presence of ice keels. Trailing wire antennae for VLF communications are still effective, although again the presence of keels keeps the wire below reception depth, unless the submarine is virtually stopped—either to remain under a Polyna or else to permit the buoyancy of the wire to find its way round or between keels. Signal strengths are also adversely affected, first because existing Western transmitter antennae are at a great distance from the Arctic Ocean and, secondly, because the proximity of the magnetic north pole creates ionic disturbances that upset the VLF signal. This latter phenomenon—known as polar-cap disturbance (PCD)—can last for a week or more, though more commonly it persists for only a few days and is prevalent during periods of high sunspot activity. Again the significance of this phenomenon is more applicable to the SSBN with its requirements for 100 percent communication reception than to the predator SSN.

Other aspects of C^3 are not specific to the Arctic environment. In

Naval War College Review, Vol. 38 [1985], No. 4, Art. 3

summary, one might say that C^3 for submarine operations, never easy, are further exacerbated by the Arctic environment.

Submarine Design. Finally, the peculiarity of the environment affects submarine design in a number of ways. It is beyond the scope of this paper to go into any great detail. Suffice it is to say that considerations range from the number of propellers (most Soviet nuclear submarines have more than one screw, partially no doubt to cover for possible ice damage to one), through the strengthening of the upper casing, and sail, to the protection of upper hull-mounted sonars. Environmental control equipment may need to be reinforced since the icecap precludes quick ventilation. Electronic equipment on board must be capable of operating at very low temperatures; periscopes and masts need heating elements. Thus it is clear that submarines need Arctic capability to be built into them at the outset in order to compete effectively in this exacting environment.

Operational Aspect

Strategic Weapons. Many of the environmental problems confronting the submarine are applicable to the strategic weapon system: navigational and heading accuracy, "hardness" against the physical barrier of the icecap, or the requirement to surface in order to release missiles. Delays in response to orders-to-fire are very probable if the launching submarine has to find or revisit a Polyna before it can fire. However, the tenor of this paper throughout has been as anti-SSBN predator, so the detailed problems associated with strategic weapons will not further be addressed, except to reiterate that these are the problems confronting the missile-firing Soviet.

Tactical Weapons Systems. To address this subject logically, let us take in sequence the problems confronting an SSN transiting the Davis Strait into the Arctic, detecting and attacking a patrolling SSBN. Clearly the classification of this paper precludes any detailed discussion, so the problems must be addressed in very general terms.

The transit. Consideration has to be given to the overriding hazards of collision with ice or grounding in the navigationally constrained straits. Ice-detecting active sonar must be used. A counterdetection opportunity may occur accordingly. Navigational accuracy is not yet a problem since Omega and Loran C are accessible on the floating wire aerial, and SatNav is useful if it becomes necessary for one reason or another to raise an antenna. Sonar conditions are poor because of marginal ice activity initially, but improve markedly as the transit progresses. Classification of any possible contact is easy: all but enemy submarines are eliminated!

On station. Sonar conditions are excellent, giving high probability of long-range detection. Reflections of target noise from the multiplicity of ice keels could cause extra difficulties in target-motion analysis. Unlike the old North Atlantic chokepoint days the target is not transiting—he is patrolling, and therefore very much quieter, alert and unpredictable. Therefore, target motion analysis will again be much more difficult.

Attacking. Problems, problems, problems. We have established that the target is within range but he is probably too quiet for passive homing weapons; if we go "active" there will be excessive reverberations, not to mention the distinct probability of the weapon homing on to an ice keel, or even striking one accidentally en route to the target; maybe it's better to track him until he leaves the ice cover, if ever he does; or maybe he'll fire his missiles before I can attack him. Maybe . . . .

Conclusions

It is clear that many problems need to be solved before under-ice warfare can be waged with anything like the confidence that open ocean temperate ASW generates. The strategic significance of the Arctic inner space is evident, and it is equally evident that neither East nor West can afford to resign control of that area to the other. There are useful systems that have not been mentioned—static emplaced arrays, nonacoustics, doppler discriminative torpedoes. However, nothing will replace or make up for the value of all-important operational in-area experience. And it is here where one faces the nagging suspicion that we have some catching up to do.