USE OF A SUBMARINE IN ICE-COVERED ARCTIC WATERS TO HELP DELIMIT THE U.S. EXTENDED CONTINENTAL SHELF

(Draft White Paper from the U.S. Arctic Research Commission)

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I. <u>PURPOSE</u>. This White Paper describes the role(s), value, and preparation requirements for a U.S. Navy nuclear submarine (SSN) to collect geophysical data, and especially multi-channel seismic reflection (MCS) data, in the Arctic Ocean that are necessary to delimit the U.S. extended continental shelf (ECS). The ECS is the area that lies beyond our 200 nautical mile (nm) Exclusive Economic Zone (EEZ) as defined in Article 76 in the 1982 Convention on the Law of the Sea (CLOS), hereafter "Convention." To provide a fallback option to data collection from surface vessels, and to increase the likelihood of timely completion of the data collection effort, the U.S. should conduct an engineering feasibility study of submarines as platforms from which to collect geophysical data. Traditional means of collecting MCS data (from surface vessels) are often compromised (such as the Danish-Russian joint effort in 2007 or Healy 06-02) or even precluded in the ice-infested waters of the high Arctic Ocean. The best interests of the U.S. will be served by acquiring MCS and other geophysical data in optimal locations, unhindered by sea ice, to best support an ECS delimitation.

II. <u>BACKGROUND.</u> As of December 2007, 157 nations, excluding the U.S., have acceded to the 1982 Convention. Although the U.S. is not yet a party, we accept the substantive provisions of the Convention and comply with them as elements of customary international law. Sixty nations are considered to have an ECS, including those few nations that have not yet acceded.

The Convention allows coastal states a 10-year deadline from the date of ratification/accession to collect data and submit the basis upon which the state's ECS would be delimited. There is a special allowance for coastal states that acceded prior to 1999. Their submission deadline is 2009. A 21-member technical committee, the Commission on the Limits of the Continental Shelf (CLCS), reviews and evaluates these submissions.

Once the CLCS provides a positive recommendation on the ECS submission from a coastal state, that state may then establish final and binding ECS limits based on the CLCS recommendations, thus providing legal certainty and enabling the state to take full advantage of its rights and natural resources in the area.

The U.S. Senate Foreign Relations Committee voted the Convention out of committee in November 2007, and should the U.S. accede, it will begin the 10-year effort to develop its submission. Norway submitted their delimitation in 2006, and other coastal States, including adjacent Canada, Denmark, and Russia, are currently delimiting their respective ECS areas. The U.S. should as well, regardless of accession. Our nation's best interests are served by collecting and analyzing data to better establish and to better understand the limits of our ECS.

III. MOTIVATION. Several factors motivate us to accelerate the pace of delimiting of our nation's ECS. These include: (1) anticipation that the U.S. will accede to the Convention within the next 1-2 years; (2) growing appreciation that the data collection and analysis effort are more arduous and time consuming than initially thought, particularly in light of the fact that over 50 percent of our anticipated ECS area falls within the ice-covered Arctic Ocean; (3) greater knowledge about the limits of our ECS puts the U.S. on a stronger footing under customary international maritime law, regardless of accession; (4) continued energy demand and the realization that considerable fossil fuel resources lie within the anticipated ECS areas, particularly in the Arctic Ocean, where, according to the U.S. Geological Survey, possibly 25%

of the world's unproven reserves are thought to exist; and (5) the ability to exercise control over marine bottom and sub-bottom research in the delimited ECS areas.

Notably, only 9 countries have yet submitted complete or partial delimitations to the CLCS. Two have received positive recommendations (Brazil and Ireland). Russia was the first nation to submit, in December 2001. As Russia has a great amount of territory boarding the Arctic Ocean, it comes as no surprise that their ECS delimitation, when added to their EEZ, constitutes roughly 45% of the entire Arctic Ocean basin. In 2002, the CLCS returned the Russian submission, stating that the data were insufficient for the proposed delimitation. Since then, Russia has been collecting additional data, from a variety of platforms. In March 2007, the Russian news agency RIA Novosti reported that nuclear submarines were being considered as data-collection platforms by the Russian Navy. There have been conflicting reports as to when Russia will resubmit, and dates of both 2008 and 2009 have been reported in the press.

As has become clear to several nations that have commenced data collection and analysis for a ECS submission, the 10-year time window is not easily met, because of the great effort and cost to do so. For a country like the U.S., which has the world's largest EEZ, and is expected to have one of the larger and more complicated ECS submissions, the 10-year limit will likely become a challenge (see Section VI). The U.S. ECS submission will span three oceans and four continental coastlines as well as Pacific Islands.

It is with such forethought that the U.S. government has formed an interagency "Extended Continental Shelf Task Force," under the leadership of the State Department, and co-chaired by the Departments of Commerce and Interior, to delimit the U.S. ECS.

IV. <u>THE ARCTIC OCEAN ECS.</u> Developing a U.S. ECS submission is significantly complicated by the fact that the Arctic Ocean, specifically the area north of Alaska, contains the largest ECS area. Of the six U.S. ECS areas that surround North America, those areas in the Arctic roughly equate to the land area of California, and represent at least 55% of the total. Collecting data in the Arctic Ocean is complicated by its remote polar location, unpredictable sea ice, and challenging weather conditions, which concomitantly yield short field seasons. In fact, it's common for ship-based Arctic Ocean science programs to redefine their objectives while underway, to avoid one or all of these challenges.

The Arctic ECS area is uniquely challenging for the following reasons:

1) Large areas have yet to be mapped and surveyed. Data that exist in some areas are sparse, poorly located, and of questionable quality.
2) All of the potential ECS area in the Arctic is covered by annual and multi-year sea ice from fall to late spring (September to May). Some regions, further north, are covered by multi-year ice year round. (See Section VI and Figures 1 and 2, below).
3) The Arctic Ocean sea ice cover is capricious. Though the timing of the advance and retreat of the cover can be predicted with some accuracy, the location of the ice edge varies widely from year to year (Figure 2). This vagary complicates planning, decreases the effectiveness of surface vessels, adds costs, and extends the data-collection period.

The CLCS submission preparation guidelines recognize the challenges of collecting data in the Arctic. They grant the CLCS some flexibility in evaluation of data submitted by an Arctic coastal state.

V. <u>ECS SURVEY REQUIREMENTS.</u> Article 76 of CLOS outlines the specific geologic and morphological criteria to delimit a nation's ECS. They are based largely on either of two formulae: (1) a distance formula that allows an extension of the shelf to 60 nm beyond the foot of the continental slope (defined as the point of maximum change in gradient at its base); and (2) a sedimentary rock thickness formula that allows extension of the shelf to where the thickness of sediments (or sedimentary rock) is 1 percent of the distance back to the foot of the slope. The following two criteria are used to determine the outer limit (maximum cutoff lines) of the continental shelf: 1) it cannot extend more than 350 nm from the coastal baselines; or 2) it cannot exceed 100 nm beyond the 2,500-meter isobath, whichever is more beneficial for the state.

In the U.S. Arctic, the continental shelf may extend as far as 600 M from the baseline. Key to implementing any of these criteria is a clear bathymetric delineation of the 2,500-meter isobath, the foot of the continental slope, and accurate geophysical data to determine seabed sediment thickness. Submission of the continental shelf limits will be based on a combination of high-resolution, state-of-the-art bathymetric and geophysical data, which includes multi-channel seismic reflection (MCS), seismic refraction, gravity, and magnetic data.

Although the criteria in Article 76 appear straight forward, specific application is challenging. Interpreting the geology and geophysics of the sediments and sub-seafloor rock formations is complicated and nuanced. It involves more than just bathymetric and sediment thickness data. Article 76 paragraphs 3 and 6 make a distinction between oceanic ridges, submarine ridges, and submarine elevations that are natural components of the continental margin, such as plateaus, rises, caps, banks, and spurs. The interpretation of these definitions impacts the definition of shelf delineation. The Convention’s wording implies that the continental shelf may extend to 200 nm on oceanic ridges, to 350 nm on submarine ridges, and to either 350 nm or 100 nm beyond the 2,500-meter isobath on submarine elevations. According to one interpretation, if the feature is morphologically continuous with the continental margin, regardless of its origin, and is not an oceanic ridge, then it is either a submarine ridge or a submarine elevation that is a natural component of the margin, depending on the degree of geologic and tectonic continuity between the landmass and the ridge. Clearly, any Arctic ECS submission will require and be based upon sound and comprehensive geological and geophysical data sets.

Portions of the U.S. Arctic ECS submission may be based on the sediment thickness formula. In addition to the difficult acquisition of MCS data, this will require precise data on the location of the foot of the continental slope (based on bathymetry) and will be limited in most areas by the position of the 2,500-meter isobath plus 100 nm.

VI. <u>HOW DATA MUST BE COLLECTED.</u> The bathymetric and geophysical data that will be collected to support the Arctic portion of the U.S. ECS submission will be the first comprehensive survey of the Arctic Ocean sector north of Alaska. These data will provide critical baseline scientific information, and ultimately greater understanding about the world's most poorly studied ocean basin.

The data necessary for the ECS submission may come from:

1) Historical archived sources of bathymetric and sparse MCS data
2) Icebreakers that can provide bathymetric, MCS, and other geophysical data
3) Submarines may provide MCS data, as well as bathymetric and gravity data
4) Other nations have demonstrated that ice camps can facilitate small data collection needs. The U.S. does not anticipate resorting to this method.

The CLCS guidelines also make reference to geomagnetic data (often collected by towed sensor) as data appropriate for inclusion in any submission.

VII. <u>APPROXIMATE ARCTIC ECS AREA OF INTEREST.</u> Several years ago, the Minerals Management Service (MMS) completed a Preliminary Application of Article 76 Guidelines with respect to the U.S. continental shelf (as best known) to assess the ocean bottom and sub-bottom areas over which the U.S. might exercise sovereignty. Some of this information was published by G.B. Carpenter, L.F. Thormahlen, and R.V. Amato in *Marine Georesources and Geotechnology*, 1996, V. 14, pp 353-359.

According to this effort, the U.S. EEZ consists of the following approximate areas (excluding territories and possessions except Midway).

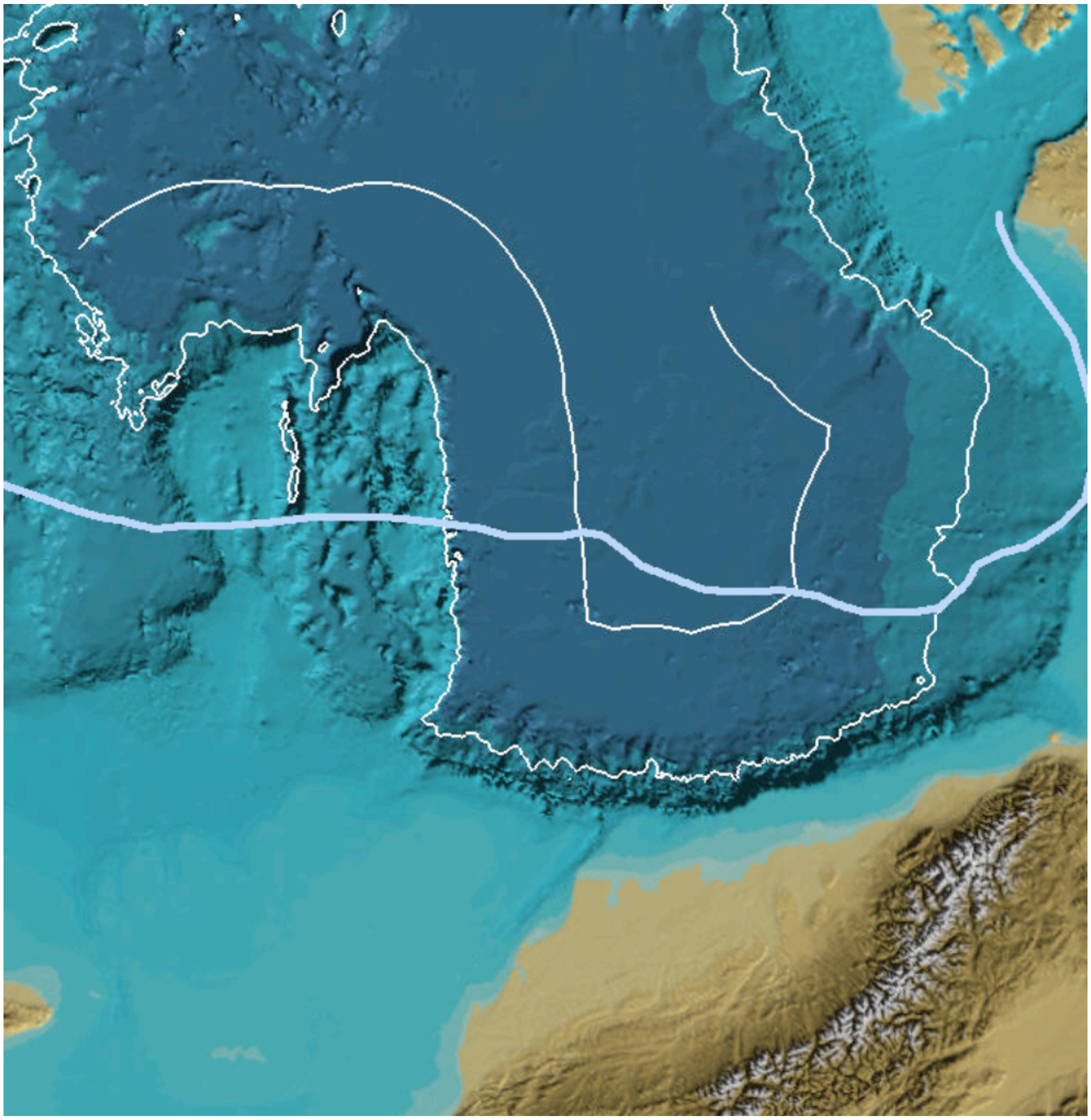
East Coast	929,000 square kilometers (sqkm)
Gulf of Mexico	692,000 sqkm
West Coast	817,000 sqkm
Hawaii	2,850,000 sqkm
Alaska	3,691,000 sqkm
Total:	8,979,000 sqkm

This area represents more than 90% of the total area of the 50 United States.

Similarly, the ECS area estimates beyond the 200M EEZ are:

East Coast (Atlantic) N	61,000 square kilometers (sqkm)
East Coast (Atlantic) S	96,000 sqkm
Gulf of Mexico	18,000 sqkm
Alaska (Arctic) NW	395,000 sqkm
Alaska (Arctic) NE/ Beaufort	7,000 sqkm
Alaska (Bering Sea) W	178,000 sqkm
Total:	755,000 sqkm

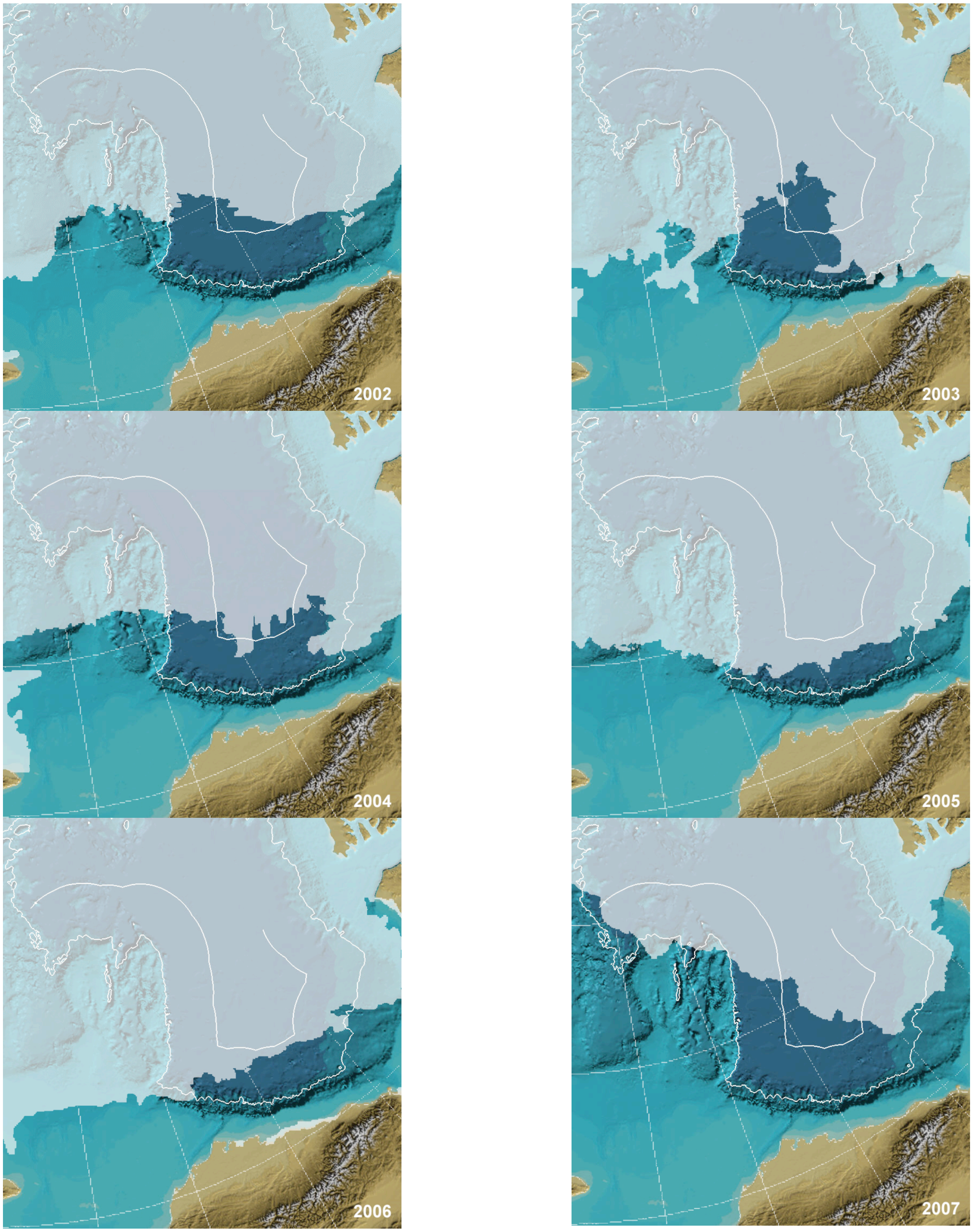
The total area is approximately equal in size to the area of Texas, and is slightly smaller than twice the size of California. Of this total estimated ECS area, over 50% is in the Arctic Ocean.



Bathymetry from Larry Mayer (UNH-CCOM) and 2002-2007 average minimum (September) ice line from Pablo Clemente-Colon (NIC). Personal Communication.

Figure 1. Bathymetry and 2002-2007 mean summer minimum ice line in the Arctic Ocean.

The thin, contorted line is the approximate location of the 2500 m isobath. The smoother line, within, is 100 nautical miles beyond the 2500 m isobath. This marks one estimate of a maximal delimitation. The heavier line that runs roughly east to west, north slope of Alaska, is the average location of the summer (September) ice minimum line for the 2002-2007 time interval.



Bathymetry from Larry Mayer (UNH-CCOM) and ice data from Pablo Clemente-Colon (NIC). Personal Communication.

Figure 2. Summer (September) minimum sea ice over six years, beginning in 2002, in the Arctic's Beaufort and Chukchi Seas

In all years, except 2007, the Chukchi and Northwind Ridges were ice-covered.

Calculating (conservatively) the estimated ocean area that is enclosed by the minimum ice line in Figure 1, and the approximate area to the north, over which the U.S. could delimit a maximum ECS, yields an area close to 300,000 sqkm.

Three observations are worth noting. First, the minimum ice line moves considerably from year to year, complicating the planning effort. Second, the longer-term average for minimum ice extent in September of each year, dating back to 1979 when satellite coverage was first available in the Arctic, is considerably south of the recent extents. Third, the area of minimum ice cover exists for no more than a few weeks each year. The ice line retreats over the short summer season, reaching a minimum in early September. It then begins a rather rapid advance south in late September and early October. Thus, it is important to note that Figures 1 and 2 depict nominal ice conditions that exist for only a short time period each year. This clearly complicates traditional ship access to and operation in the area, even by icebreakers.

Previous data-collection efforts in the Arctic ECS region, primarily by NOAA/UNH, using USCGC *Healy*, have successfully acquired bathymetric data over much of the 2,500 m isobath, and mapping the foot of the slope will commence again in 2008. As such, the lion's share of bathymetric data has been collected, and plans to collect the remainder are in place.

The outstanding need is for MCS data, which are much more difficult to collect in ice-covered waters. While the sea ice is generally retreating, there is no assurance it will continue this retreat every year. During science operations, the USCGC *Healy* spent one week during each of the 2005 and 2006 field seasons obstructed in multi-year ice north of Barrow, Alaska.

In August and September of 2007, a Danish-sponsored Arctic Ocean survey north of Greenland, involving the Swedish icebreaker *Oden* and the newly commissioned Russian nuclear icebreaker NS *50 Lyet Pobyedi* ("50 Years of Victory"), were rebuffed by severe ice, including ridges up to 10 m thick. This ice apparently damaged a propeller on the Russian nuclear icebreaker, the most powerful Arctic-class vessel in the world. MCS streamers were severed and lost on more than one occasion. Details on this expedition can be found in a daily log (particularly the August 26 and 27 entries) maintained by one of the shipboard scientists, Martin Jakobsson, at this url: http://www.geo.su.se/forsk-maringeologi-projects/oden_logbook.

VIII. RATIONALE FOR SUBMARINE SUPPORT IN THE ARCTIC ECS. The rationale and special need for a submarine in identifying the U.S. Arctic ECS is derived from the unique nature of the area. Presuming the feasibility study concludes that navigational challenges (i.e., accurately and precisely locating, geospatially, a submarine beneath the ice, such as with GPS-enabled through ice buoys) and MCS data collection from a submarine is viable, a submarine would be able to provide data of a quality and quantity that are superior to that collected from a surface vessel. The rationale and special needs can be described by these factors:

1) Of all the oceans in the world, the U.S. (and indeed the global community) knows the least about the Arctic Ocean because the environment is hostile to surface ocean vessels. Even with the large influx of data to be realized over the next two years during the International Polar Year, this deficiency will remain significant. This knowledge deficiency covers all oceanographic and marine geographic parameters – hydrography (bathymetry), seismic, magnetic, and gravity.
2) Surface vessel (icebreaker) surveys, and particularly the collection of MCS data, are significantly constrained, if not precluded by the presence of sea ice, weather, darkness, and time (season) of the year. As described earlier in this white paper, the extent and penetrability of sea ice varies dramatically year-to-year, season-to-season, and often, day-to-day. Only darkness is a predictable factor. The long cables carrying MCS sound sources and receivers from the stern surface vessels are often tangled or severed by sea ice. The participation of a suitably equipped SSN in the U.S. Arctic ECS surveys would

provide a complementary platform to the efforts of an icebreaker and would mitigate, to a large extent, the accessibility challenges to the data collection process noted above.

3) Data quality. The data collected by a submarine will likely be superior in that the cruise track will not be dictated by surface ice conditions, enabling acquisition along straight tracks at selected, optimal locations. Interference with ice and from accompanying surface vessels will not impact the reception of sound signals.

4) A submarine enables the U.S. to maximize the delimitation of the ECS area. A surface vessel's path and MCS data collection efforts are constrained, or even precluded by surface ice conditions, weather, and daylight. These conditions do not impact a submarine. In light of the results from the *Healy* cruise in 2007, that suggests that the U.S. ECS may extend further north than previously thought, MCS data collection will be required in even higher latitude parts of the Arctic, where multi-year ice infests the surface waters. This requirement further supports the development of options beyond surface vessels for MCS data collection.

5) The potential U.S. Arctic ECS area is by far the largest (greater than 50%) of all the estimated U.S. areas worldwide. Further, the Arctic sub-seabed areas, expected to be included as part of the U.S. ECS, are considered a potential repository of significant energy resources. To properly survey an area of this size will require much time and effort, as well as specialized technology.

Surveys conducted by a submarine provide a large measure of certainty to the data collection effort. The submarine is not limited by: (1) the presence of sea ice and its adverse characteristics (hardness/compression/thickness); (2) the season, thus extending the time available for collection; (3) the local weather conditions. As an example, during 2006, the joint Canadian/Danish survey team, on sea ice north of Ellesmere Island, lost more than 60% of their survey days due to weather; and (4) relying on foreign flagged and operated surface vessels, such as Canadian icebreakers or Russian nuclear ice breaker, which are not necessarily reliable from an operational or political perspective.

Having an additional platform participate in the Arctic surveys also shortens the time needed for the Arctic ECS survey effort, which becomes especially relevant if the U.S. accedes to the treaty, given the 10-year submission deadline.

The submarine, having essentially unlimited access under sea ice, would collect a more extensive data set (in quality, range, and density) than an icebreaker. A SSN is able to sail a straight track for data collection. It is not limited to the path allowed by the penetrability of the sea ice, as is the case with an icebreaker. Further, the submarine operates at a speed that is 4 to 5 times faster than that of an icebreaker. As a result, the submarine can execute a comprehensive survey more rapidly, yielding data that are more consistent and useful. Data interpolation becomes less of an issue. Unfettered access would enable the submarine to increase both the range and depth of data collected, going places the icebreaker cannot reach. Independence from the surface ice also prevents occlusion of the under-hull transducers, as often occurs when ice is swept under the hull of an icebreaker. This independence also eliminates the ice-on-ice and ice-on-hull acoustic interference that degrades the quality of bottom mapping data.

The marine geological and oceanographic data collection capabilities of the submarine were demonstrated during the six SSN ("SCICEX") cruises, conducted by the U.S. Navy on behalf of the science community during 1993-1999 period. Researchers repeatedly praised the platform's speed, mobility, quietness and access as unique attributes for Arctic Ocean data collection.

Increasing the quality, range, and density of data not only will make the U.S. ECS definition better, but it will provide the U.S. excellent resistance to counter- or conflicting claims in the Arctic by other nations should they arise.

The submarine, through its accessibility to the underside of the ice, would also provide assurance that the largest possible ECS area is identified through collection of more extensive data sets. Given that the accuracy of under ice navigation can be sufficiently improved, a requirement that is well within the realm of today's technology, the ability to conduct organized surveys, likened to "mowing the lawn," would contribute significantly to the overall quality of the Arctic survey and allow data sets to approach, generically, the quality of similar ECS surveys done in the open ocean, both by the United States and other countries.

Finally, having a submarine equipped to conduct Arctic surveys, particularly at the higher latitudes under the heaviest ice, is a capability that might well be attractive to other Arctic littoral nations. Such cooperative employment could potentially stimulate a joint ECS submission with Canada, for example, and eliminate the need to resolve concurrently the disputed Arctic Ocean maritime boundary between our countries, as is required under the CLCS Guidelines for those nations filing individual submissions. Additionally, conducting a joint and mutually observed survey in the area of the U.S./Canadian maritime boundary would remove any technical and geological issues as a part of future boundary negotiations.

Discussions by both Canadian and Danish government representatives in March 2007 at the University of New Hampshire reveal the challenges they envision in their Arctic data collection effort, particularly in the high Arctic Ocean outside their respective EEZs. Both nations acknowledge the pressures of meeting the 10-year submission deadline dictated by Article 76. Further, both nations have earlier asked the U.S. Navy for Arctic Ocean bathymetry collected by submarines. Shared data sets, based on mutual self-interest could be a strong means to build Arctic cooperation.

IX. <u>ELEMENTS REQUIRED TO USE A SUBMARINE IN THE ECS EFFORT.</u> Using a submarine as a component of an integrated program to complete the Arctic ECS surveys requires some study from both an engineering/technology and execution perspectives. This feasibility effort will address how best to use a submarine for Arctic ECS mapping, how to implement instrumentation to meet these goals, preparation of temporary alteration plans, and formal approval of those plans. Though preliminary work to confirm that a submarine would be a contributor to this effort appears significant, the certainty realized by easier and assured access under ice-covered areas, the increased data quality, the ability to maximize the area covered, and the increased speed of data accumulation (and thus project completion) are, simply stated, too large to ignore.

The following are the most significant of the necessary steps that must be completed in anticipation of submarine participation in the Arctic ECS Project:

1) A "National Priority" must be established for the ECS effort to ensure the assignment of a dedicated submarine to this project. The Navy, at present, has many military missions for submarines to perform. There are too few submarines to perform them all. However, if the National Command Authority determines that defining the ECS of the U.S. is of sufficient importance to be identified as a National Priority, and the Navy is tasked to provide resources, the Navy has informally indicated they will respond positively (Newton, 2004, personal communication).
2) A Submarine Engineering Feasibility Study must be accomplished, the cost of which is estimated to be approximately $1 million. This funding must be provided above and beyond any existing programmatic requirements. Such funding could come out of the $8M in the president's FY08 budget request to NOAA, specifically in the Ocean Exploration line item. Among the critical tasks included in that study are the following:
    a. Define design objectives for the instrumentation suite based on the requirements of Article 76, knowledge of the Arctic Ocean, and the capabilities of U.S. Navy subs.
    b. Confirm instrumentation requirements to be installed onboard the submarine. The initial notional instrument suite is projected to include:

i. Side scan swath bathymetric sonar

ii. Bell BGM-3 underway marine gravimeter

iii. High-resolution sub-bottom profiler (~75m sediment penetration)

iv. Deep penetration seismic system (~1 km penetration). The SSN would serve as both the source of the sound, as well as the receiver, thus precluding the need for an accompanying surface vessel. That is, the SSN would operate alone.

v. Oceanographic instrumentation (ADCD, CTD, in-hull water sampling capability)

c. Complete improvements and refurbish the original SCAMP swath mapping system, fix system telemetry, and test replaced transducer blocks.

d. Identify low(er) frequency sediment-penetrating source suitable for hull mounting (e.g. Deep Towed Acoustic Geophysics System (DTAGS).

e. Development of GPS "ice-buoys," or other solutions, to provide acceptable navigation accuracy. Other navigation-enhancing alternatives within the state-of-the-art will also be assessed.

f. Redesign SCAMP Temporary Alterations (TEMPALTS) to meet Navy/Naval Sea Systems Command requirements and submarine configuration (see 3. below).

3) Identify submarine dedicated to ECS project. Complete engineering ship check.

4) Complete shore-side and waterborne proof-of-concept operability tests for instrumentation.

5) Plan data acquisition, based on complementary roles with the icebreaker *Healy*.

6) In the longer run, equipment procurement and installation and submarine operating costs are envisioned to be on a par with those for the icebreaker HEALY.

X. <u>IMPACT OF ECS SURVEY ON THE ARCTIC RESEARCH EFFORT.</u> From a scientific perspective, the Arctic remains a basically unknown ocean, a *mare incognita*. Initial submarine-based efforts, such as through the SCICEX program (http://psc.apl.washington.edu/scicex/main.html), succeeded in providing a first look at previously inaccessible regions. Geological and geophysical collection from successful ECS surveys will not only be used for ECS delimitation, but will also be used in myriad ways for basic research. Further, the basic data collection suite installed on any submarine deploying through the Arctic will enable, on a not-to-interfere basis, critical data to be collected and ultimately injected into the national Arctic research effort.