National Security Implications of Climate Change for U.S. Naval Forces: Letter Report

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Committee on National Security Implications of Climate Change for U.S. Naval Forces

Letter Report

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Naval Studies Board

NATIONAL RESEARCH COUNCIL
OF THE NATIONAL ACADEMIES

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April 12, 2010

ADM Gary Roughead, USN
Chief of Naval Operations
2000 Navy Pentagon
Washington, DC 20350-2000

Dear Admiral Roughead:

In your letter dated October 17, 2008, to National Academy of Sciences President Ralph Cicerone, you requested that the National Research Council's (NRC's) Naval Studies Board (NSB) conduct a study to assess the implications of climate change for the U.S. Naval Services. Accordingly, in August 2009, the NRC, under the auspices of its NSB, established the Committee on National Security Implications of Climate Change for U.S. Naval Forces.

The study's terms of reference, provided in Enclosure A of this letter report, were formulated by the Chief of Naval Operations (CNO) in consultation with the NSB chair and director. The terms of reference charge the committee to produce two reports over a 15-month period. The present report is the first of these, a letter report issued, as requested, following the third full committee meeting.

The terms of reference direct that this study be based on Intergovernmental Panel on Climate Change (IPCC) scenarios and other peer-reviewed assessments. Therefore, the committee did not address the science of climate change or challenge the scenarios on which the committee's findings and recommendations are based. In short, this letter report summarizes the immediate challenges for U.S. naval forces in addressing each of the four areas listed below and recommends approaches for addressing these challenges. The terms of reference direct that the committee in its two reports do the following:

1. Examine the potential impact on U.S. future naval operations and capabilities as a result of climate change . . . .
2. Assess the robustness of the Department of Defense's infrastructure for supporting U.S. future naval operations and capabilities in the context of potential climate change impacts . . . .
3. Determine the potential impact climate change will have on allied force operations and capabilities . . . .
4. Examine the potential impact on U.S. future naval antisubmarine warfare operations and capabilities in the world's oceans as a result of climate change; specifically, the technical underpinnings for projecting U.S. undersea dominance in light of the changing physical properties of the oceans.

This first report is very much an interim report that neither addresses in its entirety any one element of the terms of reference nor reaches final conclusions on any aspect of the potential implications of climate change. Instead, this report highlights issues brought to the committee's attention during its first three meetings that could have potential near-term impacts, impose a need for near-term awareness, or require near-term planning to ensure that longer-term naval capabilities are protected. The committee will continue its study during the coming months and expects to complete by mid-2010 its final report, which will address all of the elements in the study's terms of reference and explore many potential implications of climate change not covered in this letter report.

In its initial three meetings, the committee received a number of helpful briefings from commands across the U.S. Navy, the U.S. Marine Corps, and the U.S. Coast Guard,[1] as well as expert briefings from individuals working at a number of other government agencies, including the following: the National Ice Center, the National Intelligence Council, the National Oceanic and Atmospheric Administration (NOAA), the Department of Energy's Oak Ridge National Laboratory, the Office of Naval Research (ONR), and the United States Geological Survey (USGS). Additionally, the committee conducted data-gathering sessions on national security and climate-change-related issues with Columbia University's Center for International Earth Science Information Network (CIESIN); the Cooperative Institute for Research in Environmental Sciences (CIRES), sponsored by NOAA and the University of Colorado, Boulder; the United Kingdom's Ministry of Defence; the Pacific Institute for Studies in Development, Environment and Security; and the Woods Hole Oceanographic Institution. When combined with the collective knowledge of the committee, these briefings are considered to constitute a sufficient basis for development of the findings and recommendations offered by the committee in this report.

BACKGROUND ON NAVAL FORCES AND CLIMATE CHANGE

The leaders of the U.S. Navy, Coast Guard, and Marine Corps have recognized the potential impact of climate change on naval forces' missions and have positioned their organizations to make adaptive changes.[2] In this regard, the CNO has recognized the linkage between energy use and climate change by establishing two key task forces: the Navy Task Force Energy (charged with formulating a strategy and plans for reducing the Navy's reliance on fossil fuels—and thus for reducing carbon dioxide emissions, operational energy demands, and, potentially, energy costs);[3] and the Navy Task Force Climate Change (charged initially with developing a roadmap for Navy actions in the Arctic, and then with addressing longer-term Navy actions regarding global climate change policy, strategy, and plans).[4] This committee engaged with the Navy Task Force Energy and the Navy Task Force Climate Change and found that each is providing strong leadership on these issues across the Navy and the Department of Defense (DOD). Both task forces are well positioned in capability and credibility to continue strong contributions within the DOD.

It is also noteworthy that the U.S. Navy and its assets are recognized by the national technical community as a critical partner in advancing the understanding of climate science and related policy implications.[5] The committee strongly supports the continuation of dedicated efforts by the Navy to be

[1]In its first three meetings, the committee heard from the U.S. Navy, Marine Corps, and Coast Guard as follows (see Enclosure D for dates, places, and briefers): (1) the U.S. Navy (Navy Meteorology and Oceanography Command, Navy Task Force Climate Change, Navy Energy Coordination Office, Navy Task Force Energy, Office of the Deputy Chief of Naval Operations for Fleet Readiness and Logistics, Office of the Deputy Chief of Naval Operations for Information Plans and Strategy [N3/N5], Office of the Deputy Chief of Naval Operations for Integration of Capabilities and Resources [N81], Office of the Commander of the Naval Installations Command, and the Navy Quadrennial Defense Review [QDR] Integration Group); (2) the U.S. Marine Corps (the Office of the Facilities Branch Head and the Office of Environmental Management Section, Headquarters Command); and (3) the U.S. Coast Guard (Commandant of the Coast Guard; and the Office of Policy Integration, USCG Headquarters).

[2]A board of retired flag and general officers also recognized this impact and provided a broader perspective on the topic of national security and climate change. See Military Advisory Board, 2007, *National Security and the Threat of Climate Change*, CNA Corporation, Alexandria, Va.

[3]CAPT James L. Brown, USN, Director, Navy Energy Coordination Office, Office of the Deputy Chief of Naval Operations for Fleet Readiness and Logistics, "Navy Task Force Energy, Perspectives and Related Climate Change Initiatives," presentation to the committee, September 17, 2009, Washington, D.C.

[4]See Vice Chief of Naval Operations Memorandum 4000 Ser N09/9U103035, "Task Force Climate Change Charter," October 30, 2009.

[5]For example, both Navy and Coast Guard assets have been highly important in providing critical scientific data associated with both ice mass and ocean changes over extended periods. Also, the Medea Program, a project of the 1990s, has been highly valuable in providing sea-ice data from military and intelligence assets that would otherwise

engaged with and to help lead these advances, within the broader context of the DOD's responsibility to assess the effects of climate change on all DOD missions, capabilities, and facilities. The Navy brings significant historical experience and unique capabilities to this arena, and the committee views these assets and related advances as supporting the national security interests of the United States.

This committee has found in the assessments it has studied strong scientific evidence to support naval leadership's continuing to study and act on the implications of climate change and how they will affect naval missions and capabilities. Some areas of current scientific knowledge of climate change, however, lack the near-term specificity that the Navy may need for planning purposes. These areas include, for example, the rate of future sea-level rise, the exact timing of an ice-free Arctic, and reliable predictions of regional climate (given the current inability to project specific regional impacts). Considering it unlikely that very precise projections of climate change will be available over the next few years, this committee believes that the Navy should adopt a risk management approach to addressing these issues. Such an approach should include a range of contingency plans for the potential sudden onset of climate-induced severe-weather disasters.

FINDINGS AND RECOMMENDATIONS

The committee focused its initial assessments either on climate change issues that it believes will have the greatest effects on naval forces or on issues that may require immediate planning. The committee views global climate change as a long-term issue that will play out over the next several decades. However, because of the long lead times in developing and changing naval capabilities and because of the potential for global climate change to have a significant impact on future naval missions, near-term awareness, planning, and decisions are needed by the U.S. Navy, Marine Corps, and Coast Guard.

The following sections of this report, in which appropriate supporting data are provided, present the committee's findings and recommendations, at this stage of the study, under the following four key topics, which are embedded in the terms of reference: (1) naval capabilities and potential climate-change-related operational issues globally, together with the closely related matter of the role of allied partnerships in regard to such global operational issues; (2) climate change impacts on global naval installations; (3) naval capabilities and potential climate-change-related operational issues in the Arctic; and (4) climate-change-related technical issues impacting naval operations, particularly in the Arctic.

1. Naval Capabilities and Potential Climate-Change-Related Operational Issues Globally

Naval Forces Responses in Future Climate-Change-Related Events

There are numerous peer-reviewed projections of increasing global stress arising from the effects of climate change as well as from the combined effects of climate change and other global trends, such as projected global population growth.[6] Current climate-change-related projections found in recent peer-

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be unavailable in the civilian sector. See National Research Council, 2009, *Scientific Value of Arctic Sea Ice Data,* The National Academies Press, Washington, D.C. In another example, SCICEX (Scientific Ice Expeditions) was a 5-year program in which the Navy made available a Sturgeon-class, nuclear-powered attack submarine for unclassified science expeditions to the Arctic Ocean to gather ice-thickness measurements. Additional information on SCICEX is available at http://www.Ideo.columbia.edu/res/pi/SCICEX/. Accessed November, 24, 2009.

[6]In many regions of the world, the impact of climate change is likely to further exacerbate the preexisting stress on water supplies and the mounting pressures of population growth. For example, Columbia University's Center for International Earth Science Information Network has compiled information from IPCC assessments, the 2005 World Bank report *Natural Disaster Hotspots: A Global Risk Analysis*, and CIESIN's gridded world population data sets to present a projected geographic distribution of vulnerability in 2050. In presentations to the committee, CIESIN representatives reported that global population nearly doubled from 1968 through 2008, and that by 2048 it could

reviewed reports portray a range of effects.[7] In turn, these reports and scientific models suggest that these effects may lead to more severe or frequent droughts, floods, storms, and other events with negative consequences for food and water supplies, leading to possibly even greater stress on the expanded population.[8] Viewed from a national security standpoint, these changes would likely amplify stresses on weaker nations and generate geopolitical instability in already-vulnerable regions.[9] A range of military missions might be necessary as a result of such conditions, including the sorts of antipiracy and counterterrorism missions now being conducted off the waters of Somalia. However, the clearest implications are for humanitarian assistance and disaster relief (HA/DR) missions, which may increase in frequency, thereby straining military transportation resources and the supporting force structures. The U.S. Navy, as a forward-deployed force in position to reach targeted disaster-relief sites faster than other agencies can, will almost surely experience increased demand for U.S. naval forces' assistance if climate-related disasters increase.[10] The demand for Navy Construction Battalion capability in support of HA/DR operations is expected to increase in proportion to the operational tempo of U.S.-sponsored international HA/DR operations.[11] Likewise, the U.S. Marine Corps should expect that it will be called on as an expeditionary ground force to assist with extreme-weather-related HA/DR events in a changing climate

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grow another 40 percent, to more than 9 billion people, adding even greater stresses to water and food supplies. CIESIN also reports that population increases are fastest in areas most vulnerable to intense storms and flooding (e.g., coastal areas, islands, and river basins). The CIESIN analysis combines its population data sets with IPCC-projected climate-change-related vulnerabilities, economic data, and past disaster-related losses to identify areas at relative high risk from one or more hazards. See Robert S. Chen, Center for International Earth Science Information Network, Columbia University, "Human Dimensions of Climate Change," and Marc Levy, Center for International Earth Science Information Network, Columbia University, "Climate Change and U.S. National Security," presentations to the committee, November 19, 2009, Washington, D.C.

[7]For example, see Thomas R. Karl, Jerry M. Melillo, and Thomas C. Peterson, 2009, *Global Climate Change Impacts in the United States,* Cambridge University Press, New York.

[8]See Intergovernmental Panel on Climate Change, 2007, "Climate Change 2007: The Physical Science Basis," Working Group I contribution to the *Fourth Assessment Report of the Intergovernmental Panel on Climate Change* (S. Solomon, D. Qin, M. Manning, Z. Chen, M. Marquis, K.B Averyt, M. Tignor, and H.L. Miller [eds.]), Cambridge University Press, Cambridge, United Kingdom and New York. See also C.P. McMullen and J. Jabbour, 2009, *Climate Change Science Compendium,* United Nations Environment Programme, EarthPrint, Nairobi, Kenya.

[9]See June 25, 2008, House Permanent Select Committee on Intelligence and House Select Committee on Energy Independence and Global Warming: *Statement of the Record by Dr. Thomas Fingar, Deputy Director of National Intelligence for Analysis—National Intelligence Assessment on the National Security Implications of Global Climate Change to 2030*. Available at http:www.dni.gov/testimonies/20080625_testimony.pdf. Accessed November 24, 2009. See also Military Advisory Board, 2007, *National Security and the Threat of Climate Change*. CNA Corporation, Alexandria, Va.

[10]A 2007 joint maritime strategy document for the U.S. Navy, Marine Corps, and Coast Guard calls out "humanitarian assistance and disaster response" as one of six capabilities that constitute the core of U.S. maritime power and that "reflect an increased emphasis on those activities that prevent war and build partnerships." See *Cooperative Strategy for 21st Century Seapower,* available at http:www.navy.mil/maritime/MaritimeStrategy.pdf. Accessed November 23, 2009. However, it is not the sole responsibility of the U.S. military to respond to national and international humanitarian and disaster-relief emergencies; many U.S. and international governmental and private agencies may be engaged in any given relief operation.

[11]For a review of U.S. Navy Construction Battalion operations, see U.S. Navy Seabees First Naval Construction Division, Strategic Plan 2008-2011, Norfolk, Va.

and to help secure U.S. interests in sensitive regions.[12] However, the pace and extent of this increase are unknown.

Based on the current uncertainty regarding the pace and extent of this demand, the Navy should not at present fund changes to force structure for humanitarian assistance and disaster relief, but over time it should consider changes to the construction of future naval platforms of appropriate classes in order to accommodate HA/DR operations and potential increases in climate-change-related mass human migration. The benefit of the Navy's providing such HA/DR support was demonstrated in the 2004 tsunami relief effort in Indonesia and in the recent earthquake relief work in Pakistan and Haiti.[13] The U.S. Navy, Coast Guard, and Marine Corps need to consider the ramifications of this enhanced HA/DR mission and the ways to prepare for it, including regular reviews of advanced staging requirements. A possible near-term investment might be considered for increased Navy Construction Battalion capacity for such deployments. If such efforts are not planned already, U.S. naval forces could benefit from a full inventory and review of the lessons learned from recent HA/DR deployments, such as the U.S. Navy, Marine Corps, and Coast Guard deployment to provide HA/DR after the January 2010 earthquake in Haiti.

Allied Forces Responses in Future Climate-Change-Related Events

An issue closely related to U.S. naval capabilities and global response to projected climate change is the role of allied forces partnerships. The committee received briefings from the National Intelligence Council suggesting that, in addition to the security challenges discussed above, the impact of projected severe climate change on food or water supplies and on disease patterns in certain regions of the world may lead to large-scale regional population movements, resulting potentially in millions of what some have termed "climate refugees" fleeing environmental "hotspots."[14,15] These assessments suggest that if such large-scale movements were to develop, U.S. naval leadership should be prepared for the possibility that allied forces might be occupied by their own domestic and regional climate-change-related responses, or that allied forces might lack the appropriate response capacities to assist with international efforts. In

[12]For example, in the aftermath of Tropical Storm Ketsana striking the Philippines on September 25, 2009, the U.S. Navy and U.S. Marine Corps worked with the Philippine government (and in support of the U.S. Department of State and the U.S. Agency for International Development Office of Foreign Disaster Assistance) to rapidly provide critically needed supplies in support of disaster relief to help mitigate human suffering and prevent further loss of life. In this case, a team of approximately 100 personnel composed of Marines from 111 Marine Expeditionary Forces flew from Okinawa to the Philippines on September 29, 2009, to conduct humanitarian assistance assessments. On September 30, U.S. Navy ships USS *Denver*, USS *Tortuga*, and USS *Harpers Ferry*, with embarked Marines and sailors of the 31st Expeditionary Unit, set sail from Okinawa toward the Philippines. On October 1, the commanding general of the 3rd Marine Expeditionary Brigade flew from Okinawa to the Philippines to lead planning and humanitarian assistance efforts. See *U.S. Marine Corp News*. Available at www.okinawa.usmc.mil/public affairs/info/archive/news. Accessed November 23, 2009.

[13]See "U.S. Navy Relief Efforts After the Indian Ocean Tsunami," December 26, 2004, Department of the Navy—Navy Historical Center, available at http://www.history.navy.mil/faqs/faq130-4.htm; and "U.S. Navy Transports UAE Donation to Earthquake Victims in Pakistan," November 3, 2005, Department of the Navy news article, available at http://www.news.navy.mil/search/display.asp?story_id=20885. Accessed November 23, 2009.

[14]MajGen Richard Engel, USAF (Ret.), Director, Climate Change and State Stability Program, National Intelligence Council, "National Intelligence Assessment on the National Security Implications of Global Climate Change to 2030," presentation to the committee, October 19, 2009, Washington, D.C.

[15]The term "climate refugee" in this report refers to persons who cross international borders because of drought, flooding, or other severe weather or extreme events related to climate change. Currently the term "climate refugee" or "environmental refugee" has no standing in international law; it is not defined with any entitled protection under the 1951 United Nations Refugee Convention or the 1967 UN Refugee Protocol, although there is a movement among many nongovernmental organizations to petition for this recognition. See Bonnier Docherty and Tyler Giannini, 2009, "Confronting a Rising Tide: A Proposal for a Convention on Climate Change Refugees," *Harvard Environmental Law Review,* Vol. 33, pp. 349-403.

such cases, the National Command Authority might require U.S. naval forces to act alone, without allied forces' assistance.

This committee has not yet fully explored the views, issues, and capabilities concerning climate change with respect to allied forces, nor has it conducted an assessment of projections involving associated climate-change-related geographic hotspots. The committee's early assessment of allied partnerships indicates that several countries, especially in Europe, are already assuming strong public military postures on climate change,[16] and those countries may be open to the establishment of cooperative partnerships for leveraging capabilities to meet potential global climate-change-related HA/DR needs. The committee plans to address more expansively in its final report issues related to allied partnerships, but it believes that early planning and engagement by U.S. naval leadership with allied partners to address climate change issues are called for.

Finding 1: Scenarios of global climate change from the Intergovernmental Panel on Climate Change project impacts on both developing and developed nations, and such impacts may be destabilizing in many parts of the world. These projected changes would affect U.S. national security and stress naval resources. In particular, naval forces might be required to carry out more frequent humanitarian assistance and disaster relief (HA/DR) missions. At the same time, U.S. naval forces would be expected to execute their ongoing national-security-related military missions and to position themselves for supporting missions in destabilized regions around the globe. Also, it is expected that the demand for U.S. Navy Construction Battalion capability would increase in proportion to the operational tempo of U.S. HA/DR operations.

Recommendation 1: Although the committee has not yet completed its full analysis of the implications of climate change for future Navy force structure, it is clear that the Chief of Naval Operations (CNO) needs increasingly to take such implications into account. The committee believes that the CNO should not in the near term specifically fund new force-structure capability to deal with the effects of climate change but should hedge against climate change impacts through planning for the modification of the existing force structure as the climate-change-related requirements become clearer. All of the U.S. naval forces (the U.S. Navy, Marine Corps, and Coast Guard) should begin to consider potential specific force-structure capabilities and training standards over the next 10 years for conducting missions arising from the effects of climate change. In particular, the Navy should review the current and projected Navy Construction Battalion capability and capacity in light of the potential acceleration of the current operational tempo as a result of climate change effects.

2. Climate Change Impacts on Global Naval Installations

Global sea-level rise is projected to be a major impact of climate change.[17] Many naval coastal installations would be affected and would likely require adaptation.

[16]The committee received a briefing on the United Kingdom's Ministry of Defence climate-change-related policies and plans from the British Defence Staff of the United States British Embassy, and will pursue discussions with official representatives of other U.S. allies. Related to this, military experts from many nations are increasingly expressing concerns about the need for attention to climate-change-related national security. For example, see "Australian Military Warns of Climate Conflict," available at http://www.reuters.com/article/environmentNews/idUSTRE5060FU20090107. Assessed November 24, 2009. See also statements endorsed by military experts of the United Kingdom, the Netherlands, and India in the October 29, 2009, press release "Military Experts from Five Continents Warn of Impact of Climate Change on Security," Institute for Environmental Security, Washington, D.C.

[17] See Thomas R. Karl, Jerry M. Melillo, and Thomas C. Peterson, 2009, *Global Climate Change Impacts in the United States,* Cambridge University Press, New York, pp. 25-47.

Measurements show that the 20th-century rate of global average sea-level rise is about 2 millimeters (mm) per year, and the rate of sea-level rise since 1993 has been measured to be about 3 mm per year.[18] This acceleration is consistent with an increase in the contribution from the melting of mountain glaciers and ice sheets on Greenland. However, the U.S. Naval Services cannot assume that the recent rate of sea-level rise will remain steady for the rest of the 21st century. Prudent planning and routine reevaluation of the rate and pace of change are necessary. The projected increased intensity of storms and storm surges also contributes to the anticipated increased vulnerability of naval coastal installations.[19]

Sea-level rise is not uniform around the globe, and the potential coastal impact of regional sea-level rise is not linear with elevation. Because of shifts in ocean circulation and the redistribution of mass in the global ocean, regional sea-level changes can vary from the global mean. Indexes of coastal vulnerability should take into account factors such as coastal topography, the local rate of relative sea-level rise, subsidence, regional extreme-weather history, population density, local freshwater supply sources, and critical infrastructure—such as communications, transportation, and utilities.

The committee reviewed an assessment of U.S. military coastal installations at risk from coastal inundations caused by sea-level rise.[20] Many of the 31 U.S. military installations identified in the assessment as being at "very high risk" or at "high risk" are naval installations. These data provide a starting point for more in-depth evaluations. As directed by requirements for the DOD's Quadrennial Defense Review (QDR), a broader analysis of global military coastal installations is also being conducted at this time.[21] This broader QDR-driven assessment will provide a foundation, but there is a clear need for a more detailed global analysis and an action plan to address the vulnerabilities of those coastal installations identified as being at very high risk and at high risk. The assumptions, decisions, and time lines for addressing these risks should be determined on a consistent basis across the DOD. The committee suggests that additional risk factors beyond the current indicators of sea-level rise, tidal range, and coastal geomorphology be included in future analyses: such additional risk factors as regional weather history and potential impacts on critical infrastructure, as outlined above, in addition to shifts in storm tracks, changes in ocean circulation, and the impact of groundwater drawdown and recharge on subsidence are critical. The committee believes that these analyses must explicitly address the broader issue of the potential for sea-level rise and more intense storm surges to impact critical military missions.

On the basis of presentations to the committee, there appear to be at least three separate Navy groups involved in the analysis of coastal-installation vulnerability issues for the Navy: the Space and Naval Warfare Systems Command (SPAWAR), the Naval Facilities Engineering Service Center (NAVFAC ESC),[22] and the Naval Installations Command.[23] Additionally, according to presentations

[18]Konrad Steffen, Director, Cooperative Institute for Research in Environmental Sciences, University of Colorado, "State of the Science for Sea-Level Rise Data," presentation to the committee, October 20, 2009, Washington, D.C.

[19]See Thomas R. Farl, Jerry M. Melillo, and Thomas C. Peterson, 2009, *Global Climate Change Impacts in the United States,* Cambridge University Press, New York, pp. 114, 149.

[20]For this particular assessment, the U.S. Geological Survey's Coastal Vulnerability Index (CVI) was used. This index estimates risks of impact related to sea-level rise using a set of factors such as rate of sea-level rise, tidal range, and coastal geomorphology. See MajGen Richard Engel, USAF (Ret.), Director, Climate Change and State Stability Program, National Intelligence Council, "National Intelligence Assessment on the National Security Implications of Global Climate Change to 2030," presentation to the committee, October 19, 2009, Washington, D.C.

[21]The 2010 Quadrennial Defense Review (QDR) is a legislatively mandated (USC 10, Sec. 118 [a]) review of the Department of Defense strategy and priorities. The review takes place every 4 years and will be provided to Congress in early 2010. For the first time, the 2010 QDR is explicitly asked to include climate-change trends in its address of the national strategic and security environment. See U.S. Department of Defense, "2010 QDR Terms of Reference Fact Sheet," April 27, 2009, Washington, D.C.

[22]See for example, Kathleen Paulson and Dallas Meggitt, 2008, *US Naval Facilities Engineering Service Center Environmental Program on Climate Change,* Naval Facilities Engineering Service Center, Port Hueneme, Calif.

provided to this committee, prior to the QDR request the U.S. Marine Corps began conducting an analysis of its U.S. coastal-installation vulnerabilities.[24] Also, the DOD's Strategic Environmental Research and Development Program (SERDP) has initiated climate-change-related military infrastructure studies.[25] This committee believes that to avoid duplication of effort and to ensure a more comprehensive and consistent assessment, a more coordinated vulnerability analysis is needed across the naval installations nationally and internationally and in conjunction with all Services.

Considering the current measurements for sea-level rise, a major resource investment is not anticipated to be required by the Navy in the near term (the next 5 years), with the exception of those naval installations identified as being at very high risk. However, in the longer term (the next 20 to 30 years), investments will have to be made for the adaption of many naval coastal installations, and those investments may have implications for decisions being made today.[26] The committee will address this issue more fully in its final report, but it believes that the current preliminary naval coastal-installation vulnerability assessment underway in support of the QDR is a good starting point and reflects a prudent course of action. The committee has not reviewed detailed vulnerability data associated with Navy Base Diego Garcia and Navy Base Guam. However, based on publicly available coastal-elevation data, the committee believes that these two naval bases may require special short-term attention and, potentially adaptive measures.

Finding 2: U.S. Navy, Coast Guard, and Marine Corps coastal installations around the globe will become increasingly susceptible to projected climate events. Several assessments now being made of naval-installation vulnerabilities appear to be focused primarily on sea-level rise and coastal inundation only. According to these current assessments, some adaptive actions are indicated owing to already-identified vulnerabilities at specific naval installations. The preliminary review of climate-change-related base vulnerabilities across the DOD—currently underway as directed by the requirements for the Quadrennial Defense Review—does not include all of the important factors affecting coastal-installation vulnerabilities, but it does provide a baseline assessment across all Services and a starting point for more in-depth analysis.

Recommendation 2: The Commander, Naval Installations Command, and the Navy Director for Fleet Readiness and Logistics should work with their U.S. Coast Guard and Marine Corps counterparts—and in conjunction with other Services and the Office of the Secretary of Defense—to ensure that a coordinated analysis of naval mission vulnerability is undertaken in order to address naval-installation vulnerability to rising sea levels and higher storm surges. Such an approach is necessary to avoid duplication of effort and to ensure that a more uniform and comprehensive evaluation is undertaken. For Program Objective Memorandum (POM)-14 planning purposes, the CNO should prepare to invest in early-stage mitigation and adaptation for targeted low-elevation naval installations identified in current vulnerability assessments as being at

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[23]CAPT Brant Pickrell, USN, Deputy Director, Shore Readiness, Commander, Naval Installations Command, "Preliminary Climate-Change-Related Naval Base Assessments—A Status Report," presentation to the committee, October 19, 2009, Washington, D.C.

[24]Elmer W. Ransom, Environmental Management Section, Headquarters, U.S. Marine Corps, and Capt Anthony V. Ermovic, USMC Facilities Branch Head, Headquarters, U.S. Marine Corps, "Marine Corps Perspectives and Climate Change Initiatives," presentation to the committee, September 18, 2009, Washington, D.C.

[25]The Office of the Secretary of Defense's Strategic Environmental Research and Development Program currently sponsors several projects related to the assessment of the impact of global sea-level rise on military infrastructure. These projects are managed under SERDP's Sustainable Infrastructure Projects Program. Descriptive information on these projects (SI-1700, -1701, -1702, and -1703) is available at http:/www.serdp.org/Research/SI-Facilities-Management.cfm. Accessed November 23, 2009.

[26]The Navy's needs, if any, would be reflected in Program Objective Memorandum (POM) submissions. The POM submission is a 5-year outlook on budget requirements. It starts with the year following the President's Budget, which is always 1 year ahead of the current year.

very high risk from more intense storm surges and other climate impacts. Other risks for naval installations as a result of projected climate change require further analysis and planning at this time but no immediate direct additional substantial investment beyond current budget plans.

3. Naval Capabilities and Potential Climate-Change-Related Operational Issues in the Arctic

Projected global climate change may have its most immediate and obvious implications for maritime operations in the Arctic region. The Arctic provides dramatic evidence of recent trends in global climate change as demonstrated by the continued significant reduction in summer sea-ice cover in the Arctic Ocean and the rapid disappearance of older, thicker, multiyear ice.[27] A result of this change is greater summer marine access and longer seasons of potential navigation. The committee does not expect that there will be routine commercial shipping in the Arctic in the foreseeable future, but a notable increase in private tourism and exploration traffic through the region is already occurring.[28] In addition, the U.S. Geological Survey notes that significant natural resources (oil, natural gas, and nonfuel minerals) may become increasingly available for exploitation as ice melts.[29] The physical indicators at hand and the current model projections provide strong evidence that future requirements for U.S. maritime operations in the Arctic will increase over the next 30 years.[30] The committee offers the following initial observations regarding naval Arctic operations.

Key Arctic Operational Challenges

Operating in the Arctic is not, at present, a priority for the Navy, although an increase in Arctic presence and operations *is* a priority for the Coast Guard. Unclassified national intelligence assessments suggest a low likelihood of significant conflict in the Arctic region in the foreseeable future.[31] However, the demand for Coast Guard missions is already increasing. The committee believes that it would be prudent for the Navy and the Coast Guard to establish a strong and consistently funded technology,

[27]On September 12, 2009, sea-ice extent reached a 2009 minimum of 5.1 million km^2. The summer minimum is the third-lowest recorded since 1979. While the 2009 minimum was an increase over that of the 2 previous years, it was still 1.6 million km^2 below the 1979-2000 average minimum. The March 2009 ice extent was 15.2 million km^2, the same as in 2008 and only 4 percent less than the 1979-2000 average of 15.8 million km^2. March is historically the month of maximum sea ice extent. See *Arctic Report Card: Update for 2009,* available at http://www.arctic.noaa.gov/reportcard/ArcticReportCard_full_report.pdf. Accessed November 24, 2009.

[28]Arctic Council. 2009. *Arctic Marine Shipping Assessment 2009 Report,* available at http://www.nrf.is/index.php/news/15-2009/60-arctic-marine-shipping-assessment-report-2009. Accessed November 24, 2009.

[29]See July 23, 2008, U.S. Geological Survey press release, "90 Billion Barrels of Oil and 1670 Trillion Cubic Feet of Natural Gas Assessed in the Arctic," available at http://www.usgs.gov/newsroom/article.asp?ID=1980&from=rss_home. Accessed November 23, 2009.

[30]An Arctic Roadmap has been prepared by the Navy Task Force Climate Change, and the committee was briefed on it. See CAPT(S) Timothy Gallaudet, USN, Deputy Director, Navy Task Force Climate Change, "Task Force Climate Change Update and Gaps and Projected Future Needs," presentation to the committee, October 19, 2009, Washington, D.C.

[31]See National Intelligence Council, *2025 Global Trends Report,* November 2008, p. 53, available at http://www.dni.gov/nic/PDF_2025/2025_Global _Trends_Final_Report.pdf. Accessed November 24, 2009. This unclassified report states in part: "Although serious near-term tension could result in small-scale confrontation over contested claims, the Arctic is unlikely to spawn major armed conflict. Circumpolar states have other major ports on other bodies of water, so the Arctic does not pose any lifeblood blockade dangers. Additionally, these states share a common interest in regulating access to the Arctic by hostile powers, states of concern or dangerous non-state actors; and by their shared need for assistance from high-tech companies to exploit the Arctic's resources."

environmental data-gathering, and modeling foundation that can support a surge in operations.[32] Both the Navy and the Coast Guard should create a foundation of operational experience in the Arctic so that the challenges are well understood by a significant portion of U.S. naval forces in the following three areas:

1. *Port/Airbase Facilities.* Arctic distances are vast, and U.S. naval support infrastructure capabilities are sparse at best in that region. The distance from the southern coast of Alaska (where there are permanent U.S. Coast Guard bases) to the northern coast (where there are limited temporary facilities during the summer months) is approximately 800 nautical miles. The ability of the U.S. Coast Guard to execute its mission responsibilities in the Arctic is marginal, although there have been summer Coast Guard operational exercise surges in the Arctic during the past 3 years. The major review of Coast Guard requirements now underway will better inform the need for protecting U.S. national security interests in the Arctic.[33] Continued Coast Guard summer operations will strengthen the U.S. national presence and capabilities in the Arctic.

2. *Command, Control, Communications, Computers, Intelligence, Surveillance, and Reconnaissance (C4ISR) Infrastructure.* The robust set of geosynchronous Earth orbit (GEO) satellites provides reliable communications for locations below 65°N or above 65°S. High-data-rate satellite communications are sparse over the polar regions. However, commercial low-rate service is available. Additionally, Global Positioning System (GPS) constellation coverage is not optimized for polar regions, and so its accuracy is reduced, but still provides adequate performance for surface navigation. The committee believes that particular attention to the enhancement of satellite communications is vital, because the requirements will become more compelling as Arctic operations increase.[34]

3. *Icebreakers.* The Navy has no surface combatants hardened for ice operations. Additionally, a recent report by the National Research Council highlighted the fact that the nation has only three multimission polar icebreakers, two of which are at the end of their designed service lives.[35] One of the icebreakers is currently in caretaker status, and the operating budgets of all three are controlled by the National Science Foundation. Considering projected increases in resource development, maritime transportation, and international competition in the Arctic, U.S. icebreaking resources are clearly inadequate for meeting national needs. This deficiency is particularly significant given the recent and continuing investment in icebreaking resources by other countries, including China, Russia, Japan, South

[32]As examples of past Navy Arctic engagement, the Office of Naval Research's Arctic research funding has dropped from about $30 million per year in the early 1990s to about $3 million per year currently. Also, the U.S. Navy's Cold War Arctic Infrastructure no longer exists. See Richard F. Pittenger and Robert B. Gagosian, 2003, "Global Warming Could Have a Chilling Effect on the Military," *Defense Horizons*, No. 33, p. 7, October.

[33]National Security Presidential Directive (NSPD) 66 of January 2009 establishes the policy of the United States with respect to the Arctic region and outlines national security and homeland defense interests in the region. In part, NSPD 66, Article III B 1, states that these interests include "such matters as missile defense and early warning; deployment of sea and air systems for strategic sealift, strategic deterrence, maritime presence, maritime security operations, and ensuring freedom of navigation and overflight." The implementation of NSPD 66 will require multiagency and full government participation. For its part, the U.S. Coast Guard has commissioned a study—the USCG High Latitude Study anticipated to be completed in mid-2010—to better define its needs to support this Arctic directive, as the committee learned in a discussion with ADM Thad Allen, Commandant, U.S. Coast Guard, November 20, 2009, Washington, D.C.

[34] Related to this, the committee reviewed information on national imaging capabilities that may become increasingly important as Arctic activities increase. Information on national imaging capabilities and the Global Fiducials Library is available at http://gfl.usgs.gov/. Accessed November 29, 2009.

[35]The three U.S. Coast Guard icebreakers are the *Polar Star,* commissioned into service in 1976; the *Polar Sea,* commissioned in 1978; and the *Healy,* commissioned in 2000. Each vessel was designed for a 30-year service life. The *Polar Star* has been in caretaker status since 2006. The *Polar Sea* is in operational condition but, because of its age, requires increasing amounts of maintenance to remain in operation. See National Research Council, 2006, *Polar Icebreakers in a Changing World: An Assessment of U.S. Needs,* The National Academies Press, Washington, D.C. See also Ronald O'Rourke, Congressional Research Service (CRS), 2009, *Coast Guard Polar Icebreaker Modernization: Background, Issues, and Options for Congress,* CRS 7-5700, RL34391, Washington, D.C., May 29.

Korea, and the European Union.[36] Icebreakers are an important naval force component that will be necessary to sustaining Arctic operations. The defining of future Coast Guard icebreaker needs and investment strategy, including the feasibility of rehabilitating existing vessels, is an imperative.

The design of the next generation of surface combatants should incorporate deliberate consideration of operating in ice-covered seas. For the Navy, a recent report by the Center for Naval Analyses noted that current surface combatants might be modified or retrofitted for Arctic operations by having steel added around the waterline but that this would provide only marginal capability.[37] Ice-capable operation requires not only hull protection, but also strengthened propellers, rudders, seawater intakes, and so on. In this committee's opinion, it is better to build ice-capable ships from the ground up, either by incorporating the capability into current designs or by redesigning a new class of vessels, as Norway and Denmark are reportedly doing. It may also be wise to build more robust under-ice capability into some fraction of future Virginia-class nuclear-powered attack submarines (SSNs) to support the projected increase in under-ice missions.[38]

Importance of Strong Maritime Partnerships

The committee recognizes that policy decisions and associated trade-offs against current national defense priorities will be necessary before additional Arctic-related resources are allocated. However, if Arctic sea ice continues to retreat at a rapid pace and the Arctic region becomes truly ice-free during the summer months as predicted by the upper-end projections—such as those adopted by the Navy Task

[36]For example, a 2006 National Research Council report that lists a world inventory estimate of polar and Baltic icebreakers states that Russia has by far the largest fleet of icebreakers, although some of them are aging and some are used to keep supply lines open to Russia's Arctic coastal settlements. Data in the 2006 study indicate that Russia has 18 icebreakers, 7 of which are nuclear-powered; Finland and Sweden are reported to have 7 icebreakers each; and Canada is reported to have 6 icebreakers. See National Research Council, 2006, *Polar Icebreakers in a Changing World: An Assessment of U.S. Needs*, The National Academies Press, Washington, D.C., pp. 57-59. China, Japan, and South Korea have also made recent investments in new icebreakers targeted for polar research. For example, see "China to Build Own Icebreakers for Poles," available at http://www.shanghaidaily.com/sp/article/2009/200910/20091008/article_415716.htm. Accessed November 24, 2009.

[37]Michael D. Bowes. 2009. *Impact of Climate Change on Naval Operations in the Arctic,* CAB D0020034.A3/1REV, Center for Naval Analyses, Alexandria, Va., April.

[38]Public news articles have reported that the nuclear-powered-submarine *Texas* (SSN-775) and its 134-member crew recently completed an Arctic mission. The *Texas* reportedly broke through the ice near the North Pole and stayed on the surface for 24 hours and was the third U.S. submarine to visit the region in 2009. For deployment on Arctic missions, Virginia-class attack submarines such as the *Texas* reportedly carry an "Arctic sensor suite" similar to that carried by the older Los Angeles-class submarines that have previously traversed waters near the North Pole. This sensor suite is not a built-in capability, but instead only an add-on before deploying to an Arctic region. A Navy spokesperson has been quoted as saying that "Virginia-class submarines are not ice-hardened, and there are no plans to add ice-hardening to their designs." See "Loose Cannon and Nuclear Submarines," *CanWest News Service,* November 16, 2009, and "VA-Class Submarines Carry Arctic Sensor Suite in Northern Waters," *Inside the Navy*, November 30, 2009.

Force Climate Change[39]—the current naval asset posture may be insufficient for the U.S. Navy's maritime domain awareness strategy and insufficient to support U.S. national security interests.[40]

In the committee's opinion, strong maritime partnerships will be an important component of Arctic engagement. The U.S. Coast Guard reported to the committee that it is increasing its maritime partnerships with other Arctic nations,[41] and the committee sees a need for such partnerships in the Arctic region (including bilateral and multinational alliances) to be strengthened and extended for both the Navy and the Coast Guard.[42] This should involve particular attention to cooperation with Canada, with the potential for the sharing of facilities and capabilities.

There are also national and international policy implications for naval operations in the Arctic. For example, the fact that the United States has signed but not yet ratified the United Nations Convention on the Law of the Seas (UNCLOS)[43] will become even more problematic with time and as more states call for international recognition of their claims in the Arctic. The UNCLOS provides a legal framework for the settlement of such disputes.[44]

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[39]Throughout this report, the term "ice-free" is used to mean that sea ice is diminished to the point that ice-hardened vessels are not required for safe navigation. In the near term, ice-laden Arctic waters will continue to have an ice cover of variable thickness and duration and will continue to pose navigational hazards for non-ice-hardened vessels. The Navy Task Force Climate Change uses a projection of ice-free summer months in the Arctic by the year 2030 based on work conducted for the Department of Defense by the Oak Ridge National Laboratory using outputs from the Community Climate System Model version 3 (CCSM3). See Karsten Steinhaeuser, Esther Parish, Alex Sorokine, and Auroop R. Ganguly, 2009, "Projected State of Arctic Sea Ice and Permafrost by 2030," Oak Ridge National Laboratory, Oak Ridge, Tenn.

[40]For example, see U.S. Navy, "Maritime Domain Awareness Concept" (MDA 2007), available at http:www.navy.mil/navydata/cno/Navy_Maritime_Domain_Awareness_Concept_Final_2007.pdf. Accessed November 23, 2009. See also U.S. Navy, Marine Corps, and Coast Guard, "Cooperative Strategy for 21st Century Seapower," available at http:www.navy.mil/maritime/MaritimeStrategy.pdf. Accessed November 23, 2009. Also, recent news articles report that Russia's Security Council has publicly outlined plans to create a dedicated Arctic military force to protect the country's interest in the Far North. One goal of the plan is "to increase the effectiveness of cooperation with the border agencies (coast guards) of neighboring states in the fight against terrorism on the high seas, combat illegal migration and defend marine life and resources." See "Russia's New Arctic Fighting Force," available at www.wired.com/dangerroom/2009/russias-new/. Accessed November 24, 2009.

[41]CAPT James J. Fisher, USCG, Chief, Office of Policy Integration, Headquarters, "The Coast Guard Has 143 Years of Arctic Service," presentation to the committee, September 18, 2009, Washington, D.C.

[42]See National Research Council, 2008, *Maritime Security Partnerships,* The National Academies Press, Washington, D.C.

[43]The United Nations Convention on the Law of the Seas (UNCLOS) comprises 320 articles and 9 annexes governing all aspects of ocean space, including marine scientific research, commercial activities, the permissible breadth of the territorial sea (the part of the ocean nearest the shore, over which the coastal state enjoys sovereignty), and the settlement of disputes relating to ocean matters. A full profile of the UNCLOS, its origin, and its original issues is provided in a publicly available report, *Law of the Sea: The End Game, Intelligence Community Assessment,* published by the National Intelligence Council in 1996. The report is available at http://www.dni.gov/nic/special_endgame.html. Accessed November 23, 2009.

[44]U.S. Navy and U.S. Coast Guard leadership have provided public testimony on the potential value and impact of UNCLOS ratification on U.S. naval operations. For example, the congressional testimony of former Chief of Naval Operations Admiral Vernon Clark states that the Law of the Sea Convention "supports our ability to operate wherever, whenever, and however needed under the authority of widely accepted law. The Convention codifies the right to transit through, over, and under essential international straights and archipelagic waters. It reaffirms the sovereign immunity of our warships and other public vessels. . . . And it preserves our rights to conduct military activities and operations in exclusive economic zones without the need for permission from or prior notice to foreign governments." See Statement of Admiral Vernon Clark, U.S. Navy (Ret.), former Chief of Naval Operations, to the United States Senate Committee on Foreign Relations. Available at www.virginia.edu/colp/pdf/ClarkTestimony071004.pdf. Accessed December 14, 2009.

Finding 3: Activities in the Arctic sponsored by commercial enterprises and nation-states are increasing. However, neither the U.S. Navy nor the U.S. Coast Guard is currently well equipped for increased maritime operations in the Arctic, or for what might become contentious positioning for territorial sovereignty and for natural resources among bordering nations. This situation may pose a risk for future U.S. national security in the longer term owing to the inability of current U.S. naval assets to project a routine military presence in the region, despite the opening of new sea-lanes. Partnerships with other nations will help mitigate this risk, although the U.S. failure to ratify the United Nations Convention on the Law of the Seas (UNCLOS) exacerbates the matter.

Recommendation 3: The Chief of Naval Operations should support the initiatives of the Commandant of the U.S. Coast Guard to define future Coast Guard icebreaker needs, as well as return operational control to the Coast Guard as soon as possible. The committee sees a need in the Arctic region for increased partnerships, including bilateral and multinational alliances. These partnerships should be strengthened and extended for both the Navy and the Coast Guard. The CNO should also continue his efforts, together with other military and political leaders, to secure rapid U.S. ratification of the UNCLOS.

4. Climate-Change-Related Technical Issues Impacting Naval Operations, Particularly in the Arctic and at High Latitudes

In its initial deliberations, the committee identified four general areas of climate-change-related technical issues that may affect naval operations: antisubmarine warfare (ASW), sensors, communications, and information and charting systems. The committee's preliminary observations on these systems are offered below.

Antisubmarine Warfare

Global climate change is projected to have a growing impact on the properties and dynamics of the ocean. This committee received initial briefings on two areas associated with these changes: (1) the direct effect of changing thermal structure, ocean salinity, and acidification on the performance of acoustical sensors and torpedoes; and (2) the future viability of Navy databases that are used in tactical planning. The second of these is of more concern for naval warfighting capabilities, especially antisubmarine warfare.[45]

Warming of the upper layers of the ocean produces downward-refracting acoustical conditions, which exist routinely during the summer months throughout much of the world's ocean area. These conditions normally produce shorter acoustic detection ranges, but this is nothing inherently new or climate-change-related and is not outside the operating scope of current systems. Some ocean areas—most notably the high northern latitudes of the Atlantic—may also have reduced salinity in the upper layer due to freshwater input from melting land-ice and from higher than average precipitation and runoff into rivers. This reduced salinity may also affect acoustical propagation conditions, but, similar to the warming of upper layers discussed above, it produces nothing inherently outside the operating scope of current systems. In general, the U.S. Navy needs to monitor the changes in Arctic water mass on an ongoing basis, with the monitoring supported by high-resolution bathymetric data in the Navy's databases.

[45]This letter report addresses only the most immediate concerns of potential ASW implications in the Arctic. The committee has received briefings which suggest that potential increases in ocean acidification will have only minor effects on sound transmission; acidification thus does not receive expansive coverage in this letter report as an immediate item of concern. All aspects of the potential impact of increases in ocean acidification on naval operations, including the most recent research in this area, and broader climate change implications for ASW in the world's oceans, will be explored during the preparation of the committee's final report.

According to presentations to the committee, the ocean temperature and salinity data that currently support the Navy's ASW tactical planning may need attention. Fleet ASW platforms make tactical predictions based on in situ measurements of ocean temperature versus depth, using expendable bathythermographs (XBTs). These in situ measurements of temperature are then combined with historical measurements of salinity to produce profiles of sound velocity. The temperature data can be gathered by unmanned underwater vehicles (UUVs) and thermometry systems. The profiles are then used to calculate how sound will propagate and thus to determine how best to employ acoustic sensors. An altered ocean can cause two problems with this system: (1) The in situ XBT temperature profiles are compared to climatological values contained in the Navy's historical ocean-temperature databases. The committee was informed that if this in situ measurement deviates too much from historical norms, the actual, in situ reading is disregarded or assigned a different statistical weighting.[46] (2) As mentioned above, in some areas such as the high-latitude North Atlantic, the oceans may experience reduced salinity in their upper layers. Thus, the databases with historical data on salinity used in at-sea tactical predictions may be inaccurate and could lead to incorrect ASW decisions regarding employment of the acoustical sensors.

Sensors

Global Positioning System coverage for surface navigation is slightly degraded in the high latitudes (50-ft. horizontal precision has been demonstrated at the North Pole), but this coverage is adequate for the navigational purposes of surface ships. However, due to low satellite-elevation angles, GPS altitude precision in high latitudes is substantially degraded and may adversely affect certain aircraft operations. Taken together, these conditions make precision search-and-rescue operations difficult, especially in severe weather.

As ocean-floor surveys and mineral exploration operations increase in the Arctic, accurate underwater navigation and position fixing will become increasingly important. Although relative undersea navigation techniques are well developed, absolute-reference undersea navigation is not, and it should be further developed for this region. Additionally, interest in high-accuracy bathymetric data will accelerate. Satellites now provide abundant information about the retreat of Arctic ice caps, but data on ice thickness continue to be sparse. Innovative ways to obtain that data (such as through the use of UUVs or submarine upward-looking sonar) should be explored.

Communications

In general at the present time, commercial voice and low-data-rate communications in the high latitudes are robustly supported by Iridium satellites. However, as discussed above, high-data-rate communications provided by GEO-based satellites degrade quickly above 65° latitude and have no coverage at the poles. This inherent GEO limitation equally affects commercial communications and secure Geo-based military communications. Reliable high-data-rate communications coverage in high latitudes should be explored further.

[46]Naval operators do not actually throw out XBTs based on a fixed deviation from historical climatology data. Instead, they use statistical techniques that assign error probabilities (based on climatology and other factors) to each data point in the XBT, and then weight each data point when assimilating it into an ocean model run.

Information and Charting Systems

Accurate nautical charts of the Alaska region are limited. For example, the nautical charts of the region show vast areas that have never been surveyed or that have not been surveyed for years.[47] These limitations include widespread gaps in sounding and shoreline data on nautical charts of the region and 2-meter-level errors in the state geodetic positioning framework. There are also large gaps in tidal data and tidal-current-prediction coverage. These shortcomings have potential implications for U.S. naval operations in the broader Arctic region that the committee believes should be addressed in a review of high-latitude U.S. naval research needs.

Findings and Recommendations

Finding 4: Naval operations that depend on an accurate knowledge of the ocean's properties and of atmospheric conditions could be adversely impacted, based on projections indicating that Earth is continuing to warm, if the supporting ocean and atmospheric databases are not updated. Additionally, naval sensors, communications, satellite observation, and charting systems would be significantly challenged with respect to both capacity and performance in supporting expanded levels of naval operations in high latitudes.

Recommendation 4: The Department of the Navy (the Office of the Assistant Secretary of the Navy for Research, Development and Acquisition, in conjunction with the Office of Naval Research) should begin a critical review of climate-change-related research, technology, and supporting systems—especially those related to expanded naval operations in high latitudes. In addition, the Department of the Navy and the U.S. Coast Guard should reestablish a program of routine operations in the high latitudes to develop a better understanding of the requirements for improved performance of sensors, communications, satellite communications, and information and charting systems, as well as to plan for continual awareness of the state of the Arctic through a steady focus on data gathering and supporting research and technology development.

THE WAY AHEAD

The committee plans to continue its work over the coming months to provide an expanded and more comprehensive examination of the topics covered in this letter report and to complete its final report expeditiously. Furthermore, in the preparation of its final report, the committee plans to explore additional climate-change-related topics, such as the potential impacts on the hydrological cycle and regional freshwater balances, potential changes in disease vectors and marine and terrestrial ecosystems, and the ability of the naval forces to train and operate in more extreme weather conditions—including the potential for naval vessels to experience more severe and unpredicted storms at sea. The committee will also address the general topic of risk management for naval forces and will comment on the possible benefits of applying the U.S. Navy's unique ocean and ice scientific data collection capabilities to support and enhance the understanding of potential impacts of climate change critical to national security and future naval operations.

[47]NOAA is responsible for providing nautical charts of the Alaska region. The fundamental geospatial infrastructure that NOAA provides for the rest of the nation is lacking for Alaska and the Arctic, in particular. Alaska is the only state without digital shoreline imagery and elevation maps that meet nationally accepted standards. Also, the state's reference system has neither the density of control points to support submeter-level accuracies for surveying and positioning activities, nor vertical data coverage for the western half of the state to support the accurate determination of elevation heights. See CAPT James J. Fisher, USCG, Chief, Office of Policy Integration, Headquarters, "Waterways Management in the Arctic," communication to the committee, September 25, 2009.

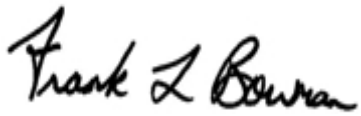
In the committee's opinion, U.S. maritime forces are more likely than other U.S. military forces to experience more direct impacts of climate change on their operations, installations, and missions. U.S. naval leadership should thus continue to exercise a strong voice and leadership in influencing the U.S. and international military adaptive response.

ACKNOWLEDGMENTS

The committee thanks Captain Timothy Gallaudet, USN, and it also thanks Commander Esther McClure, USN, for their invaluable work as early-stage liaisons to the committee and for their input on briefings for the committee to receive. Additionally, the committee thanks members of the Chief of Naval Operations staff, N81 in particular, and the leadership of the Navy Climate Change Task Force for meeting with the committee throughout the course of the study to date.

The committee would be very happy to brief you and your staff regarding the views expressed in this letter.

Sincerely,



ADM Frank L. Bowman, USN (Ret.), *Co-Chair*

Dr. Antonio J. Busalacchi, Jr., *Co-Chair*

Committee on National Security Implications of Climate Change for U.S. Naval Forces

Enclosures

A Terms of Reference
B Committee on National Security Implications of Climate Change for U.S. Naval Forces
C Acknowledgment of Reviewers
D Summary of Data-Gathering Sessions

Enclosure A
Terms of Reference

At the request of the Chief of Naval Operations, the Naval Studies Board of the National Research Council will establish a committee to study the national security implications of climate change for U.S. naval forces (i.e., the U.S. Navy, Marine Corps, and Coast Guard). Based on the Intergovernmental Panel on Climate Change assessments and other subsequent relevant literature reviewed by the committee, the study will:

1. Examine the potential impact on U.S. future naval operations and capabilities as a result of climate change (e.g., how will U.S. future naval operations be impacted and what capabilities will be needed for U.S. future naval forces as a result of climate change? This includes an assessment of the U.S. Coast Guard and Marine Corps, and where the U.S. Navy might be required to supplement or augment their capabilities).
2. Assess the robustness of the Department of Defense's infrastructure for supporting U.S. future naval operations and capabilities in the context of potential climate change impacts (e.g., are there any U.S. military installations and/or forward-deployed bases providing support to U.S. naval forces that are potentially vulnerable as a result of climate change?).
3. Determine the potential impact climate change will have on allied force operations and capabilities (e.g., are there any allies who may need U.S. naval force support as a result of climate change? Conversely, which allied force operations and capabilities may U.S. naval forces wish to leverage as a result of climate change?).
4. Examine the potential impact on U.S. future naval antisubmarine warfare operations and capabilities in the world's oceans as a result of climate change; specifically, the technical underpinnings for projecting U.S. undersea dominance in light of the changing physical properties of the oceans.

This 15-month study will produce two reports: (1) a letter report following the third full committee meeting that summarizes the immediate challenges for U.S. naval forces in addressing each of the four above areas, as well as recommends approaches to address these challenges; (2) a comprehensive report that addresses in greater depth the full terms of reference.

Enclosure B
Committee on National Security Implications of Climate Change for U.S. Naval Forces

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Enclosure C
Acknowledgment of Reviewers

This report has been reviewed in draft form by individuals chosen for their diverse perspectives and technical expertise, in accordance with procedures approved by the National Research Council's Report Review Committee. The purpose of this independent review is to provide candid and critical comments that will assist the institution in making its published report as sound as possible and to ensure that the report meets institutional standards for objectivity, evidence, and responsiveness to the study charge. The review comments and draft manuscript remain confidential to protect the integrity of the deliberative process. We wish to thank the following individuals for their review of this report:

Robert Duce, Texas A&M University,
Florence Fetterer, University of Colorado, Boulder,
Paul G. Gaffney II, VADM, USN (Ret.), Monmouth University,
Jacques Gansler, University of Maryland,
James D. Hull, VADM, USCG (Ret.), Annapolis, Maryland,
William A. LaPlante, Johns Hopkins University, Applied Physics Laboratory,
Joseph Pedlosky, Woods Hole Oceanographic Institution, and
John E. Rhodes, LtGen, USMC (Ret.), Balboa, California.

Although the reviewers listed above have provided many constructive comments and suggestions, they were not asked to endorse the conclusions or recommendations, nor did they see the final draft of the report before its release. The review of this report was overseen by Robert A. Frosch of Harvard University. Appointed by the National Research Council, he was responsible for making certain that an independent examination of this report was carried out in accordance with institutional procedures and that all review comments were carefully considered. Responsibility for the final content of this report rests entirely with the authoring committee and the institution.

Enclosure D
Summary of Data-Gathering Sessions

The Committee on National Security Implications of Climate Change for U.S. Naval Forces first convened in September 2009 and held three full committee meetings prior to issuing this letter report. In addition to deliberating on its tasks and approach and preparing its letter report, the committee also participated in the data-gathering sessions at these meetings, which are summarized below.

- *September 17-18, 2009, in Washington, D.C.* First full committee meeting: Briefings on current climate-change and energy-related initiatives from the Navy Task Force Climate Change; the Navy Task Force Energy; the Navy Quadrennial Defense Review Integration Group; the Office of the Deputy Chief of Naval Operations for Integration of Capabilities and Resources (N81); the Office of Facilities Branch Head, U.S. Marine Corps; the Office of Environmental Management Section, Headquarters, U.S. Marine Corps; and the Office of Policy Integration, Headquarters, U.S. Coast Guard. Additionally the committee received briefings on recently completed climate-change-related reports by the Center for New American Security, the CNA Corporation, and the National Research Council.
- *October 19-20, 2009, in Washington, D.C.* Second full committee meeting: Briefings on climate-change-related national security issues, naval installation vulnerabilities, and current research activities by representatives from the National Intelligence Council, Woods Hole Oceanographic Institution, Oak Ridge National Laboratory, the Navy Task Force Climate Change, Naval Installations Command, the Office of Naval Research, the U.S. Geological Survey, the National Ice Center, the National Oceanic and Atmospheric Administration, the University of Washington, and the University of Colorado.
- *November 19-20, 2009, in Washington, D.C.* Third full committee meeting. Briefings on human dimensions, allies' perspectives, water resource issues, and maritime operational perspectives of climate change from Columbia University's Center for International Earth Science Information Network, the Pacific Institute for Studies in Development, Environment, and Security, the British Defence Staff of the United States British Embassy, the Office of the Deputy Chief of Naval Operations for Information Plans and Strategy, and the Commandant, U.S. Coast Guard.