Assessment of Construction Techniques and Innovative Materials for Military Engineering in Cold Regions

Office of the Deputy Assistant Secretary of Defense
(Facilities Investment and Management)
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The estimated cost of this study for the Department of Defense is approximately $20,000 in Fiscal Years 2017 - 2018. This includes $18,000 in expenses and $2,380 in DoD labor.
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Purpose

Respond to House Report 114-537 accompanying H.R. 4909, the National Defense Authorization Act for FY 2017:

Innovative Construction Materials and Design Process for Military Engineering in Cold Regions

The committee is concerned that the Department of Defense may face challenges to operating in the Arctic, sub-Arctic, and other extreme cold environments, should the need for operations arise. The committee is aware that the Department of Defense is developing an implementation plan for the National Strategy for the Arctic Region. The committee notes that the implementation of the plan may entail engineering challenges such as ability to construct, maintain, and retrofit horizontal and vertical infrastructure in cold regions. Therefore, the committee directs the Secretary of Defense to perform an assessment of advanced adaptive construction techniques and innovative materials needed to address the challenges of changing physical environments which will enable the Department of Defense to rapidly project force in austere cold regions. The committee directs the Secretary of Defense to provide a briefing to the House Committee on Armed Services, no later than March 1, 2017, on the results of the assessment and the requirements for adaptive construction techniques and innovative materials for extreme cold environments.

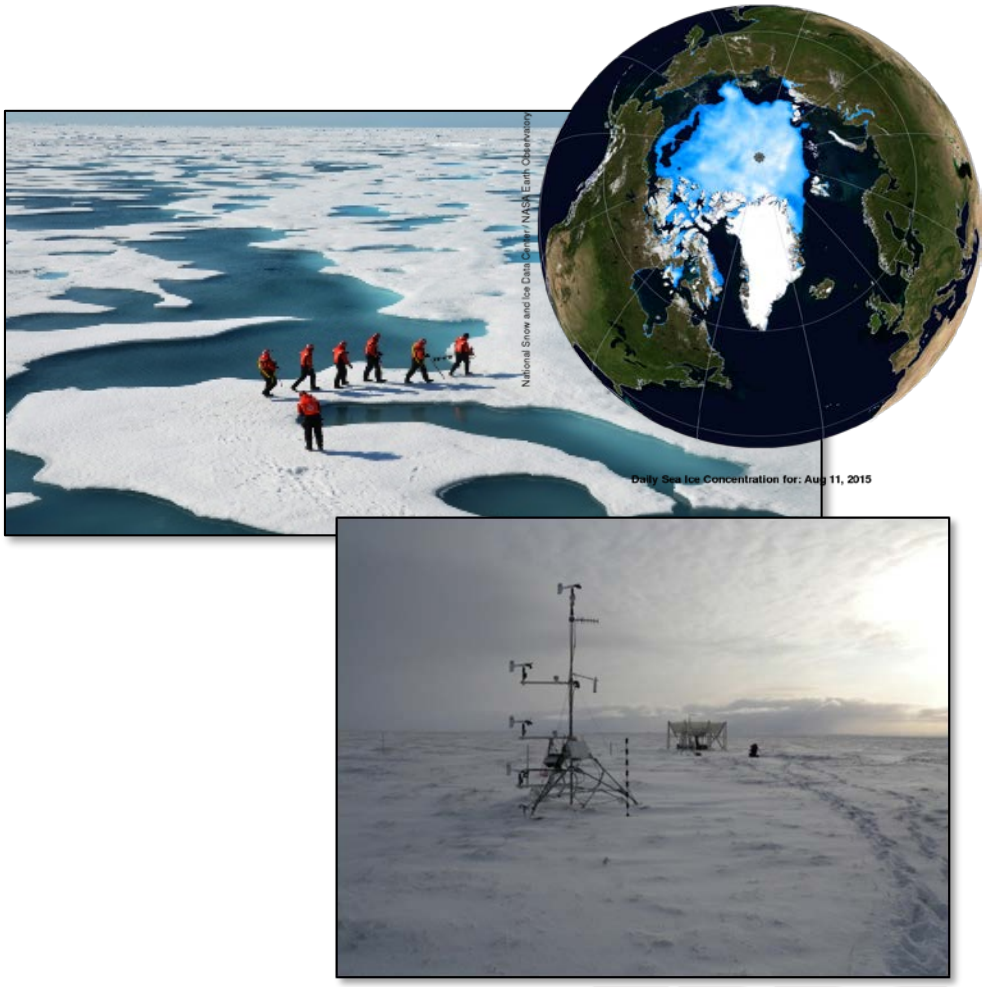
The briefing is late because the Department needed to identify funding sources and to obtain CRREL technical expertise to perform the research and develop the briefing.

Assessment Overview

- The Arctic environment and its requirements
- Proven past DoD Arctic and sub-Arctic construction methods and materials
- Recent advances and emerging technologies in construction techniques and materials applicable to DoD Arctic operations
- Additional innovation required to fully meet DoD requirements in Arctic operations

The Arctic Domain

- Vast, remote and largely inaccessible
- Variety of environments, with low winter temperatures and high winds
- Geopolitical shifts are occurring in the region due to climate warming
- Arctic domain awareness is key to the DoD Arctic strategy



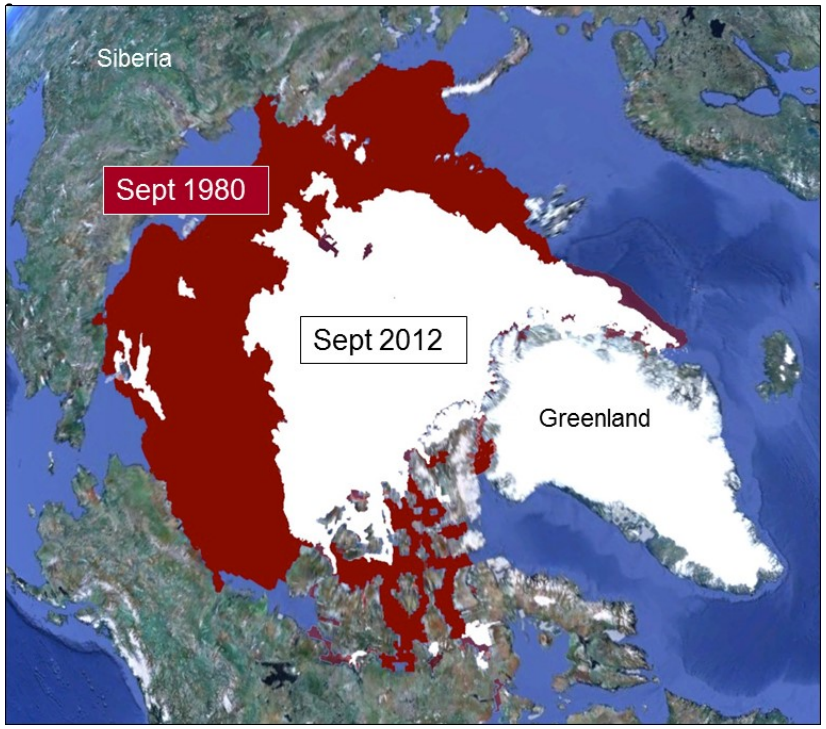
The Changing Arctic

A warming climate has resulted in…

- *Increased accessibility*
  - Maritime traffic
  - Resource extraction
  - Tourism

And this equates to….

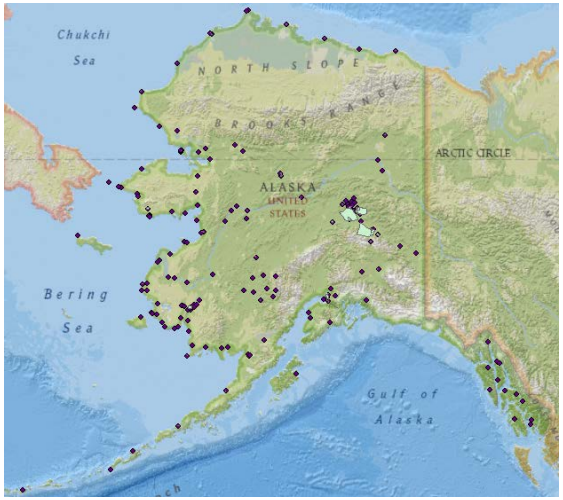
- *Increased development*
  - Stations, bases, towns
  - Roadways and airfields
  - Ports



September 2012: 3.5 million square kilometers

Current Installations

- Alaska: Five large installations (Joint Base Elmendorf Richardson, Ft. Wainwright, Eielson AFB, Clear AFS, and Ft. Greely); numerous surveillance and tracking stations
- Canada: numerous surveillance and tracking stations
- Greenland: One large installation (Thule AB)



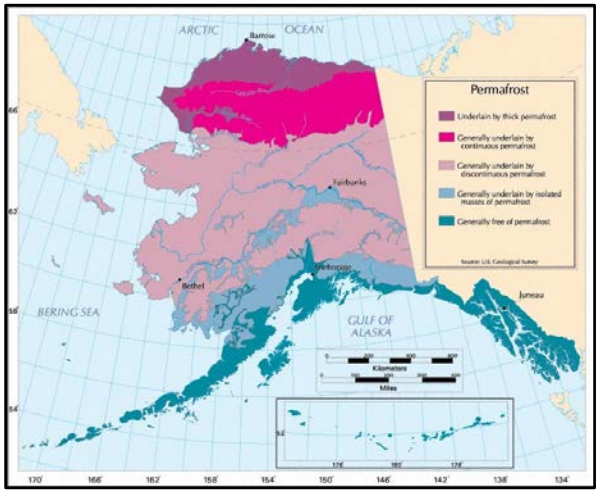
Defense Installations Spatial Data Infrastructure (DISDI); May 2016

IcyLands, Univ. of Washington 2010

Requirements in the Arctic

- High-performance materials: lightweight, high-strength, resistant to freeze/thaw cycles, resistant to thermal expansion and contraction, durable in extreme cold, high thermal efficiency
- Minimized logistics: provide for rapid installation with minimal logistics footprint at remote locations
- Retrofit capable: readily re-purposed and reconfigured

Structure Icing



Varying Permafrost Terrains

Extreme Snow Loading

Proven Construction Methods

- Pre-manufactured Insulated and Interlocking Panels:
  - Used to construct most structures on Thule AB, Greenland, from July to October 1951
  - Are still in use today and are easily re-purposed
- Pre-made Panels Assembled On-Site:
  - Used to construct 63 surveillance and tracking radar stations across Alaska, Canada, and Greenland from 1952 to 1956
  - Prefabricated insulated panels (similar to the Thule AB panel) shipped to Alaska, assembled into structures in a heated hangar, and further transported to specific sites for permanent placement
  - Are still in use today and providing excellent service

Thule AB

DYE-3 radar facility on Greenland ice cap - 1977

Emerging Technologies

Recent innovations in materials

- Cold-weather concrete (US Army ERDC – CRREL): Depressed freezing point via admixtures facilitates longer construction season
- Cellular concrete (US Army ERDC – CERL): Lightweight and high insulation value for use in structural panels
- Flexible polyethylene piping (commercial industry): Facilitates utility distribution in sub-freezing environments
- Engineered insulation (3M, Dow): Increased R-values with increased strength and resistance to water absorption

Cold weather concrete

Non-freeze-bursting pipe

Emerging Technologies (cont.)

Mobile Additive Manufacturing (MAMDFI)

- On-site construction via 3-D printing or other expedient process using polymer/carbon fiber, foam, concrete, or indigenous material
- High-strength space frames, beams, forms and obstacles
- Meets requirements to minimize logistics, increase durability, and increase energy efficiency
- Mature technology for temperate applications, but not for Arctic applications
- R&D conducted by US Army ERDC-CERL, Oak Ridge National Laboratory, NASA, and various universities

Mobile Additive Manufacturing

3-D Printing

Emerging Technologies (cont.)

Rapid-strength-gain indigenous materials

- Geo-polymers with rapid strength gain (24-48 hours)
- Carbonate cement produced onsite using local feedstocks
- Cellulose fibers (sisal, jute, burlap) to improve mechanical performance
- Meet requirements to minimize logistics
- Technology is in infancy for temperate and Arctic applications
- R&D conducted by US Army ERDC-CERL, Oak Ridge National Laboratory, industry

Chips of woody fiber

Formed Mineral Slurry

Emerging Technologies (cont.)

Rapid Installations Component Construction (RICC)

- Manufactured wall, floor, and ceiling panels
- Reutilized ISO shipping containers
- High thermal and logistics efficiency
- Meets requirements to minimize logistics; precludes pre-manufacture or staging of components
- Mature technology for temperate applications, but not for Arctic applications
- R&D conducted by US Army ERDC-CERL and industry

Rapid Deployable Facilities

Large scale camp systems

Technology Gaps

#1 Arctic requirement: expedient infrastructure

- Durable and adaptable encampment design
- Rapid-assembly, interlocking, interchangeable components
- Modules easily reconfigurable in the field
- Incorporation of innovative materials to achieve mission specs and service life goals
- Indigenous minerals and fibers
- Lightweight and strong structural and sheet materials
- Minimize need for large pre-stockpiling
- Facilitate use of CONUS-manufactured or on-site manufactured elements

On-site frame and truss manufacture demonstration – Ft. Bragg

Finished demonstration structure

Conclusions

- Future Arctic force projection will require durable, useful, efficient, and adaptable infrastructure
- Lessons learned from Cold War-era projects are informing technology development and future solutions
- Rapid Installations Component Construction (RICC) may provide an effective solution, but still needs refinement for large-scale production
- Other promising methods and materials are in early stages of development