DoD Arctic Infrastructure - Technology Gaps and Research Needs

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SERDP • ESTCP SYMPOSIUM
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Agenda

- DoD and the Arctic
- Climate warming related issues
- Refined engineering parameters
- Contingency basing
- Arctic construction
- Energy production and distribution
- Site determinations
- Mitigation and repair strategies

US ARC

US DoD

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Background

- U.S. DoD currently operates five major installations, and many dozens of minor installations in Arctic/sub-Arctic regions
- These regions are vast, frozen terrains with difficult climatic conditions
- DoD has a long and storied past with operations and installations in the Arctic
- New missions may require additional temporary or longer term installations
- Technology and engineering advances have occurred, however gaps still exist

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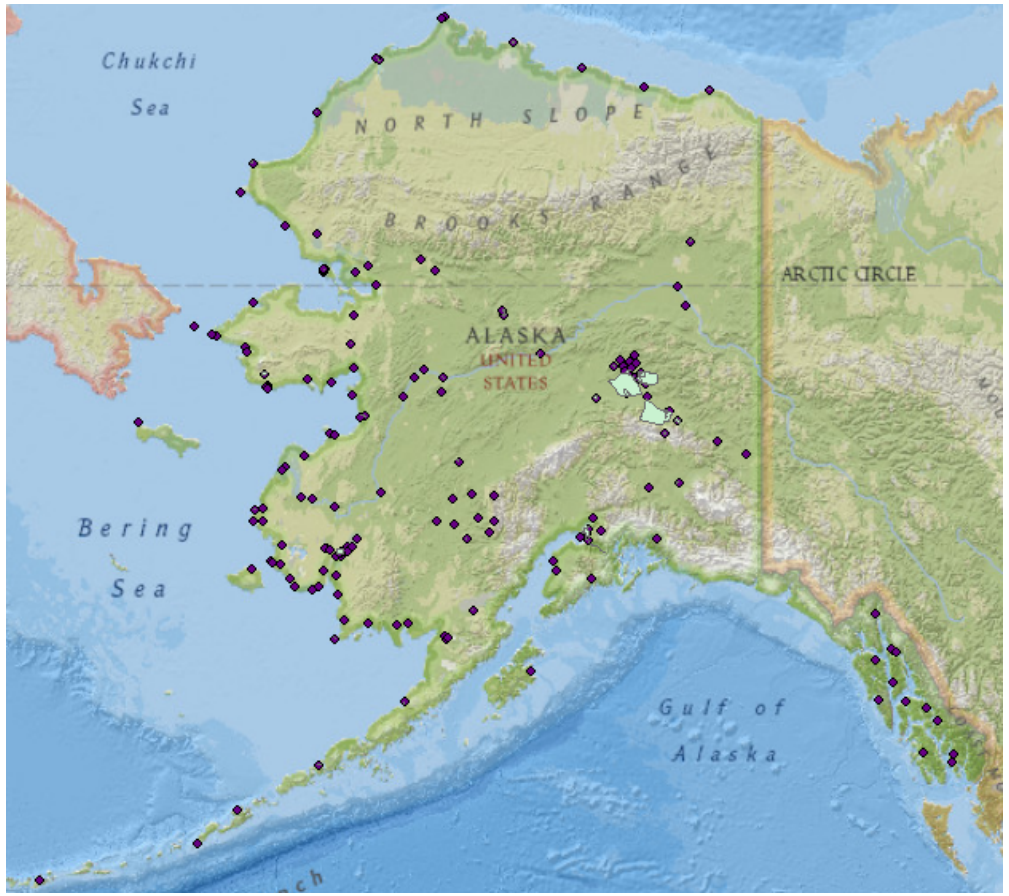
Arctic and Subarctic Installations

- Alaska – 5 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 – 1 large installation (Thule AB)



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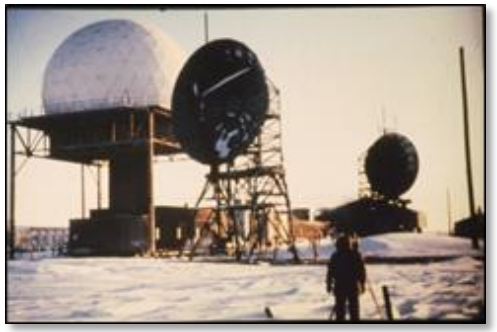
Challenges

- Extreme cold, high winds, and darkness
- Very remote with difficult logistics
- Ice-rich founding soils are good when frozen but cause severe problems upon thawing
- Snow and ice accumulation can be severe causing adverse effects
- Energy consumption is high, use is critical, and cost is high



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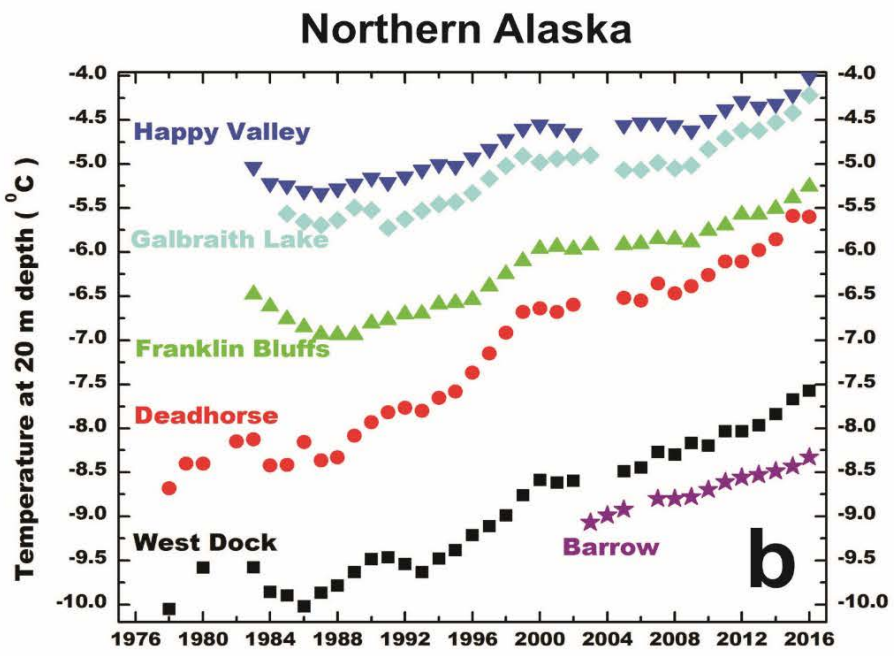
Climate Warming

Vast, austere, and rapidly changing environment

- Air temperatures have been rising, and are expected to rise many degrees by end of the century
  - In response, permafrost temperatures have been rising since the late 1970's
  - Far northern locations in Alaska have increased over 2°C
  - Worst case scenarios further increase permafrost temperatures another 4° to 5°C by end of the century



PF Temps (Romanovsky)

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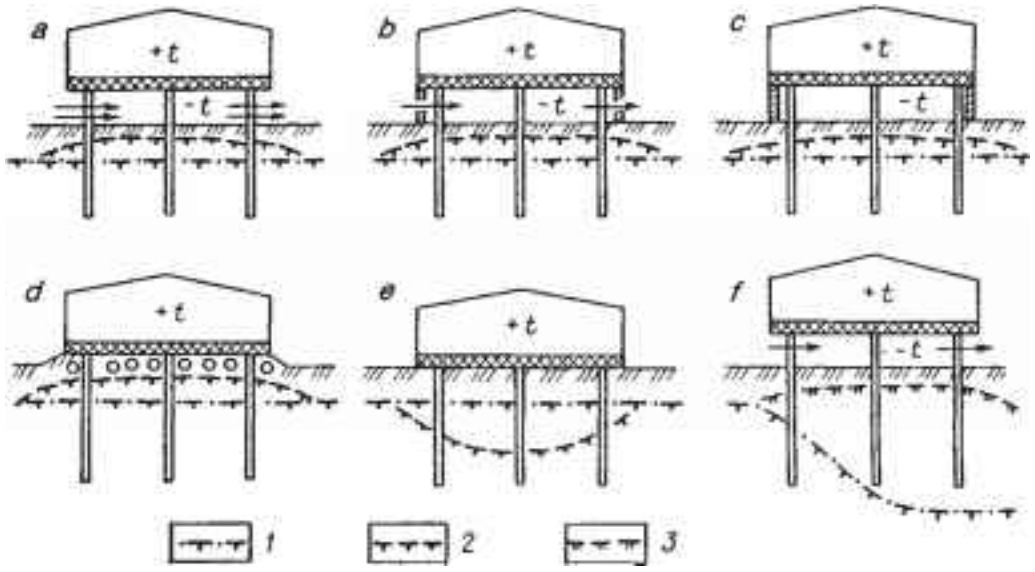
Geotechnical

- Permafrost temperature is very important for infrastructure design
- Methodology is needed to assist engineers and planners with forecasting of future permafrost temperatures
  - Requirements:
  - Consistency and repeatability
  - A ‘living’ guideline, automatically updated with latest climate prediction
  - Flexible via multiple scenarios



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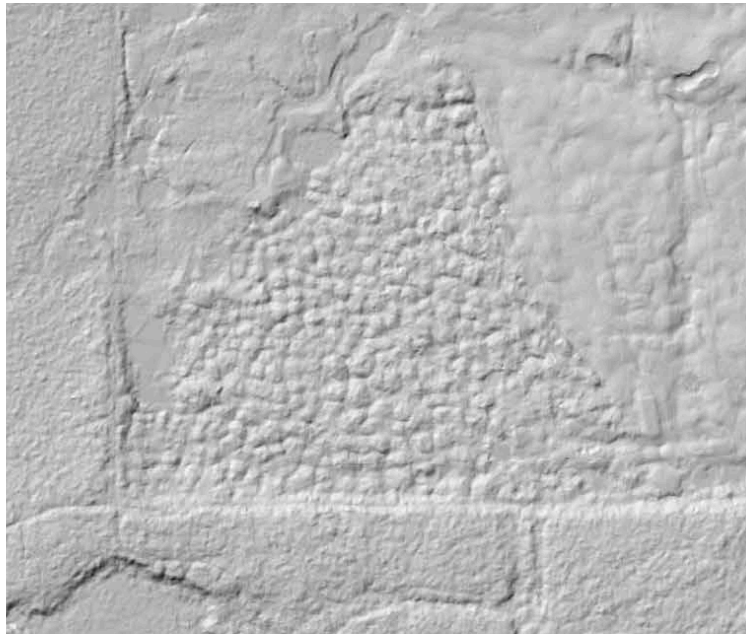
Geotechnical con't

- Increased precipitation is causing increases in rapid slope movements (active layer detachments, retrogressive thaw slumps, blowouts…..)
  - Aerial imagery and elevation data collection (LiDAR) is particularly useful to identify existing and developing slope movements
  - Predictive capabilities are needed to forecast locations of these potential rapid slope movements



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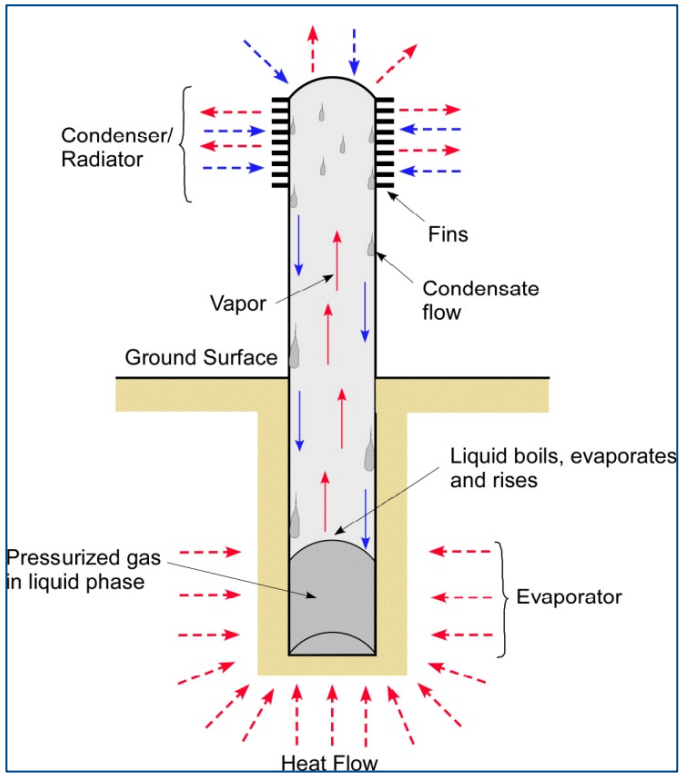
Geotechnical con't

- Refined engineering parameters for design
  - Thaw consolidation parameters
  - Strength of frozen soil – soil type vs. temperature
  - Strength of saline soils
  - Seismic shear wave testing and ultimate seismic hazard classification
  - Bi-modal foundation systems viability



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Rapid Structures

- Current rapid encampment systems (Bear Base, Force Provider….) are not Arctic rated
  - Must meet -60°F and 120 knot wind conditions
  - Deployable and re-deployable at low temperatures
  - Foundation and slab must account for ice-rich permafrost conditions
  - Modular or soft-structures should utilize shipping container as a structure component

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Design of Permanent Installations

- Current Arctic and sub-Arctic installations rely on one-off, stick-built construction similar or identical to CONUS construction techniques
  - This type of construction requires cutting and assembly of component pieces on-site, by skilled technicians; carpenters, electricians, plumbers……
  - Pre-manufactured modules CONUS or other population center provides for delivery of a nearly complete unit, plug-n-play

Ft. Carson – 120,000 ft^2

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Power Production and Utilization

- Although reliable – near 100% reliance on JP-8 or JP-10 fuel for power production has tremendous operational, logistical, and environmental draw-backs
  - Integration of renewable resources
    - Summer – Solar and wind
    - Winter – wind, ground source heat pumps
  - Utilization of micro-grid technology
  - Re-utilization of waste heat - should be standard
  - Waste heat fluid – water-over-glycol mixtures

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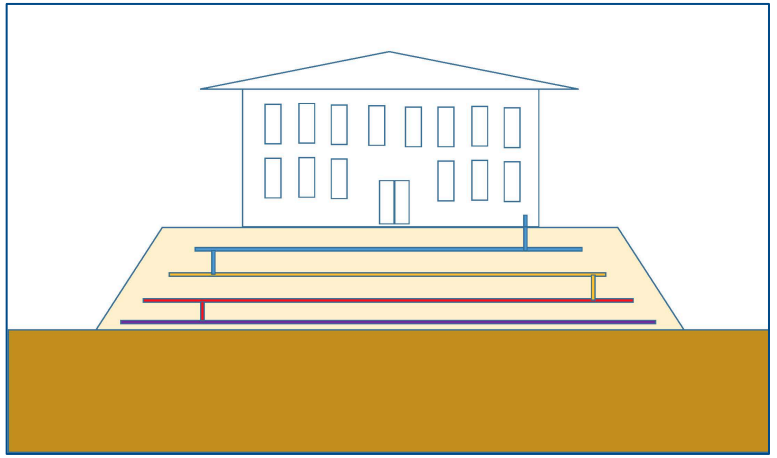
Utilization of Ground and Water Body Heat Storage

- Ground Source Heat Pump (GSHP) technology is viable at near freezing temperatures
  - COP improvements provide economical heat extraction of ‘cold’ media
  - Successful indoor heating via +2°C water or soil
  - Maintain frozen soil while heating the structure
  - GSHP can be powered with renewables



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Reduction of Glycol as Hydronic Heating Fluid

- Waste heat transmitted via ‘pure’ water, eliminating glycol solutions
  - Greater heat capacity of water vs. glycol
  - Water is environmentally friendly
  - Water is much less costly
  - Tools and appurtenances required to insure cold season emergency protocols are successful

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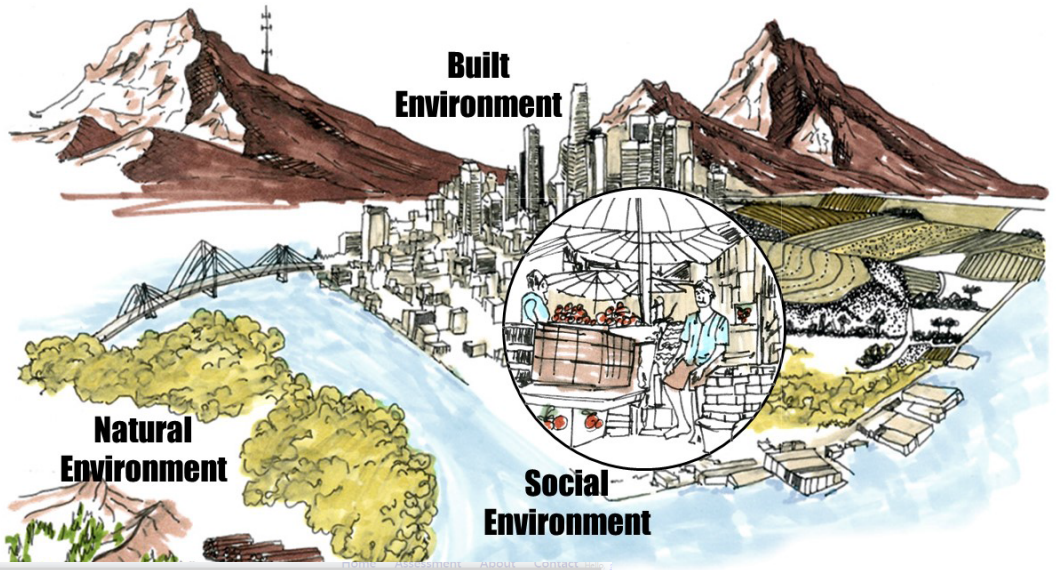
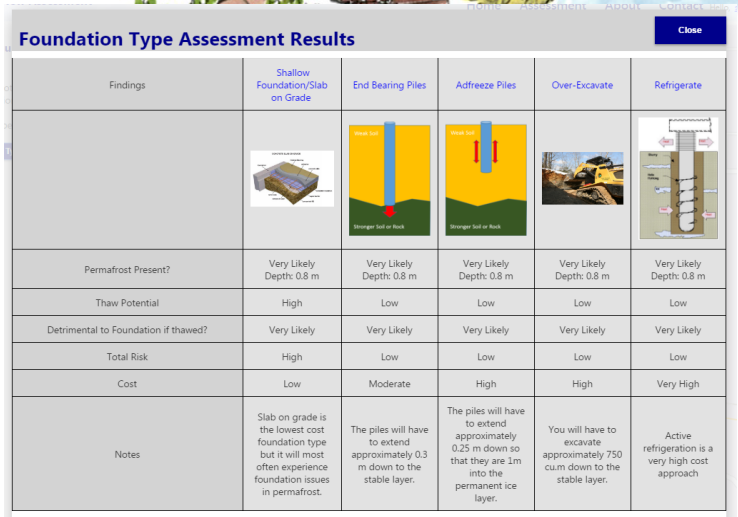
Arctic Installation Siting Systems

- Siting, design, and construction of Arctic installations is complex
  - Natural data (geotechnical, climatological, hydrogeology….) is integrated with the proposed built condition (use, topo obstacles, logistics hubs, installation size……)
  - Insures optimal placement and eases design complexity (geohazard avoidance), leading to reduced cost, logistics and manpower





Foundation Type Assessment Results

Close

Findings	Shallow Foundation/Slab on Grade	End Bearing Piles	Adfreeze Piles	Over-Excavate	Refrigerate
Permafrost Present?	Very Likely Depth: 0.8 m	Very Likely Depth: 0.8 m	Very Likely Depth: 0.8 m	Very Likely Depth: 0.8 m	Very Likely Depth: 0.8 m
Thaw Potential	High	Low	Low	Low	Low
Detrimental to Foundation if thawed?	Very Likely	Very Likely	Very Likely	Very Likely	Very Likely
Total Risk	High	Low	Low	Low	Low
Cost	Low	Moderate	High	High	Very High
Notes	Slab on grade is the lowest cost foundation type but it will most often experience foundation issues in permafrost.	The piles will have to extend approximately 0.3 m down to the stable layer.	The piles will have to extend approximately 0.25 m down so that they are 1m into the permanent ice layer.	You will have to excavate approximately 750 cu.m down to the stable layer.	Active refrigeration is a very high cost approach

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Mitigation and Repair Strategies

- Infrastructure on ice-rich terrain may suffer from poor initial design and poor alterations later
  - Strategies are needed to affect repairs and insure asset longevity
  - Methods need testing and guidance must be produced

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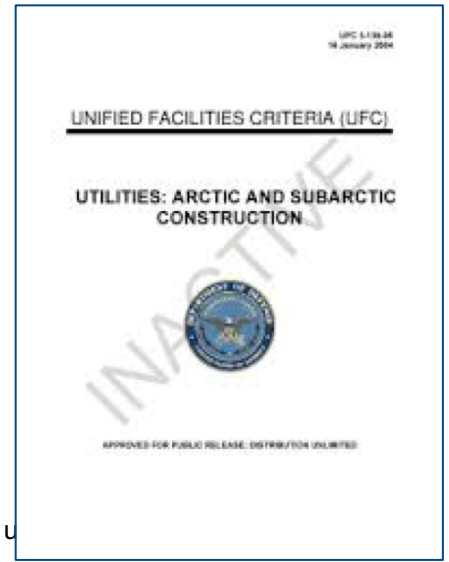
Revision of UFC 3-130 series (in-active status)

- Unified Facilities Criteria (UFC) 3-130 Arctic and Sub-Arctic Construction all seven volumes are ***in-active***
  - Volume 2 (Site Selection and Development) is revised and in review, utilizing work conducted in SERDP RC-2436
  - Volumes 1, 3-7 are badly in need of revision, much of the work discussed here would be incorporated into a full revision



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Conclusions

- Further expansion into the Arctic domain is anticipated
- DoD's nearly 70 yr Arctic presence illustrates great benchmark advancements, but improvement is always needed
- Climate warming issues are forcing the need for refined engineering parameters
- Contingency basing is now in the forefront as 'projected force' mission set takes precedent
- Arctic construction must evolve to 'modular' methods
- Energy production and distribution *must* involve renewables and heat recovery
- State-of-the-Art site characterization will maximize efforts across the installation
- Lastly - mitigation and repair strategies will absolutely be required to overcome mission crippling design shortfalls, allow for continued Arctic adaptation at remote/austere locations, and insure mission critical components continue service

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Thank you !

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