Technical Architecture for Arctic Security
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Evolving Arctic Security Situation

**Today: Emergent Situation**
Existing international collaborations
Insufficient navigation aids
Limited communications
Lack of basic infrastructure

**Near term: Increased Traffic**
Communication capacity
Environmental impact
Search & rescue authority/operations

**Far term: Uncertainty**
Permanent exploitation assets
Disputes over natural resources
Increased international cooperation
Retreat of Summer Arctic Ice: 1979-2011

- Opens new, shorter routes
- Access to undiscovered resources

Arctic region warming faster than the rest of the planet

Creating a logical long-term investment strategy for US agencies and industry

NATIONAL STRATEGY FOR THE ARCTIC REGION

“Foster partnerships with the State of Alaska, Arctic states, other international partners, and the private sector to more efficiently develop, resource, and manage capabilities, where appropriate and feasible, to better advance our strategic priorities in this austere fiscal environment.”

MAY 2013

- **Evolve Arctic Infrastructure and Strategic Capabilities** – We will carefully tailor this regional infrastructure, as well as our response capacity, to the evolving human and commercial activity in the Arctic region.

- **Enhance Arctic Domain Awareness** – endeavor to appropriately enhance sea, air, and space capabilities as Arctic conditions change, and to promote maritime-related information sharing with international, public, and private sector partners...
The changing global climate and the diminishing Arctic ice cap have made the Arctic more accessible now and in the foreseeable future.

When combined with economic and political developments, the changing Arctic is the most significant physical global event since the end of the last Ice Age. An unresolved strategic territory, the increased activity suggests that the region could become the subject of intensive negotiations and possible friction and confrontation relating to resources, ocean access, and sovereignty. In light of those changes and challenges, the Hoover Institution Arctic Security Initiative has been put in place to address the strategic and security implications of increased activity and to identify opportunities for shaping a safe, secure, and prosperous Arctic.

(http://www.hoover.org/research-teams/arctic-security-working-group)
Complex architecture / problem space
- Evolutionary development, much uncertainty
- Many stakeholders, regional/commercial/military
- Multi-national agreements and cooperation
- System of system with many performance gaps
- Balance of priorities
- Need for technology roadmapping and investment strategy
- Lack of tradespace insight for policy making
SE Process

Concept Analysis
- Gaps
- Stakeholders
- Concept of Operations

Requirements
- Customer Requirements
  - Derived Requirements
  - Requirements V&V
- Behavioral Analysis

Functional Architecture
- Functional Analysis
- Functional Architecture
- CSE
- Physical Architecture

Project Charter SignOff
- Updated CSE
- Updated Physical Architecture
- Updated Functional Architecture
- Updated Functional Analysis

Advanced Behavior
- Simulation & Robust Design
- Grand Menu
- Market Survey
- Elements Prioritization
- Tool Design & Development

Detailed System Design
- SoS Review
- Tool Life Cycle Risks
- Tool Life Cycle
- Architecture
- Life Cycle Risks
- Architecture
- Life Cycle

Trade Space Analysis
- Life Cycle Management Plan
Gap Analysis

Gap#1 Satellite Communications
Gap#2 Radio Communications
Gap#3 Aids to Navigation (AtoN)
Gap#4 Real-Time Navigation
Gap#5 Forecasting Messaging
Gap#6 Charting
Gap#7 Monitoring Arctic
Gap#8 Search & Rescue
Gap#9 Use of Situation Reports (SITREPS)
Gap#10 C3 Search and Rescue (SAR) Log
Gap#11 International Coordination
Gap#12 Interagency Coordination
Gap#13 Commercial capabilities
Gap#14 Scalability
Gap#15 User Friendly
Gap#16 Reliability
<table>
<thead>
<tr>
<th>System</th>
<th>Characteristics</th>
<th>Polar (&gt;80)</th>
<th>Sub-Polar (70 N - 80 N)</th>
<th>Other (&lt; 70 N)</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Terrestrial</strong></td>
<td></td>
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<tr>
<td>HF, MF</td>
<td>Safety related messages and voice communications</td>
<td>Ok, but unsuitable for digital communications</td>
<td>Ok, but unsuitable for digital communications</td>
<td>Ok, but unsuitable for digital communications</td>
</tr>
<tr>
<td>VHF, digital VHF, GSM, 3G</td>
<td>Line-of-sight, voice and low data rate</td>
<td>No base stations, Ok ship-to-ship</td>
<td>Few base stations, OK ship-to-ship</td>
<td>VHF is OK close to the coast, GSM/3G limited coastal coverage</td>
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<tr>
<td><strong>Satellite</strong></td>
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<tr>
<td>GEO satellites</td>
<td>Medium capacity, low to medium latency</td>
<td>Not available</td>
<td>Potential problems with quality and availability</td>
<td>OK (Except in special areas)</td>
</tr>
<tr>
<td>LEO satellites, Iridium Open Port</td>
<td>Currently max 128 kbps High and variable latency</td>
<td>Potential problems with quality</td>
<td>Potential problems with quality</td>
<td>Ok, except for areas around equator</td>
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<tr>
<td>HEO satellites</td>
<td>Properties comparable to GEO. Currently unavailable</td>
<td>Expected to provide good coverage, capacity and quality in the Polar and Sub-Polar areas. Spare capacity can be used in other sea areas. Not yet implemented</td>
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<td>Stakeholder</td>
<td>Interests</td>
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<td>-------------------------------------------------------</td>
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<tr>
<td>Senior Arctic Official</td>
<td>Arctic Council senior member, chairs the council during host country term</td>
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<tr>
<td>U.S. Coast Guard (USCG)</td>
<td>Primary agency responsible for law enforcement and incident response in the region</td>
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<tr>
<td>Department of Defense</td>
<td>DoD agencies provide support to the Arctic through their normal missions and capabilities, which support the Arctic Theater although sometimes are limited by the environment.</td>
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<tr>
<td>U.S. Navy</td>
<td>Executive agency for Maritime Domain Awareness, provides global support as required</td>
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<tr>
<td>U.S. Air Force</td>
<td>Enhanced Polar Satellite communications, provides global support as required</td>
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<tr>
<td>U.S. Army, U.S. Marine Corps</td>
<td>Provides global support as required</td>
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<tr>
<td>National Oceanic &amp; Atmospheric Administration (NOAA)</td>
<td>Science, services, and stewardship, including information and products</td>
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<tr>
<td>Dept. of the Interior, Bureau of Ocean Energy Management</td>
<td>Mineral Management Services</td>
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<tr>
<td>The Arctic Council</td>
<td>International governance, agreements, and priorities</td>
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<tr>
<td>Indigenous populations</td>
<td>Approval over changes to the infrastructure</td>
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<td>Commercial marine traffic</td>
<td>Shipping, recreation, fishing, etc.</td>
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<tr>
<td>Commercial Oil &amp; Gas, Mineral Industries</td>
<td>Development</td>
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<td>Non-government Organizations</td>
<td>Stewardship and oversight of the region</td>
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<tr>
<td>Private Salvage /Search &amp; Rescue industry</td>
<td>Commercial response services</td>
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Near Term Vignettes

- Stranded ships
  - Tourist Cruise
  - Oil/mineral
  - Exploration team
  - Fishing
- Disruption of indigenous folkways
- Ecological disasters
  - Oil Spill

**Common thread: all result due to dynamic “landscape” as ice melts**

Mission Analysis

- **Primary: Search and Rescue (SAR)**
  - Governed by IMO International Aeronautical and Maritime Search and Rescue (IAMSAR) guidelines, MSC.1/Circ.1367, 24 May 2010

- **Primary: Maritime Domain Awareness (MDA)**

- **Primary: Maritime Transportation**
- **Supporting: Law Enforcement & Coastal Security**
- **Supporting: Marine Environmental Protection**
- **Supporting: Oceanographic Research**
- **Supporting: Environmental Forecasting (NOAA)**
ARCTIC COUNCIL MANDATE:
SUPPLY BASIC SAR CAPABILITY TO THE REGION

Route
- Location
- Time

Alert
- Damage assess.
- accuracy
- Reporting status
- location

Dispatch
- Tasking

Deploy

Update

Rescue

Situational Awareness
- Current locations
- Current status
- Current Capabilities

C2 Air/Sea Orders
- Text
- Satellite assets
- Air asset types
- Sea asset types

New Orders

Assessment

Gaps

SAR Assets
- On station updates
- More precision

Clear Water  Mixed  Icy Water
Factors that Drive SAR Mission Requirements (lessons learned)

- **Reporting**
  - Unreliable vessel reports and tracking lead to false searches

- **Event location**
  - Weather
  - Distance to responding ships
  - Distance to responding aircraft
  - Accurate coordination and reporting of search areas

- **Communication**
  - Ship positioning/occlusion
  - Bandwidth/channels for data, particularly internet data
  - Effective C2 capability (operational picture)

- **Navigation**
  - Routing through or around ice
  - Real time updates

- **General**
  - Technology standardization and interoperability
  - Language and country unique operations
• Arctic Communication gaps form SoS capstone opportunity for Masters students
• Completed gap/capabilities analysis, SySML model, Tradespace analysis tool, initial simulation
Trade Space Analysis for Arctic Communications

**Requirements/ Functional Architecture**

- Requirement Decomposition and Functional Analysis
- Prepare Prioritization Matrix (Customer Requirements and Engineering Characteristics)
- Prepare QFD (Customer Requirements to Functions)
- Functional Decomposition Tree

**Trade Space**

- Initial Physical Architecture (with Technology Component)
- Technology Market Survey
- Identify Technology Options for each Critical Element
- Determine Technology Impact Matrix (TIM) for each Critical Element
- Create Morphological Matrix for each Critical Element
- Perform TOSIS for all selection Architecture options
- Prepare Grand Menu
- Trade Off

**Physical Architecture**

- Physical Architecture

**Additional Processes**

- Determine Decision Matrix for AOA
- Get Weight for Measure of Performance
- Identify Architecture Components (Critical Elements) eligible for Market Survey
- Prepare QFD (Functions to Critical Elements)
- Prepare QFD (Critical Elements to Measure of Performance)
- Identify Architecture Components (Critical Elements) eligible for Market Survey
- Perform Cognitive Systems Engineering Analysis
- Functional Architecture
- Scenario based Evaluation
- Architectural Risk
Summary

- Evolving problem
- International stakeholders expecting US leadership
- Unique technical environment
- Limited budgets, higher priorities
- Lack of insight for policy-making
- Solid understanding of current/future technical architecture promotes:
  - Investment planning/technology roadmaps
  - Tradespace analysis
  - Multi-stakeholder decision making
  - Balance of support based on evolving needs
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