Colloquium- “Meeting the Communication Requirements of a Changing Arctic”
Arctic Region Communications Small Satellites (ARC-Sat)

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Operational Problem Statement

Organizations with operational responsibility in the Arctic lack the capabilities necessary to meet emerging challenges and operational requirements in the Region

- Organizations are unable to support near- and mid-term Arctic operations to include: Humanitarian Response, Environmental Response, International Search & Rescue (SAR), and Counter-Trafficking (to include WMD)
- Shortfalls to these missions include:
  - Inadequate coverage and throughput of communications relay to support Arctic operations
  - Inadequate Maritime Domain Awareness (MDA) in the Arctic Region to coordinate responses to regional security issues
  - No capability for near-real time data-extraction of unattended sensors in the Arctic Region
- Existing and planned capabilities cannot satisfy these shortfalls
  - Iridium, Thuraya, and INMARSAT do not meet growing requirements for tactical communications and cannot interrogate unattended sensors
  - Existing AIS collection in the Arctic has gaps and restrictions to data dissemination and sharing that inhibit collaborative Maritime Domain Awareness

ARC-Sat will provide immediate capabilities through responsive orbital assets to support emergent operational requirements in the Arctic Region
# Desired Capabilities

*U.S. and its Arctic partners contribute to the peaceful opening of the Arctic in a manner that strengthens international cooperation*

- **Technical**
  - Communications relay to support Arctic operations
    - Periodic coverage to support voice relay and IP data communications
    - Communications relay with waveform and frequency agility to support existing and developing systems
  - Enhanced Maritime Domain Awareness (MDA) in the Arctic
  - Remote data extraction from unattended sensors
  - Reception and relay of emergency position-indicating radio beacon (EPIRB) transmissions
  - Satellite fractionation for LEO long-baseline interferometry
- **Operational:** CONOPS and TTP
  - Arctic Environmental Awareness to plan and execute collaborative international response
  - Communications to coordinate international response to Arctic environmental and humanitarian issues

*ARC-Sat will enable collaboration and cooperation through enhanced communications and data sharing in the Arctic Region*
# FASTSAT TYPE “Mothership”

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Value</th>
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<tbody>
<tr>
<td>Total Mass (kg)</td>
<td>180</td>
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<tr>
<td>Orbit</td>
<td>400 – 850 km</td>
</tr>
<tr>
<td></td>
<td>30° - 99°</td>
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<tr>
<td>Stabilization</td>
<td>3-Axis</td>
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<tr>
<td>Attitude Control</td>
<td>0.1°</td>
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<tr>
<td>Attitude Knowledge</td>
<td>0.02°</td>
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<tr>
<td>Downlinks (Mbps)</td>
<td>5 (S-band)</td>
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<tr>
<td></td>
<td>150 (X-band)</td>
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<tr>
<td>Uplink (kbps)</td>
<td>300 max (S-band)</td>
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<td>Ground Networks</td>
<td>STDN, SGLS</td>
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<tr>
<td>Encryption</td>
<td>AES, COMSEC</td>
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<tr>
<td>Mission Life</td>
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<tr>
<td>Number Payloads</td>
<td>4 x 3U CubeSat</td>
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<tr>
<td></td>
<td>4 x Integrated</td>
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<td>Payload Mass (kg)</td>
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<td>Payload Power (W)</td>
<td>30 – 50 W Avg.</td>
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<td>Payload Interface</td>
<td>RS-422 (5)</td>
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<td>SpaceWire (2)</td>
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<tr>
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<td>Digital (20 in/40 out)</td>
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<tr>
<td>Payload Data (GB)</td>
<td>8</td>
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</table>

- Deploy Four 3U CubeSats or Two 6U CubeSats
- On-Demand, On-orbit Assets,
- Constellation Deployment
- Communications “Mothership”
- On-Orbit Charging, Status, & Upgrades
- System Design In Process
ARC-Sat Operational View

Mission Concept
- 1 Minisatellite Mothership
  - CubeSat Launcher
  - AIS, Data-X, & EPIRB Receivers
  - Communications package
- 4 Communications CubeSats
- 650 km low-earth-orbit (LEO)
- Circular orbit (eccentricity = 0)
- 90-98° Inclination
- Up to 10Mbps total data throughput
- UHF SatCom

Payloads
- Mothership launches CubeSats and has extensive computational, control, and data store-and-forward capacity
- Mothership and 4 CubeSats with software-defined radios enable over the horizon communications
- AIS provides global Maritime Domain Awareness
- Data-X provides data collection from unattended sensors
- EPIRB relay supports Search & Rescue

An innovative, multi-agency collaboration that provides MDA, communications relay, and data-extraction
Mission-Tailored Communications

**Powerful**
- 5 Software-Defined Radios (SDRs) total
  - 1 SDR on each of 4 cube-sats
  - 1 SDR on the mothership
- 24 Voice Channels per CubeSat
- As high as 2 Mbps per SDR
- Mothership has S-Band and X-Band downlinks for combined 11 Mbps
- 13.48 minutes in satellite foot-print for overhead Arctic pass

**Compatible**
- Joint Tactical Radio System (JTRS)
- Airborne & Maritime/Fixed Station (AMF)
- UHF Satellite Communications
- Wideband Network Waveform
- Soldier Radio Waveform (SRW)
- Mobile User Objective System (MUOS)

**Flexible**
- Controllable Virtual Beam
  - Each SDR has wide-Beam for total-area coverage
  - Steerable Beams for greater link margin and higher throughput (to include a 3db reserve)
- Reprogrammable in-flight from the ground
Example of Technology Push

ARC-Sat provides greater bandwidth by capitalizing on low-cost, advanced CubeSat technology

- Current commercial systems are simultaneous multi-user but have max data rate limitations
- ARC-Sat integrates a MicroSat and two CubeSats to provide robust, adaptable communications relay
- DARPA algorithms enable formation flying and precision spotlighting of directional beams
- ARC-Sat can tailor the link margin to the mission and environment through beam-forming, precision spotlighting, waveform shaping, and channel bundling
ARC-Sat Provides Year-Round Global Capability, with a Polar Focus

**Orbit**
- Altitude: 650 km (LEO)
- Eccentricity: 0 (Circular)
- Inclination: 98°
- Period: 97.7 minutes

**Ground Track**
- Diameter: 5,529 km
- Area: 24 million km²
- Speed Over Ground: 6.836 km/s
- Time in view for overhead pass: 13.48 min

- With a track overlap of 50.8% at the Equator, ARC-Sat will cover the Earth twice per day
- ARC-Sat will provide service to each point on the Earth
  - Minimum of 4 times per day at the Equator
  - Up to 14 times per day at the Poles
Coverage in Other Critical Regions

Central America

Antarctic
Orbit Parameters and Daily Ground Track

One Day of Coverage

Orbit
- Altitude: 650 km
- Eccentricity: 0 (Circular)
- Inclination: 98°
- Period: 97.7 minutes

Ground Track
- Diameter: 5,529 km
- Area: 24 million km²
- Speed Over Ground: 6.836 km/s
- Time in view: 13.48 min (overhead pass)

With a track overlap of 50.8% at the Equator, ARC-Sat will cover the Earth twice per day.

ARC-Sat will provide service to each point on the Earth from 4 times per day at the Equator, up to 14 times per day at the Poles.
Use Scenario: Arctic Search & Rescue

Sequence of Events

1. Ship suffers an engineering casualty and is dead in the water (DIW)
3. Ship begins sending Automatic Identification System (AIS) distress message
4. ARC-Sat detects EPIRB beacon and forwards ship’s location and information to USCG District 17
5. ARC-Sat feeds the AIS distress message into the Volpe Center’s global AIS system
6. ARC-Sat provides communications relay support
   1. Two CubeSats re-orient to provide priority support to distress vessel
   2. Two CubeSats re-orient to provide priority support to response force
   3. Mothership provides general support
7. ARC-Sat provides data link between response force and the National Ice Center (NIC) for updates on sea-ice, sea surface conditions, and surface weather via the Arctic Collaborative Environment (ACE) system
Thank you

Questions ?