



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*

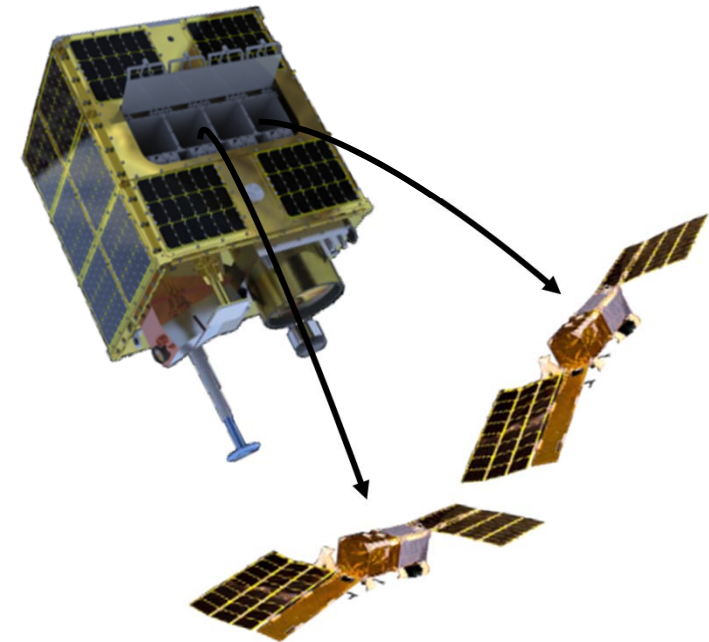
- Technical
  - Communications relay to support Arctic operations
    - Periodic coverage to support voice relay and IP data communications
    - Communications relay with waveform and frequency agility to support existing and developing systems
  - Enhanced Maritime Domain Awareness (MDA) in the Arctic
  - 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”



<b>Total Mass (kg)</b>	180
<b>Orbit</b>	400 – 850 km 30° - 99°
<b>Stabilization</b>	3-Axis
<b>Attitude Control</b>	0.1°
<b>Attitude Knowledge</b>	0.02°
<b>Downlinks (Mbps)</b>	5 (S-band) 150 (X-band)
<b>Uplink (kbps)</b>	300 max (S-band)
<b>Ground Networks</b>	STDN, SGLS
<b>Encryption</b>	AES, COMSEC
<b>Mission Life</b>	2 - 4 yr
<b>Number Payloads</b>	4 x 3U CubeSat 4 x Integrated
<b>Payload Mass (kg)</b>	45 - 50
<b>Payload Power (W)</b>	30 – 50 W Avg.
<b>Payload Interface</b>	RS-422 (5) SpaceWire (2) Digital (20 in/40 out)
<b>Payload Data (GB)</b>	8



- **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

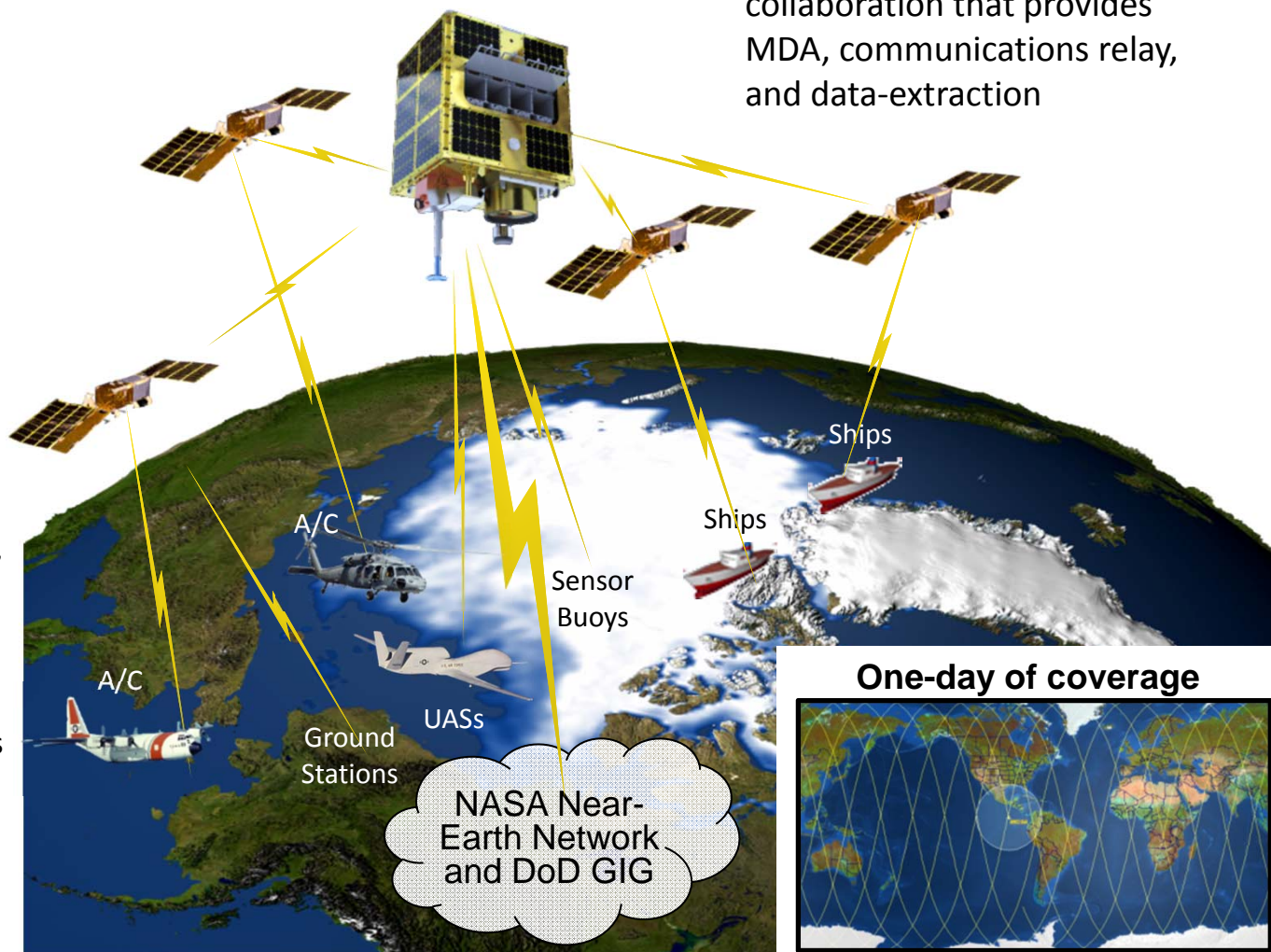
## Mission Concept

- 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



One-day of coverage



# Mission-Tailored Communications



## Powerful

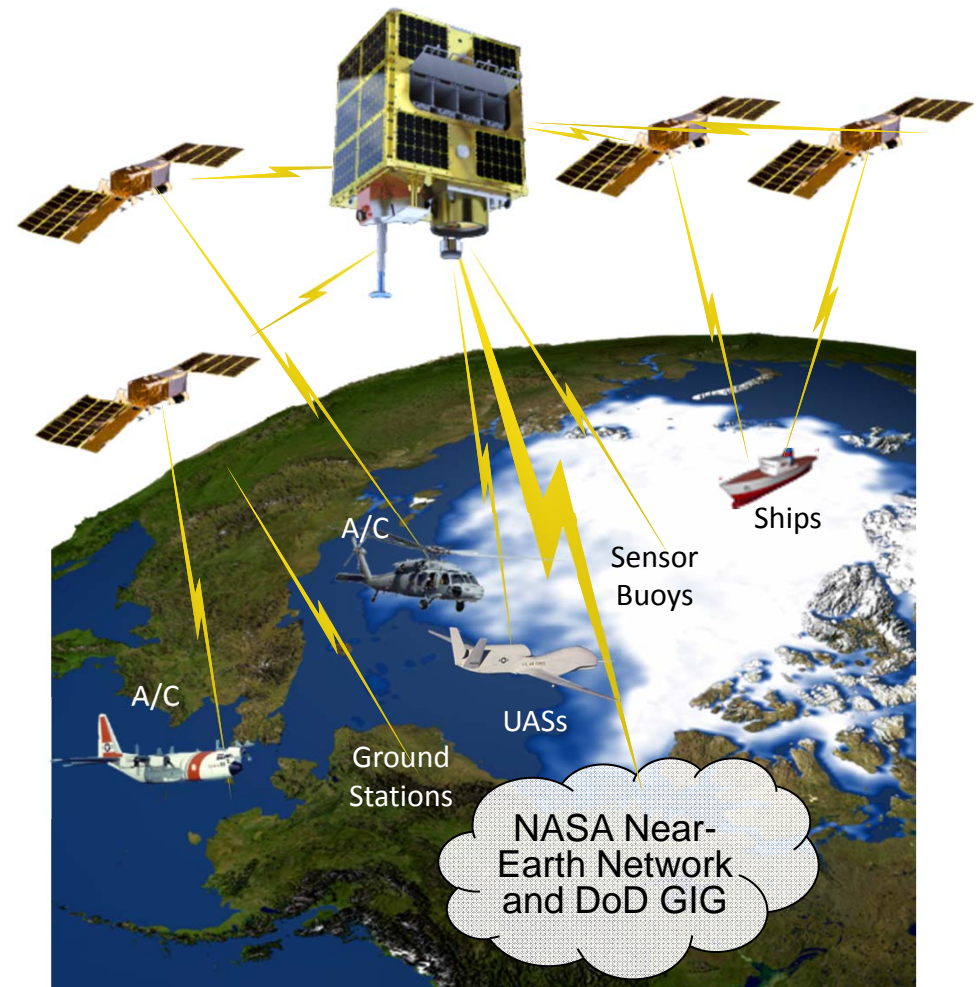
- 5 Software-Defined Radios (SDRs) total
  - 1 SDR on each of 4 cube-sats
  - 1 SDR on the mothership
- 24 Voice Channels per CubeSat
- As high as 2 Mbps per SDR
- Mothership has S-Band and X-Band downlinks for combined 11 Mbps
- 13.48 minutes in satellite foot-print for overhead Arctic pass

## 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

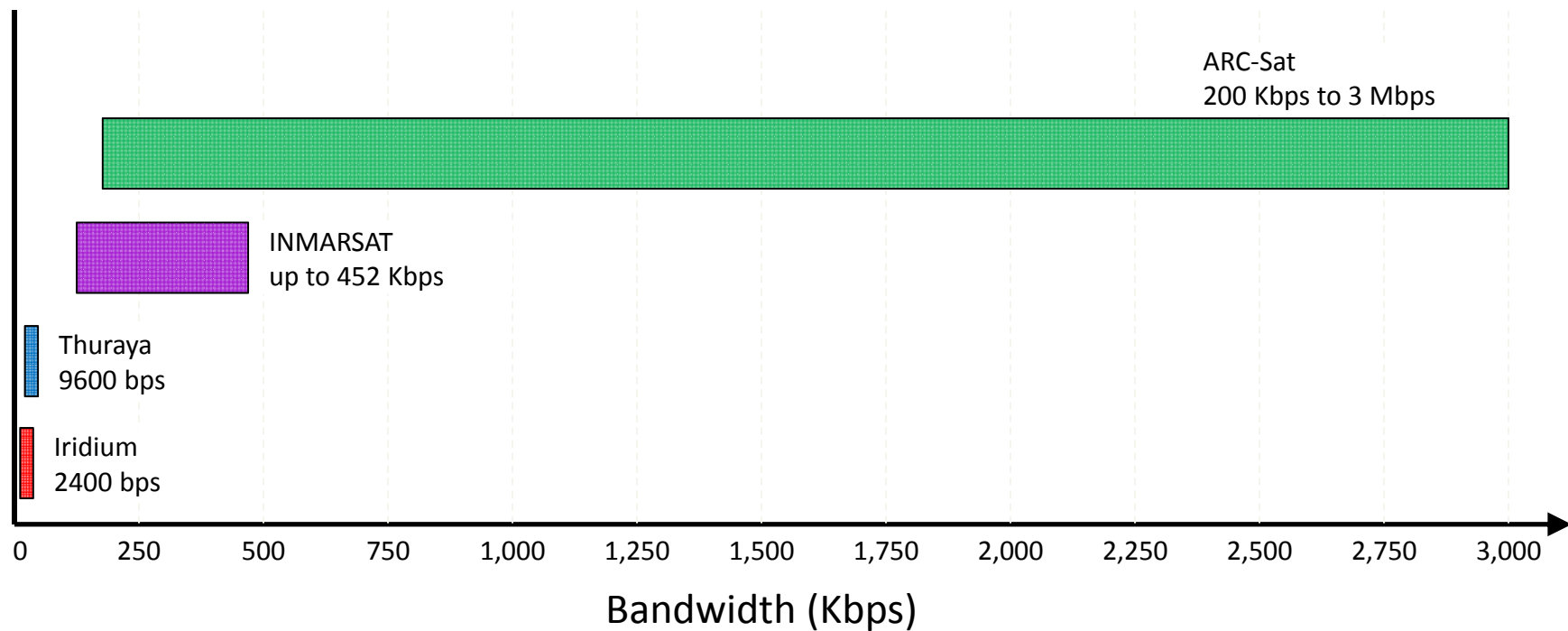
- Controllable Virtual Beam
  - Each SDR has wide-Beam for total-area coverage
  - Steerable Beams for greater link margin and higher throughput (to include a 3db reserve)
- Reprogrammable in-flight from the ground



# 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

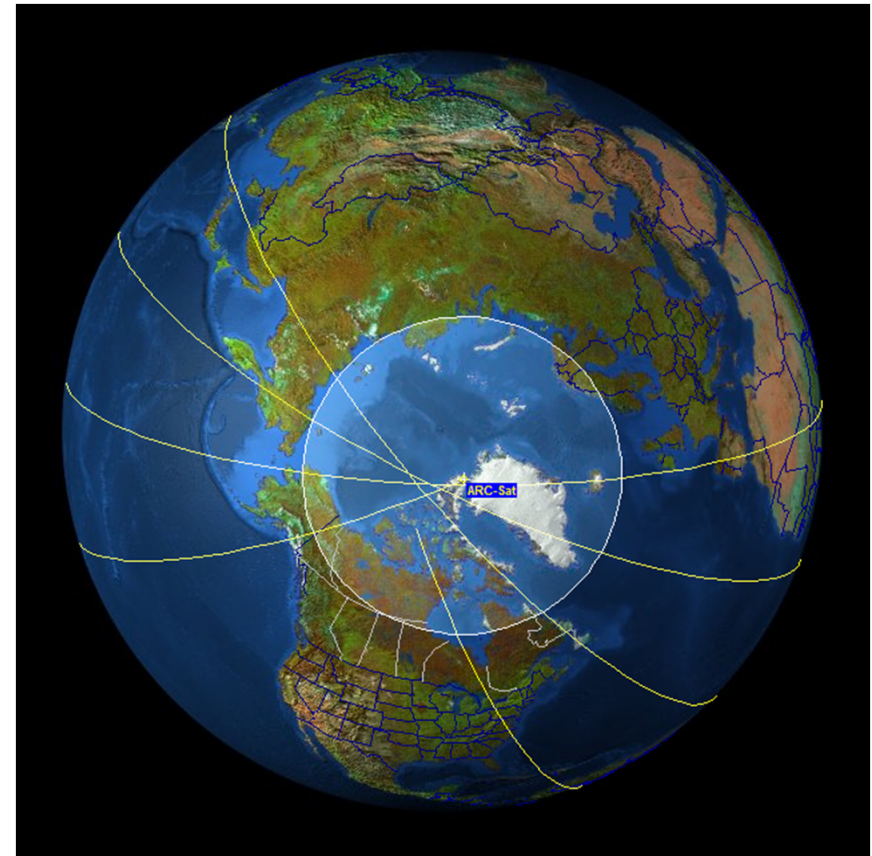


## Orbit

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

## Ground Track

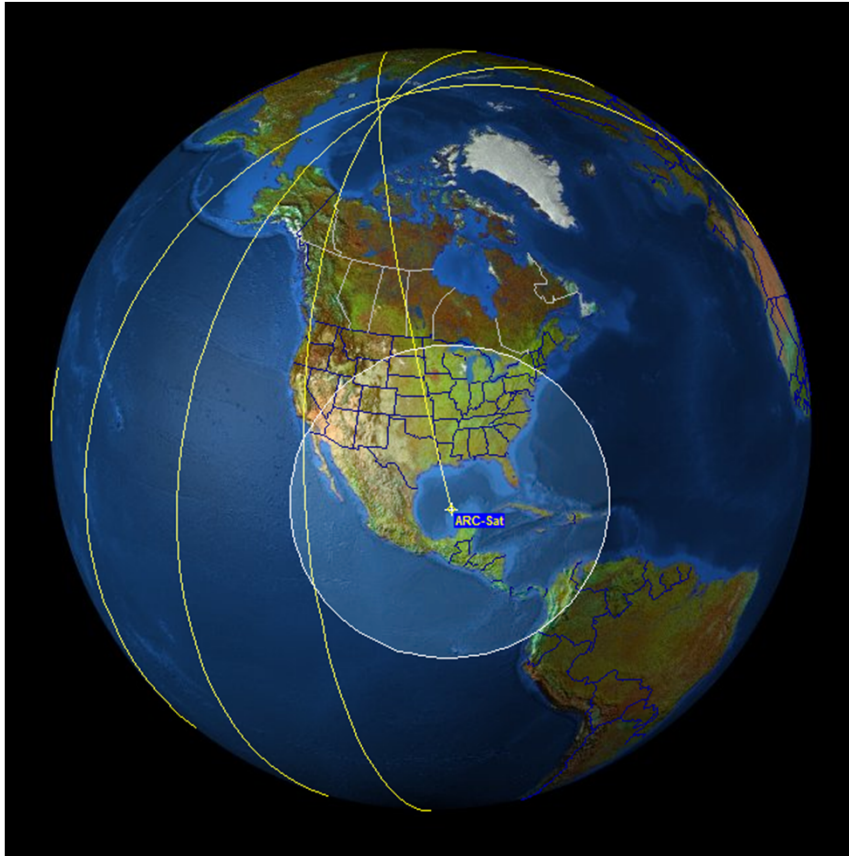
- Diameter: 5,529 km
- Area: 24 million km<sup>2</sup>
- Speed Over Ground: 6.836 km/s
- Time in view for overhead pass: 13.48 min
- With a track overlap of 50.8% at the Equator, ARC-Sat will cover the Earth twice per day
- ARC-Sat will provide service to each point on the Earth
  - Minimum of 4 times per day at the Equator
  - Up to 14 times per day at the Poles



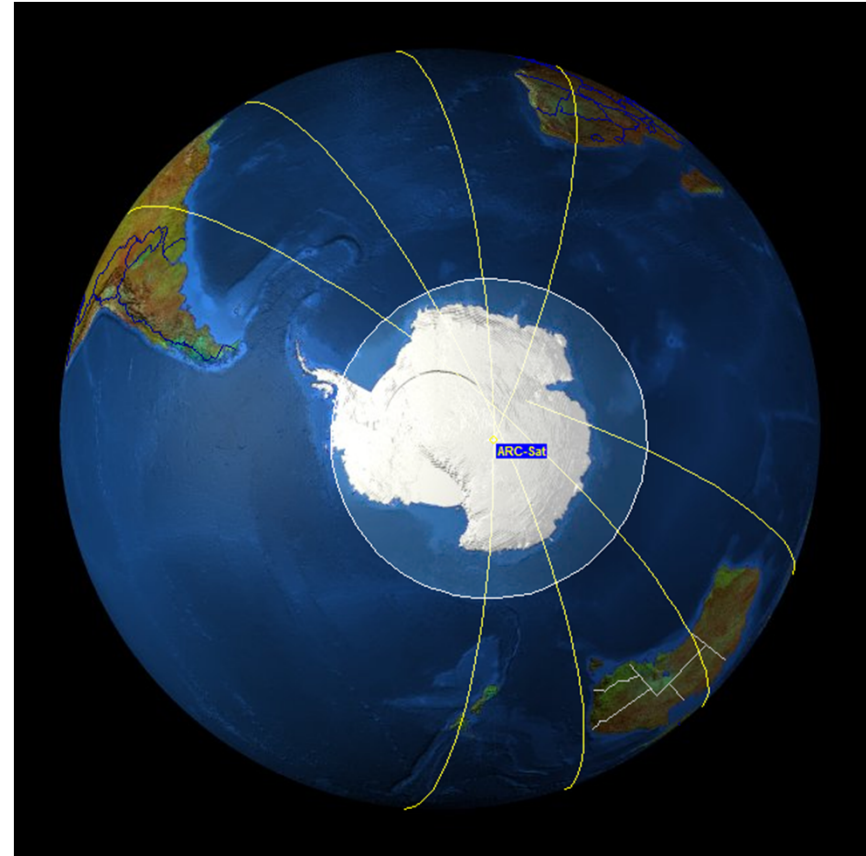
Typical ground coverage and track



# Coverage in Other Critical Regions



Central America

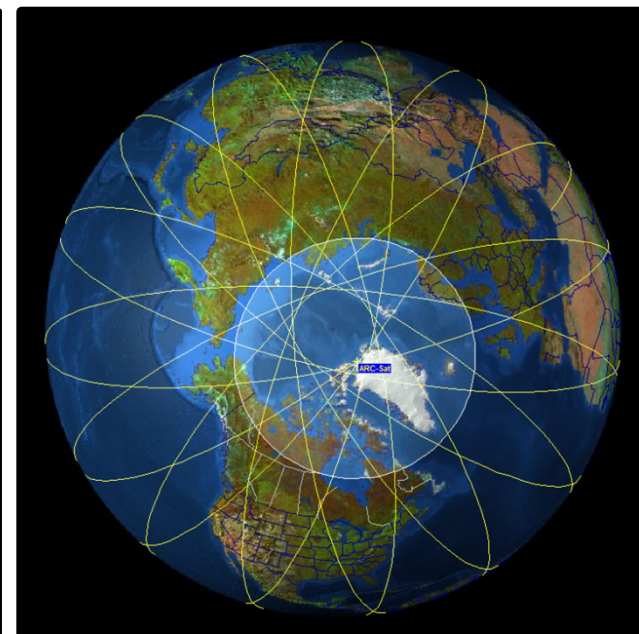


Antarctic

# 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 km<sup>2</sup>
- 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

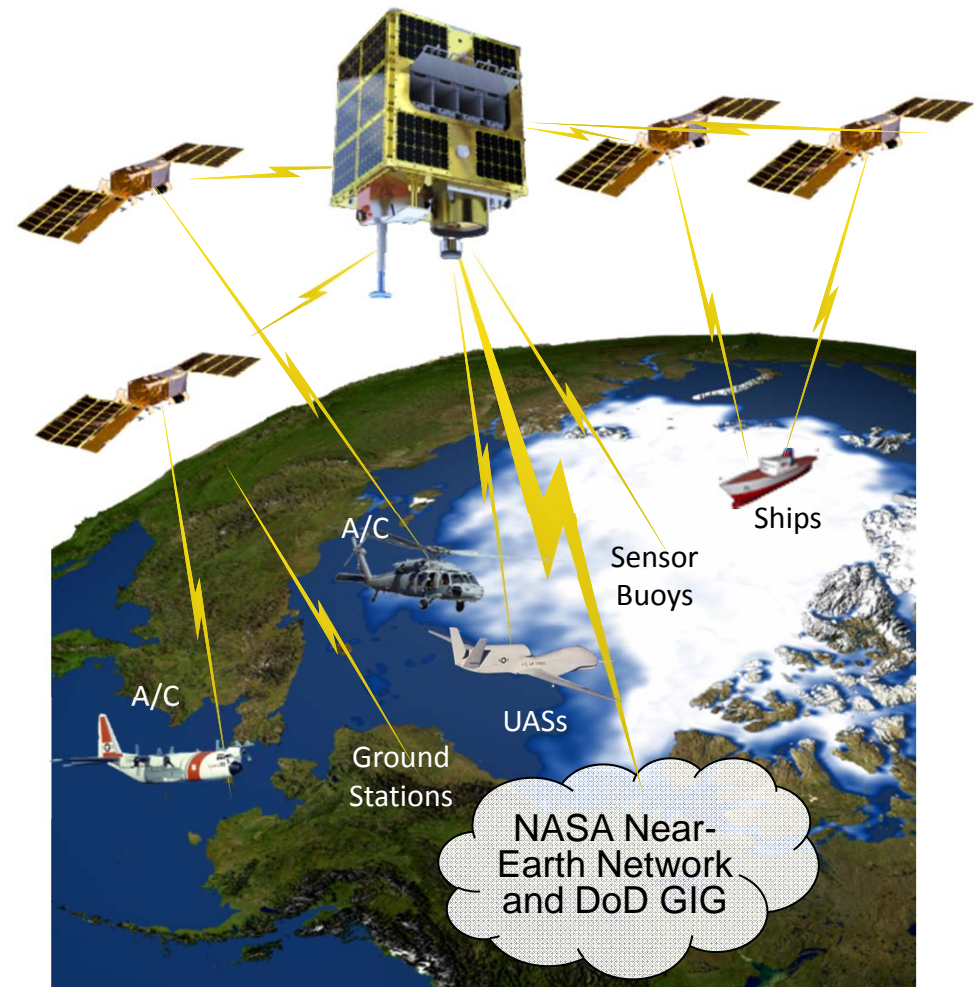
ARC-Sat will provide service to each point on the Earth from 4 times per day at the Equator, up to 14 times per day at the Poles

# Use Scenario: Arctic Search & Rescue



## Sequence of Events

1. Ship suffers an engineering casualty and is dead in the water (DIW)
2. Ship activates 406 MHz digital Emergency Position Indicating Radio Beacon (EPIRB)
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 ?