SCI 329 RSM *Capabilities for Sensing, Search, and Surveillance in the Arctic*

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Safety and Security for the Arctic Operational Space: Lessons Learned on Multiple Sensor Surveillance

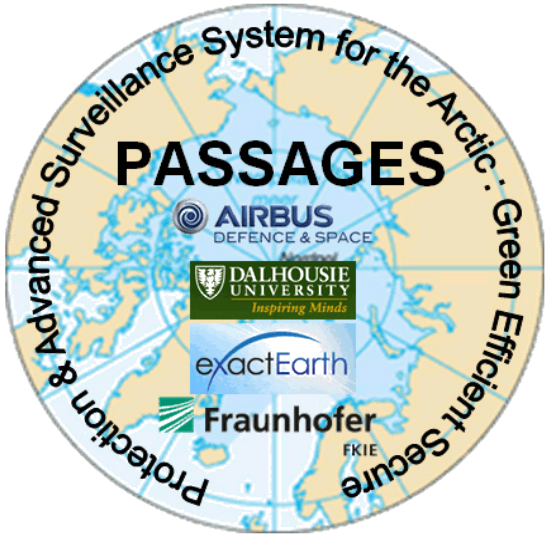
AIRBUS DEFENCE & SPACE DALHOUSIE UNIVERSITY Inspiring Minds Fraunhofer FKIE exactEarth

Agenda

1. Introduction PASSAGES Research Project & System Approach
2. Safety and Security Risks
3. Key System Features:
   - Space-based wide area surveillance
   - Chokepoint surveillance
   - Assessments of Risks to Ships
   - Multi-Sensor/-Source Data Fusion
4. Field Studies of Multi-Sensor Data Fusion
   - Field Studies in the Canadian Arctic
   - Input Data and Multi-Sensor Data Fusion
   - Example for Chokepoint Monitoring in Bellot Strait
5. Lessons Learnt & Outlook

Introduction: PASSAGES

Protection and Advanced Surveillance System for the Arctic: Green, Efficient, Secure



Project: joint Canadian-German R&T project, 2013-2016

Goal: specify the requirements and the modular architecture of an innovative maritime system to support secure and safe operations in arctic waters with a focus on the Northwest Passage

Sponsors	NSERC-CRD exactEarth Ltd.	Airbus Defence & Space Germany Federal Ministry for Economic Affairs and Energy
Project Team	Dalhousie University exactEarth Ltd.	Airbus Defence & Space Fraunhofer FKIE

NSERC CRSNG

Bundesministerium für Wirtschaft und Energie

"The PASSAGES Research Project: A Joint Canadian-German Approach to Create Situation Awareness in Canadian Arctic Waters", https://www.youtube.com/watch?v=FuaZo4gqkml

PASSAGES: maritime situational awareness in arctic environment

System: help clients to **maintain sovereignty**, **systematically plan** an operation, **safely execute** it, and **efficiently manage** available resources and vessel traffic in the Northwest Passage

Activities:

- Stakeholder analysis
- Concept of Operations
- System Architecture
- Validation of Concepts

- Analysis of 7 operational use cases (transit, resource export, re-supply, SAR, env. protection, cruises, small & non-cooperative vessels):
  - Traffic modeling
  - Risk assessments
  - Analysis of current and new sensors
  - Development of new concepts for data fusion and traffic anomaly detection
  - Creation of decision-support tools

Safety and Security Risks

2016 - 2023

Safety:

- remote, vast, harsh environment, darkness
- lack of infrastructure & resources
- sea ice (sheets, flows, icebergs, frozen spray,...)
- uncharted waters
- arctic operations are high-cost
- increasing maritime traffic due to longer ice-free season

Security:

- sovereignty over large and remote maritime and coastal areas
- outdated surveillance systems (e.g. NORAD)
- protection of environment and (not precisely localized) natural resources
- compliance with national and international laws & regulations of increased shipping
- prevention of illegal activities: e.g. trafficking, spying, illegal fishing
- much more realistic prospect of an attack in the Arctic than in 2016

To protect our Arctic interests we must have the capacity to deter and defend

Canada's North could become a new front line in the geopolitical tensions between China and the United States and between Russia and NATO countries.

Source: Toronto Star, April 26 2023

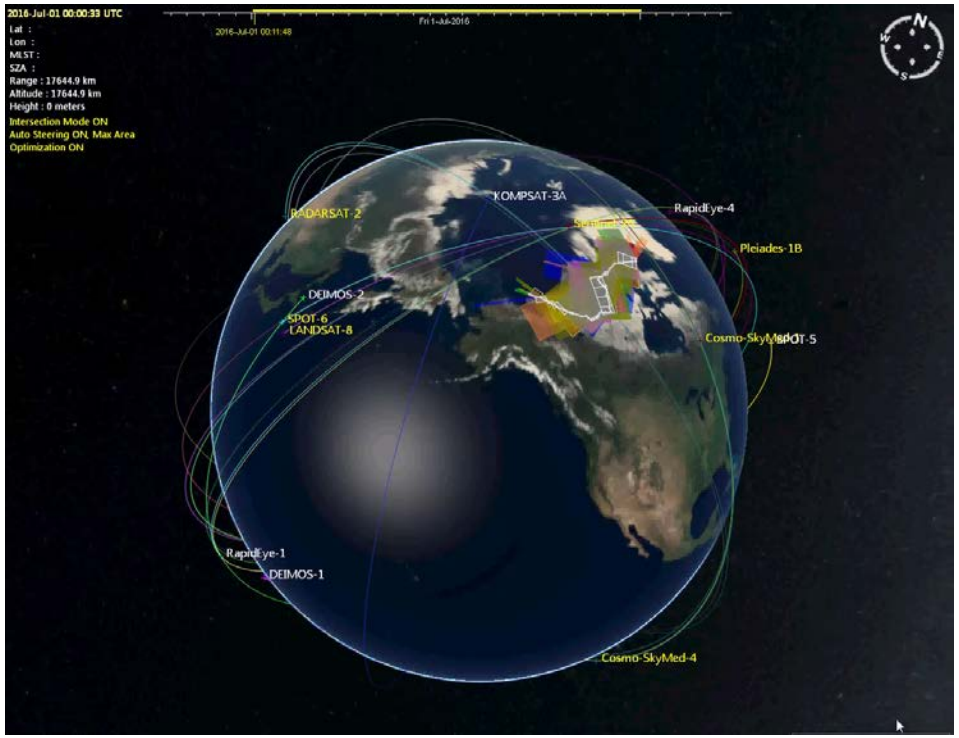
Denmark Wants to Prioritize Arctic Defense and Put the Baltic Sea Second

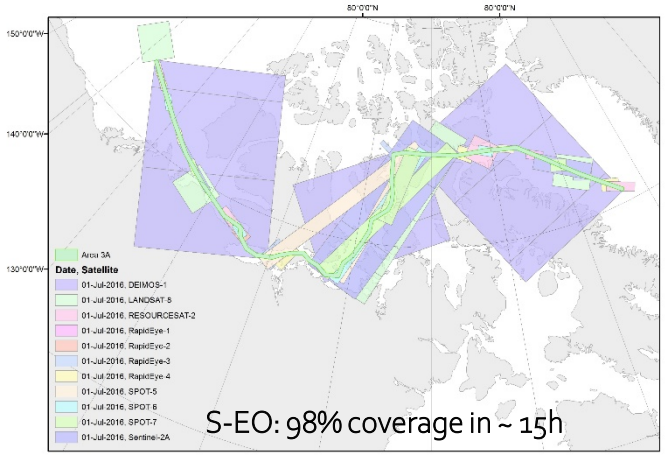
The US Department of Defense's northernmost installation, Thule Air Base (now Pituffik Space Base) is located on the northwest coast of Greenland. The installation plays a key role in the US military's ability to detect and provide early warnings of ballistic missile attacks. *(Photo: NASA)*

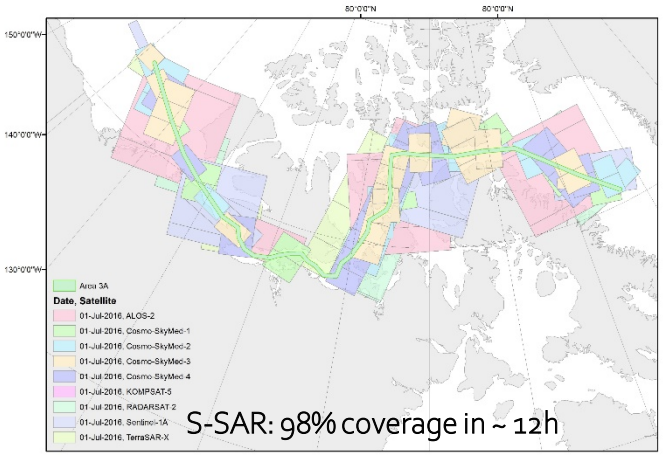
Source: High North News, May 03 2023

Key System Features – Space-Based Wide Area Surveillance

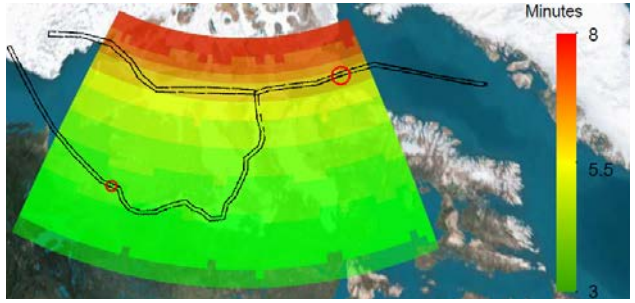
Simulated coverage of NWP by commercial SAR and EO satellite sensors



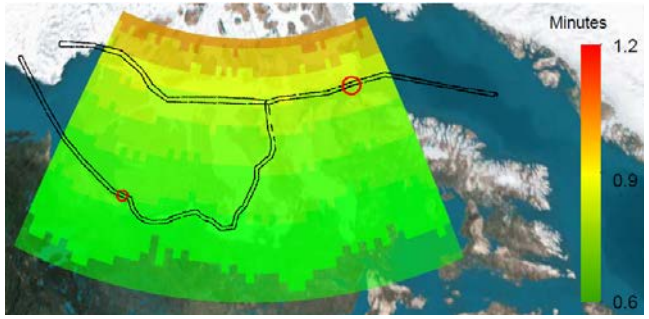




S-EO: coverage time per day (3 – 8 min)

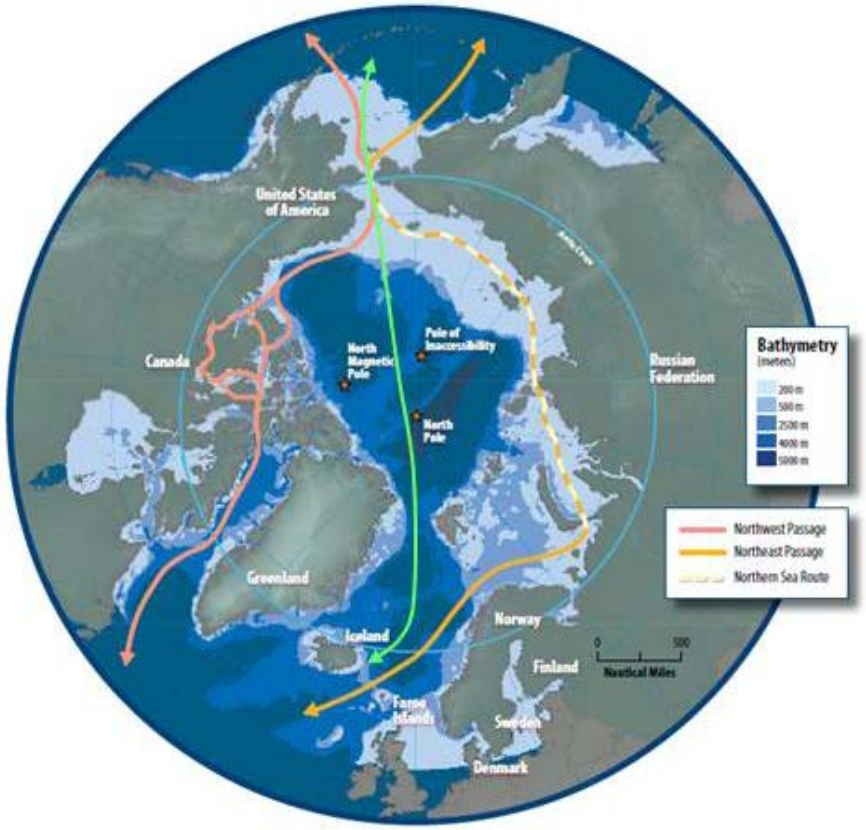


S-SAR: coverage time per day 0.6 – 1.2 min)



Key System Features – Chokepoint Surveillance

Suggested chokepoint monitoring in the Northwest Passages



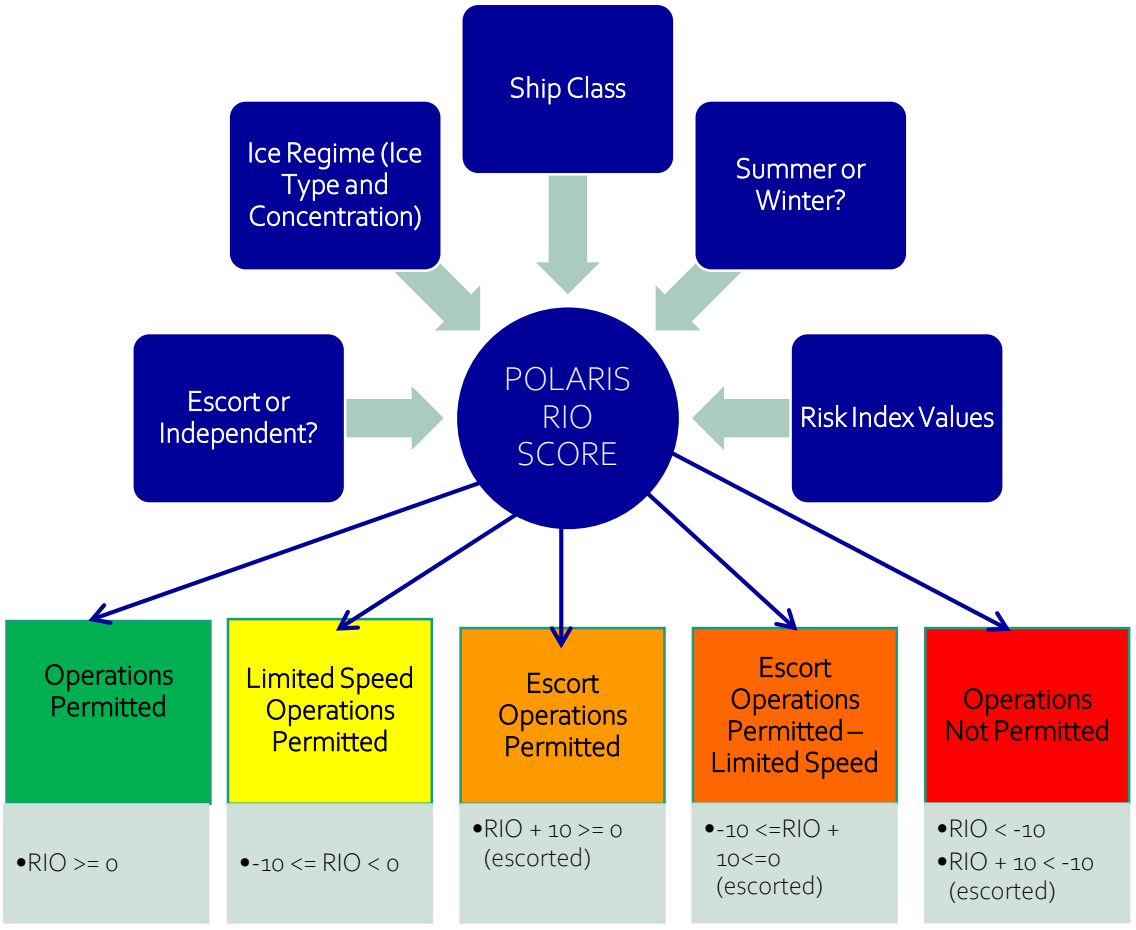
Source:AMSA 2009

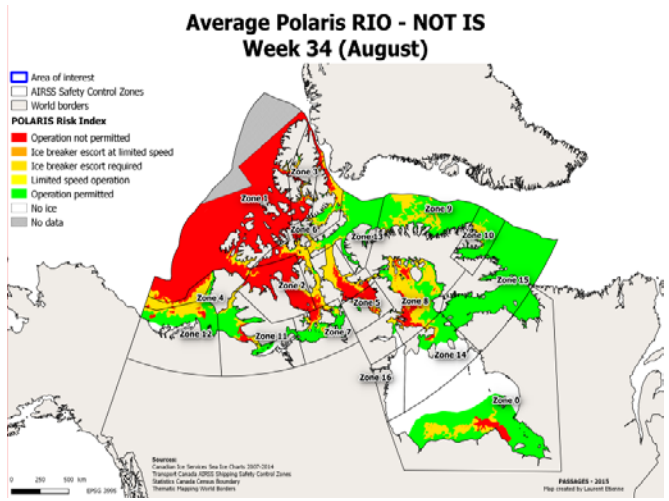
Source: http://www.tc.gc.ca/eng/marinesafety/debs-arctic-map-750.htm

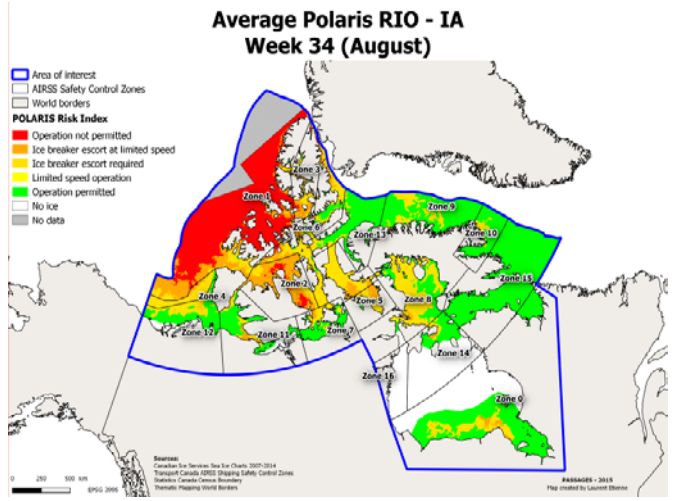
"Persistent maritime traffic monitoring for the Canadian Arctic", Proc. SPIE 10190, 4 May 2017

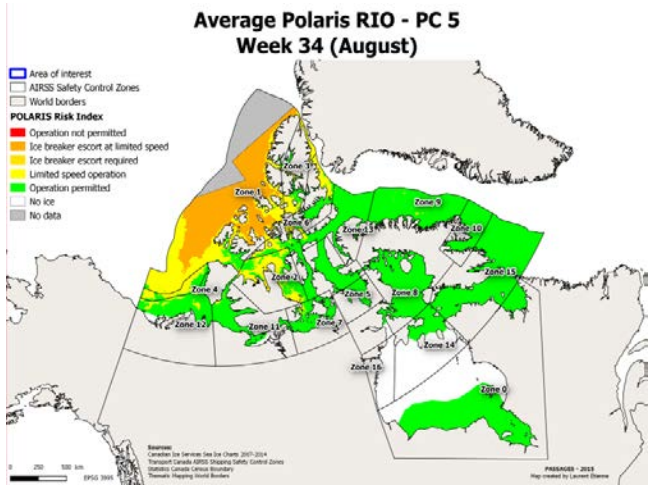
Key System Features – Assessment of Risks to Ships

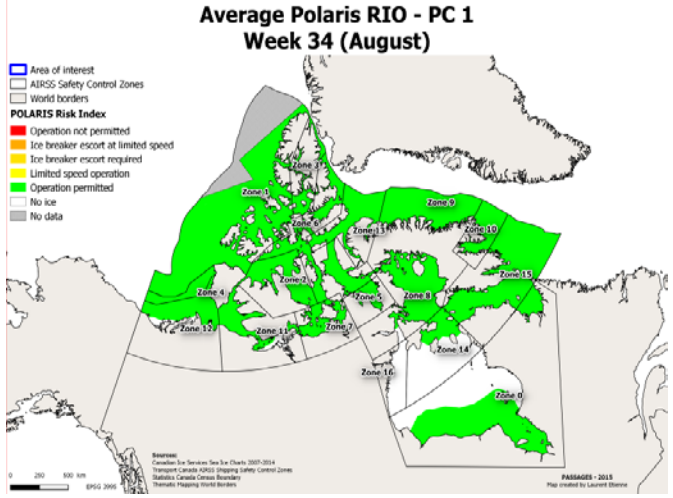
POLARIS Risk Framework







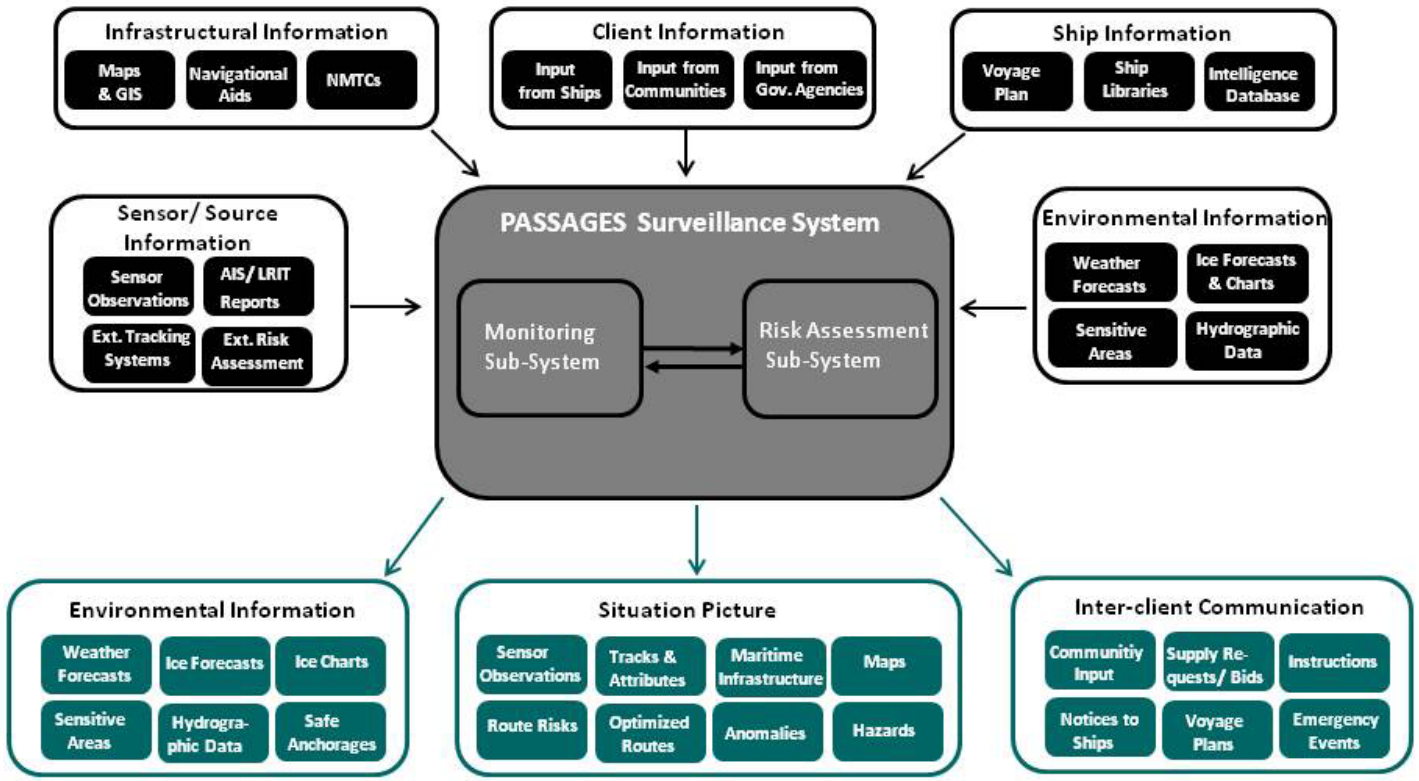




"Making sense of Arctic maritime traffic using the Polar Operational Limits Assessment Risk Indexing System (POLARIS)", 9th Symp. Int. Soc. For Digital Earth (ISDE), IOP Conf. Series: Earth and Environmental Science 34 (2015) 012034

Key System Features – Multi-Sensor/-Source Data Fusion

PASSAGES Stakeholder: "*in the Arctic, everything that can see, hear, feel, smell … should be treated as a sensor*"



Service / Platform-Sensor	Object Detection	Object Tracking	Risk Assessment	Vessel Route Optimization	Anomaly Detection
S-AIS	x	x			
S-LRIT*	x	x			
S-SAR	x	x	x	x	x
S-EO/IR	x	x	x	x	x
HAPS-SAR	x	x	x	x	x
Airborne-SAR	x	x	x	x	x
Airborne-EO/IR	x	x	x	x	x
Tactical UAV-Ice Radar	x		x	x	
Ship-Ice Radar	x		x	x	
Ship-Echo Sounder	x		x	x	
OTH Radar	x	x			x
Active Coastal Radar	x	x			x
Passive Radar	x	x			x
Radar Beacon/ Reflector			x	x	
Fixed Visual/ Acoustic Aids			x	x	

* Note that LRIT is usually only provided to national authorities

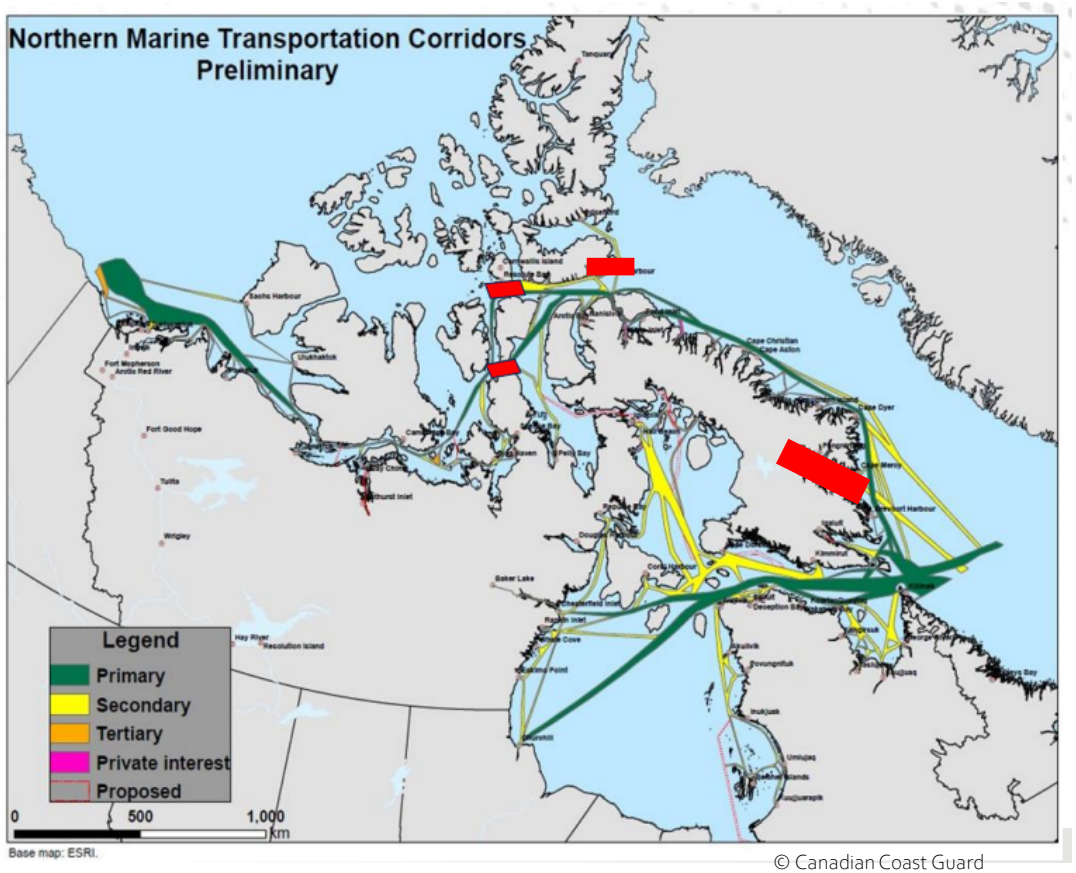
"Persistent maritime traffic monitoring for the Canadian Arctic", Proc. SPIE 10190, 4 May 2017

"PASSAGES - a system for improved safety and security of maritime operations in arctic areas," in E. Shahbazian, G. Rogova (eds.), 47 of NATO Science for Peace and Security Series – D, 2016, ISBN 978-1-61499-715-3.

Field Studies in the Canadian Arctic

Scenarios under consideration:

- Chokepoint Monitoring (Bellot Strait)
- Open Waters Monitoring (Resolute Bay)
- Search and Rescue (Devon Island)
- Covert Coastal Monitoring (Frobisher Bay)



© Canadian Coast Guard

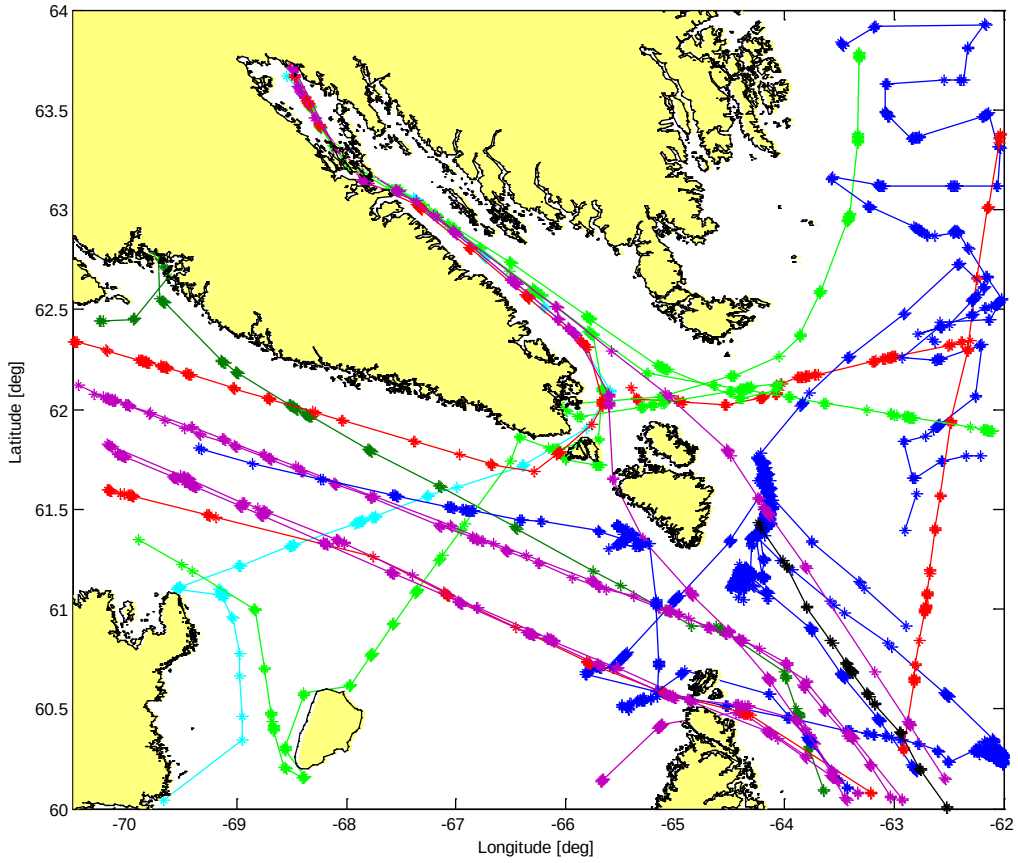
Enhanced Maritime Traffic Picture for the Canadian Arctic, 10th Future Security 2015. Security Research Conference. Berlin, Germany, 15–17 September 2015

Chénier, R, Abado, L, Sabourin, O, Tardif, L. Northern marine transportation corridors: Creation and analysis of northern marine traffic routes in Canadian waters. *Transactions in GIS*. 2017; 21: 1085– 1097. https://doi.org/10.1111/tgis.12295

Available Input Data Source

S-AIS (Satellite Automatic Identification System)

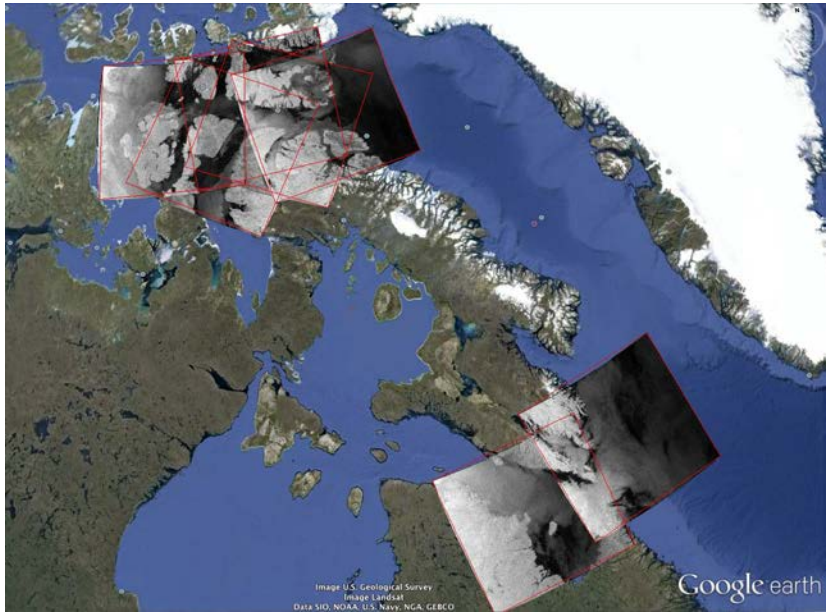
- **Real Data** from exactEarth Ltd
- Cooperative Vessels
- Vessels > 300t (500t)
- Vessel ID, Position, Velocity, SOG, COG, Heading, Timestamp, Type
- Measurements come as bursts with inter-bursts of 90 mins
- Discontinuous tracks



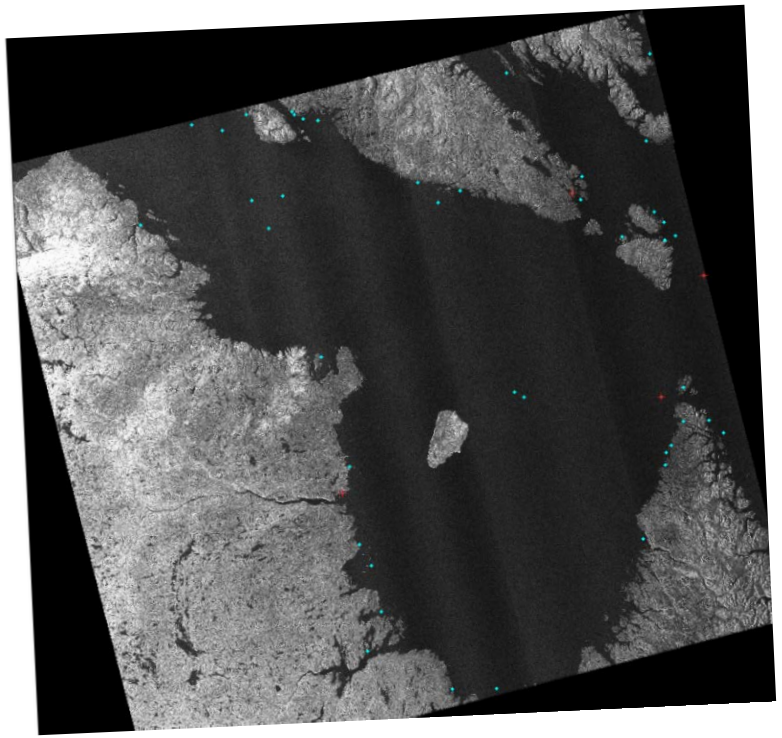
Available Input Data Source

S-SAR (Satellite Synthetic Aperture Radar) Images

- **Real Data** from RadarSAT-2 and TerraSAR-X
- Position, Heading, Length
- Low satellite revisit time for continuous surveillance
- False detections, in particular due to **ice**



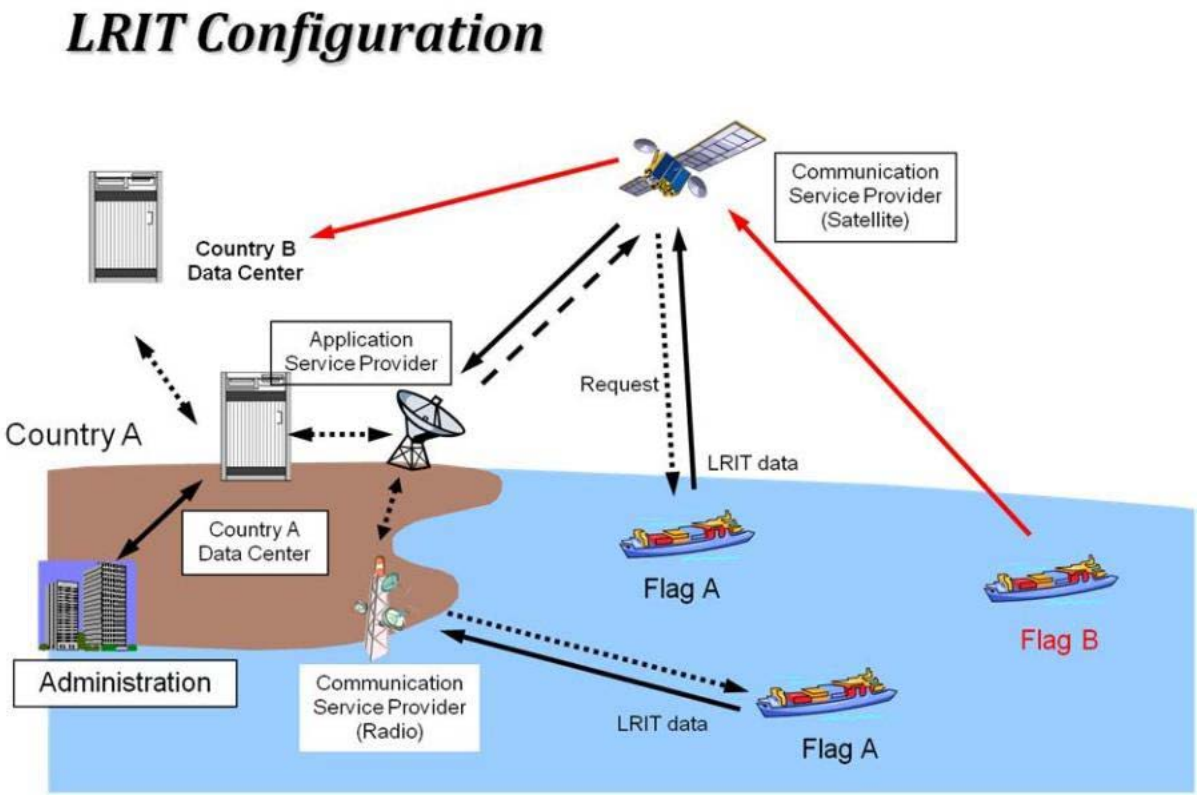
Validated with S-AIS
Not validated



Available Input Data Source

LRIT (Long Range Identification and Tracking)

- **Real Data** from Canadian Coast Guard
- Cooperative Vessels
- Vessel ID, Position, Timestamp
- Every 6 hours, can be polled any time



Additional Data Source

Active Radars

Sensor Principle

- X-band Active Electronically Scanning Array
- Large detection ranges (even small targets)
- 120°and 240°azimuth coverage

Output

- Object Detection (Position, Velocity)
- Tracks

Platforms

- Antenna arrays installed on hill, tower, lifting platform
- Potentially aircraft, UAS, airship

© Hensoldt GmbH

Additional Data Source

Passive Radars

Sensor Principle

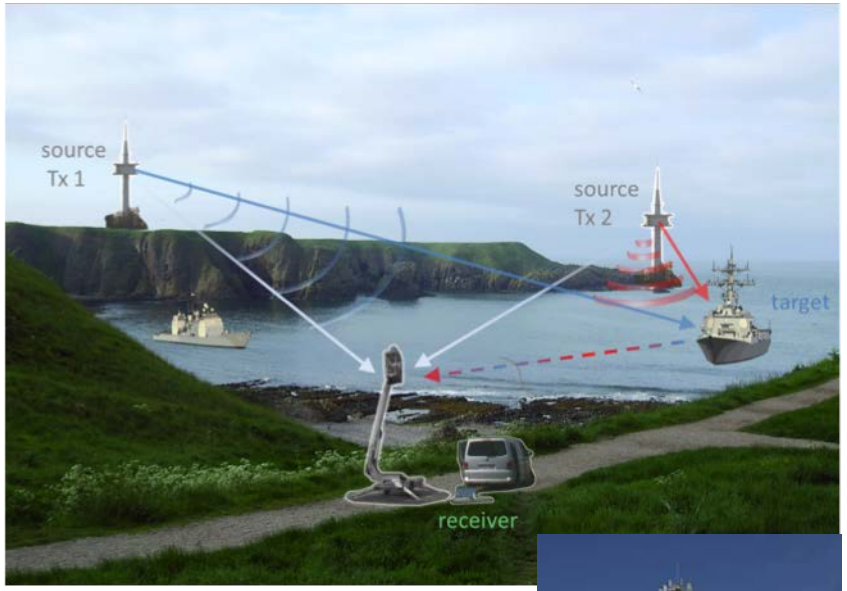
- Multistatic radar using signals from non-cooperative illuminators in the surveillance area (e.g., GSM, UMTS, LTE, DAB, FM, HF, VHF)

Output

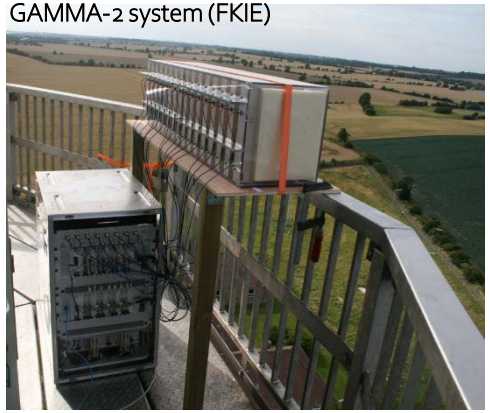
- Object Detection (Position, Velocity)
- Tracks

Platforms

- Antenna arrays installed on hill, tower, lifting platform
- Potentially aircraft, UAS, airship



GAMMA-2 system (FKIE)



R. Zemmari, M. Broetje, G. Battistello and U. Nickel, "GSM passive coherent location system: performance prediction and measurement evaluation", *IET Radar Sonar Navigation*, 8 (2), 2014

Additional Data Source

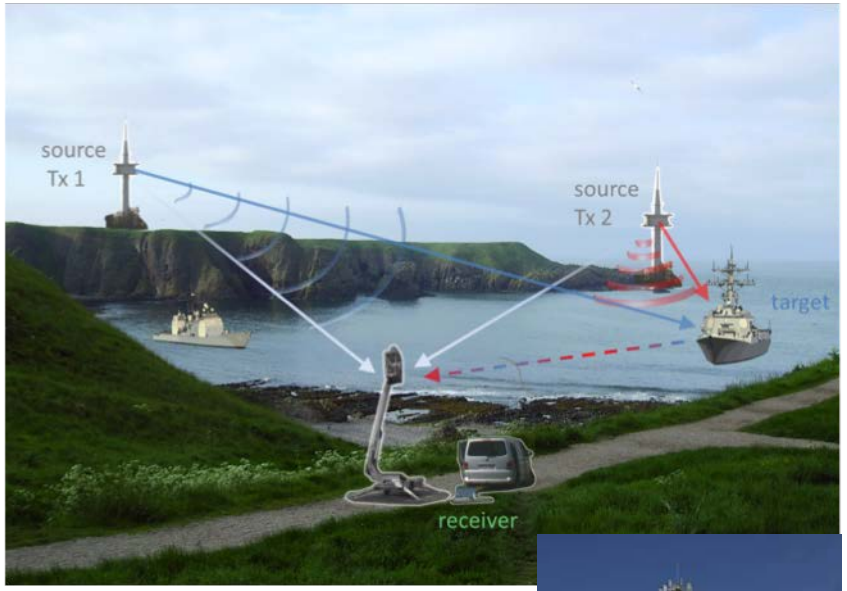
Passive Radars

Advantages

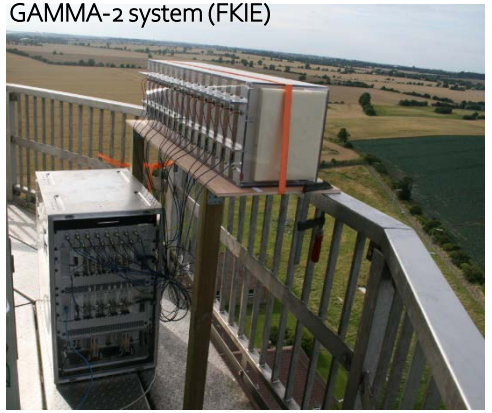
- Covert tracking ⟶ detection of non-collaborative vessels (not equipped with AIS or not using it)
- Reduced electro magnetic pollution
- Reduced installation and maintenance costs
- Not subject to authorization by safety authorities

Weakness

- Availability of broadcasting stations in remote areas



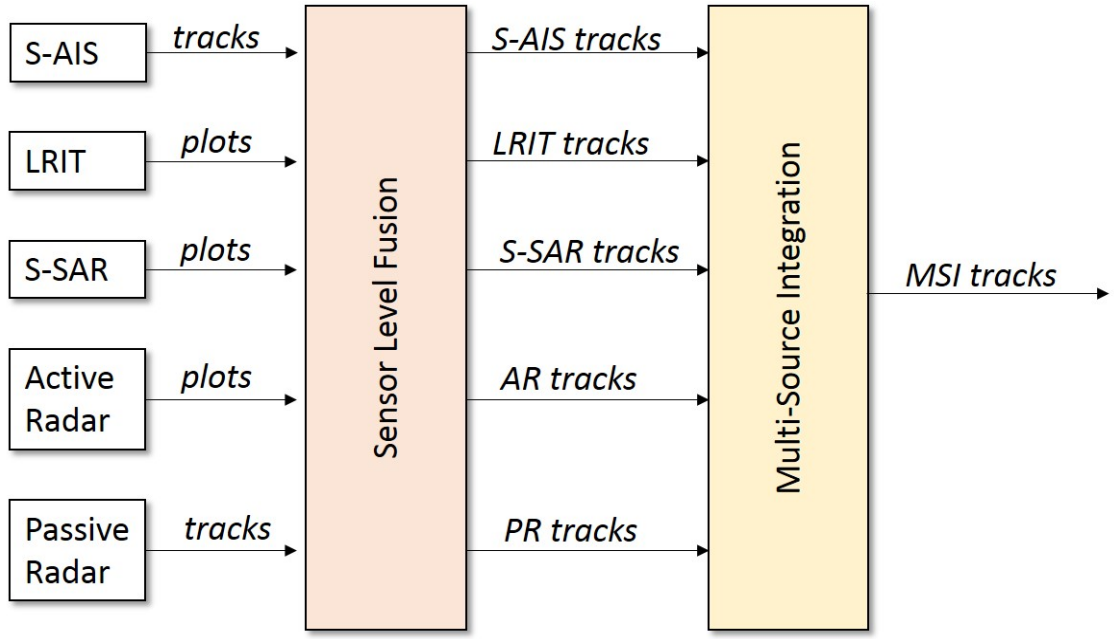
GAMMA-2 system (FKIE)



Data Fusion Engine in PASSAGES

Building Blocks

- Data Fusion to process in a common framework information from heterogeneous data sources
- Hybrid approach between centralized and distributed architectures
- Sensor Level Fusion
  - integration of measurements from a class of sensors with similar characteristics and integration of track or navigation data from an external source

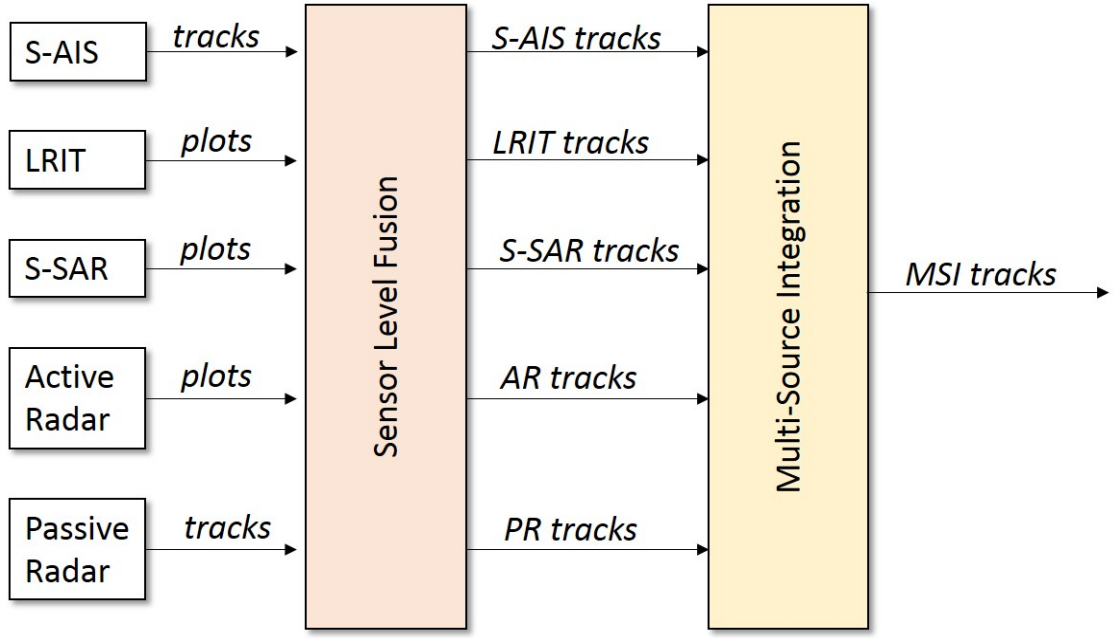


"Multi-sensor maritime monitoring for the Canadian Arctic: Case studies," *19th Int. Conf. on Information Fusion (FUSION)*, Heidelberg, Germany, 2016

Data Fusion Engine in PASSAGES

Building Blocks

- Data Fusion to process in a common framework information from heterogeneous data sources
- Hybrid approach between centralized and distributed architectures
- Multi-Source Integration
  - Integration of data from sensor level tracks into system level tracks (MSI Tracks = Multi Source Integrated Tracks)
  - Track to track correlation and association
  - Kinematics and attribute integration
  - Identification and classification



Example: Chokepoint Monitoring (I)

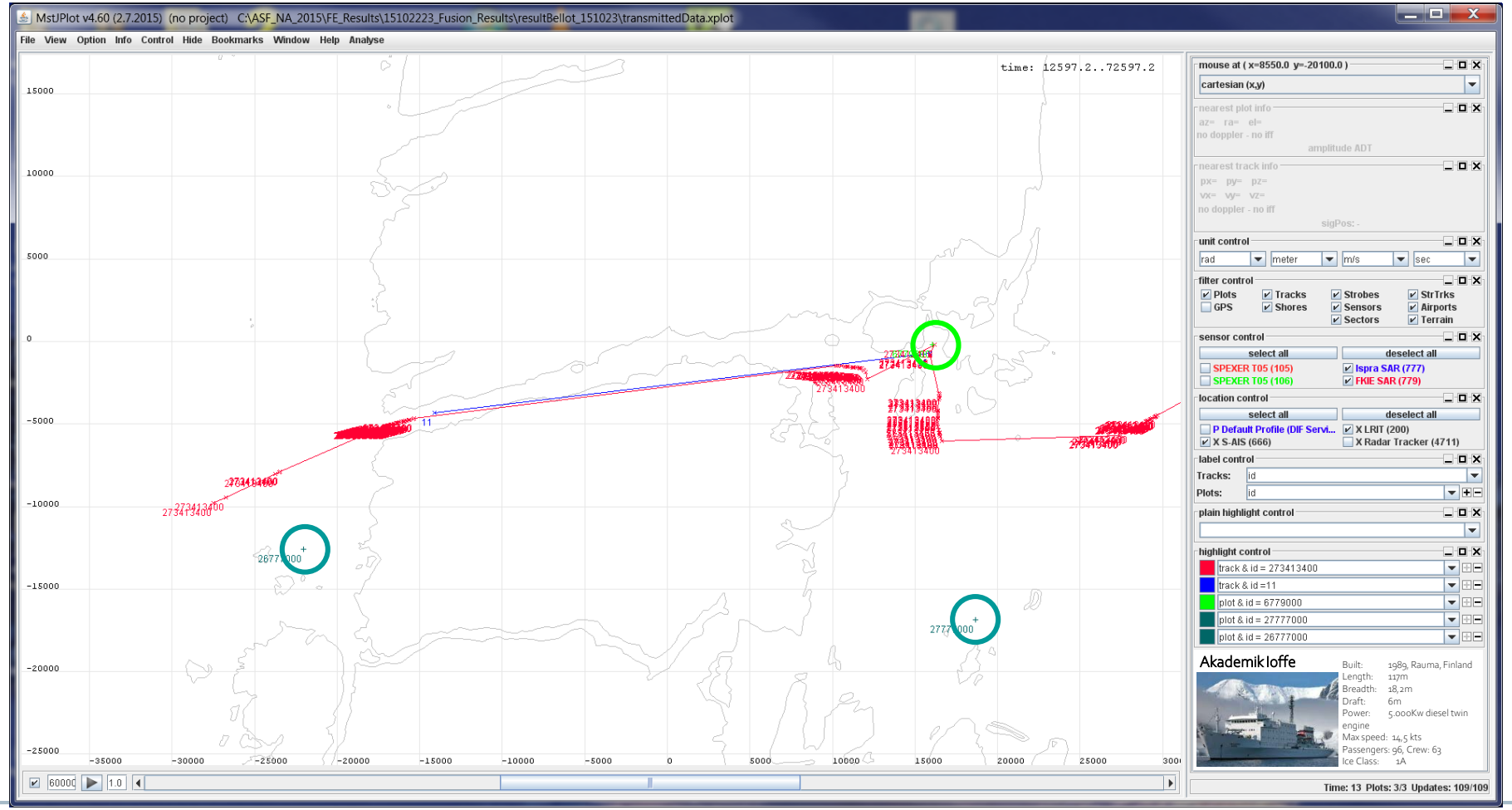
Bellot Strait

- Popular shortcut
- 30km length, up to 2km width
- Tidal difference between [7-22]m
- Icebergs
- Strong and fast currents

Example: Chokepoint Monitoring (II)

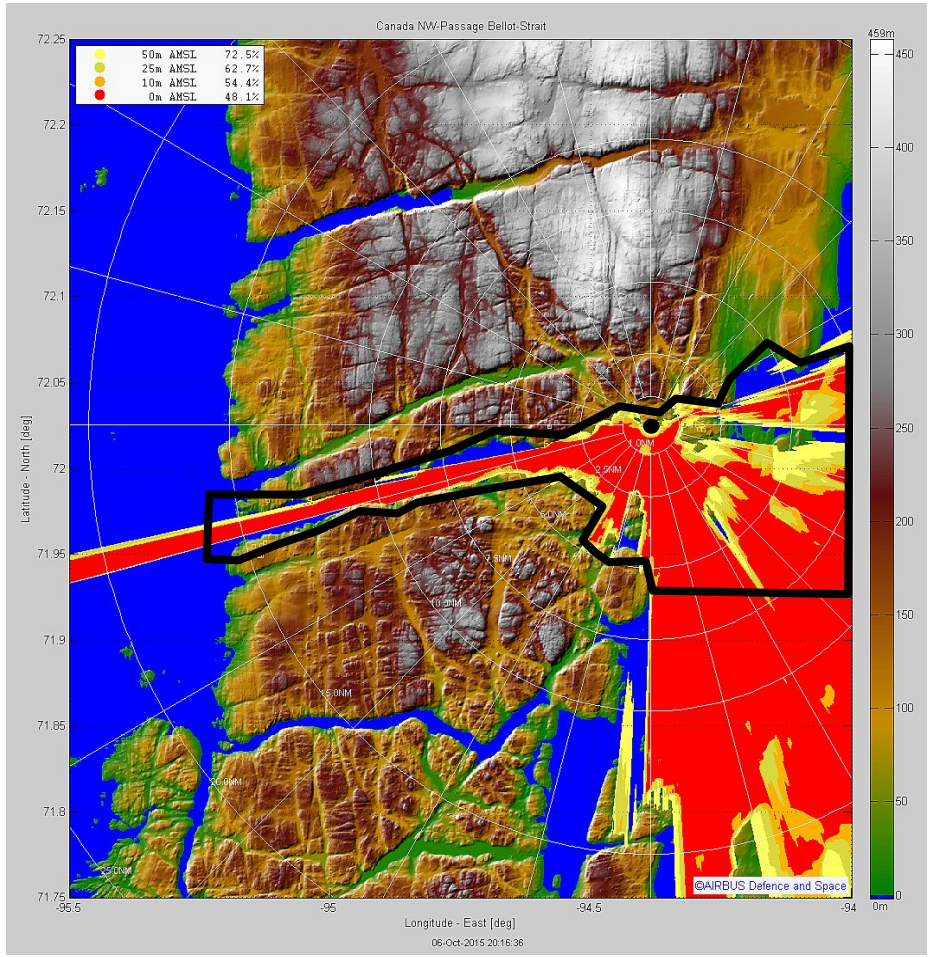
Real Data: S-AIS (red), LRIT (blue), S-SAR (circle)

90 min gap



Example: Chokepoint Monitoring (III)

Simulated radar coverage



Spexer 2000 Coastal Radar

© Hensoldt GmbH

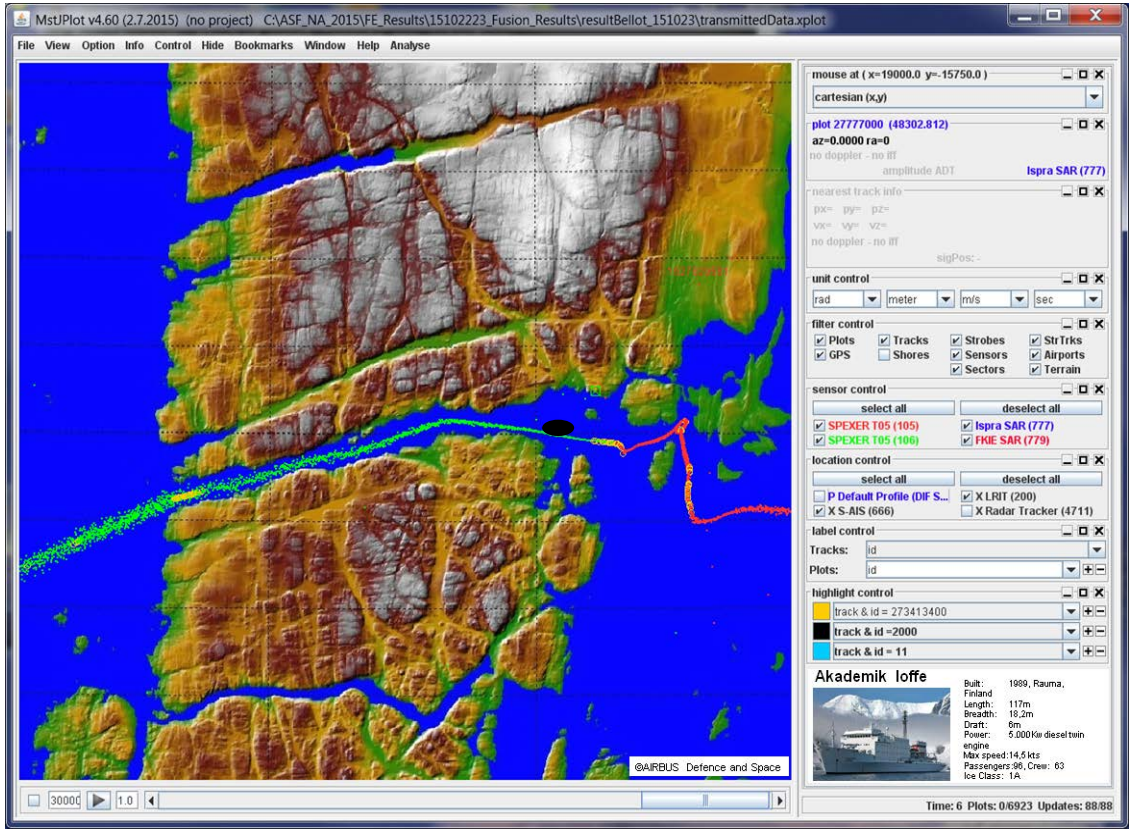
- X-band Active Electronically Scanning Array
- Increased detection & target assessment
- Low rate of false alarms
- Large detection ranges (even small targets)
- 120° and 240 ° azimuth coverage

Example: Chokepoint Monitoring (IV)

Data Fusion Results

- Simulated Data: Spexer™ 2000 Coastal Radar (red & green)
- Radar location in terms of maximum coverage determined with LoS analysis

► Continuous vessel monitoring



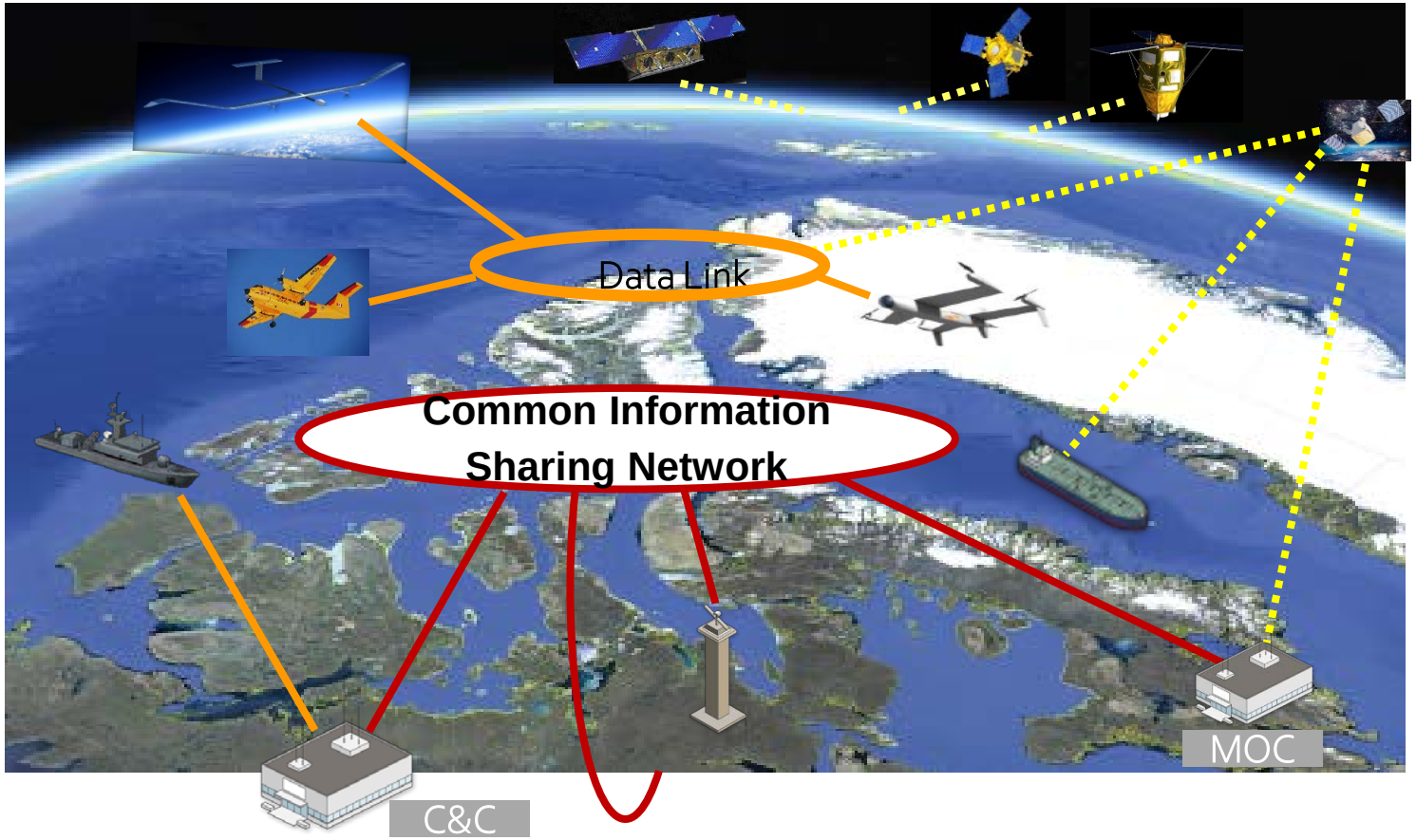
"Multi-sensor maritime monitoring for the Canadian Arctic: Case studies," *19th Int. Conf. on Information Fusion (FUSION)*, Heidelberg, Germany, 2016

Lessons Learnt

Multiple Sensor Surveillance indispensable to

- plan operations systematically, including risk assessment
- execute operations safely
- maintain sovereignty & security

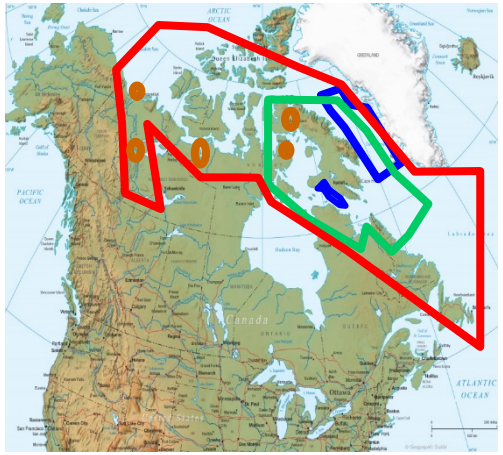
in the Arctic

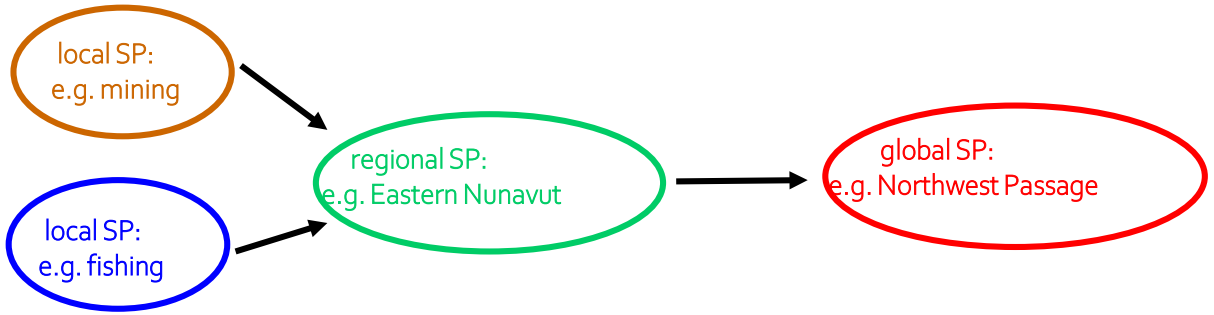


Outlook

The Arctic Operational Space:

- will be increasingly more relevant and contested
- will require NATO's and the Arctic States' joint efforts to guarantee security and safety of operations
- will need persistent monitoring of operations
- will require the use of commercial assets (e.g. satellites, vessels) as sensors of opportunity
- will use complementary sensor data to generate operation-specific real-time situation picture





Thank you for your attention!

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