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

A Canadian-German research project

Arctic Shipping Forum North America 2014
St. John’s, NL Oct. 20 – 21, 2014
# A Canadian-German Partnership: July 2013 – June 2016

<table>
<thead>
<tr>
<th>Sponsors</th>
<th>NSERC-CRD</th>
<th>Airbus Defence &amp; Space</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>exactEarth Ltd.</td>
<td>Germany Federal Ministry for Economic Affairs and Energy</td>
</tr>
<tr>
<td>Project Team</td>
<td>Dalhousie University</td>
<td>Airbus Defence &amp; Space</td>
</tr>
<tr>
<td></td>
<td>exactEarth Ltd.</td>
<td>Fraunhofer FKIE</td>
</tr>
<tr>
<td>Experts</td>
<td>Norstrat Consulting</td>
<td></td>
</tr>
<tr>
<td></td>
<td>YOU</td>
<td></td>
</tr>
</tbody>
</table>
PASSAGES: to provide reliable maritime situational awareness

Project To specify the requirements and the modular architecture of an innovative maritime system to support multi-lateral operations in Arctic waters with a focus on the Northwest Passage

System To help clients systematically plan an operation, safely execute it, efficiently manage available resources and vessel traffic in the Northwest Passage

Activities
- Stakeholder analysis
- Concept of Operations
- 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

Associated Projects
- Shipping Companies and Arctic Navigation
- Shipping in the Canadian Arctic: Answering the Questions of Who
- The need for an integrated and collaborative approach to managing future maritime traffic in the Arctic
Outline

Dr. Ronald Pelot  
Industrial Engineering  
Dalhousie University

Dr. Camilla Mohrdieck  
Airbus Defence & Space  
Ulm, Germany

Dr. Martin Ulmke  
Fraunhofer FKIE  
Bonn, Germany
The MV Akademik Shokalskiy, Antarctica

- 8 Dec, 2013: sailed from Bluff, NZ to Antarctica
- 74 passengers: journalists, scientists, tourists, crew

INCIDENT 25 Dec: trapped in ice a few miles from coast

- Chinese Snow Dragon: rescue halted because of ice
- French L’Astrolabe: rescue halted because of ice
- Australian Aurora Australis: rescue halted because of ice

RESCUE 2 Jan: Helicopter from Snow Dragon brings passengers to Aurora Australis

- U.S. Polar Star tasked to assist Akademik Shokalskiy and Snow Dragon, but they break free of the ice themselves

OBSERVATIONS

- "We have learned from nature, as humankind always does," Andrew Peacock said, that it's possible to be "caught by an unexpected and not predicted" situation.

- “Great example of multi-lateral cooperative nature of Antarctic operations” (Mick Kinley, AMSA)
The Clipper Adventurer, Canadian Arctic

- 14 Aug. 2010: sailed from Kangerlussuaq, Greenland to Kugluktuk, NU
- 128 passengers + 69 crew

INCIDENT 27 Aug. 2010: ran aground in 3 m of water

- 1915h: JRCC Trenton advised of the grounding
- 1932h: CCGS Amundsen tasked from Lady Franklin Point

RESCUE 29 Aug: passengers transferred to CCGS Amundsen

- 29 Aug: CCGS Sir Wilfrid Laurier tasked for pollution control
- 31 Aug: CCGS Sir Wilfrid Laurier arrives at Clipper Adventurer
- 14 Sept: Clipper Adventurer refloated

OBSERVATIONS

- Adventure Canada CEO Matthew Swan reported to the CBC news channel, “…It’s a part of the world where you do your best, but there are blank spots on the map.”
- “How can risk be minimized for the increasing number of cruise ships and tourists visiting the Canadian Arctic?” E.J. Stewart and J. Dawson.
Risk analysis within the PASSAGES Project

**Risk → Surveillance**

- Use risk assessments to prioritize surveillance needs
- Yields guidance on spatial distribution of diverse risks
- Aligns with Canadian Coast Guard Arctic marine corridors

**Surveillance → Risk**

- Use traffic monitoring system for:
  1. Planning: generate/improve risk models to develop mitigation strategies
  2. Operations: assist with near real time risk assessment & reduction

Dr. Laurent Etienne
The Need for Risk Management in Polar Shipping

- High winds
- Freezing spray
- Visibility
- Ice conditions
- Chart accuracy
- Dynamic shoreline
- Hull strength
- Engine Failure
- Lack of ice experience
- Lack of Nav aids
- Loss of communications
- Emergency response coordination
- Vessel Accident
- Technological failure
- Management
- Weather
- Geography
Risk Management Options

Hazards → Delivery Mechanism → Immediate Consequences → Ensuing Consequences → Ultimate State

Prevention → Detection → Response → Recovery

Vulnerability → Resilience → Interfere with Process → Strengthen System → Lower Consequences

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

**PASSAGES is:**
- a vessel-traffic-management System
- for government agencies and
- a maritime navigation-support System
- for commercial & private clients
- operating in Arctic waters

**PASSAGES supports:**
- Protection of special areas
- Surveillance of:
  - transit traffic
  - destination traffic
  - resource development traffic
  - fishing activities
  - cruise and private ships
- Safety and Security operations
- Efficient planning, execution & resource management

**PASSAGES uses:**
- Advanced data fusion:
  - AIS, LRIT reports
  - synthetic-aperture radar
  - active coastal radar
  - passive radar
  - passive AIS
  - optic & IR imagery
  - env., nav. & ship information
- Advanced risk models
- Advanced anomaly detection
PASSAGES is:

Vessel Traffic Management System

= Support System for Planning and Executing Safe and Efficient Sailing Voyages

Vessel Traffic Monitoring and Control System

government agencies, e.g.: • CCG, • TC, • Env. Can.

commercial and private operators, e.g.: • commercial ships, • shipping companies, • ship insurers, • maritime industry, • fishing vessels, • private ships, • northern communities

Support System

for Planning and Executing Safe and Efficient Sailing Voyages
PASSAGES supports: long/medium-term planning of an operation
PASSAGES supports: execution of an operation

- **near-real time**

- **recursive update of operational plan if required**

**government agencies**
- other clients, e.g.:
  - northern communities

**PASSAGES**
- sensor data, contextual information, vessel tracks & attributes, behavior patterns

**anomalies**
- anomaly identification & warning
  - spatio-temporal risk analysis
    - archiving, add. contextual/ risk information

**government agencies**
- other clients, e.g.:
  - northern communities

**commercial/private operators**
- ship starts operation
  - sit. picture

**anomalies**
- risks
  - suggestions for risk prevention/ mitigation
    - confirmation of action
  - suggestions
    - conf. of action

**government agencies**
- other clients, e.g.:
  - northern communities

**commercial/private operators**
- ship starts operation
  - sit. picture

**anomalies**
- risks
  - suggestions for risk prevention/ mitigation
    - confirmation of action
  - suggestions
    - conf. of action

**government agencies**
- other clients, e.g.:
  - northern communities

**commercial/private operators**
- ship starts operation
  - sit. picture

**anomalies**
- risks
  - suggestions for risk prevention/ mitigation
    - confirmation of action
  - suggestions
    - conf. of action

5/4/2015
System Interfaces

Observations

Information Providers

Government Agencies

Ship/ Shipping Company

Northern Communities

Other Companies e.g. mining

PASSAGES

Services:
- contextual information
- situation picture
- warnings of abnormal ship behavior
- notification of maritime risks
Benefits for Clients

During Planning Phase:

• ensure a **systematic** and **timely planning** of activities

• follow a **pre-defined** and **automated planning procedure**

• **keep** government agencies and commercial/ private operators (incl. northern communities) **involved** and **informed** during entire planning phase

• minimize **individual** and **overall** navigational risks

• help **coordinate** multilateral efforts and **share** resources

• **archive** operational plans and decisions for later use

• act as **single point of contact** for all involved actors

• act as **communication nexus** between government authorities and operators
Benefits for Clients

During Execution Phase:

- provide clients with **maritime domain awareness**

- **continually update and disseminate** important environmental and navigational information

- support government agencies in **monitoring and controlling** vessel traffic

- **automatically detect and warn** of anomalous ship behaviour

- **in-time and spatio-temporal** risk analysis

- act as **communication nexus**

- **archive** suggestions and decisions for later use
Main System Functions

**PASSAGES**

**Information & Data Acquisition**
- collect sensor data & contextual information
- monitor vessel traffic

**Maritime Domain Awareness**
- fuse & integrate sensor data & inform.
- maintain situation picture

**Analysis and Decision Support**
- detect anomalies
- analyze risks

**Information Archiving & Dissemination**
- archive products & communications
- disseminate products & information as needed
Sensor and Information Fusion

Sensor data
- Remote sensing
- Medium range
- Short range
- Persistent
- On demand
- Cooperative
- Active/passive sensing

Context information
- Geography
- Weather and Ice
- Sea lanes
- Ship schedules
- …

Building blocks for Situation Picture:
- Which objects are there?
- How many?
- Where and when?
- How do they behave?
- What are their properties?
- Do they interact?
- Who exactly? (ID)
- What are their intentions?
- …
**Backbone: Satellite AIS**

**Commercially available (e.g. exactEarth)**

Required for:
- All ships >300 tons gross on international voyages
- Cargo ships >500 tons on any route
- Passenger ships of any size built after 2002

**Weaknesses**
- Not required for small ships
- Provide position reports, not tracks
- Possible false reports, spoofing, or switched off
- Limitations due to spacecraft availability
  - Temporal and spatial gaps

![Generated Tracks August 2013](cumulative AIS position reports, August 2013)
Space Borne Imaging Sensors (active / passive)

Commercially available

Sensors
- Still and Motion Imagery
- Optical, Infrared, Multi-spectral, Polarimetric
- Synthetic Aperture Radar (SAR)

Output
- Images (multi-spectral)
- Potentially elevation
- Object detection and classification
- Change detection
- Possibly tracks

Weaknesses
- Weather dependent (EO, IR)
- Limited resolution
- Limitations due to spacecraft availability

Medium Range Sensors and Platforms

- **Surveillance radar**
  - Air surveillance radar (primary, secondary)
  - Coastal radar

**Weaknesses**
- Not (yet) available/installed

- **Airborne sensors**
  - **Platforms:**
    - Patrol aircraft
    - UAS (MALE)
    - Airship / balloon

  **Sensors:**
  - Electrooptics (EO)
  - Infrared (IR)
  - SAR
  - EM direction finding antenna
  - ...

**Weaknesses**
- Not persistent
- Limited availability

Example: aircraft detection from aerial SAR

Dash-8 surveillance aircraft, Transport Canada

Saab 340 MSA: EO, IR, SAR, AIS

IAI Heron 1

Qinetiq Zephyr HAP
Up to 14 days endurance
Short Range Sensors and Platforms

perimeter control, choke point surveillance

- **SONAR**
  - Fixed Sonar arrays
  - Rapidly Deployable Sonar (RDS)
  - AUV missions

**Output:**
- Object detection
- Bearings
- Localization
- Classification

**Weaknesses**
Maintainability and communication requirements

- **Fixed or Airborne Sensor Nodes**
  - EO + ...

**Weaknesses**
- Need local infrastructure
- Weather dependence of sensors and platforms
- Airborne: small endurance

Example: Digital Hydrophone array
LDHA-2279 (Omnitech Electronics Inc.)

Schiebel Camcopter S-100 VTOL
Proposal: Passive Radar

Sensor principle
Multistatic radar using non-cooperative illuminators, e.g. GSM, UMTS, LTE, DAB, FM, HF, VHF

Output
• Object detection
• Tracks
• Short-medium range surveillance

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

Weaknesses
Availability of broadcasting stations
Sensor Data Fusion

Goal: Extraction of *Situation Picture Building Blocks*

Tasks:

**Data alignment**
- Common coordinate system
- Time synchronization (out-of-sequence data)

**Centralized fusion**
- Align, correlate, and fuse *sensor data*
- Theoretically optimal use of (heterogeneous) sensor data
- Requires high communication bandwidth
- More susceptible to false data, misalignments, etc.

**Decentralized fusion**
- Tracking of data from each sensor
- Correlate tracks: which tracks describe the same object?
- Aggregate tracks: combine heterogeneous information, e.g. position and ID
- Fuse *tracks*: improve estimates, bridge gaps, etc.

Integration and Fusion with background information
- Ice situation, weather
- Coastlines, bathymetry
- Arctic marine corridors, sea lanes, shipping schedules
Example: Vessel route prediction based on learned sea lane patterns

Last recorded measurement

T = 0 (yellow point)

After T = 15 min

Ground Truth

After T = 30 min

Ground Truth

After T = 45 min

Ground Truth

After T = 60 min

Ground Truth

After T = 90 min

Cyan points = actual vessel course (Ground Truth)

Magenta point: corresponding Ground Truth point in relation to the prediction time

Probability Map: red mean higher position probabilities
PASSAGES: support operations in the arctic

Canadian Arctic Shipping Routes

Arctic Ocean Bathymetry (m)
- 200 m
- 500 m
- 1000 m
- 2500 m
- 4000 m
- 5000 m

Arctic Communities

Shipping Routes, 2004

Thank you for your attention