"Canada's Third Generation High Frequency Surface Wave Radar (HFSWR) System for Persistent Surveillance of the EEZ"

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Canada's Third Generation High Frequency Surface Wave Radar System, Peter Moo, Tony Ponsford, David DiFilippo, Rick McKerracher, Nathan Kashyap, and Yannick Allard, published in the Journal of Ocean Technology (JOT)- special issue on Maritime Domain Awareness Vol 10, No. 2 pages 22-28. 2015.

Requirement For Radar

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New Zealand navy attempts to board two illegal fishing boats in Southern Ocean

By Felicity Ogilvie and Gregor Salmon

Updated Wed 14 Jan 2015, 1:56am

PHOTO: Crew members fishing illegally in the Southern Ocean haul in a Patagonian toothfish. (Supplied: NZ Defence Force)

Photograph by: Handout, RCMP

The Telegraph

By Miranda Prynne, News Reporter
11:18AM GMT 23 Jan 2014

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Ghost ship carrying cannibal rats could be heading for Britain

A deserted cruise liner which is believed to have been drifting around the North Atlantic for a year carrying nothing but hordes of rats could be heading for British shores, it has been claimed

Set sail from Canada bound for Caribbean where it was to be scrapped when towing cable snapped and the boat was sent adrift

Radars for Maritime Domain Awareness

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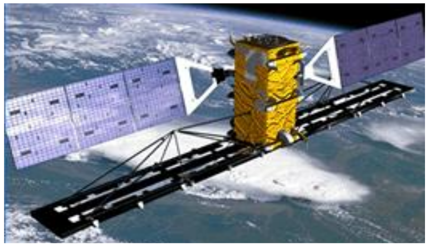
Surveillance

Land-based VTS radars
- 20m vessel 60 km
- Persistent Tracking

Land-based HFSWR
- 20m vessel, 280 km
- Persistent Tracking
- Day/night dependency

Land-based OTH radars (HF)
- 20m vessel, 3000 km
- Persistent Tracking

Reconnaissance


Courtesy Radarsat International

Space-based C-Band radars
- Minimum detectable vessel 25m
- Approx. 500km swath
- Vessel Position Update ~ every 2-days

Airborne radars
- 20m vessel to ~ 100km

Ship-based Navigation radars
- 20 m vessel to ~40 km in calm conditions

Persistent Surveillance requires fixed platforms
Reconnaissance requires platform mounted radars

Why HF Surface Wave

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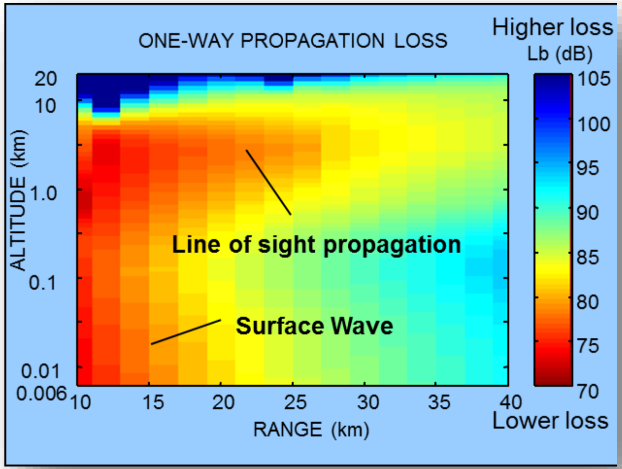
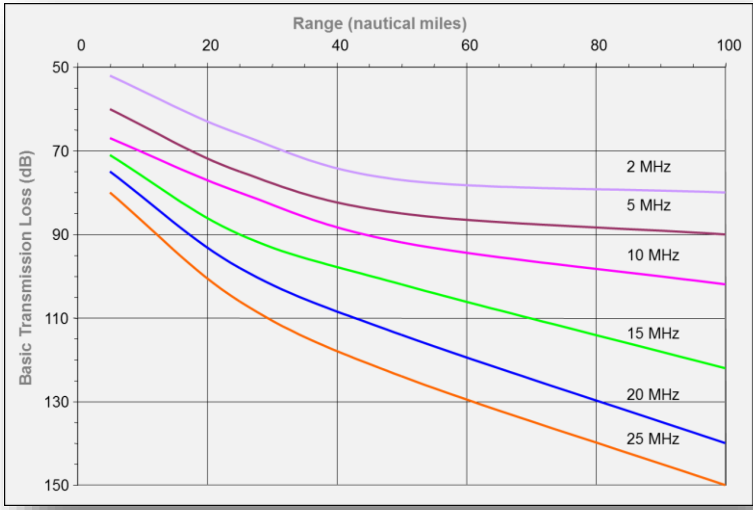
Propagates to beyond the horizon by defraction around the earth and refraction in the lower atmosphere above the earth



- attenuate directly as functions of distance (range), frequency and surface roughness
- propagate efficiently in vertical polarization only
- requires a conducting surface, such as a saline ocean, to propagate.

Basic Transmission Loss Smooth Earth

Dielectric Constant=80, Conductivity = 4 mhos/m)



Propagation losses increase with increasing frequency as does the rate of increase. Additional losses due to Sea State increase with frequency as does the rate of increase

HFSWR Principle of Operation

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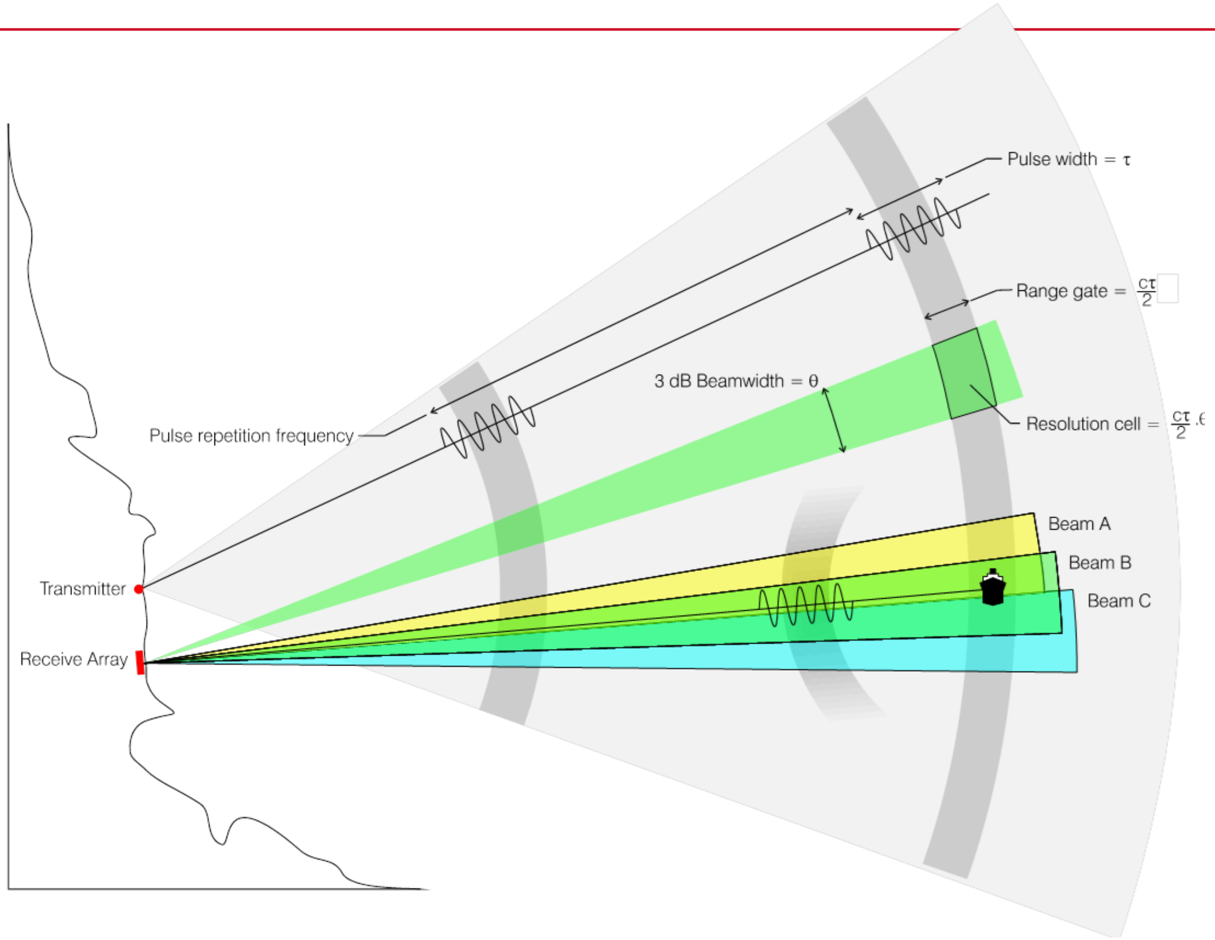

Raytheon's HFSWRs are Coherent Pulse Doppler systems specifically designed for surveillance of the 200 nautical mile EEZ

HFSWR Program Timelines

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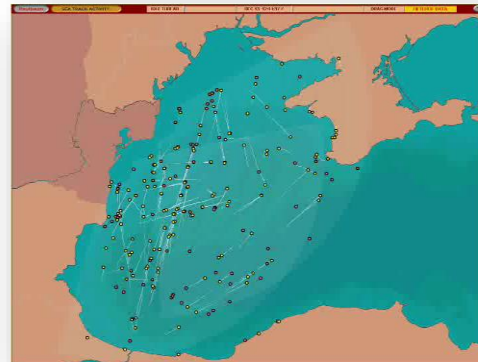
1988-2002: Canadian R&D
2003-2007: SWR503 System Operational with Canadian Navy



Movie Black Sea

2009: Second International Sale. Two Systems for coverage of the Black Sea.

Movie Asia

2008: First international sale to Asian Navy.

2011-15: Raytheon Canada executes PASE TDP contract to develop 3rd Generation HFSWR system for Canadian Government.

Persistent Active Surveillance of the EEZ (PASE) TDP Objectives

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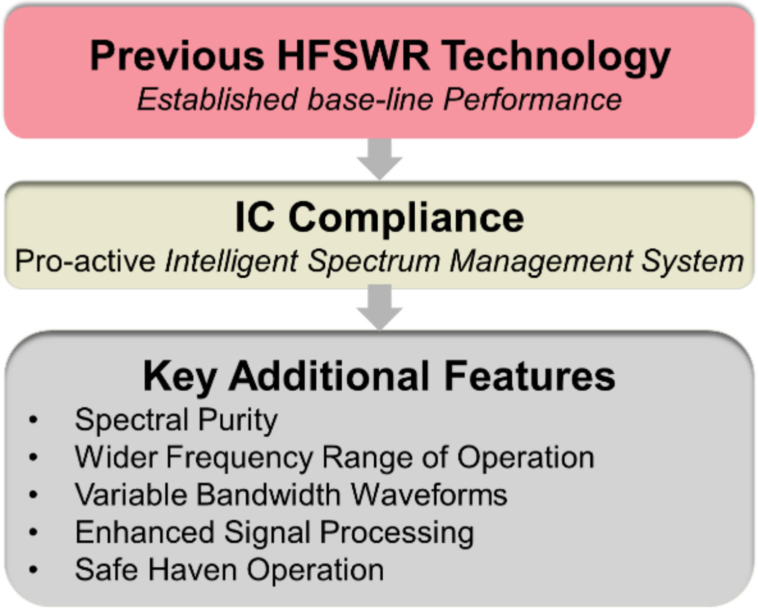
- PHASE 1 was a comparative study of EEZ surveillance options study carried out by Defence Scientists.
  - Confirmed that HFSWR was most viable sensor based on a combination of cost and performance*

- PHASE 2 was the development of a 3rd Generation HFSWR that:
  - Software defined, Cognitive Radar Architecture.
  - Meet 2009 Industry Canada spectrum management guidelines for operation on a non interference/non protective basis whilst providing 24/7 operation.
  - Provides enhanced detection and tracking performance of small vessels.



*DiFilippo, D.J., Riddolls, R.J., Dickson, R., Pinnell, J., Sensor Options analysis for persistent, active surveillance of the EEZ, DRDC Technical Report 2010-254 December 2010

3rd Generation HFSWR Design Highlights

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- Direct Conversion Receiver-Exciter technology
  - A software based radar approach
- Extensive use of COTS products
- Computer Operating System
  - All S/W functions (SCS, SDP, GUI, PE, Tracker and Database) hosted on a common processing system with industry standard Linux OS.
- Custom Transmitter
  - excellent gain and phase linearity
  - Resulting in low and constrained side-lobes
- Intelligent Spectrum Monitoring
  - Automated Pro-active Option Available
  - Cognitive Operation Enabled

PASE HFSWR Site

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VAA Radar Site Layout*

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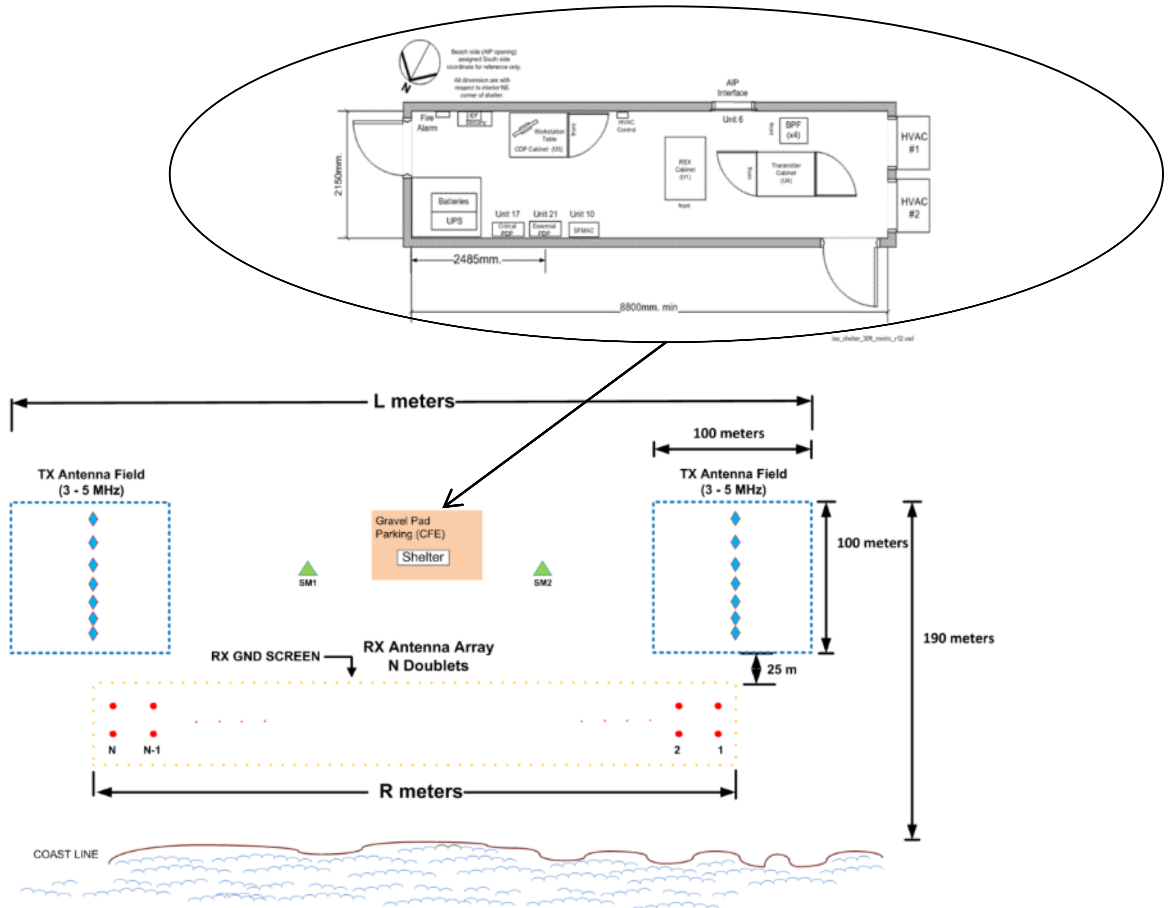
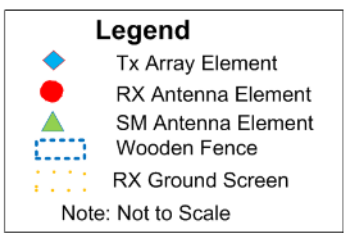
* Patent pending





The VAA configuration provides enhanced detection of small vessels in clutter

Virtual Aperture Array* (MIMO)

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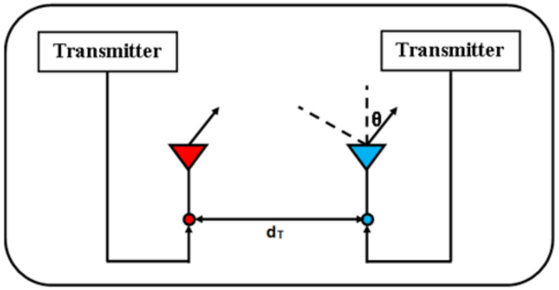
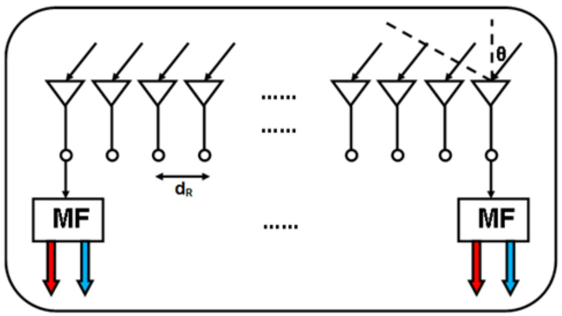
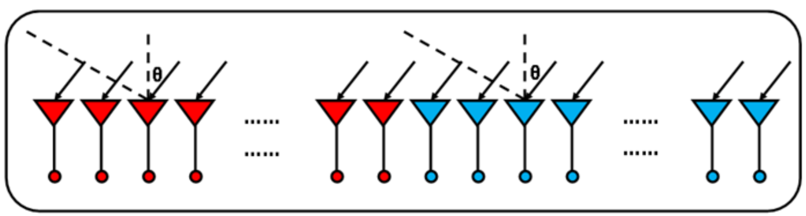


Transimitter

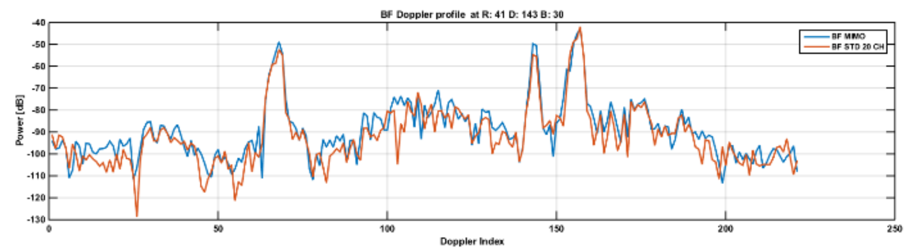


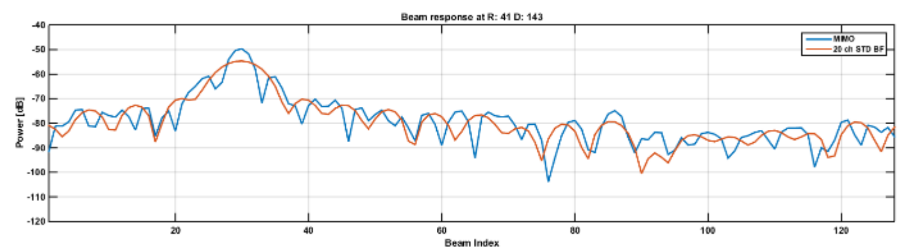
Receiver



Virtual Array

During operation, the HFSWR sends pulses simultaneously through the two transmit antennas. On receive, the pulse return from both antennas are separated to form the virtual array (2 x physical aperture in size).





* Patent Pending

Raytheon's VAA Technique Enhances Small Vessel Tracking

Intelligent Spectrum Management

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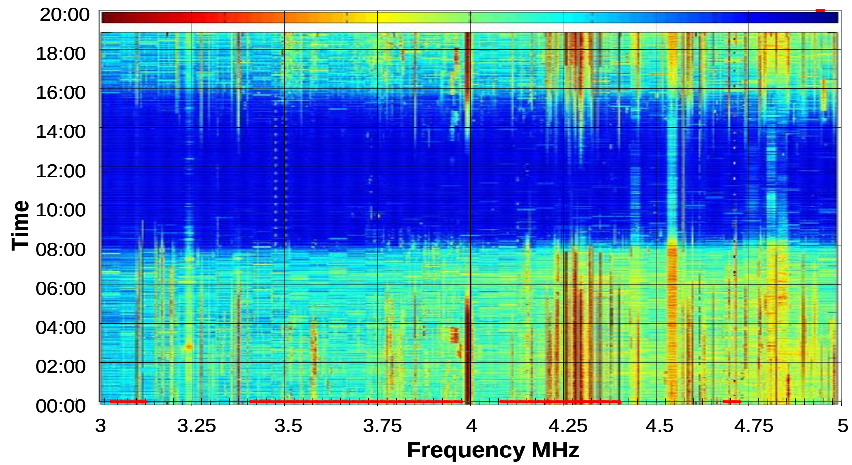
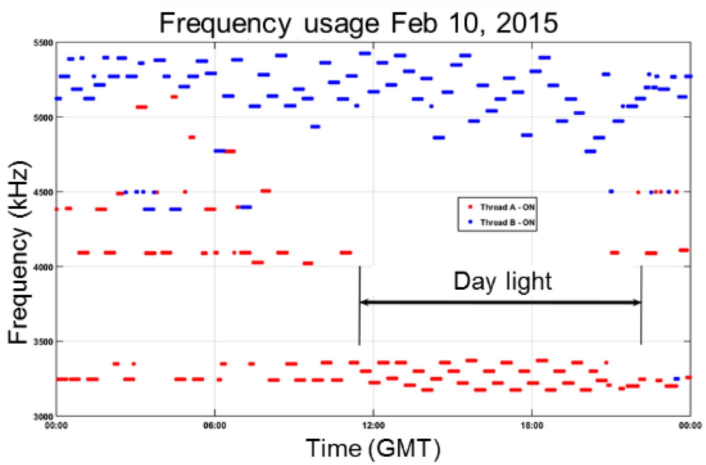
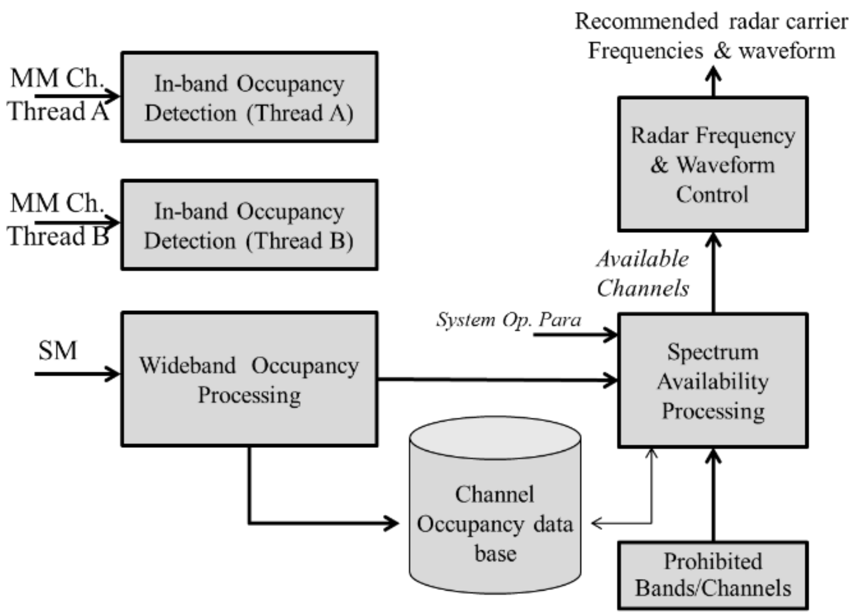




Pro-Active Remote Intelligent Spectrum Management (PRISM)



Pro-Active Remote Intelligent Spectrum Management (PRISM) Enables Cognitive Operation Where the System Adapts to the Local Environment

PRISM - Intelligent Spectrum Management

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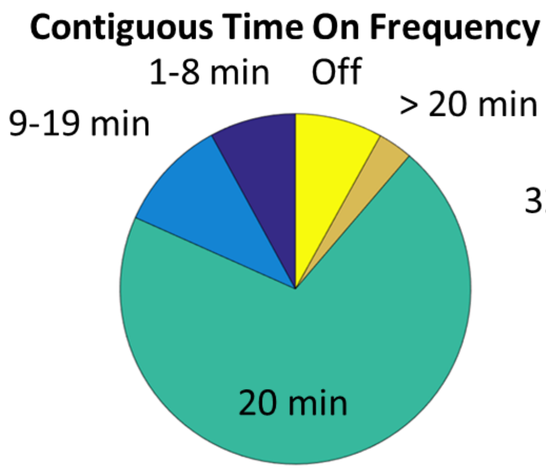
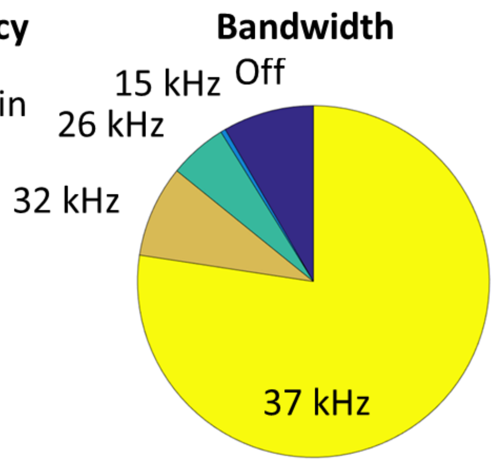
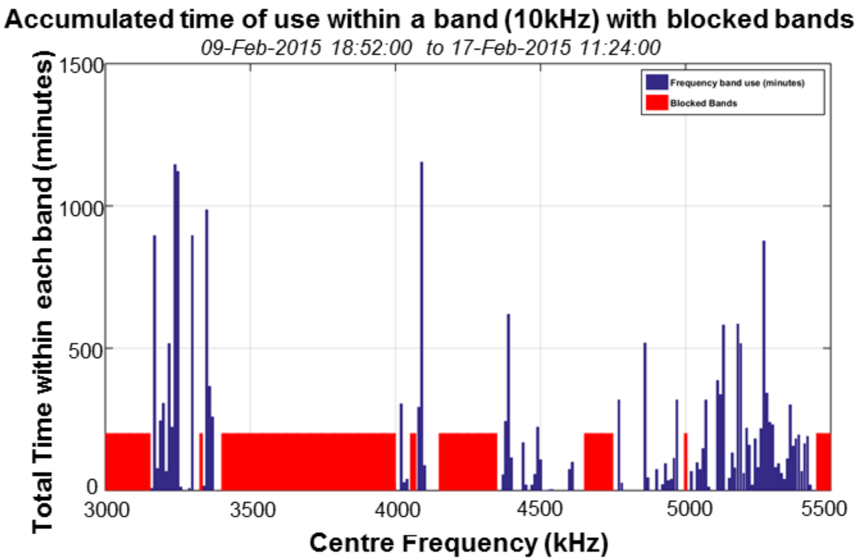
PRISM: Performance Stats over 192 hour period

THREAD 1 OF 2







PASE HFSWR Performance

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	VESSEL TYPE	MAXIMUM DETECTION RANGE (km)		
		Sea States 0-4* *0-15 knot wind* day/night	**Sea States 5-6** *15-25 knot wind* day/night	**Sea State 7** *25-35 knot wind* day/night
	**Small Vessel** *65 ft trawler*	230/210	75/75	
	**Medium Vessel** *~1000 ton displacement*	300/220	300/220†	180/180†
	**Large Vessel** *>3000 ton displacement*	370/260	370/260	370/260

VAA SIGNIFICANTLY IMPROVES TRACK RANGE FOR VESSELS THAT WOULD OTHERWISE BE CLUTTER LIMITED

Example – SysSAT Text Run

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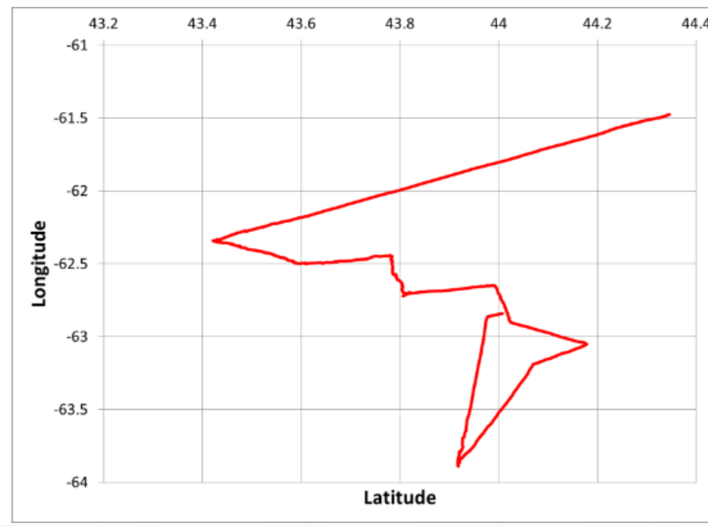
- The test asset MV Strait Explorer is classified as a category 2 target.
- Sea States at the time of the trials were Gale Force >7
- Vessel was tracked continuously throughout the day/night
- System maintained track on vessel whilst operating in Frequency Agile Mode.
- The Tracker correlated PLOT Data from two frequency threads each with two processing streams (CITS).
- Vessel tracked to predicted night-time range

Lgth: 46m, Beam: 11m, Displ: 1100 tons



Vessel continuously tracked for ~ 27 hours through extreme maneouvres, including stop-go, with 2058 associated plots (approx 1 min update rate)

Data Exploitation

Collect	Correlate	Analyze	Respond
			

Kinetic Anomalies

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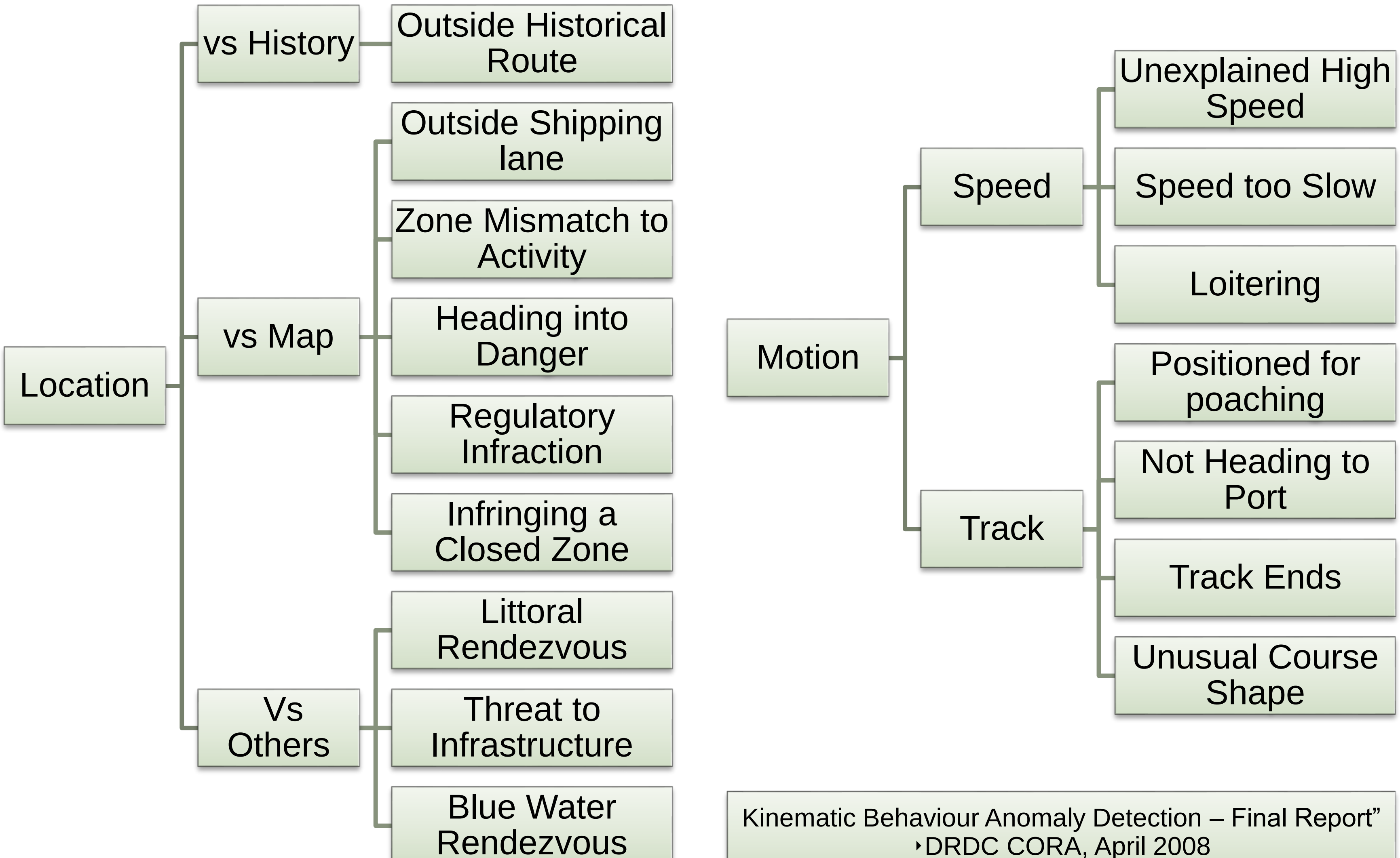

Kinematic Behaviour Anomaly Detection – Final Report”
- DRDC CORA, April 2008

Multi-Source Data Association

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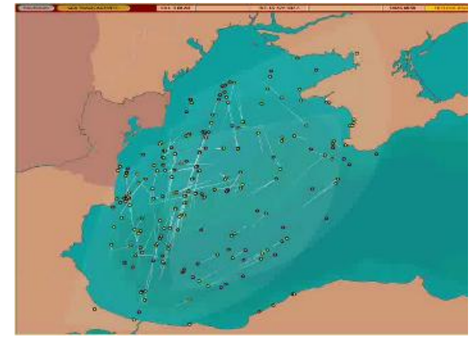
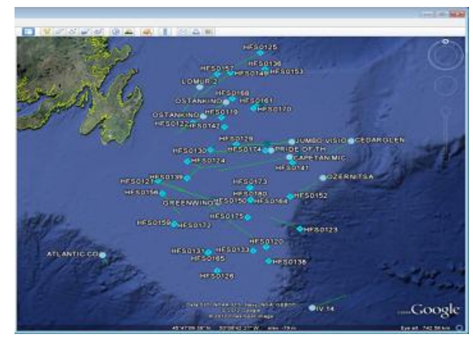
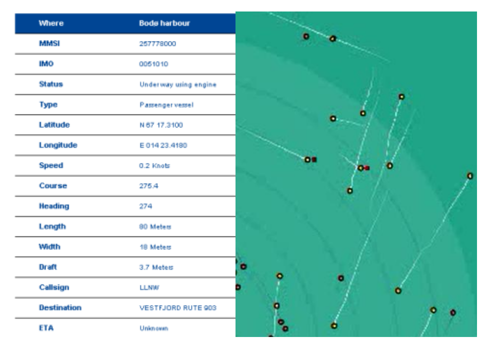
Level 1: Low level association combines several like sources of raw data.



Level 2: Intermediate level association combines various features from different sources with some common attributes.



Level 3: High level fusion combines kinamatic and/or attribute data from dissimilar sources



Need for Persistent Surveillance

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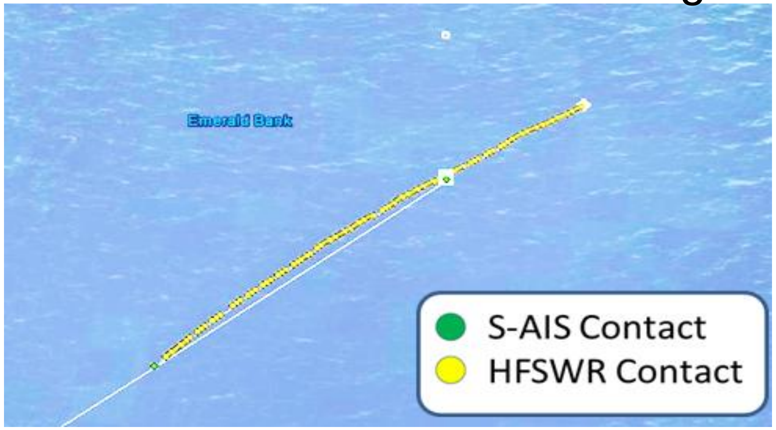
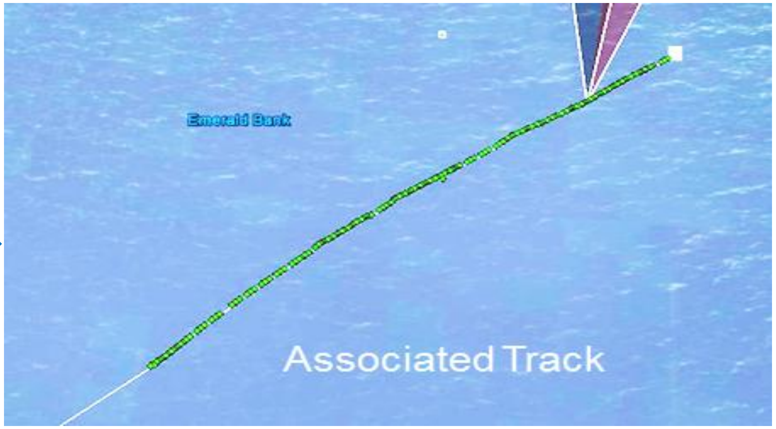
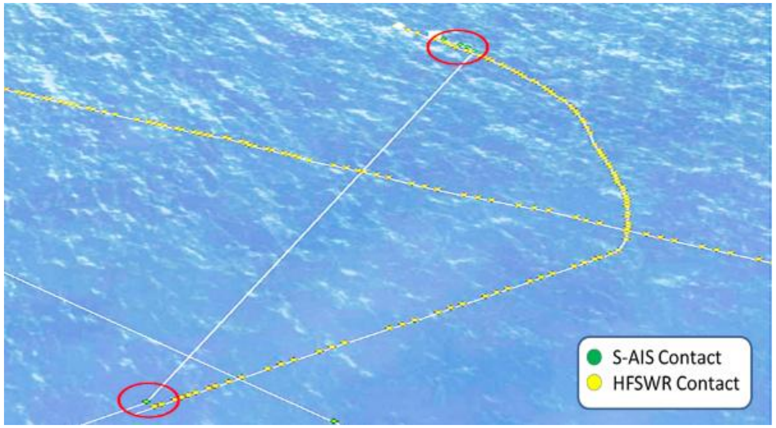
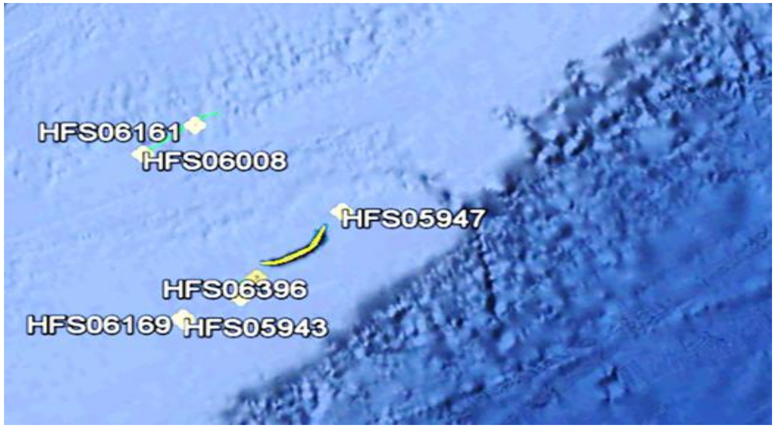
Associating HFSWR data with AIS







Vessel manoeuver recorded by the HFSWR track but missed by S-AIS



Dark Vessels (non-reporting) as tracked by HFSWR

PASE Summary

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- **PASE HFSWR System met contractual performance requirements for all vessels and sea states.**
  - Pro-active Spectrum Management minimizes the probability of causing interference to other users
  - The VAA technique was shown to nearly double small vessel detection
  - Cognitive Operation maximizes system performance for local environment
  - Value of persistency in radar tracking demonstrated
  - Added value of associating HFSWR data with other systems demonstrated