High-level Closed-loop Fusion and Decision Making with INFORM Lab

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Introduction - Large Volume Surveillance Problem (in peacetime)

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- Non-denial surveillance (detect, track, and identify) of **all seafaring vessels** in a large littoral volume of surveillance
- Non-denial surveillance and tracking of **all small vessels and coastal traffic in specific areas of interest** when alerted
- Identification and tracking of **Vessels of Interest**
- **Maximization of coverage** of the area of responsibility, while **minimizing risk and response time** to unforeseen events
- **Data sharing and information fusion** to provide situation awareness to decision makers to allow appropriate military or law enforcement response.

Large Volume Surveillance

INFORM Lab testbed

- The **primary purpose** of the INFORM Lab system is:
  - A testbed to evaluate Distributed Information Fusion (DIF) and Dynamic Resource Management (DRM) algorithms in the context of littoral surveillance
- The **secondary purposes** of the INFORM Lab system are:
  - Create a simulator to explore concepts to improve maritime domain awareness
  - Develop distributed DF and RM architecture
  - Develop a toolbox of distributed DF and RM algorithms
  - Develop an architecture to model distributed inter-platform communication networks.
  - Develop measures of success (MOE, MOP, metrics) for the situation analysis application
  - A testbed to try-out new SW technology, (e.g. intelligent agents).

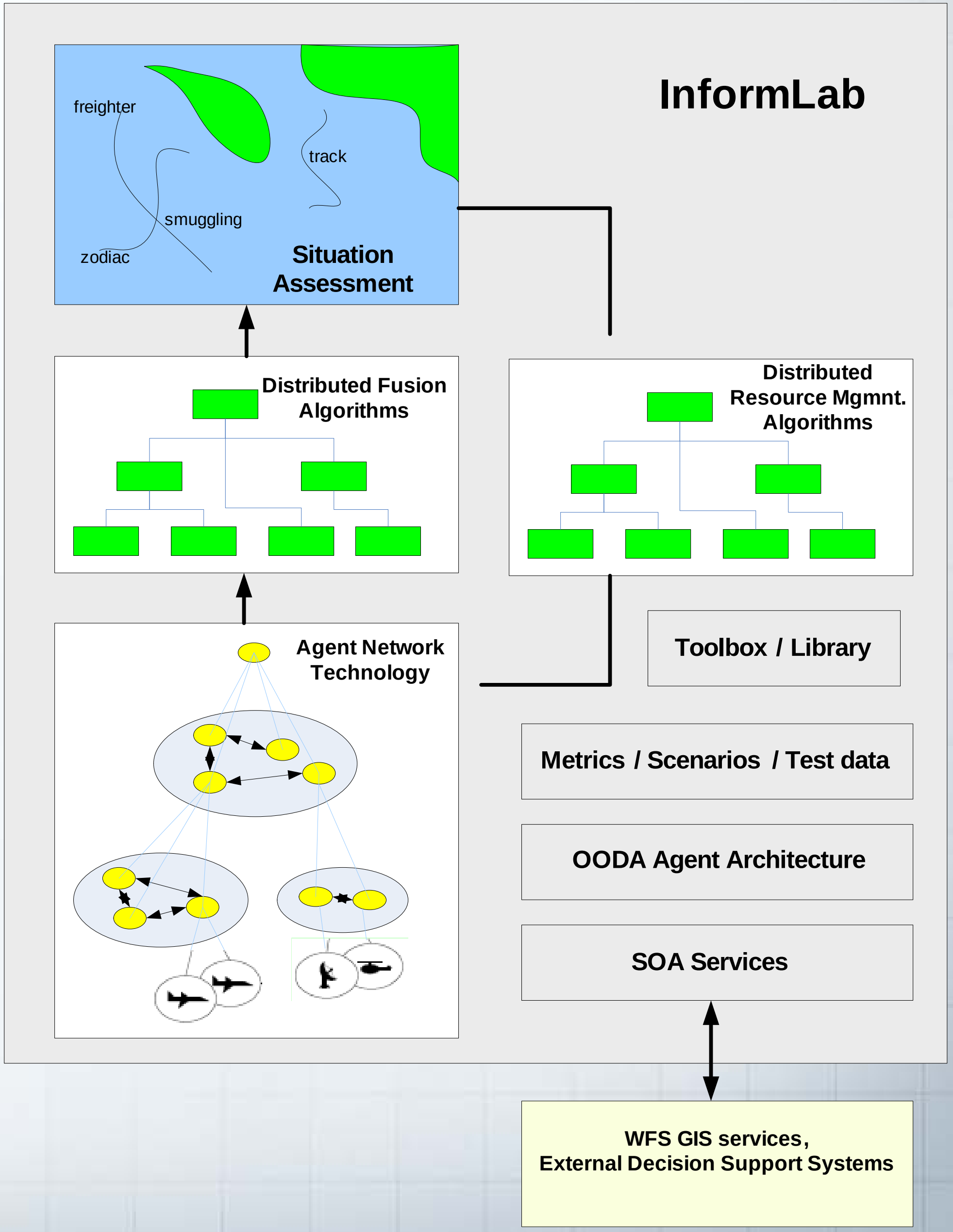
System Development Guidelines

- Uses open standards
- Uses modern architecture (e.g. Service Oriented Architecture, Agents)
- Is flexible:
  - plug-and-play
  - toolbox for platforms & sensors,
  - "net-centric" play vs "command-central" play
- Has documentation on how to add new components to the testbed
- Makes it easy to generate new demonstrations

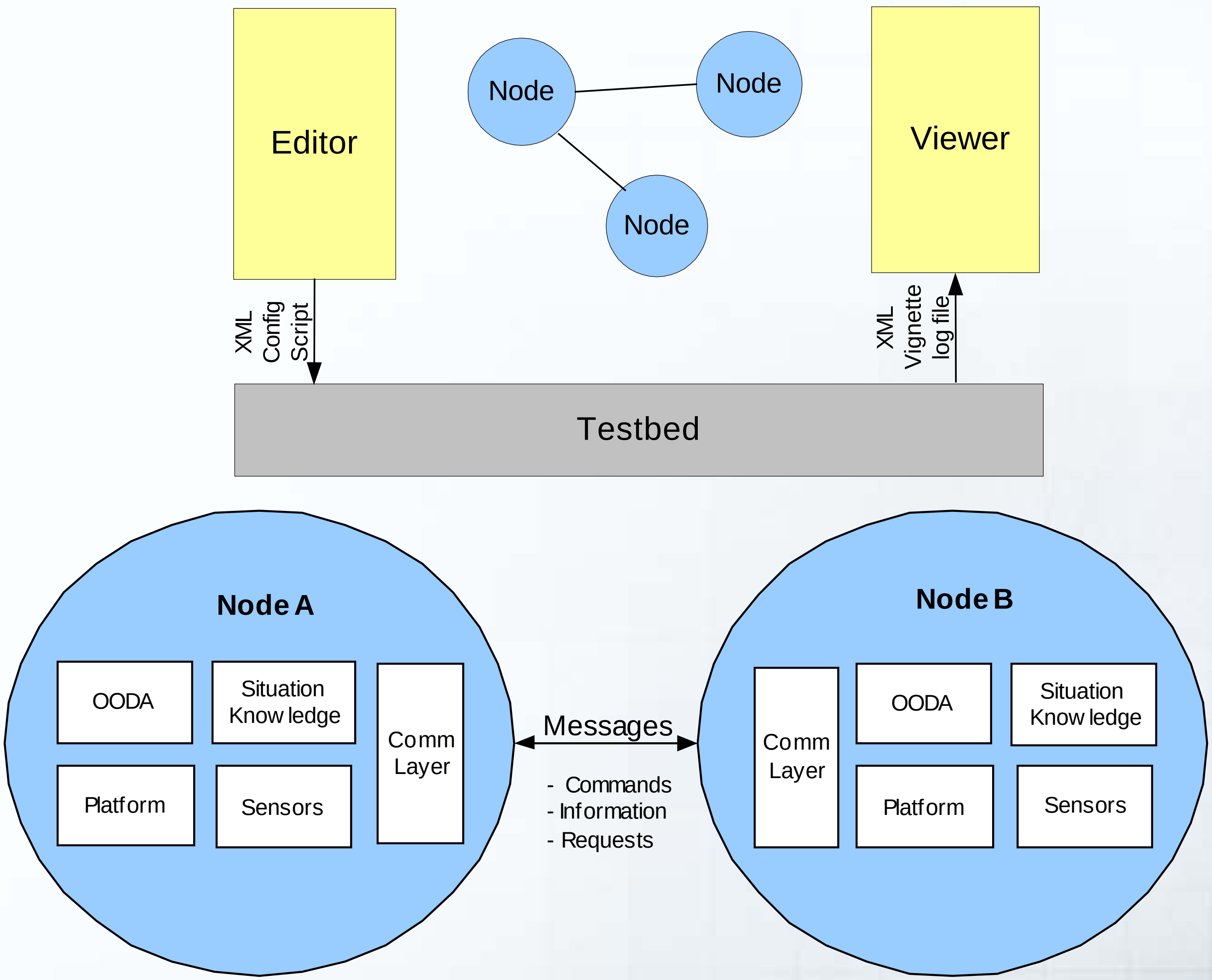
INFORM Lab Components

- goals and situation evidence
- distributed information fusion
- distributed dynamic resource management
- auto-configurable architecture

applied to **2 scenario types** and **multiple vignettes**



INFORM Lab multi-agent architecture

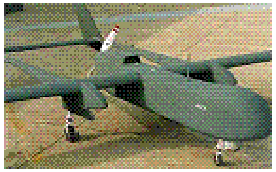


INFORM Lab platforms

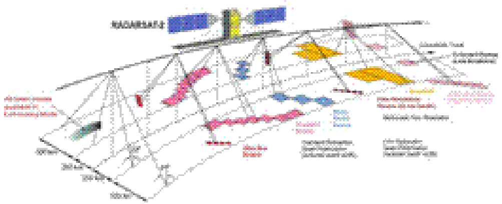
Aurora CP-140

CH-148 Cyclone

Commercial Fishing Boat

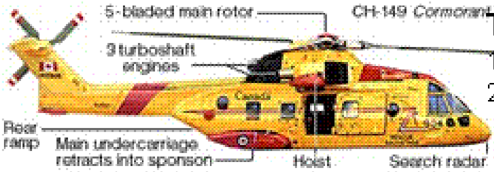


Eagle-2



Radarsat-2

Halifax Class Frigate



SAR Cormorant

SENSOR CAPABILITIES

EO/IR

1. L3 Wescam MX-20
2. Naval On-Board MHP EO Sub-System
3. IAI Multimission Optronic Stabilised Payload (MOSP)

Scanning Radar

1. Ericsson Sea Giraffe SG-150 Medium Range Radar
2. Raytheon SPS-49 Long Range Radar
3. Telephonics APS-143(V)3
4. Honeywell RDR-1400C Colour Weather and S&R RADAR

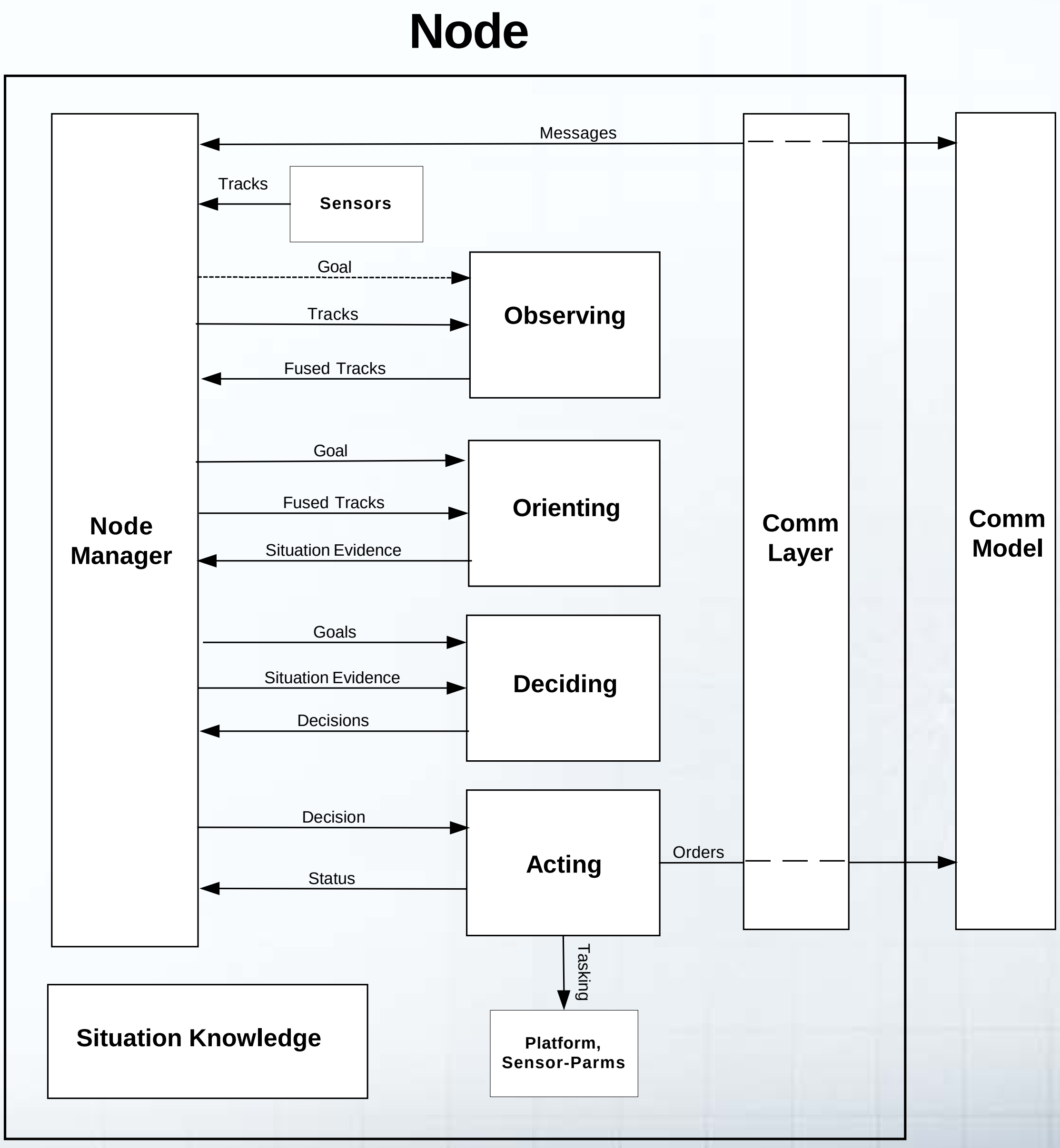
Imaging Radar

1. Naval On-Board MHP Radar Sub-System
2. Elta EL/M-2055 SAR
3. Radarsat-2 SAR Imagery
4. Ground Radar

Transponder

1. AIS
2. Naval On-Board MHP IFF/SIF Sub-System

Internal structure of an OODA node



Goals and Situation Evidence

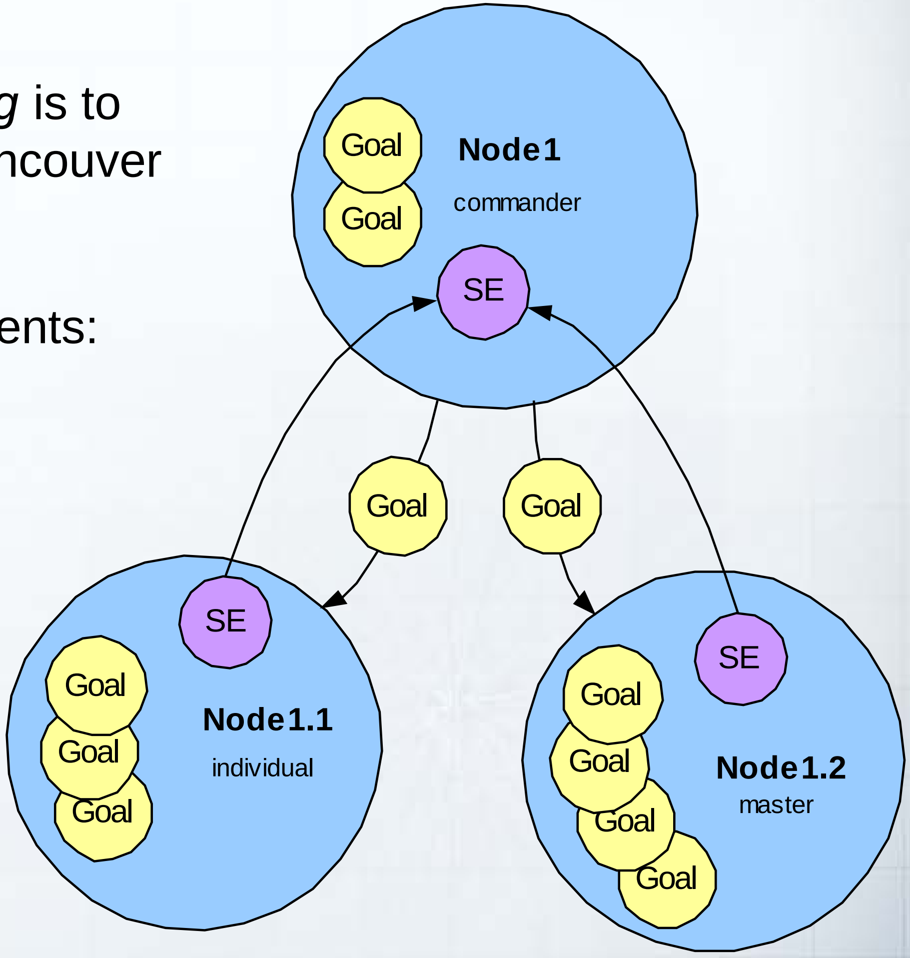
Goal example: proposition *isSmuggling* is to be asserted in the area of northern Vancouver Island during the next 12 hours

SE = Situation Evidence has 4 elements:

1. time stamp
2. proposition
3. proposition qualifiers
4. SE objects

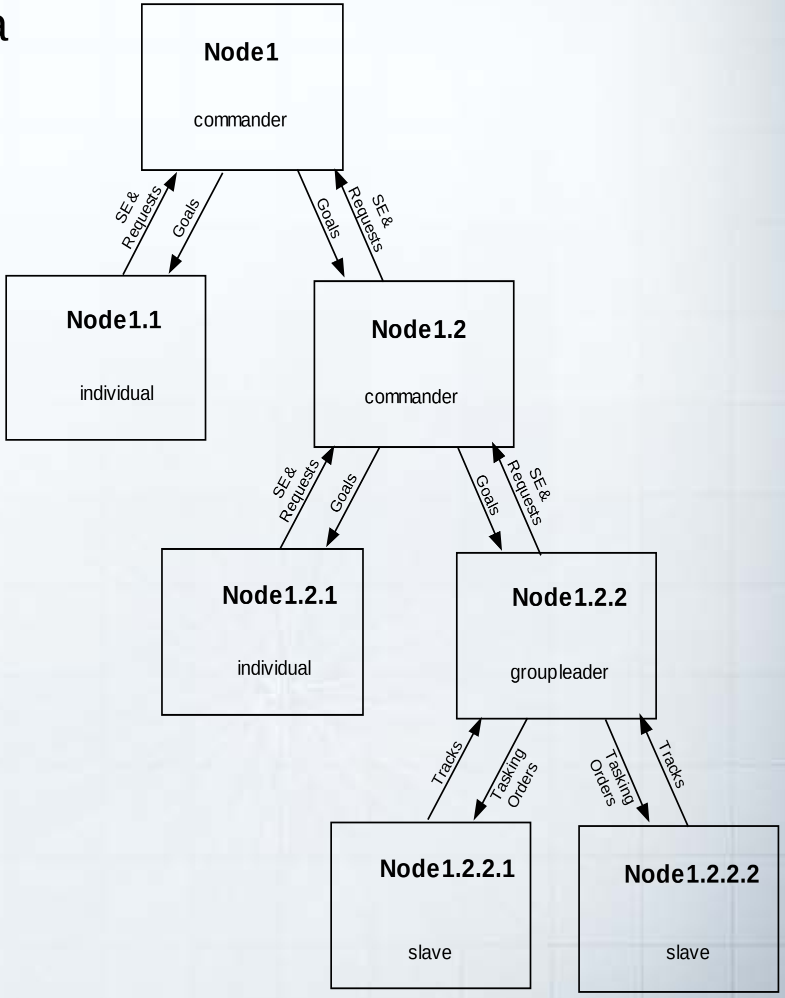
e.g. velocity with two qualifiers

1. value
2. covariance



More details about C2 Node hierarchy

Slave (UAV)**:** Orientation and Decision function are switched off; Receives tasking orders from a *Master* and acts on them directly. Forwards the readings of its built-in sensors directly to its *Master*.

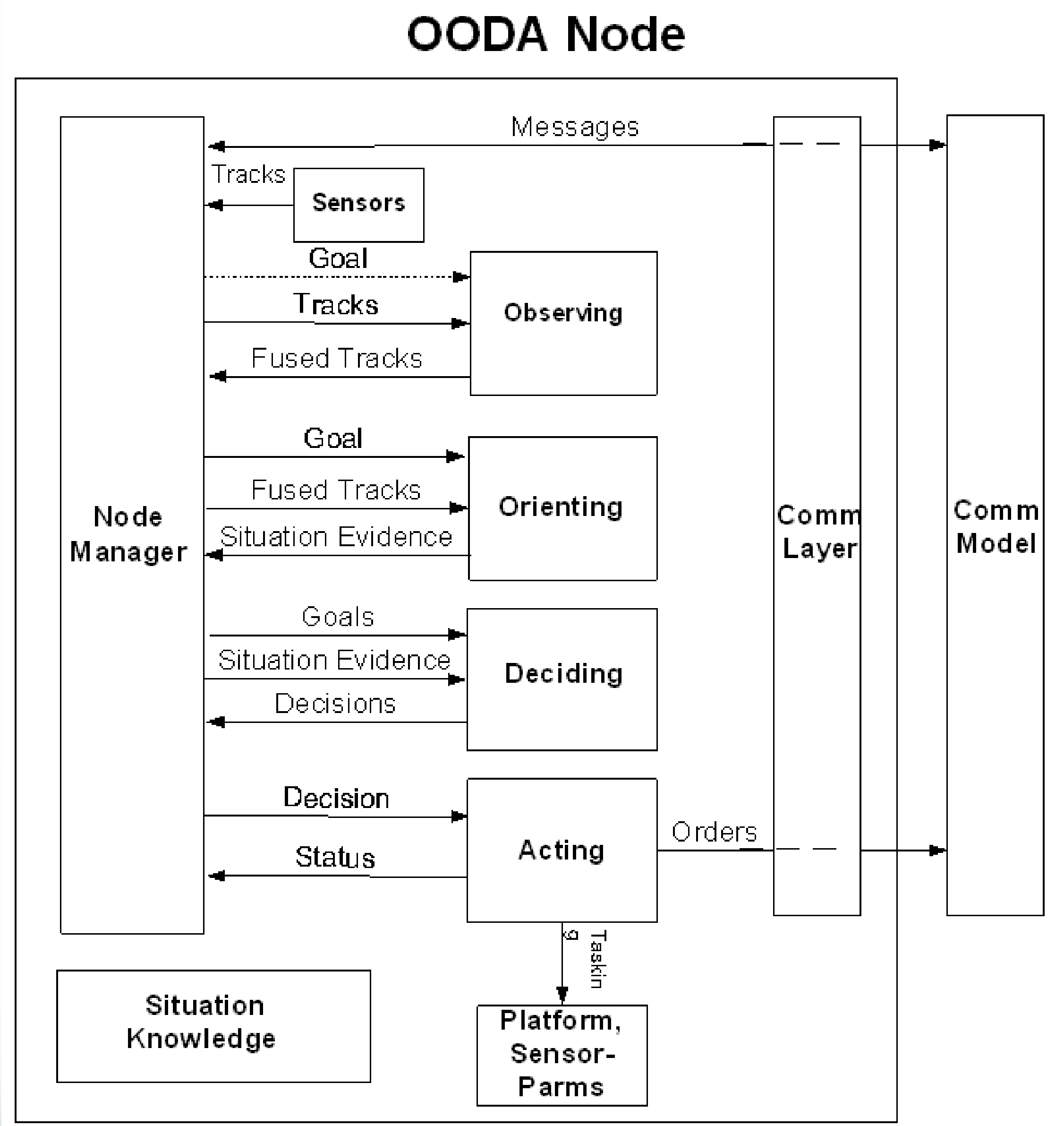


Autonomous Individual (helicopter)**:** Takes a goal as input; manages its own sensor(s); does not command other nodes; may get tracks from other nodes.

Master (group leader)**:** Takes goal as input; manages a group of slave nodes; sends schedules to slave nodes; receives tracks or situation evidence from slave nodes, e.g. UAV controllers.

Commander**:** Takes goal as input; issues goals to autonomous individuals, masters, and other commander nodes; compiles situation evidence obtained from sub-servant nodes into a common situation understanding, e.g. the **captain of a large ship or a base commander.**

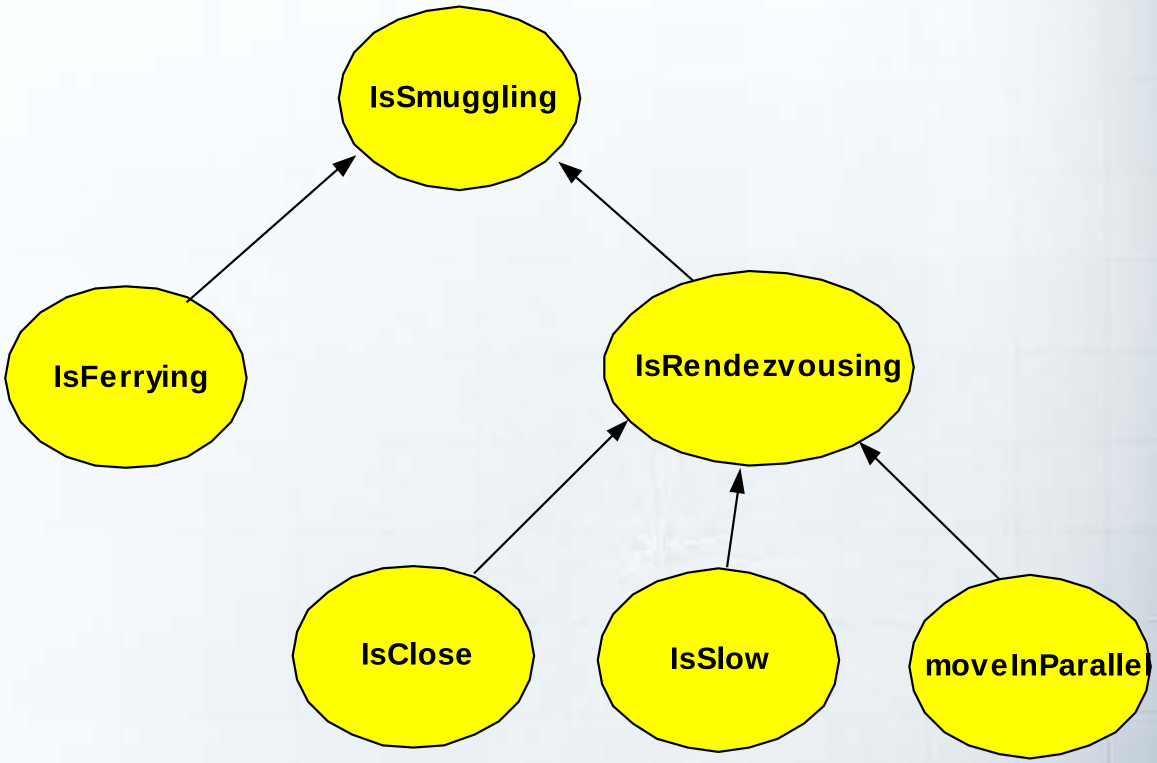
OODA node and INFORM Lab functions



- The Observing function of a node corresponds to a Level-1 data fusion capability
- The Orientation function corresponds to Level-2 information fusion
- The Deciding function performs the Resource Management task
- The Acting function implements the decisions made by the Deciding module.

Distributed Information Fusion

- Goals are decomposed into subgoals all the way down down to Situation Evidence
- Orienting implemented as an Expert System
- Uncertainty formalized by evidence theory and fuzzy logic



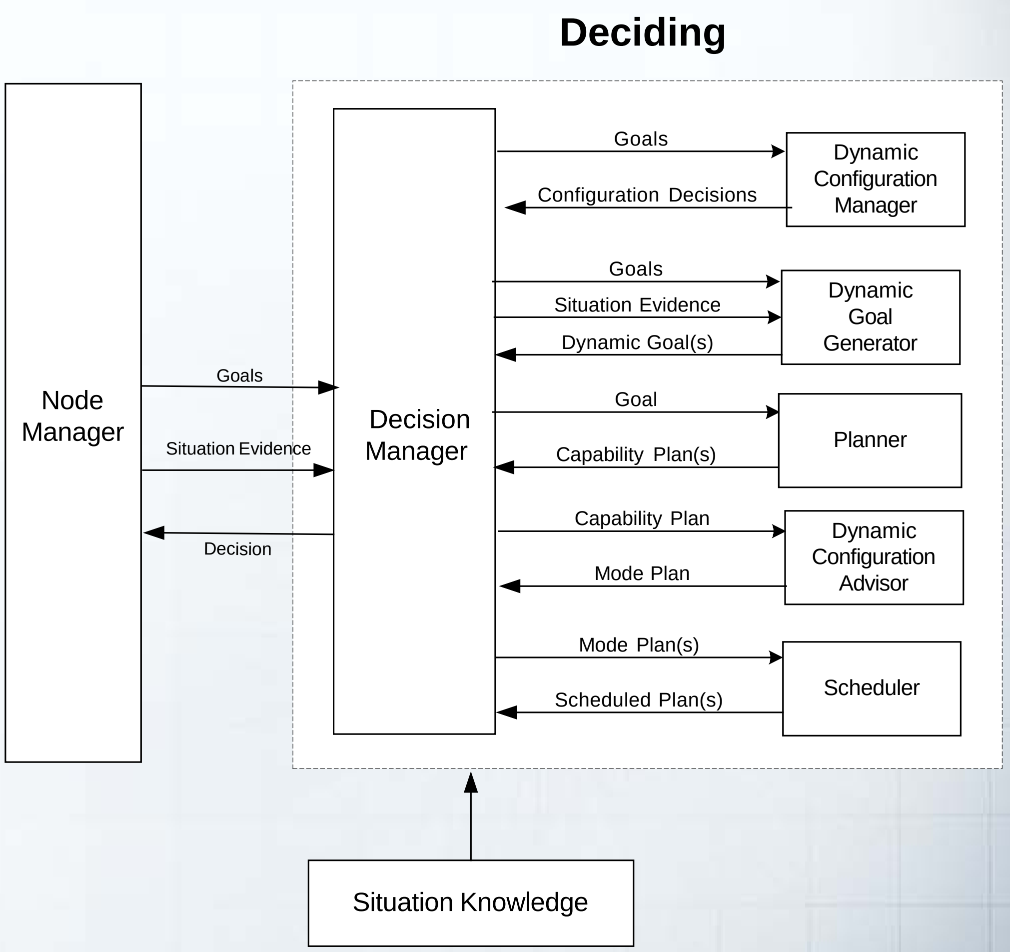
Dynamic Resource Management

DCM monitors the comms and the node capabilities, and makes resource allocation decisions.

DGG takes node goals and SE provided by Orienting as input, and outputs additional goals or removes old goals.

A goal comes into the Planner module, and may split it up into several new goals to be sent to subservient nodes, or it elaborates the goal by generating a capability plan.

DCA takes a capability plan as input and outputs a mode plan.



Auto-configurable IF architectures

A multi-layer network architecture, called Dynamic Resource Configuration & Management Architecture (DRCMA), is adopted to represent a distributed fusion network.

A key requirement is the need for efficient management of IF nodes under dynamically changing conditions.

The DRCMA model is formally described in terms of a distributed Abstract State Machine (ASM) with real-time constraints.

It has 5 functions:

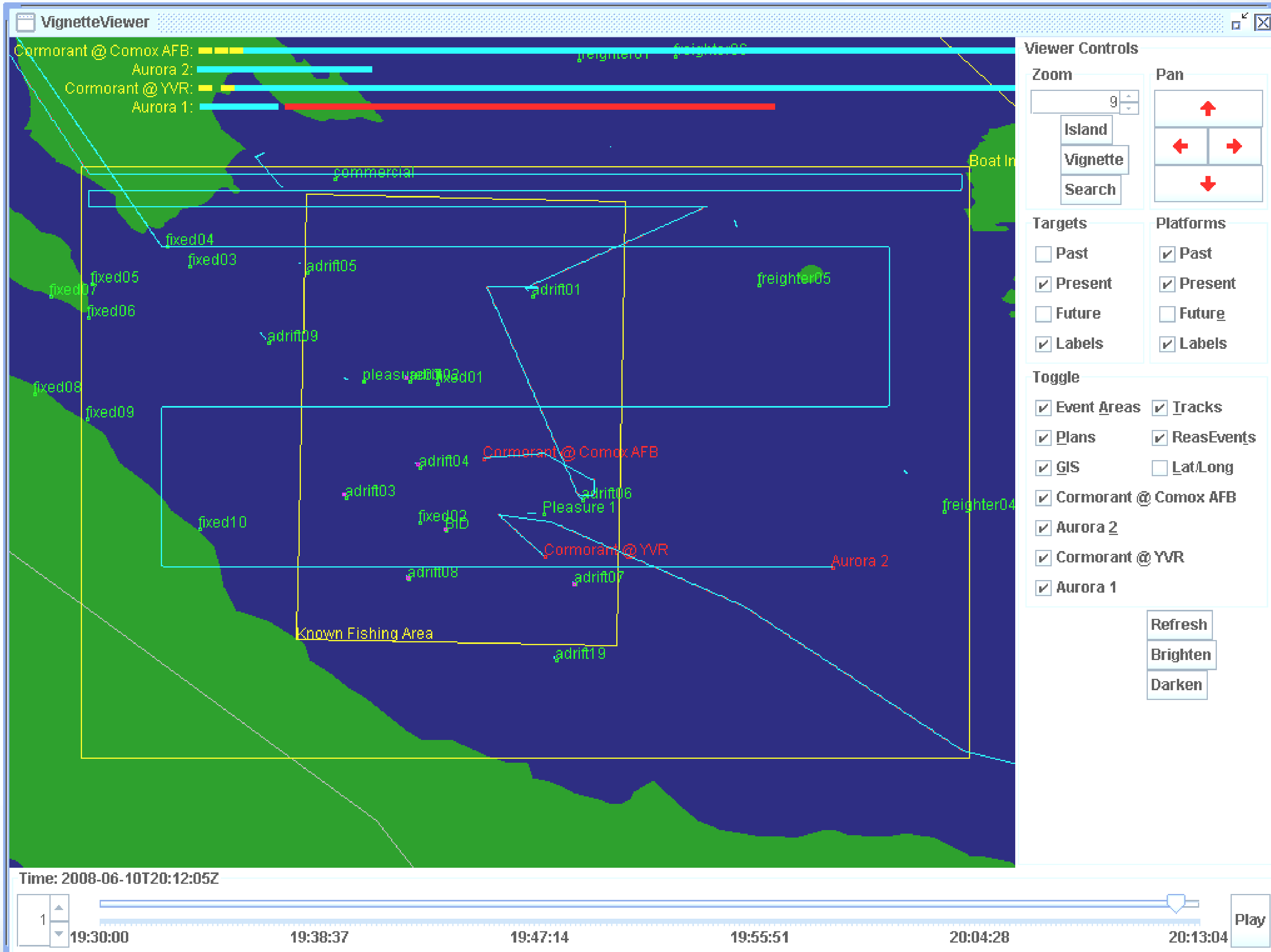
1. Task Decomposition
2. Resource Clustering
3. Resource Management
4. Fault Tolerance
5. Communication Framework, for
   - communication from control centers to resources and vice versa
   - intelligent exchange of information
   - management of meta-data required to identify the origin of info

Vignette 1: Cooperative Search and Rescue of a fishing boat in distress – platforms

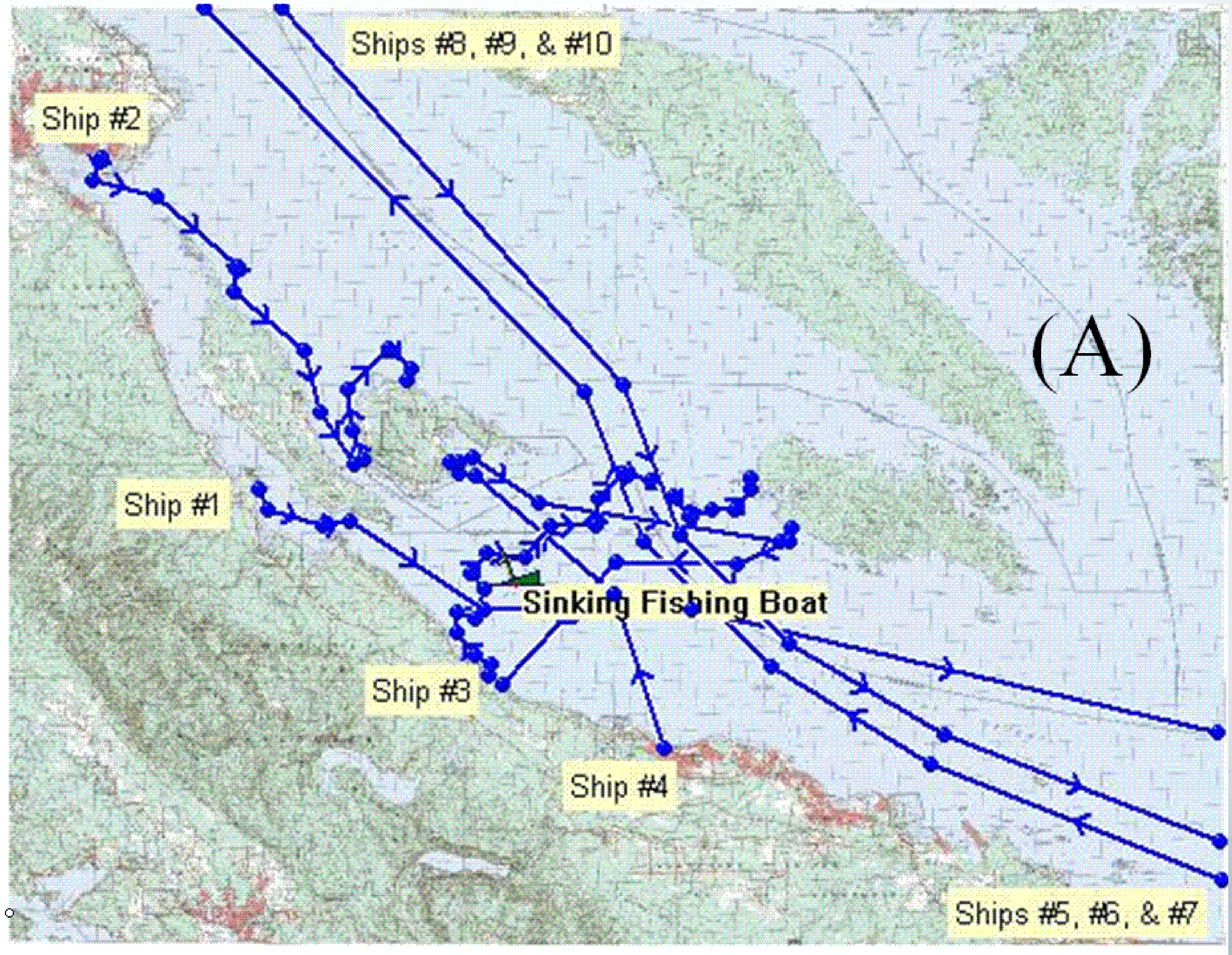
- 1 Target: the fishing boat
- 10 other boats
- 2 CP-140s: the CP-140s will be on missions in the area doing a normal reconnaissance activity
- 2 Cormorants – one from Comox, one from YVR
- Clutter - The area within 30 nm of the report contains numerous adrift and fixed clutter

BASICALLY THIS IS A VIGNETTE TO TEST THE FUNCTIONALITY OF THE TESTBED

Cooperative Search vignette



Vignette 1 overall final situation close-up



Vignette 2 – Non-cooperative search

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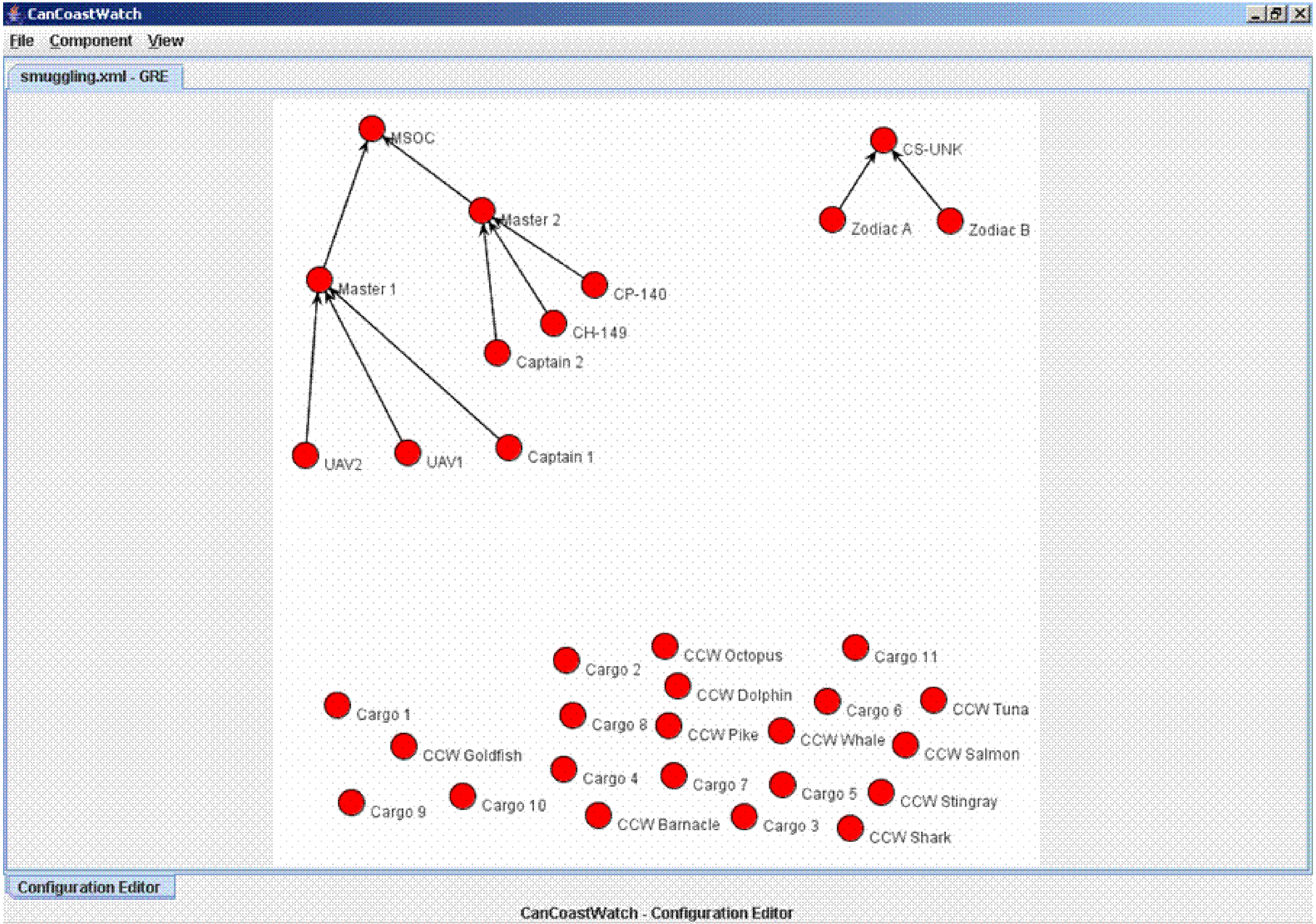
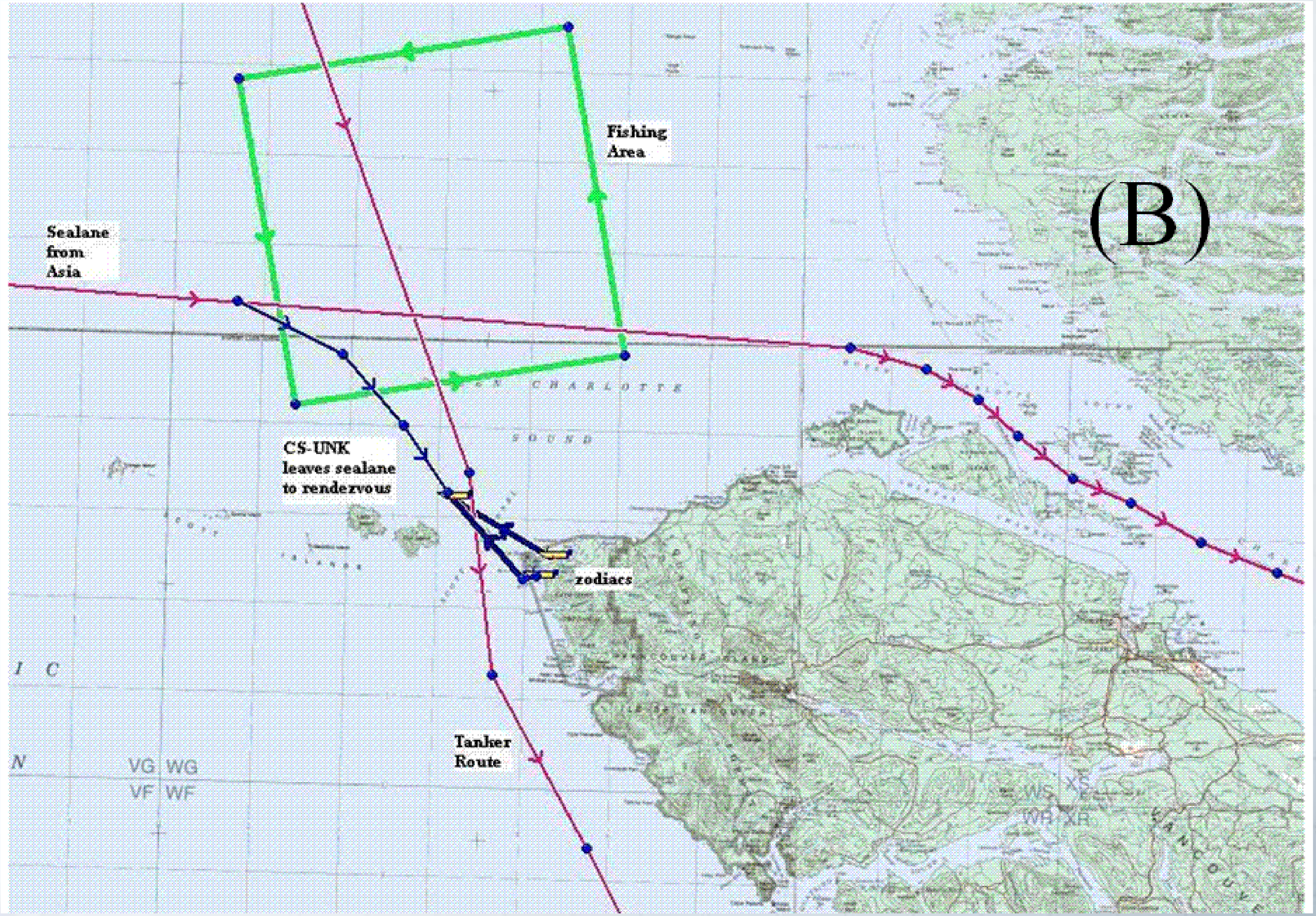
- **Goals**
  - ➢ Test OODA Nodes & their components
  - ➢ Show hierarchical Nodes & Goals
  - ➢ Show Non-Cooperative Search behaviour
  - ➢ Show inter-node communication
  - ➢ GIS-based path-planning
- **Key Behaviours**
  - ➢ **Rendez-vous** of mother-cargo-ship CS-UNK with 2 zodiacs
  - ➢ **Ferrying** behaviour of zodiacs between beach & CS-UNK
  - ➢ **Suspicious behaviour**: CS-UNK deviating from sea lane, failing to use AIS
  - ➢ **Elusive behaviour**: CS-UNK and zodiacs disperse when they sense being watched to avoid being detected as rendez-vous-ing

THIS VIGNETTE IS DEMANDING ADVANCED DISTRIBUTED FUSION AND DYNAMIC RESOURCE MANAGEMENT

Network design for vignette 2



Vignette 2 with intended behaviours



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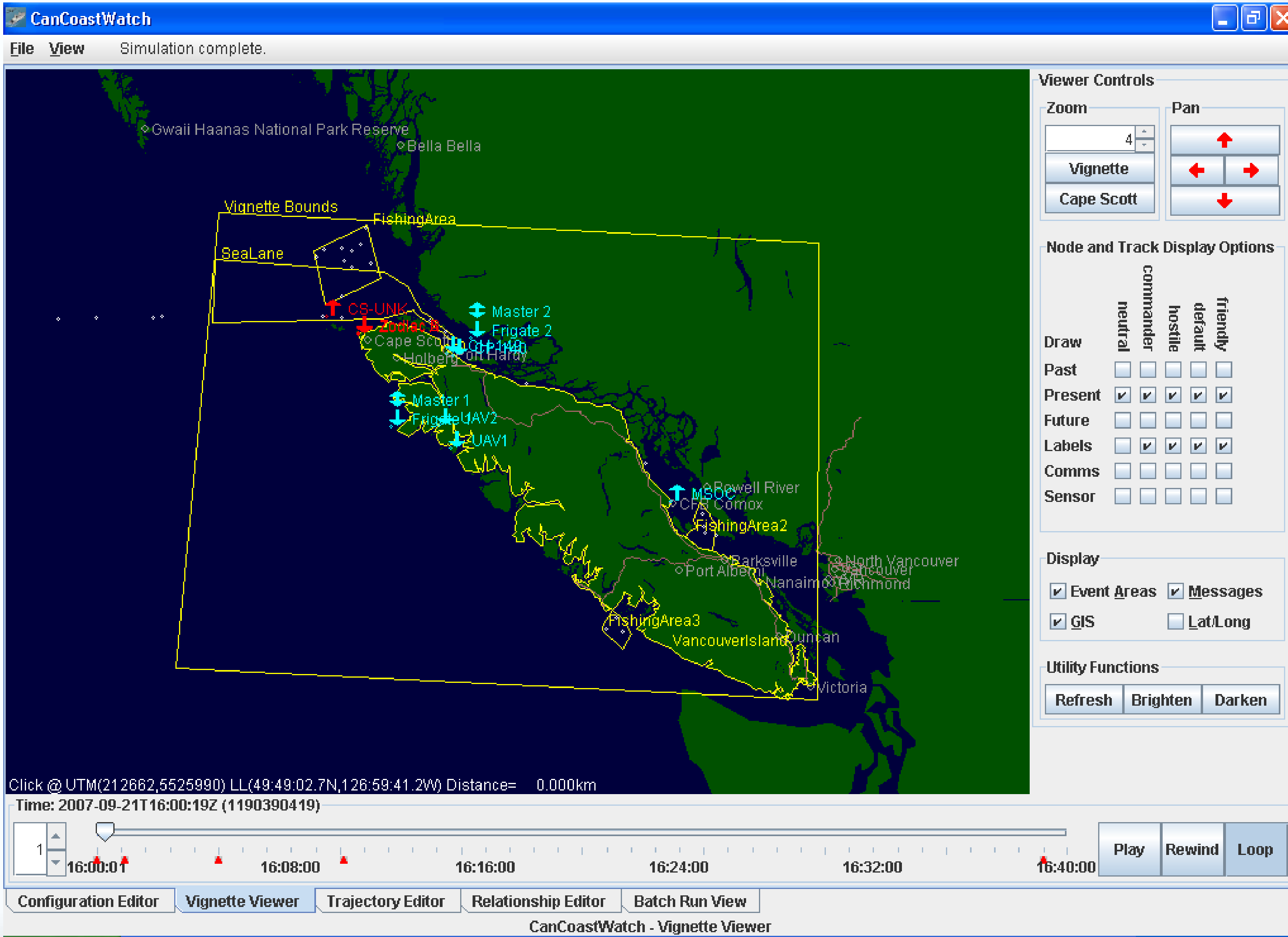
Vignette 2 screen capture – initial situation

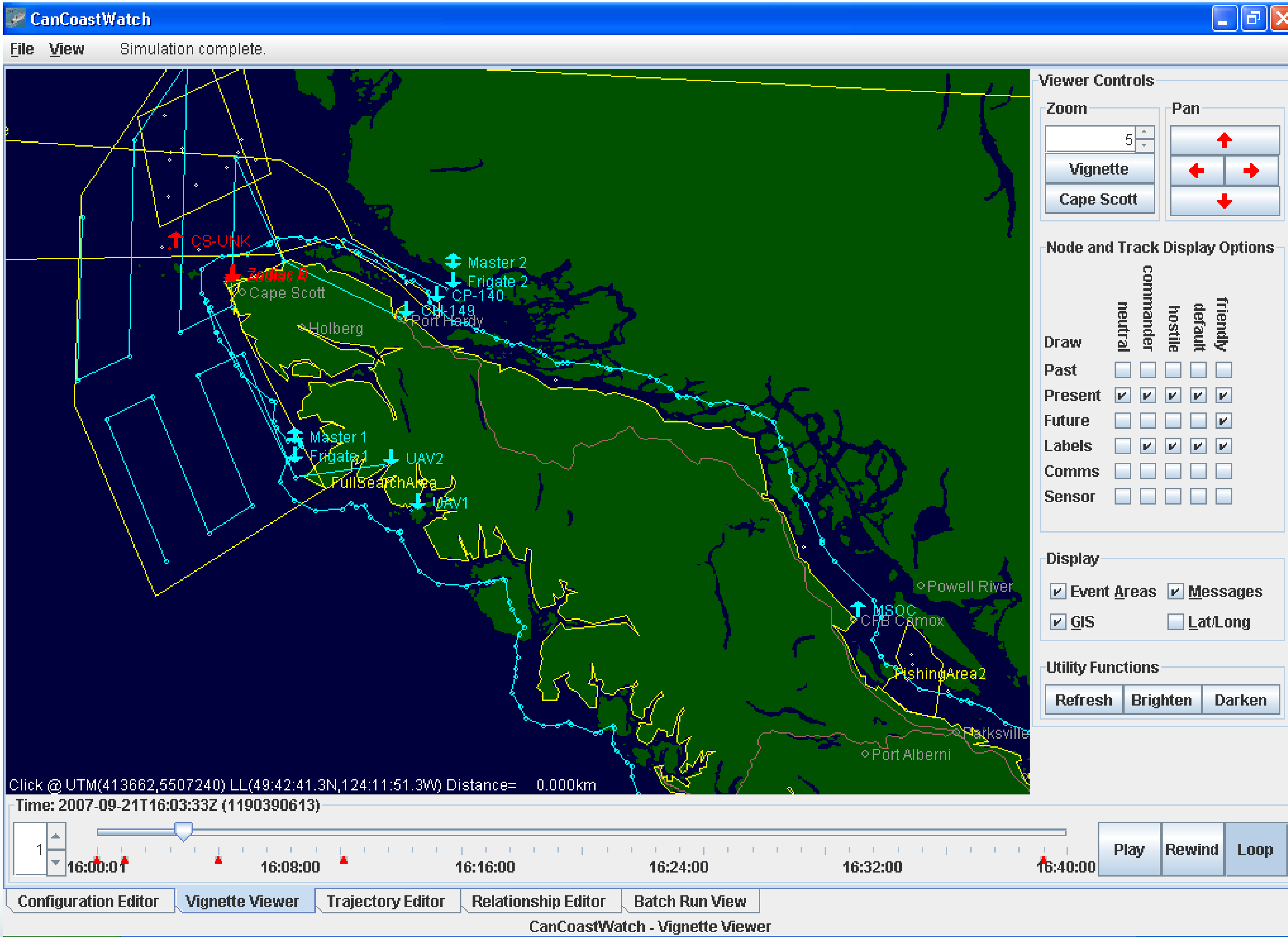


DIF example

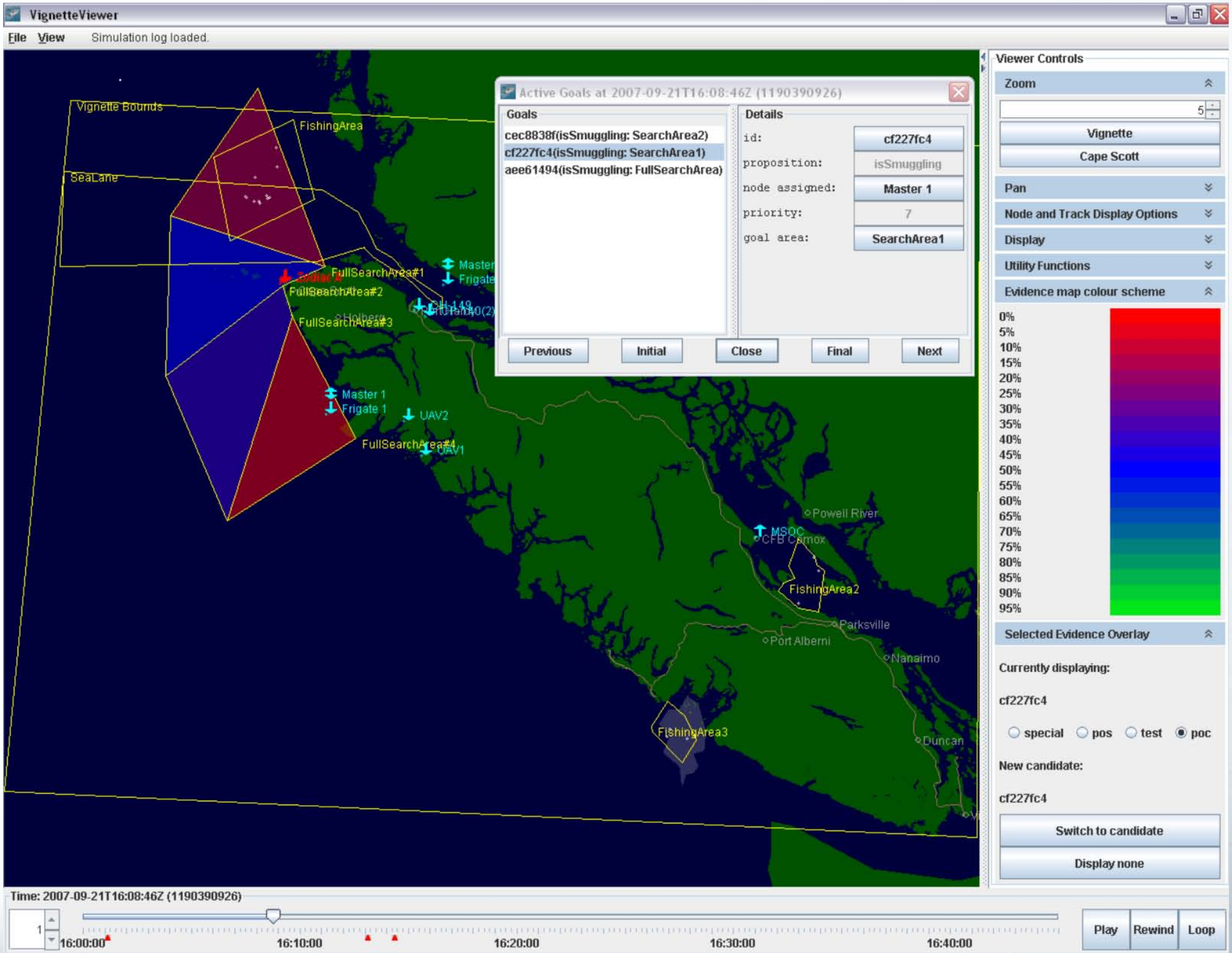
- Identifying an *isFerrying* activity that in turn requires confirmation of *isLargeShip(s1)* AND *isShipNearShore(s1)* AND *isMovingSlowly(s1)* AND *isSmallShip(s2)* AND *isMovingBetweenBeachAndLargeShip(s2,b,s1)*

- Identifying *an isRendezvousing* activity that in turn requires confirmation of *isLargeShip* AND *isSmallShip AND isTandemMotionBetweenShips* where the tandem motion is defined by *isShipsHaveSameHeading(s1,s2)* AND *isShipMovingSlowly(s1)* AND *isShipMovignSlowly(s2)* AND *areNear(s1,s2)*

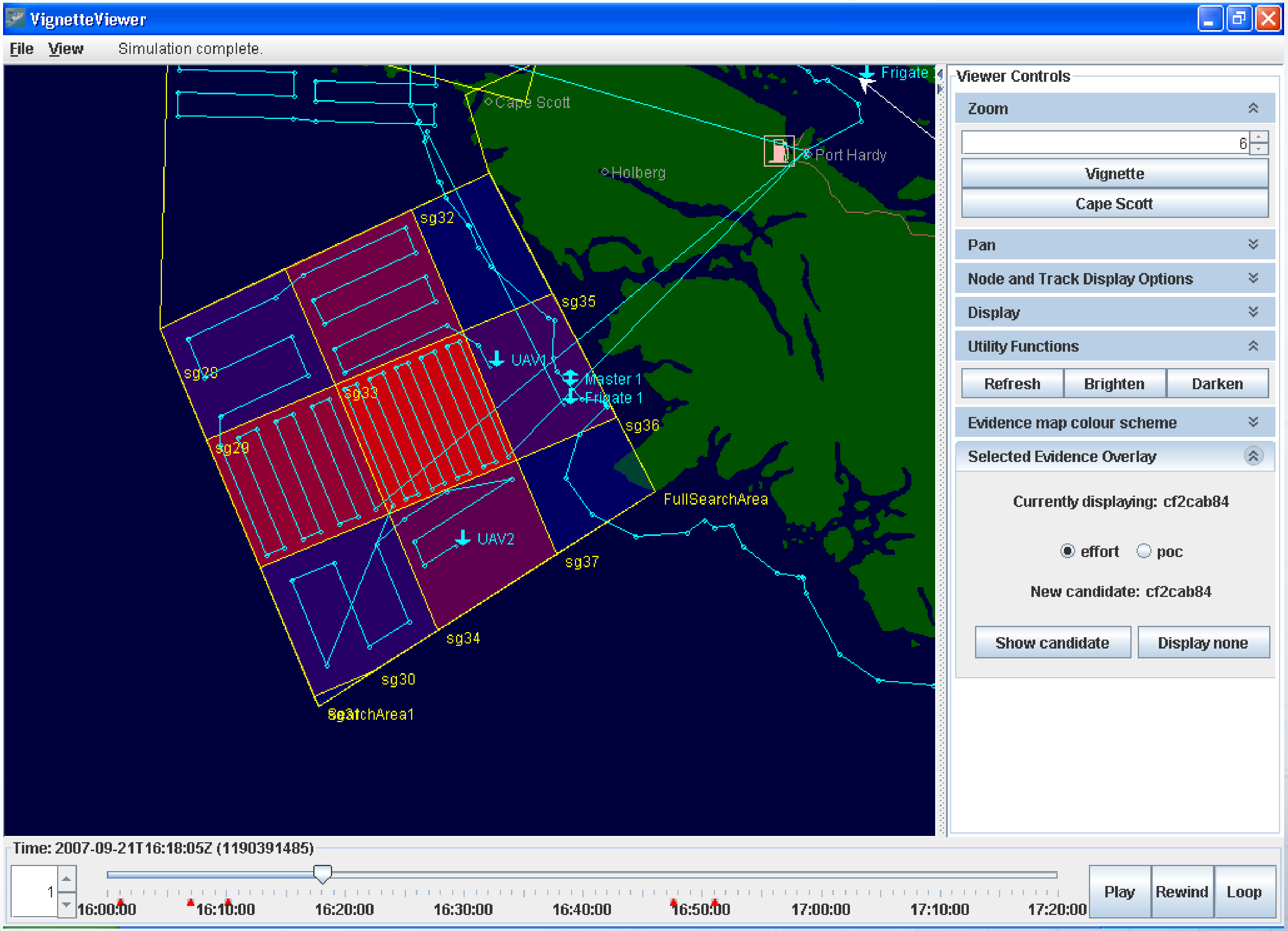
Vignette 2 screen capture – search begins



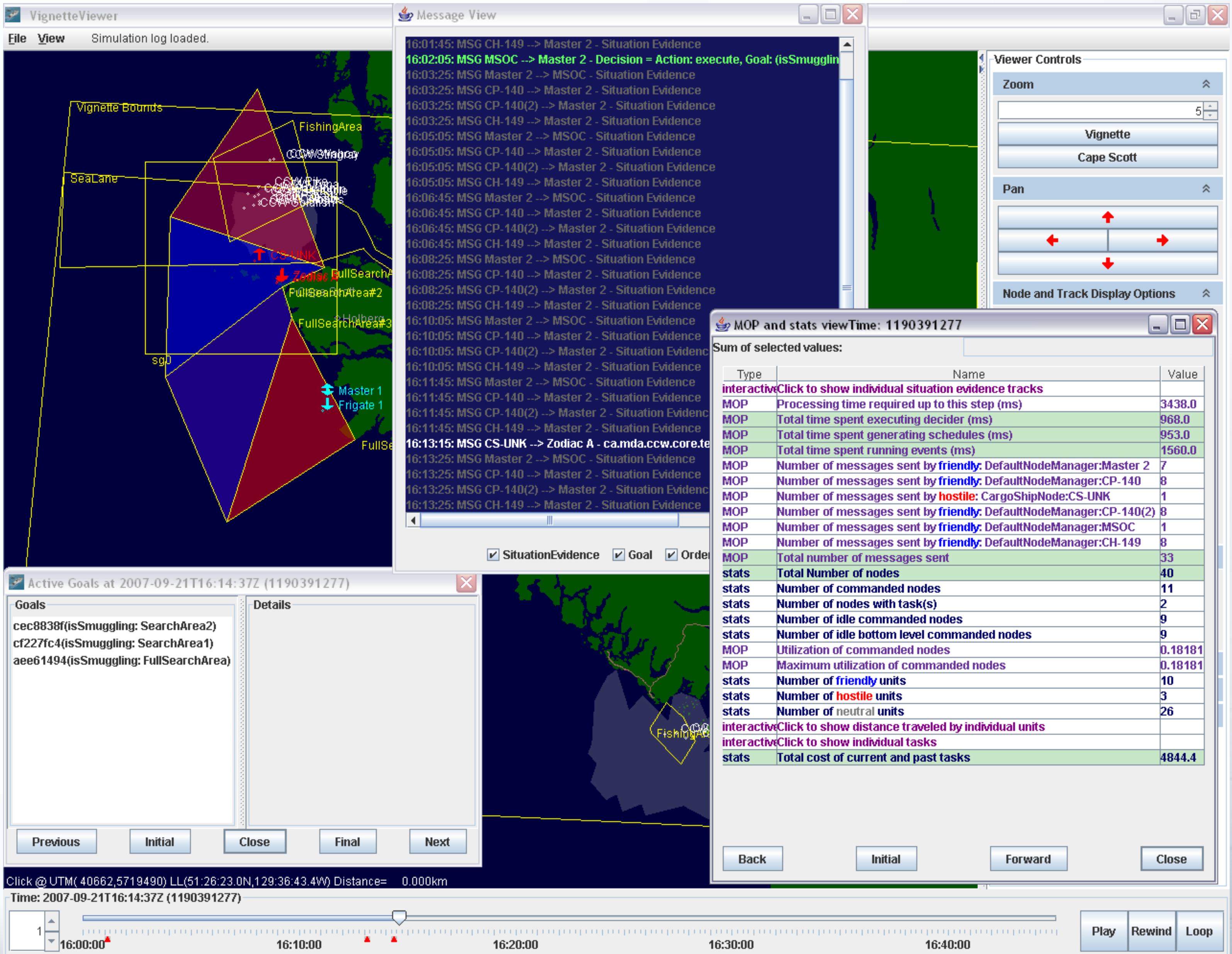
Vignette 2 screen capture – SE for search area



Vignette 2 – planning for a search area



Vignette 2 – output options



Conclusions and outlook

- 2 scenarios/vignettes have been implemented and tested
  - one cooperative SAR – easy
  - one non-cooperative search – challenging
- Level-2 fusion for situation analysis
- Could answer the following questions:
  - What sensors and what platforms should be used and how, in order to maximize situation awareness?
  - How to fuse information from heterogeneous systems?
  - What are the optimal information sharing and distributed information fusion architectures?
  - How to dynamically manage ad-hoc remote communication networks?
- On-going testbed work to be reported at regular intervals
  - University papers report on algorithmic subsets of testbed (SFU, U Victoria for DCM, U Calgary for DIF, SFU for DRCMA)

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