

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

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Introduction - Large Volume Surveillance Problem (in peacetime)

- 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

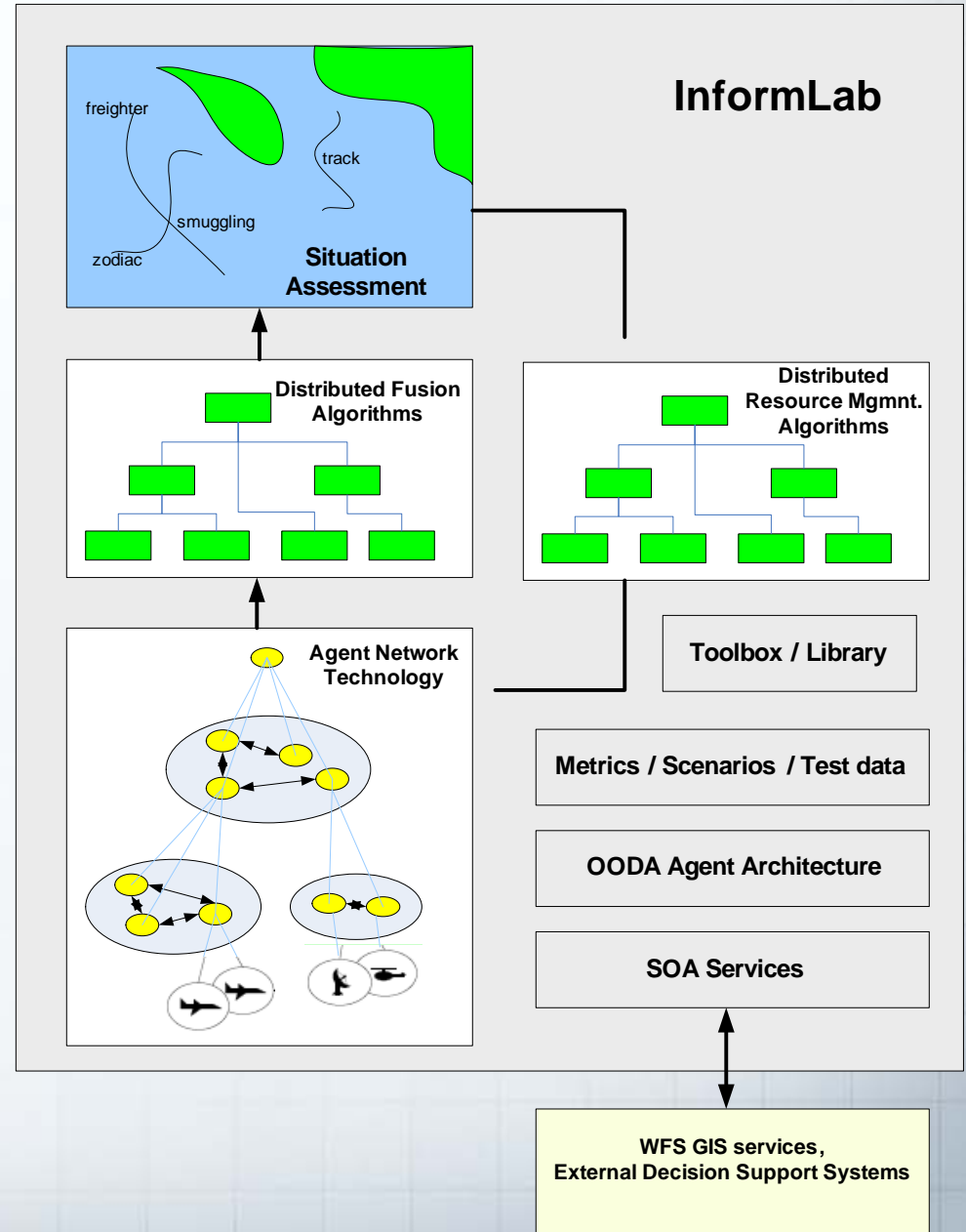
- The **primary purpose** of the INFORM Lab system is:
 - A testbed to evaluate Distributed Information Fusion (DIF) and Dynamic Resource Management (DRM) algorithms in the context of littoral surveillance
- The **secondary purposes** of the INFORM Lab system are:
 - Create a simulator to explore concepts 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

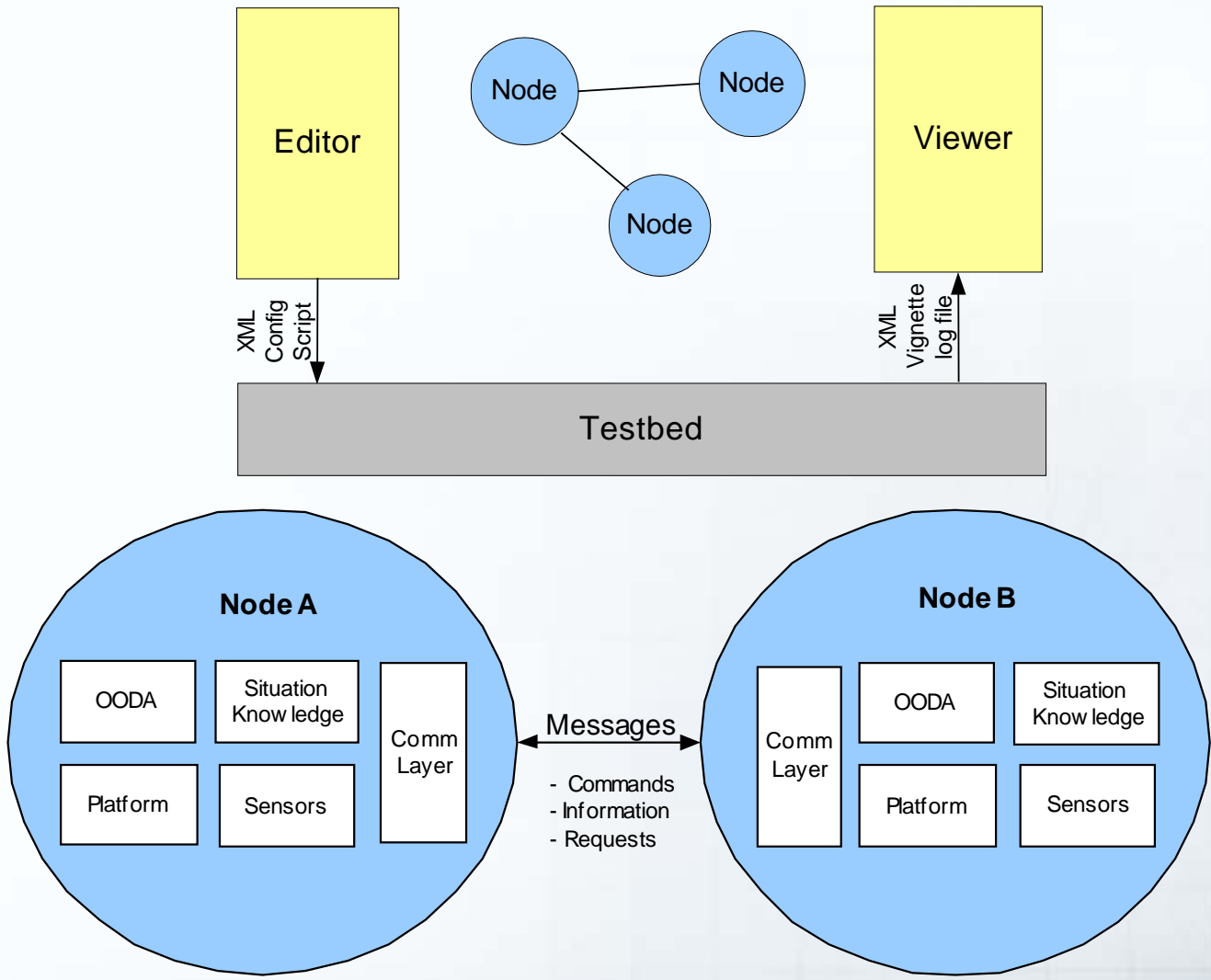
- Uses open standards
- Uses modern architecture (e.g. Service Oriented Architecture, Agents)
- Is flexible:
 - plug-and-play
 - toolbox for platforms & sensors,
 - “net-centric” play vs “command-central” play
- Has documentation on how to add new components to the testbed
- Makes it easy to generate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



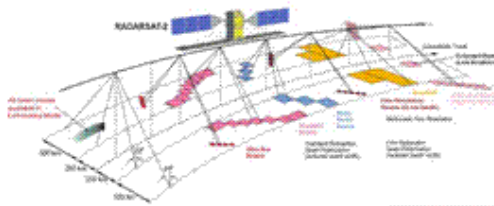
INFORM Lab multi-agent architecture



INFORM Lab platforms



Aurora CP-140



Radarsat-2



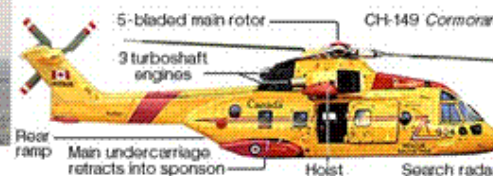
Halifax Class Frigate



CH-148 Cyclone



Eagle-2



SAR Cormorant



Commercial Fishing Boat

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

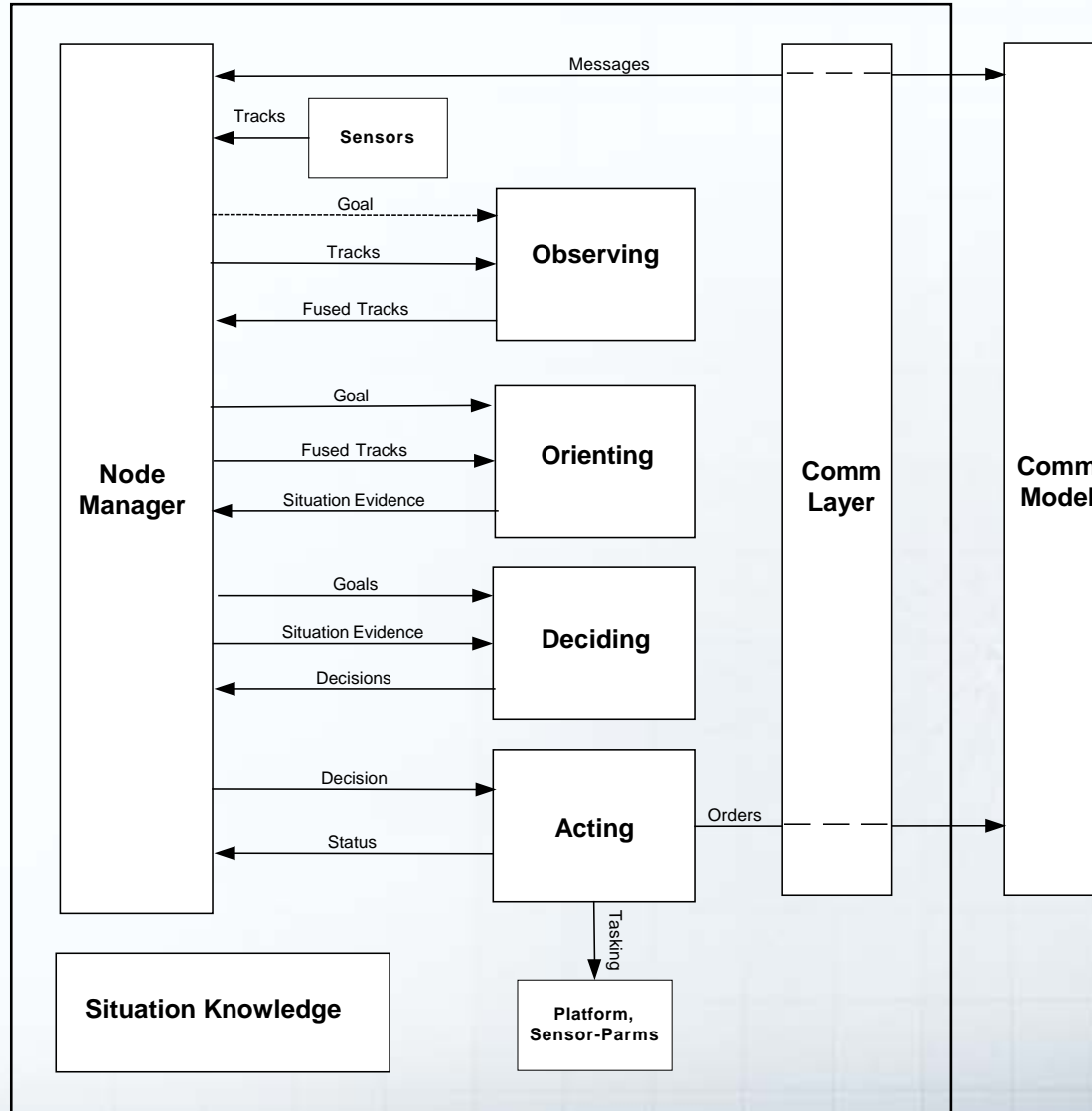
1. Naval On-Board MHP Radar Sub-System
2. Elta EL/M-2055 SAR
3. Radarsat-2 SAR Imagery
4. Ground Radar

Transponder

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

Internal structure of an OODA node

Node



Goals and Situation Evidence

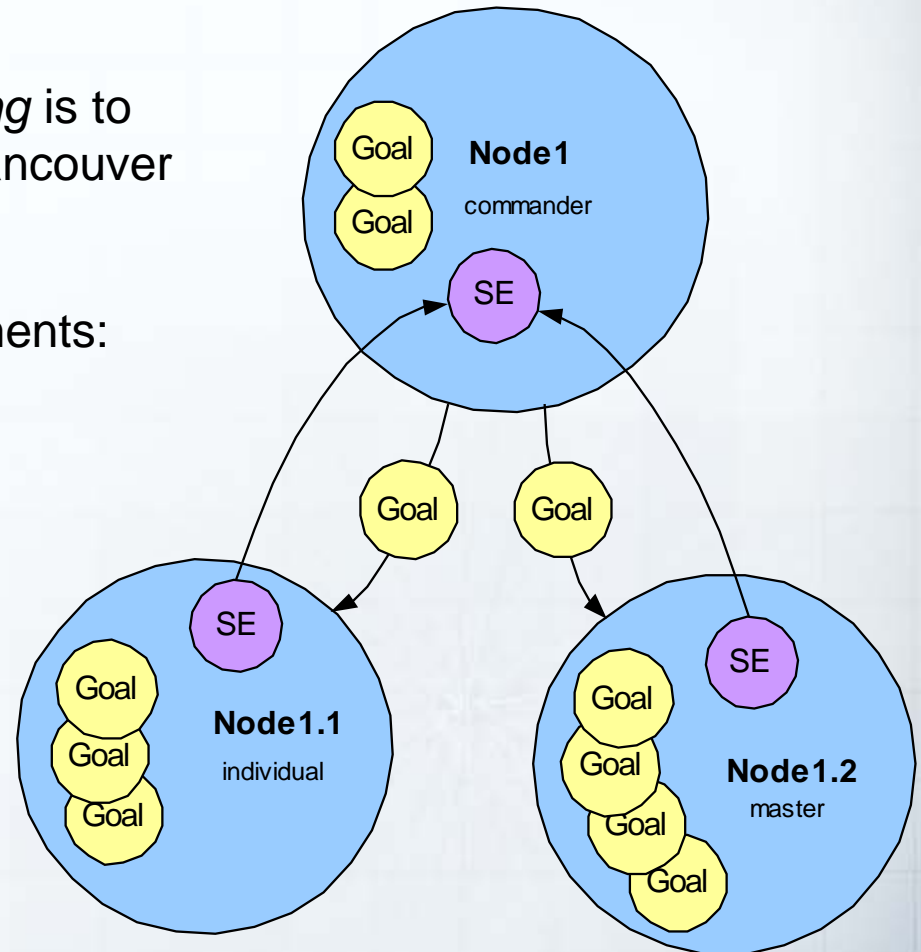
Goal example: proposition *isSmuggling* is to be asserted in the area of northern Vancouver Island during the next 12 hours

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



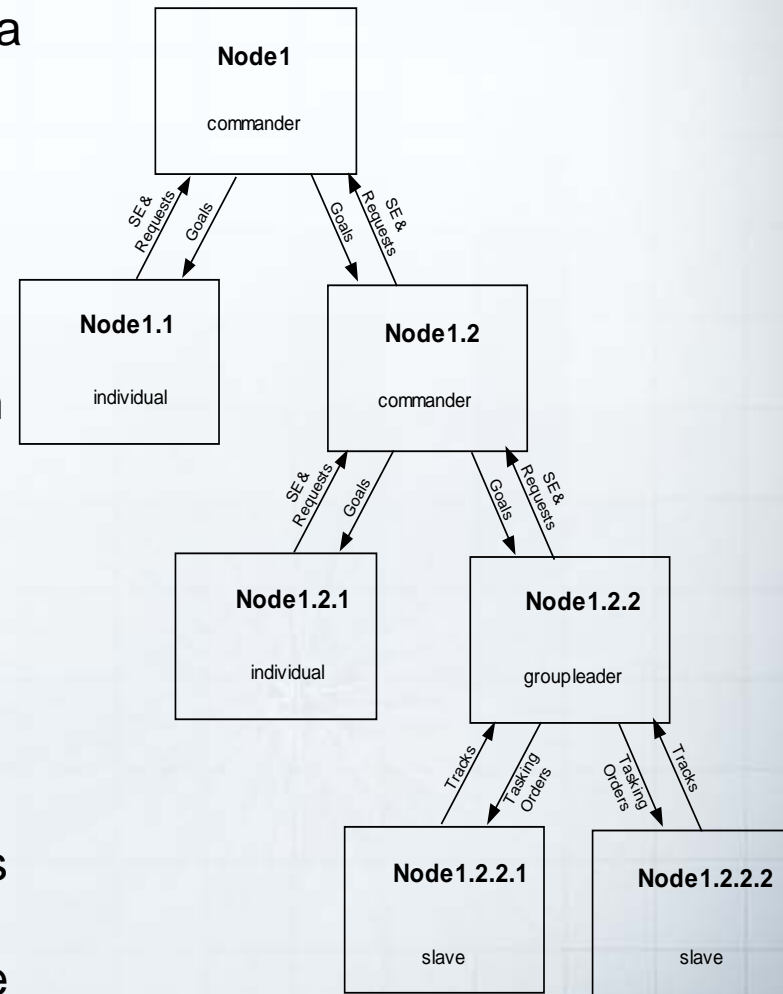
More details about C2 Node hierarchy

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.

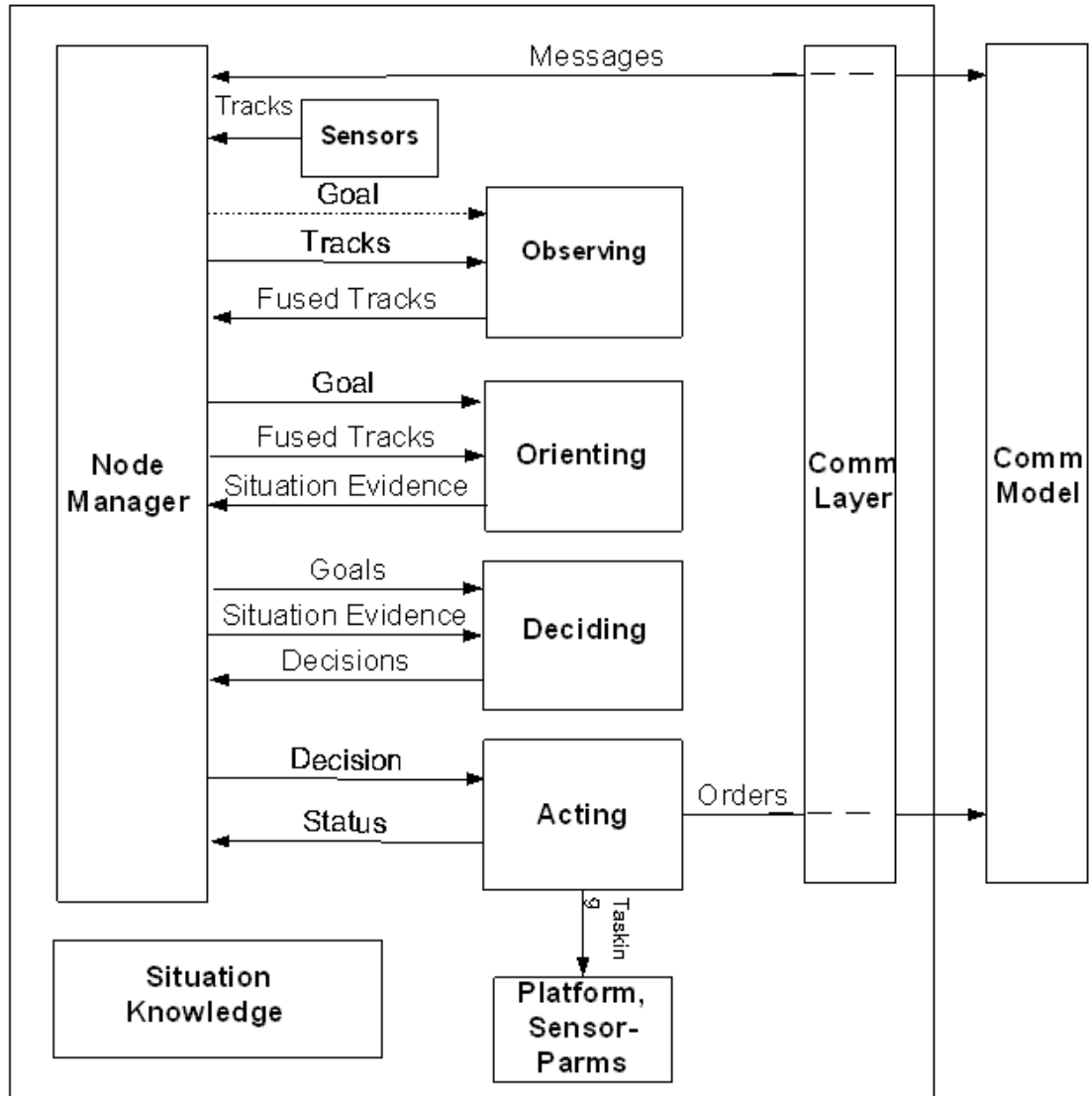
Master (group leader): Takes goal as input; manages a group of slave nodes; sends schedules to slave nodes; receives tracks or situation evidence from slave nodes, e.g. UAV controllers.

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

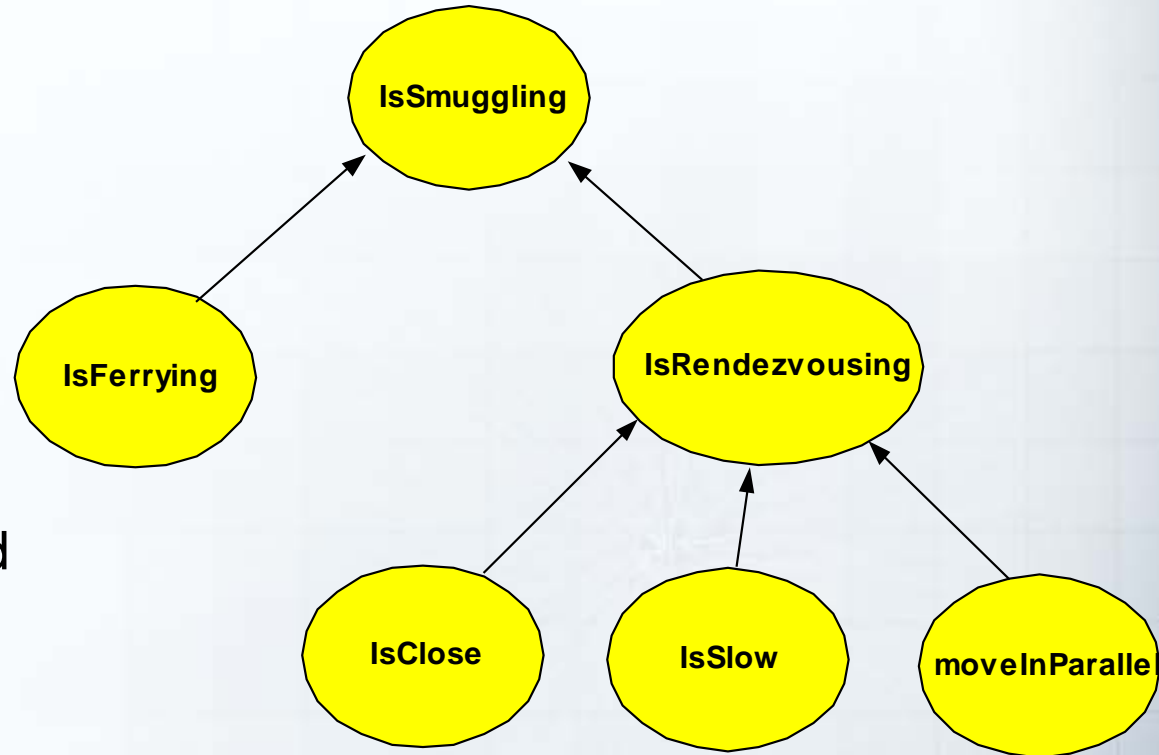
OODA Node



- The Observing function of a node corresponds to a Level-1 data fusion capability
- The Orienting 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



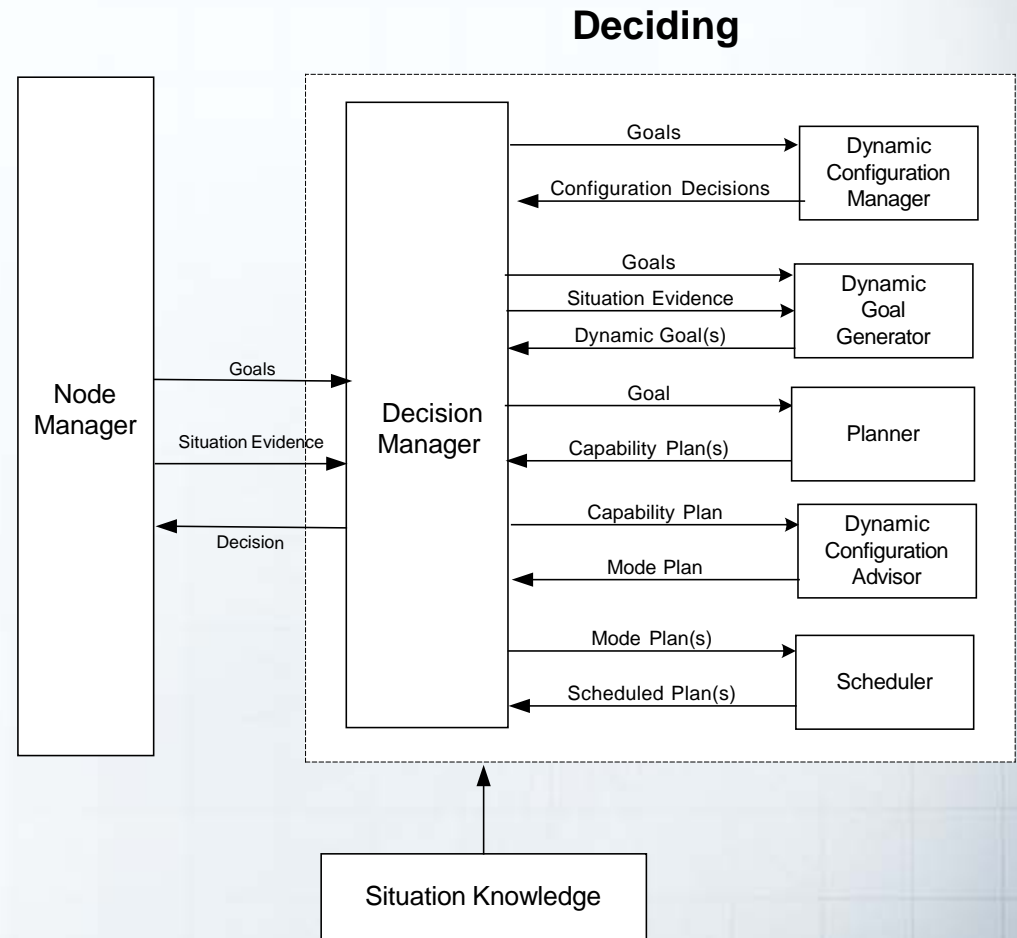
Dynamic Resource Management

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:

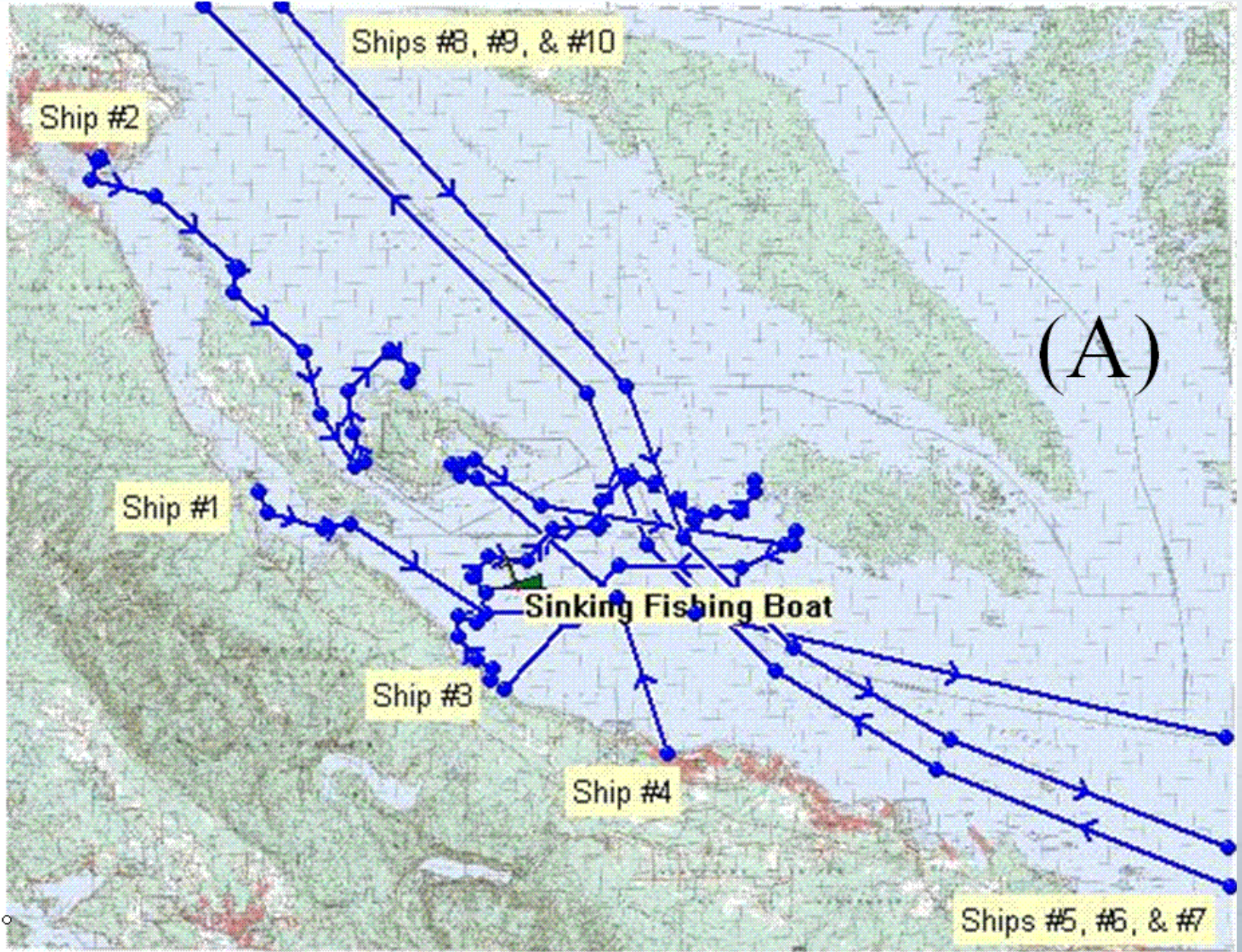
1. Task Decomposition
2. Resource Clustering
3. Resource Management
4. Fault Tolerance
5. Communication Framework, for
 - communication from control centers to resources and vice versa
 - intelligent exchange of information
 - management of meta-data required to identify the origin of info

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

Vignette 1 overall final situation close-up



Vignette 2 – Non-cooperative search

- **Goals**

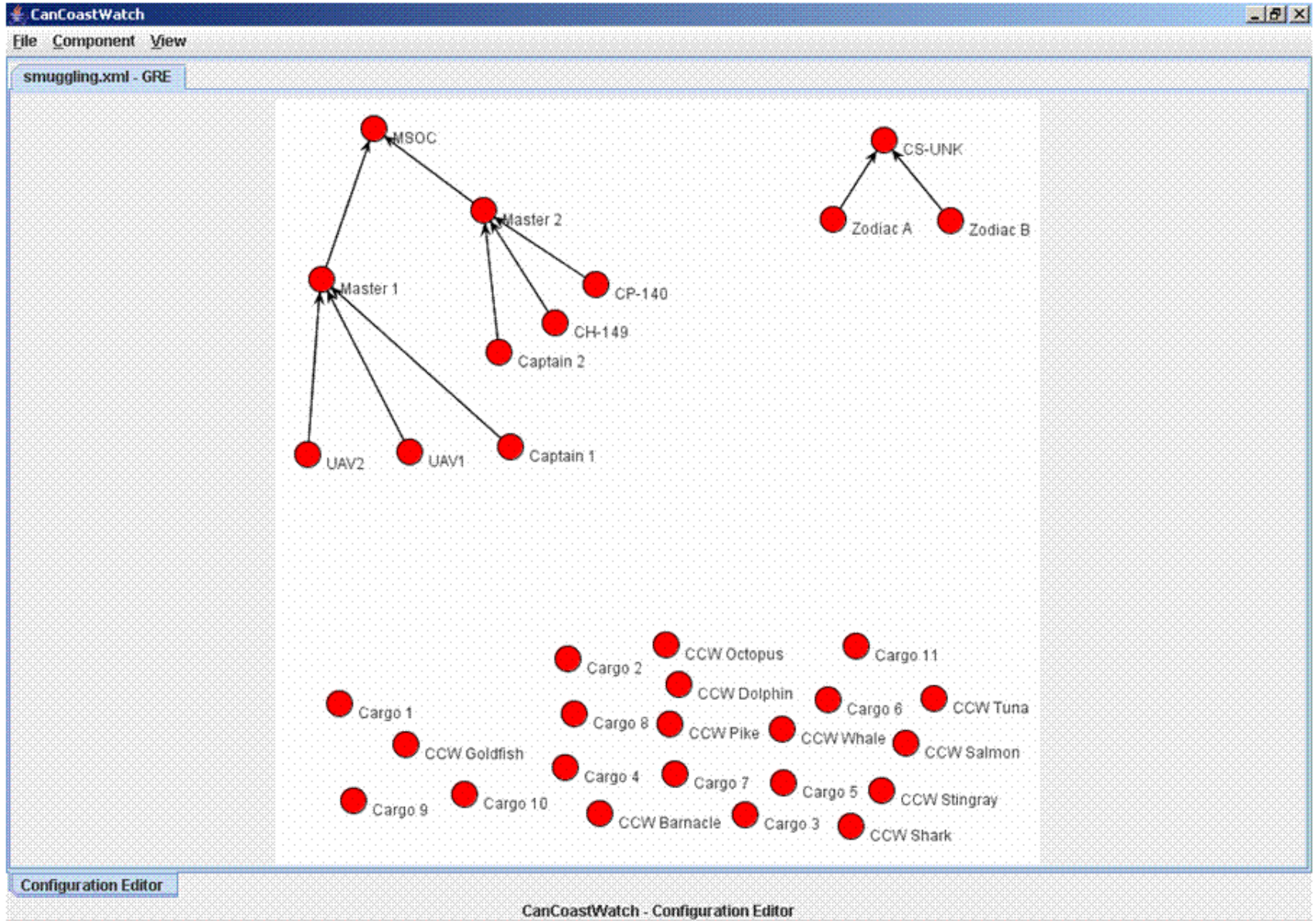
- Test OODA Nodes & their components
- Show hierarchical Nodes & Goals
- Show Non-Cooperative Search behaviour
- Show inter-node communication
- GIS-based path-planning

- **Key Behaviours**

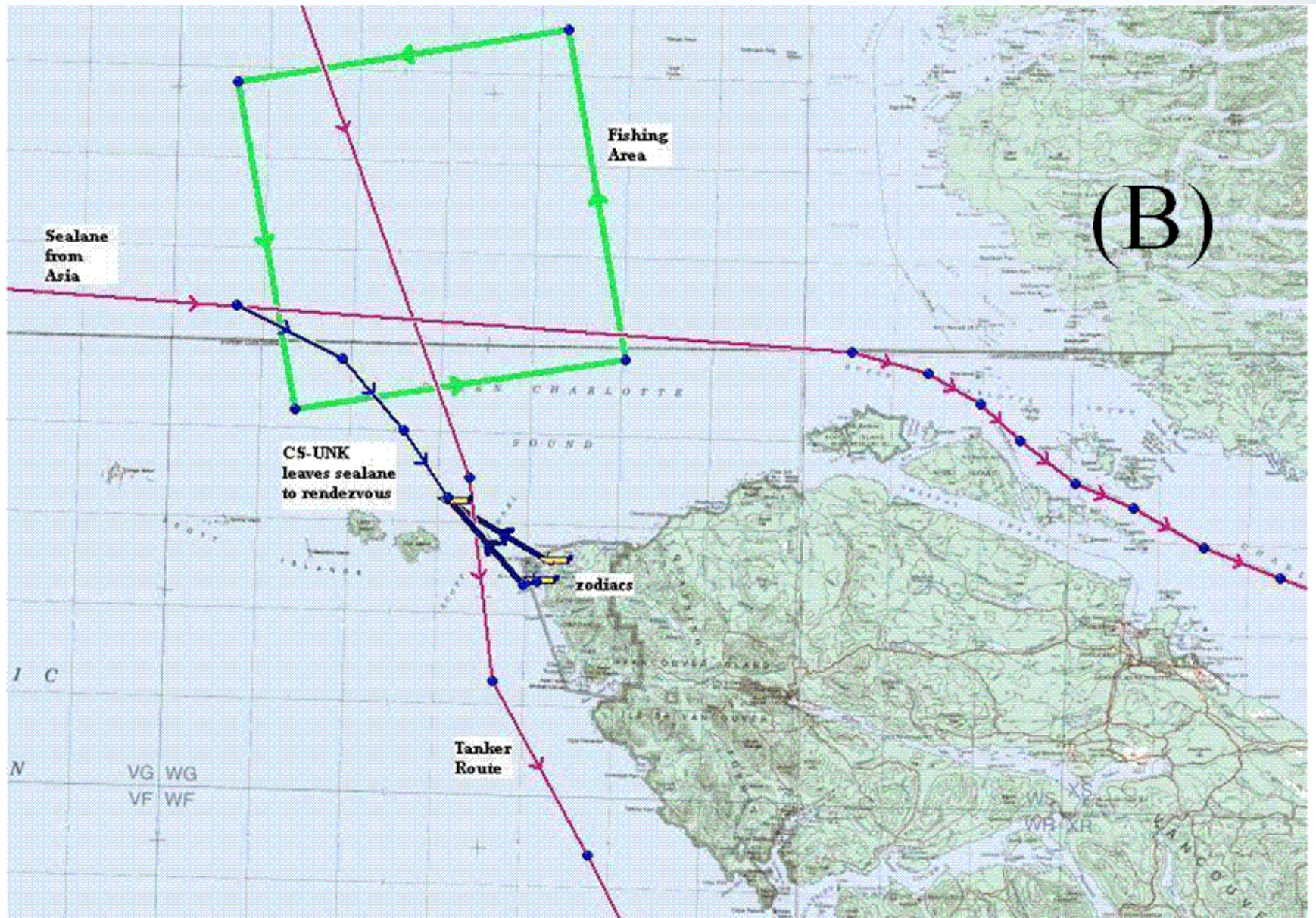
- **Rendez-vous** of mother-cargo-ship CS-UNK with 2 zodiacs
- **Ferrying** behaviour of zodiacs between beach & CS-UNK
- **Suspicious behaviour**: CS-UNK deviating from sea lane, failing to use AIS
- **Elusive behaviour**: CS-UNK and zodiacs disperse when they sense being watched to avoid being detected as rendez-vous-ing

**THIS VIGNETTE IS DEMANDING ADVANCED DISTRIBUTED
FUSION AND DYNAMIC RESOURCE MANAGEMENT**

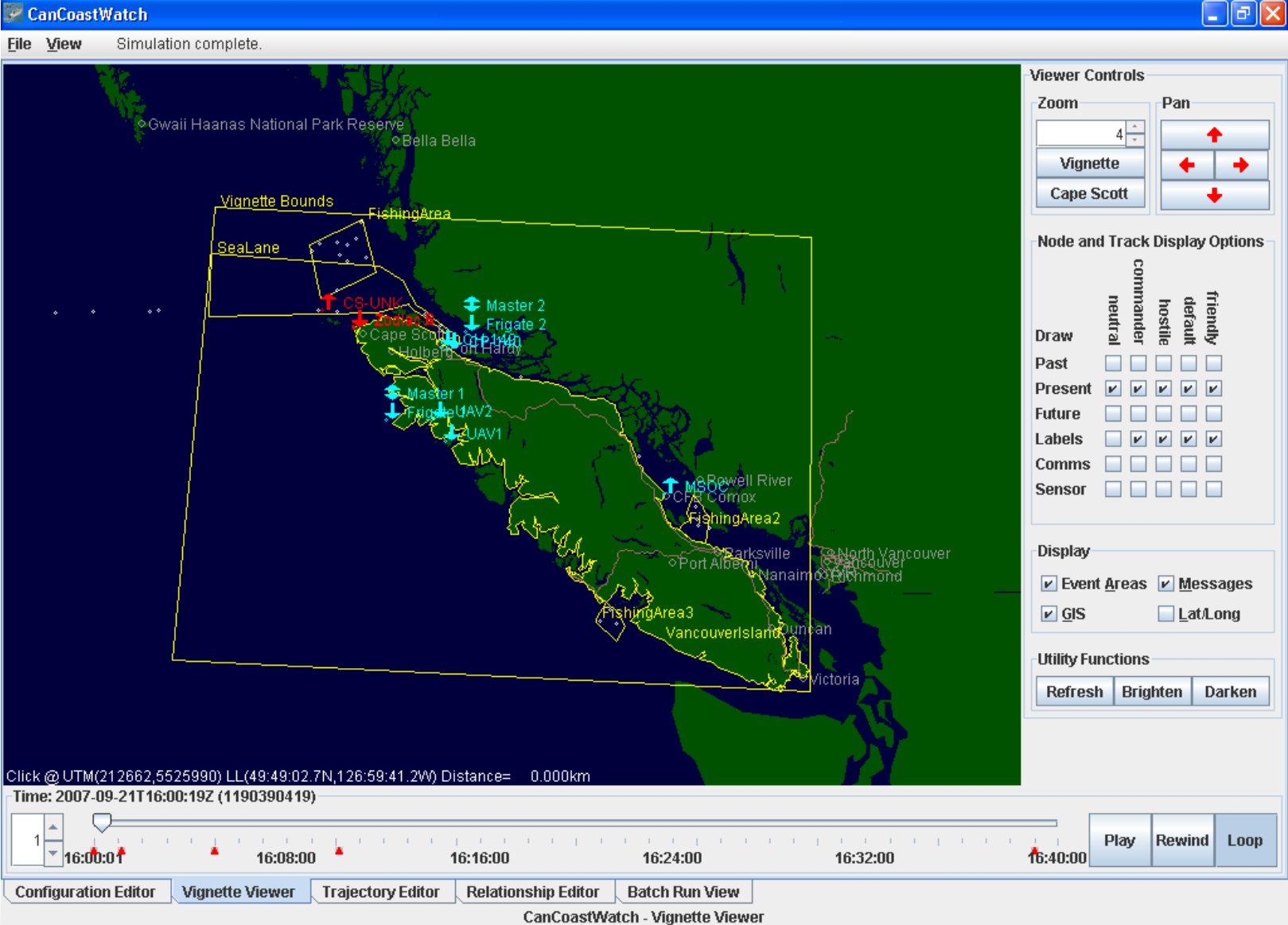
Network design for vignette 2



Vignette 2 with intended behaviours



Vignette 2 screen capture – initial situation



CanCoastWatch Simulation complete.

Viewer Controls

Zoom: 4
 Vignette
 Cape Scott

Pan: ↑, ↓, ←, →

Node and Track Display Options

Draw	neutral	commander	hostile	default	friendly
Past	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
Present	<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>
Future	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
Labels	<input type="checkbox"/>	<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>
Comms	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
Sensor	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>

Display

Event Areas Messages
 GIS Lat/Long

Utility Functions

Refresh Brighten Darken

Click @ UTM(212662,5525990) LL(49:49:02.7N,126:59:41.2W) Distance= 0.000km
 Time: 2007-09-21T16:00:19Z (1190390419)

16:00:01 16:08:00 16:16:00 16:24:00 16:32:00 16:40:00

Play Rewind Loop

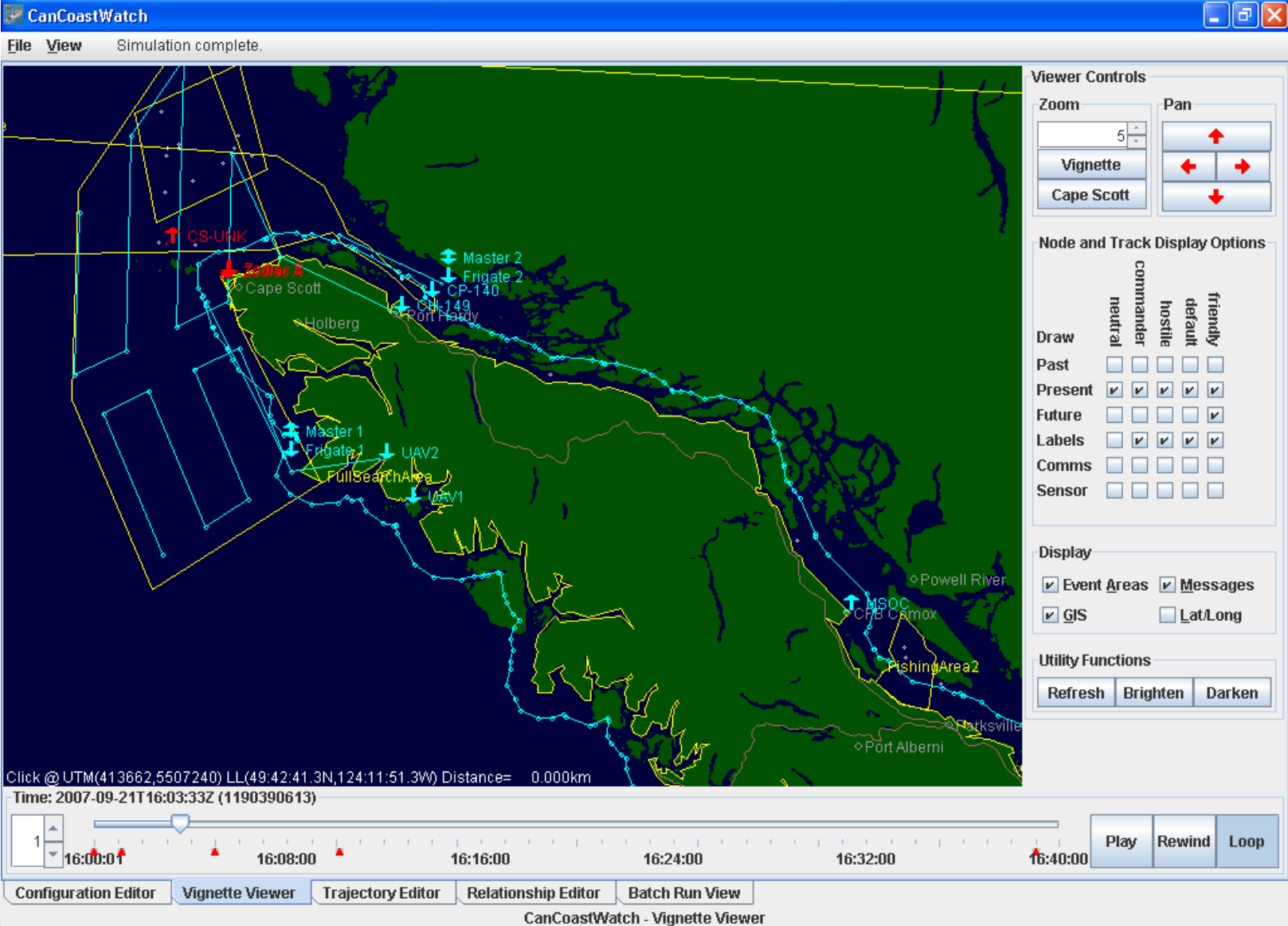
Configuration Editor Vignette Viewer Trajectory Editor Relationship Editor Batch Run View

CanCoastWatch - Vignette Viewer

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 *isShipMovingSlowly(s2)* AND *areNear(s1,s2)*

Vignette 2 screen capture – search begins



The screenshot displays the CanCoastWatch Vignette Viewer interface. The main window shows a map of a coastal region with various search areas and vessel tracks. The interface includes a menu bar (File, View), a status bar (Simulation complete.), and a detailed control panel on the right. The control panel has sections for Viewer Controls (Zoom, Pan), Node and Track Display Options (Draw, Past, Present, Future, Labels, Comms, Sensor), Display (Event Areas, Messages, GIS, Lat/Long), and Utility Functions (Refresh, Brighten, Darken). At the bottom, there is a timeline for the simulation and a set of playback controls (Play, Rewind, Loop).

Viewer Controls

Zoom: 5
Vignette
Cape Scott

Pan: ↑, ←, →, ↓

Node and Track Display Options

Draw	neutral	commander	hostile	default	friendly
Past	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
Present	<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>
Future	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input checked="" type="checkbox"/>
Labels	<input type="checkbox"/>	<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>
Comms	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
Sensor	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>

Display

Event Areas Messages
 GIS Lat/Long

Utility Functions

Refresh Brighten Darken

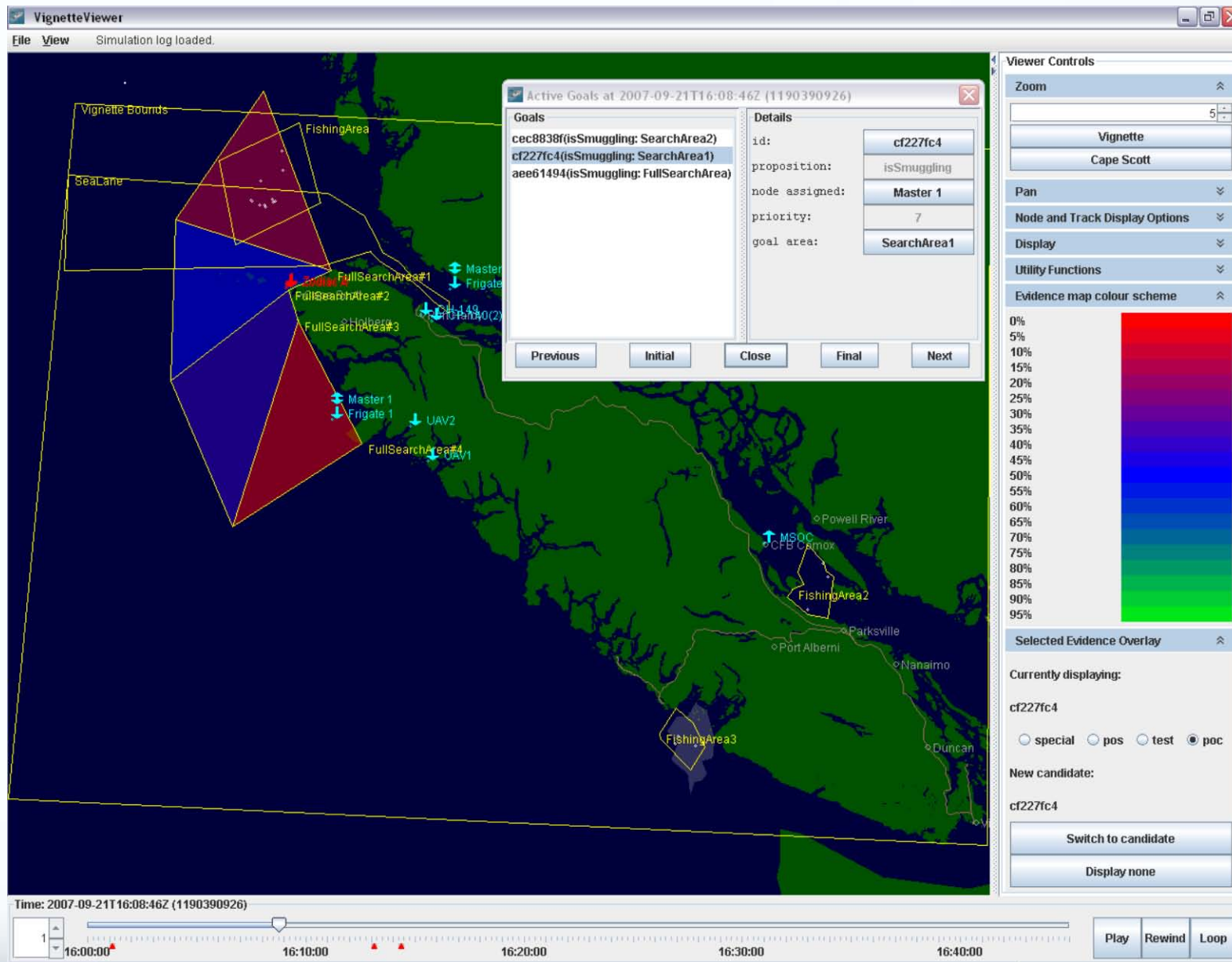
Click @ UTM(413662,5507240) LL(49:42:41.3N,124:11:51.3W) Distance= 0.000km
 Time: 2007-09-21T16:03:33Z (1190390613)

Timeline: 16:00:01, 16:08:00, 16:16:00, 16:24:00, 16:32:00, 16:40:00

Configuration Editor Vignette Viewer Trajectory Editor Relationship Editor Batch Run View

CanCoastWatch - Vignette Viewer

Vignette 2 screen capture – SE for search area



The screenshot displays the VignetteViewer application interface. The main window shows a map of a coastal region with several search areas and entities. A pop-up window titled "Active Goals at 2007-09-21T16:08:46Z (1190390926)" is open, showing details for goal **cf227fc4**.

Goals	Details
cec8838f(isSmuggling: SearchArea2)	id: cf227fc4
cf227fc4(isSmuggling: SearchArea1)	proposition: isSmuggling
ae661494(isSmuggling: FullSearchArea)	node assigned: Master 1
	priority: 7
	goal area: SearchArea1

The map includes labels for "Vignette Bounds", "SeaLane", "FishingArea", "FullSearchArea#1-4", "Master 1 Frigate", "UAV1", "UAV2", "MSOC", "CFB Comox", "Powell River", "FishingArea2", "Parksville", "Port Alberni", "Nanaimo", "Duncan", and "Holberg". A color scale legend on the right indicates evidence levels from 0% (white) to 95% (red).

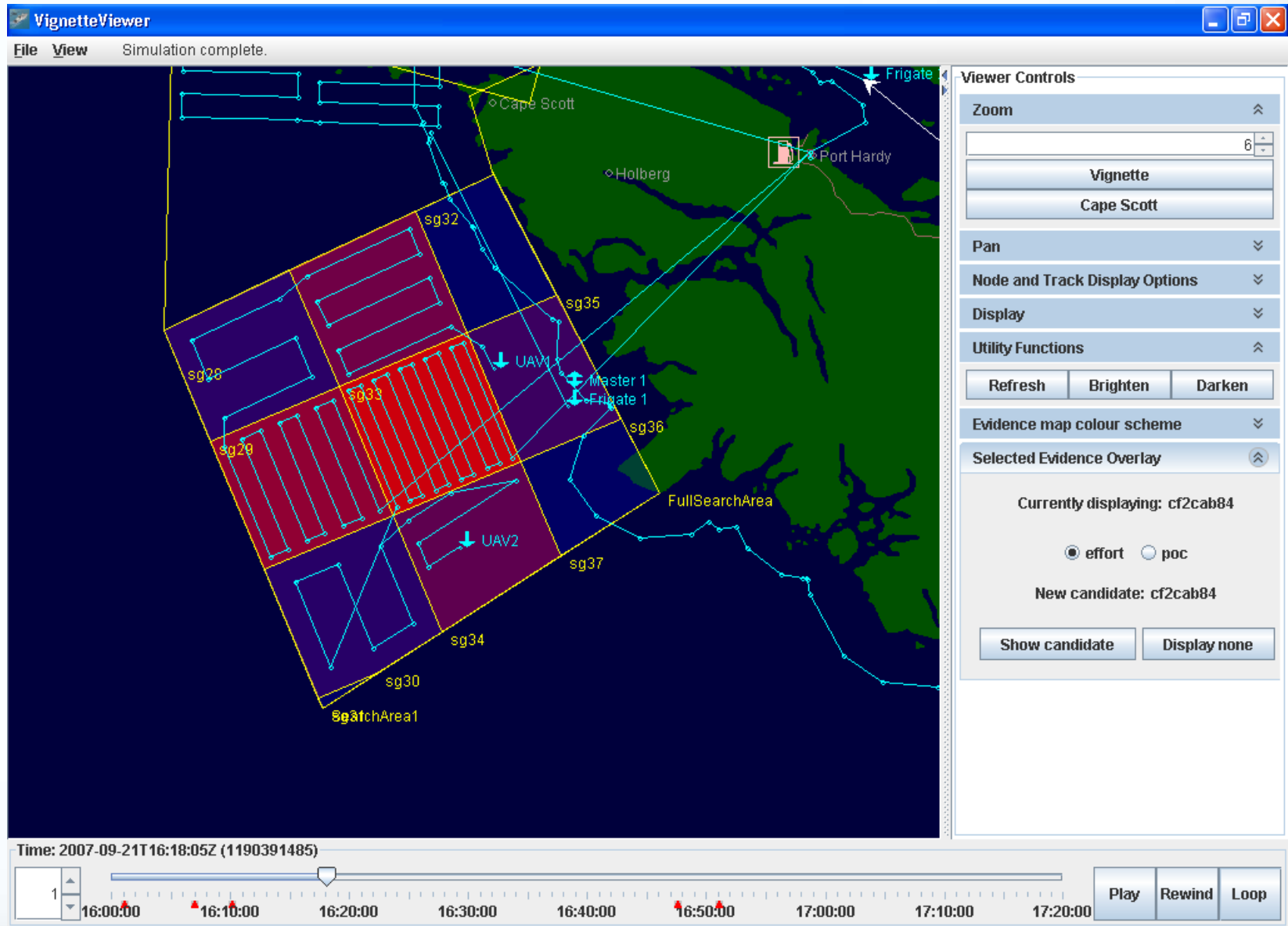
Viewer Controls on the right include: Zoom (set to 5), Vignette (Cape Scott), Pan, Node and Track Display Options, Display, Utility Functions, Evidence map colour scheme, and Selected Evidence Overlay (Currently displaying: cf227fc4, poc selected).

Time: 2007-09-21T16:08:46Z (1190390926)

Timeline: 16:00:00, 16:10:00, 16:20:00, 16:30:00, 16:40:00

Buttons: Play, Rewind, Loop

Vignette 2 – planning for a search area



VignetteViewer Simulation complete.

Viewer Controls

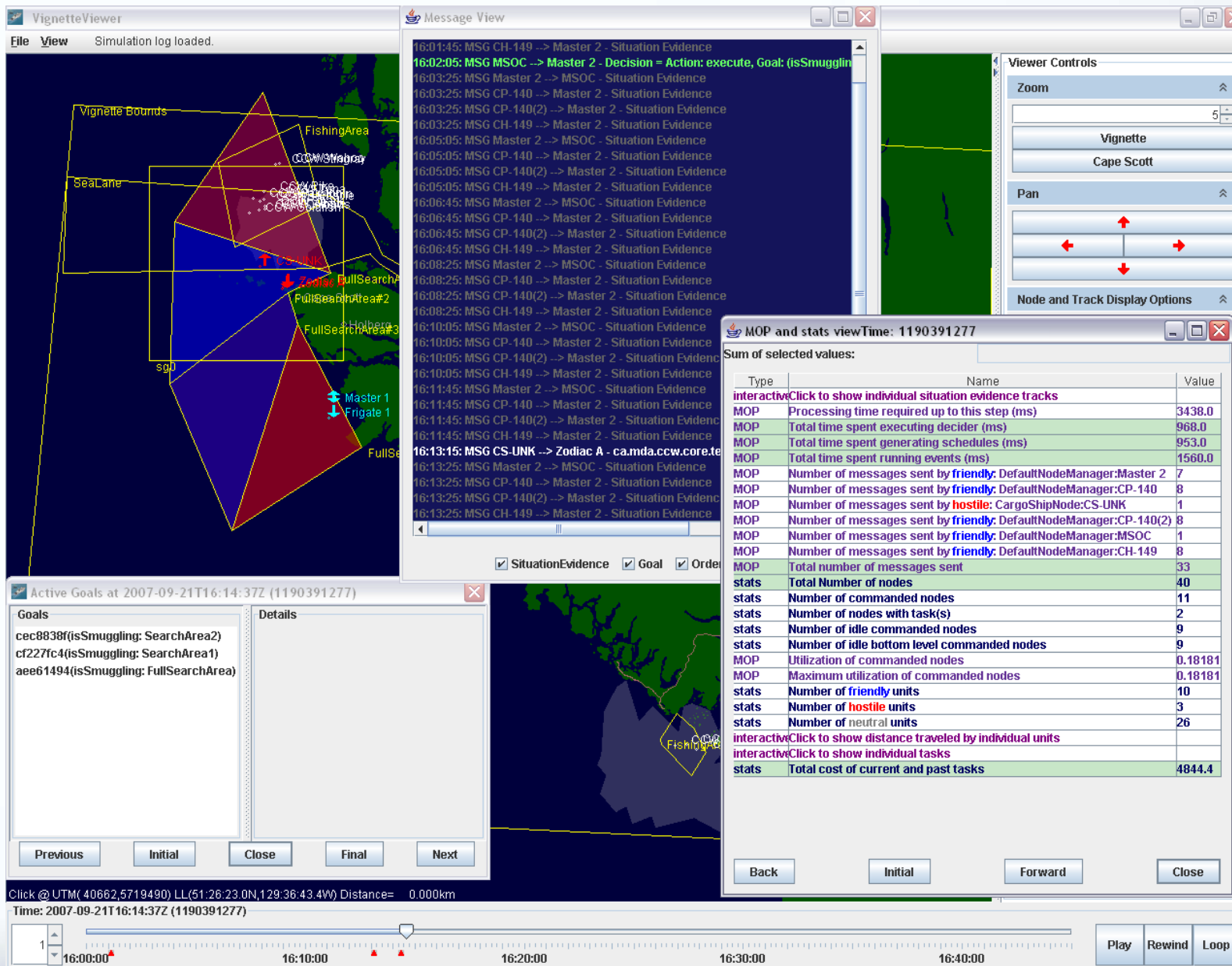
- Zoom: 6
- Vignette
- Cape Scott
- Pan
- Node and Track Display Options
- Display
- Utility Functions: Refresh, Brighten, Darken
- Evidence map colour scheme
- Selected Evidence Overlay: cf2cab84
- Currently displaying: cf2cab84
- effort poc
- New candidate: cf2cab84
- Show candidate | Display none

Time: 2007-09-21T16:18:05Z (1190391485)

Timeline: 16:00:00, 16:10:00, 16:20:00, 16:30:00, 16:40:00, 16:50:00, 17:00:00, 17:10:00, 17:20:00

Buttons: Play, Rewind, Loop

Vignette 2 – output options



The screenshot displays the VignetteViewer application interface. The main window shows a map with various search areas and units. A 'Message View' window is open, displaying a log of simulation events. An 'Active Goals' window lists search areas. A 'MOP and stats view' window is open, showing a table of performance metrics.

Message View Log:

```

16:01:45: MSG CH-149 -> Master 2 - Situation Evidence
16:02:05: MSG MSOC -> Master 2 - Decision = Action: execute, Goal: (isSmuggling
16:03:25: MSG Master 2 -> MSOC - Situation Evidence
16:03:25: MSG CP-140 -> Master 2 - Situation Evidence
16:03:25: MSG CH-149 -> Master 2 - Situation Evidence
16:05:05: MSG Master 2 -> MSOC - Situation Evidence
16:05:05: MSG CP-140 -> Master 2 - Situation Evidence
16:05:05: MSG CH-149 -> Master 2 - Situation Evidence
16:06:45: MSG Master 2 -> MSOC - Situation Evidence
16:06:45: MSG CP-140 -> Master 2 - Situation Evidence
16:06:45: MSG CH-149 -> Master 2 - Situation Evidence
16:08:25: MSG Master 2 -> MSOC - Situation Evidence
16:08:25: MSG CP-140 -> Master 2 - Situation Evidence
16:08:25: MSG CH-149 -> Master 2 - Situation Evidence
16:10:05: MSG Master 2 -> MSOC - Situation Evidence
16:10:05: MSG CP-140 -> Master 2 - Situation Evidence
16:10:05: MSG CH-149 -> Master 2 - Situation Evidence
16:11:45: MSG Master 2 -> MSOC - Situation Evidence
16:11:45: MSG CP-140 -> Master 2 - Situation Evidence
16:11:45: MSG CH-149 -> Master 2 - Situation Evidence
16:13:15: MSG CS-UNK -> Zodiac A - ca.mda.ccw.core.te
16:13:25: MSG Master 2 -> MSOC - Situation Evidence
16:13:25: MSG CP-140 -> Master 2 - Situation Evidence
16:13:25: MSG CH-149 -> Master 2 - Situation Evidence
    
```

Active Goals at 2007-09-21T16:14:37Z (1190391277)

Goals	Details
cec8838f(isSmuggling: SearchArea2)	
cf227fc4(isSmuggling: SearchArea1)	
ae661494(isSmuggling: FullSearchArea)	

MOP and stats viewTime: 1190391277

Sum of selected values:

Type	Name	Value
interactive	Click to show individual situation evidence tracks	
MOP	Processing time required up to this step (ms)	3438.0
MOP	Total time spent executing decider (ms)	968.0
MOP	Total time spent generating schedules (ms)	953.0
MOP	Total time spent running events (ms)	1560.0
MOP	Number of messages sent by friendly: DefaultNodeManager:Master 2	7
MOP	Number of messages sent by friendly: DefaultNodeManager:CP-140	8
MOP	Number of messages sent by hostile: CargoShipNode:CS-UNK	1
MOP	Number of messages sent by friendly: DefaultNodeManager:CP-140(2)	8
MOP	Number of messages sent by friendly: DefaultNodeManager:MSOC	1
MOP	Number of messages sent by friendly: DefaultNodeManager:CH-149	8
MOP	Total number of messages sent	33
stats	Total Number of nodes	40
stats	Number of commanded nodes	11
stats	Number of nodes with task(s)	2
stats	Number of idle commanded nodes	9
stats	Number of idle bottom level commanded nodes	9
MOP	Utilization of commanded nodes	0.18181
MOP	Maximum utilization of commanded nodes	0.18181
stats	Number of friendly units	10
stats	Number of hostile units	3
stats	Number of neutral units	26
interactive	Click to show distance traveled by individual units	
interactive	Click to show individual tasks	
stats	Total cost of current and past tasks	4844.4

Click @ UTM(40662,5719490) LL(51:26:23.0N,129:36:43.4W) Distance= 0.000km
Time: 2007-09-21T16:14:37Z (1190391277)

Timeline: 16:00:00, 16:10:00, 16:20:00, 16:30:00, 16:40:00

Buttons: Play, Rewind, Loop

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)**

DEFENCE



DÉFENSE