CARACaS multi-agent maritime autonomy for USVs in the Swarm II harbor patrol demonstration

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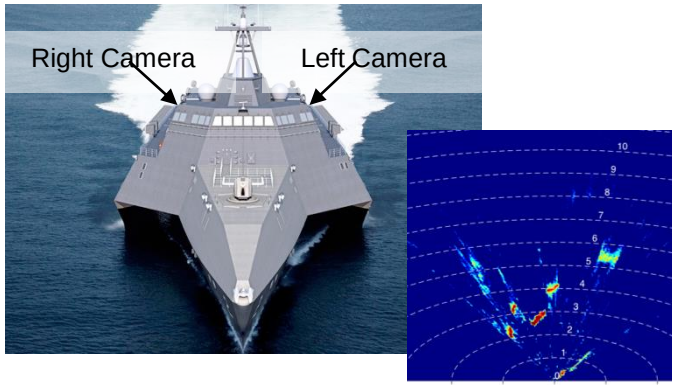
Current Projects in Maritime Autonomy

ASW Continuous Trail Unmanned Vehicle (ACTUV)

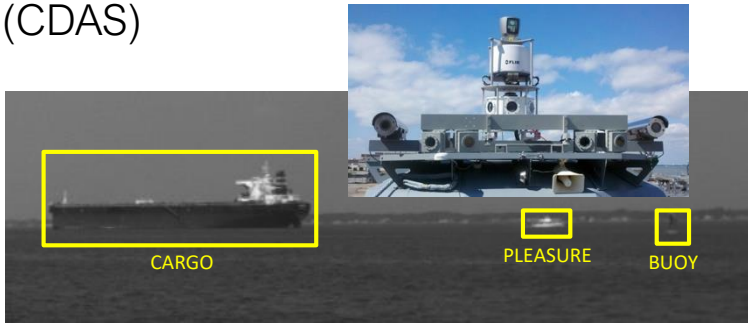
USV Swarm

Unmanned Influence Sweep System (UISS)

Mechanically Uncoupled Stereo EO/IR (MUSE)



Contact Detection and Analysis System (CDAS)



CARACaS (Control Architecture for Robotic Agent Command and Sensing)

A multi-mission, multi-agent autonomy development platform

Open Architecture

Standards based

Fee free licensing for government use

CARACaS Autonomy Architecture establishes module decomposition and provides execution engines

CARACaS Software Framework (CSF) libraries/services used by developers in creating modules

CARACaS Autonomy Toolkits for testing, executing, and analyzing the software

CARACaS Autonomy Architecture

Autonomy Application
- Command Dictionaries
- Mission Models & Behaviors
- Customized Motion Planning
- Hardware Interfaces

Autonomy Modules
- Mission Executive
- Behavior Engine(s)
- Planning Libraries
- Perception & Control Modules

Architecture Definition
- Module Decomposition
- World Model Specification
- Interface Control Documents

CARACaS Autonomy Toolkits

Operator Toolkit
- Command Interface
- Mission Model Composer
- Mission Visualization
- Software Process Mgmt

Developer Toolkit
- Simulation Engine
- Introspection Tools
- Algorithm Visualization
- Module Replay

Architectural Services
- Health Monitoring
- Parameter Management
- Data Logging & Playback

Middleware
- Data-Centric Communications
- Synchronous Messaging
- Command & Data Handling

CARACaS Software Framework

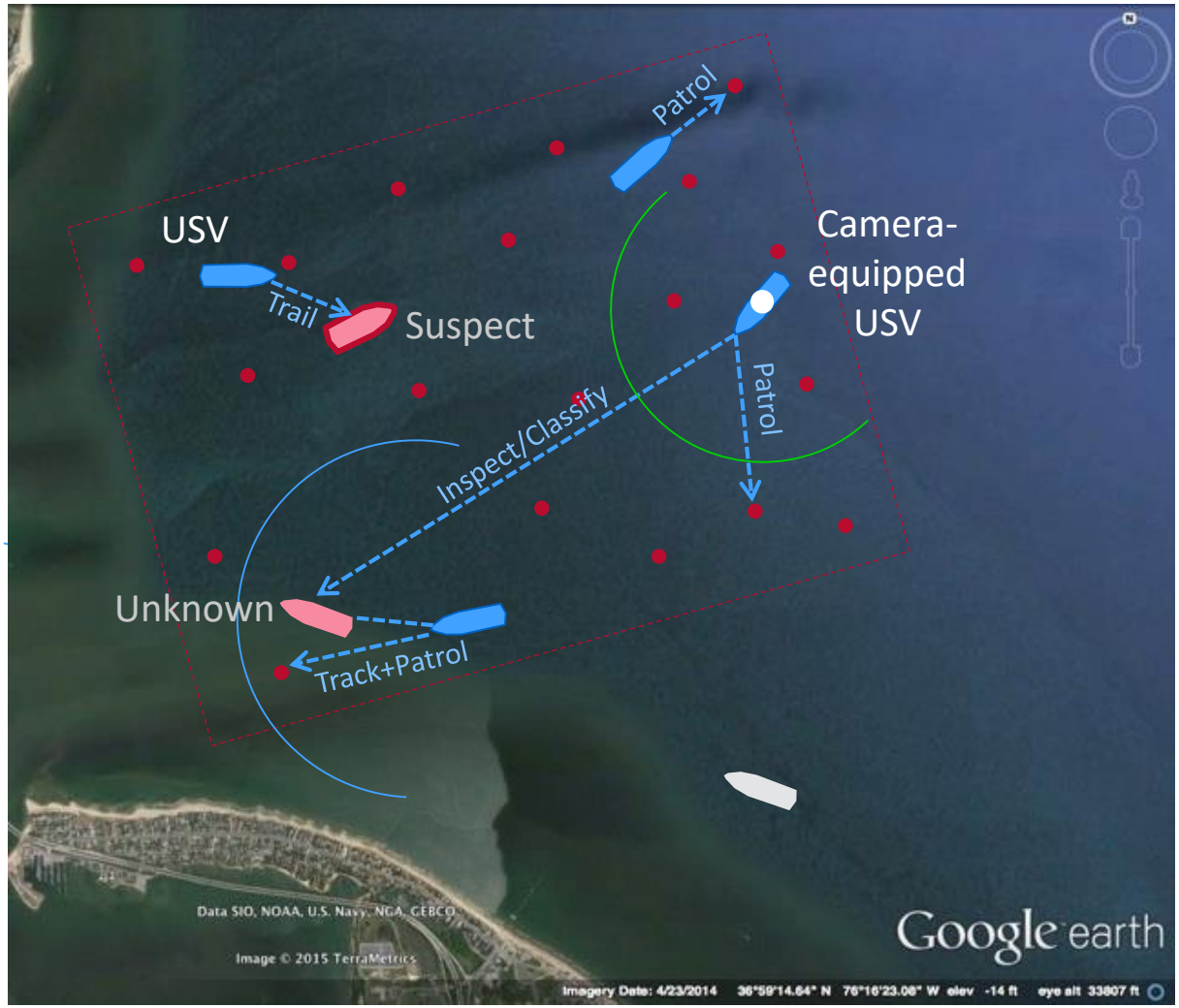
USV Swarm 2 Demonstration (SEP 2016)

Behaviors

- **Patrol** – cooperatively monitor a defined area
- **Track** – keep a vessel in radar range, while patrolling nearby
- **Inspect** – dispatch a USV with cameras to classify a vessel
- **Trail** – closely follow a suspect vessel

Technology Objectives

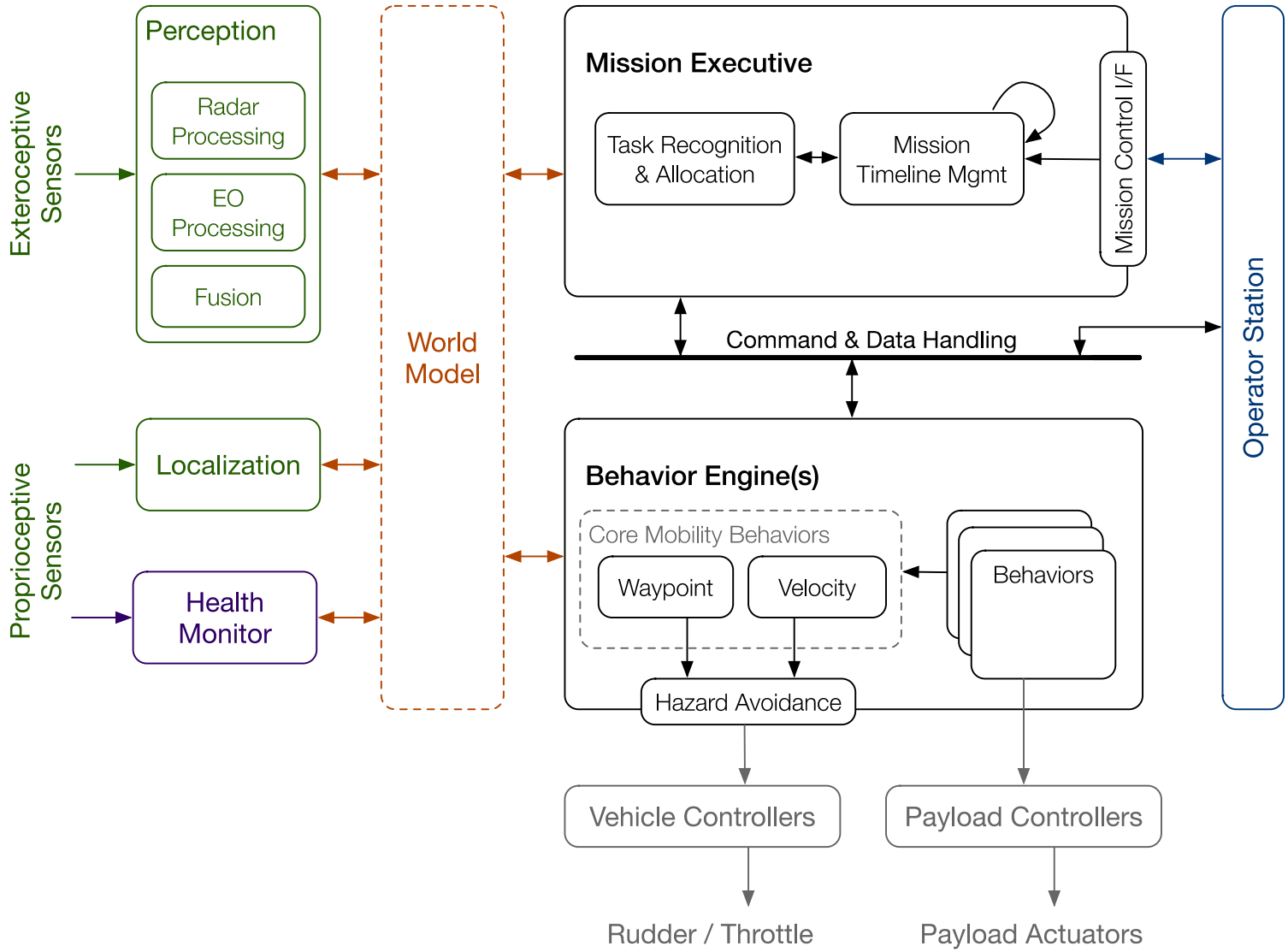
- Higher levels of autonomy / less operator input
- Autonomous task recognition and allocation
- Planning for heterogeneous teams
- Adaptation to attrition and subsystem failures
- Decreased bandwidth requirements



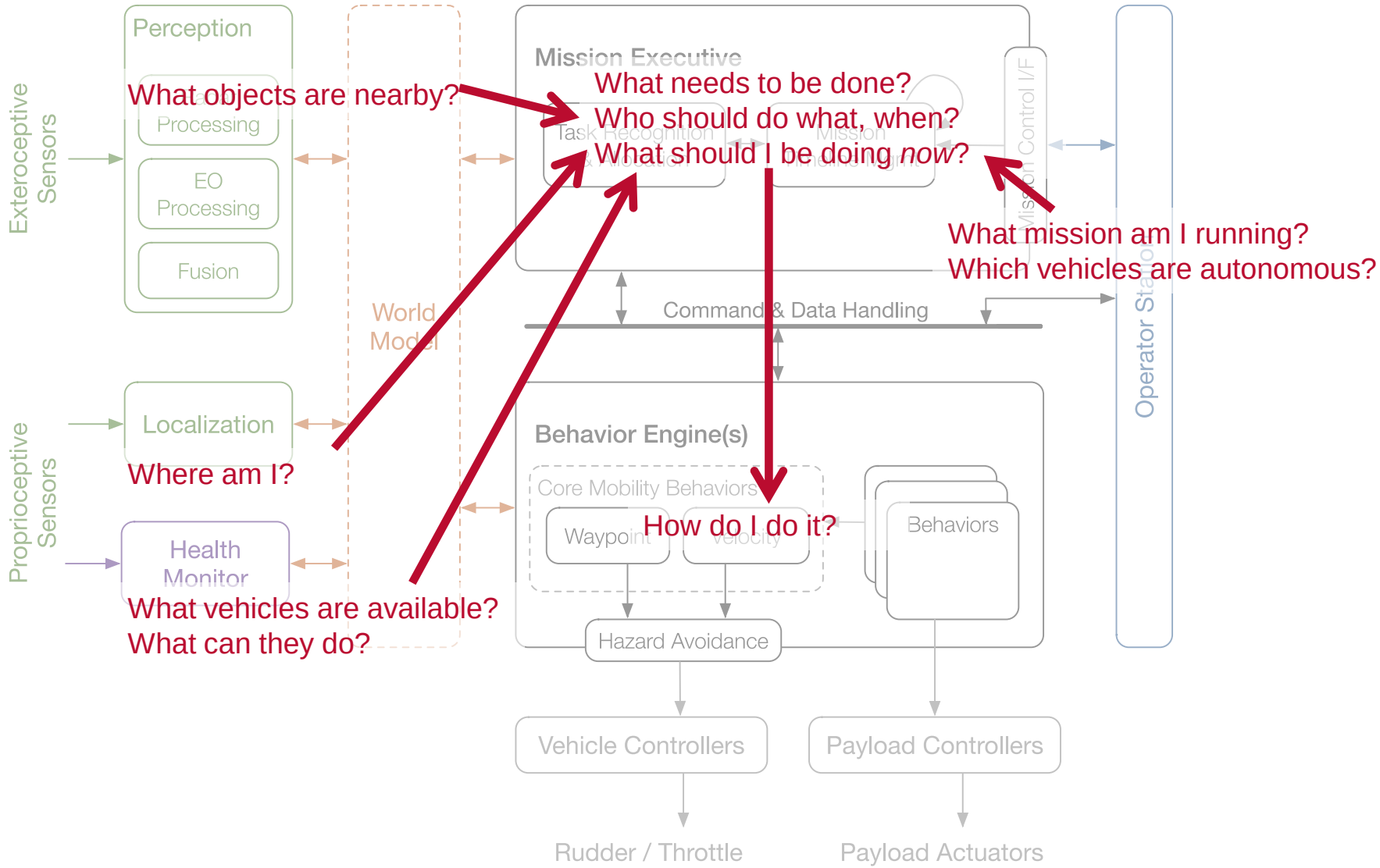
Key Ideas for Swarm 2 Autonomy

- Autonomy must be capable of event-driven operations in highly dynamic environments.
  - Not just sequenced, waypoint-driven missions
  - Swarm needs to *recognize* the tasks required to complete its mission as well as *allocate* those tasks to agents
  - Missions are complex and composed of multiple behaviors
- Focus was multi-mission autonomy architecture with customizable behaviors.
  - Not necessarily optimizing a “patrol agents” system
  - Use a specific, sufficiently complex example to define and exercise a multi-agent autonomy architecture and corresponding cooperative behaviors
- Autonomy systems should be robust and flexible
  - No software component knew any of the following beforehand:
    - how many USVs would be participating
    - how many USVs had camera systems
    - how many contacts might be encountered
  - Discovering conditions in runtime and re-planning accordingly enables both operational flexibility and robustness to health faults / changing conditions

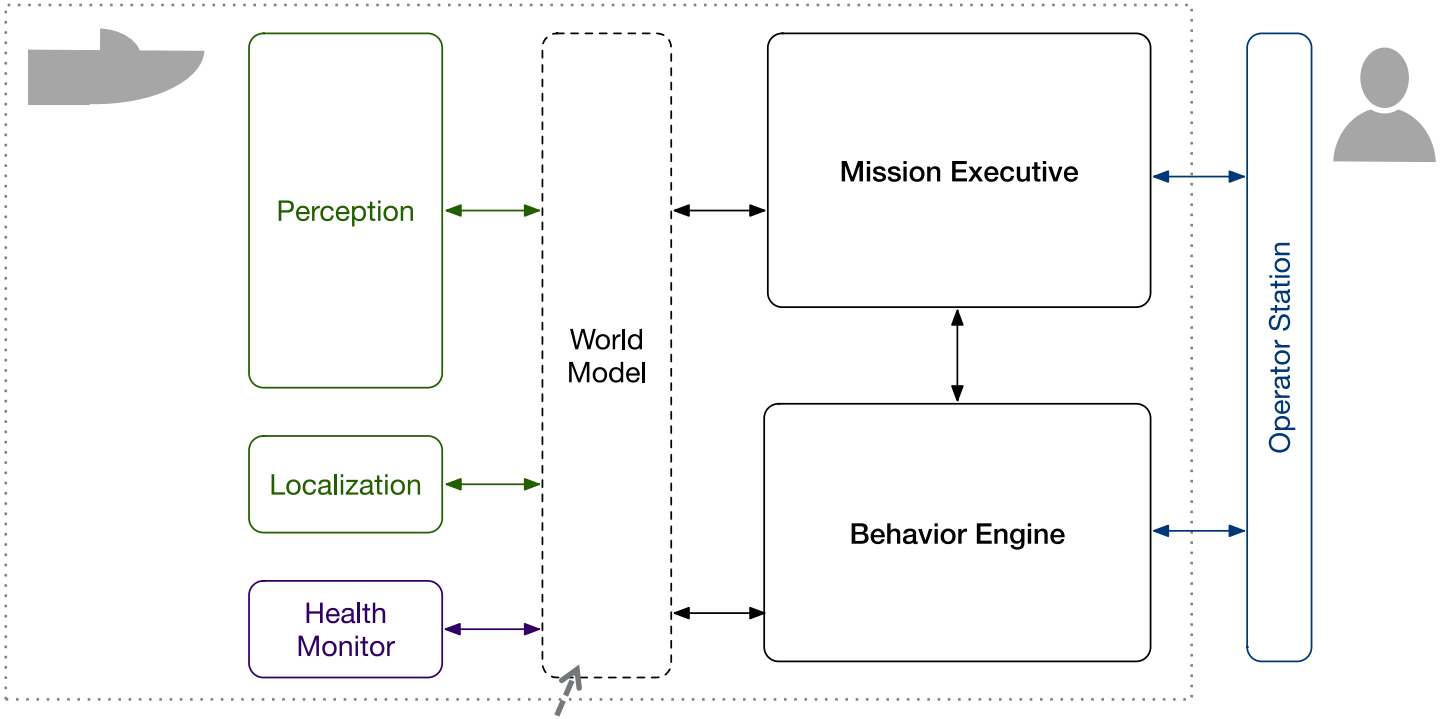
CARACaS: Functional Architecture

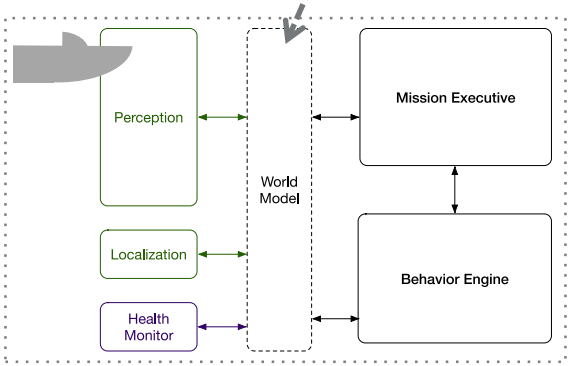


CARACaS: Functional Architecture



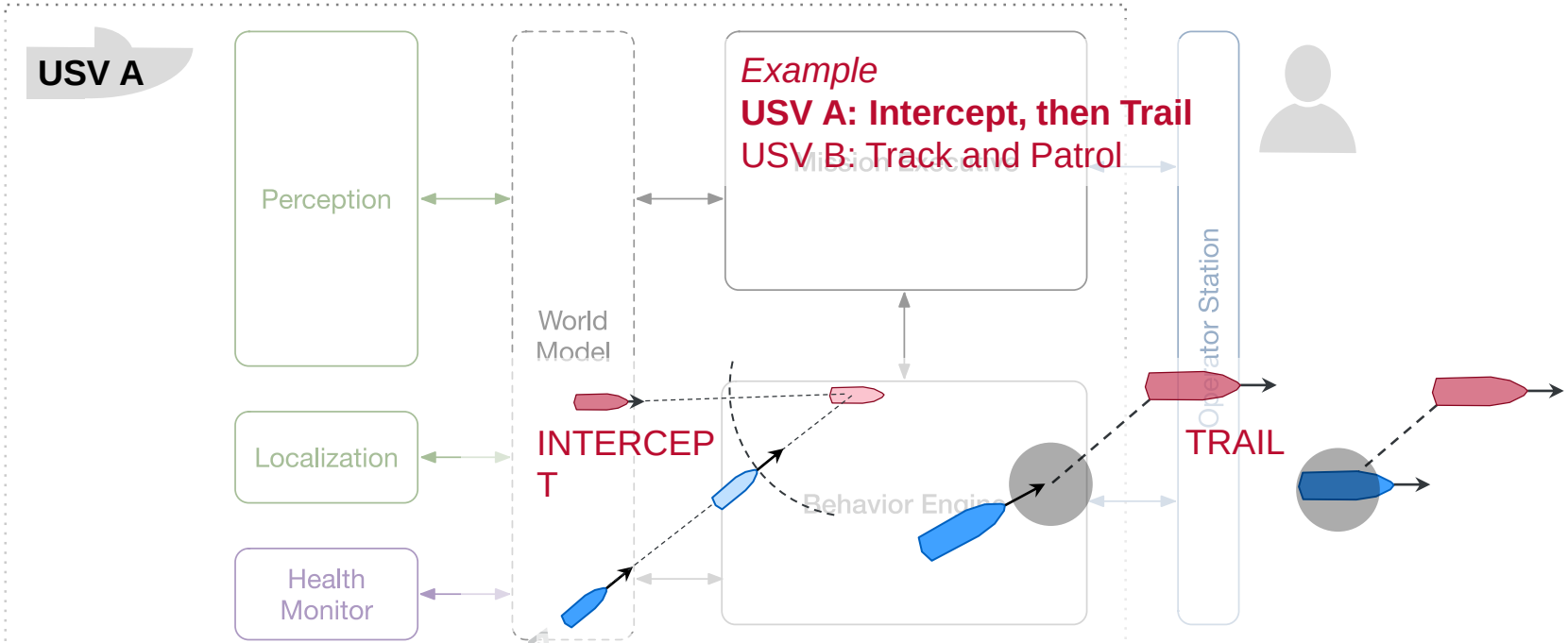
Cooperative Autonomy for USV Swarm





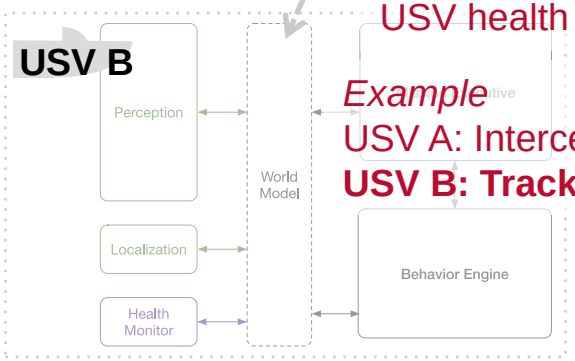
- World Models are synchronized (communications allowing).
- All Planning is decentralized.
- Mission Executive creates a timeline for itself *and* predictions of other agents' plans.
- Agents execute their own local plan; no additional communication needed.

Cooperative Autonomy for USV Swarm



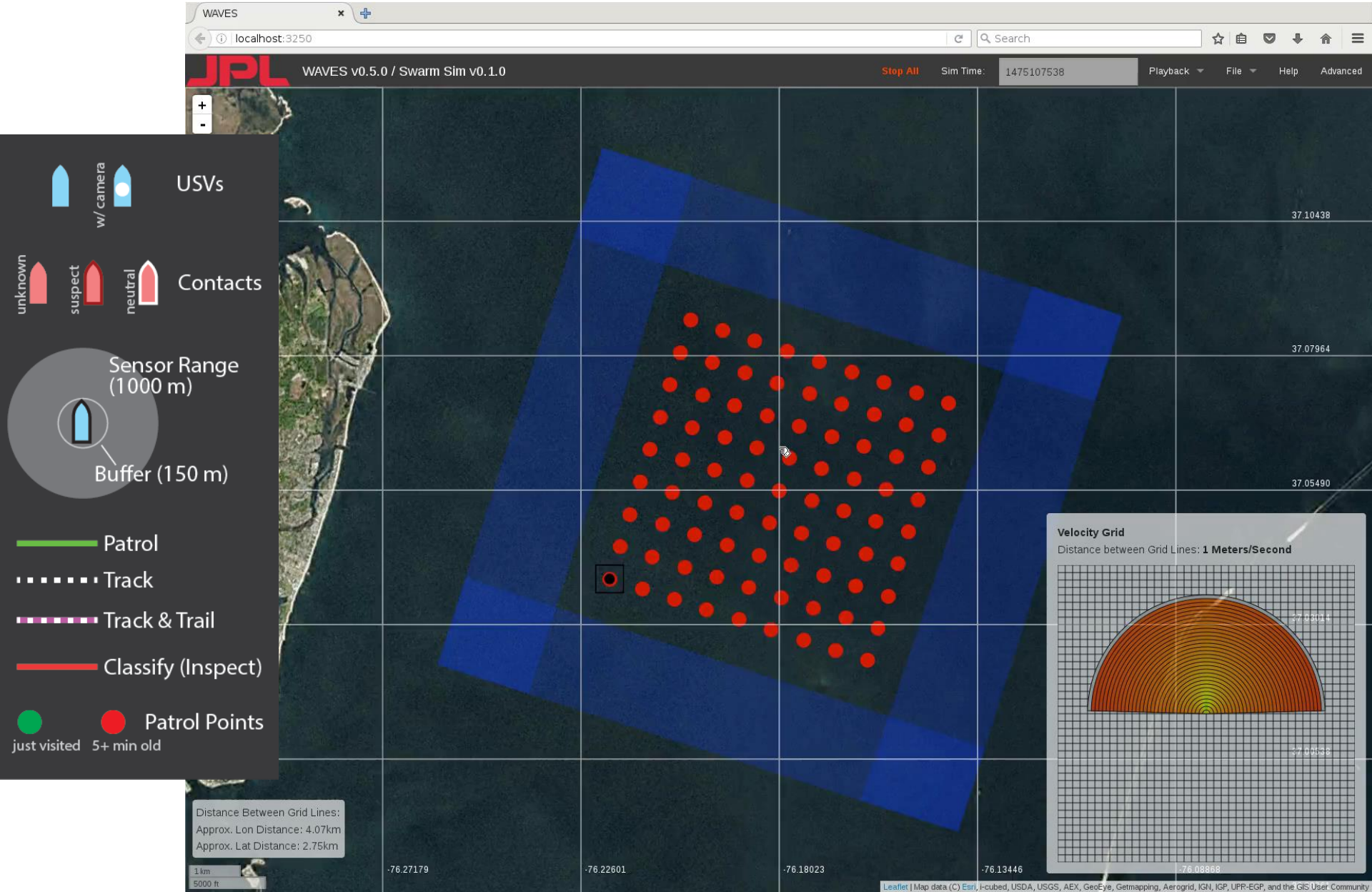
Example
USV A: Intercept, then Trail
USV B: Track and Patrol

Track list (all contacts & USVs)
Vessel classification
Patrol point visit times
USV health and status



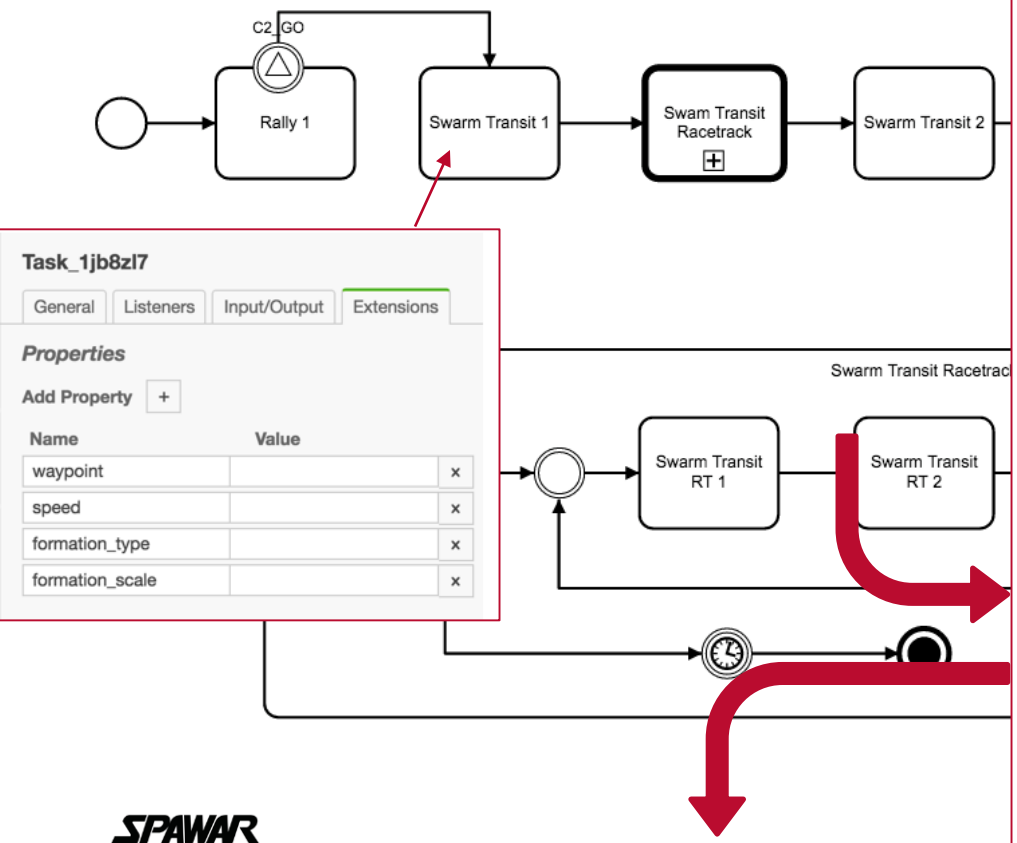
Example
USV A: Intercept, then Trail
USV B: Track and Patrol

Swarm 2 Mission Video



Human Element: Defining a Mission

CARACaS Mission Executive ingests missions in
Business Process Modeling and Notation (BPMN)

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3.    <bpmn:process id="Process_1" isExecutable="false">
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5.        <bpmn:extensionElements>
6.          <camunda:properties>
7.            <camunda:property name="waypoint" value="[lat, lon]" />
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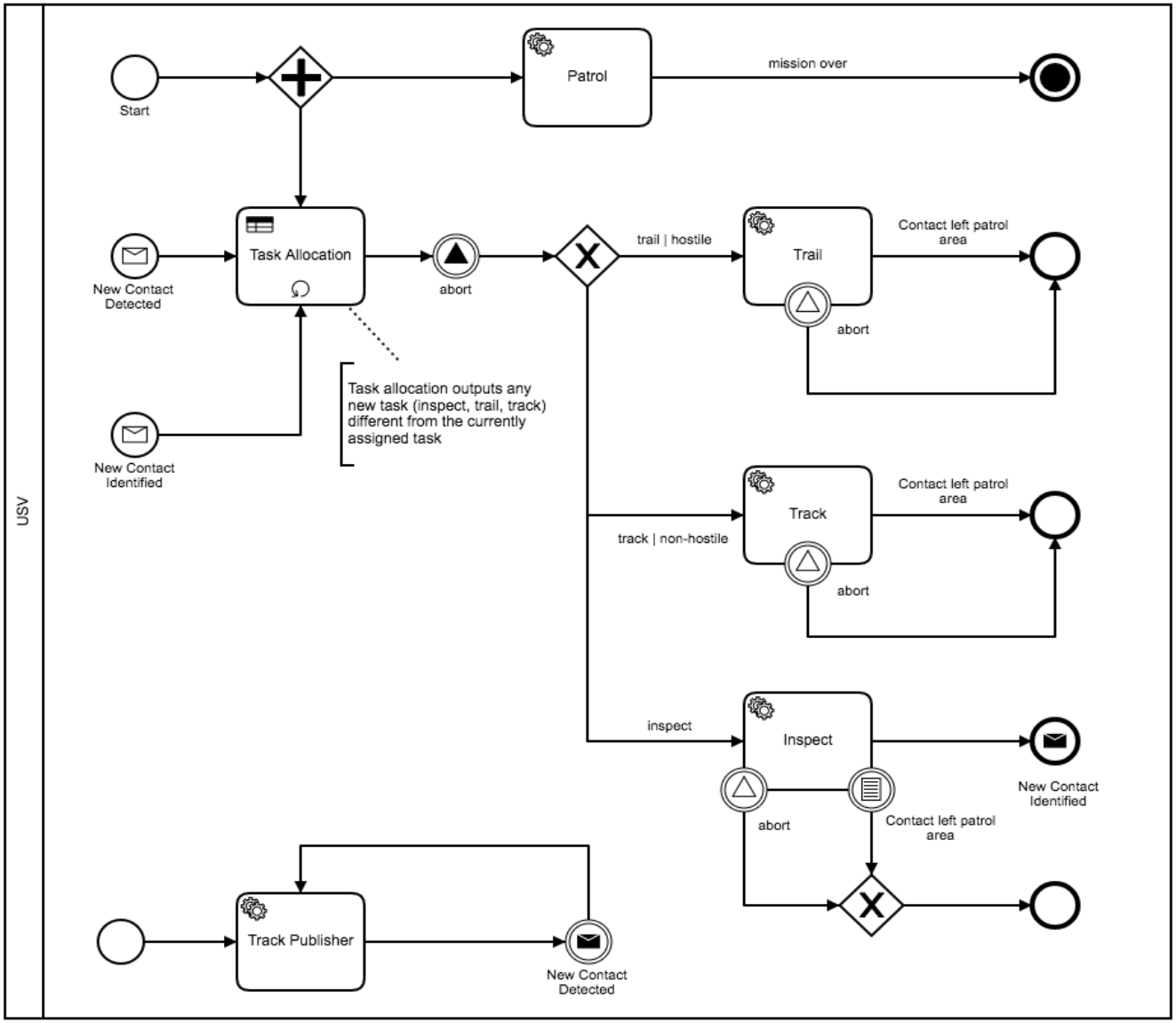
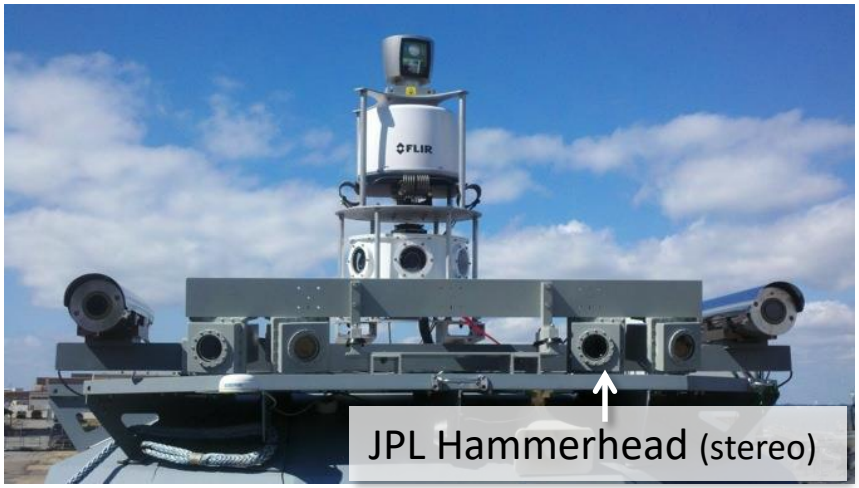
Model Verification
Interpretation by Autonomy
Mission Status Updates

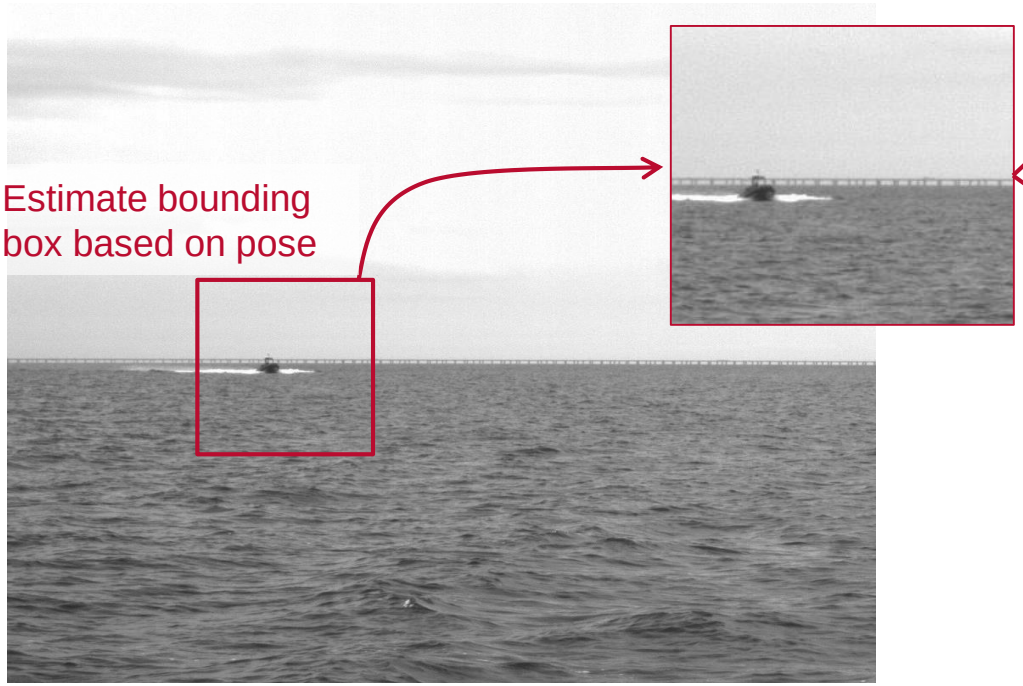
SPAWAR
Systems Center PACIFIC

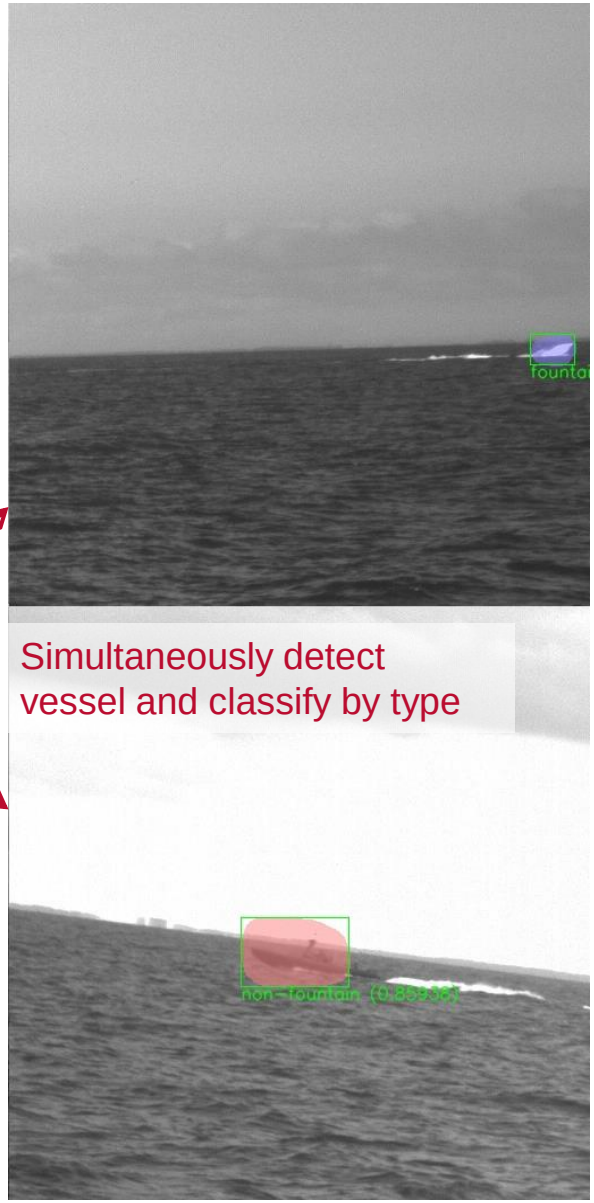
Swarm 2 Mission Model Diagram



CDAS EO Processing (Contact Detection and Analysis System)







Conclusion

- Summary
  - CARACaS provides an autonomy software framework for multi-agent coordination and control.
  - The Swarm 2 mission demonstrated performance in dynamic, event-driven missions requiring multiple behaviors and shared world modeling.
  - Autonomy has been designed for user-friendliness, robustness to failures, and flexibility for operational variables.
- Next Steps
  - Maturing situational awareness / robustness to perception noise
  - Further demonstrating “building block” approach to missions through behavior composition
  - More complex teaming scenarios (e.g., USV subgroups with closely coupled behaviors)

Acknowledgments

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