Autonomous Systems Innovation Summit

Future Capabilities

Perception, Understanding and Intelligent Decision Making

Presenter: Dr. Thomas McKenna
ONR 341

Panel 2 Objectives

Autonomous systems with increased intelligence and the ability to adaptively collect and process sensor data into actionable information, with the goal of minimizing or eliminating human intervention.

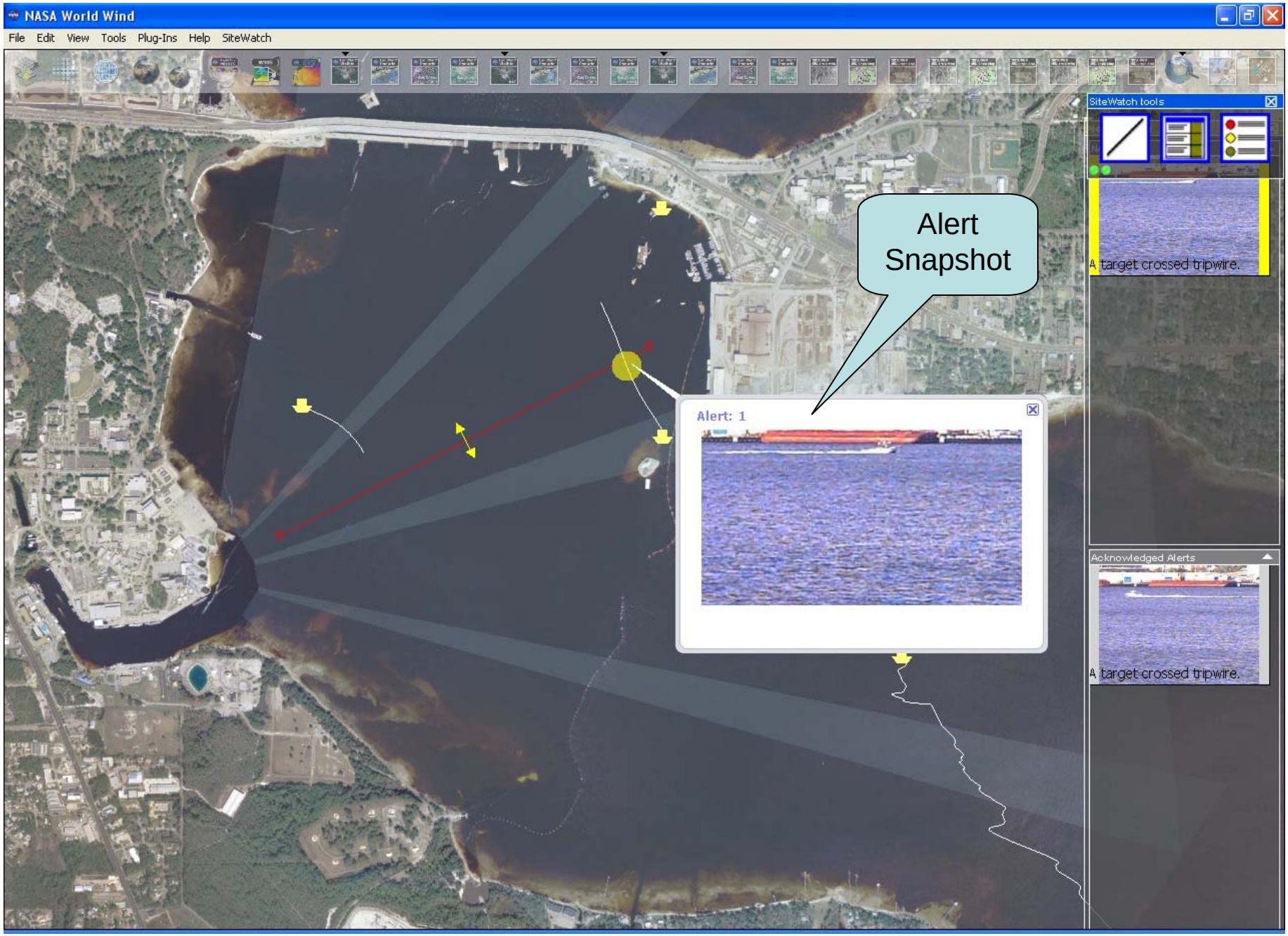
Tough Problems

- **Autonomously adjudicate between wide area exploration and dynamic region of interest (ROI) exploitation (broad area coverage with immediate “zoom” to ROI)**
- **Learning context (environmental), adaptive recognition and scene understanding to semantic level for presentation to a system or person (information is extractable)**
- **Autonomous vehicle tasking/maneuvering based on interaction between mission level objectives and (feature-based) perception (bottom-up & top-down) to include reprogrammable/adaptive/taskable**
- **Automated processing (intelligence) from sensor data to information to actionable understanding presented to the warfighter and the system to include multiple warfighters (parsing data) or entire system**

Exploration / Exploitation Tradeoff

- Autonomously adjudicate between wide area exploration and dynamic region of interest (ROI) exploitation (broad area coverage with immediate “zoom” to ROI)
  - An autonomous system that can recognize sensing gaps, needs to fill those gaps, then knows when they are filled, or if they are not filled if that is ok or requires additional understanding
  - The system decides which task to devote it’s resources to – original larger task or more complete accomplishment of an individual task – mission optimization

Examples:
Intelligent Video Surveillance
USSV / UV Sentry
Autonomous Mine Warfare


NASA World Wind
File Edit View Tools Plug-Ins Help SiteWatch
SiteWatch tools
A target crossed tripwire.
Alert Snapshot
Alert: 1
Acknowledged Alerts
A target crossed tripwire.

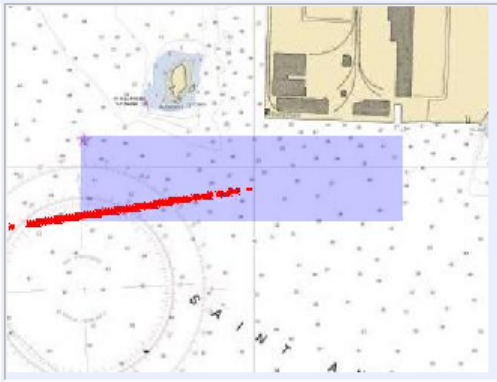
Geopositional Alert

Event: 1

Date/Time: 11/8/2006 12:26:19 PM

Sensor: FNCIVSSVR1c83f0f81-6fde-41a6-831a-6a7ba090fe9c:

Message: Alert: [Anything] [Loiters] south_of_ppc(Ground Plane) where loitering time is at least 1 minutes 30 seconds



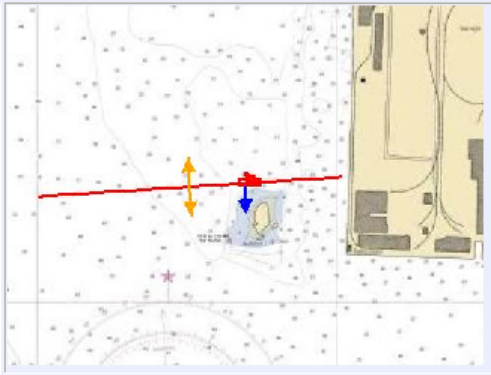
- **Alert detected**
- **Map coordinates are assigned**
- **Previous locations recorded**

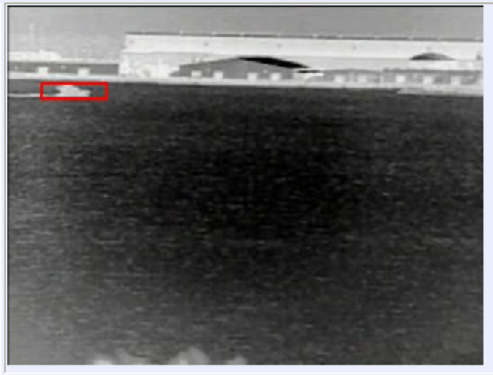
Event: 19

Date/Time: 11/8/2006 12:40:54 PM

Sensor: FNCIVSSVR1c83f0f81-6fde-41a6-831a-6a7ba090fe9c:

Message: Alert: [Anything] [Crosses] map_trip1 in Any Direction



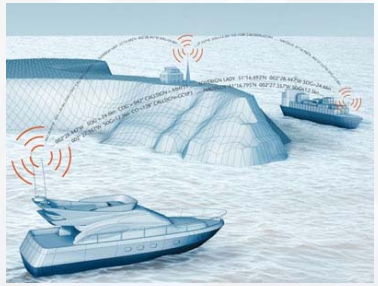


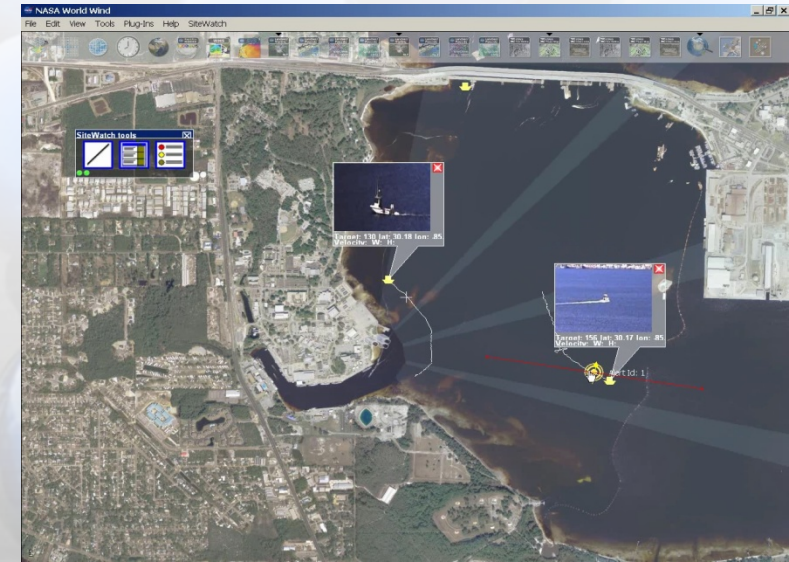
POC: Thomas McKenna, ONR 341

Performer: ObjectVideo

Automatic Fused Ship Tracking with Video, AIS, GPS, RADAR

- Input
  - Video from multiple wide view cameras (fixed and mobile)
  - Target positional information
    - AIS
    - RADAR
    - GPS enabled BlackBerry/cell phone
    - RFID
- Output
  - Geo-registered targets, rules, alerts, camera positions and FOVs
  - Camera FOV on geo-spatial map
    - Satellite images, Electronic Nautical Charts or Digital Elevation Maps

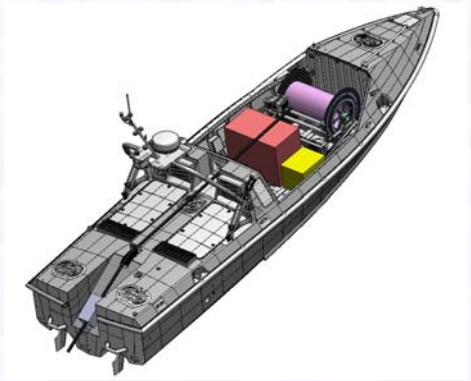




Dynamic Exploitation Windows within Large Field of View

Unmanned Sea Surface Vehicles

USSV-High Tow Force

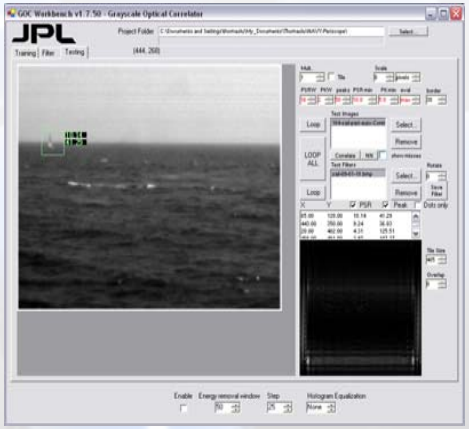


MCM-USV

USSV-High Speed

Autonomous Launch, Recovery & Refueling

SENSORS:
Wide-Baseline Stereo: Short-range EOIR
360o Field of View Periscope Camera
Long-range EOIR
Stereo LWIR
Radar
LIDAR



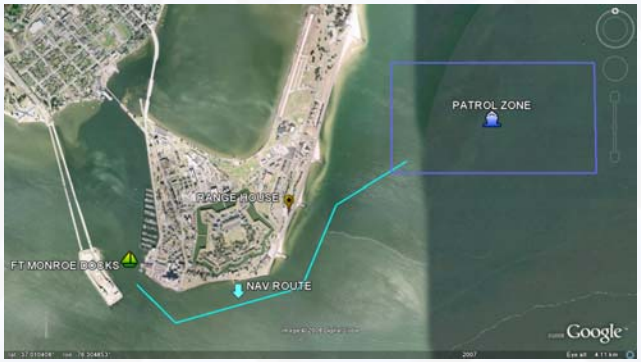
Intelligent Autonomy

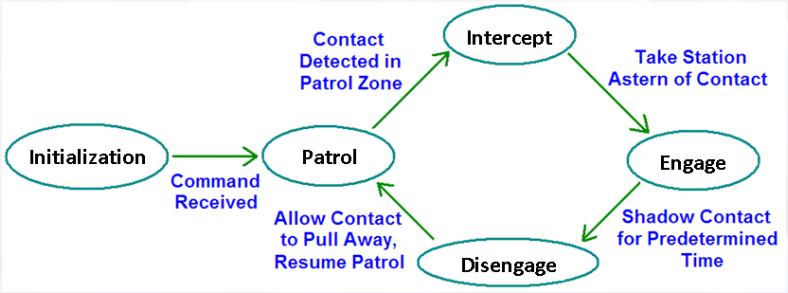
POC: Robert Brizzolara, ONR Code 333

USSV Tactical Behaviors

Tactical Behaviors:

- Go to waypoint by deadline
- Avoid hazard and replot path
- Search
- Trail
- Asset patrol and protection
- Intercept
- Dock
- Maneuver for optimal sensor viewpoint



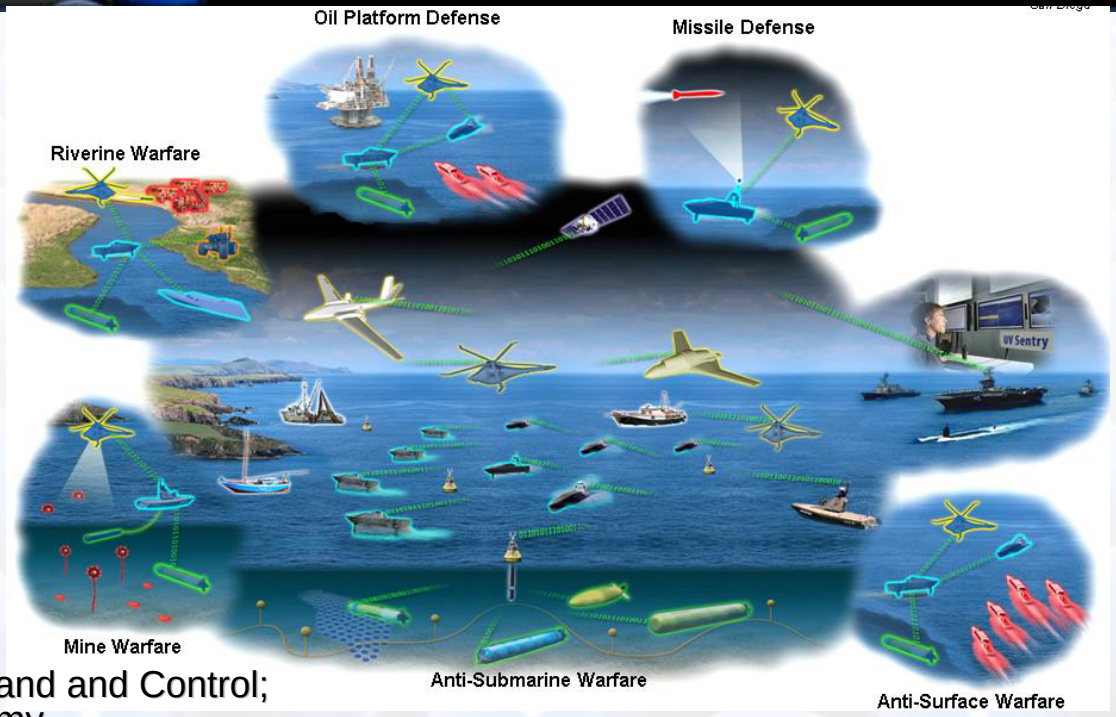


Automated detection, ID and tracking of 2 small boats and a helicopter from a USV

Examples of face detection in shore-to-ship and simulated USV-to-ship scenarios

Maneuver to Obtain Biometrics

UV Sentry – The Future of Unmanned Systems

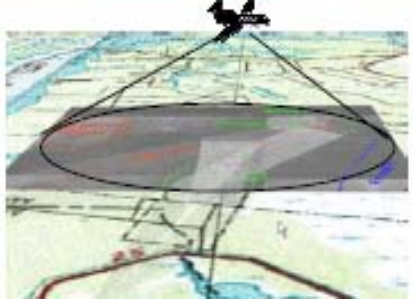


New Capabilities:

- Autonomous Command and Control; Cooperative Autonomy
- Automated data fusion into common operational picture
- Automated target discernment: detection, identification, tracking, determination of intent
- Automated launch, recovery, and replenishment of vehicles

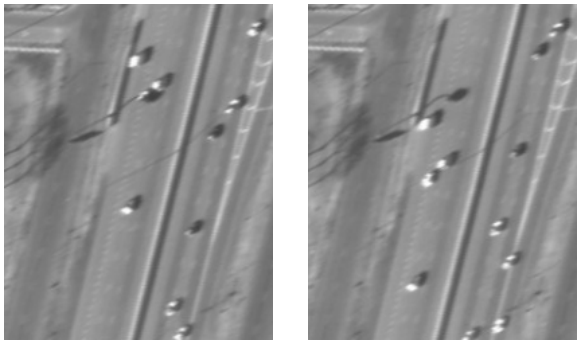
- Attributes
  - Invert Vehicle-to-Operator Ratio
  - Multi-mission & Multi-domain
  - Persistent
  - Scaleable & Adaptable
  - Combined Ops with Manned Systems
  - Efficient Asset Management

Angel-Fire Video Data



- Angel Fire (AF), a new ISR platform, provides continuous surveillance over a large area.
  Image: 66 Mega Pixels covering 4km x 4km

- AF provides an opportunity to detect and track large number of moving objects over long period of time and over a large area
- Desired Capability
  - **Track hundreds or even thousands of vehicles**
  - **Maintain track for non-overlapping sensors.**
  - **Maintain track with occlusions, stops, turns**
  - **Exploit terrestrial camera views**
  - **Track a single vehicle of interest (fingerprint)**
  - **Ability to download ROI imagery to ground vehicles / watercraft**



Patches from two adjacent AF video frames

POC: Martin Kruger, ONR Code 30

[Video]

3D Model Based Fingerprint Association

Video Tracklet 1

Video Tracklet 2

Create
Fingerprint &
Match

Find Closest Model
And Refined Pose

Rendered View Using
3D Model

Find Closest Model
And Refined Pose

This approach is extensible to watercraft

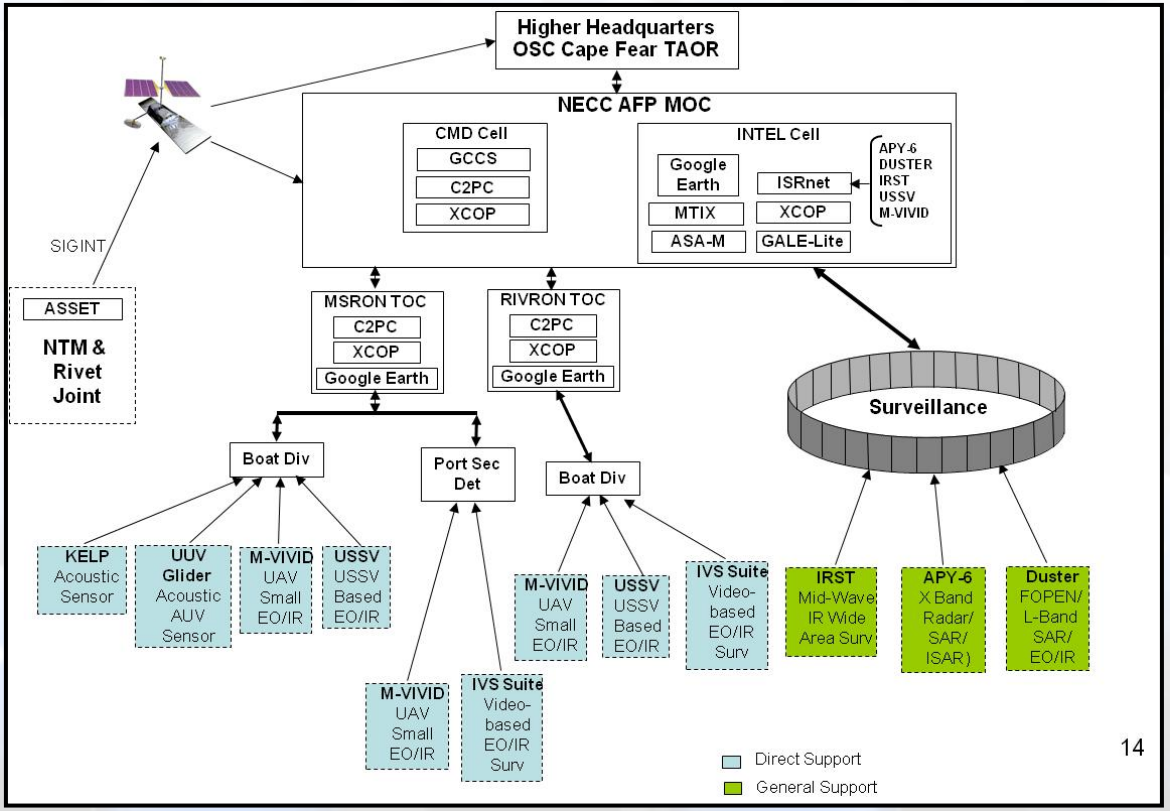
Operational Adaptation

Demonstrate integration of ONR prototypes to create synergistic warfighting capabilities to enable naval forces to operationally adapt to assymetric and irregular threats by providing affordable, scalable, and persistent maritime and littoral surveillance to generate better situational awareness and support faster decision cycle tempo.

Demonstrate autonomous interaction between different sensor platforms to exploit advanced technological capabilities while reducing human interface requirements

Operational Adaptation - SIMEX

- **Examine the impact of selected ONR sensors in the Counter-Insurgency Process**
- **Evolve OA TTP and SOP for multiple sensors integrated with ISRnet to track IW targets in a cluttered maritime environment**
- **Evolve TTP and SOP for and potential operational contributions of multiple (EO/IR, acoustic, SAR/ISAR) sensors mounted on various autonomous platforms (AUV, USV, UAV) to support the F2T2 (find, fix, track, & target) process**
- **Evolve TTP for cross-cueing between sensors to detect, classify, identify, locate, and track targets**



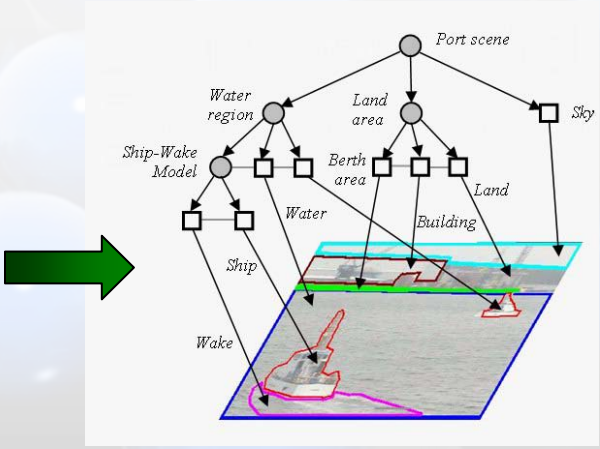
Scene Understanding

- Learning context (environmental), adaptive recognition and scene understanding to semantic level for presentation to a system or person (information is extractable)

Automatic Scene Understanding

- Develop algorithms for automatic understanding of visual scene
- Extraction of semantics and contextual information
  - Modeling of semantics and syntactic relationships between elements using attribute grammar
- Text report generation

Input video



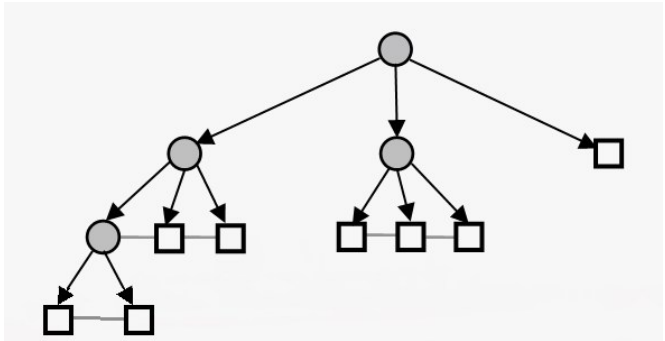
Semantics inference

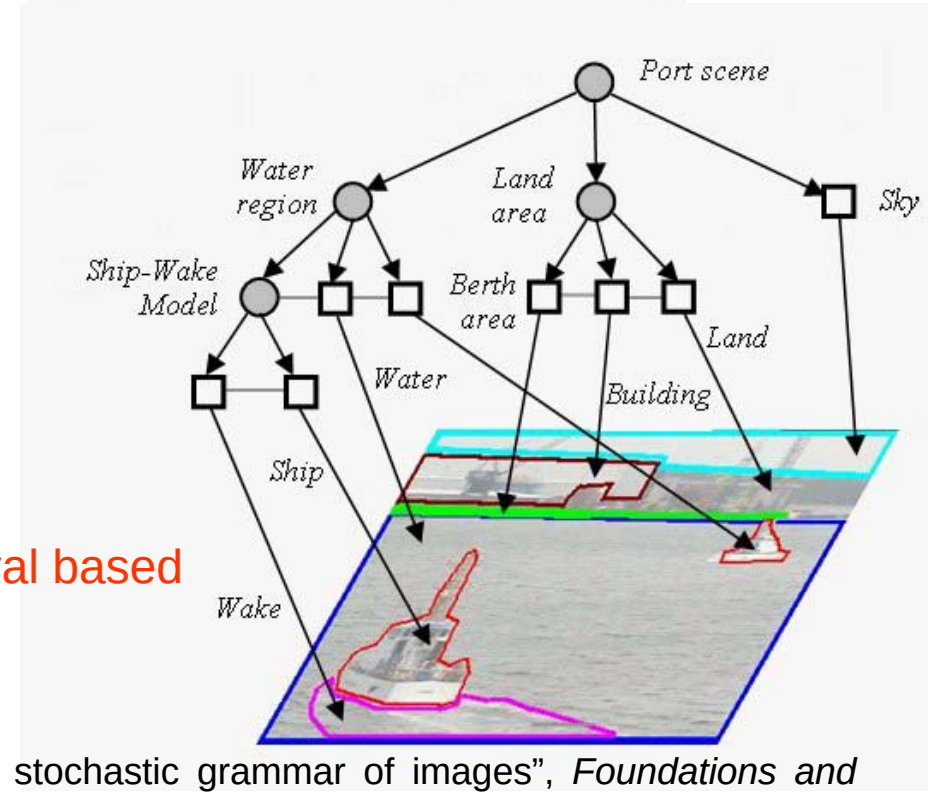
Text Report

POC: Behzad Kamgar-Parsi, ONR 311

Stochastic Attribute Graph Grammar (AG)

- Terminal nodes
  - Basic visual elements
- Non-terminal nodes
  - Composite visual elements
- Production rules
  - Define how *non-terminal nodes* can be expanded
- Configurations
  - Instances that can be generated by *production rules* starting from *root node*





Scene ontology enables intelligent retrieval based on actions and interactions

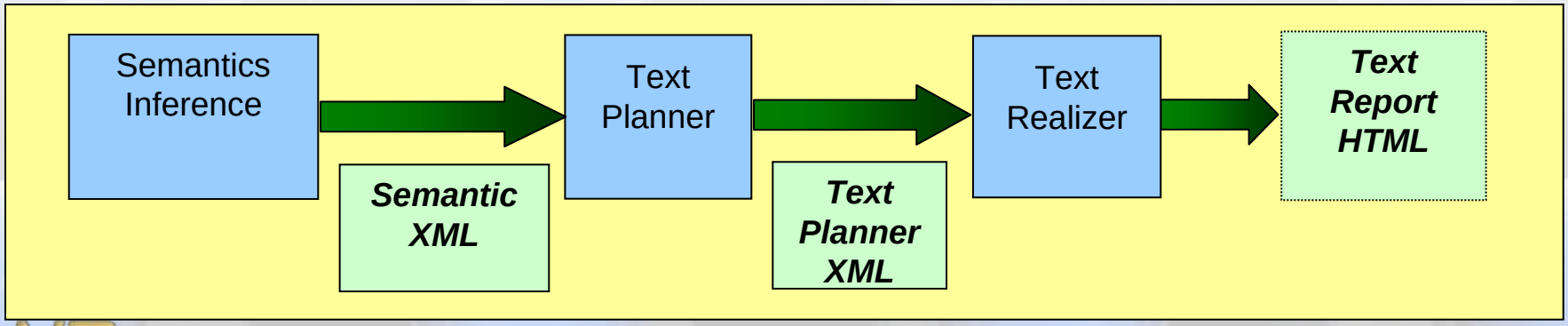
Ref: S.C. Zhu and D.B. Mumford, "Quest for a stochastic grammar of images", *Foundations and Trends of Computer Graphics and Vision*, 2006.

Automatic Text Generation

- Urban scene: traffic monitoring
  - ROIs
    - Road, intersection
  - Events
    - Abnormal speed
    - Failure to yield at intersection

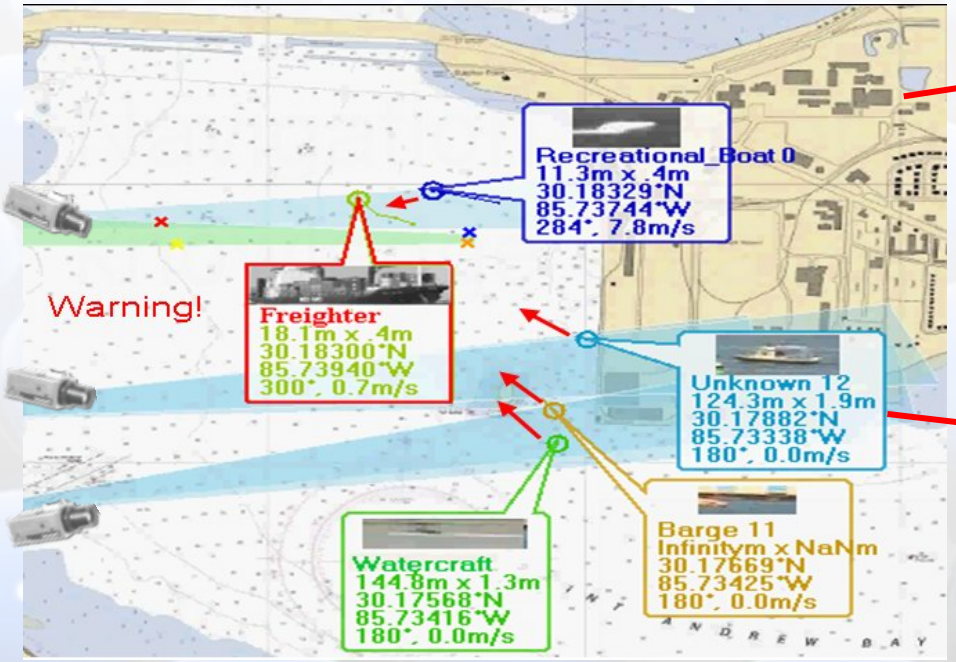
"Dhow 12 entering zone of exclusion alpha at 08:25 with estimated speed 0.7 m/s."

- Maritime scene
  - ROIs
    - Water area near land
  - Events
    - Watercraft moving near land
    - Watercraft following another



Text Data Placed Into Context

- Distributed networked sensors
- Multi-modality data:
  - Navigation sensor, map information, knowledge database, other sensors



Map-based analysis and display

Sensor network

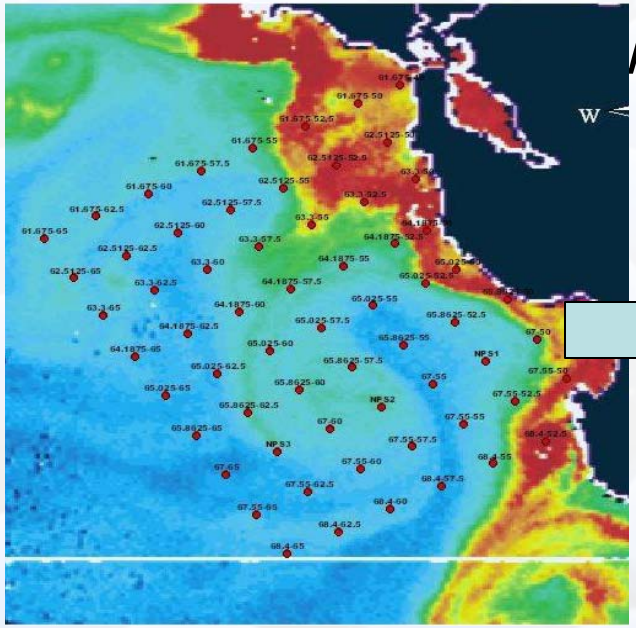
Geographic and Metric information

Cross-camera tracking

Autonomous Vehicle Tasking

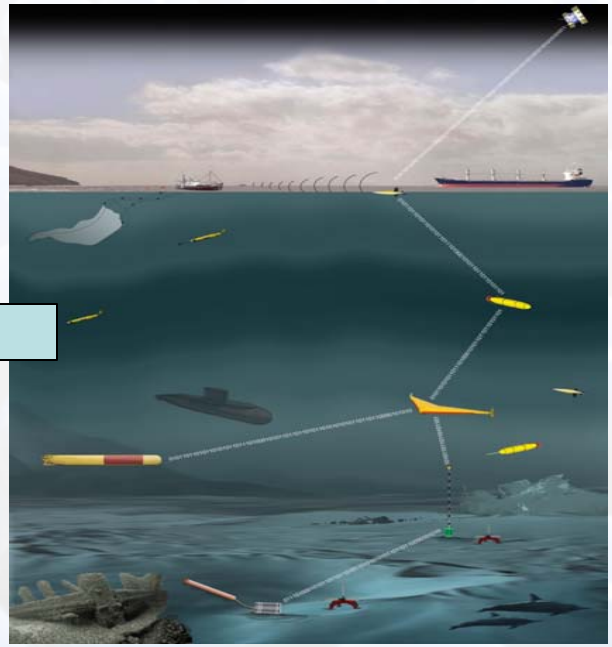
- Autonomous vehicle tasking/maneuvering based on interaction between mission level objectives and (feature-based) perception (bottom-up & top-down) to include reprogrammable/adaptive/taskable
  - And then understand if the sensing task has been accomplished or not, and if not, optimize

Autonomous Vehicle Tasking



Issues:

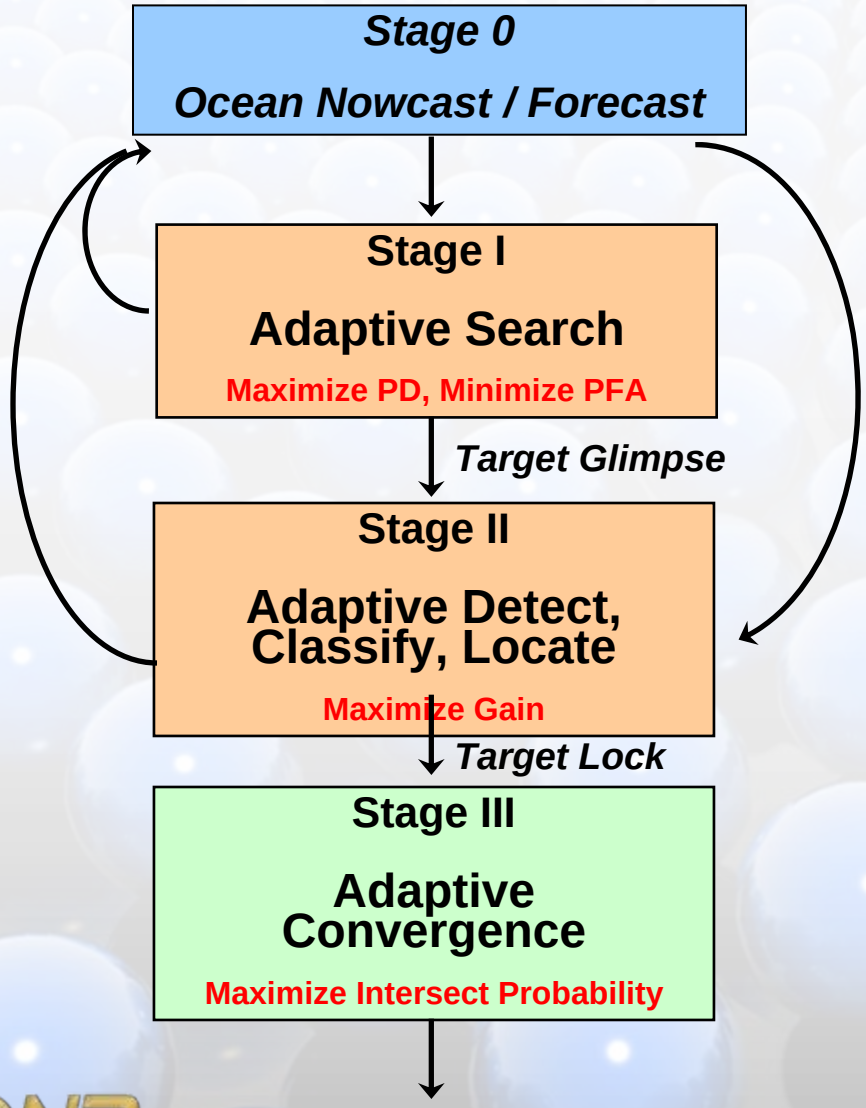
- **How to resolve difference in the demands of different levels of control**
- **How to communicate adaptation to human operators**
- **Sparse low bandwidth communication**
- **Which system is correct or optimum**



Human Operators with Field Optimization aids task multiple vehicles and provide top down directions

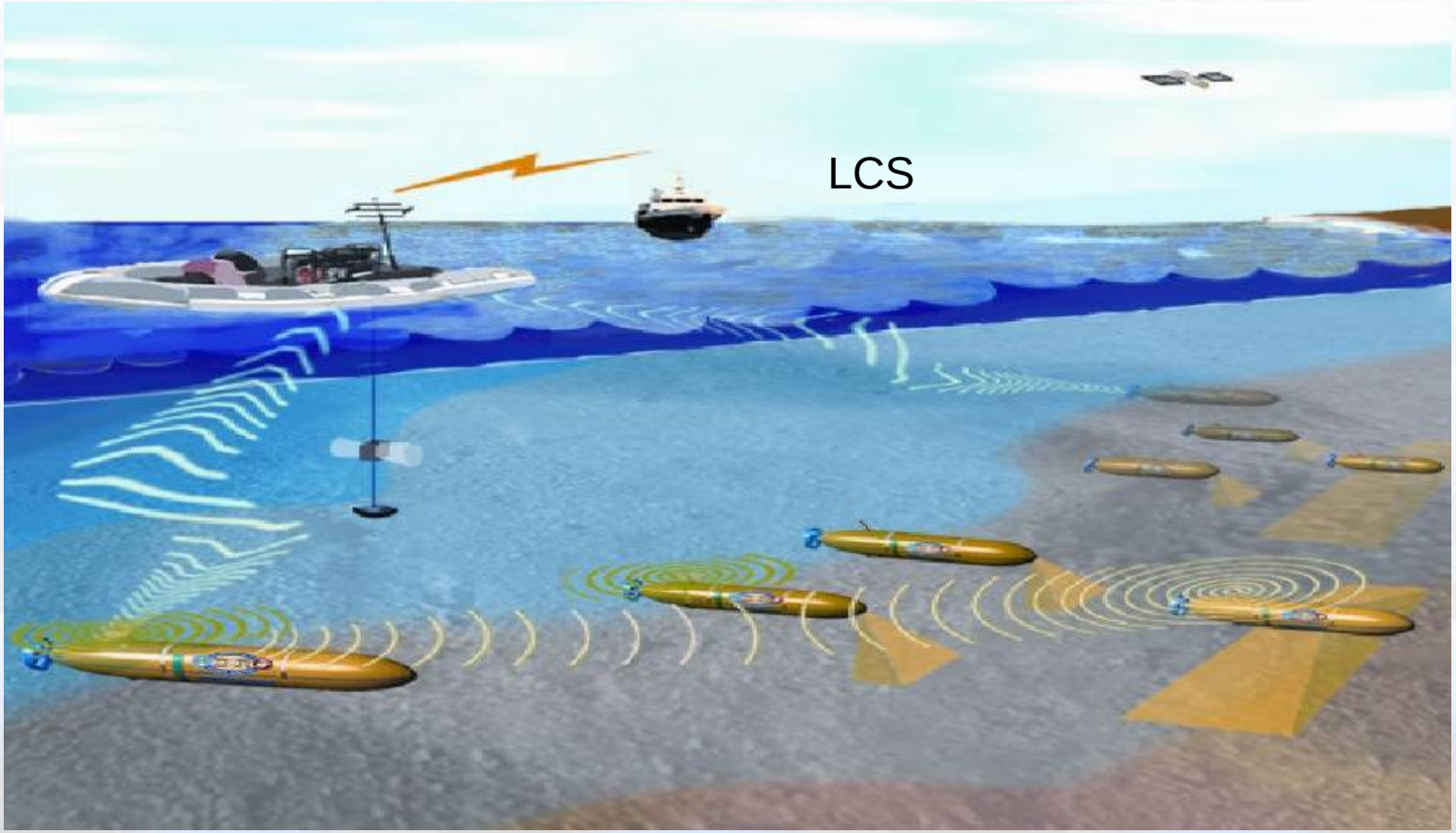
Autonomous vehicles adapt to environment to increase performance and pushback on tasking

POC: Dan Dietz & Theresa Paluszkiewicz, ONR Code 32



Needs	Opportunities
Ocean Fields with Uncertainty	*Glider fleet*
Noise Statistics	*Targeted measurements*
Signal Cues	*Data assimilative models*
	DADS, Remote Sensing
Environment exploitation algorithms	*Efficient propagation models*
Mobile, adaptive aperture arrays	*Vector sensor towed arrays*
Efficient optimization algorithms	*Efficient intercept algorithms*
	Advanced signal processing
Mobile, self-focusing arrays	*Cooperative behavior control networks*
Convergence optimization	*Mobile, network control*
	Multi-static targeting
	Active interference

USVs Deliver-Launch-Recover & Cue UUVs for MCM



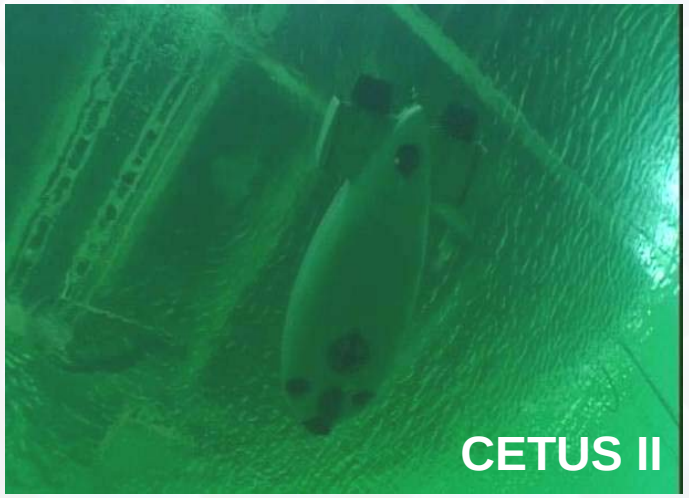
SHD FNC Undersea Cooperative Cueing and Intervention for MCM Operations

POC: Tom Swean & Jason Stack, ONR Code 32

AUV Technology for Confined Area Search / Inspection

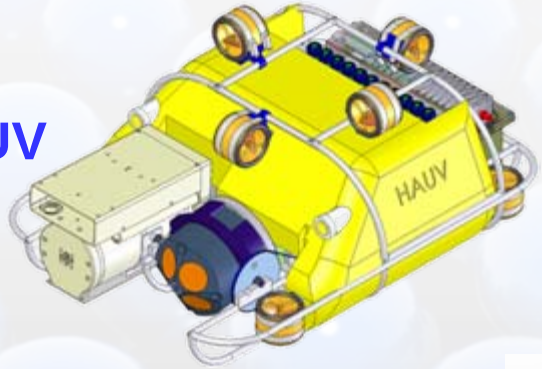
Objectives

- Provide the capability to search / inspect ship berths, piers and ship hulls for threat objects
- Small shipboard footprint
- Testing in operationally realistic environments
- Transition candidates for Navy EOD UUV Program

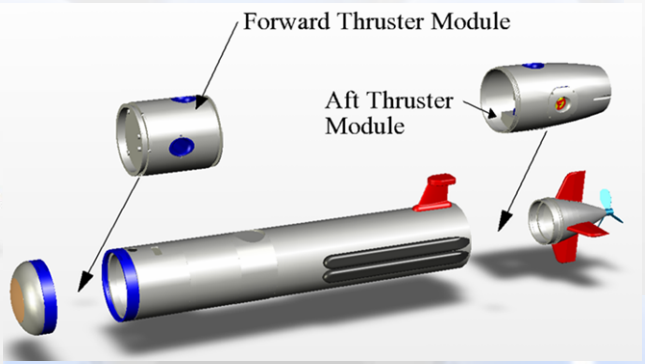


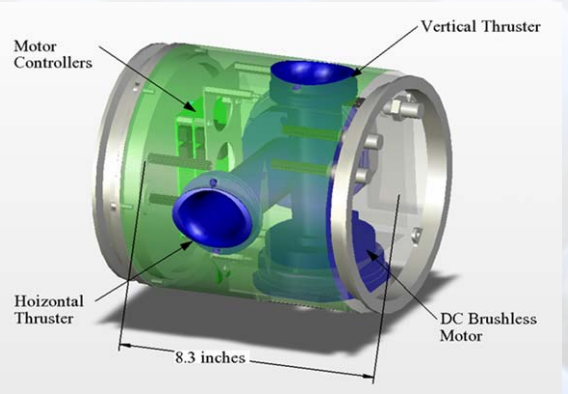
(DACP Program)

HAUV

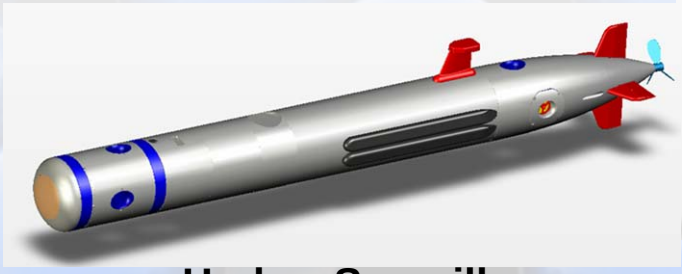


Thruster Pack Integration





Forward Thruster Module

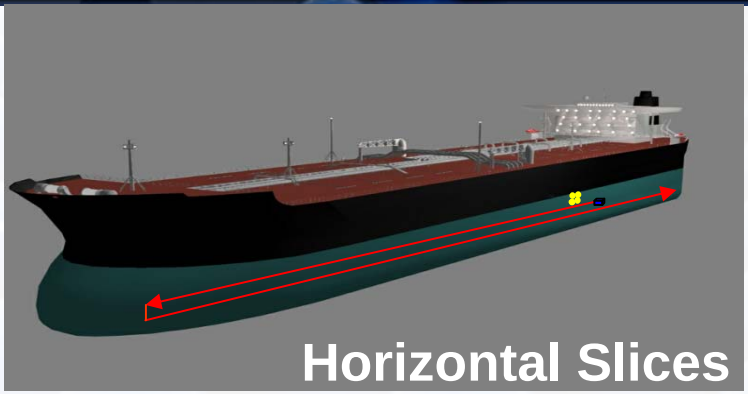


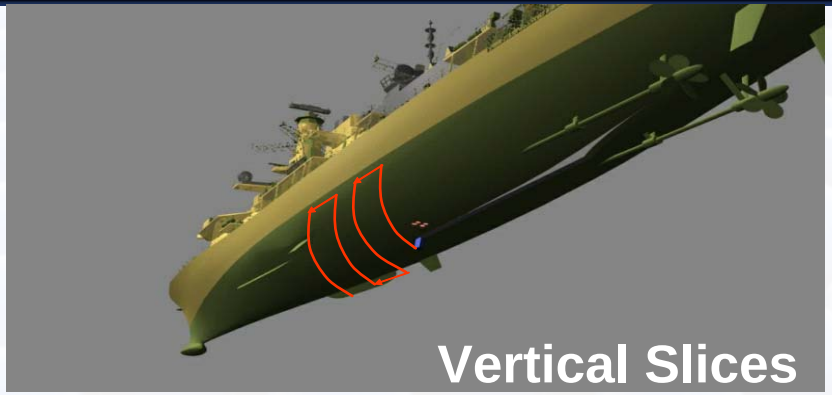
Harbor Surveillance Configuration

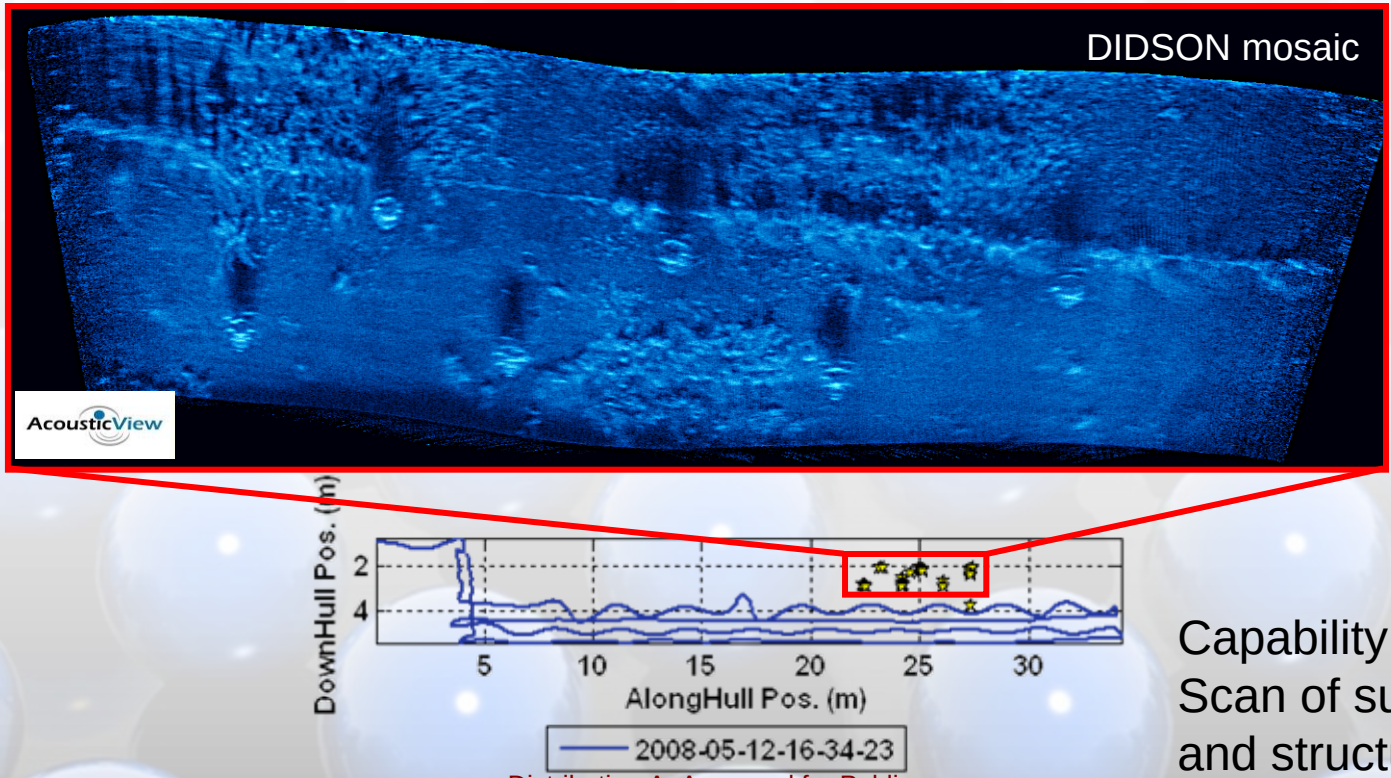
REMUS Hybrid

POC: Tom Swean, ONR Code 32

Hull Inspection Strategies



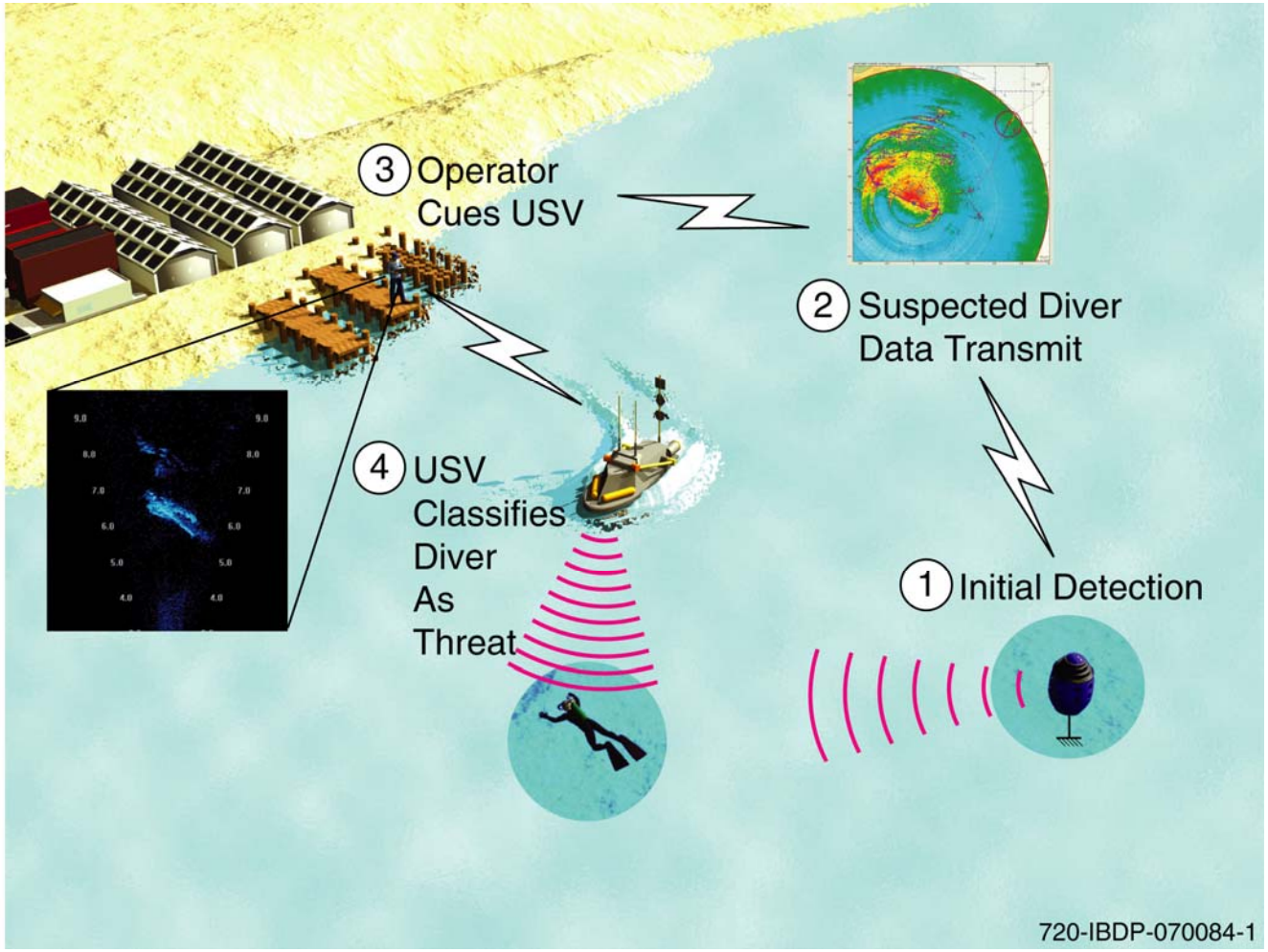




Capability: Automated Scan of surfaces and structures

Terminal Swimmer Detection & Targeting

- ***After an early warning detector signals a potential threat, the USIV is dispatched to that site, deploys the underwater imaging equipment, intercepts the threat, and gives the USIV operator and commanders the images required to take further action or not.***



SHD FNC Defense of Harbor and Near-Shore Naval Infrastructure Against Asymmetric Threats

Performer: Foster-Miller / QinetiQ

POC: Bob Headrick, ONR Code 32

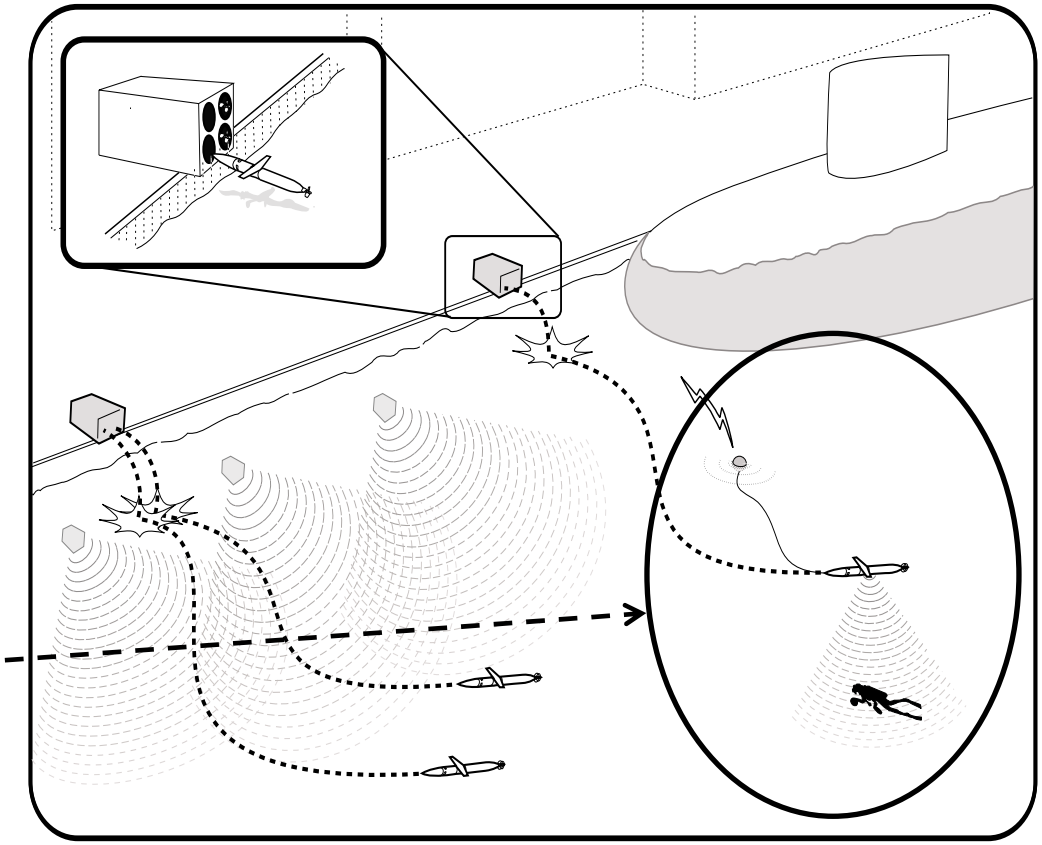
High Speed UUV for Reacquisition, ID and Localization of Swimmers

Ranger UUV:

- 90 deg/sec
- 4 Knots
- Mine Neutralizer Program

New Class of UUV:

- Fast & Maneuverable
- Low Cost Expendable
- Swimmer Defense



SHD FNC Defense of Harbor and Near-Shore Naval Infrastructure Against Asymmetric Threats

Performer: Nekton Research

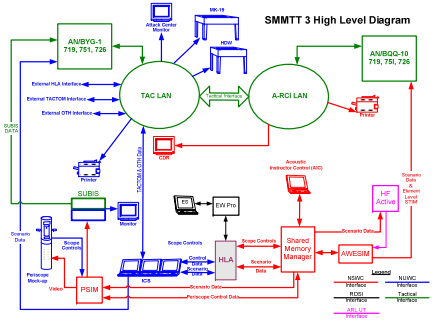
POC: Bob Headrick, ONR Code 32

Information to Warfighter

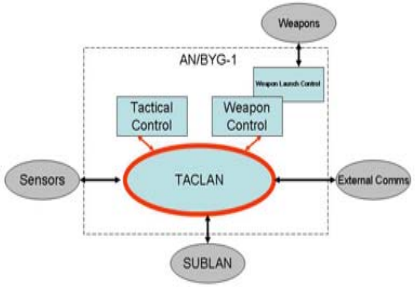
- Automated processing (intelligence) from sensor data to information to actionable understanding presented to the warfighter and the system to include multiple warfighters (parsing data) or entire system

Information Management

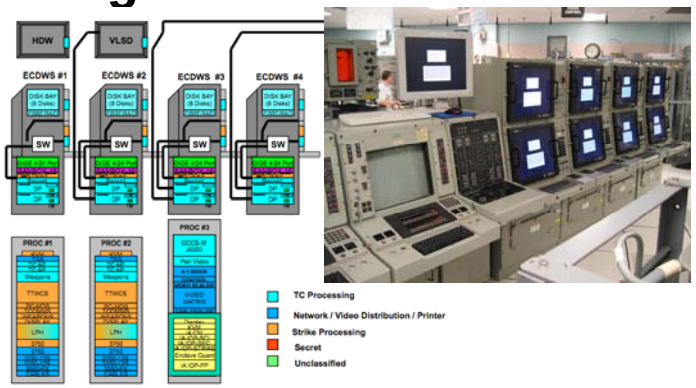
Enabling Technologies



Access to simulation environment that is accepted by the community

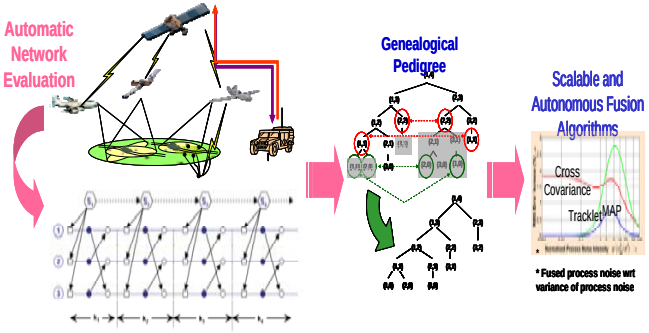


Access to a network that has evolved to support fusion



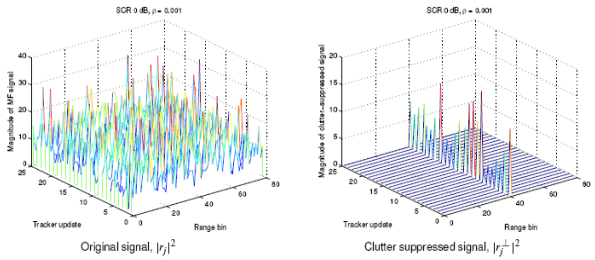
Availability of computational resources

Modern Trackers

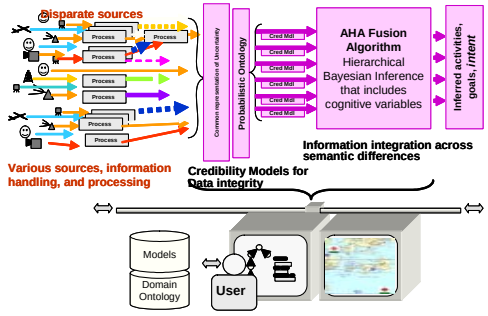


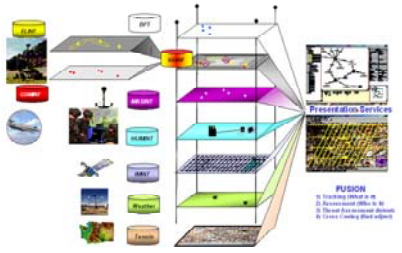
Uncertainty management systems

Information driven path planning



Management and feedback to sensors

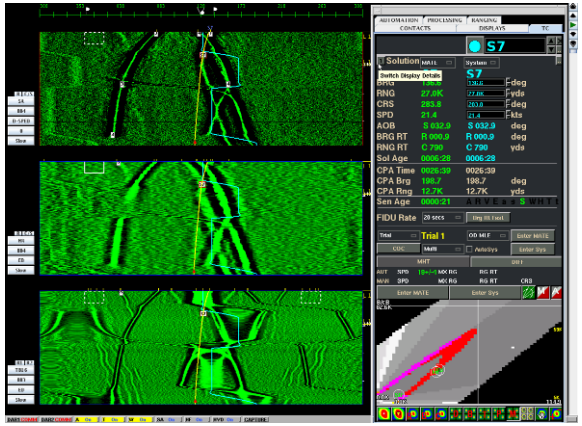




Fusion strategies for disparate sensors

Shipboard Information Display
(including uncertainty of information)

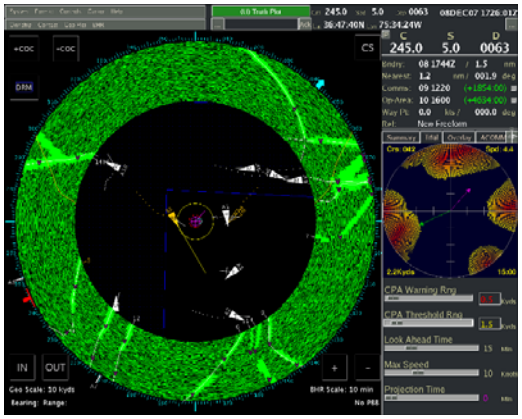
Common Broadband with Sonar Sweep up



Enables a shared PBB view across command, sonar, and fire control

CMP-FY08-03 "Exceptional Expertise for Submarine Command Team Decision Making"

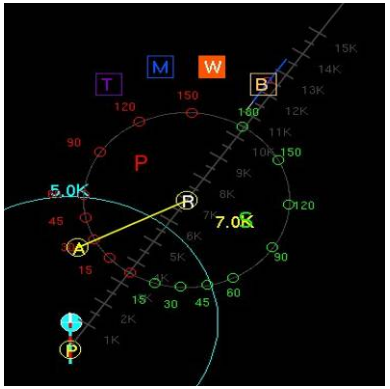
Interactive Battlespace Awareness Layout (I-BAL)



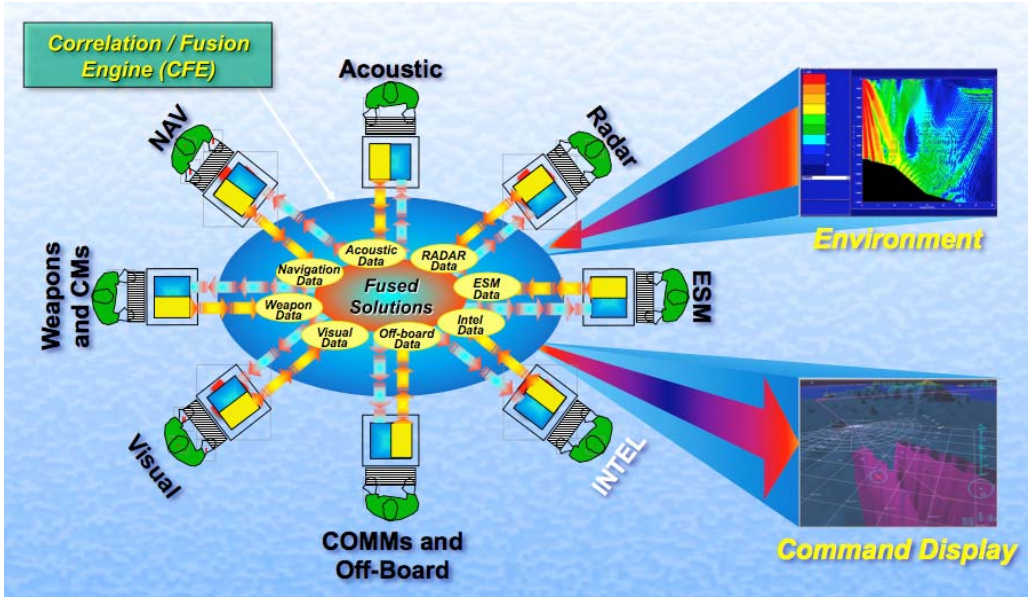
Course-speed plot supports forward path decisions

Prioritize and manage contacts with tools to project time and range to CPA. Visually fuses high quality solutions from AIS, Radar, Periscope with raw Sphere PBB

Improved Quick Observation Interface

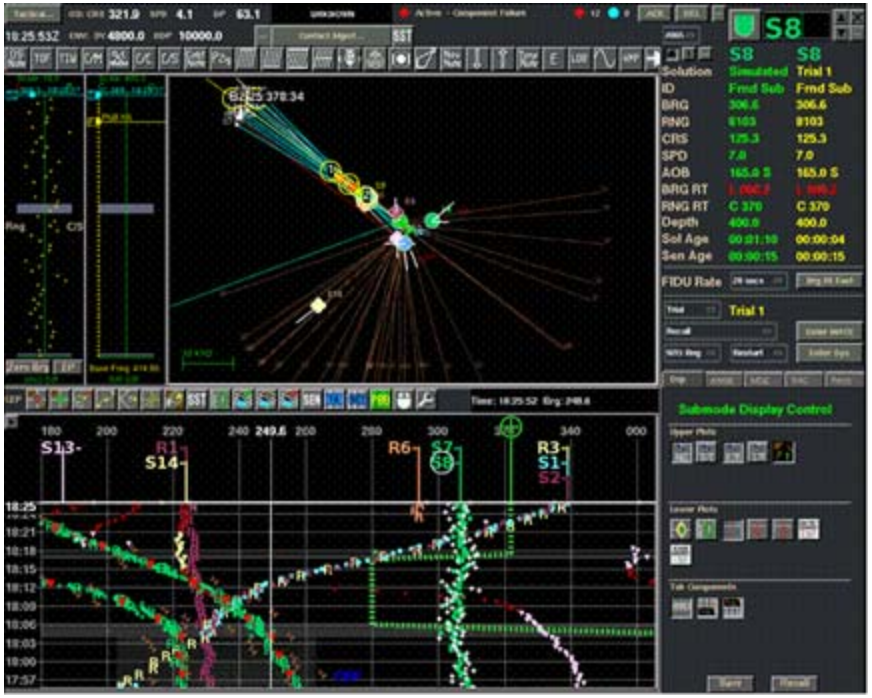


Shortens time spent entering data



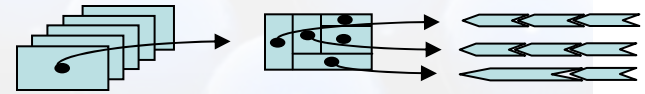
Data, track, and Information fusion that supports situation awareness and decision making

Human-Centric Display

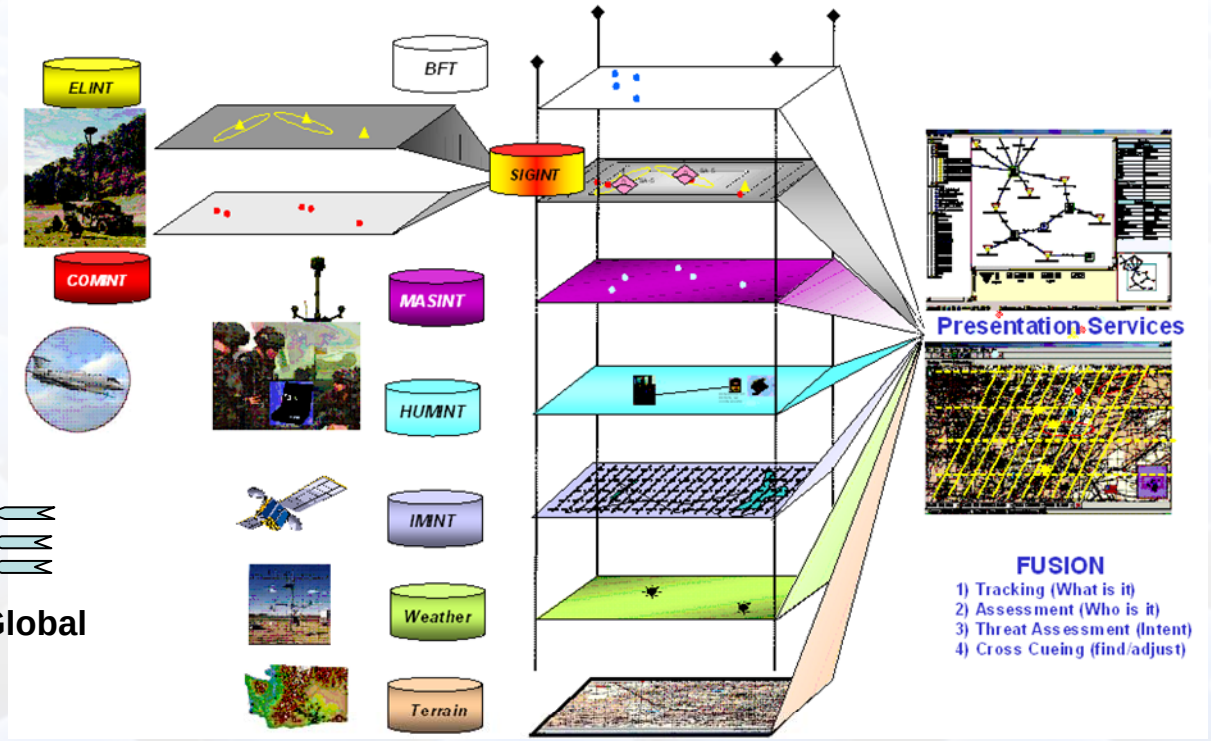


Exploiting Disparate Types of Information Sources

Strategic Level Information Fusion

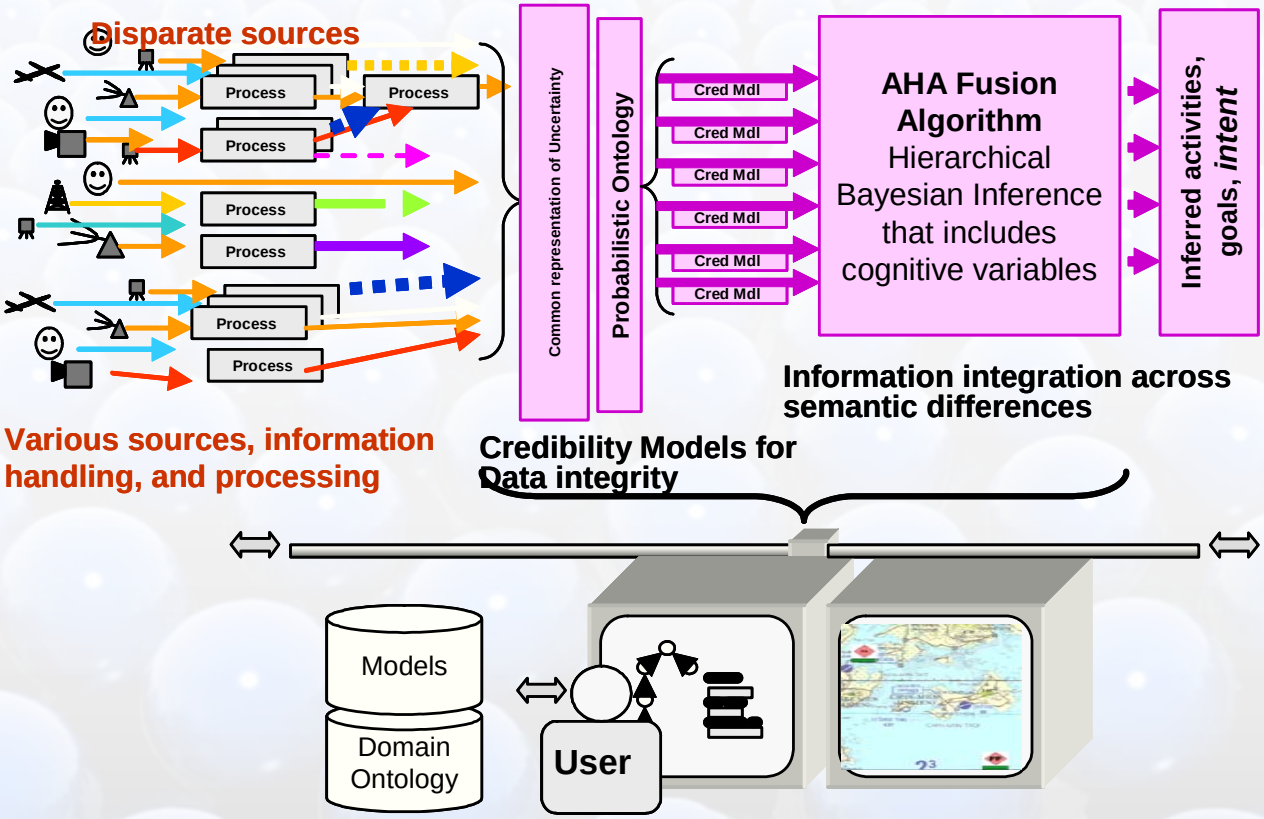


Fusion and Exploitation: Local to Global



- Data reside in different spaces – type, dimensionality, …
- Developing new computational and statistical methods to *map data from all sources into a mathematically commensurate framework* using
  - Innovative methods based on multi-dimensional scaling
  - Projections based on novel classification-tree distances
  - Polynomial representation of graphs

Adaptive Hierarchical Fusion

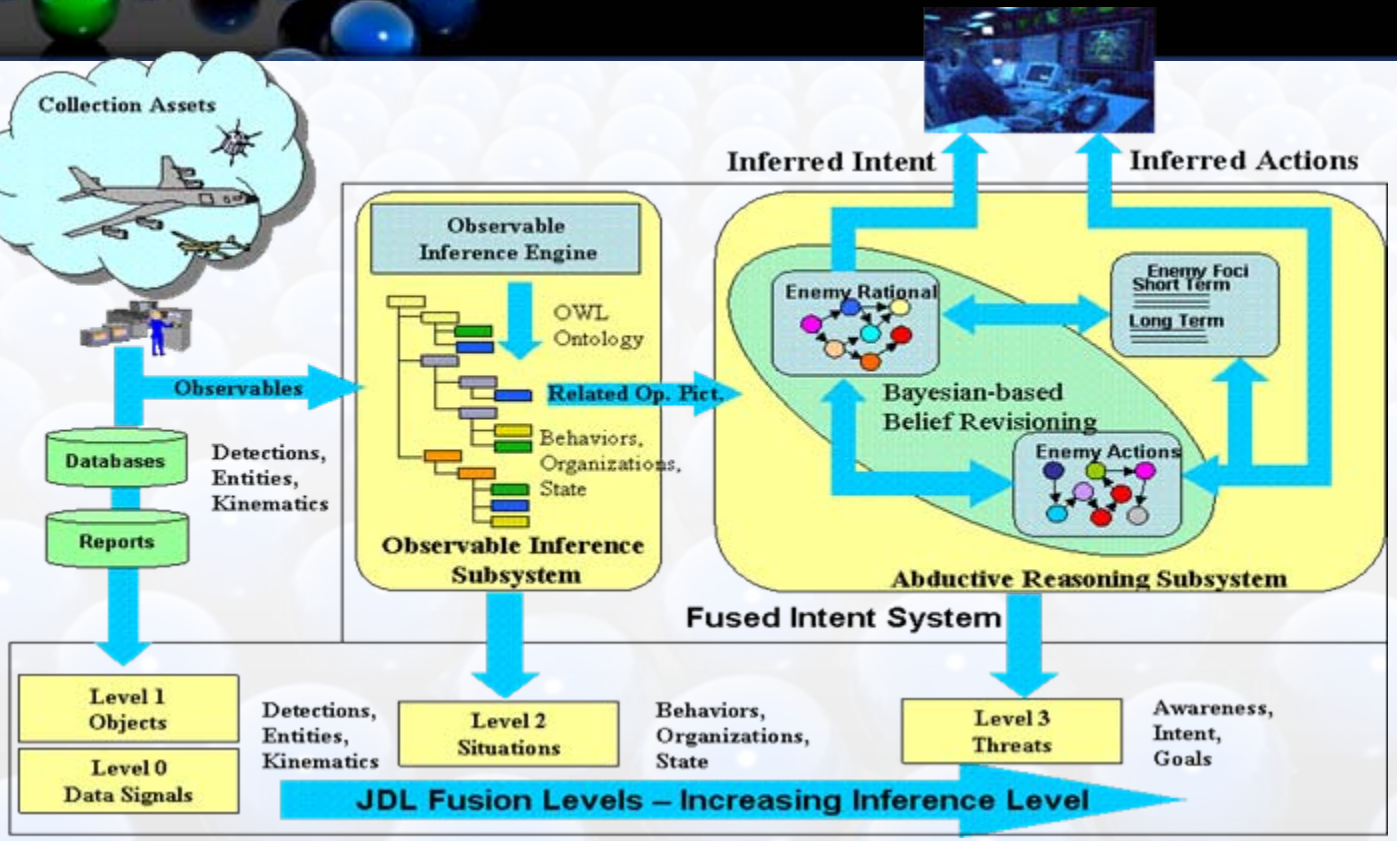


Develop novel and innovative algorithms for representing uncertainty in fusion

- ***Common representation of uncertainty*** **(e.g., from legacy data sources) using Bayes nets and probabilistic ontologies**
- **Characterizes propositional rules, relational rules, and priors of disparate data sources**

Results in analysis of inferred activities, goals, and intent

Fused Intent System



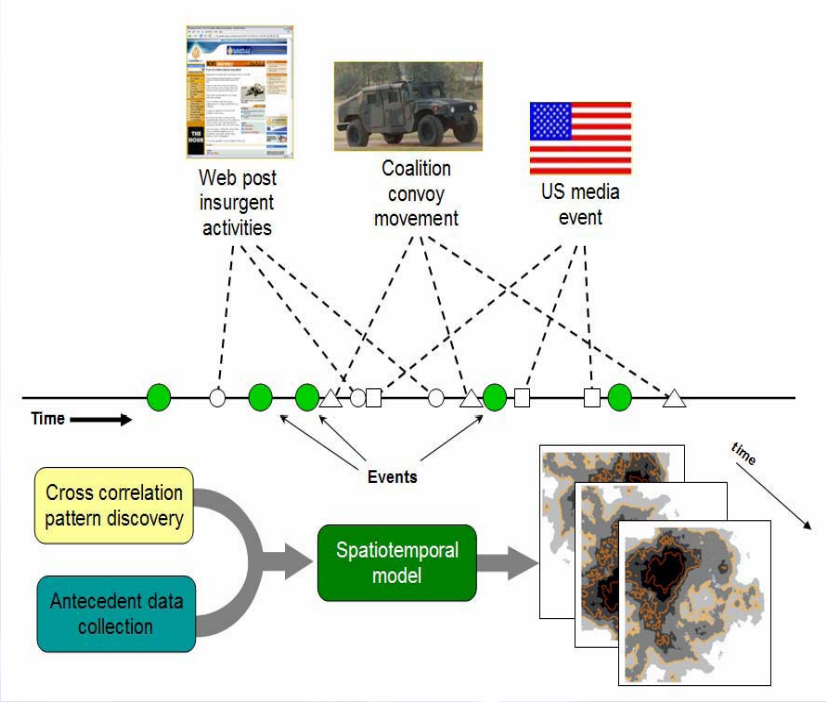
Developed *methodology to determine adversarial behavior*

- Using ontological modeling to classify observables
- Using Bayesian-based abductive reasoning to evaluate probable actions

Provides rank ordering of probable adversary actions incorporating ontological and probabilistic information

Discovery of Antecedents

When a significant activity is cataloged, the system will compare the timing and placement of the event against temporal and spatial antecedents. By examining the temporal and spatial relationships to discover antecedents, preventative or directive action can be taken to influence the enemy's decision process.



Future Capabilities Synopsis

Autonomous target detection, geolocation, recognition and tracking from the distributed system of sensors.

Cross-cueing and coordinated tasking across autonomous sensor platforms to enable common picture (detect, classify, identify, locate and track)

Autonomous adjudication and tasking between wide area exploration and dynamic region of interest exploitation

Inferring hostile intent: Mission-related scene understanding and Identification of cues in data that provide clues about intent, activity recognition, recognition of anomalous behaviors

Learning context and environment and adapting sensors and processing to the context and environment

Autonomous vehicle tasking that reflects both mission objectives and emerging sensed contingencies

Automated processing from sensor data to information fusion and intent recognition and human-centric presentation to warfighters