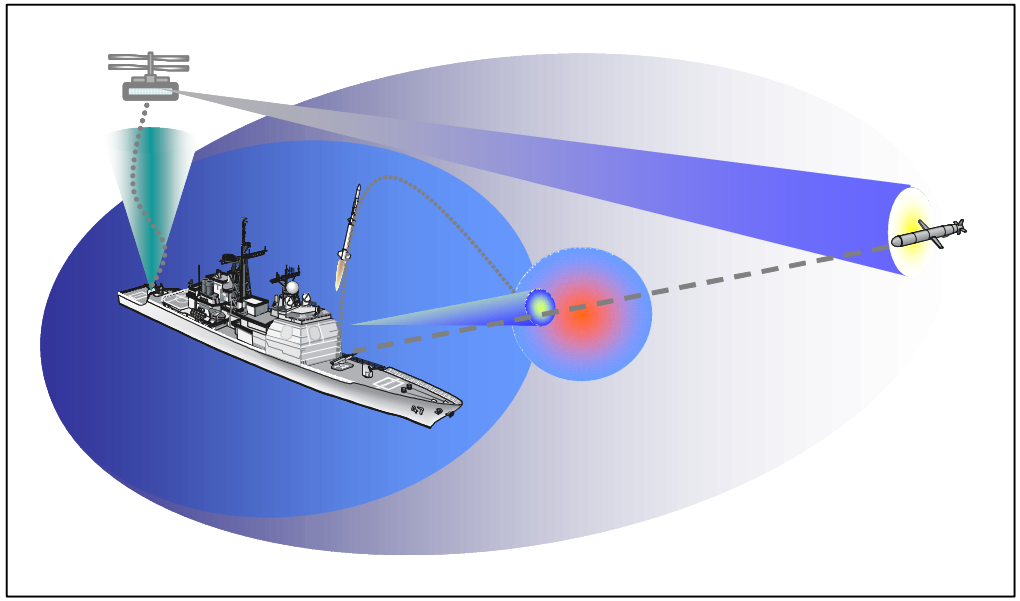
Maritime Domain Awareness

The Information Integration Challenges and Responses



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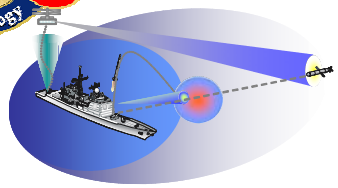
April 18, 2006

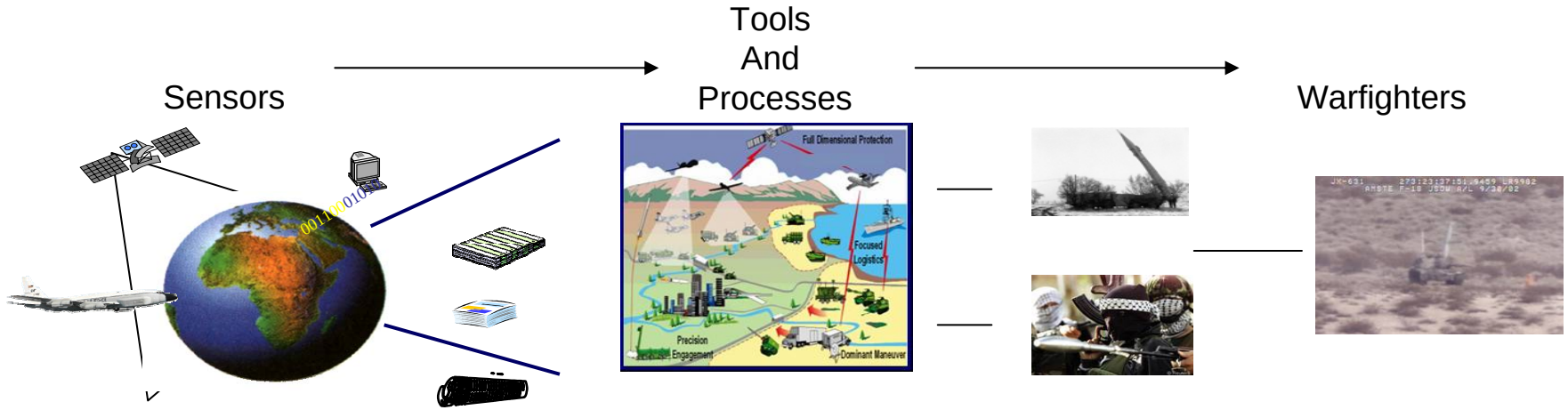


Global War on Terrorism (GWOT) / Maritime Domain Awareness (MDA)

- The enemies of yesterday were predictable, homogeneous, rigid, hierarchical, and resistant to change
- ***Today's enemies are dynamic, unpredictable, diverse, fluid, networked and constantly evolving leading to complex problem sets***
- In the context of GWOT, MDA takes on a strategic dimension and must:
  - Collect, fuse, and disseminate enormous quantities of data drawn from U.S. joint forces, U.S. government agencies, international coalition partners and forces, and commercial entities to understand the behavior of all entities in the battlespace
  - Complexity is compounded by:
    - Threats have no formal doctrine
    - Fewer analysts are available to work more data and more problems
    - Required reaction times have decreased from days to minutes

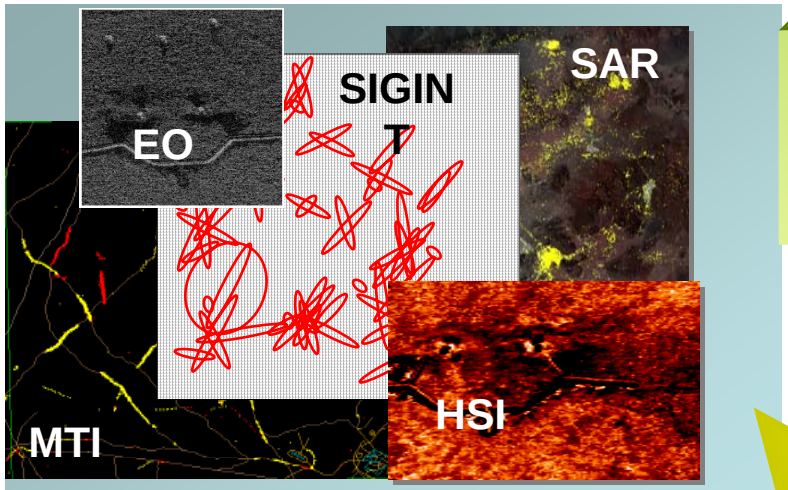
Warfighting Requirements

- Future operational environments - *Global War on Terrorism (GWOT) and Maritime Domain Awareness (MDA)* – require technologies to support information needs:
  - Regardless of location
  - Consistent with the user's level of command or responsibility and operational situation
- Navy FORCEnet will achieve this in part by relying on Discovery and Invention (D&I) projects and Enabling Capability products



Develop knowledge through the fusion and contextualization of information from disparate sources and domains

The Challenge

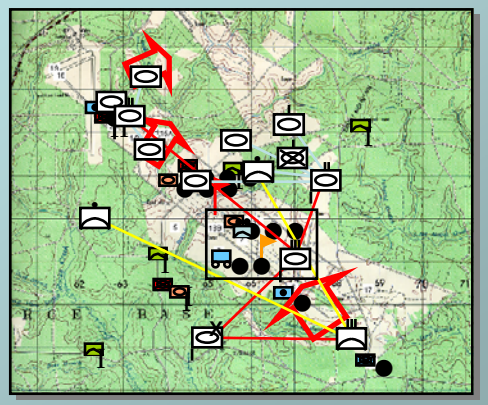


What I see?

Make sense of what I see, only to find out that I need a little more.

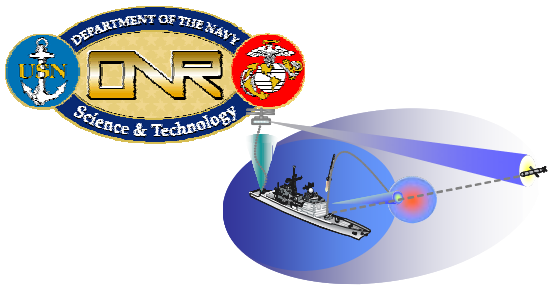
GOAL:
Reduce uncertainty enough to support effective decision making!

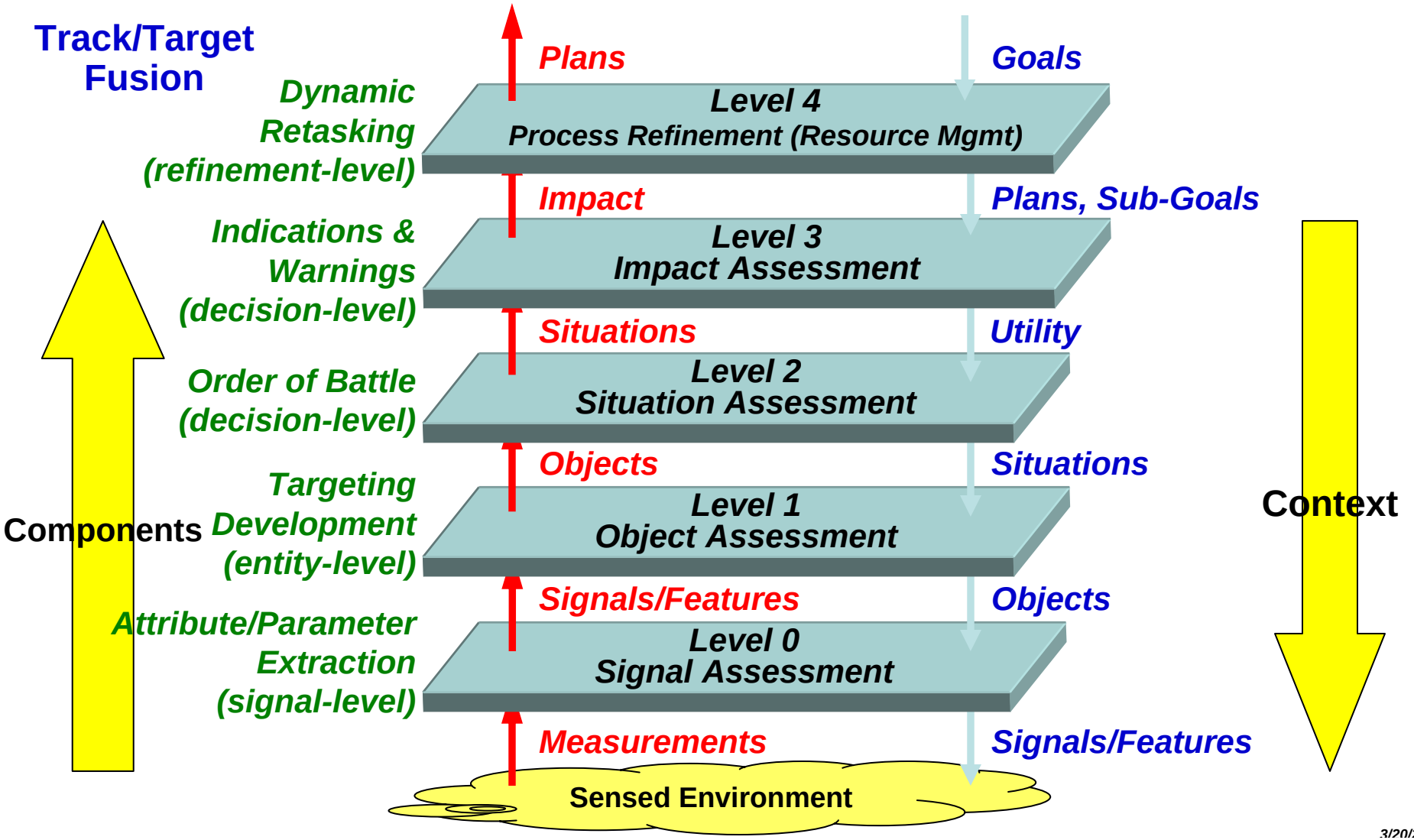
What I need to know!



How can I get the data that will tell me what I want to know?

Logical Flow Across the JDL Data Fusion "Levels"





Linking Fusion and Operational Challenges

Level 3 - Threats

Intentions:
Red Plans, Objectives

Context Examples:
Red: Past methods, training, feasible objectives
Blue: vulnerabilities, opportunities to deter

Level 2 - Situations

Activities:
Motion, Routes, Comms,

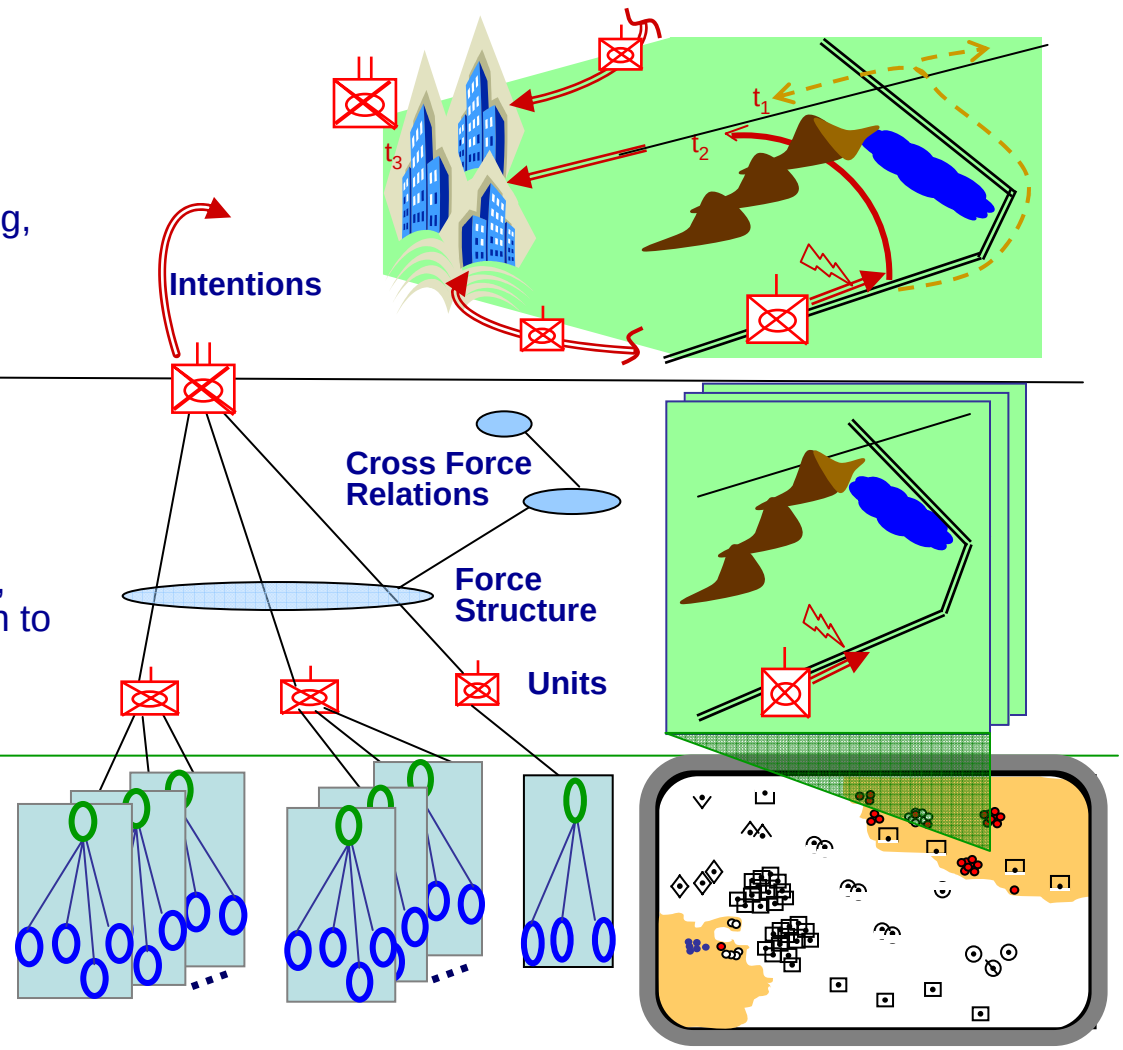
Context Examples:
Terrain, Wx, Trafficability, White traffic, Where/when to look, for what

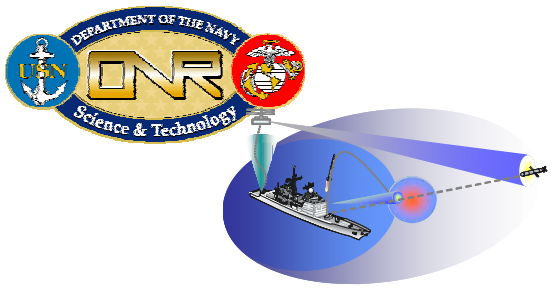
Units:
Capability, mobility

Level 0 / 1

Objects:
position, kinematics, ID

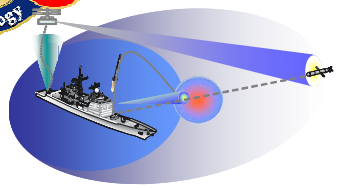
Observations:
multiple sensors





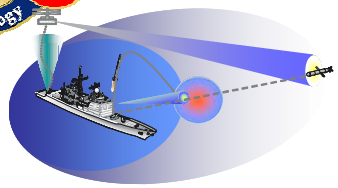
Today's Limitations

- **Operating pattern data is not linked to the picture**
  - Warfighters depend on heavy manpower intensive interpretation to understand the relationships affecting the operational situation
- **Integration of national and tactical sensor data processes (e.g., COMINT, HUMINT, ELINT, IMINT, etc.) are manually established**
  - Warfighters struggle in the volume of unassociated raw multi-int data and are incapable of understanding or extracting relationships between battlespace objects in a timely fashion.
- **Warfighter cannot drill-down to see what data was used to create the track**
  - Contact pedigrees are not preserved and often stripped as the information is fused.
  - Warfighters face ambiguities and inconsistencies in the Combat ID picture resulting from multiple collects and conflicting data reports
- **Sensor data that doesn't "add up" to a track is lost**
  - Valuable information from multi-media formats including imagery are manually integrated to track information.



Today's Technical Challenges

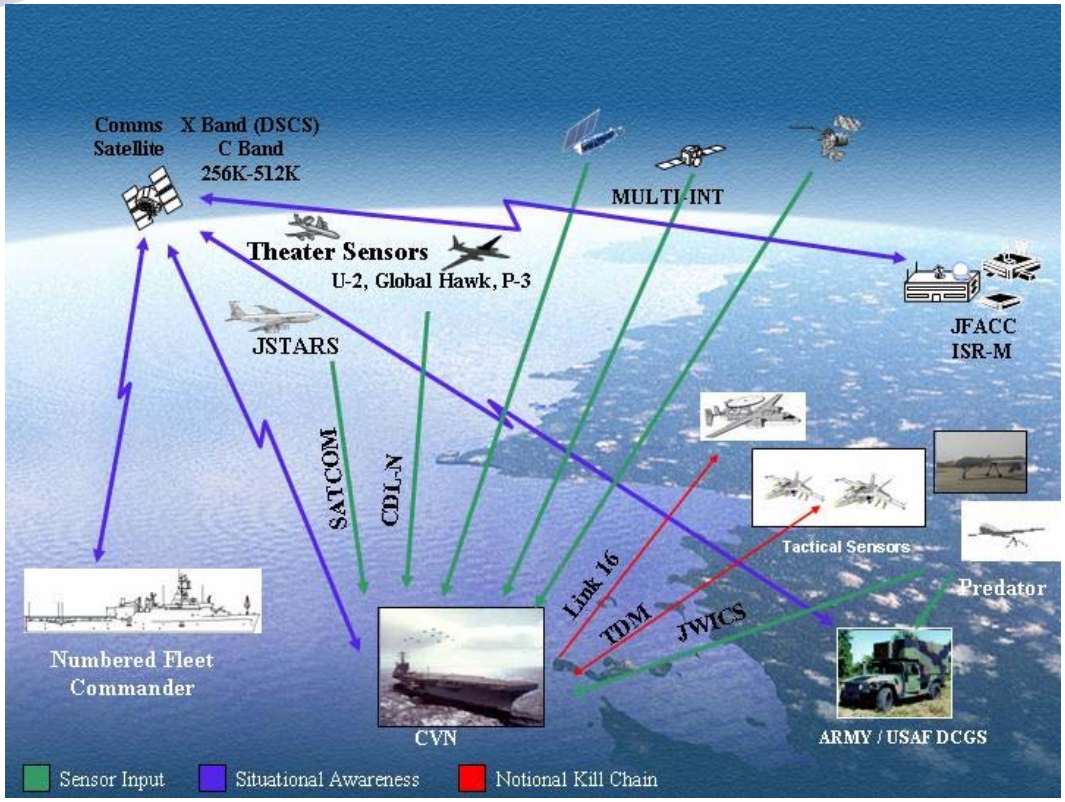
- Networks do not address semantic interoperability
- Levels 2 & 3 must be addressed globally in terms of resource priorities and allocations
- Technology to support ways to represent higher levels of abstraction and information aggregation
- Different Levels of Confidence are derived from different sources
- Identification of techniques for representation of knowledge uncertainty
- Identifying techniques for aggregating and managing hypotheses about battlespace activities/behaviors
- Environments for M&S are not mature enough to support sound, scientific experimentation needed to develop fusion systems
- Environments that allow analysts to develop and modify knowledge bases to perform automated analysis and interpretation are not adequate to meet knowledge representation and reasoning requirements nor fast enough to make timely changes during operations



Current Navy S&T Effort

- Current programs examine critical S&T needs for
  - Automatic association and merger of information for unified presentation
  - Automated recognition and cueing for significant patterns of information, computer-aided reasoning for task-oriented information dissemination
  - Timely, accurate information and sensor fusion from heterogeneous sources
- Specific Goals
  - Automated image understanding: 40% of imagery collected not screened due to availability of analysts
  - Automated integration of disparate sources of information
    - Minimizing uncertainty of information; Maximizing its expected value
    - Ability to uncover trends in activity, links among objects, and hidden models of behavior/activity
    - Preservation of data integrity
  - Level 2 / Level 3 Information Fusion
    - Understanding technical relationships and future developments

Level 1/ Entity Based Fusion



Naval Relevance

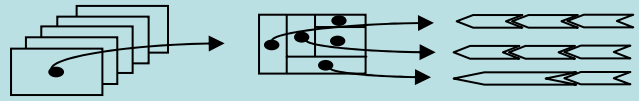
— Maintain Track and ID consistent with commander's priorities – increased confidence in the ground and maritime picture

— ID of significant military entities (reduced fratricide, higher certainty about the target engaged) and fewer false recognition and Timely sensor information shared with combat systems

— Smart management of tactical sensors

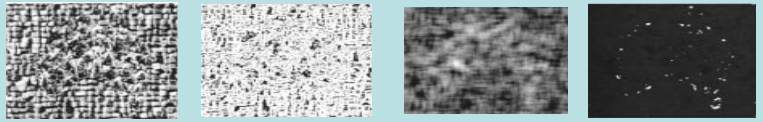
Multivariate Spatial-Temporal Data Conditioning

- Capturing and conditioning data from multiple sensors and sources
  - Processing over multiple fusion levels and multiple levels of data mining and discovery processes
    - Multi-level attribute characterization within a consistent mathematical framework
    - Represents behavior for individuals and groups and model behavior of targets and events in a commonly understood framework
  - Coarse-to-fine grain resolution
    - Spatial, Temporal, Spectral, Informational, Knowledge Extraction
  - Focuses on preparation and mapping of data from all source types into a mathematically commensurate framework.

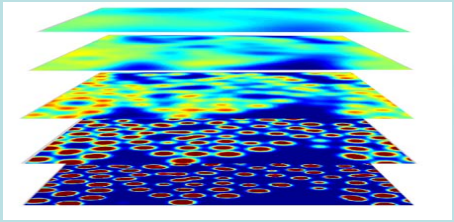


Coarse-to-Fine Grain Conditioning

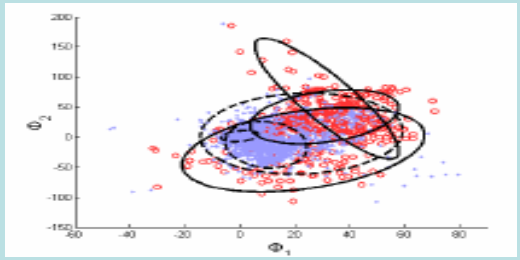
Knowledge
- Domain
- Representation
- Development Processing
- Specification



Texture **Edges** **Texture Energy** **Texture Points**

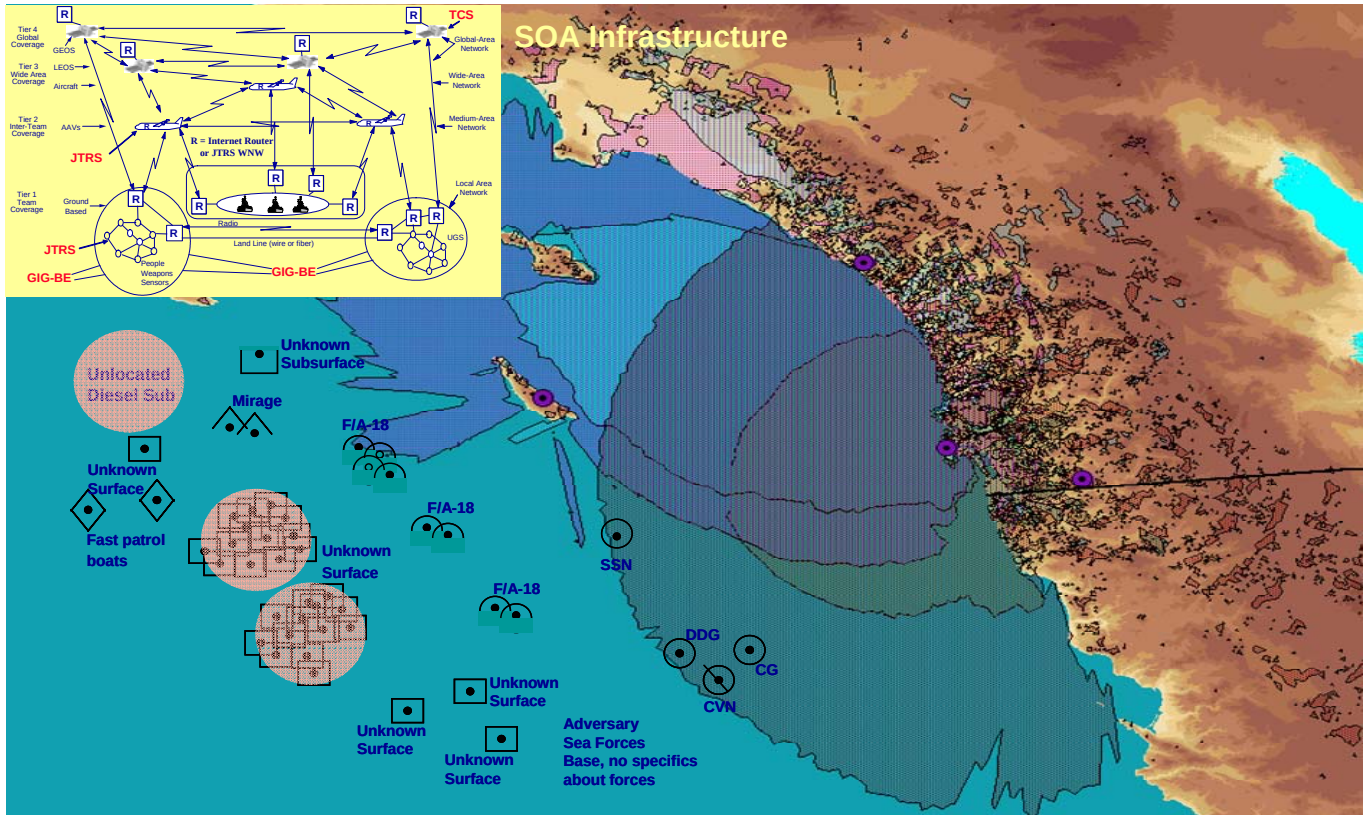


Environmental Impact on Target Location



Mixed Gaussians

Level 2/3 Fusion Approach



Naval Relevance

- Automated capability to recognize anomalies that indicate hostile intent in the maritime / littoral domain.
- Improved decision support through automated production of decision-quality information
- Reduces manpower requirements

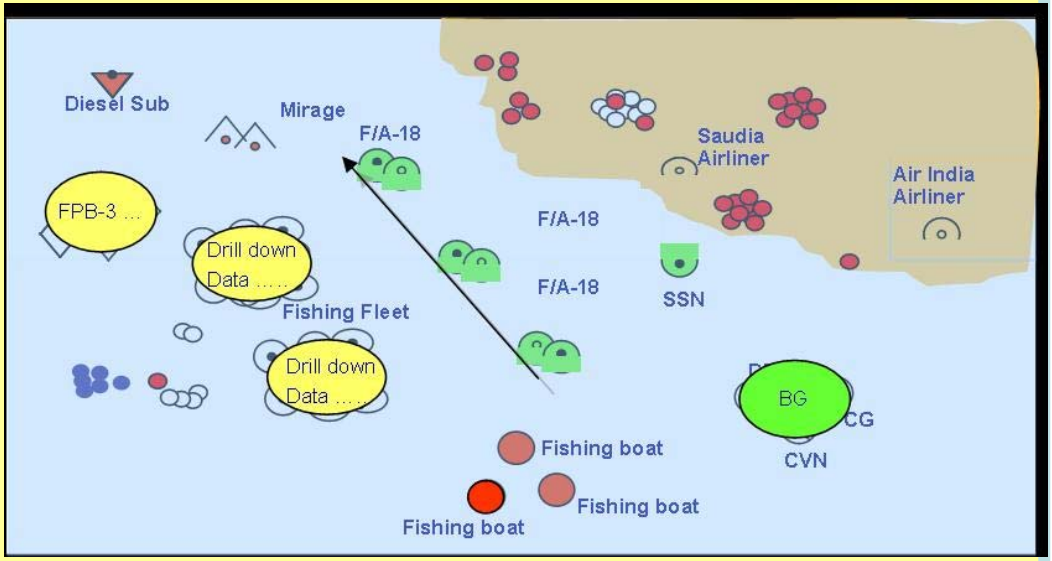
Level 2/3 Fusion: Combat ID Implications

Current Capability

- Lots of data from many sources
- Little understanding about how entities and events relate
- Manual capability to manage multiple hypotheses about the meaning of
  - Groups of entities
  - Events that may potentially be related

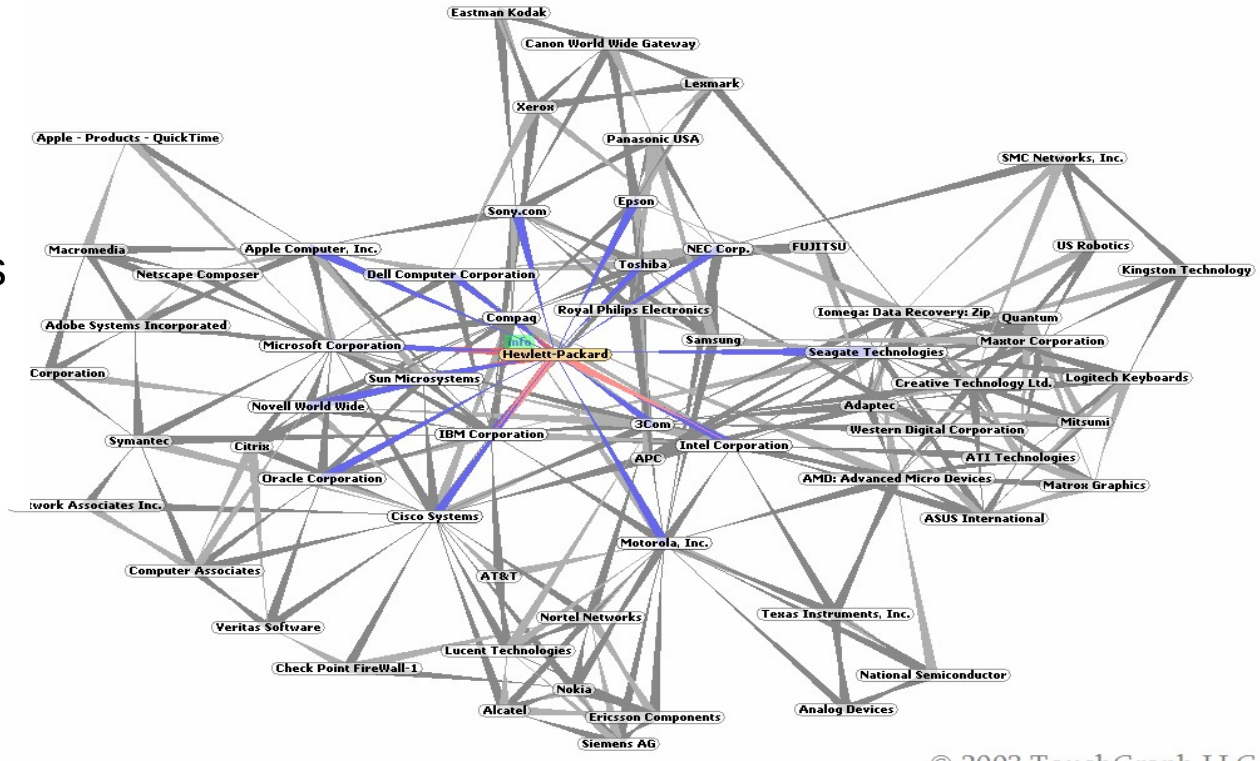
ONR's Products Produce:

- Data from many sources automatically exploited
- Warfighter-relevant understanding about how entities and events relate
- Automated capability to manage hundreds of multiple hypotheses about the meaning of
  - Groups of entities
  - Events that may potentially be related



Context-Aided Inferencing

- Inferences to support fusion processing
  - Underlying components of a situation
    - Elemental relations, behavior dependencies
- Models capture constraints
  - Physical properties
  - Political, economic conditions
  - Relationships (not necessarily directly observable)
- For example
  - High Tech Companies
  - Relationships with foreign Governments
  - Efforts to sell to adversary groups



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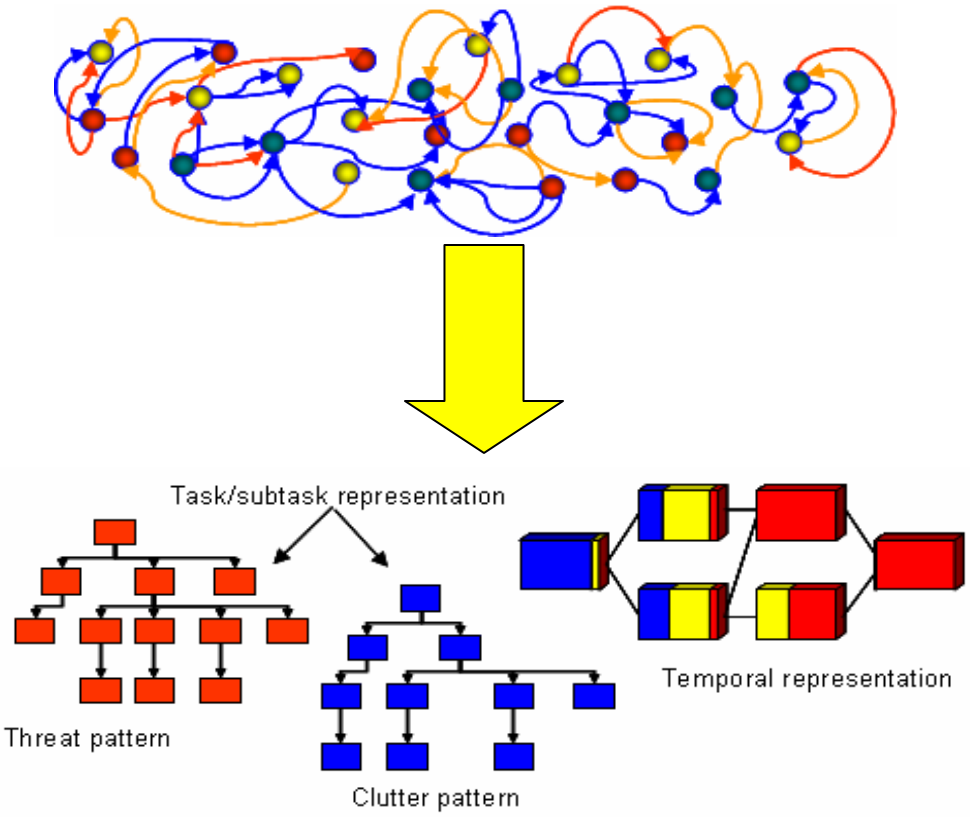
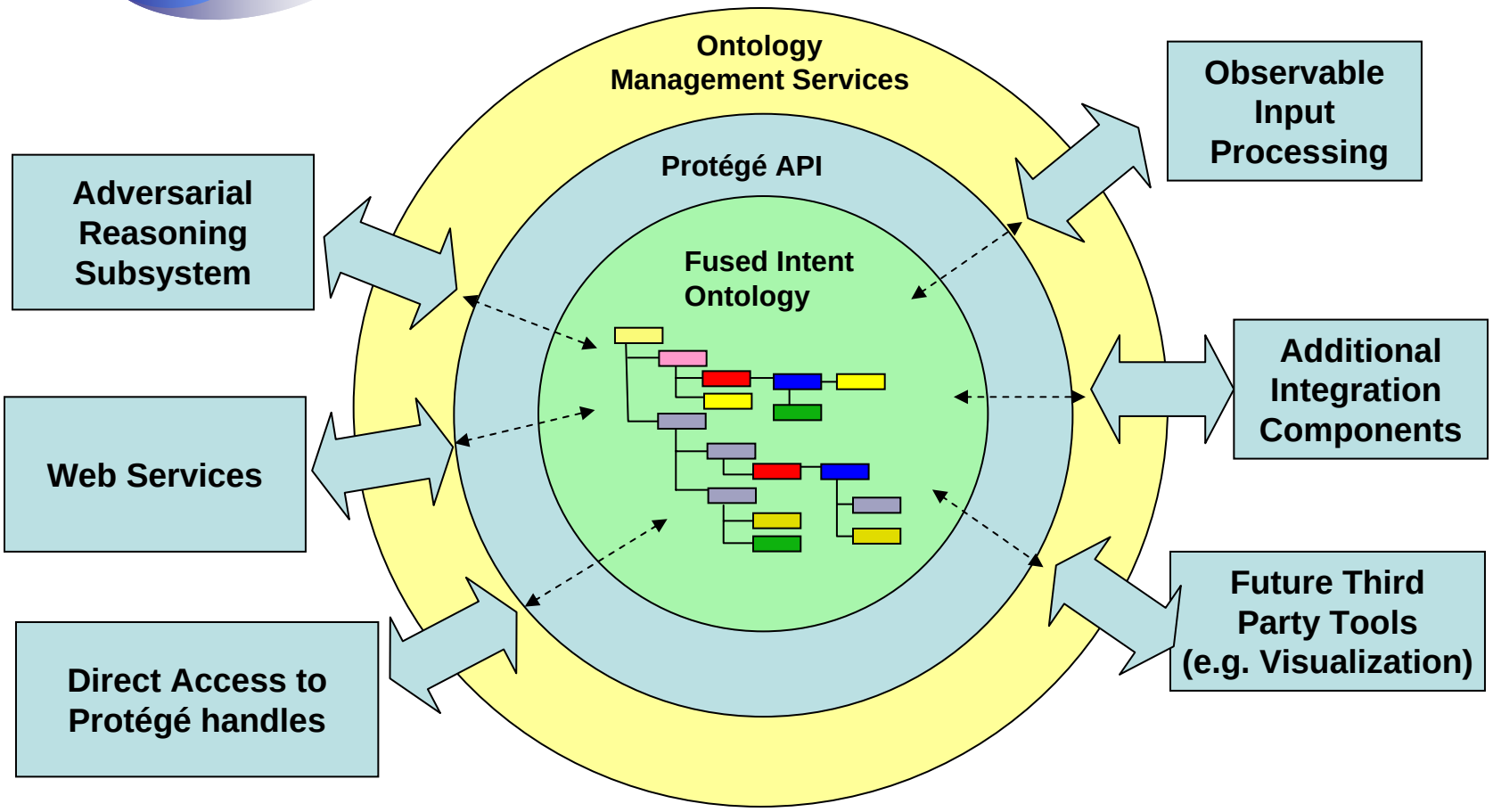
Theory of Detection for Naval Targets Using Transactional Networks

Naval Relevance

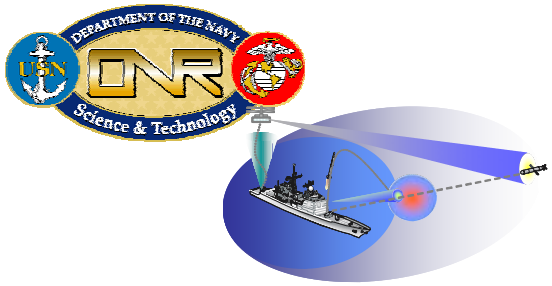
- Detecting, classifying, and tracking potential hostile activities in massive amounts of transactional noise
  - –Important in GWOT
  - –Complements MDA ship tracking
- Ability to detect threat events and organizations prior to attack
  - –Supports precision strike (Sea Strike)
  - –Enhanced common tactical picture
  - –Detection of shipping anomalies for Naval Intelligence
  - –Commander has increased confidence in intelligence information



Ontology Management Services are Critical to Level 2/3 Fusion



The bottom line: if the ontology isn't right, the integration cannot supported.



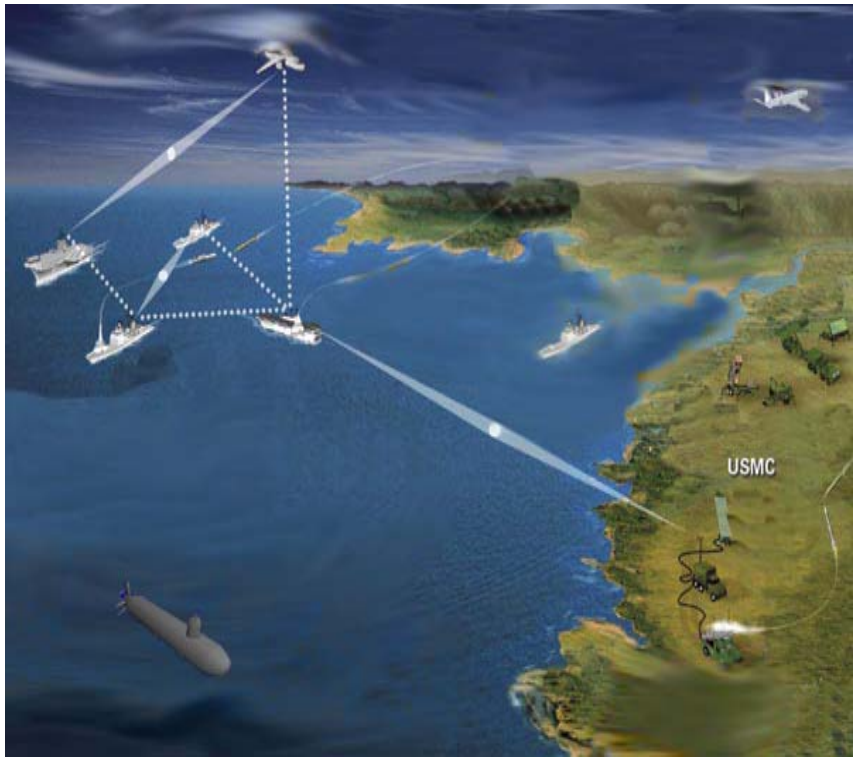
Level 2/3 Framework
JDL Model Extensions

		Traditional Fusion Levels			
		Objects ID Tracking (1)	**Situation Assessment (2)**	**Threat Assessment (3)**	**Process Refinement (4)**
Context	**Perception**	Element Acquisition Common Referencing	Element Acquisition Common Referencing	Capability	
	Comprehension	Contextual Analysis Object Classification and Recognition Object Interpretation/ Assessment Explanation	Contextual Analysis Situation Classification and Recognition Situation Interpretation/ Assessment Explanation	Opportunity	**Performance Assessment**
	Projection (Anticipation)	Estimate Future State Expectation Matching	Estimate Future State Expectation Matching	Intention Worst Case Most Likely Relevance	
		Uncertainty, Confidence & Pedigree Management			*Internal* / *External*
		Fusion Performance Management			
		HCI	Sources	Products	Main

3/20/2005

Goal and Context for Combat ID in the Maritime Domain to Reveal Contact Intent

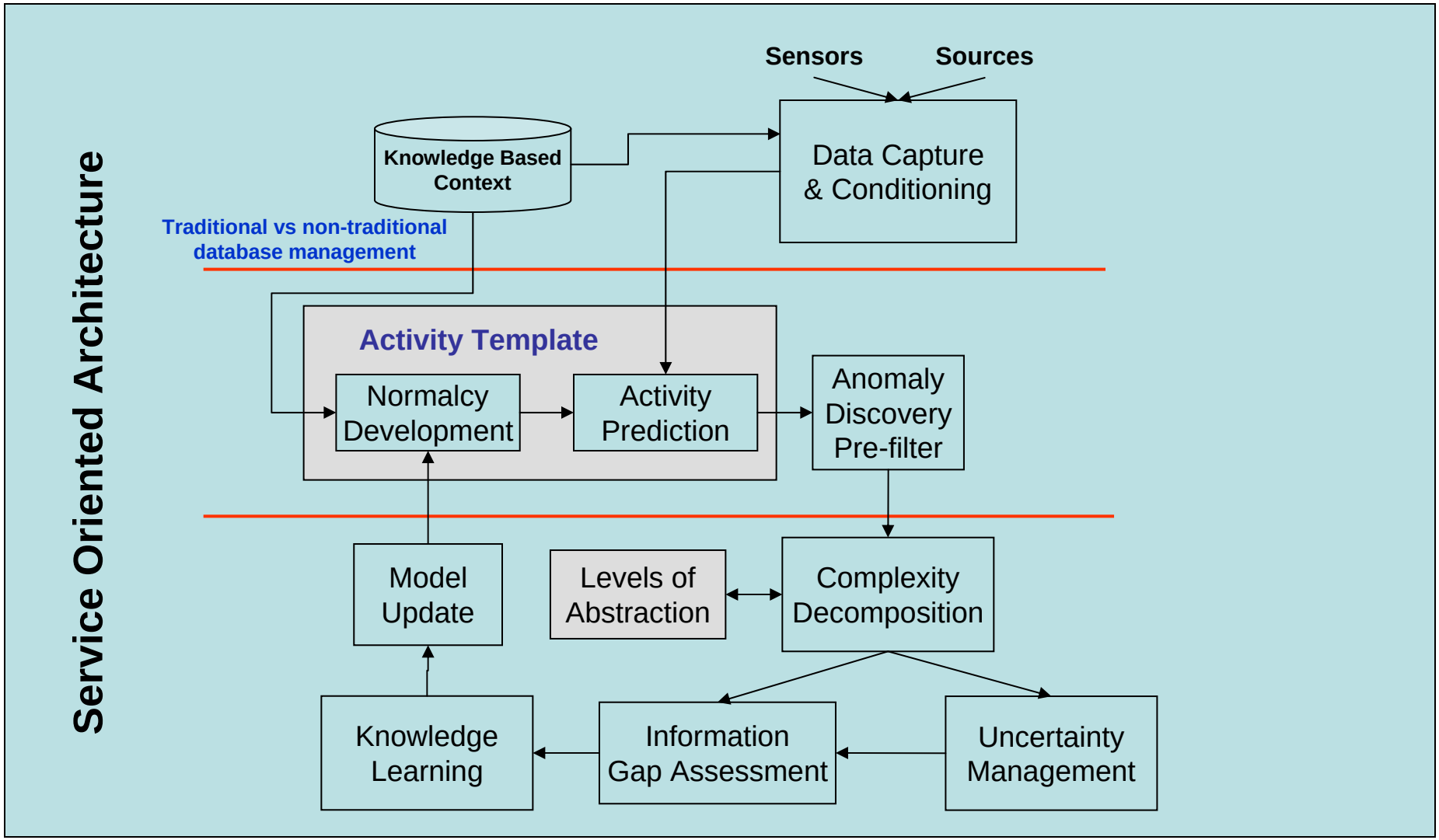
- **GOAL:**
  - Develop proof-of-principle demonstration of (semi) automated machine reasoning Level 2 / Level 3 fusion within an MDA environment
  - Develop relationships among such entities as sea surface, subsurface, and ground-borne objects, events, and the situation
  - Understand situations (e.g. routine activity/behavior, adversary capabilities and dependencies, own force vulnerabilities), and
  - Anticipate threats (e.g. adversary options, enabling events/activities)
- **CONTEXT**
  - Weather, terrain, topology, traffic flow
  - Activity patterns, open source records, market demands, hostile actions
  - General influences: Political, economic, cultural
  - Non-standard transactional data: Financial records, cargo manifest, etc.



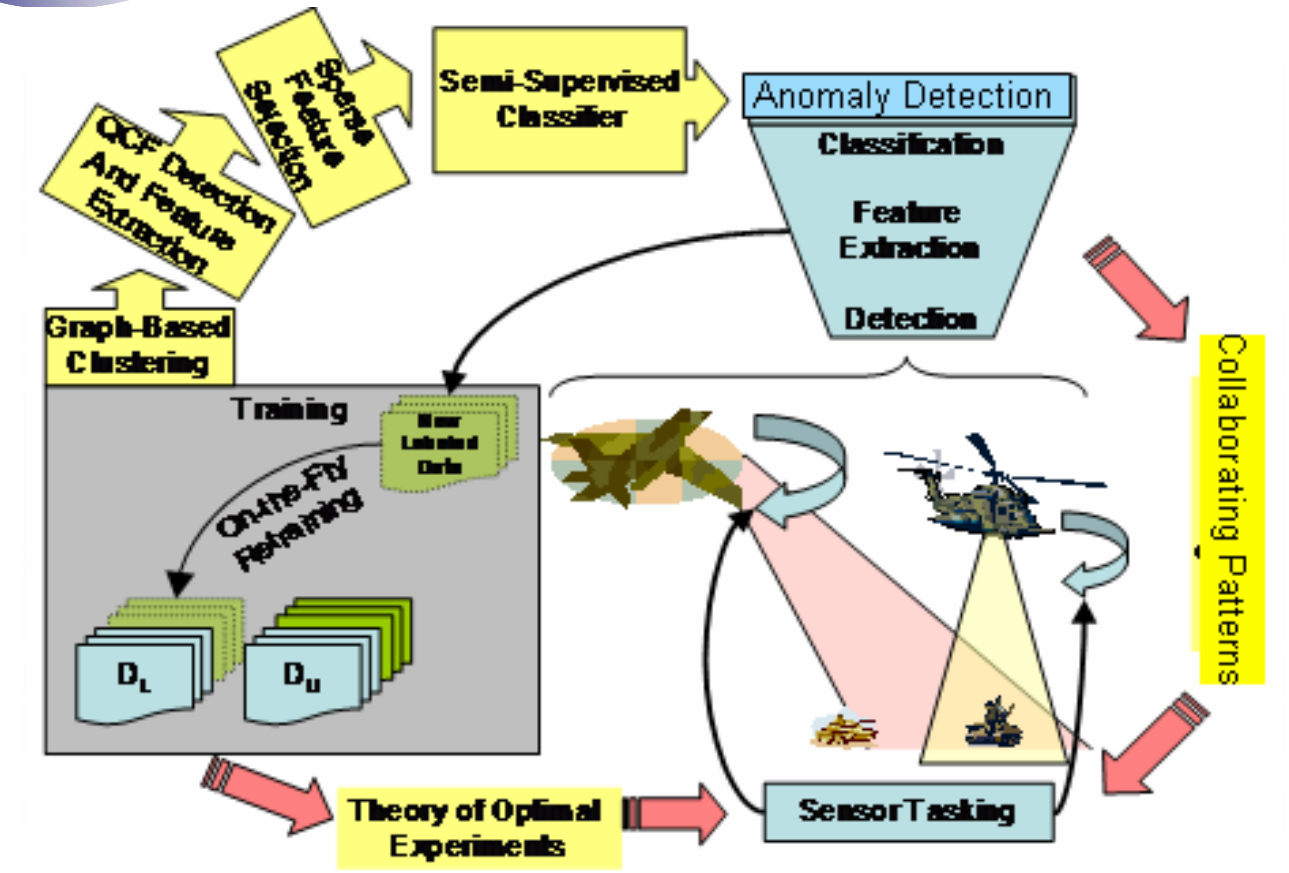
Naval forces (surface, subsurface, air, ground) operating in the maritime domain.

Start Date: FY07

Combat ID in the Maritime Domain to Reveal Content Intent Conceptual Architectural



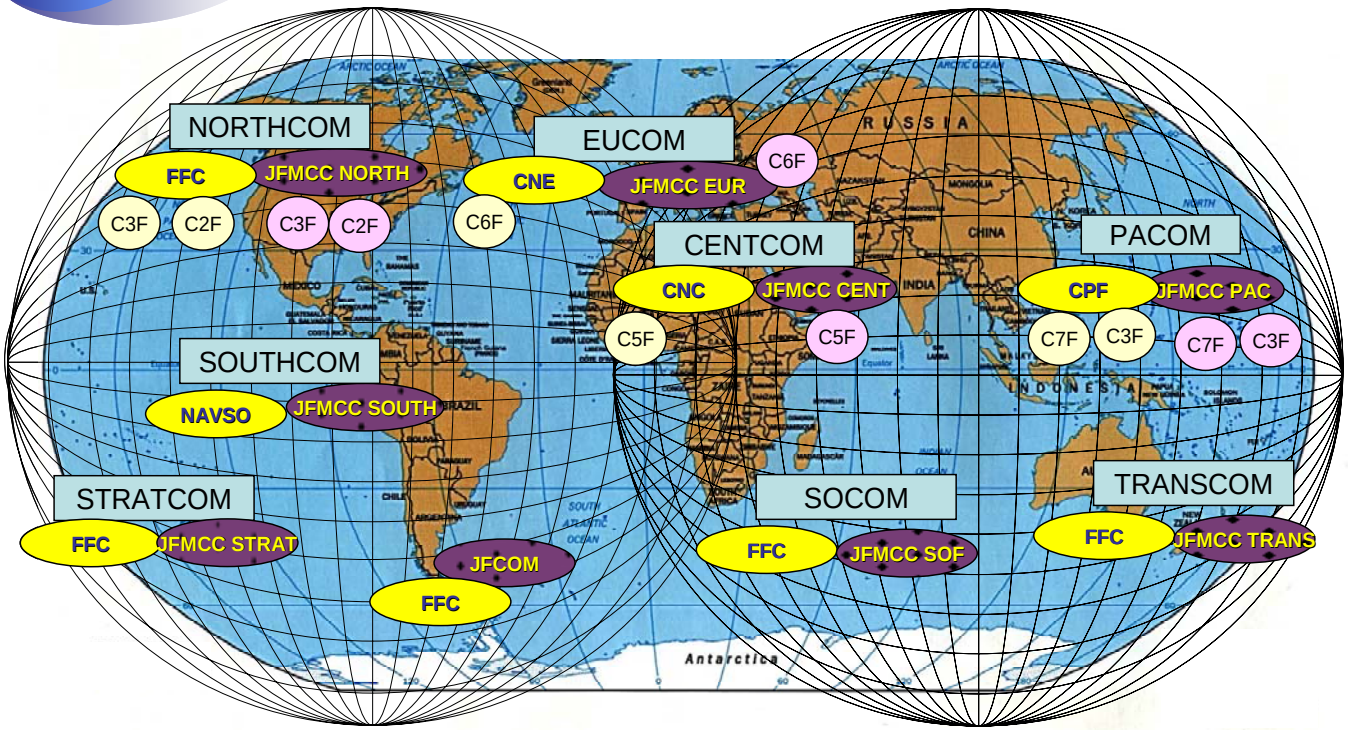
Multi-Sensor Information Integration



Naval Relevance

- Improved urban and base security through ability to detect anomalous behavior
- decisions/control using multi-sensor imagery, video and intelligence, consistent with FORCEnet objectives
- Reduced shipboard workload: system designed to ease the burden of the military analyst

Globally Netted Joint/Coalition Force Maritime Component Commander



New Operational Capability

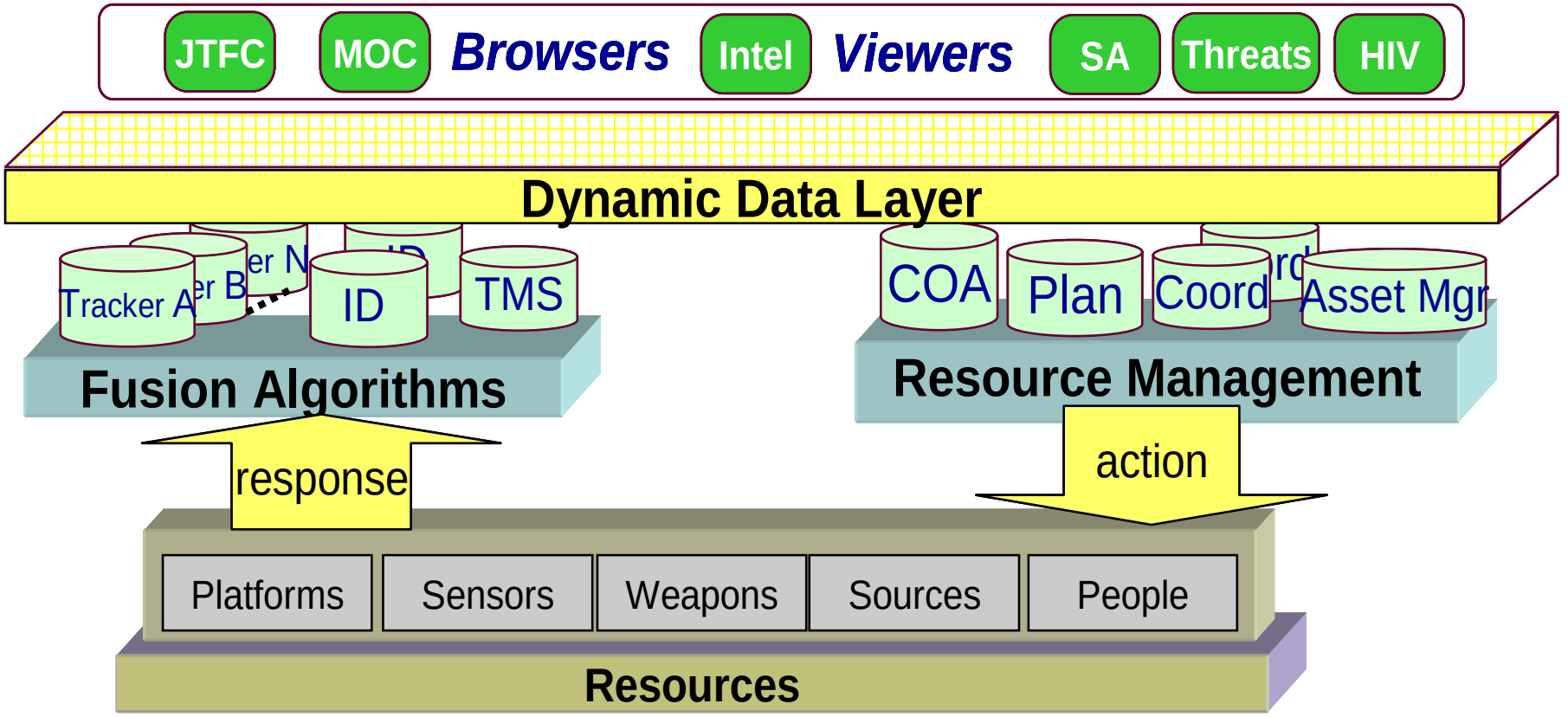
New technologies and processes to perform global monitoring of maritime activity across Joint / Coalition Force Maritime Component Commanders (J/CFMCC) to develop a Global Maritime Domain Awareness (MDA) that supports Regional COCOM Maritime missions.

– Dynamic Virtual Data Layer

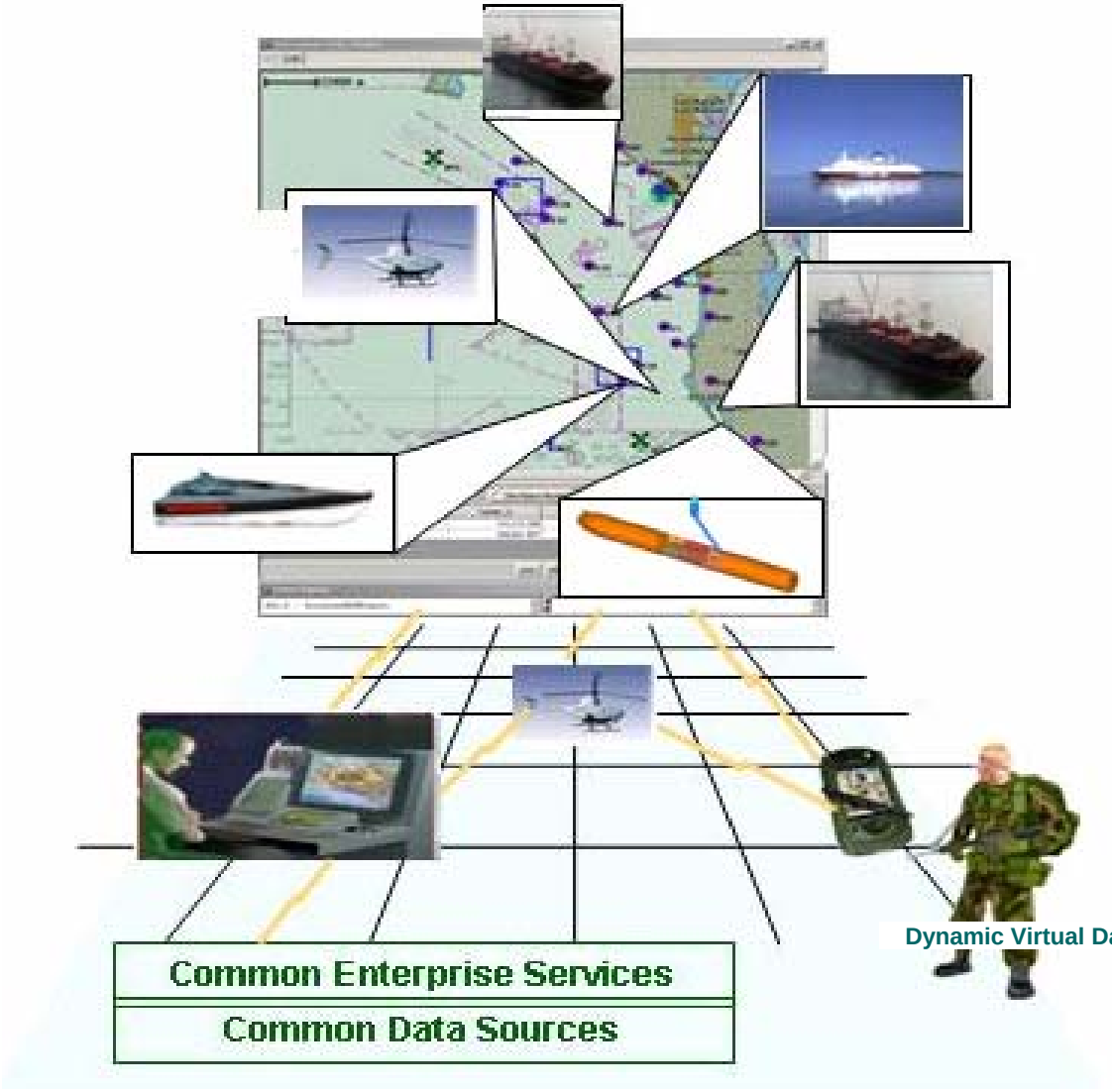
– Role Relevant Visualization

– Collaboration Assistant

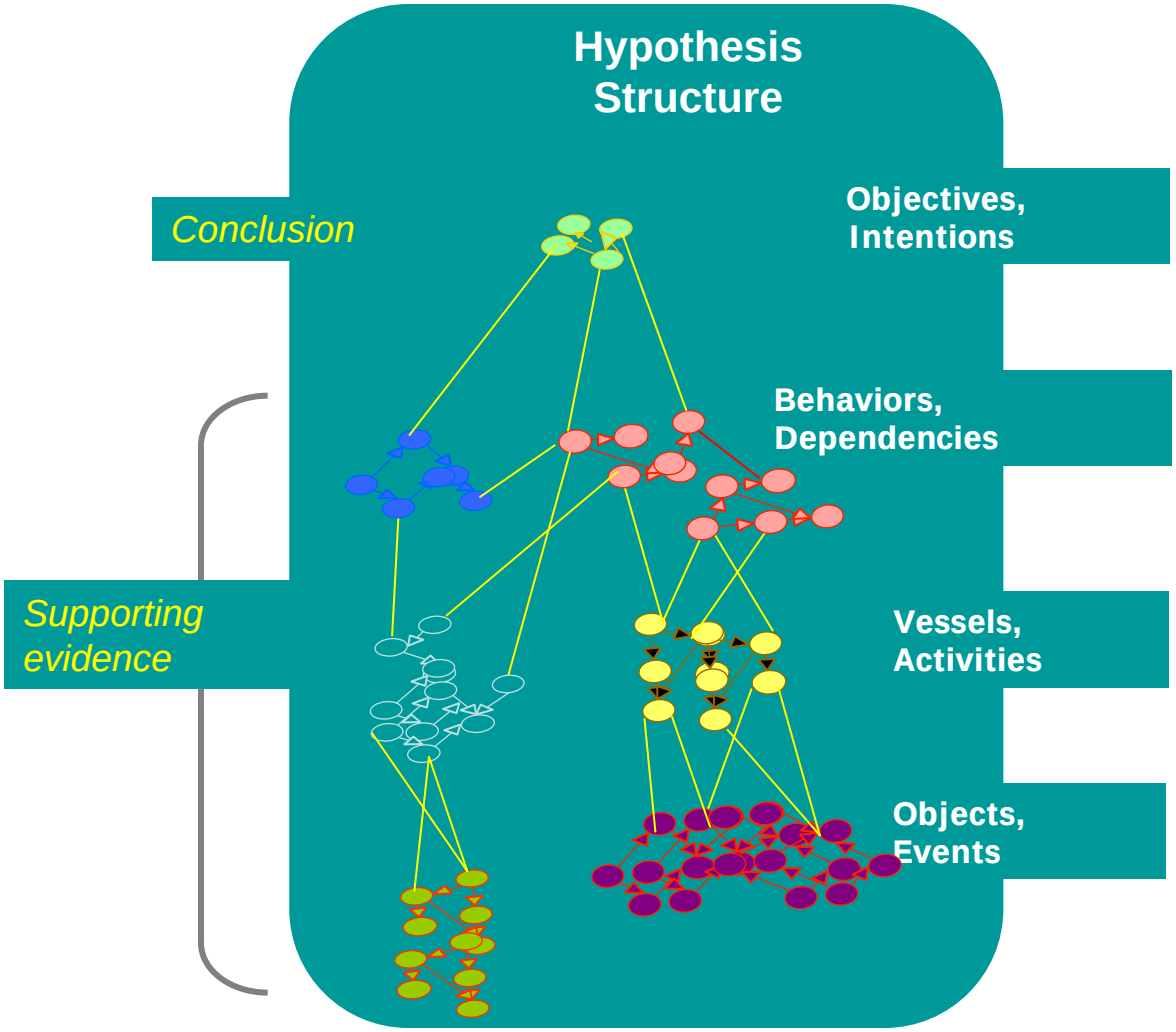
Dynamic Virtual Data Layer

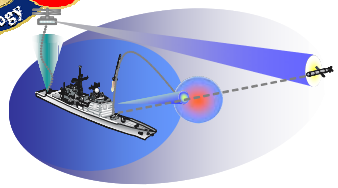


Role Relevant Visualization



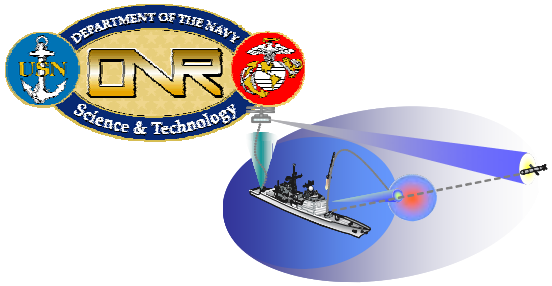
Collaboration Assistant





Why Now?
Several DoD/NSF Relevant Efforts

- Knowledge Discovery and Data Dissemination (KDD)
  - Learning:
    - Using prior knowledge bases / SMEs
    - Actively; request new data and analyses to improve inferencing
    - Incrementally and cumulatively; make full use of knowledge
  - Data mining is “finding a needle in a haystack”
  - KDD help analysts “reassemble” needles hidden in many haystacks
    - Knowledge based inference and relational patterns
    - Temporal and Spatial relationships
    - Heterogeneous data sources and Fragmented knowledge
- Predictive Analysis for Naval Deployment Activities (PANDA)
  - Identify high risk vessels by observing patterns of behavior
    - Patterns are complex and hidden in noise
    - Identify significant deviations from normal behavior
  - Four areas of study
    - Motion based pattern learning
    - Prediction and activity monitoring
    - Anomaly processing and presentation
    - Adaptive context monitoring



Why Now?
Several Promising Technologies

For Example

- Blackboard methods/tools are now more robust including commercially available generic blackboards
  - Enables both *relational* structure to maintain alternate hypotheses and *control* structure to satisfy decision maker and computational constraints
  - Leverages new capabilities in agent based computing, semantic annotation, and knowledge representation
- Bayesian reasoning and other inferencing technologies have advanced to allow practical approximation algorithms
  - Structure of Bayes nets supports control reasoning for “anytime” algorithm solutions
  - Trades-off quality and complexity allowing potential “design-to-time” control
  - Variety of inductive (e.g., Fuzzy algebra, Dempster’s combination) and abductive methods
- Techniques for visualization of complex information have advanced to aid humans in hypothesis management and solution visibility.
  - Hybrid continuous / discrete probabilistic prediction for intelligent simulation of threat activity under real physical constraints (e.g. terrain, weather, lightning)

Final Thoughts

- MDA consists of two key components: information and intelligence
- Both combine in the COP to create a substantive, layered presentation of the global maritime environment
- There are many programs that include a COP
- No single one source captures all of the maritime information warfighters need — or that is currently available
- S&T programs are addressing the need to effectively integrate and fuse inputs to achieve the synergies offered by a comprehensive situational awareness picture
- The goal monitor vessels, people, cargo and designated missions, areas of interest within the global maritime environment, access all relevant databases, and collect, analyze and disseminate relevant information

Questions