Sensor Ontology Integration for the Knowledge Management for Distributed Tracking (KMDT) Program

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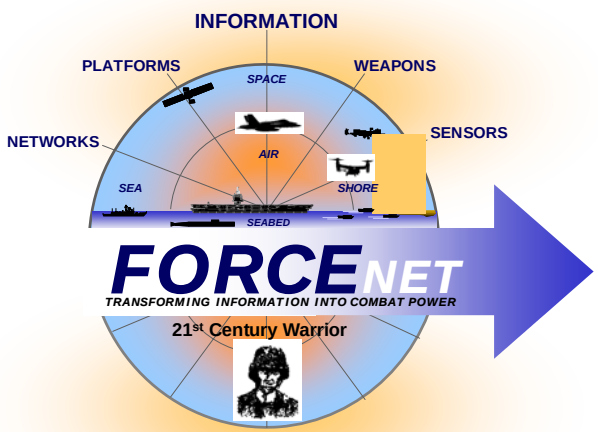
Presentation Outline

- **Introduction to KMDT**
  - Motivation for project
  - Impact on operational forces
  - Technical objectives
- **Objective 1: Line of bearing cross fixing**
- **Objective 2: Intelligent software agents**
- **Objective 3: Sensor-ontology integration**
  - Description of noun and verb ontology
- **Objective 4: Modeling and simulation**
  - Description, concepts
  - M&S Scenario

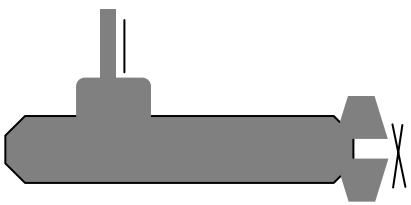
Why KMDT?

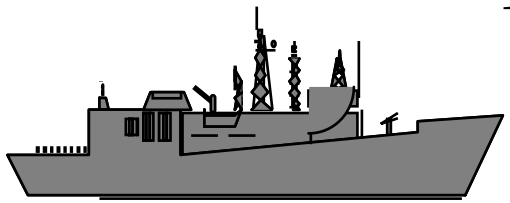


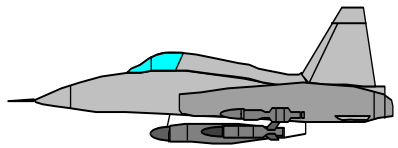
- Navy & Marines need more complete information on unknown contacts in the battle space.
- The Navy needs a better way to use more sensor information for level-one sensor fusion (<40% used.)
- Data are lost because they cannot be correlated with other data to reach the threshold of information on which decisions can be based.

KMDT Automates Integration - Disparate Information Sources

- Automation includes network-based messages and software agents.
- Integration involves level-one data fusion.
- Heterogeneous sensor types are located on in different platforms – mobile and fixed.

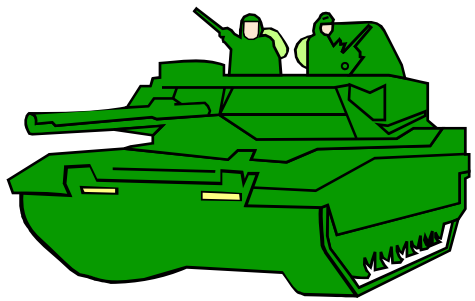






KMDT's Operational Impact

- Agent-acquired information will support the Navy and Marine Corps to reduce uncertainty in command centers.
- Distributed homogeneous and heterogeneous sensor information will be used more efficiently.
- The network will be used to meet the same requirements as current message systems.
- Sensor ontologies will enable integration of information bases and increase understanding of the battle space.
- Help prevent fratricide incidents through better target classification.



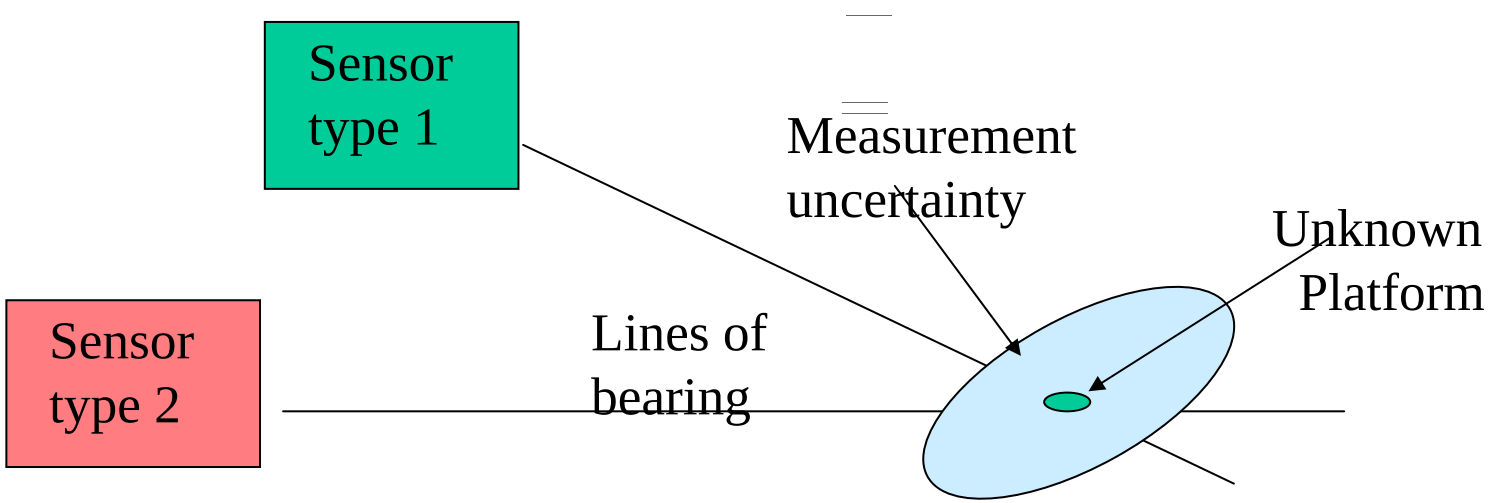
KMDT Technical Objectives

- Develop **cross-correlation algorithm** -provides localization of unknown platforms.
- Use intelligent software **agents** to search secure networks for line-of-bearing (LOB) cross correlation and other information. **(Metrics)**
- Merge **sensor ontologies** - concepts re: different sensor types & their capabilities. **(Metrics)**
- Implement **modeling and simulation. (Metrics)**

KMDT

KMDT Technical Objective 1: Cross-Correlation Algorithm

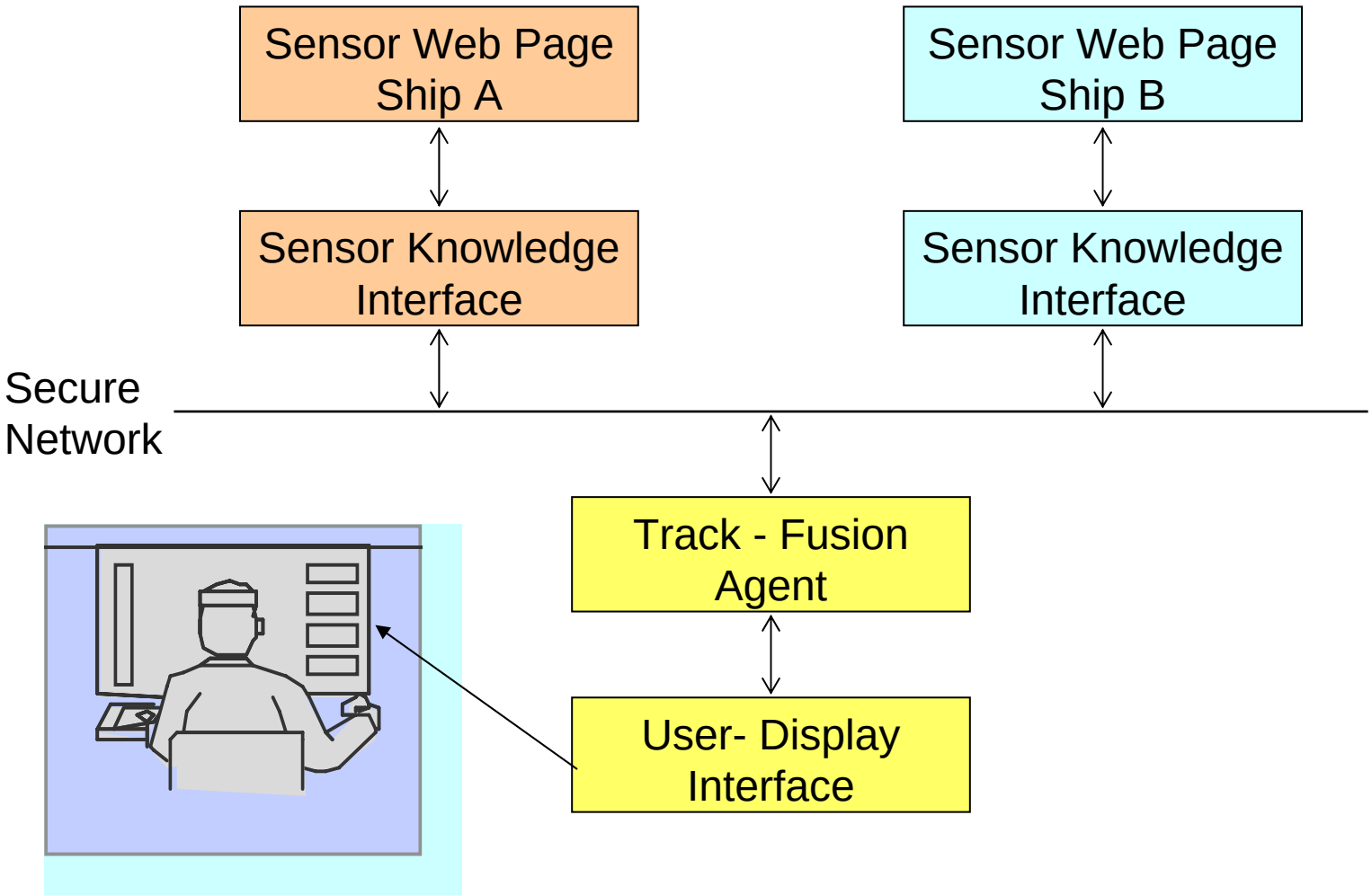
- Localizes unknown platforms using Line-Of-Bearing cross fixing.
- Uses both similar and disparate sensor types (e.g. electro-magnetic and acoustic) localize platform position and
- Reduces tracking uncertainty and errors



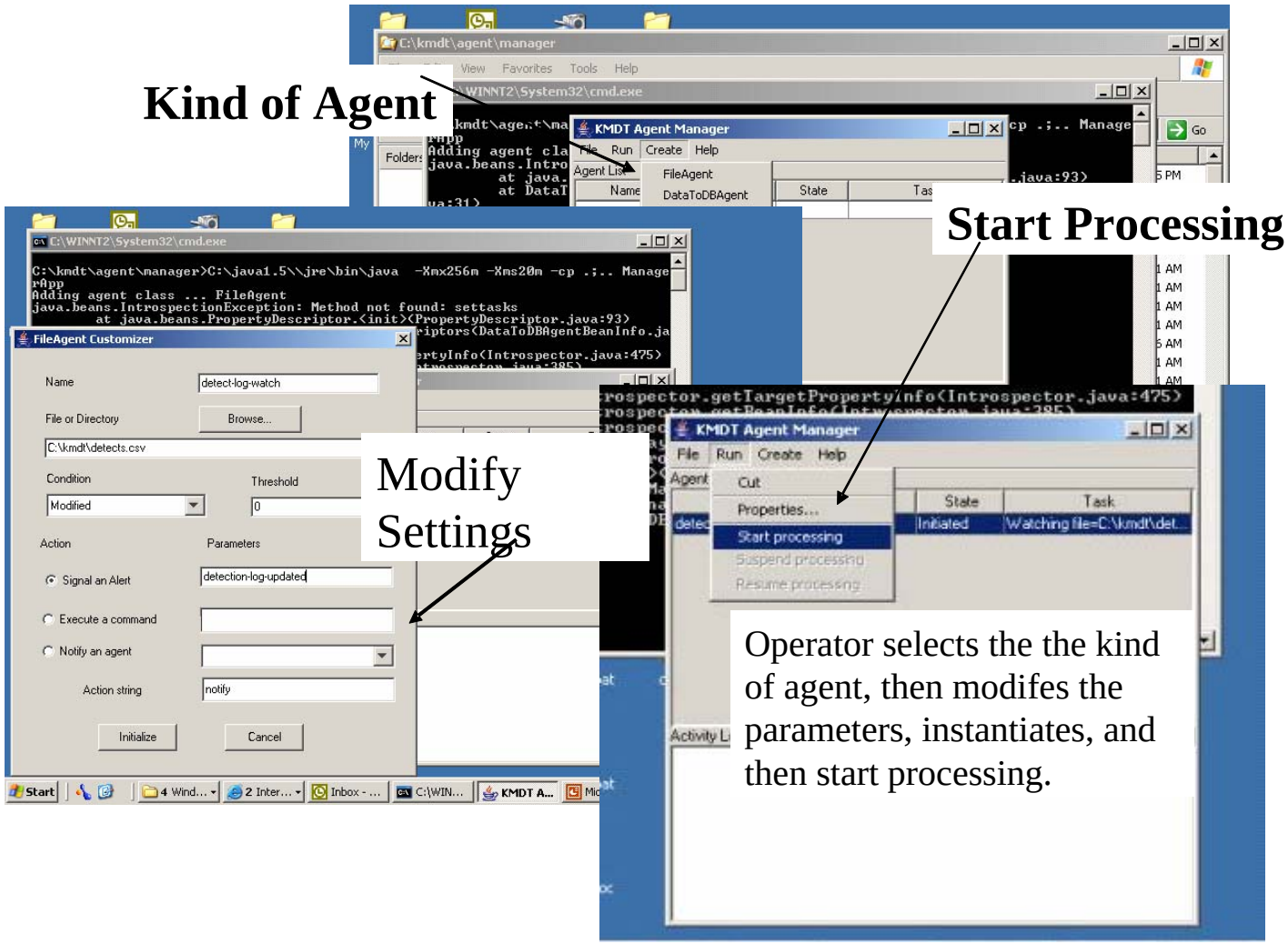
KMDT Technical Objective 2: Intelligent Agents

- Search secure networks for line-of-bearing (LOB) cross correlation and other information.
- Access sensor ontology & database for task coordination
- Acquire sensor information at the message level for network-based correlation and tracking.
- Using the network as a medium of data sharing, agents perform message-level data retrieval, fusion and integration, thus bringing key missing data to the attention of ship commanders.

KMDT Application - Agent Functional Diagram

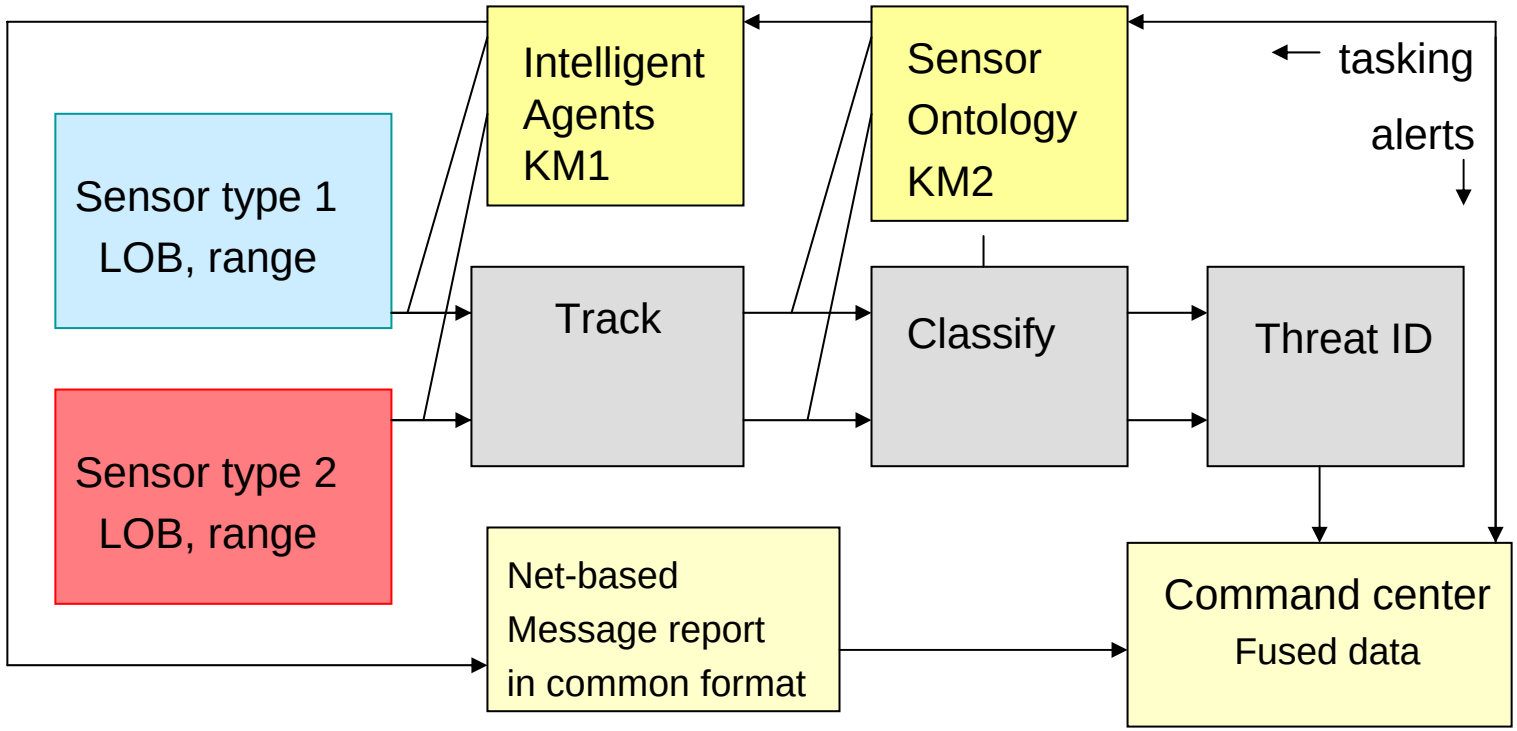


Agent Input Screen



Operator selects the the kind of agent, then modifes the parameters, instantiates, and then start processing.

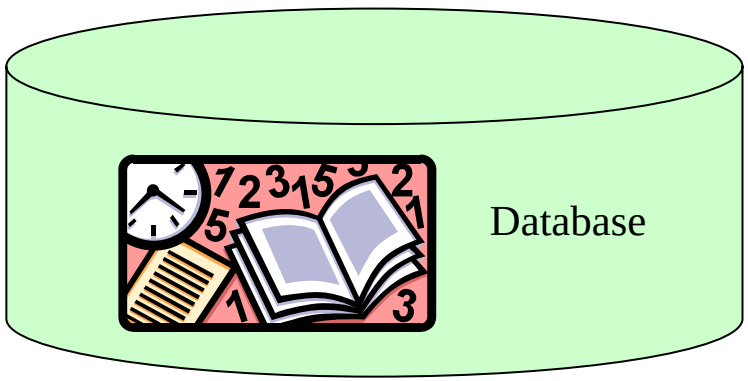
KMDT Information Flow

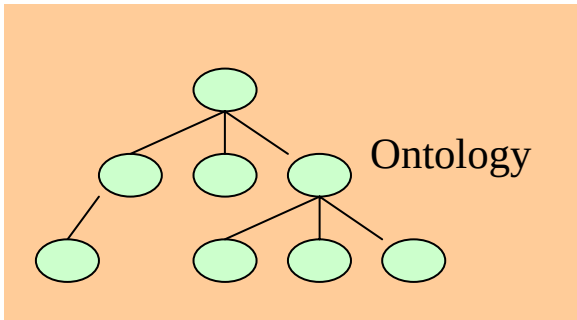


Operators in command centers task intelligent agents to find sensor data at the message level on the network.

KMDT Technical Objective 3: Ontology - Terminology Definitions - 1

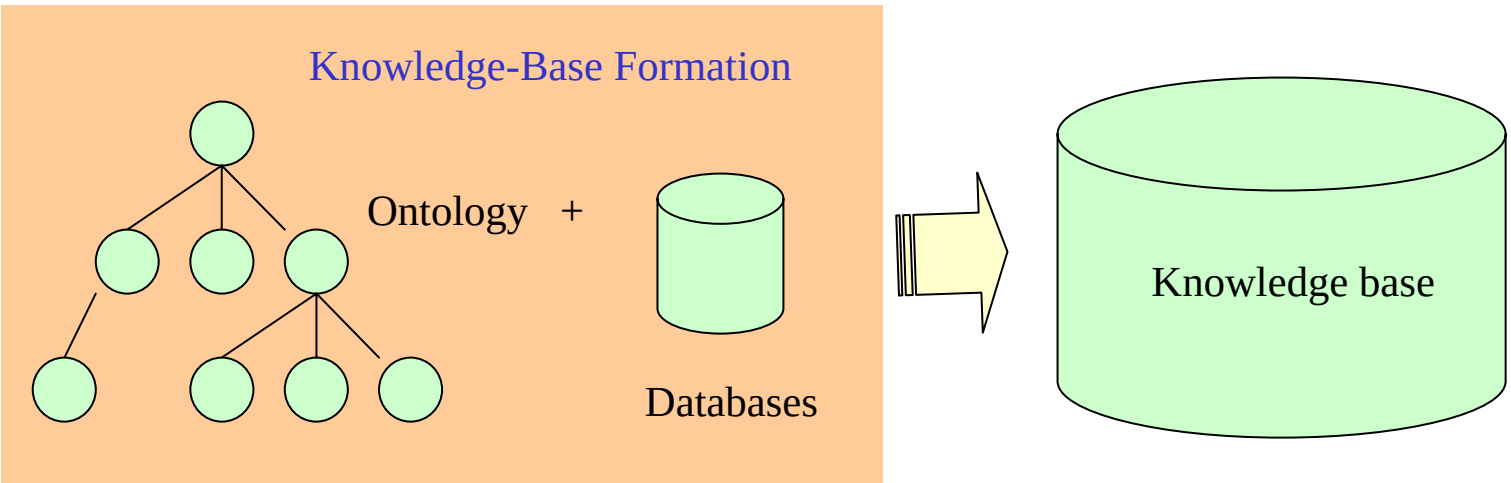
- Database - A state of information. A collection of facts structured according to a model that allows information to be stored **implicitly**. Conclusions can be **inferred** from the data.
- Ontology – Systematic account of existence. Concepts and their relationships are represented in a hierarchy that includes object and and action concepts. Every knowledge base is a representation of one or more ontologies.





Ontology Terminology Definitions - 2

- <u>Knowledge base</u> - A state of information. Can be a collection of rules structured according to an ontology that allows assertions to be stored **explicitly**. Conclusions can be drawn using an inference engine. Higher level of aggregation.

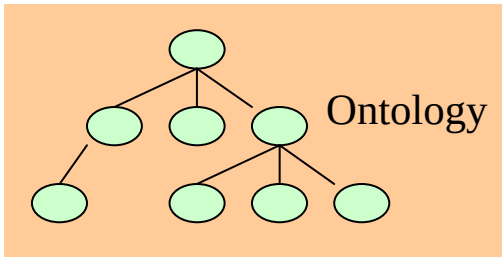


KMDT Sensor Ontology Integration

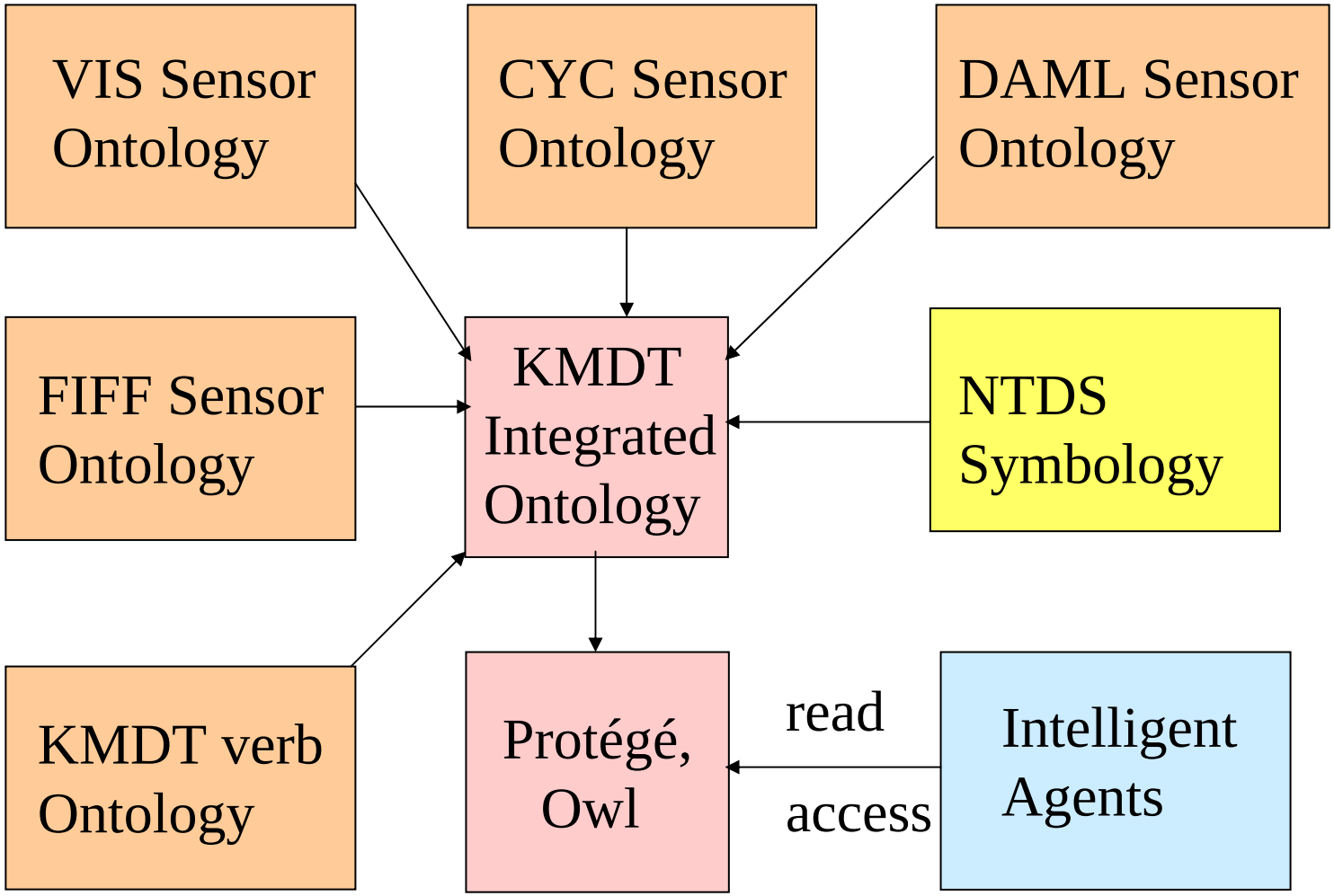
- Common, merged sensor ontology defines concepts, maps metadata about disparate sensor systems, fills gaps not covered explicitly in an existing sensor ontology. Example: verb ontology.

- Ontology serves as the basis for a knowledge base and agent-based data fusion.

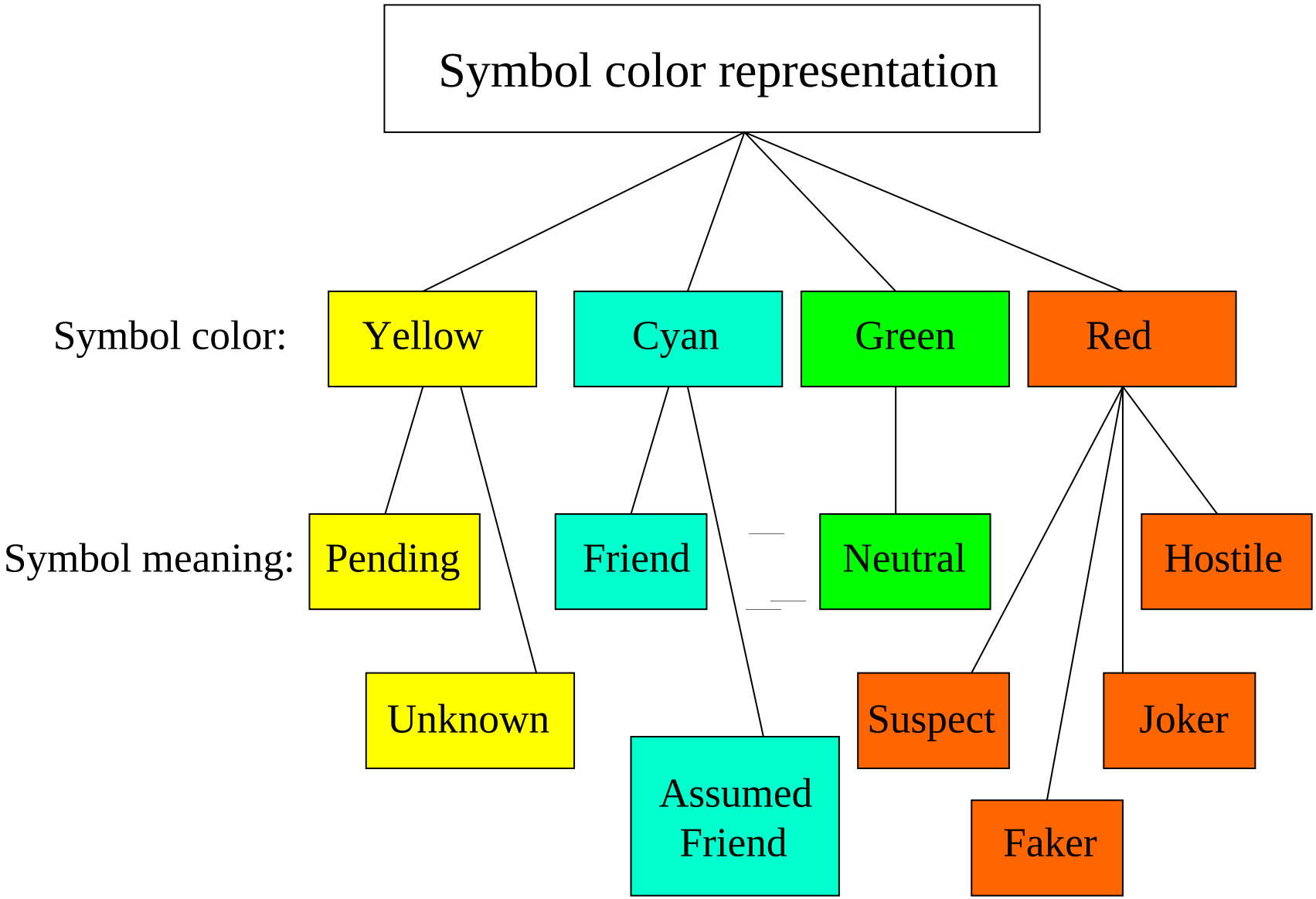
- Intelligent agents coordinate their tasks.
  - Match commander's requirements to sensor capabilities
  - Data correlation and platform tracking



KMDT Ontology Integration and Use



Target-classification ontology implicit in the NTDS symbology standard



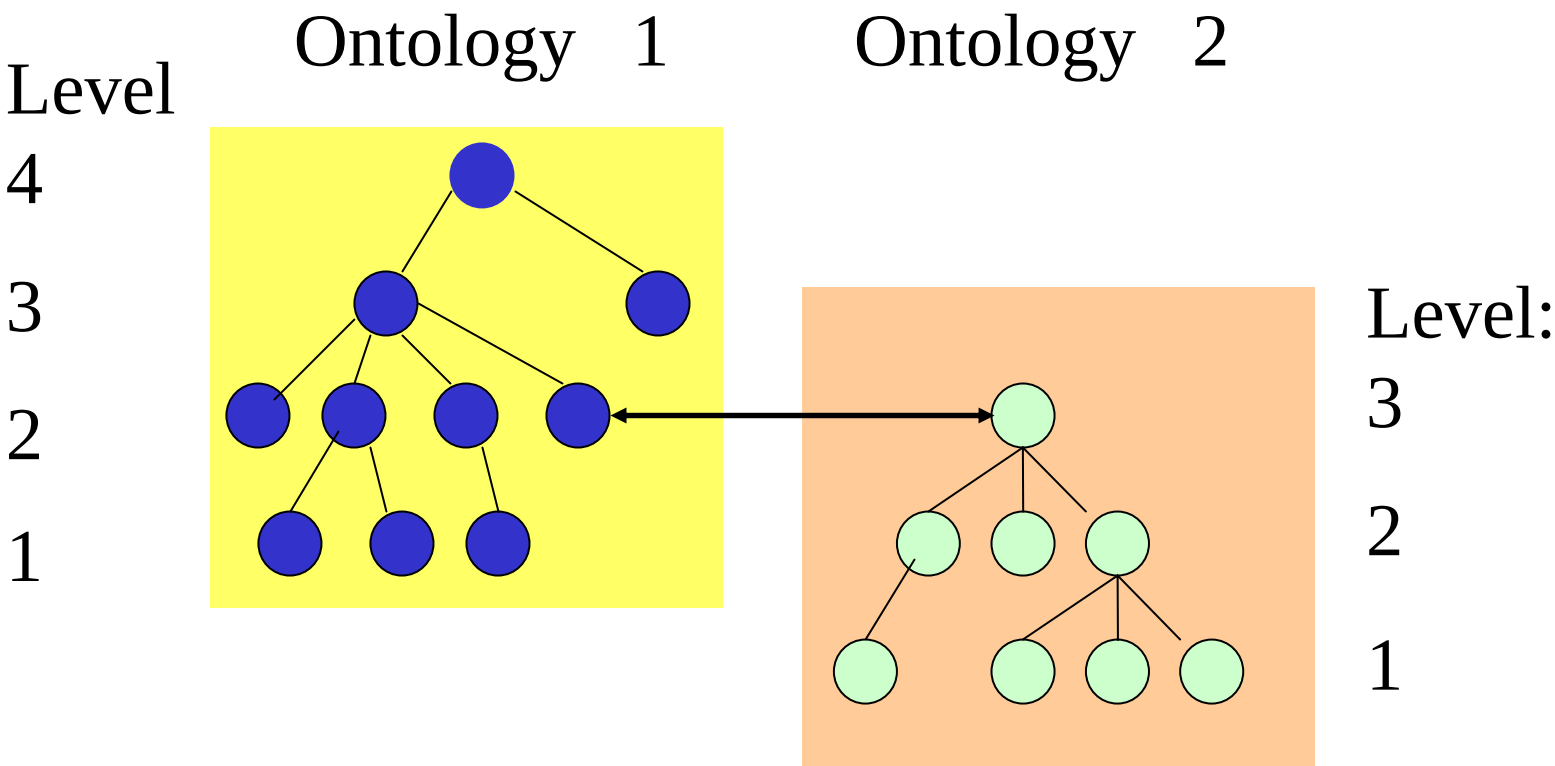
KMDT Noun Ontology Components

Concept | Ontology	VIS	Cyc	DAML	FIFF	Davis
Sensor type:	x	x	x	x	x
Active	x	x	x	x	x
Passive		x	x	x	x
Radar		x		x	x
Acoustic	x	x			
Magnetic	x	x			
Electro-optic	x	i		x	
Electro-Magnetic		x	x	i	x
Mechanical		i	x		
Biological		x	x		
Chemical		x	x		
Radioactive			x		
Cyber		i	x		
Optical	i	x	x		
Microwave			—	x	
Geometry	x	x		x	
Track	x	i	—		
Signal	x	x	i		x
Resolution			x		
Environment	x	x			
Contact	x		x	x	
Range		x	x	x	
Goal		x	i	x	
Sensor mode			x		
Sensor location	x	x	x		i
Sensor data	x	x	x		

Verb & Predicate Components

Subject	Verb	Object	Relationship Type	Arity
Noise	Masks	Signal	Equivalent 1	Binary predicate
Signal	Is masked by	Noise	Equivalent 1	Binary predicate
Noise	Does not mask	Signal	Equivalent 2	Binary predicate
Signal	**Is not masked by**	Noise	Equivalent 2	Binary predicate
Signal	Propagates in	Medium		Binary predicate
Period	Is reciprocal of	Frequency	Noun inverse	Binary predicate
Frequency	Is reciprocal of	Period	Noun inverse	Binary predicate
Target	Changes	Location		Binary predicate
Target	Emits	Signal		Binary predicate
Sensor	Receives	Signal+noise		Ternary predicate
Algorithm	Processes	Signal+noise		Ternary predicate
Operator + Signal	Detect	Target		Ternary predicate
Operator + Signal	Detect	False alarm		Ternary predicate
Operator + Signal	Classify	Target		Ternary predicate
Operator + Signal	Identify	Target		Ternary predicate
Operator+2 signals	Localize	Target		Quaternary predicate
Operator +Signals	Track	Target		**Variable-arity predicate**
Environment	Enhances	Resolution	Verb inverse	
Environment	Degrades	Resolution	Verb inverse	

The Same Concept Occurs in Multiple Ontologies

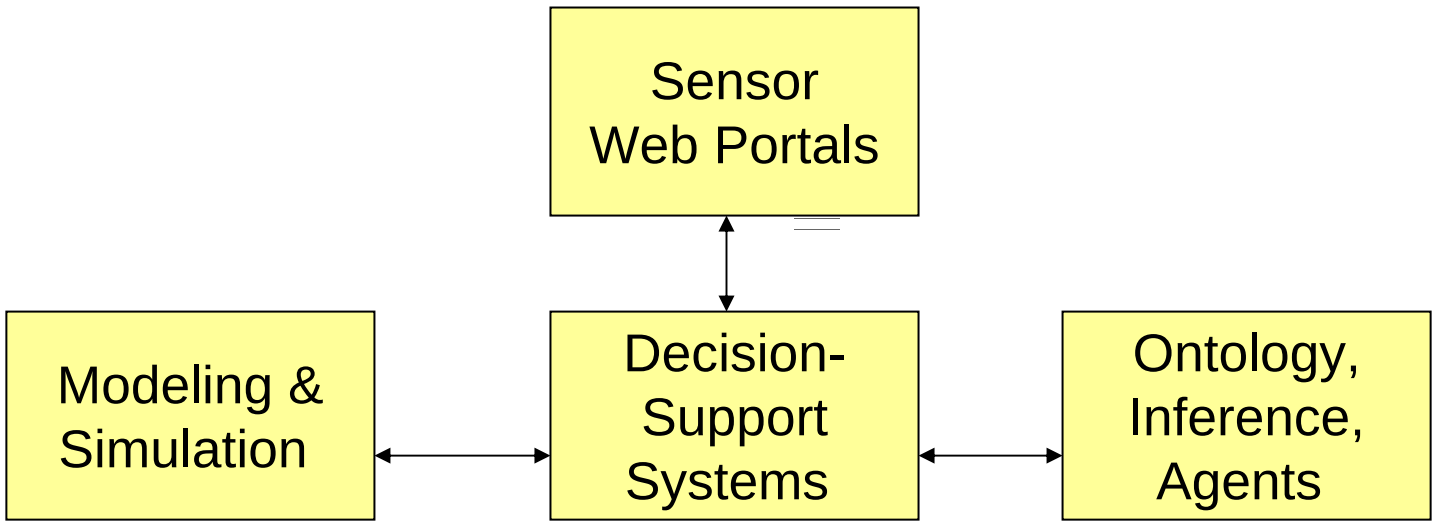


● = Concepts in Ontology 1

○ = Concepts in Ontology 2

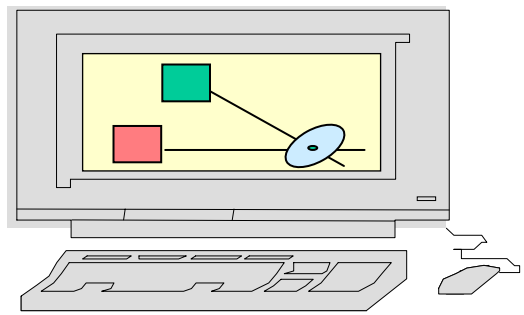
KMDT Technical Objective 4

Modeling and simulation. – Focus is on agent and ontology performance at the message level to improve command-decision efficiency. Simulate agent-assisted data fusion in FORCEnet-based scenarios. (Ref. 14)



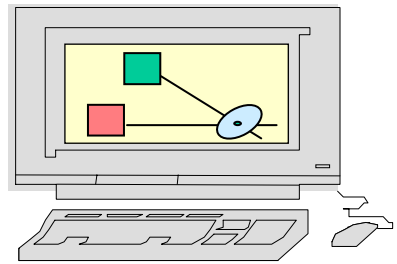
Modeling and Simulation: Motivation

- Allows many tests to be conducted using software without costly field trials.
- Enables progressively more complex models, scenarios, and technologies to be tested systematically.
- Helps predict system behavior.



Modeling and Simulation: Concept of Operations

- Initial effort focus is on simplified concept of operations, scenarios.
- Software intelligent agents access processed, message-level data on web portals.
- Unprocessed, “raw” sensor data:
  - Are difficult for agents to interpret.
  - Increase bandwidth requirements over the LAN.



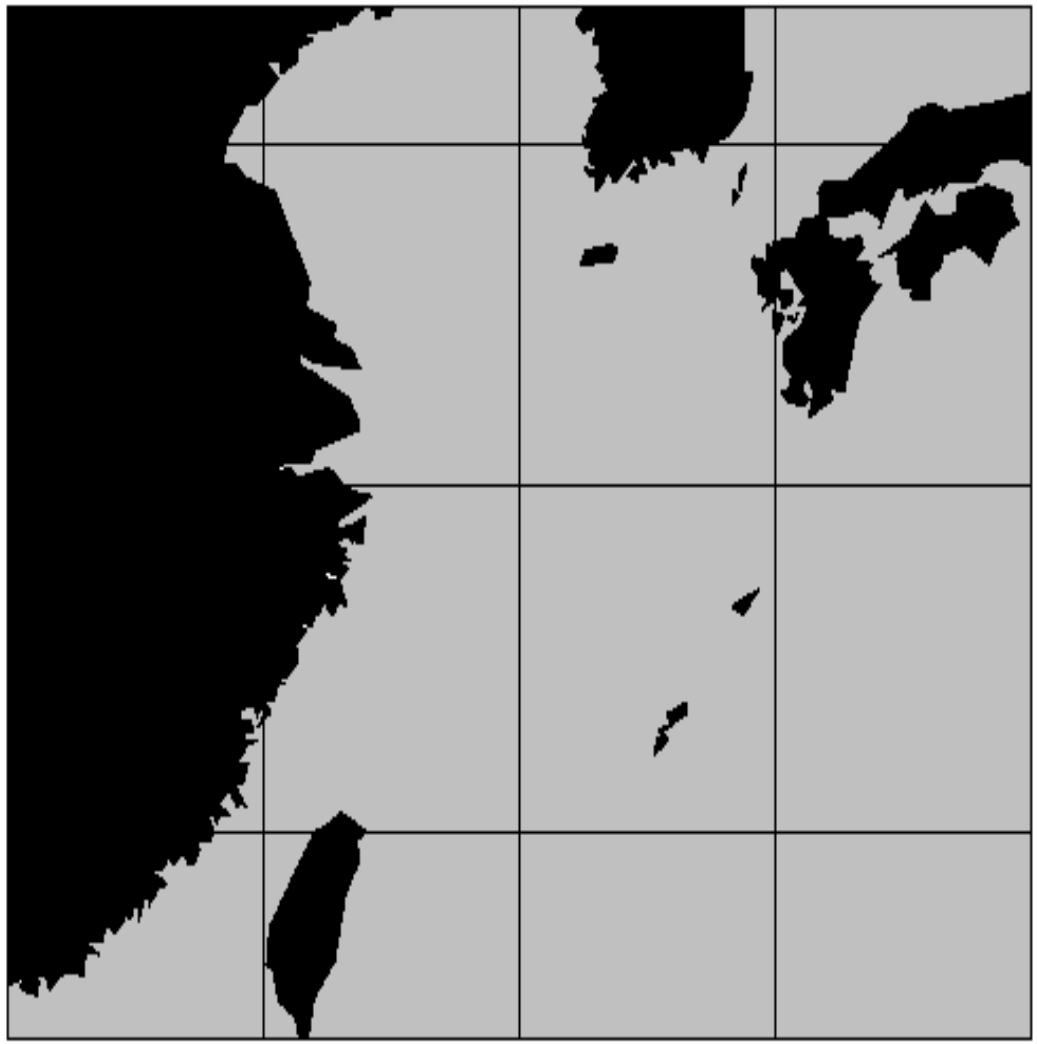
- Messages posted to the web portals consist mainly of
  - LOB information
  - Contact frequency data derived from sensors of various types (active, passive; acoustic, optical, etc.)
  - Metadata about the contact and the remote, friendly platform that generated the LOB.

Modeling and Simulation: Approach

- Each sensor platform has a standard web portal.
- Each sensor has a web page within the portal of the platform that controls it.
- URL are known to all nodes on the secure LAN.
- An intelligent agent is deployed to find pertinent web portals, reads data on these web portals, and evaluates whether the data on the pages satisfy a pre-determined set of criteria.
- Agents perform passive query of web portals that does not involve platform response.
- Agents access the sensor database and ontology for information in addition to that provided in the operator's input screen. – most important in heterogeneous fusion

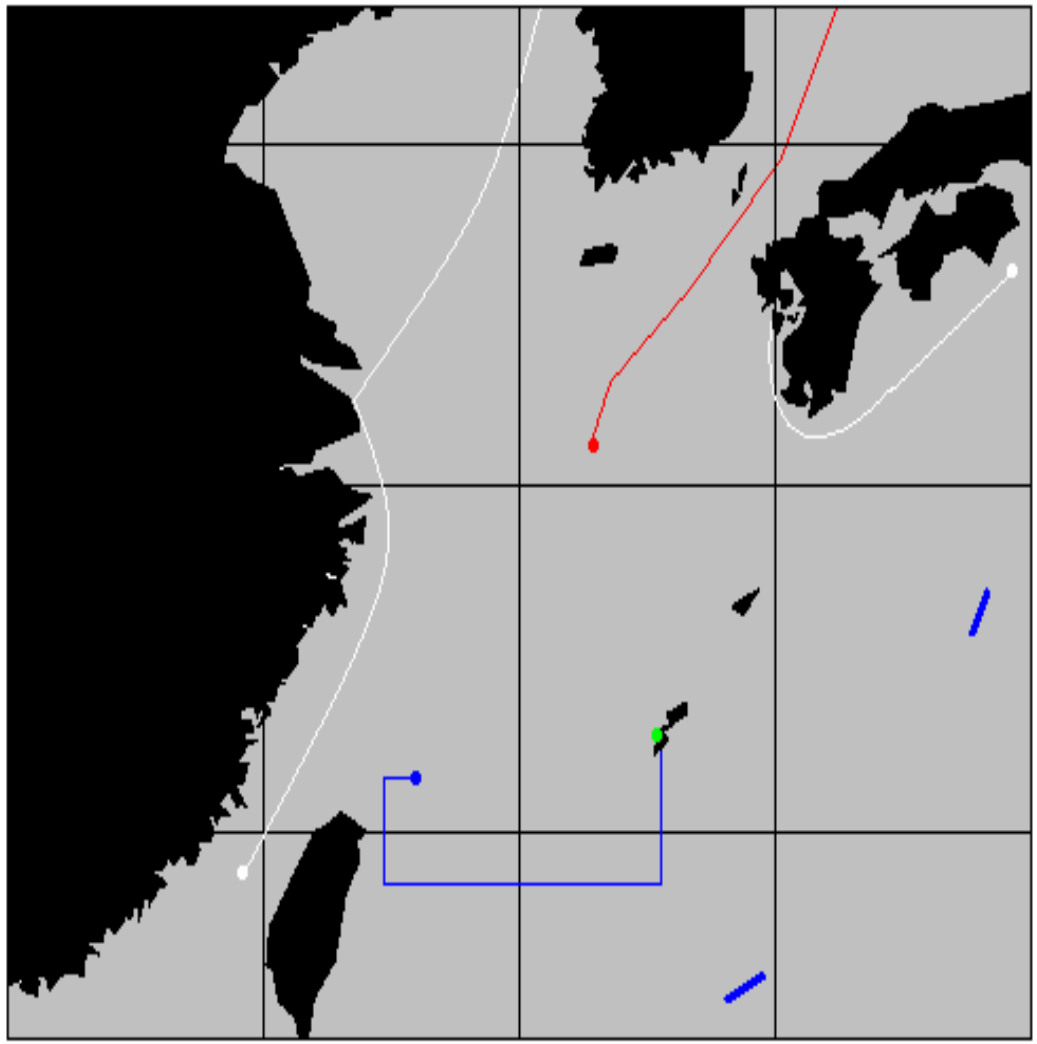
Modeling & Simulation Area

- Theater of operations
  (E. China sea and vicinity)
  - Littoral and deep-water environments
  - Sea access via straits and open ocean
  - Proximity of mainland and islands
    - Land-based sensor sites
    - Air bases
    - Ports of opportunity



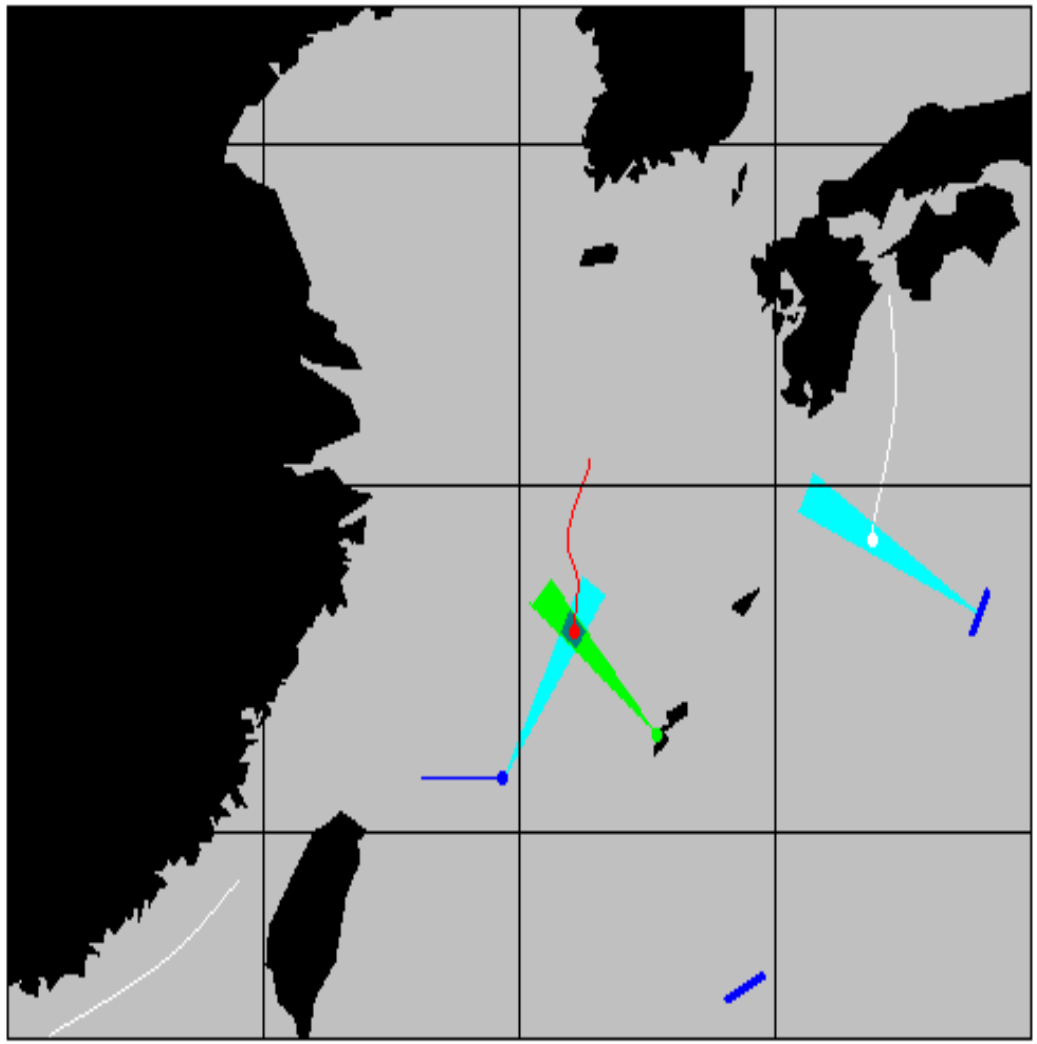
Modeling & Simulation Features

- Targets (classification initially unknown)
  - Surface
  - Submarine (future model extension)
  - Air (future model extension)
- Sensor platforms
  - Mobile
    - Surface vessel
    - Aircraft
  - Fixed
    - Deep-water array
    - Barrier
    - Land-based
- Motion models
  - Quasi-random
  - Waypoint track



Modeling & Simulation Sensor Types & Data

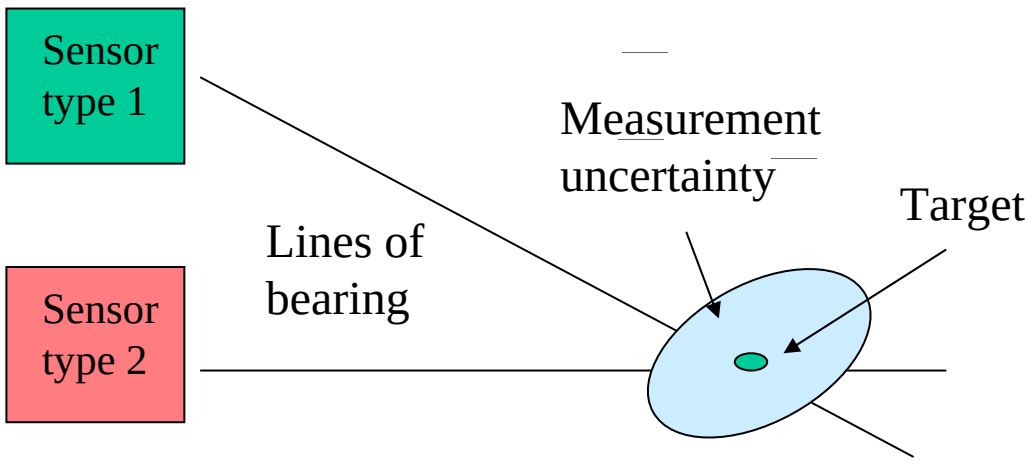
- Sensor systems
  - Acoustic (fixed or mobile)
    - Passive
    - Active
  - Electromagnetic (fixed or mobile)
    - Passive
    - Active
  - Optical
- Target measurements
  - Azimuth (LOB), elevation angle
  - Range, range rate
  - Pulse length, rep. Rate
  - Received SNR
  - Other classification attributes



BACKUP SLIDES

KMDT Intelligent Agents

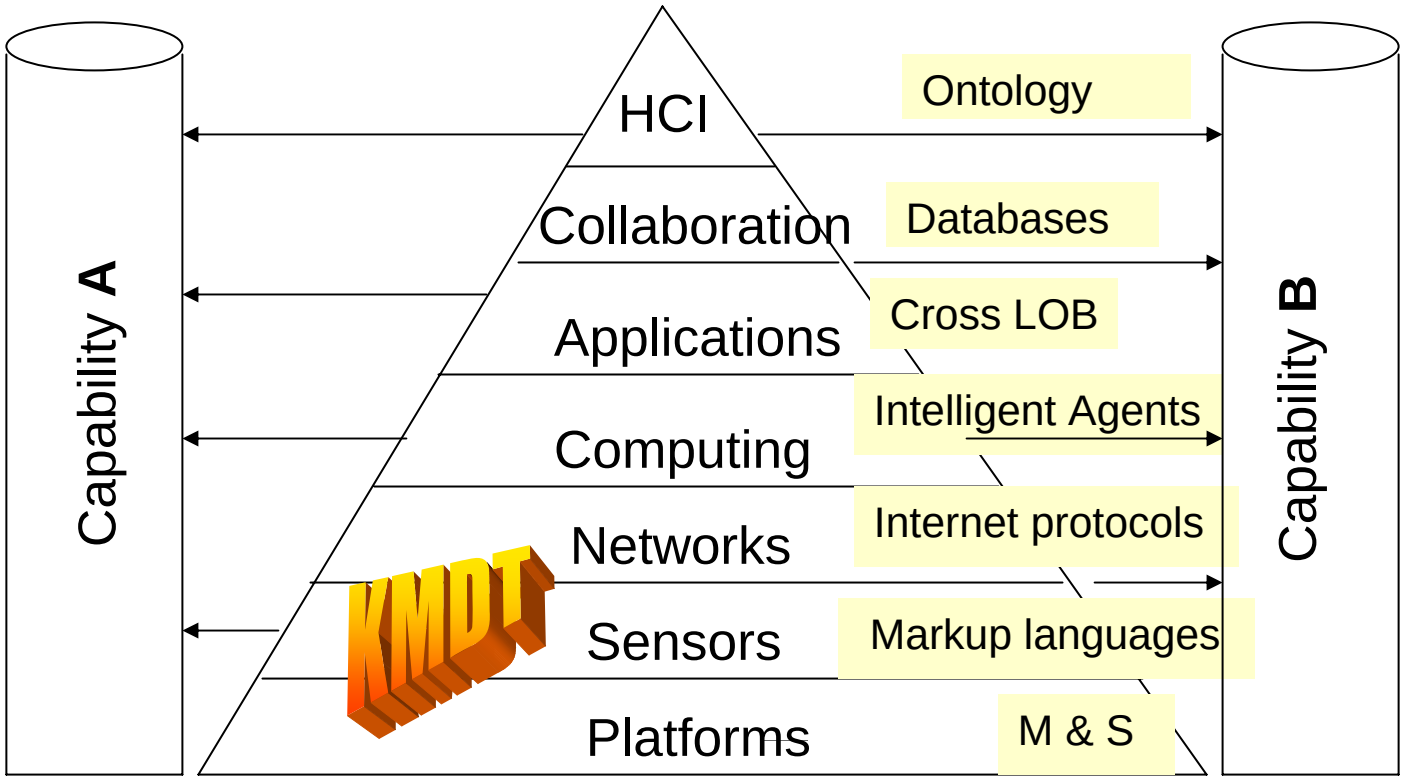
Intelligent agents for line-of-bearing tracking. – Agents access web portals, respond to sensor analyst tasking, seek missing data from other sensors, perform correlation and report the results on the network. Agents also can alert command-center personnel.



M&S Design Details

- Platforms update their web portals when new data are received and processed at the message level.
- Each mobile platform updates its position on the web portal frequently.
- Sensor data posted on the web portal have an associated date and time.
- Frequency of update is under operator control in the simulation.
- The initial simulation design is illustrated on the next slide.

Summary – KMDT Supports Composable FORCEnet



KMDT provides key enabling technologies to support composable FORCEnet. KMDT bridges the gap between capabilities: heterogeneous sensor types that otherwise would be stovepipes.

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KMDT Recent Publications

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