Information Fusion of CB and non-CB Assets

Chemical and Biological Defense Science and Technology Conference

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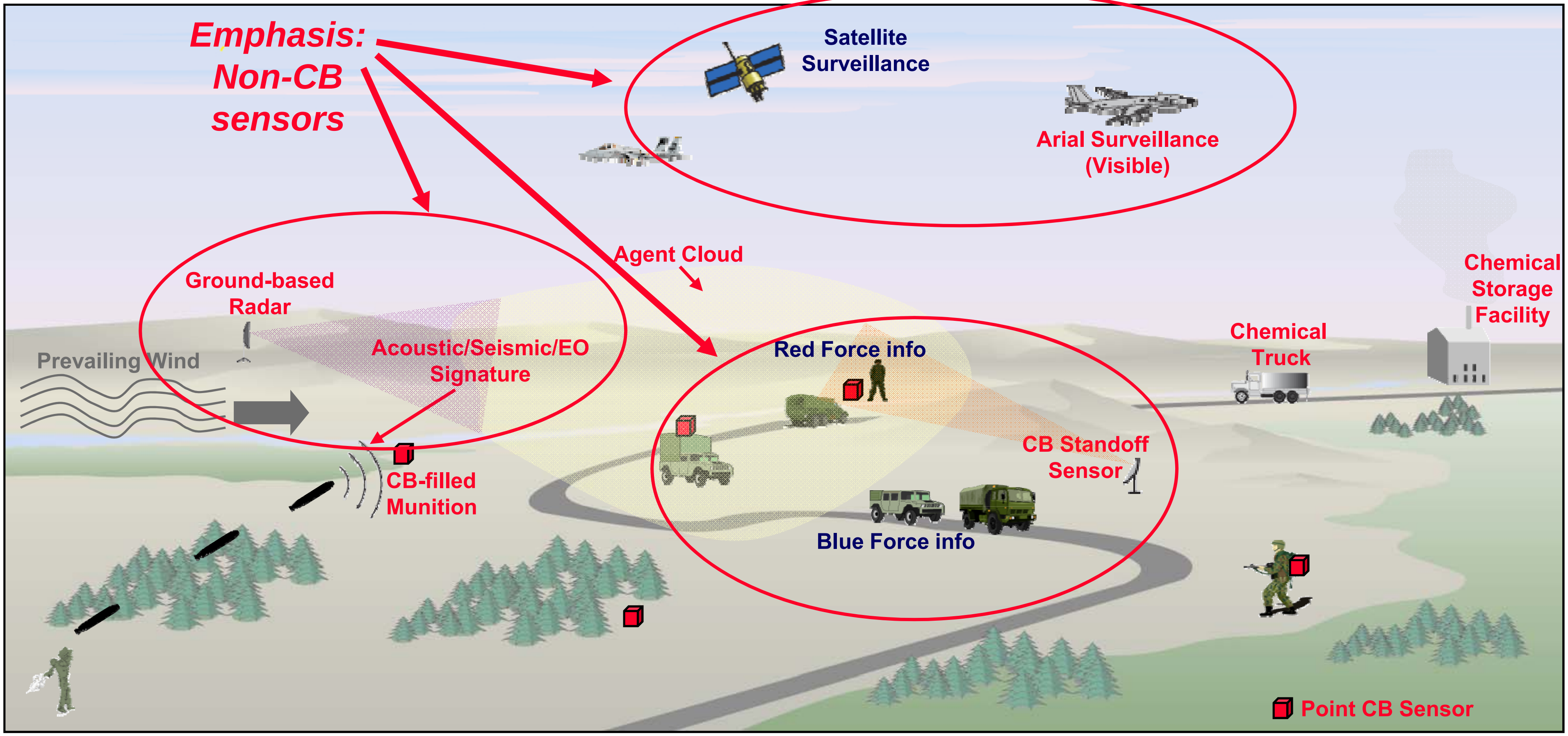
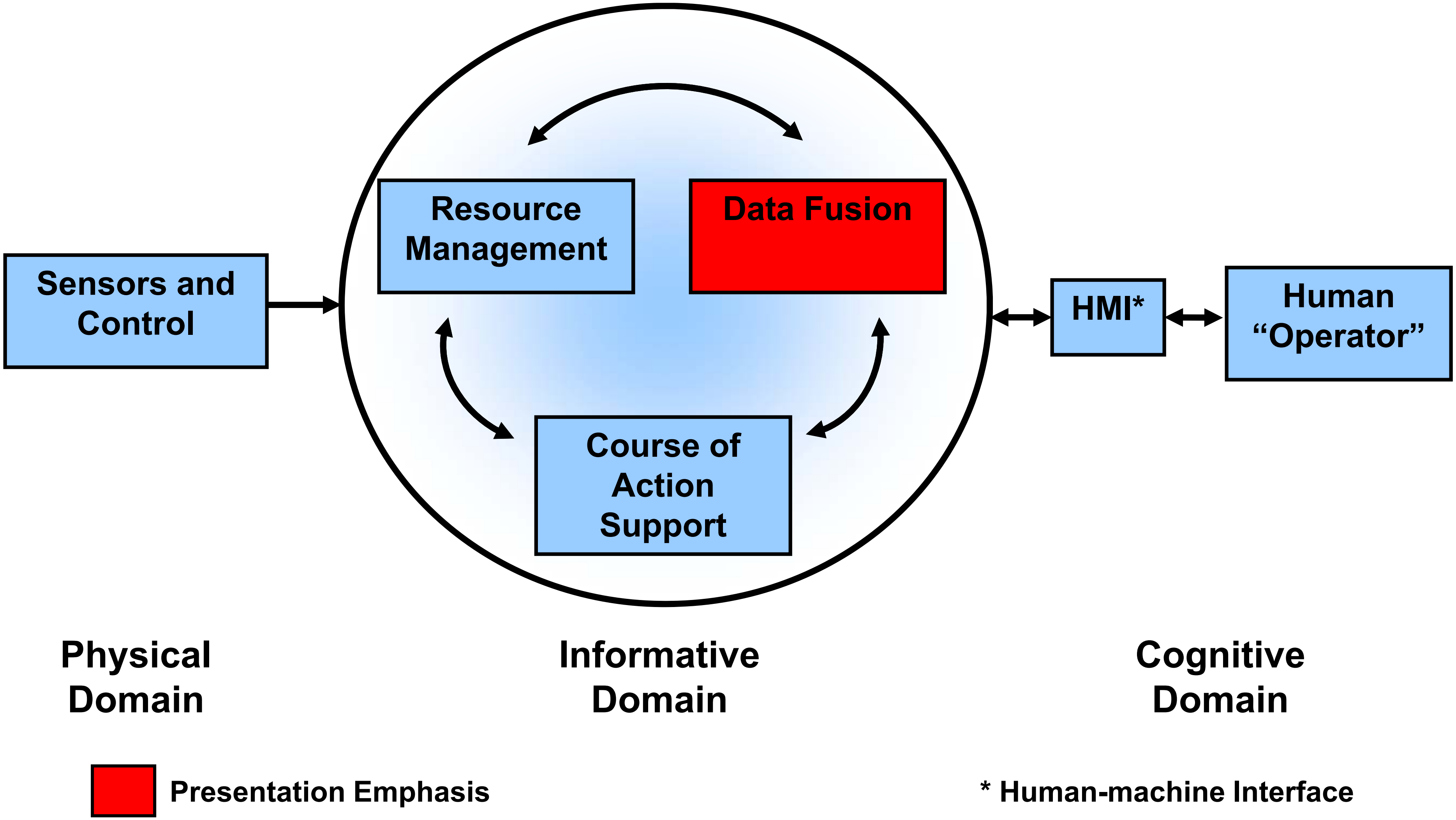
The Problem



Full value of CB sensing will require fusion of disparate CB and related CB information sources

Decision Support "Vision"



MARS-JFP* Objectives

- ***Overall: Develop and demonstrate effective fusion systems for CB/non-CB sensors***
  - **Initial emphasis on introduction of non-CB resources**
  - **Enhanced performance relative to CB-only systems**

- ***Current presentation: Sensor utility and fusion development framework***
  - **Overall approach and analysis scenarios**
  - **Sensor utility analysis**
  - **Path forward**

Central issue is to demonstrate whether non-CB sensors serve to confirm or deny occurrence of CB alarms.

***Military Applications of Reconnaissance and Surveillance – Joint Force Protection**

Fusion Objectives

- **Demonstrate utility of non-CB sensors in CB attack classification**
  - Ability of non-CB sensors to confirm/deny CB alarms

    Upon CB alarm, search earlier in event chain for corroborating evidence

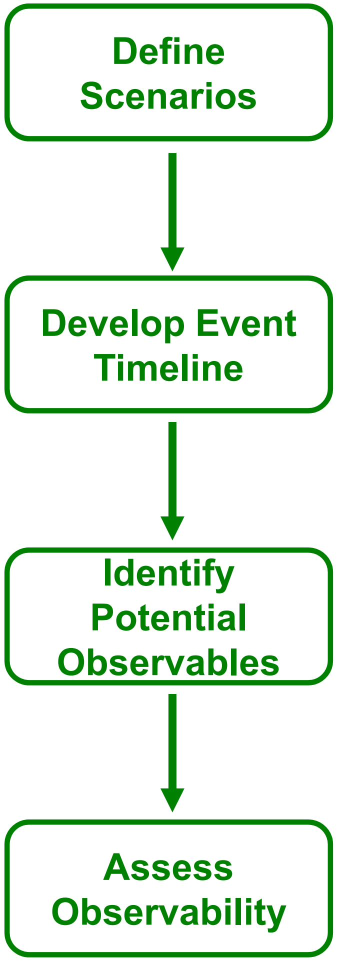
  - Earlier warning of attack (prior to CB release)

    Alert upon detection of early events in attack chain and watch for subsequent CB alarms

- **Demonstrate ability to estimate and predict plume propagation**
  - Ability to interpolate sensor readings
  - Ability to leverage information from contributing events (e.g., impact location; agent mass)

The fusion approach leverages the full attack event chain to determine whether or not a CB event is likely to be in progress and estimate severity

Sensor Utility Analysis



- **Representative CB attack examples**
  - Chemical and Biological
  - Covert and Overt
- **Enumerate steps to effect attack**
  - Preparation
  - Execution
  - Effects
- **Enumerate potentially observable phenomena**
  - Equipment (e.g., launchers)
  - Projectiles
  - Explosions
  - Clouds , etc.
- **Signature above background**
- **Sensor available to FOB**
- **Need for additional algorithms**
- **Scanning / Tasking capability**

Event Timeline – Rocket Attack MLRS Type with GB

Attack Preparation → Launcher Setup → Rocket Launch → Warhead Detonation → Cloud Propagation → Personnel Effects

Attack Preparation	Launcher Setup	Rocket Launch	Warhead Detonation	Cloud Propagation	Personnel Effects
T < -10 minutes	T > -10 minutes	T = -40 seconds	T = 0 seconds	T = 0 to 20 minutes	T = 0 to 30 minutes

Observable Signatures

Attack Preparation	Launcher Setup	Rocket Launch	Warhead Detonation	Cloud Propagation	Personnel Effects
• Agent / weapon acquisition • Agent/ weapon transport • Planning activity • Communications	• Launcher Transport • Launcher Installation • Personnel Activity • Launcher Onsite	• Rocket Launch Event (Projectile Exit) • Launch Flash • Thermal Effect • Projectile Motion	• Concussive Effects (Acoustic, Shock) • Visible Flash • Thermal Effects • Entrained Particulates (e.g., dust) • Shrapnel	• Vapor cloud (Chemical) • Droplet cloud (Chemical)	• Visible Effects on Personnel • Self Reported Effects on Personnel

Signature Detectability – Firefinder Radar
GB MLRS Rocket Attack

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• Agent / weapon acquisition • Agent/ weapon transport • Planning activity • Communications	• Launcher Transport • Launcher Installation • Personnel Activity • Launcher Onsite	• Rocket Launch Event (Projectile Exit) (Detectable by Design) • Launch Flash • Thermal Effect • Projectile Motion (Detectable by Design)	• Concussive Effects (Acoustic, Shock) • Visible Flash • Thermal Effects • Entrained Particulates (e.g., dust) (Potentially Detectable) • Shrapnel	• Vapor cloud (Chemical) • Droplet cloud (Chemical) Droplets not persistent	• Visible Effects on Personnel • Self Reported Effects on Personnel

Requires observable radar cross section

Detectable by Design
Potentially Detectable
Not Detectable

Sensor Recommendations

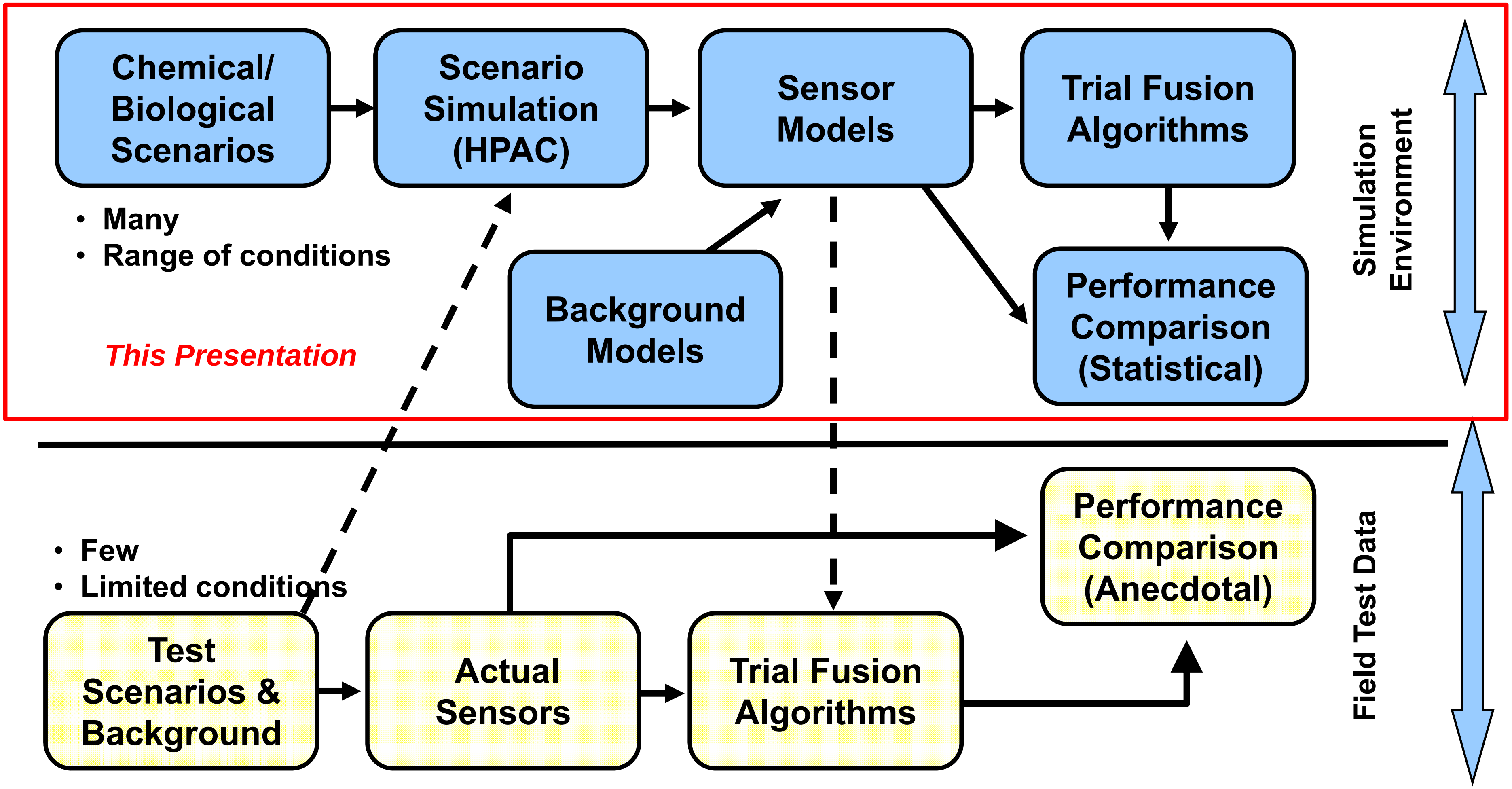
Sensor Class	Example Types
Firefinder radar	TPQ 36/37
Ground surveillance radar	ARSS, MSTAR
Acoustic	UTAMS, HALO
Chemical Point/Standoff	JCAD/JSLSCAD
Biological Point/Standoff	JBTDS; JBPDS/JBSDS
CB UAS/UGS	Chem/Bio Raven
Visible/IR Cameras	Orion, DefendIR HD
Intelligence	DCGS feeds

- **Covers contributing events and plume detection**
- **Emphasizes sensors likely to be available at medium to large FOBs**
- **More advanced sensors (e.g., hyperspectral or fast scanning backscatter LIDAR) likely in future implementations**

- **Most sensors support attack confirmation**
- **Early detection and characterization are covered less effectively**

Sensor Class	Early Detection	Confirmation	Characterization (Discrimination)
Radar	Firefinder Only	Ground Surveillance Only	
Acoustic/ Seismic	X	X	Possibly
Visible/IR		X	Possibly
CB Sensors	Standoff Only	X	X
Intelligence	X	X	

Structure of Fusion Test/ Simulation System



- **Near-term** emphasis on establishing a simulation environment to test sensor utility and fusion algorithm performance.
- **Medium-term** plan to validate with select test data

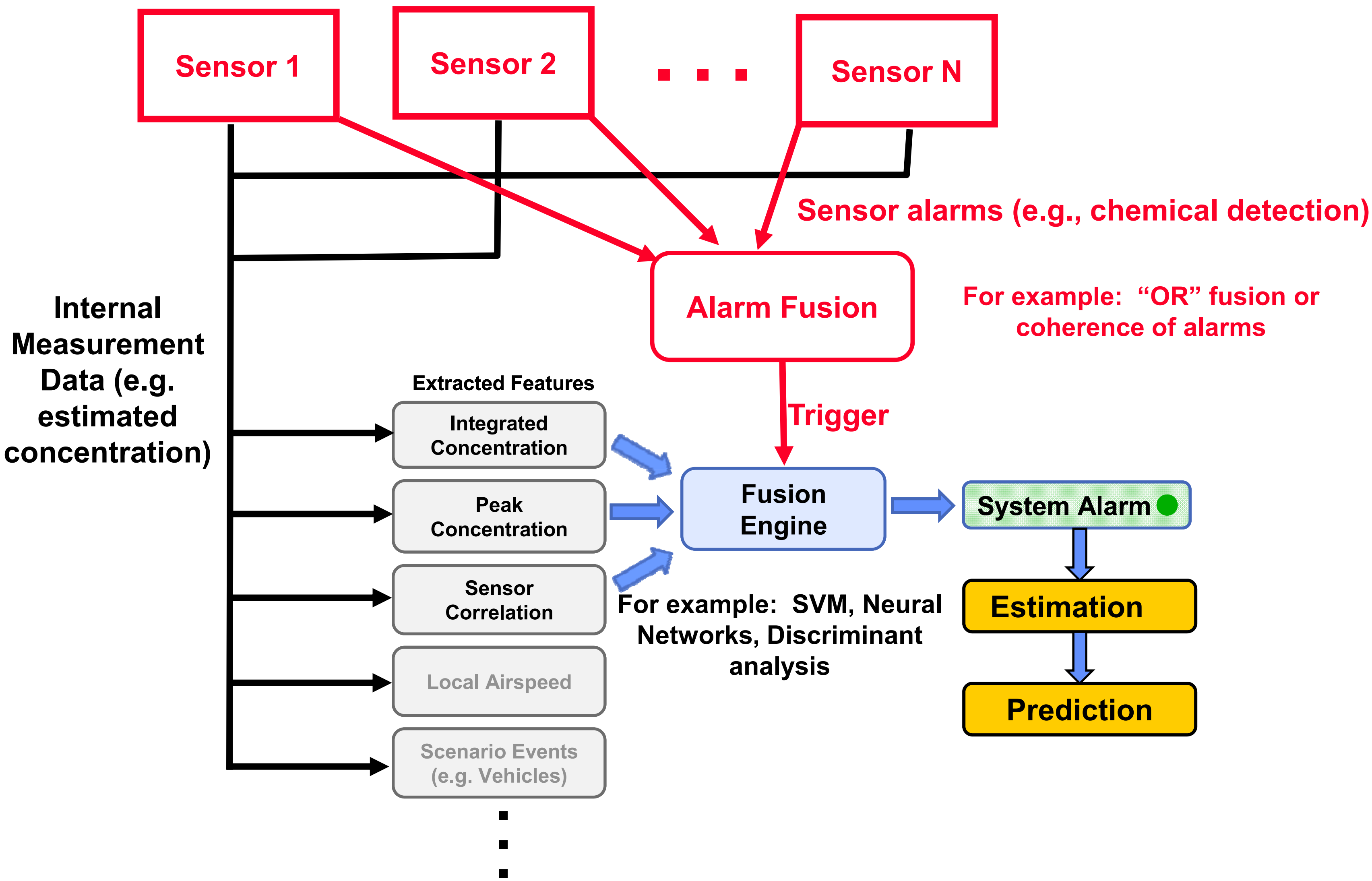
Initial Fusion Algorithm Overview

- **Classifier identifies "most-likely" attack**
  - Bayesian classifier modified by "time-window" rules
  - Based on sensor inputs and estimates of prior probabilities
  - Ranks selected attack scenarios by likelihood
  - Initial algorithm solely alarm-based

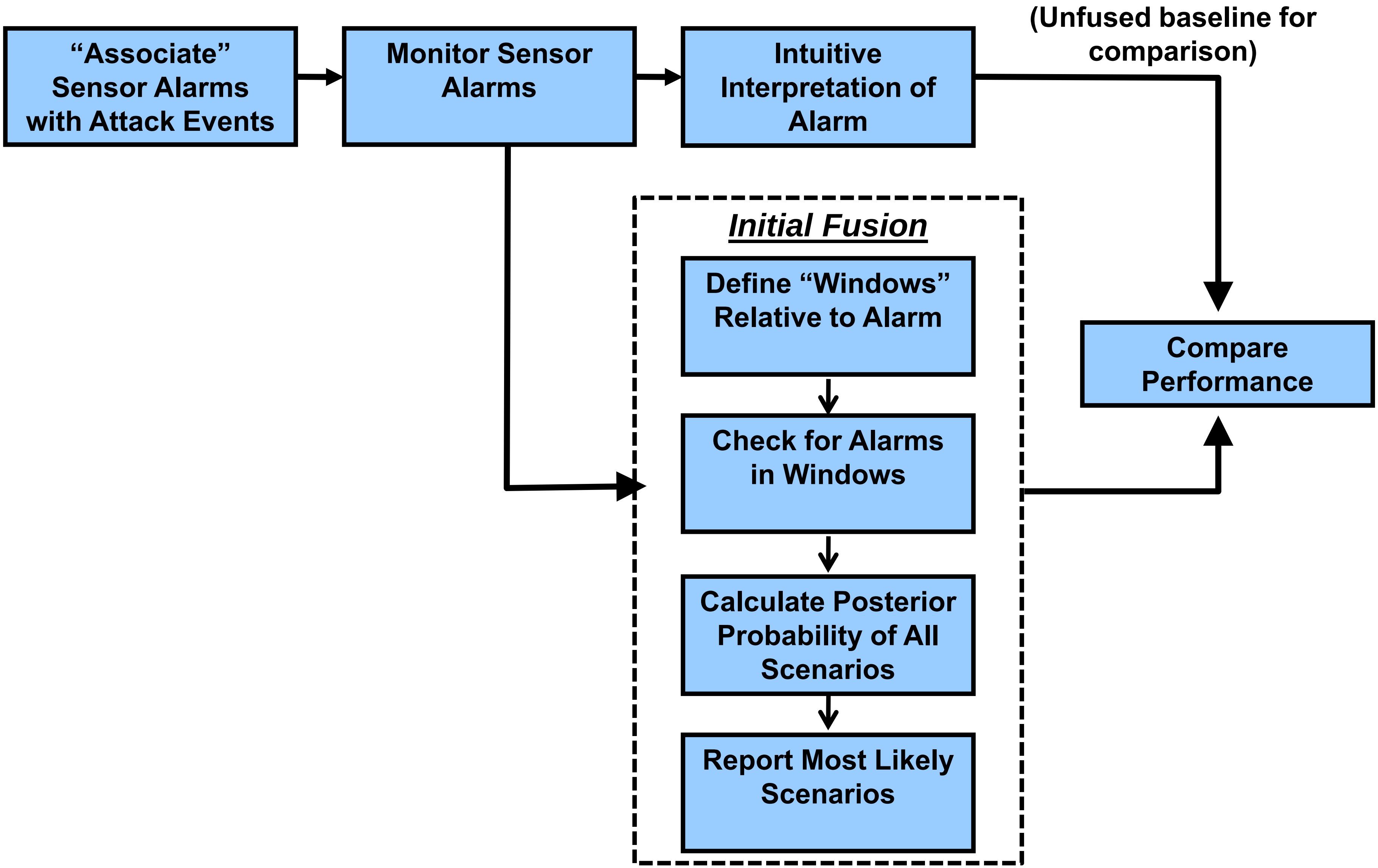
- **Estimation/Predication algorithm identifies area likely to be affected**
  - Predicts regions believed to be above a threshold concentration
  - Estimates "belief" in the contamination state
  - Refines estimates as more sensor information becomes available

Early algorithms provide capability with "look and feel" of more advanced fusion techniques

Alarm vs. Feature Based Fusion



Preliminary Fusion Algorithm Approach



Algorithm Performance

Intuition

Actual \ Classifier	No Attack	RAM (GB)	RAM (HE)	Truck Sprayer (VX)
No Attack	0.40	0.04	0.39	0.16
RAM (GB)	0	0.97	0	0.03
RAM (HE)	0.01	0.01	0.97	0.01
Truck Sprayer (VX)	0.02	0.01	0.04	0.93

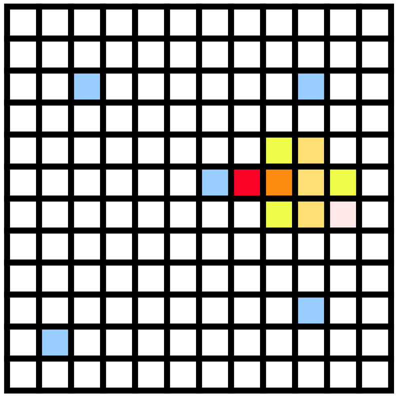
Bayesian Classifier

Actual \ Classifier	No Attack	RAM (GB)	RAM (HE)	Truck Sprayer (VX)
No Attack	0.93	0.00	0.06	0.01
RAM (GB)	0	0.99	0	0.01
RAM (HE)	0.01	0.00	0.99	0
Truck Sprayer (VX)	0.16	0.02	0.03	0.81

Bayesian classifier substantially improves performance

- *Enhanced identification of "No Attack" scenarios*
- *Some loss in ability to detect "Truck Sprayer"*

Agent Spread Estimator



- Sensor measurement or other information

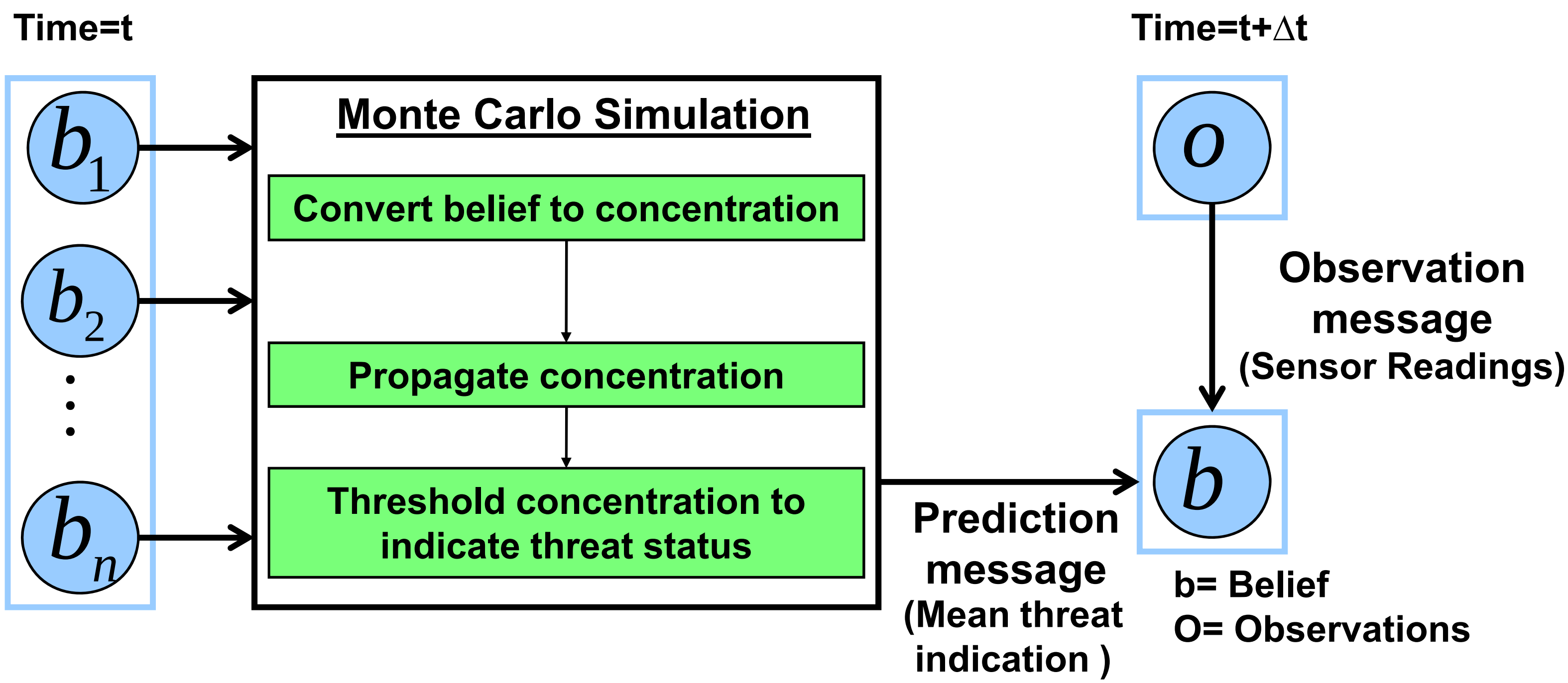
to - Relative belief

- Region of interest discretized into a uniform grid
- CB sensors detect threatening levels of CB agent
  - Binary alarms
  - Node concentrations not available
- Belief is the likelihood of a significant concentration of hazardous agent at each grid node
  - Likelihood is estimated from current observations and previous beliefs

Estimator/predictor provides the estimated "belief" over time that a particular node is above the sensor detection threshold

- **Basis to decide which areas are likely to have been affected**

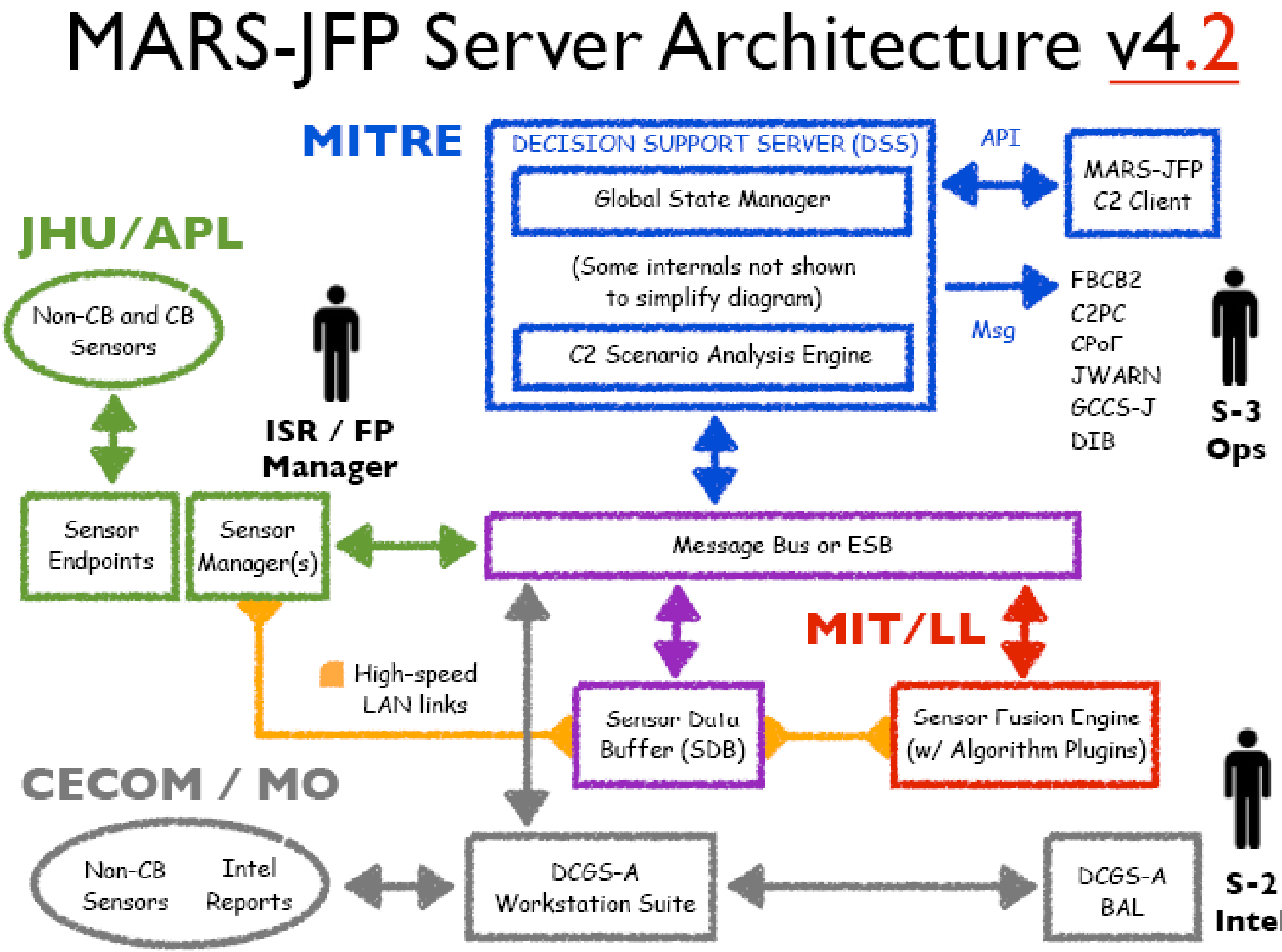
Belief Propagation Inference



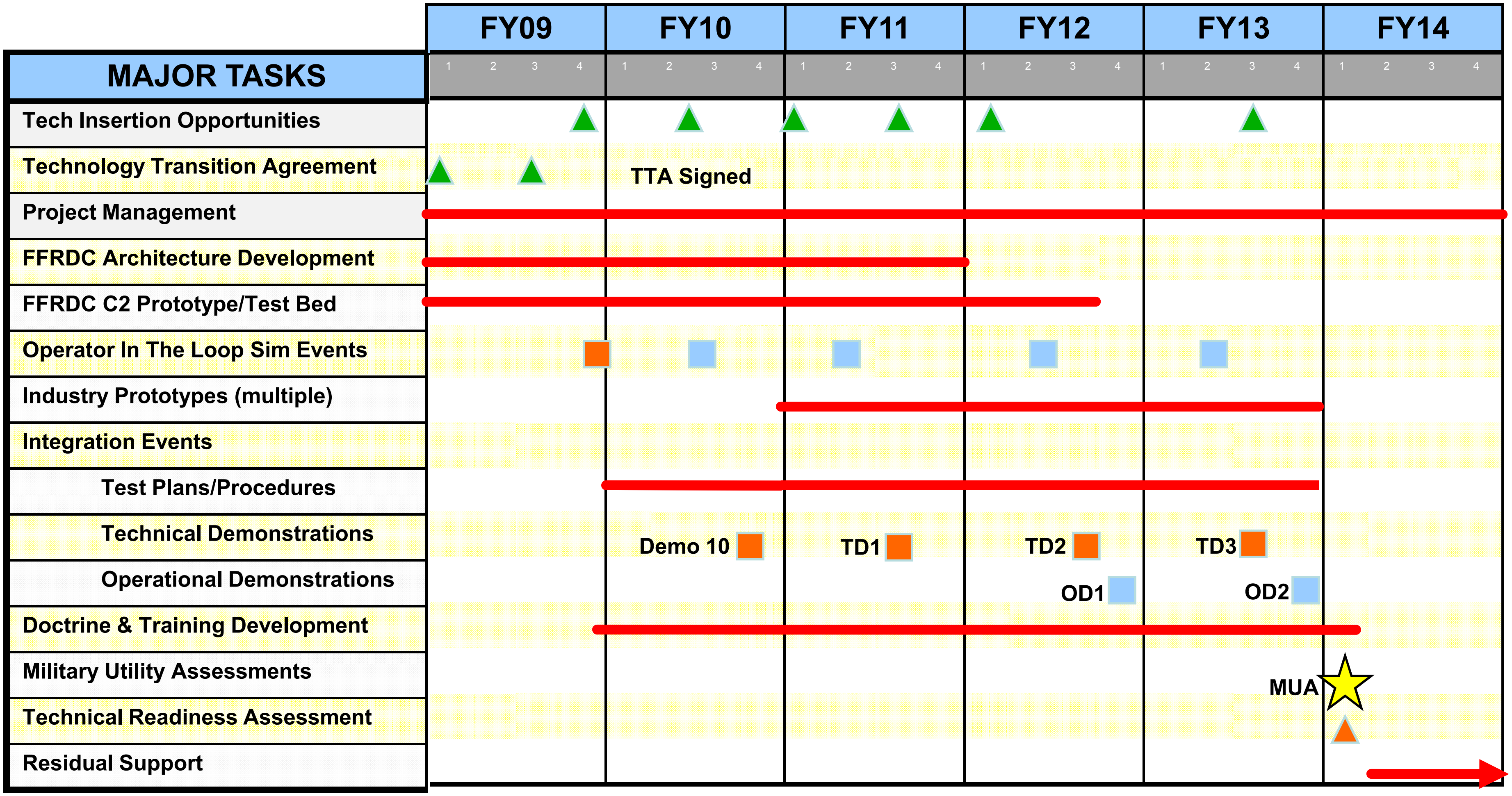
- **Belief is propagated based on <u>previous</u> belief and <u>current</u> observations**
  - **Current belief determined by a normalized combination of the propagated (predicted) belief and the observation result.**

Belief must be converted to concentration to apply dispersion models.

System Context



MARS-JFP Schedule



Path Forward

Future S&T Integration and Transition Opportunities

- **Capability Demonstration Integration**
  - Spiral updates to MARS-JFP prototype
    - Integration of enhanced fusion algorithms into overall demonstration system
    - Integration of broader range of actual and/or simulated sensor assets
  - Demonstrate system concept in simulated exercises (SIMEX)
  - Participate in future Field Tech Demo's (Empire Challenge, etc)

- **System Analysis**
  - Performance assessment methods
  - Identifying S&T projects for potential integration into MARS-JFP

- **System Level Test and Evaluation Capabilities**
  - Open air test grid challenges for wide area, cross domain, and mobile asset (UAS/UGV) assessments