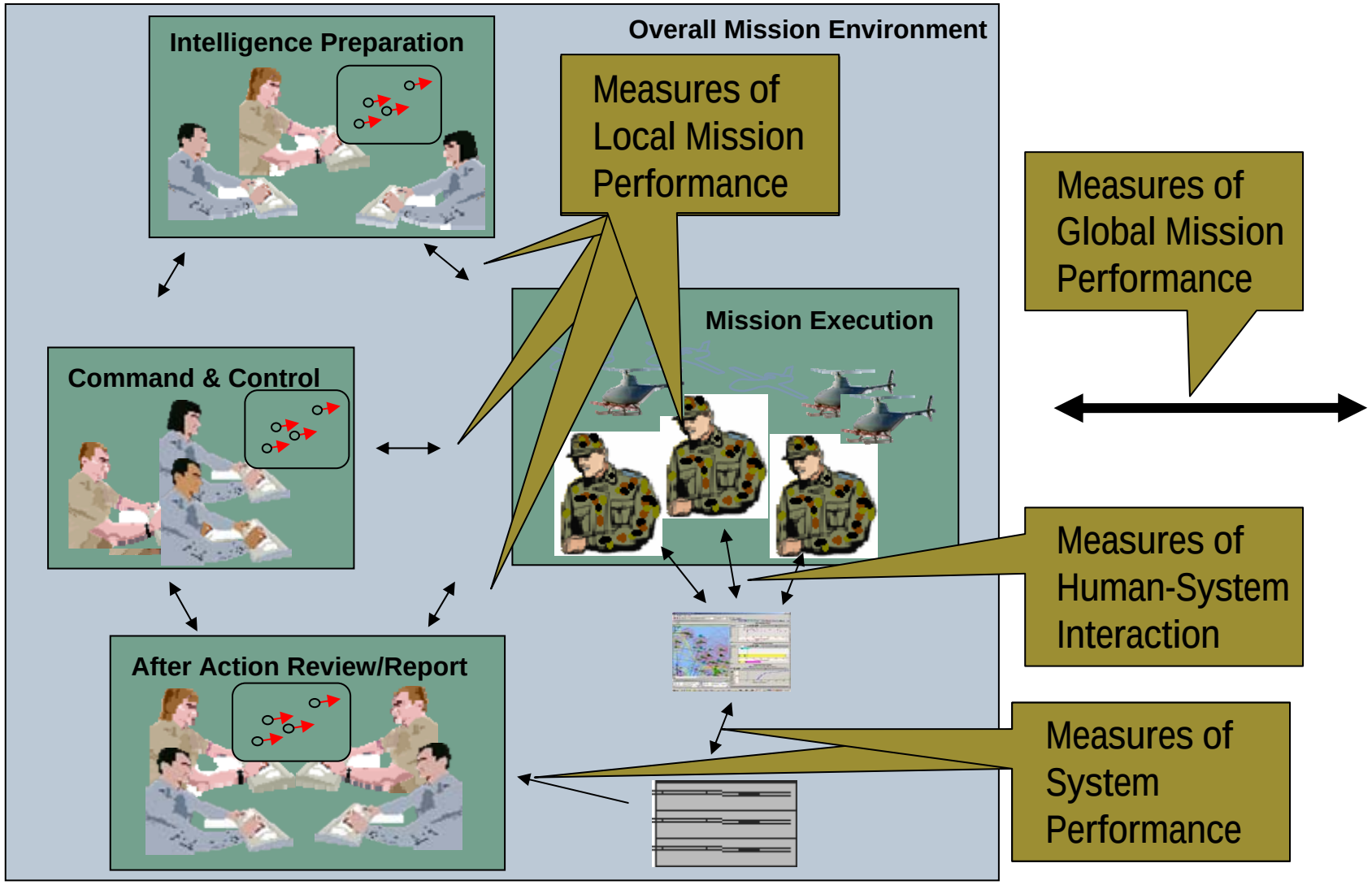
An Agent-based Approach to Evaluating the Impact of Technologies on C2

Stacy Lovell, Michael Linegang, Georgiy Levchuk

June 20, 2006

© 2006, Aptima, Inc.

Technology Evaluation for Complex Systems



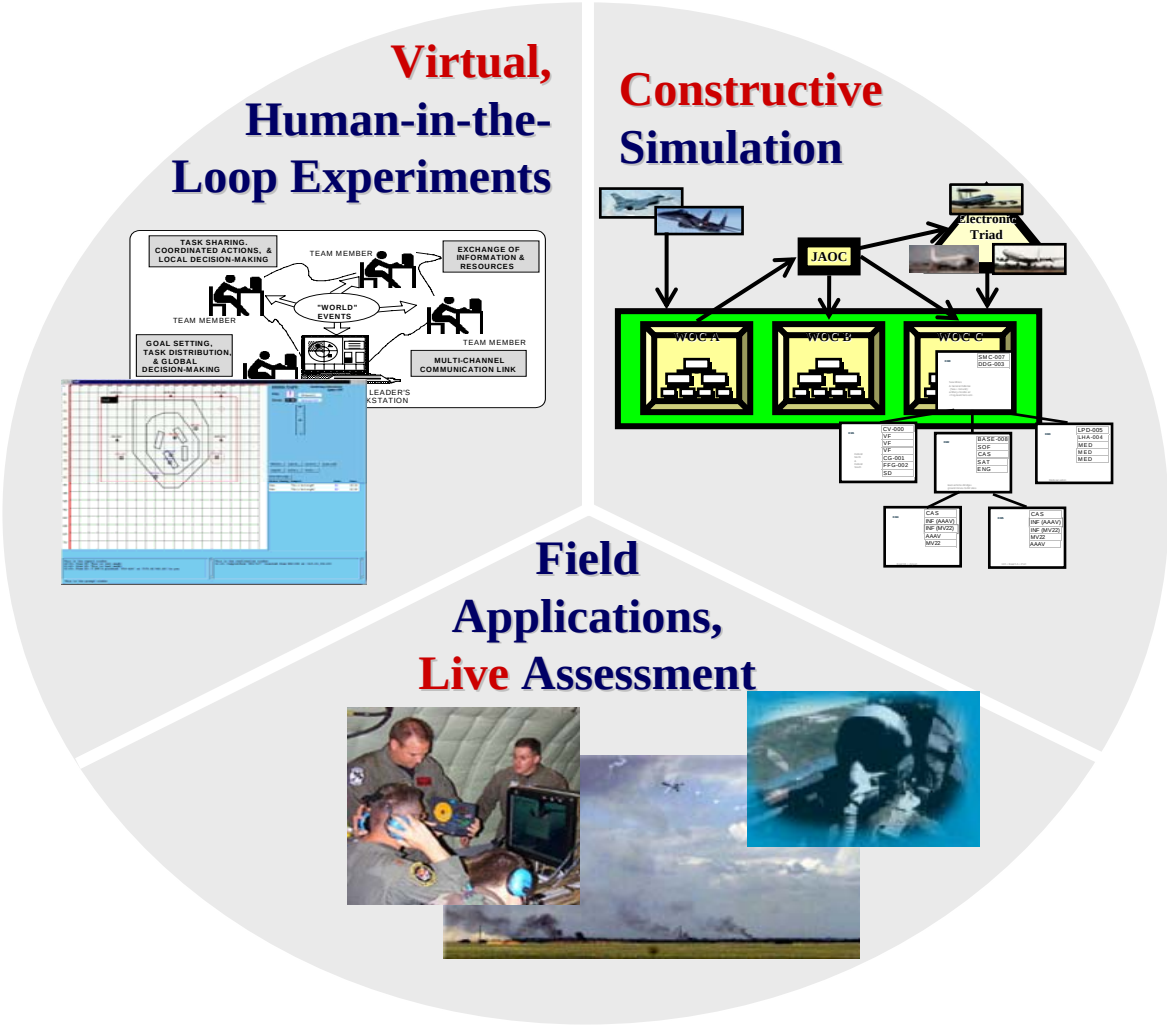
Impact of Technologies on C2

- Evaluate **operational structures**
  - Expectations for crew size and composition
  - Predictions for human-in-the-loop testing
  - What-if analysis for mission parameters
  - Initial training requirements
- Evaluate **organizational structures**
  - Optimized organizational structures and processes
  - Integrated organizational solutions
  - Additional crew and training requirements
- Evaluate **system design**
  - Link system design to operational requirements
  - Interface design
  - Performance metrics
  - Model early in the life cycle of human-machine system to guide human-in-loop testing and avoid costly redesign later

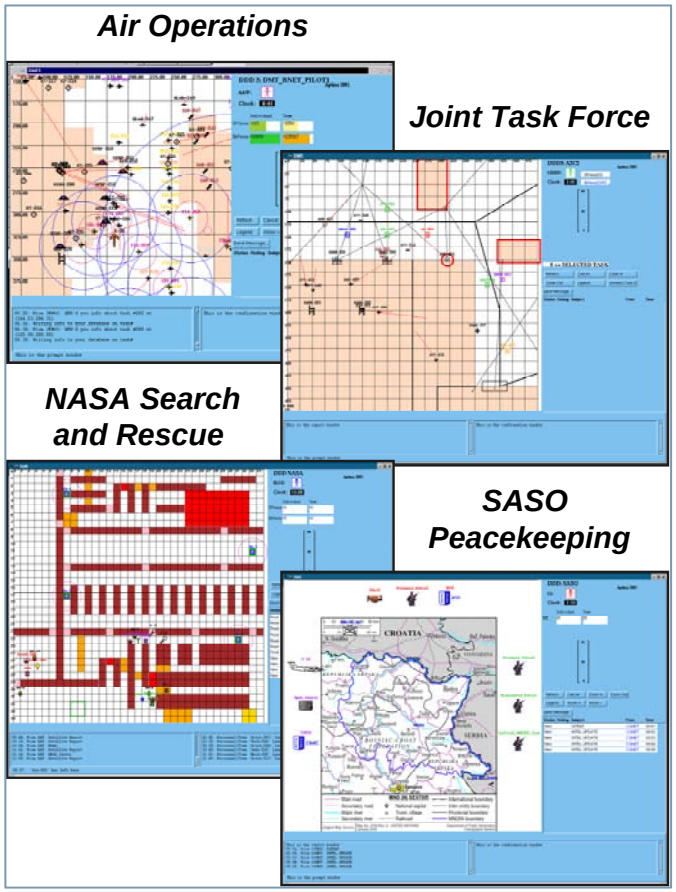
© 2006, Aptima, Inc.

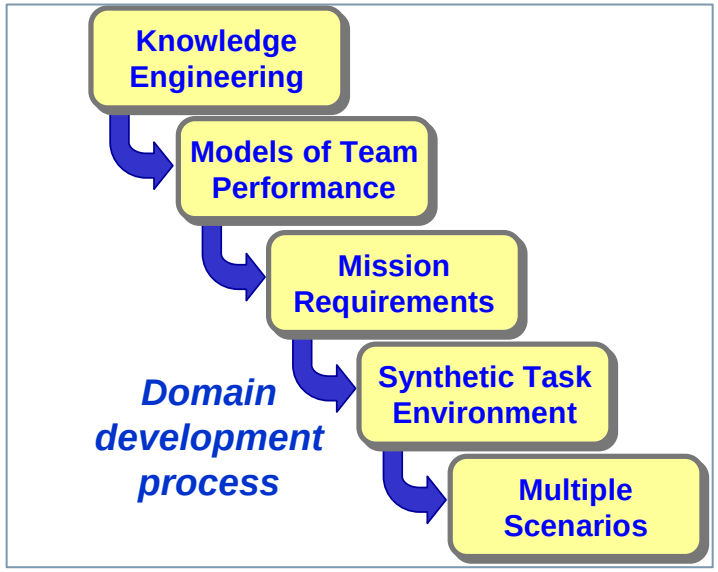
Approach

- Interdisciplinary Approach
  - Studying performance and processes of command and control organizations in all three domains of interest
- Measurement Expertise
  - Metrics' applicability and feasibility for various application domains
- Integration
  - Effort focused on direct interaction between field & simulation settings



Distributed Dynamic Decision-making Environment (DDD)



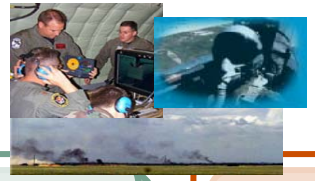


- Mid-fidelity distributed team-in-the-loop simulator
  - Control-realism balance
  - Capture the essential elements of many different team C2 tasks
  - Experiments in a number of different tactical environments
- Multiple uses
  - Performance research; Team training; Technology insertion effects; Agent-human calibration
- Basic constructs
  - Tasks, assets, resources, organization

© 2006, Aptima, Inc.

Mutual Interactions Between M&S and Field Experiments

Field Assessment



DDD Outputs

Focused field studies & technology decisions enabled by:

- Range of critical values (i.e., where technologies makes a difference)
- Large-N experiments (Statistical stability)
- Extensive technology sensitivity (vary packages & parameters) & TTP testing
- Impact of second-order factors

DDD Inputs

Improve parameterization of simulation:

- Durations & frequencies
- Locations of obstacles, targets, forces
- Adversary feasible actions & action-reaction behaviors
- Perf. parameters of technologies
- TTPs range & Rules of Engagement

DDD Simulations

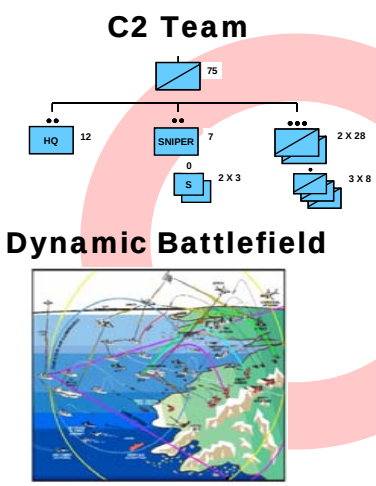
Assessment using DDD: Simulation Setup

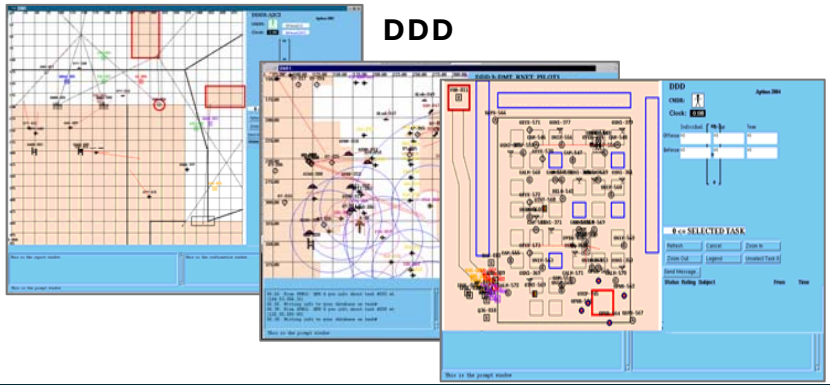
Real-world

- **BLUE Forces Organization**
- **Technologies parameters & TTPs**
- **Vignettes, missions, scenarios**

DDD Virtual Environment

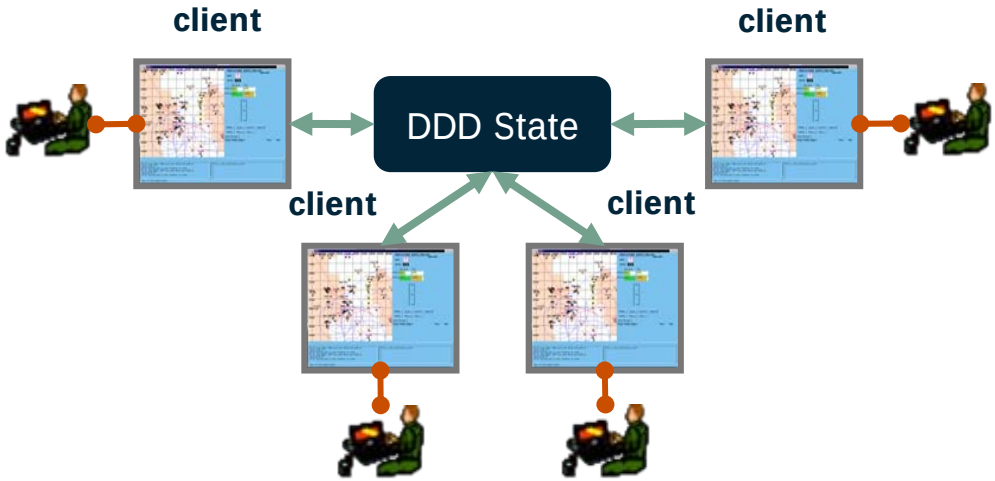
Real-world		DDD Virtual Environment	
BLUE Forces Organization	• SMEs input	• Commanders • Resources: Units, capabilities	Command Control Communication Information access
Technologies parameters & TTPs	• Tech specs • Table-top exercises • Life experiments	• Technology control & capabilities • Technology utilization rules	Maneuver constraints Capability Fuel, firepower Range (id, kill,…) Action delay
Vignettes, missions, scenarios	• SMEs input • Training docs	• Mission design: events, enemy actions, targets, mission tasks, attacks	Engage duration Appearance time —||— location Enemy maneuver Action/reaction

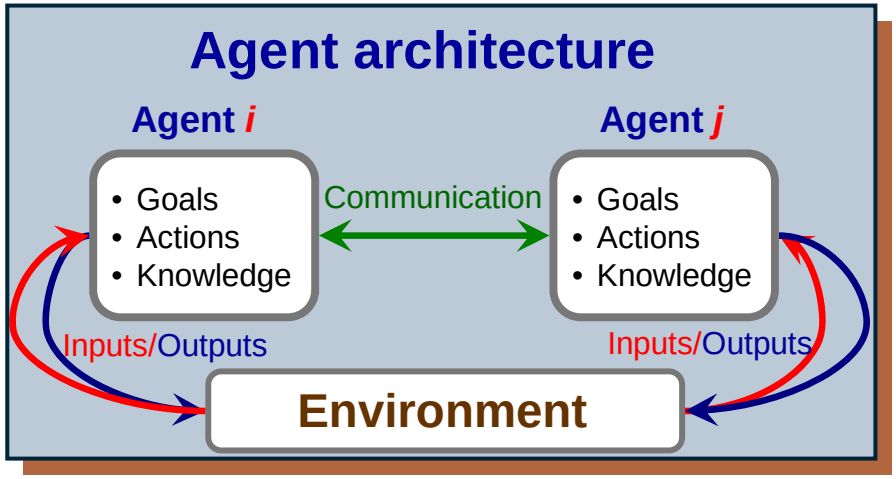




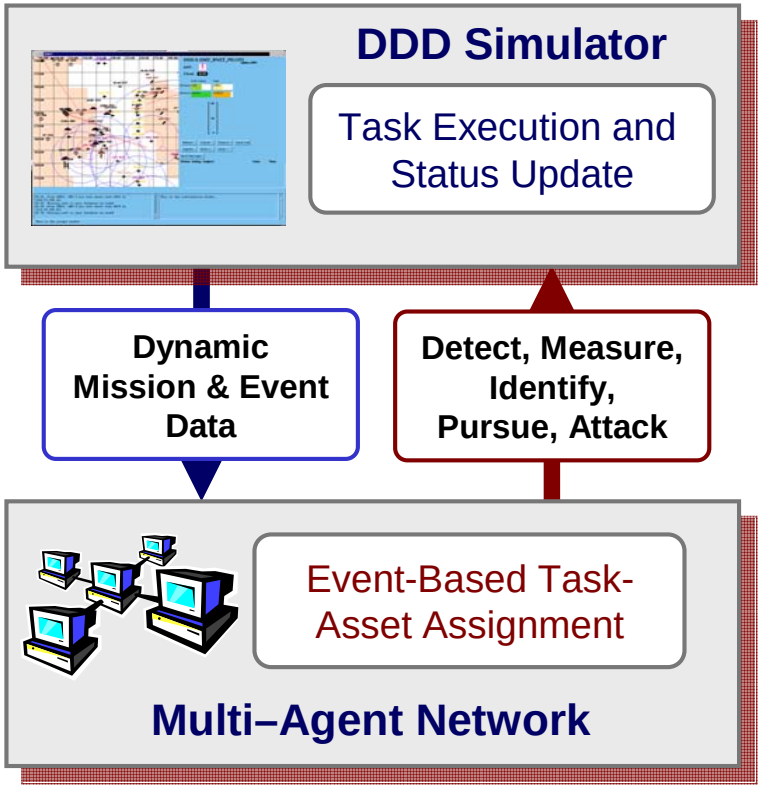
Agents and DDD: Integration

- **Mode-1:** Human in the loop
- **Mode-2:** Agent-based Simulations





Agent-DDD Interaction



© 2006, Aptima, Inc.

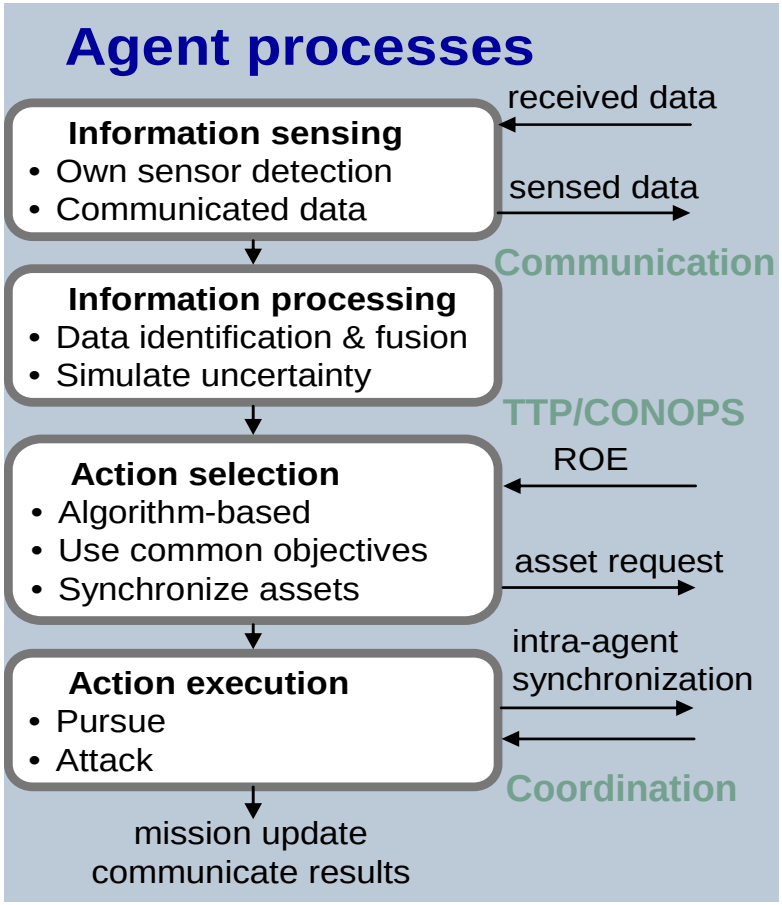
Agents and DDD: Decision Process

- Action Selection to maximize task value
  - Priorities of targets/tasks
  - Precedence of tasks & time window
  - Action impact

$$\text{task value} = \frac{(\text{task priority}) \cdot (\text{execution reward})}{(\text{time window})}$$

- Resource Allocation based on **greedy** search to minimize the cost
  - Capabilities/efficiency to execute selected task
  - Capabilities for the rest of the mission
  - Distance to / quickness in reaching the target (impact on task completion time)

$$\text{asset cost} = \frac{(\text{effect on task completion time}) \cdot (\text{capability for other tasks})}{(\text{capability per selected task})}$$



Assessment using DDD: Measures and Metrics

Technology Test Plan

- **Information Superiority**
- Sustainability
- Mobility
- Training
- Survivability
- Etc.

What to measure

Raw Data for measure calculation

DDD Simulation

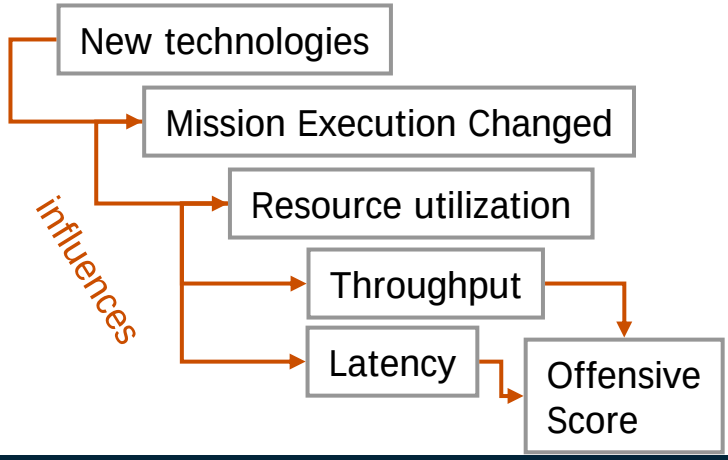
Log files data (who what when):
- Engagement times (**when**)
- Engagement classes & outcomes (**what**)
- Engagement parties (**who**)

- Interdependent measures

Simulation Measures

- Latency:
  - difference between event appearance and event execution
- Throughput:
  - number of executions per time (attacks, found entities)
- Gain/reward:
  - aggregated value from execution
- Defensive & offensive scores:
  - number of enemy/friendly attacks/destructions
  - enemy/friendly casualties
- Resource utilization
  - number of engagements

Dependencies



Scenario Assumptions & Simulation Setup

Scenarios:

- Missions vetted with SMEs, various tasks explored
  - Conduct area reconnaissance
  - Enter building & clear a room
  - Establish an observation post
  - Patrol a route
- Vignettes within missions (responding to high risk threats)
  - IEDs, VBIEDs, snipers, rockets, mortars, small arms fire, insurgent activities, etc.

Measures:

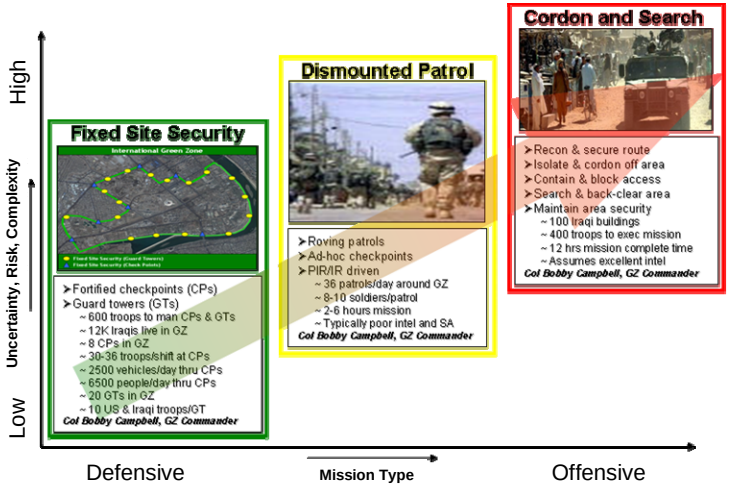
- Determined DDD and field experiment overlaps, independent metrics
  - DDD can not test battery life of equipment, field experiments can not test all possibilities

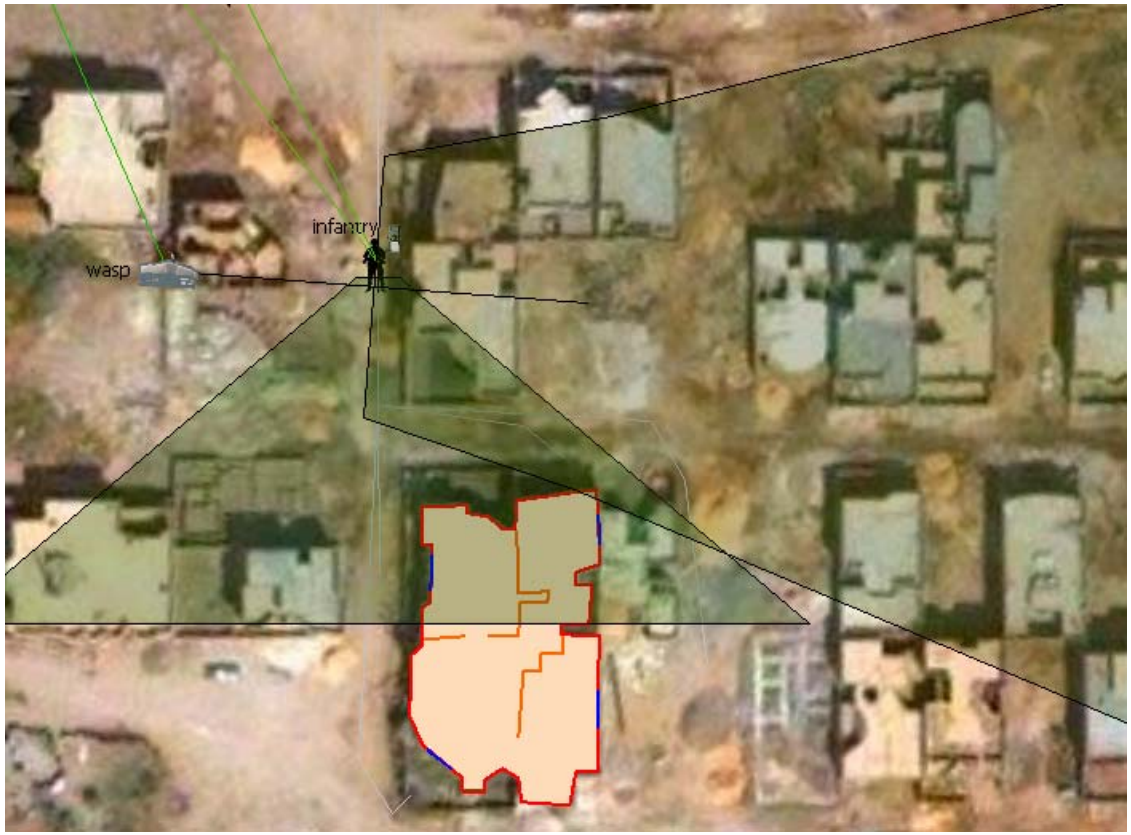
Technologies/TTPs:

- Determined relevant attributes which can be measured
  - i.e., average time to clear a room and average rate of movement using unattended sensor, MAV, etc.
- Obtained TTP for employment of technologies

© 2006, Aptima, Inc.

Scenarios and Simulation Examples

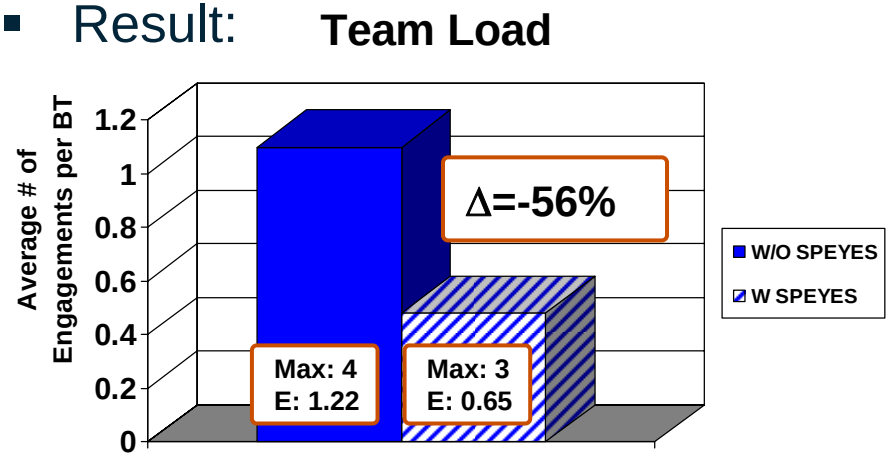




Example Question : Technology/workload effects

- Challenge:
  - Will utilizing sensing technology to secure buildings free up troops to accomplish other tasks?

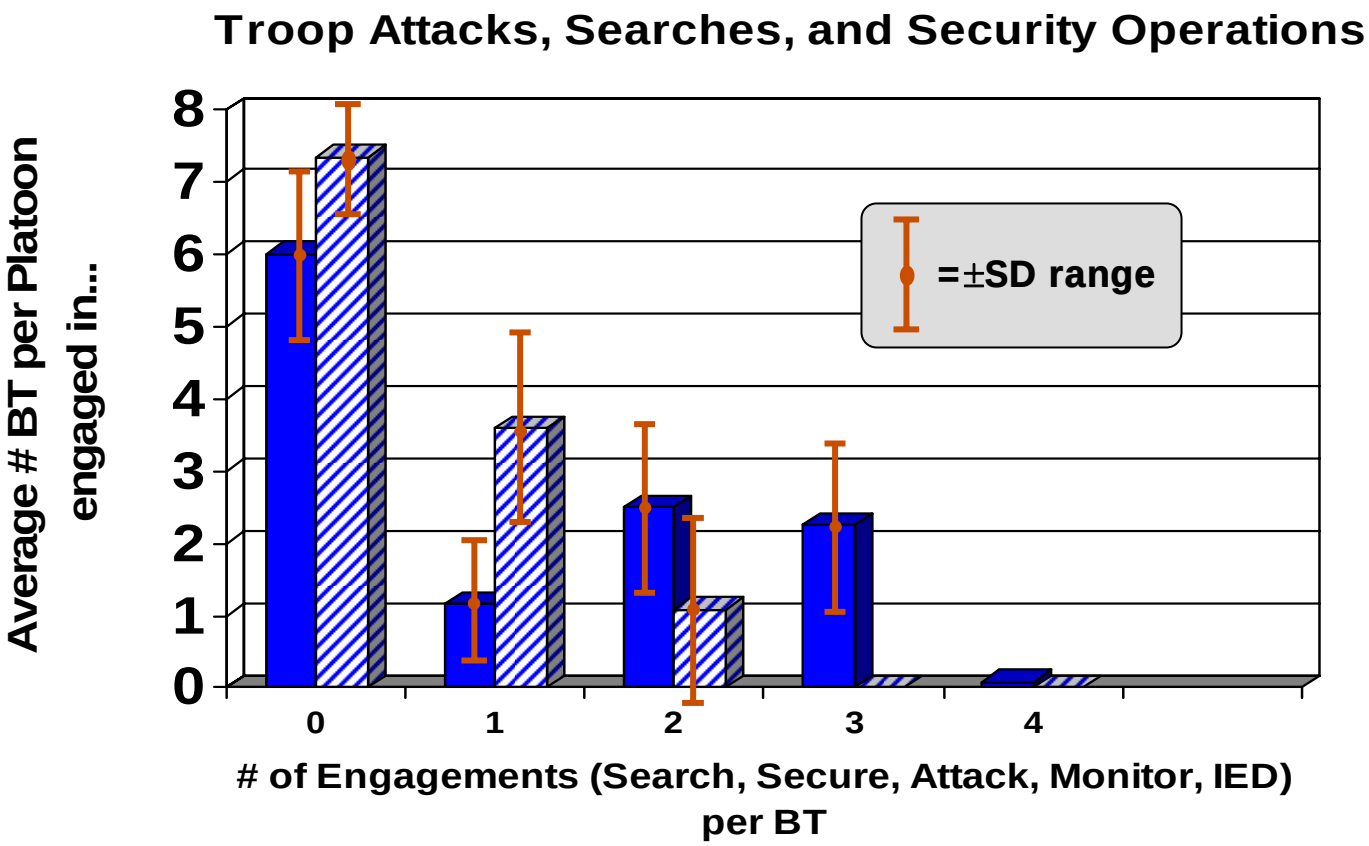
- Result:



- Scenario Parameters:
  - 2 sensors per buddy team
  - Utilized on average 2 sensors per building

- Comment:
  - Technology allows alternative resource employment to reduce load and increase number of executed tasks

Analysis Example : Potential Workload Reduction Assessment



Combinations of technologies help reduce troop workload

W/O Tech.

W Tech.

- # of BT per platoon: **12**

Implications:

- Generate analysis of effect of technologies on casualty reduction
- Field tests for alternative manning employment with technologies

Benefits of Agent-based Approach

- M&S Value
  - Can fulfill a key complementary role in the testing and evaluation of technologies and associated TTPs for C2
- Model Validation and Enhancement
  - DDD models, parameters, measures, and scenarios are adjusted to account for that which is learned in field experimentation
- Testing Technology Integration
  - Has the potential to test technology integration concepts before they are inserted in the field
- Sensitivity Analysis
  - Has the potential to explore through sensitivity analyses, the effects of performance improvements of the technologies on key MOP/MOE
- Field Experimentation Focus
  - Can support experiment design, staffing, technology use, & measurement and focus field studies on most relevant parameters

© 2006, Aptima, Inc.

Summary

- **Purchasing and funding decisions**
  - In terms of a viable solution, agent-based simulations predict that the technologies can improve local mission performance
- **Engineering decisions**
  - In terms of performance objectives, simulations provide baseline predictions of magnitude of performance improvements expected from these technologies
  - In terms of reliability, simulations assess different tasks and missions, providing insight about circumstances that may challenge systems

© 2006, Aptima, Inc.

Questions/Comments

Questions?

For more information contact:

Stacy Lovell
Aptima, Inc.
781.496.2462
slovell@aptima.com