



U.S. Army Research, Development and Engineering Command

Warfighter Associate: Decision Aiding and Metrics for Mission Command



TECHNOLOGY DRIVEN. WARFIGHTER FOCUSED.

Applied Systems Intelligence:
Army Research Lab:
CERDEC:

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- Software that offers assistance to users (collaboration, situation awareness development, and decision support) based on a model of tasks and task performance in a complex, dynamic environment
- An intent interpretation engine –observes user actions (along with the changing state of the battle-space) to infer goals and needs
- Helps in planning (what should be going on, given the situation)
- Knowledge engineering is a major part of the architecture – doctrinal and subject matter expertise, maintained separately from the executable, can be leveraged to help users dealing with tough problems
- Leverages 20+ years / \$30M of ongoing artificial intelligence and knowledge engineering work

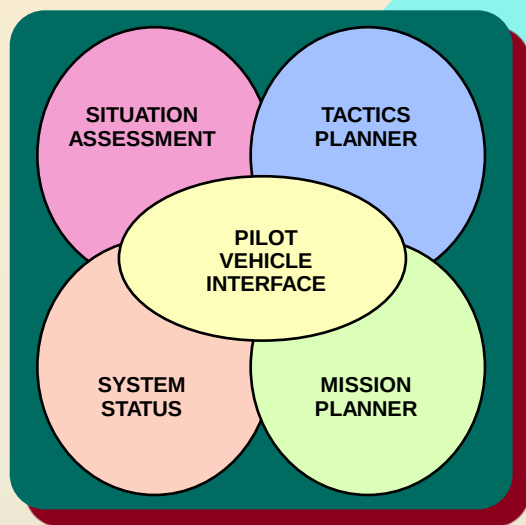


- A widely used command-and-control platform used in Tactical Operations Centers to synchronize/share work products and achieve a common operational picture
- Typically three displays per user duty station
- Training and use are challenging (annual training and field support budget around \$300 million)
- Busy screens, displays not always updated with current data, significant data / alerts not always there
- Cognition is distributed
 - Across individuals
 - Across teams (multi-team systems)
 - Across environments
 - Across artifacts

→ ***One-to-one human-system understanding does not scale directly to the human-networked system***



Pilot's Associate Concept



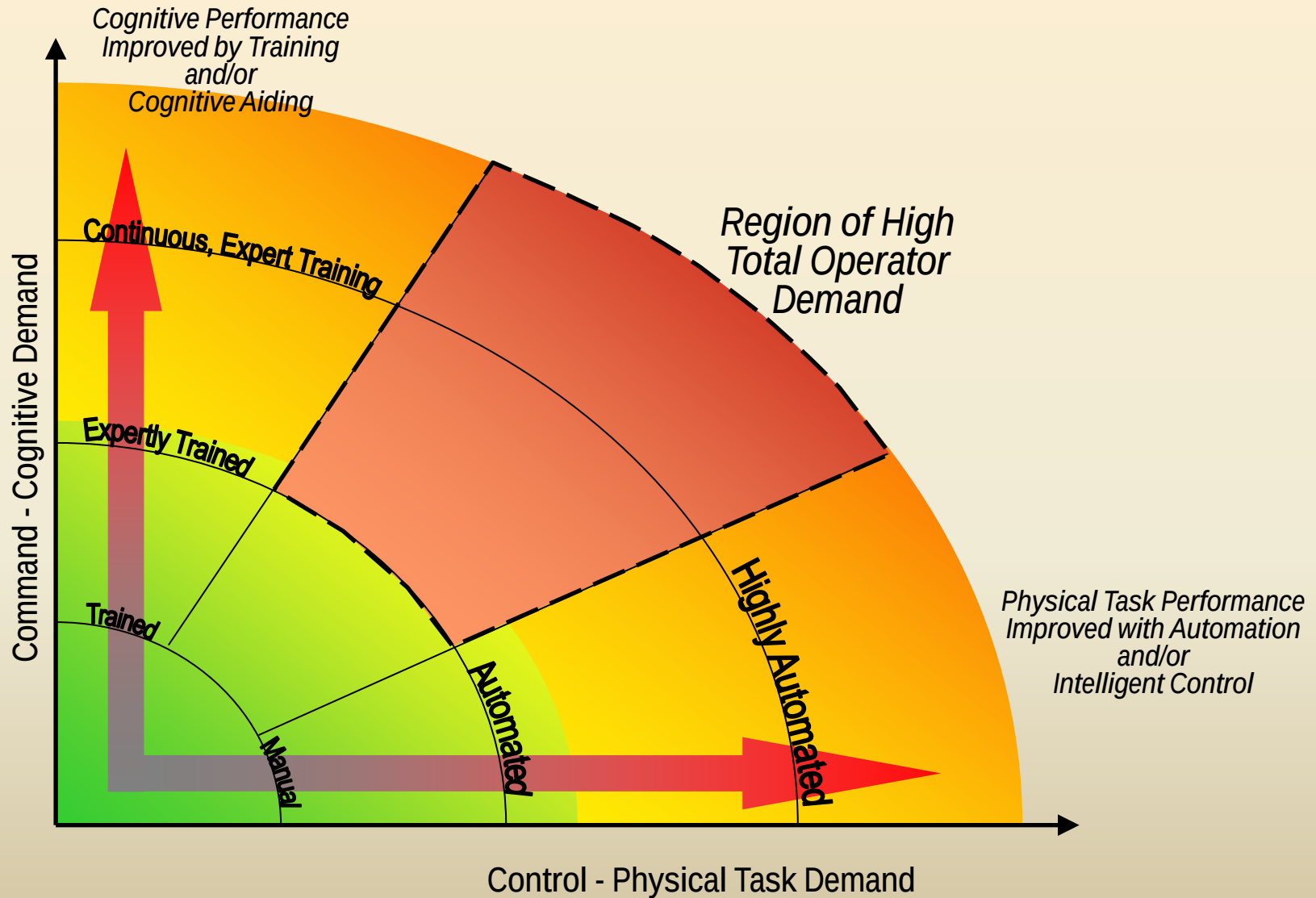
PILOT'S ASSOCIATE

**ENHANCED
SITUATIONAL
AWARENESS**

**BETTER
DECISIONS**



**IMPROVED
COMBAT
EFFECTIVENESS**



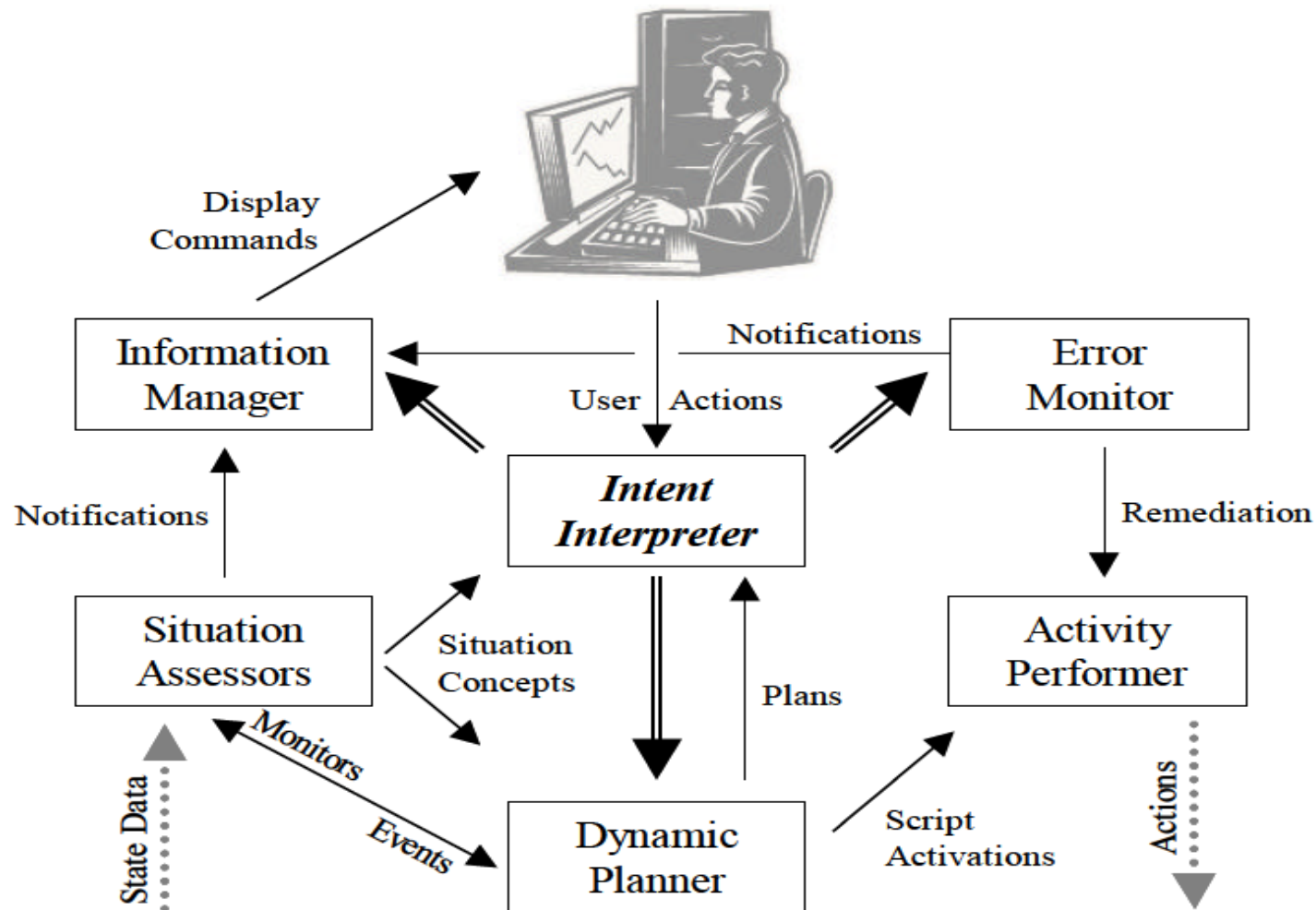
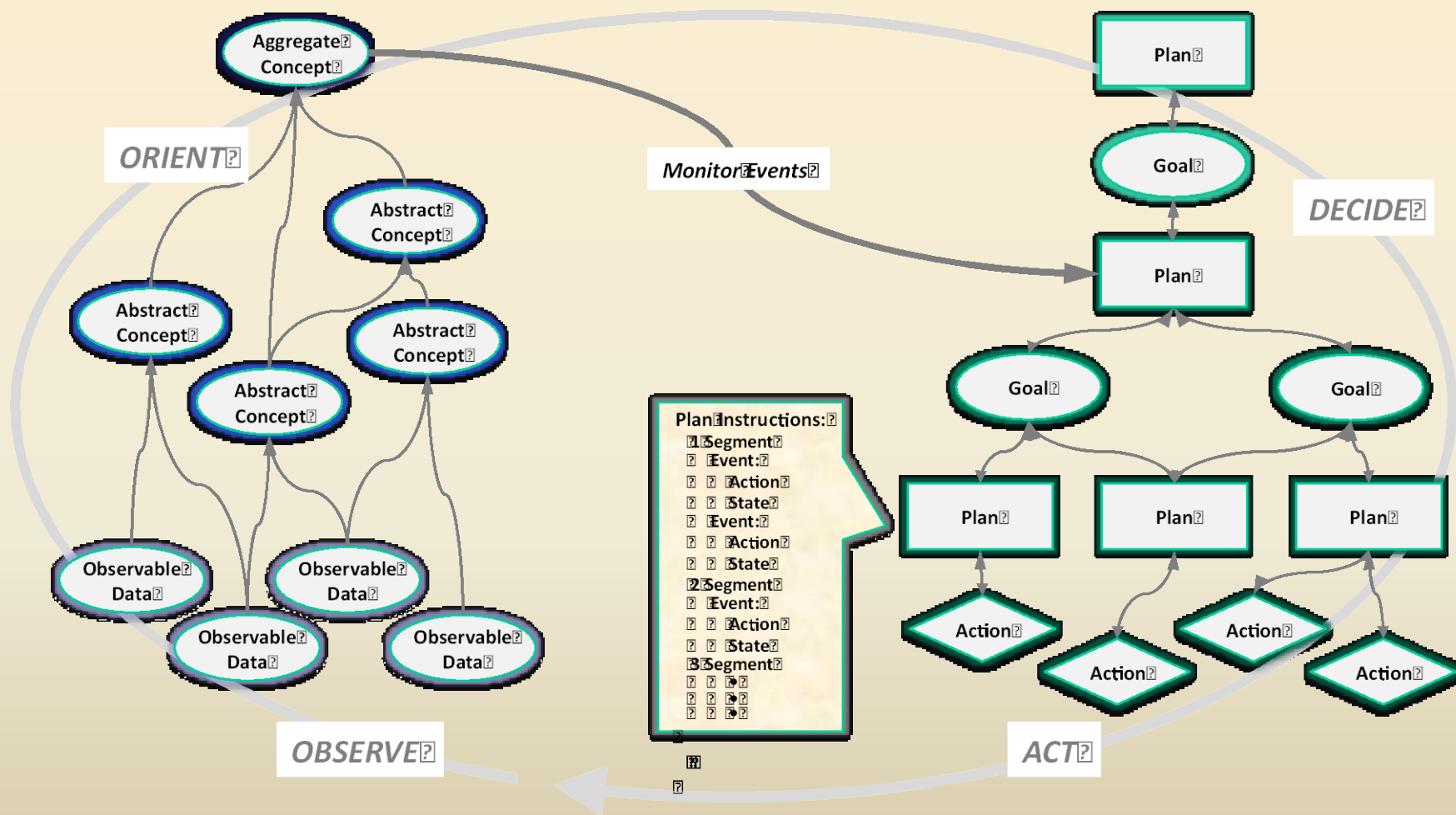


Figure 2—Primary Associate System Interactions



The OODA Loop





Warfighter Associate: What does it know?

- ✓ All normal doctrinal operations
- ✓ Troops in Contact
- ✓ Personnel Recovery/ downed aircraft
- ✓ MEDEVAC
- ✓ IED, VBIED, SVIED, P-IED
- ✓ CASEVAC
- ✓ POO/POI
- ✓ Airspace ROZ
- ✓ HVT
- ✓ ISR asset and management
- ✓ Unit boundaries
- ✓ Joint and coalition coordination
- ✓ Minefields
- ✓ Demonstrations
- ✓ Air Threat



- **Brigade Combat Team and Battalion Drills from Operation Iraqi Freedom / OEF**
- **Field Manual 3.0 Operations Feb 2008**
- Field Manual 5.0 The Operations Process Mar 2010
- Field Manual 7-15 The Army Universal Task List Mar 2005
- **Joint Publication 3.0 Joint Operations Feb 2008**
- Field Manual 6.0 Mission Command Aug 2003
- Field Manual Interim 3.24-2 (FM 90-8, FM 7-98) Tactics in Counterinsurgency Mar 2009
- 4IBCT 3ID KM_SOP Final 071630APR10
- 2009 Army Capstone Concept
- ARTEP 3-91-MTP BCT Battle CMD Staff 200507
- FM 3-24.2 TACTICS INCOUNTERINSURGENCY(FM 90-8, FM 7-98)APRIL 2009
- FM 7-0 TRAINING UNIT SAND DEVELOPING LEADERS FOR FULL SPECTRUM OPERATIONS FEBRUARY 2011
- FM 3-90 TACTICS
- FM 1-02 OPERATIONAL TERMS AND GRAPHICS DEPARTMENT OF THE ARMY SEPTEMBER 2004
- 1st AIR CAVALRY BRIGADE TACSOP 01 JUL 08
- DOD MIL-STD-2525C INTERFACE STANDARD COMMON WARFIGHTING SYMBOLOGY 17 NOVEMBER 2008
- GTA 21-08-002 Basic Combat Training Smart Card APRIL 2008
- **Knowledge from Roles from FCS program- 22 completed roles from squad to Company level. 118 incomplete roles.**



Plan-Goal Graph (PGG). The goals, plans and actions that describe the causality of a domain are linked together in a directed graph.

- o Top-level nodes of the graph are abstract goals, which are linked to abstract sub goals. These are then linked to more concrete plans that might achieve them.
- o The bottom-most input nodes are the primitive actions.

Intent Interpretation. Proceeds by attempting to find a path through the Plan-Goal Graph (PGG) from an action to a plan or goal instance that has previously been inferred.

- o **Bottom-up** algorithm for intent interpretation (observe user actions)
- o **Top-down** planning/concepts (what should be going on, given the situation)
- o Missing node instances needed to form the path are created hypothetically as the path is discovered.
- o Intentions provide the **context** for decision-support to provide alerts and critical information requirements to the operators.



A dynamic real-time model of intentions provides mission command with the ability to engage in high up-tempo operations with support for planning and plan execution and fault tolerance. It fosters a richer human-computer collaboration and addresses the complexity of mission command systems.

- **Focus of attention for assessment**. Intent can be used to determine the critical aspects of the environment to be monitored and assessed to support dynamic planning and plan execution.
- **Control of distributed planning and execution**. Gives mission command greater control over dynamic planning and plan execution.
- **Conflict detection and resolution**. Intentions can be used to detect potential conflicts before they appear in execution.
- **Information management**. Intent provides a basis for proactive dissemination of relevant information to the tactical edge and to coalition partners.
- **Discrepancy analysis and remediation**. Intentions are essential to identifying discrepancies in planning and in execution, and in determining the best means for error correction.
- **Agile Development of Knowledge**. The underlying knowledge can be easily modified to reflect new constructions of operational knowledge. Allows for a complete audit trail to support the evolution of domain-knowledge.

- The Plan Goal Graph (PGG) is a directed graph that holds the goals, plans, and actions that describe domain causality
- The Concept Node Graph (CNG) holds the model of the battle space – reported information from sensors, data feeds, command and control system messages, etc.
- These graphs encapsulate the knowledge from 18 Army publications, including field manuals, standard operating procedures, and written guidance from operations in Iraq and Afghanistan.
- Graphs also contain subject matter expertise on the best responses to high-intensity events (e.g., demonstrations, person of interest sightings, multiple IEDs, etc.) that are not recorded in formal publications.
- As the executable runs, the currently active nodes in the PGG and CNG are noted and saved. The active nodes states can be analyzed to show several potential cognitive metrics



A **campaign of experimentation** is not just a collection of experiments but involves a series of steps in moving from concepts to capabilities and hypotheses to understandings. *(Alberts & Hayes, 2007)*

- **Goals** The goal is experimentally address the usefulness of prototype technologies that could be used to assist battlefield commanders and their mission-command staff in the development of situational awareness, decision making, and collaboration.

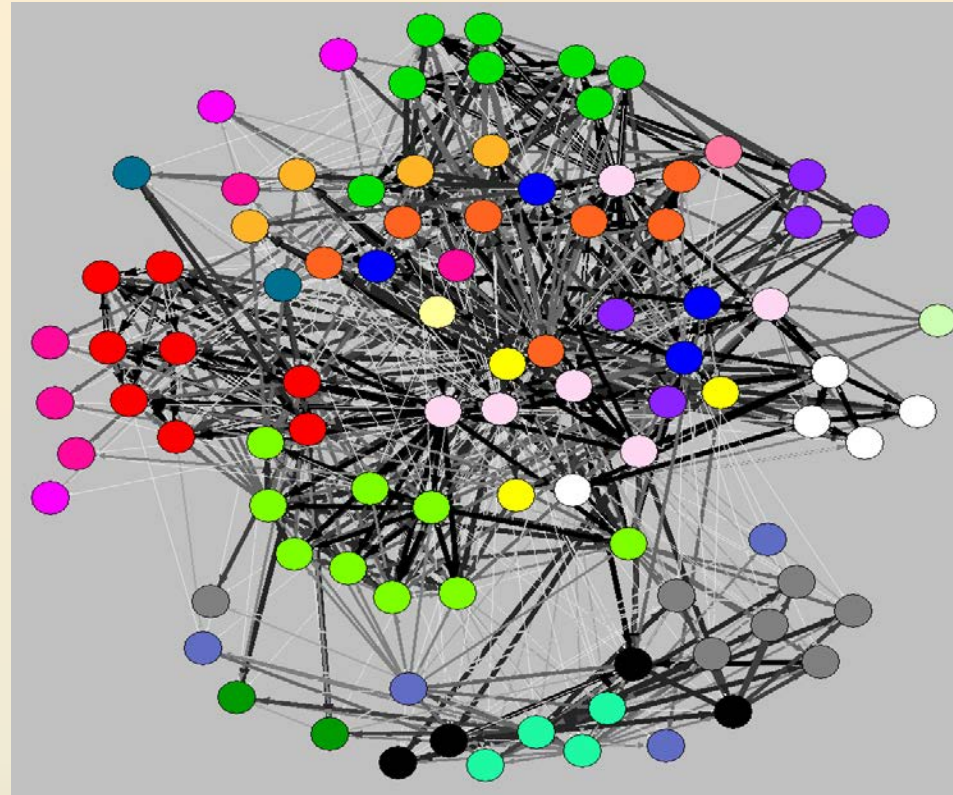
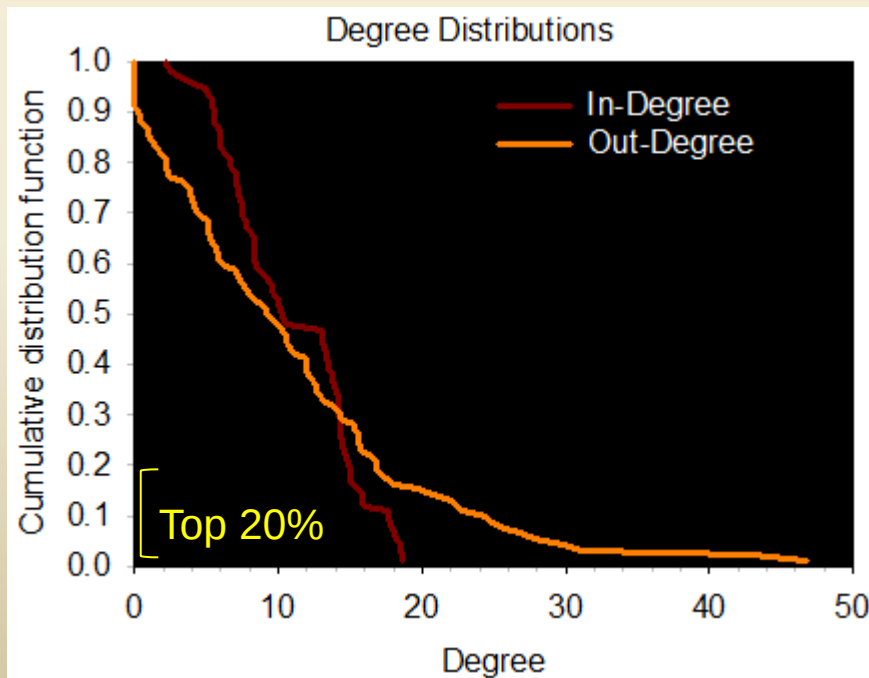
- **Reduction of data clutter**
- **Optimization of data relevance**
- **Decision aiding and improved situation awareness (SA)**
- **Synchronization of teams and collaboration**



Field Study – FY10-FY11

- **Field Study:**

- **Network Science:** used graph theoretic approach to examine mission-command collaborative information flows. Metric was the number of self-reported mission-critical collaborations over a two-week military exercise.



- **Degree Distributions:** highlights the Pareto Principle -- the top 20% of the mission-command staff is heavily involved in collaborations.
- Our experimentation plan focuses on providing decision-support to three of those individuals: **S3** (maneuver), **S2** (intel), and **FSO** (fires)

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Experimental Validation of Prototype Technology:

between-group experimental design:

- CPOF alone (baseline)
- CPOF with the Warfighter Associate

Metric Development: The Warfighter Associate can also be used to develop useful metrics of performance rooted in an analysis of the workflow (activation of goals, plans, and concepts):

- cognitive workload (objective measure)
- currently active plans & goals
- timing to complete tasks
- necessary collaborations (shared plans & goals)



Data Analysis Tools and Metric Development

- **Instance Viewer**: shows currently active nodes in the unified Plan-Goal-Graph (PGG) and Concept Node Graph (CNG) for each running instance of the Warfighter Associate.
 - **Heat Map**: view work activity as a PGG '*heat map*' summed over epochs.
 - **Cognitive Workload**: yields the number of concurrently active PGG nodes over a time frame.
- **Log Analyzer**: captures PGG instance start and stop times, monitor events, and notification events for each running instance of the Warfighter Associate.
 - **Task Completion Timing**: automated metric.
- **Shared Event Analyzer**: captures the time and content of each shared PGG and CNG node instance and display a representation of the shared events between multiple WA Instances.
 - **Force Synchronization**: metric reflecting the timely co-activation of essential tagged PGG nodes by collaborators in response to shared significant events (e.g. battle drill) and across time.
 - **Collaborative Information Flows**: method to tag hypothesized collaborative information flows on the PGG (as input and output arrows) and metric to assess whether they were supported.



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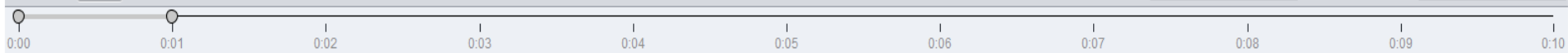
Applied Systems Intelligence

Open Config Save Config Manage Select Associates ☒ Real Time ? Help

[Graphs](#)
[Reports](#)
[Charts](#)
[Configuration](#)

Heatmap: ☒ Count ☐ Commonality ☐ Recentness

PGG Node Search: (select node) CNG Node Search: (select node)



 Add Bookmark
 (no bookmark set)
 Remove Bookmark

FSO - Actions On IED

OM_928991	
PatternName	Actions On IED
unitId	1-74 HBCT
reportId	EA1322931731-1
Parents:	Each Threat Managed - OM_928896
Children:	none

S2 - Each Threat Managed

S3 - Each Threat Managed

[illegible]

 Add Bookmark
 (no bookmark set)
 Remove Bookmark

FSO - Enemy Position Report

lon	-110.334
readiness	FMC
observedTime	09-22-2011 19:13:40
callSign	IED
source	cpof
description	unset
Parents:	Enemy Unit - IED1
Children:	none

S2 - Enemy Position Report

S3 - Enemy Position Report



Graphs Reports Charts Configuration

Timeline	Associate	Start Time	Update / Stop Time	Duration	Name	Attributes	Type	Lifecycle State
Commonality	FSO	12-03-2011 11:59:48 Slider: 0:00.02	---	ongoing	Active Activity Based P...	• Instancelid: Demonstration • activity: Demonstration • name: Demonstration • etiov: 0 • ltiov: 1999999999 • status: unsatisfied • isActive: 1	Concept	Current
Output	FSO	12-03-2011 11:59:48 Slider: 0:00.02	---	ongoing	Active Activity Based P...	• Instancelid: Downed Aircraft • activity: Downed Aircraft • name: Downed Aircraft • etiov: 0 • ltiov: 1999999999 • status: unsatisfied • isActive: 1	Concept	Current
Sharing	FSO	12-03-2011 11:59:48 Slider: 0:00.02	---	ongoing	Active Activity Based P...	• Instancelid: IED • activity: IED • name: IED • etiov: 0 • ltiov: 1999999999 • status: unsatisfied • isActive: 1	Concept	Current
	FSO	12-03-2011 11:59:48 Slider: 0:00.02	---	ongoing	Active Activity Based P...	• Instancelid: IED Assembly Point Transport • activity: IED Assembly Point Transport • name: IED Assembly Point Transport • etiov: 0 • ltiov: 1999999999 • status: unsatisfied • isActive: 1	Concept	Current
	FSO	12-03-2011 11:59:48 Slider: 0:00.02	---	ongoing	Active Activity Based P...	• Instancelid: IED Cache • activity: IED Cache • name: IED Cache • etiov: 0 • ltiov: 1999999999 • status: unsatisfied • isActive: 1	Concept	Current
	FSO	12-03-2011 11:59:48 Slider: 0:00.02	---	ongoing	Active Activity Based P...	• Instancelid: IED Construction • activity: IED Construction • name: IED Construction • etiov: 0 • ltiov: 1999999999 • status: unsatisfied • isActive: 1	Concept	Current
	FSO	12-03-2011 11:59:48	---	ongoing	Active Activity Based P...	• Instancelid: IED Cross Border Transport	Concept	Current



Show:

- ☒ Associate
- ☒ Start Time
- ☒ Update / Stop Time
- ☒ Duration
- ☒ Name
- ☒ Attributes
- ☒ Type
- ☒ Lifecycle State

Include:

- ☒ Plans
- ☒ Goals
- ☒ Concepts

Filter rows:



Chart Type: **Count** Sharing

Event Analyzer

Plans:

- Actions On Contact
- Actions On Demonstration
- Actions On Insurgent Leader
- Actions On POI
- Actions On POO
- Actions On Potential IED
- Avoid Enemy Unit Activity
- Capture Insurgent Leader
- Complete Mission Phase
- Complete Personnel Recovery Mission
- Conduct Search Using Own Equipment
- Coordinate Fires
- Coordinate For Intel With Higher And Lower Echelon
- Coordinate For Most Appropriate Equipment For Task

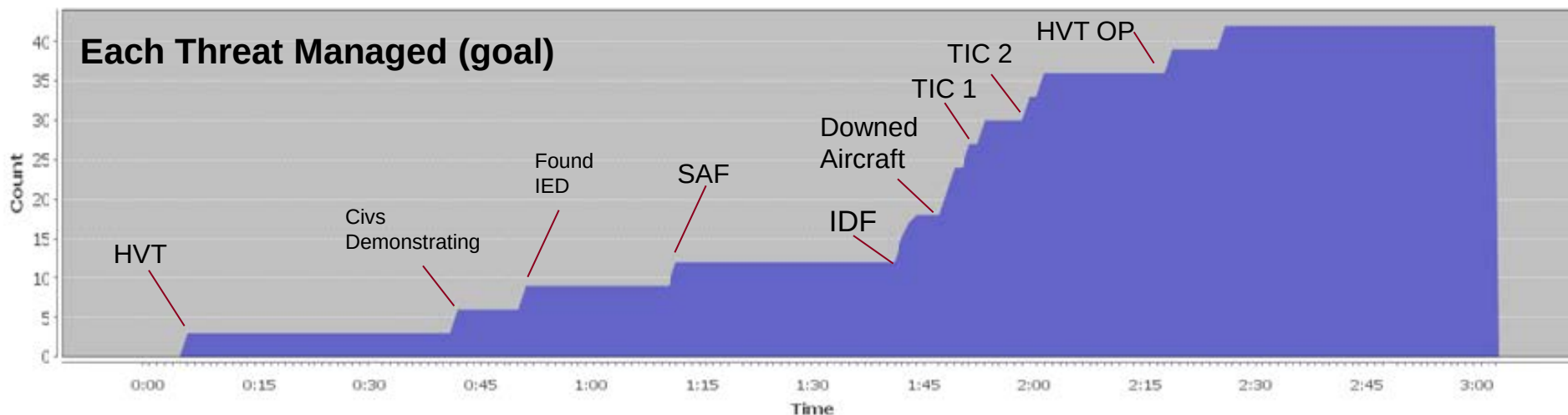
Goals:

- Air Security Provided For Medevac
- Air Threat Handled
- Aircraft Informed Of Threat
- Airspace Managed
- Aware Of Area Of Interest
- Aware Of Hostile Group
- Aware Of Key Enemy Entities
- Aware Of Key Leaders
- Battle Position Maintained
- Casualties Recovered
- Contact Resolved
- Context Provided
- Crowd Dispersed
- DART Dispatched

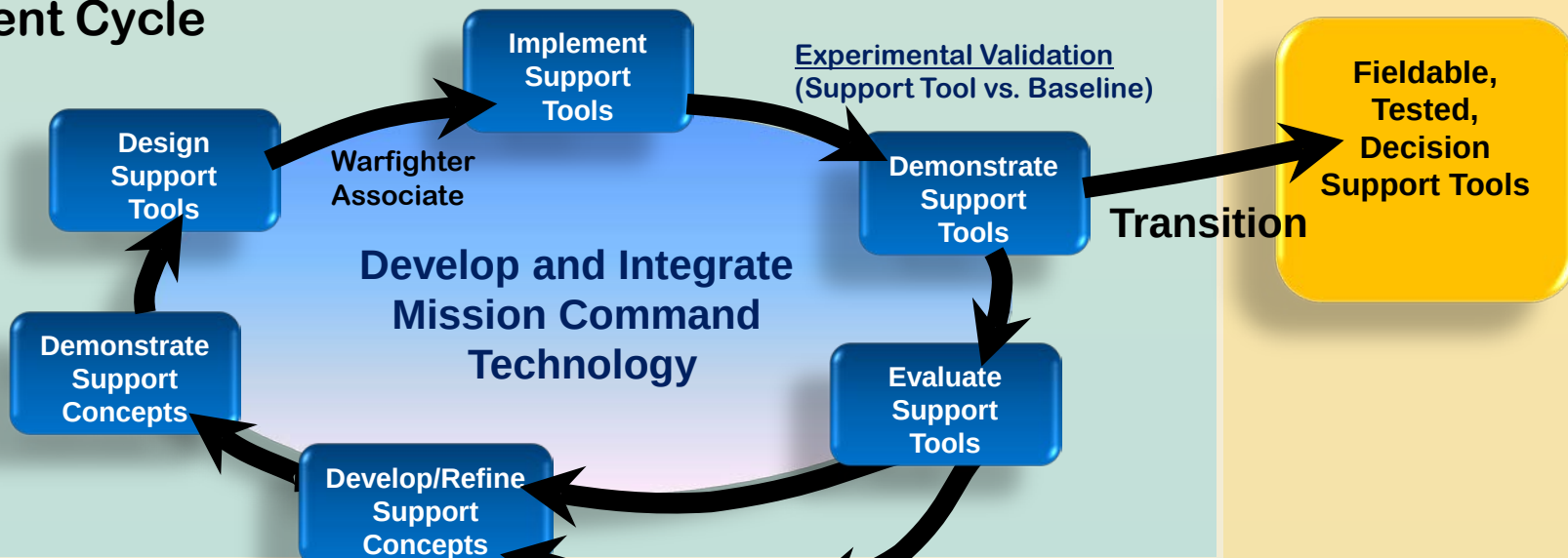
Concepts:

- Active Activity Based PIR
- Active Activity Based PIR And Active Threat
- Active NAI Based PIR
- Active NAI Based PIR And Entity
- Active NAI Based PIR And Equipment
- Active NAI Based PIR And Point
- Active NAI Based PIR And Unit
- Active Threat
- Active Threat ISR Coverage
- Activity Based FFIR
- Activity Based PIR
- Air Threat
- Air Threat Equipment Type
- Air Threat From Chat

Each Threat Managed (goal)



Development Cycle



Research Cycle



TECHNOLOGY DRIVEN. WARFIGHTER FOCUSED.

- Make systems more effective by addressing the “CSI” challenge – Cognitive science, Social science, Information science
- Four bodies of work focused on the problem space:
 - Warfighter Associate
 - Intelligent Presentation Services – context-sensitive, display-sensitive, dynamic UIs
 - Metrics development – driven by in-house experimentation framework
 - Socio-cognitive meta-network analysis (team synchronization, Commander’s Intent execution, virtual interest groups, information recommender)

- Building out additional roles (e.g., S-6 Network Management).
 - Prototyping interfaces with other systems of record (e.g., FBCB2).
 - Developing knowledge bases and prototypes for lower-echelon operations (company and below).
 - Political, Military, Economic, Social, Infrastructure, Information, Physical Environment, and Time (PMESII-PT) workbench.
 - Integrating with another set of intelligent agents that learn from past behavior.
 - Consider different visualizations, triggers for behavior, etc
- Experimentation capabilities to enable assessment of cognitive performance.

- Facilitates the dynamic manipulation of UIs in response to changes in context / cognitive challenges / user actions – in a way that is sensitive to the available display size
 - Enables device-agnostic software – one executable can drive big display, laptop, handheld device
- Experimentation framework can be used to quickly assess alignment of warfighter and systems capabilities

- Experimentation framework at Aberdeen Proving Ground facilitates collection of data for analysis
- Three-hour scenario with intense activity requiring collaboration, situation awareness, and decision making
- Soldiers (or civilians) can role play
- Advanced prototypes intended for programs of record or rapid response prototypes (mobile devices, lower echelons) can be evaluated
- Ongoing planning to insert prototypes and collect data at future Army testing events

- Using existing tools as well as specific techniques to extract meaningful measures from discourse (chat, eventually other means of communication)
- Team synchronization and understanding of Commander's Intent
- Team strength / vulnerability analysis
- Find people of interest in the greater network
- Recommend information to help solve problems
- Analyzing the network during periods of cognitive challenge

- The technology research project overlaps with current technology development project at Aberdeen Proving Ground
- Future technology development projects focused on Mission Command should use this work
 - Address difficult problems by using Associate Technology – develop and share the expertise across organizations
 - Use Intelligent Presentation Services to manipulate smaller UIs of company level and below soldiers
- Project Manager – Mission Command (PM-MC) is target for Warfighter Associate (integration into CPOF)
- PM-MC also developing “Command Web”, a web service to support thin-client functionality (Intelligent Presentation Services enables this)



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Thank you!

TECHNOLOGY DRIVEN. WARFIGHTER FOCUSED.

- **What is the Command Post of the Future (CPOF)?** Command-and-control platform for synchronizing/sharing work products and achieving a common operational picture.
 - o The U.S. Army will spend \$224M for CPOF training and support in FY2011.
- **What is the Warfighter Associate?** it is an intent interpretation engine that observes actions and the state of the battle-space to infer user goals and needs.
 - o Developed by:  **Applied Systems Intelligence**
 - o **Knowledge engineering** is a major part of the architecture
 - o The emergence of genuine **human-centered computing**
- **CASEL experimentation.** Brigade-level command and control research of key decision-makers: Maneuver (**S3**) – Intel (**S2**) – Fires (**FSO**). Involves mastery of technical, scenario, and analytical elements.



Actions. Entities interact with the environment by performing actions. Actions represent the primitive manipulations of the environment and are the directly observable inputs to the intent interpreter.

Scripts. Scripts represent procedural knowledge as weakly ordered sequences of events. Events are composed of actions and constraints. Scripts are segmented and provide serial and parallel execution paths.

Plans. Plans represent abstract methods that might be expected to achieve one or more goals. While a plan may have a script associated with it that defines its nominal execution, this is not required.

Goals. Goals represent desired states of the environment that may be achieved at some time in the future as a result of plan execution.

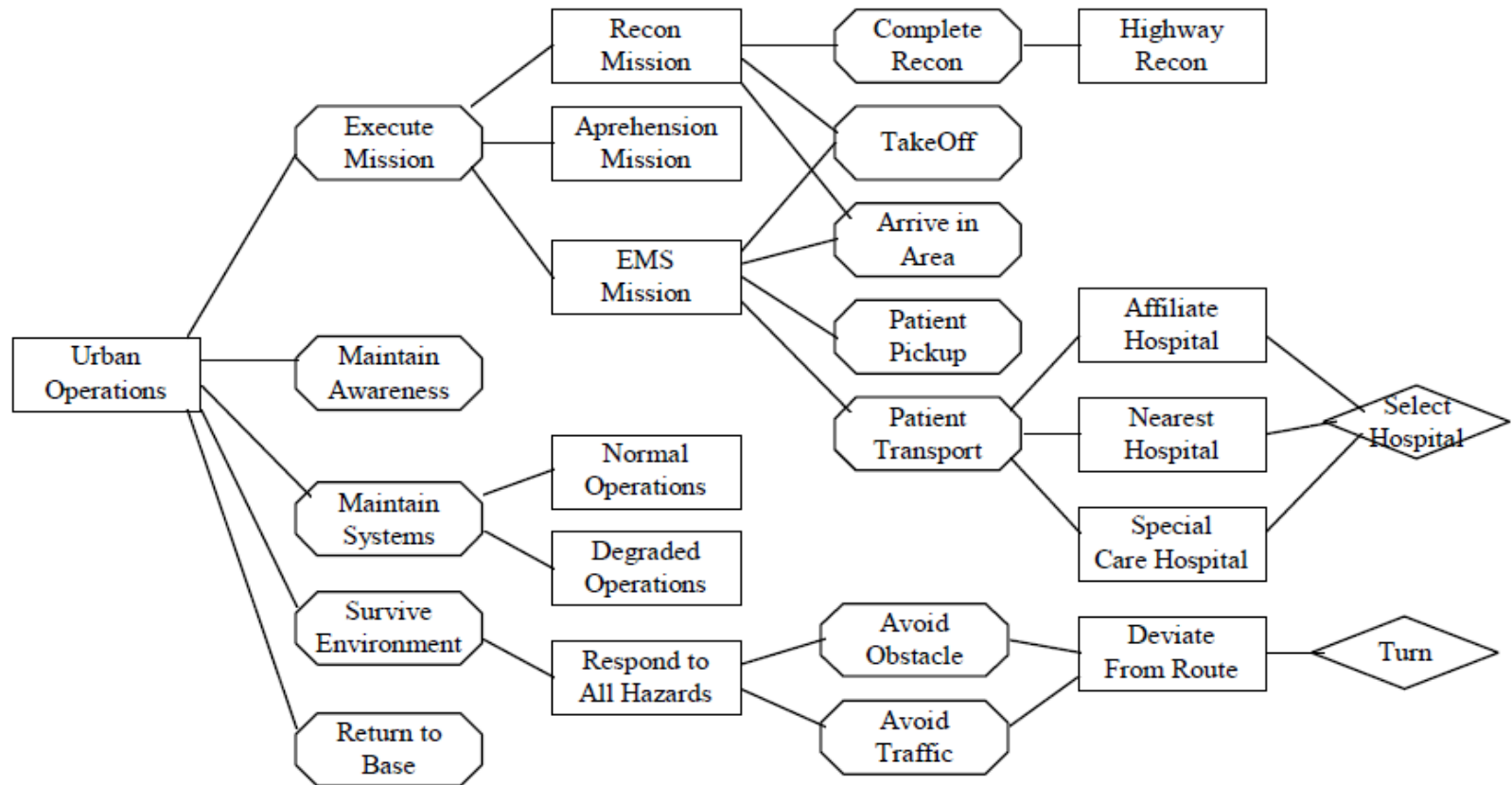


Figure 1 –Sample Plan-Goal Graph Segment for Emergency Helicopter Operations

- The intent interpretation model combines a procedure follower with a search process to provide efficient interpretation of both procedural and non-procedural behaviors.
- Each entity is assumed to have multiple simultaneous intentions that are dynamically changing as the entity interacts with its task environment.
- As each observation is processed, its likely interpretation is found, but the interpretation is repeatedly refined as new data is received.