

# “Mixed-Initiative Planning in a Distributed Case-Based Reasoning System”

## C2 Architectures and Technologies



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# Overview



- Future C2 Challenges and Vision
- Related Work & MI Challenges
- Approach Overview
- Architecture & Supporting Technologies
- User Interface Mockup
- Future Work / Research Areas
- Conclusion



# Future C2 Challenges



- **US forces being called on to support two types of conflicts:**
  - Traditional force-on-force engagements
  - Smaller-scale conflicts characterized by insurgency tactics and time-sensitive targets of opportunity
    - **Requires a flexible C2 process that can adapt to any level of conflict**
    - **Requires full-spectrum, joint warfighting capability (air, land, sea, & cyber)**
- **Air Force moving towards a model of continuous air operations not bounded by traditional Air Tasking Order plan-execute cycle**
  - **Requires highly synchronized, distributed planning and replanning capabilities**
  - **Requires transition from process of Observation and Reaction → to Prediction and Preemption**



# Distributed Episodic Exploratory Planning (DEEP) Overview



- Research platform for distributed, mixed-initiative planning
- Objectives:
  - Provide a **mixed-initiative planning environment** where human expertise is captured and developed, then adapted and provided by a machine to augment human intuition and creativity.
  - Support **distributed planners** in multiple cooperating command centers to conduct distributed and collaborative planning.
- Technologies:
  - Experience-Based Reasoning
  - Multi-Agent Systems
  - Distributed Blackboards
  - Exploratory Simulation



# Related Work



- DARPA Program - *Mixed Initiative Control of Automa-teams (MICA)* (Final Tech Report 2004)
- *Expectation Failure as a Basis for Agent-Based Model Diagnosis and Mixed Initiative Model Adaptation during Anomalous Plan Execution* (Mulvehill 2007)
- *A Model of Types and Levels of Human Interaction with Automation* (Sheridan 2000)



# Challenges



- Mixed-Initiative Interaction Challenges (Horvitz 07):
  - Recognition of relevant problems
  - Decomposition of the problems into subproblems
  - Identification of subproblems that might be best solved through automation
  - Solution of the subproblems
  - Integration of human and machine contributions
  - Communication and coordination about this reasoning and problem solving

*Horvitz, E. (2007). Reflections on Challenges and Promises of Mixed-Initiative Interaction. AI Magazine Volume 28 Number 2 (2007) AAAI. pp 19-22.*



# Objective



- *Agile C2 requires a “rich and continuous set of interactions between and among participants...and with the broadest distribution of decision rights.”* Alberts (2007)
- The current DEEP implementation lacks this *“continuous set of interactions”*
- This approach supports more agile C2



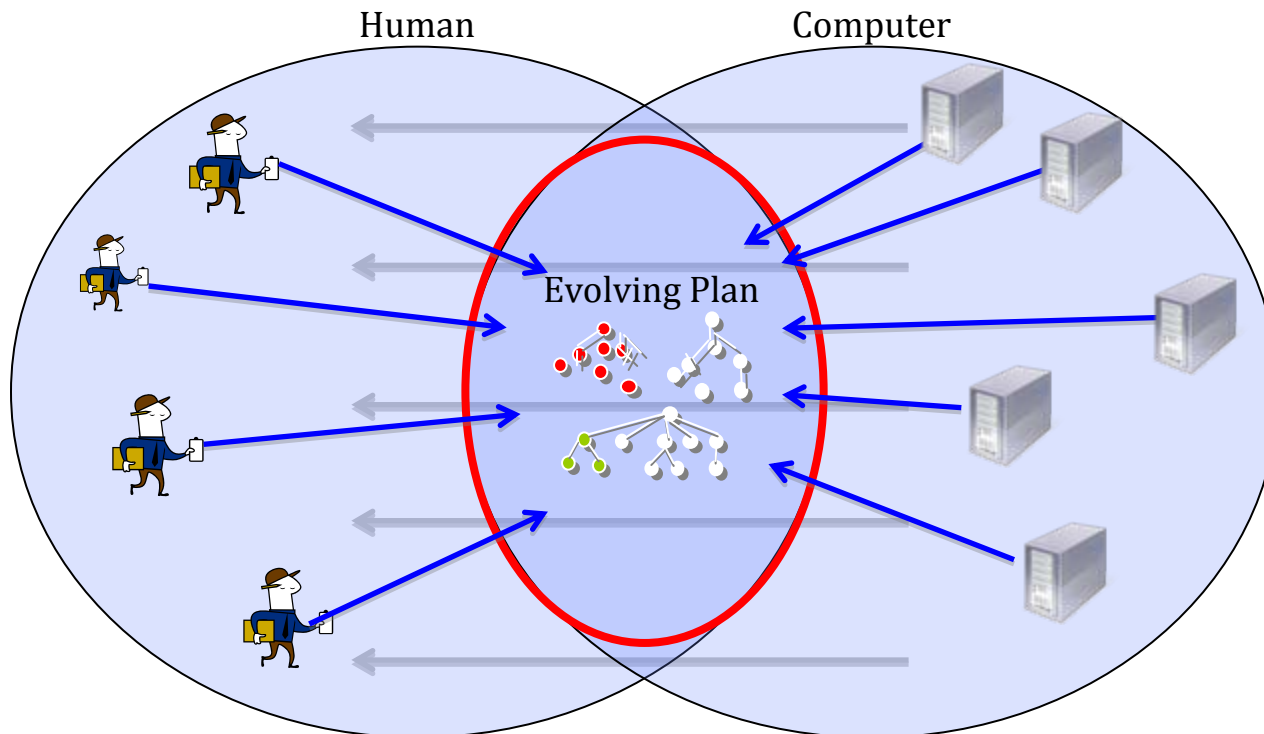
# Approach Overview

## Human Contribution

- Template Development
- Library Usage
- Constraint

## Computer Feedback

- Critic Agent Analysis
- Experience-Based Suggestions
- Exploratory Analysis
- Warnings / Alerts







# User Interactions



- Library
  - Template Specification
  - Instance Specification
- Drag and Drop
- Positive/Negative Constraints



# Feedback



- Critic Agent Analysis
- Experience-Based Suggestions
- Exploratory Analysis
- Warnings & Alerts



# Architecture & Supporting Technologies



- DEEP components:
  - **Distributed AI Blackboard** for multi-agent, non-deterministic, opportunistic reasoning
  - **Experience-Based Reasoning** to capture and retrieve experiences
  - **Episodic Memory** for powerful analogical reasoning
  - **Multi-Agent System** for mixed-initiative planning
  - **Plan Representation** for human-to-machine dialog
  - **Simulations** for exploration of plausible future states



# Distributed Episodic Exploratory Planning (DEEP)

## Distributed Blackboard



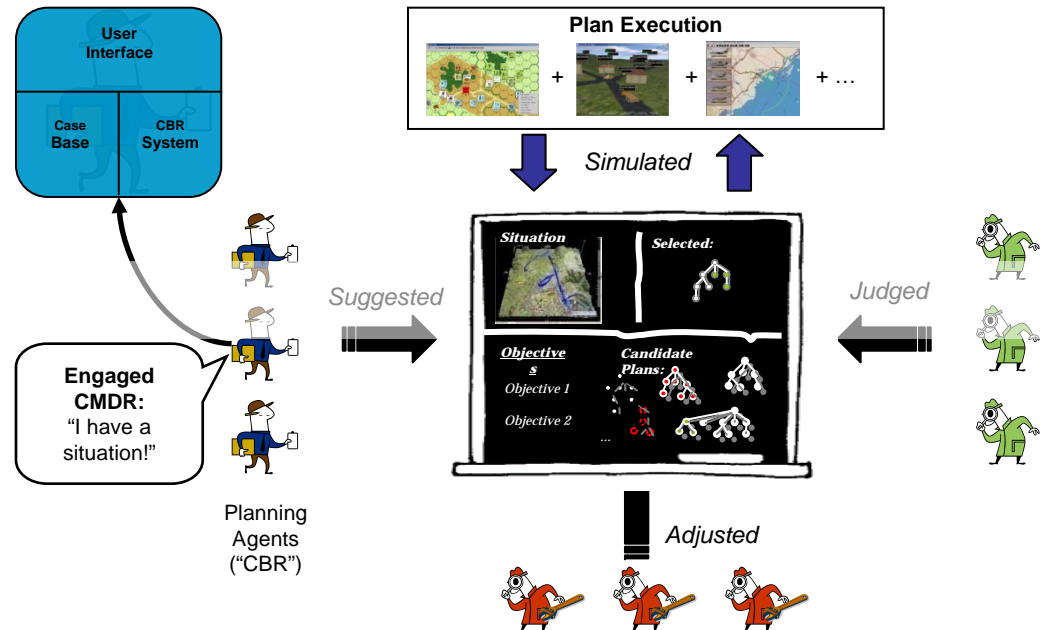
- Distributed Shared Data Structure

- Provides

- Multi-agent, non-deterministic, opportunistic reasoning
- Persistent storage
- System messaging

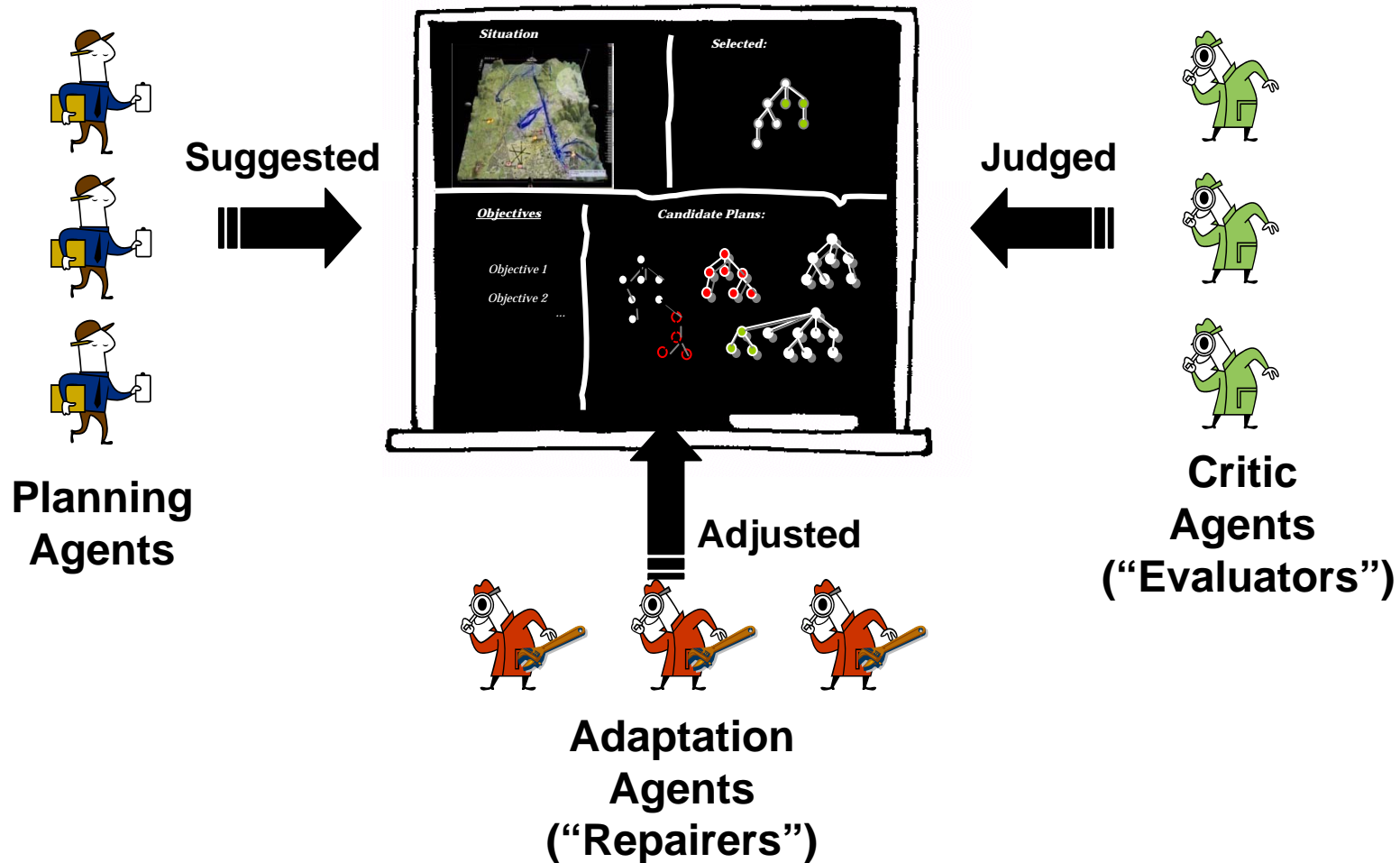
- Components

- Core Data Store
- Knowledge Sources
- Control





# Distributed Episodic Exploratory Planning (DEEP) Multi-Agent System





## Critic Agents

- **Adaptation Critic Agents**
  - Plan repair
    - Example – Capabilities Agent checks actor roles and makes sure the present actors are capable of performing their assigned roles
- **Scoring Critic Agents**
  - Plan evaluation
    - Example – Weather Agent uses weather knowledge and data to evaluate plan actions
- **Execution Selection Critic Agents**
  - Determines top rated plans
  - Mixed-initiative decision point



*Bringing it all together...*

# User Interface Mockup

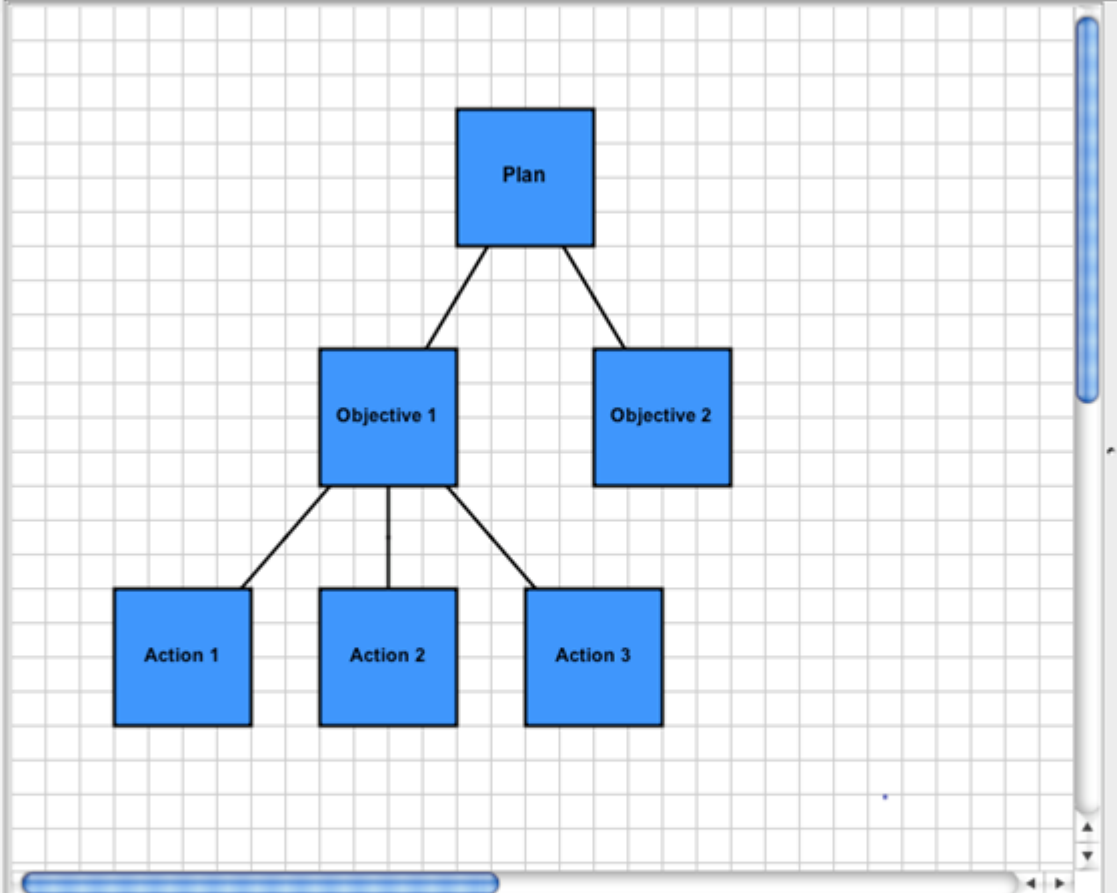
DEEPER Mockup

File View Remote Tools

Add Positive Constraint Add Negative Constraint

Plan

- Plan
  - Objective 1
    - Action 1
    - Action 2
    - Action 3
  - Objective 2



Library

- Library
  - Actions
    - Action 1
    - Action 2
    - Action 3
  - Plan Templates
    - Humanitarian Relief
    - Anti-Insurgency
    - Force-on-Force

Scores

Critic	Score	Color
Weather	95	Green
Logistics	20	Red
JAG	100	Blue

Suggestions

Suggestion	Type	Origin
Action A	Action	Case 73
Action B	Action	Case 41
Action C	Action	Case 11
Action D	Action	Case 11
Action E	Action	Case 11
Action F	Action	Case 27
Action G	Action	Case 27
Action H	Action	Case 6



# User Interface Mockup

The screenshot displays the DEEPER Mockup software interface. The main workspace features a hierarchical diagram on a grid background, enclosed in a large red circle. The diagram is structured as follows:

- Plan** (Root node)
- Objective 1** (Child of Plan)
- Objective 2** (Child of Plan)
- Action 1** (Child of Objective 1)
- Action 2** (Child of Objective 1)
- Action 3** (Child of Objective 1)

The interface includes a menu bar (File, View, Remote, Tools), a toolbar with various icons, and a left sidebar with a tree view showing the plan structure. On the right, there is a **Library** panel with folders for **Actions** (Action 1, Action 2, Action 3) and **Plan Templates** (Humanitarian Relief, Anti-Insurgency, Force-on-Force). Below the library is a **Scores** table:

Critic	Score	Color
Weather	95	Green
Logistics	20	Red
JAG	100	Blue

At the bottom, a **Suggestions** table lists various actions and their origins:

Suggestion	Type	Origin
Action A	Action	Case 73
Action B	Action	Case 41
Action C	Action	Case 11
Action D	Action	Case 11
Action E	Action	Case 11
Action F	Action	Case 27
Action G	Action	Case 27
Action H	Action	Case 6

# User Interface Mockup

The screenshot displays the DEEPER Mockup software interface. The main workspace shows a hierarchical plan diagram with a root node 'Plan' connected to 'Objective 1' and 'Objective 2'. 'Objective 1' is further connected to 'Action 1', 'Action 2', and 'Action 3'. A red circle highlights the 'Library' panel on the right, which contains a tree view of 'Library' with sub-items 'Actions' (Action 1, Action 2, Action 3) and 'Plan Templates' (Humanitarian Relief, Anti-Insurgency, Force-on-Force). Below the library is a 'Scores' table:

Critic	Score	Color
Weather	95	Green
Logistics	20	Red
JAG	100	Blue

At the bottom of the interface is a 'Suggestions' table:

Suggestion	Type	Origin
Action A	Action	Case 73
Action B	Action	Case 41
Action C	Action	Case 11
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**Plan**

- Plan
  - Objective 1
    - Action 1
    - Action 2
    - Action 3
  - Objective 2

**Library**

- Library
  - Actions
    - Action 1
    - Action 2
    - Action 3
  - Plan Templates
    - Humanitarian Relief
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**Plan**

- Plan
  - Objective 1
    - Action 1
    - Action 2
    - Action 3
  - Objective 2

**Library**

- Library
  - Actions
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# Future Work



- Plan Visualizations
- Adjustable Autonomy
- Commanders Intent
- Tailored Information
- Other Human Entry Points



# Conclusion



- This approach has promise to enhance DEEP's agility by providing users a functional way to interact with an adjustably-autonomous system providing the following capabilities:
  - Level-Independent Mixed-Initiative Planning
  - Asynchronous Mixed-Initiative Planning
  - Plan Oriented Machine Interaction



# Questions?



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# Backups







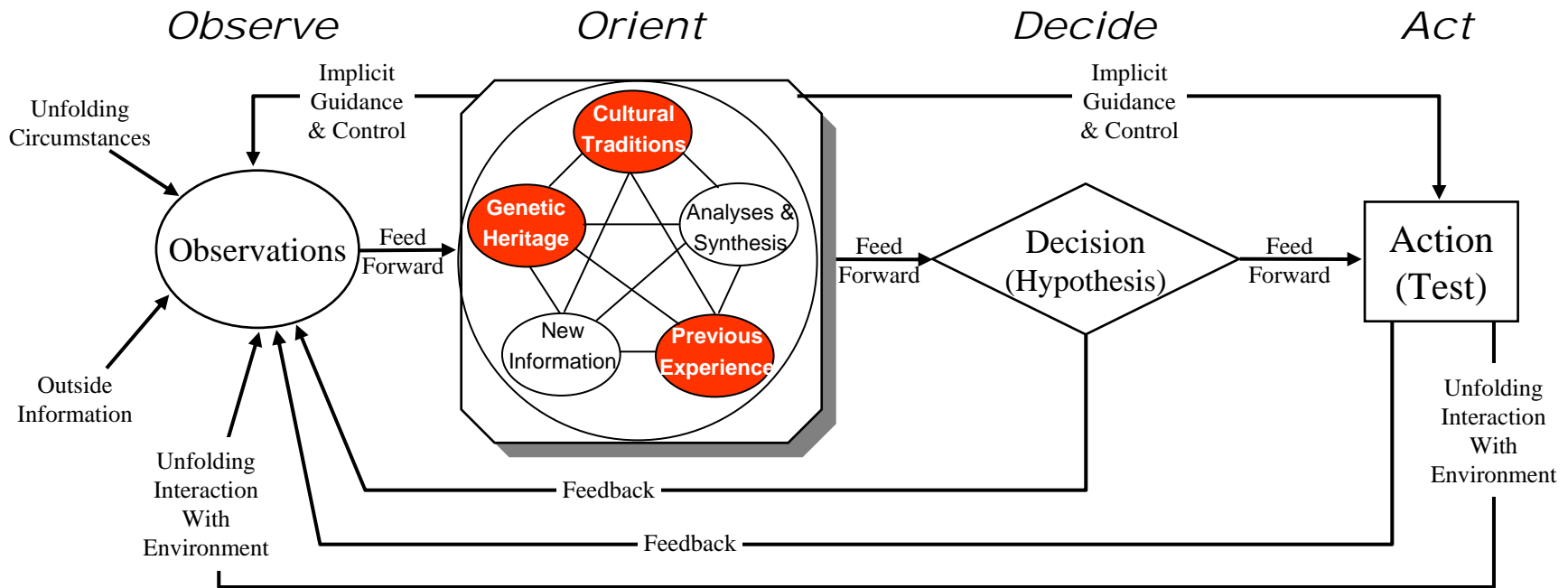
# Distributed Episodic Exploratory Planning (DEEP)

## The Importance of **Experience** in Planning



- “Most of the time spent in orient phase **reducing the fog of war**”
- “Orientation relies on an **experience base**”
- “Experience is the basis for the increasing requirement of **creativity** in plans”

--John Boyd



- **Harness an experience base to rapidly**
  - Rapidly **recognize** the situation
  - **Plan** better by recalling prior successes and/or failures
  - Creatively **explore** what the plan may accomplish

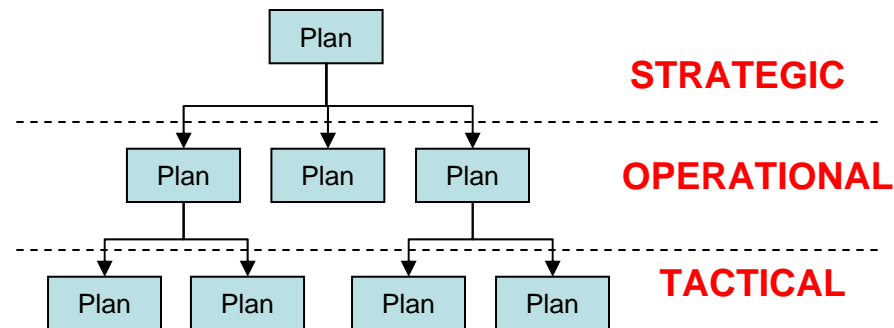
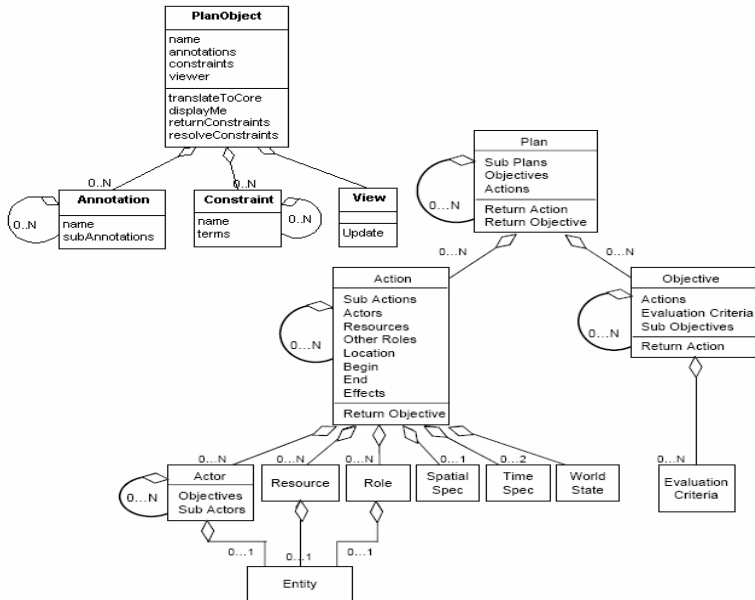


# Distributed Episodic Exploratory Planning (DEEP) Building Block for MIP/Distributed C2



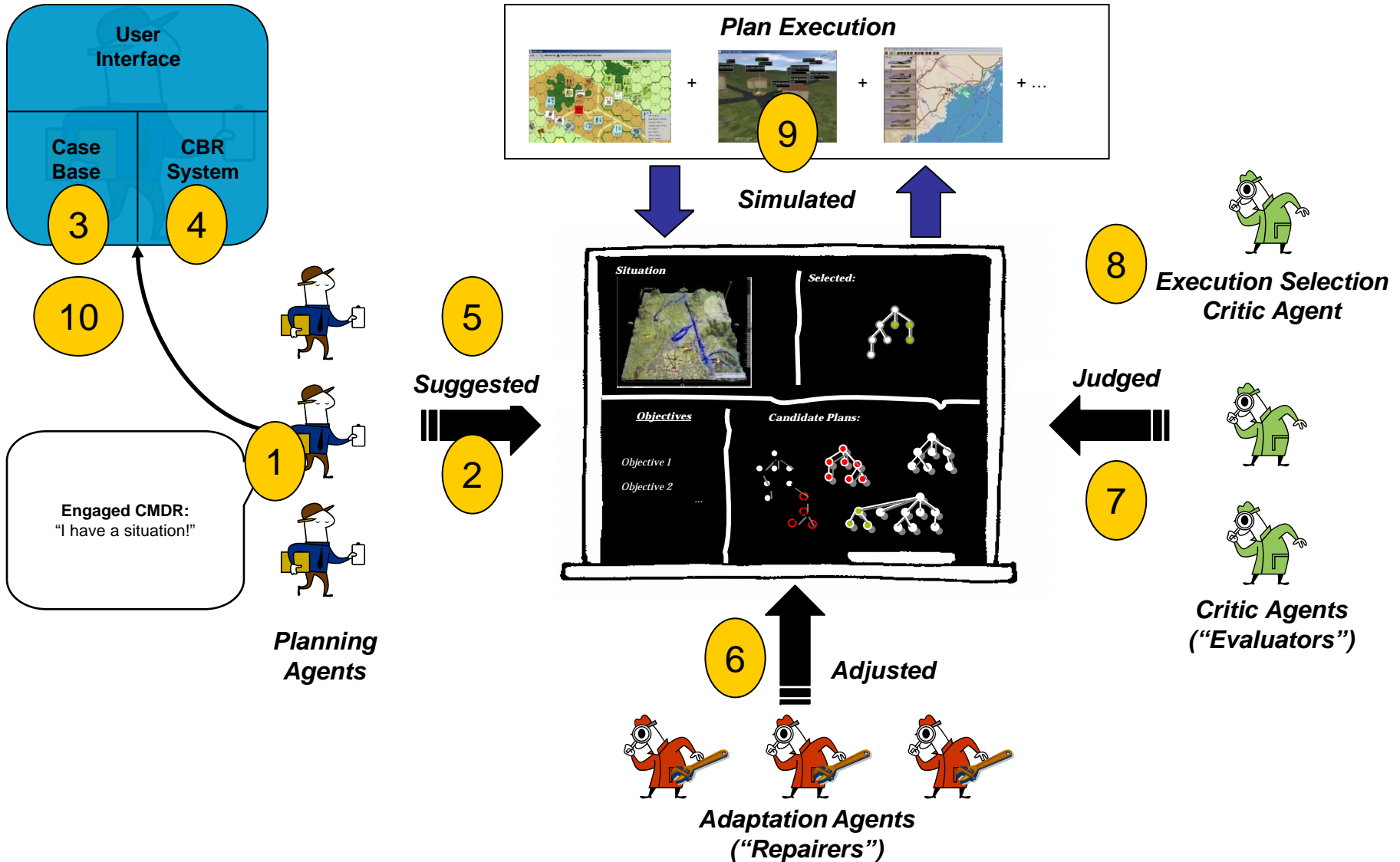
- Core Plan Representation (CPR)
  - Object-oriented plan framework developed under ARPI (Air Force Research Laboratory Planning Initiative)
  - Motivation: **Interoperability**
  - Extended for DEEP (effects, outcome, costs,..)

- Provides
  - Human-machine dialog (mixed-initiative)
  - Recursive (multi-level)
  - Plan fragments (dist. C2)
  - Interoperable C2 (both integrated and joint)





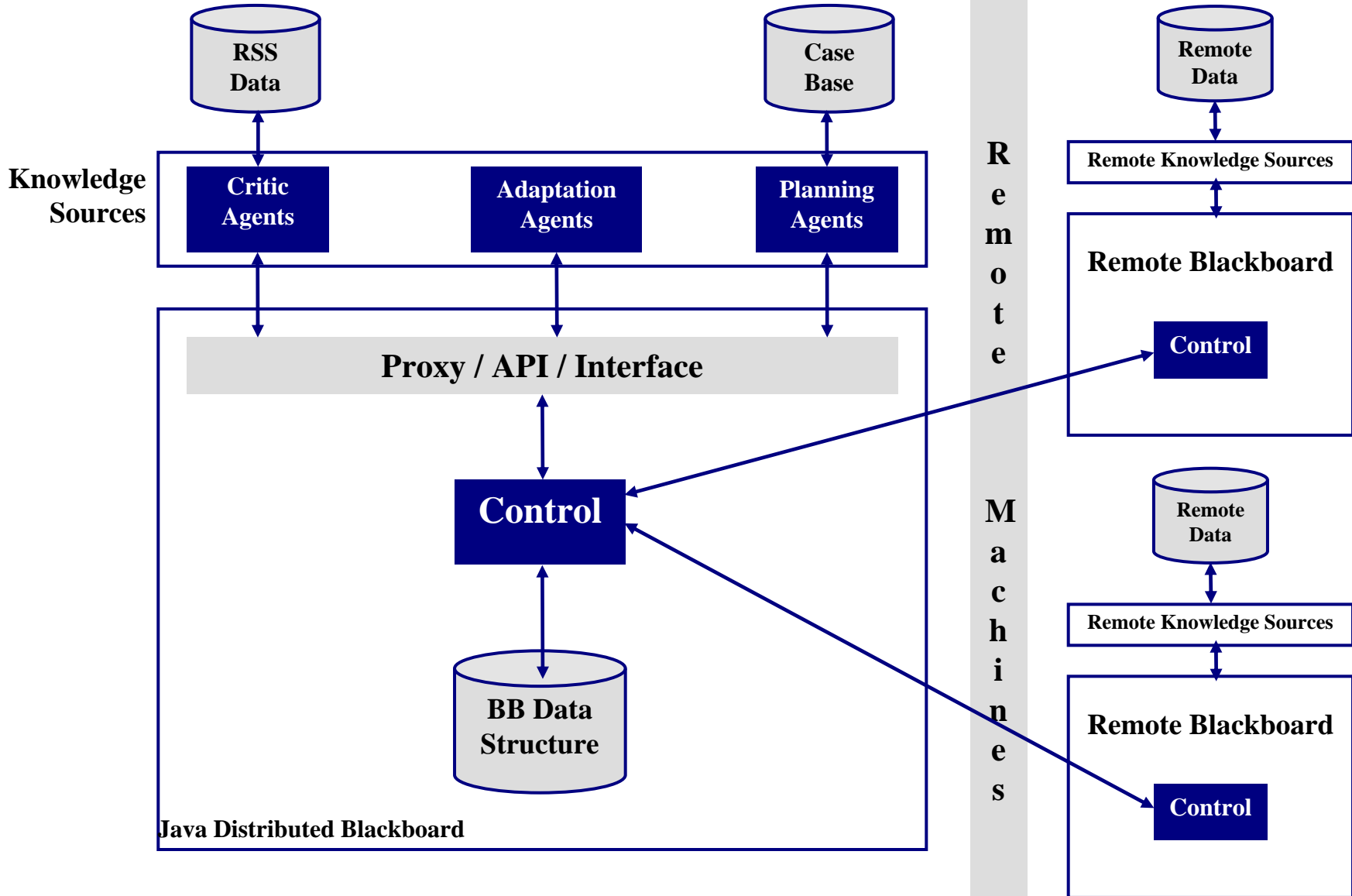
# Distributed Episodic Exploratory Planning (DEEP) Architecture Diagram





# Distributed Episodic Exploratory Planning (DEEP)

## Distributed Blackboard Architecture





# Objective

Better, faster, more creative planning



## Current AOC Planning



### BOGSAT

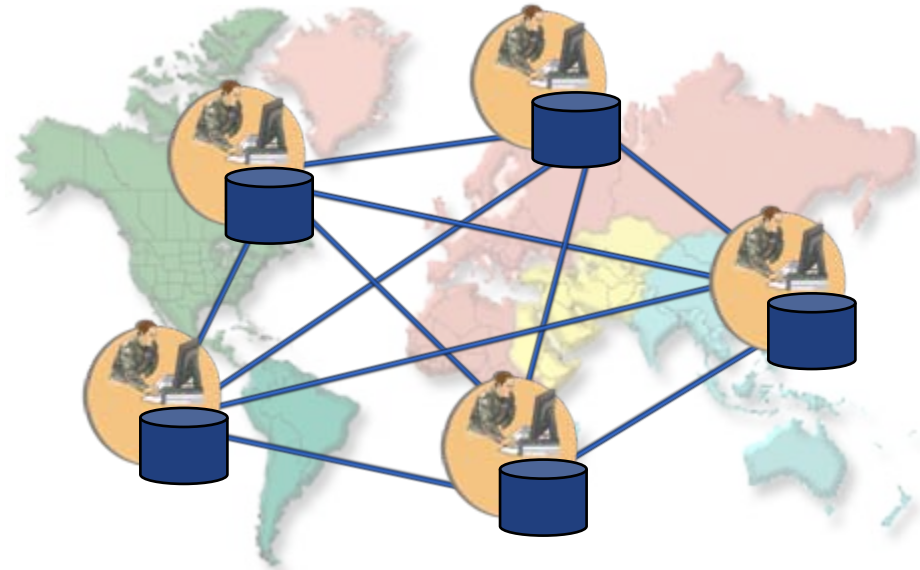
- Bunch of Guys/Gals Sitting Around a Table

### Constrains planning

- **Quality**
  - Finite experience
- **Speed**
  - Limited automation
- **Creativity**
  - Finite diversity

Improve planning quality,  
speed, and creativity

## Graphic from “AF C2 Enabling Concepts” May 2006 AF/A5



- **Experienced-based**
  - Orient and decide faster than adversaries with better plans
- **Mixed-initiative**
  - Syntheses of the strengths of both human and machine
- **Net-centric**
  - Expert team formation with greater diversity and creativity



# Distributed Episodic Exploratory Planning (DEEP) Planning Agent



- Interact with case-base reasoning system
- Mechanism for mixed-initiative interaction

