Semantic Interoperability in Distributed Planning

June 19, 2008

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Outline

Introduction – Future C2 Requirements

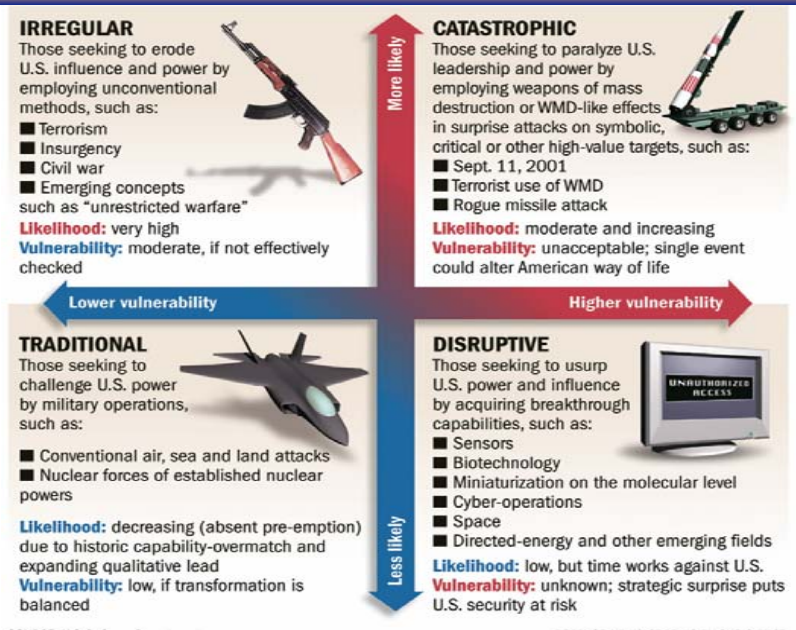
Framework for Distributed Mixed-Initiative Planning

Leveraging Semantic Technologies

Conclusion

Future C2 Planning Requirements

- **US forces being called on to support <u>two</u> 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 the level of conflict**
  - ➢ **Requires full-spectrum, joint warfighting capability (air, land, sea, & cyber)**

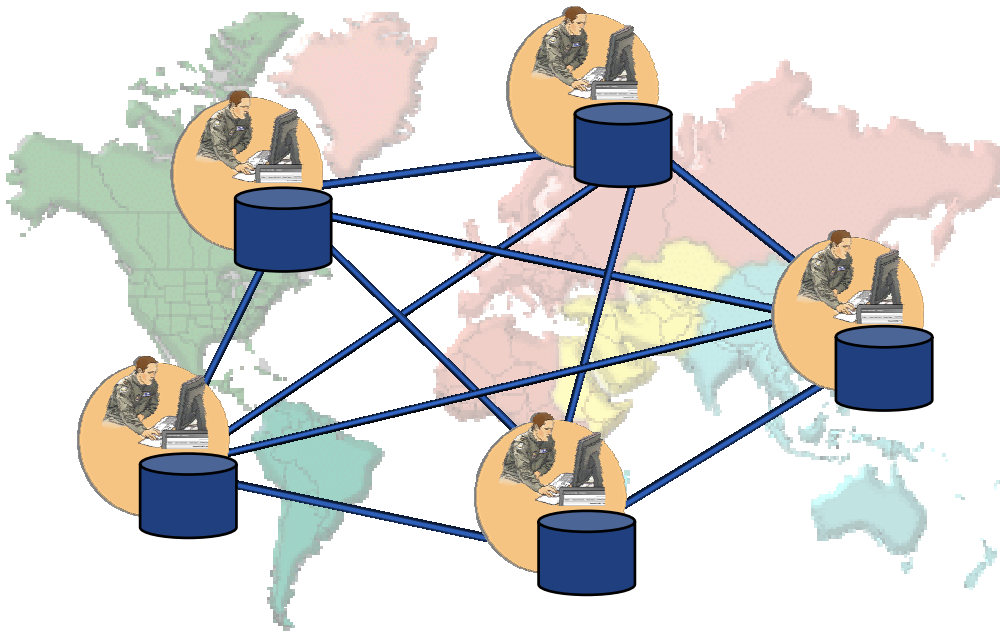


- **Air Force moving towards a model of <u>continuous</u> air operations not bounded by traditional 24-hour Air Tasking Order cycle**
  - ➢ **Requires highly synchronized, distributed planning and replanning capabilities**
  - ➢ **Requires transition from process of Observation and Reaction → to Prediction and Preemption**

Challenges for the Future AOC

"AF C2 Enabling Concepts"
May 2006 Draft Document, AF/A5

- **"… geographically separated but … function as if collocated."**
  - **Distributed /Reachback planning**
- **"… maximize distributed network capabilities should engaged AOC encounter a catastrophic event …"**
  - **Redundant/Backup planning**
- **"… day-to-day, steady state C2 of continual lower-end contingencies."**
  - **Continuous planning**
- **".. rapidly adapt to the level of conflict by connecting with worldwide capabilities, including joint and coalition forces."**
  - **Flexible, scalable, tailorable C2**



"The AF will begin immediately to restructure JEFX-08 to focus on Joint C2 as one of its primary initiatives."
CSAF Memorandum, 3 Aug 2005

Objectives of the DEEP project

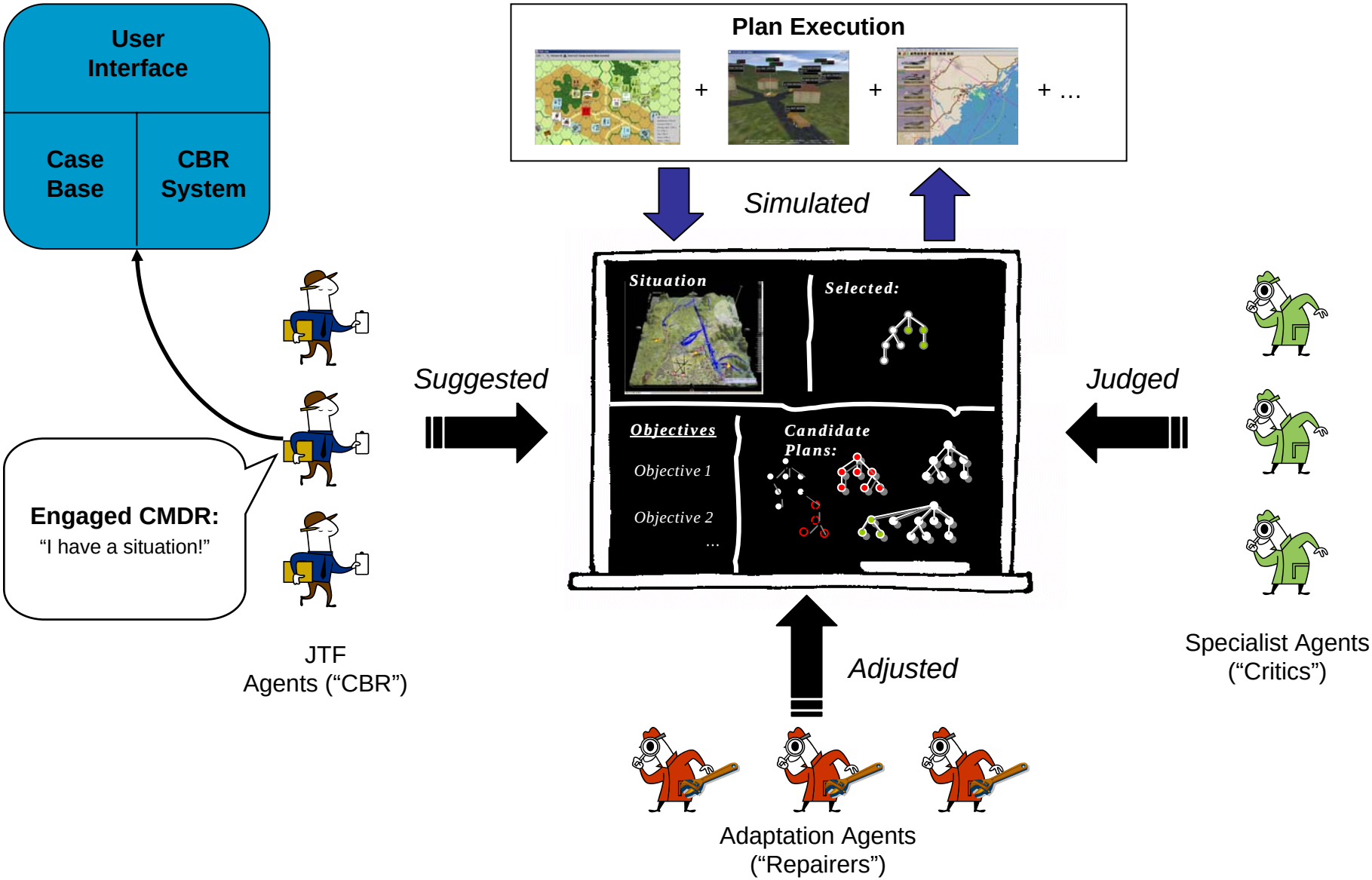
- **Develop in-house a prototype system for distributed, mixed-initiative operational-level planning that improves decision-making by applying analogical reasoning (i.e. the anticipation aspect of CPE) over an experience base**

- **Augment human intuition and creativity**

- **Specifically:**
  - **AI Blackboard for multi-agent, non-deterministic, opportunistic reasoning**
  - **Case Based Reasoning to capture experiences (successes and/or failures)**
  - **Episodic Memory for powerful analogical reasoning**
  - **Multi-Agent System for mixed initiative planning**
  - **ARPI Core Plan Representation for human-to-machine common dialog**
  - **Constructive Simulation for exploration of plausible future states**

"Plans are worthless — but planning is everything."
Dwight D. Eisenhower

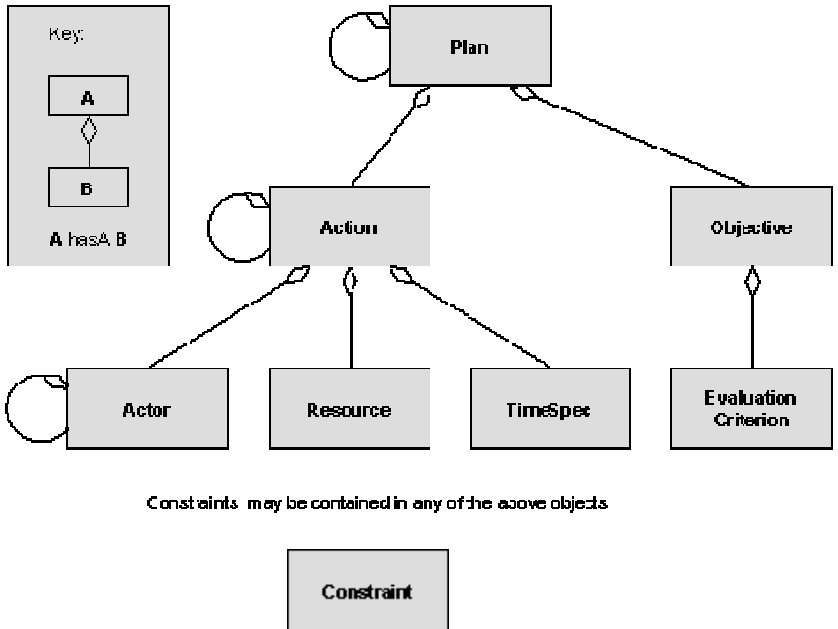
DEEP Architecture

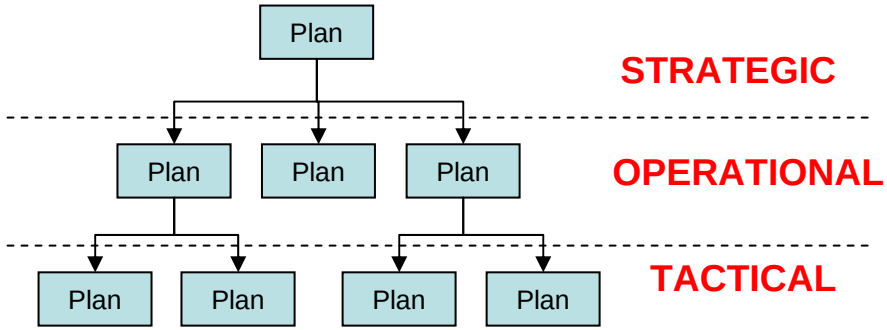


Framework for Distributed Mixed-Initiative Planning

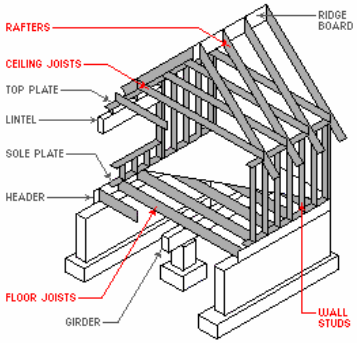
- **Core Plan Representation**
  - **Object-oriented plan framework developed under ARPI**
  - **Motivation: Interoperability**
  - **Extended for DEEP (effects, outcome, costs,..)**

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



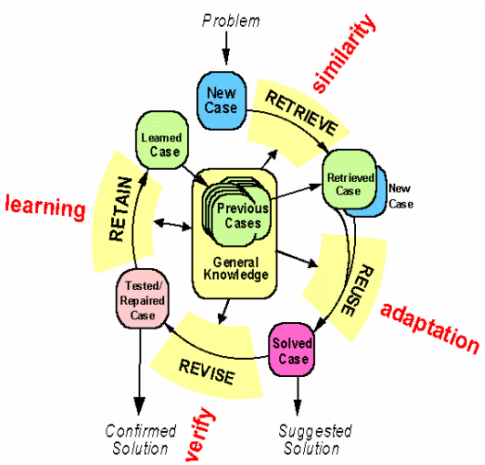


DEEP adaptation of CPR



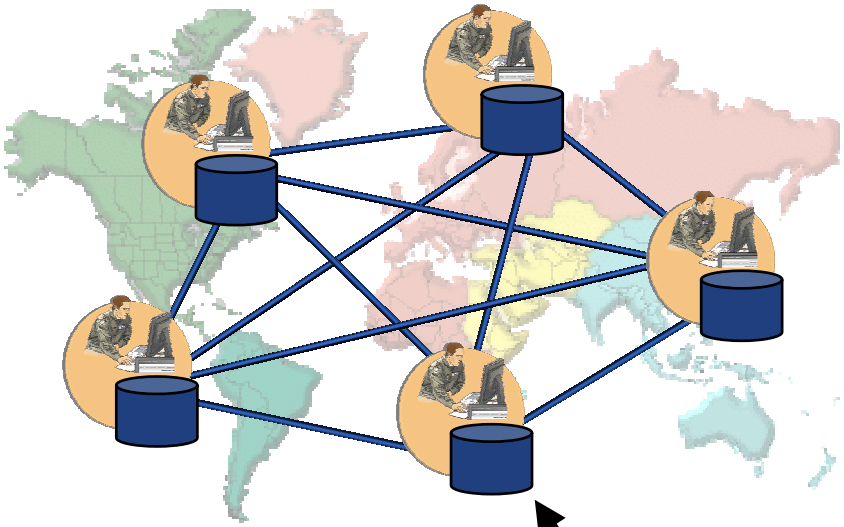
APRI-CPR model specification was too abstract to be used directly

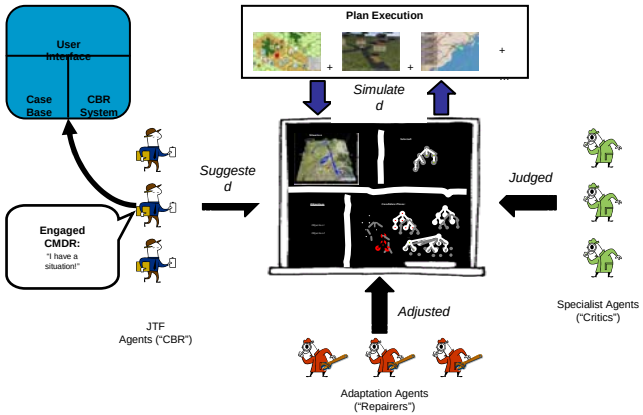
Planning information within DEEP is structured (taxonomy based), making the free text used in ARPI-CPR inadequate



DEEP uses a CBR system for plan selection and storage

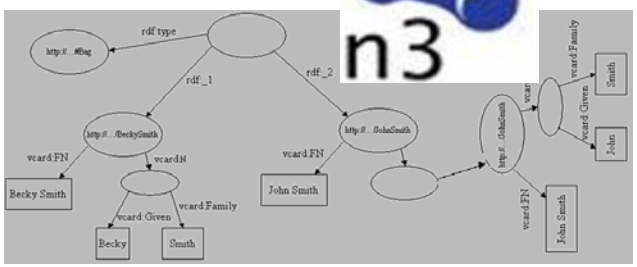
Leveraging Semantic Technologies





semantic web framework Jena

n3



Need for semantics

Hard coded and Implied Semantics

- Difficult to extend
- Defined terms have meaning only to people that developed them
- Interpretation must be programmed into application

Semantic technologies enable us to say

I am talking about this specific “Thing”

This “Thing” has the following capabilities

- Fly
- Transport
- Bombard
- etc …

Why RDF in N3

Simple, provides a shorthand non-XML encoding of RDF

Designed with human-readability in mind

Extendible

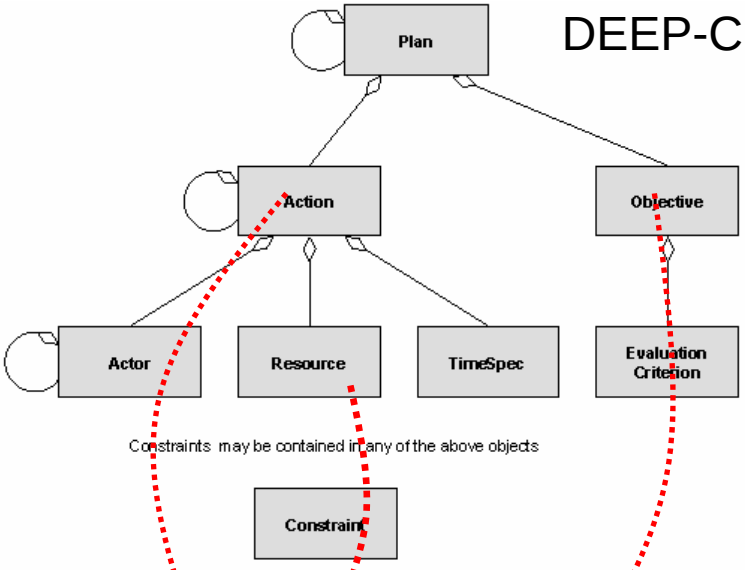
Much more compact and readable than XML RDF encoding

- XML RDF can be misleading to the human eye
  - RDF=Graph, while XML = Hierarchy tree

Has sentence like structure

DEEP-CPR Semantic extensions

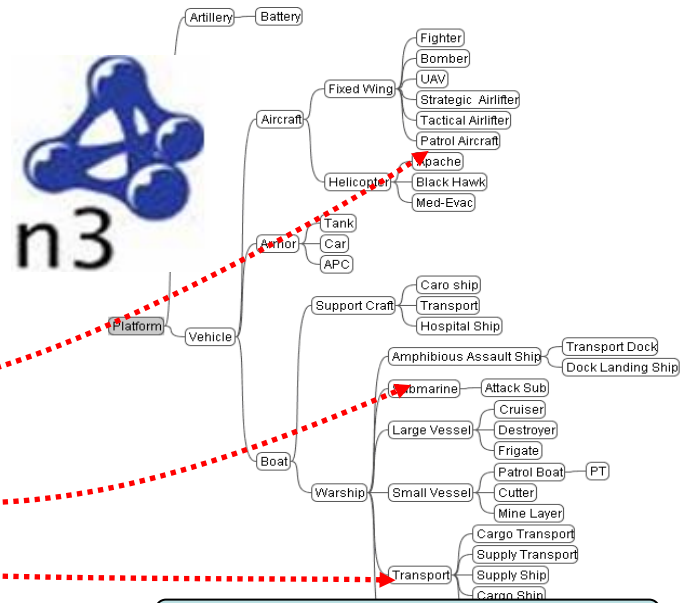
DEEP-CPR Plan has a well defined object-oriented structure



These objects are expressed with taxonomy terms

DEEP Semantic Interface

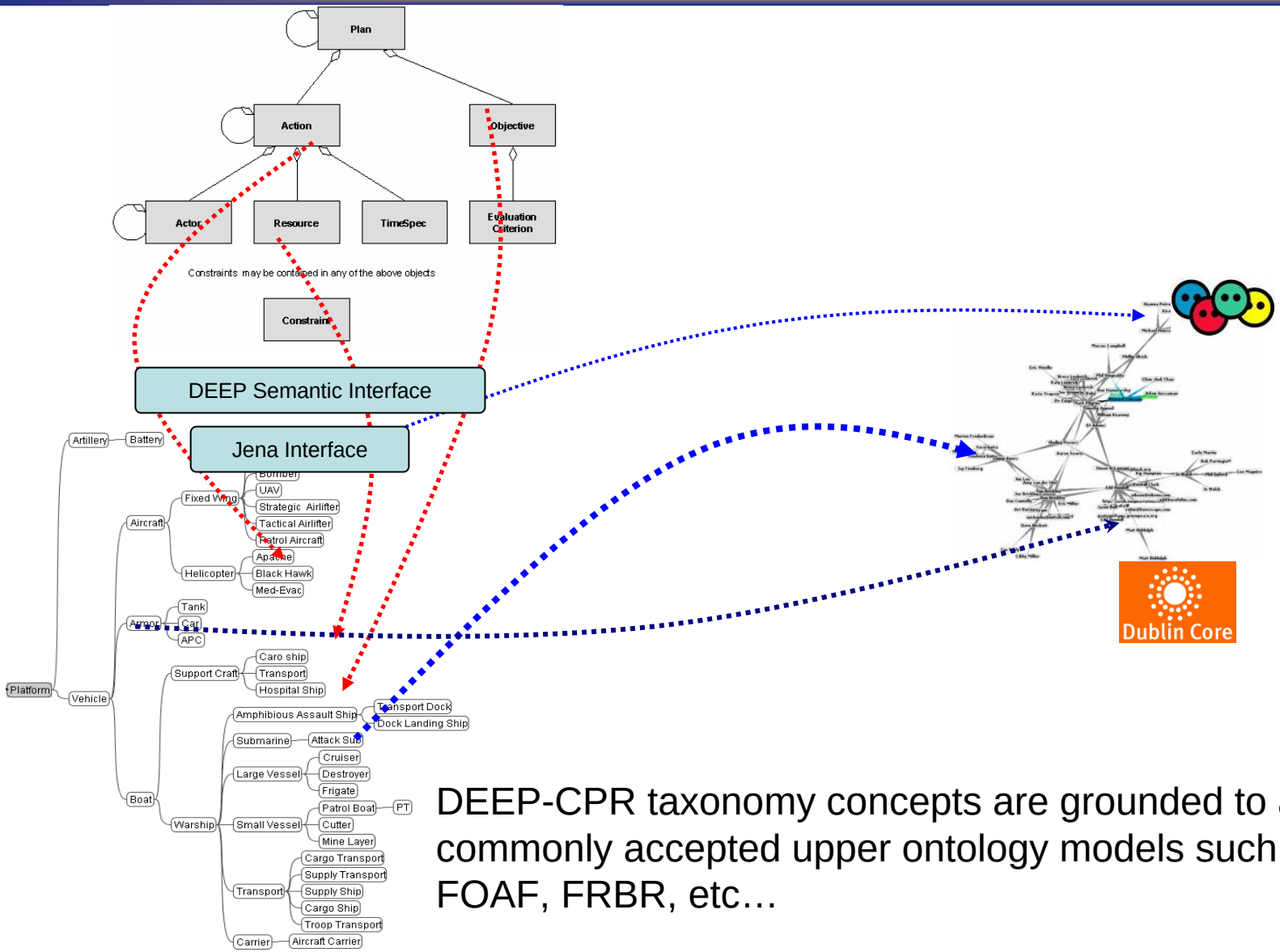
Jena Interface



Deep Taxonomy (N3)

DEEP-CPR taxonomies are encoded in RDF for capturing semantics

DEEP-CPR Semantic extensions



DEEP-CPR taxonomy concepts are grounded to a commonly accepted upper ontology models such as DC, FOAF, FRBR, etc…

Semantic Technology Benefits

Expressive, Descriptive

- Individual meaning and context can be represented and attached to information
- Each concept can be given any number of properties that provide both supplemental information as well as the relationship it has to other concepts

Abstraction

- Provides a structure that can be directly interpreted as layers of abstraction

Longetivity

- Formal definitions of information semantics provide a structure that can be represented beyond a specific applications

Interoperability

- Provides a more formal basis for promoting predictable data transformation between information spaces

Semantic Technology Challenges

Building ontologies

- Requires knowledge engineers
- Effective within a small domain

Indexing ontologies

- Currently no standard methods for indexing and allowing searches over ontological concepts and relationships

Ontology versioning

- Ramifications on dependant ontologies when source ontology changes

Structure vs. Flexibility

- Restrictions placed on a concept will be inherited by any instance of that concept type

Conclusion

DEEP project has successfully completed year one of four-year effort

Presented a number of extensions, both existing and planned to the CPR framework

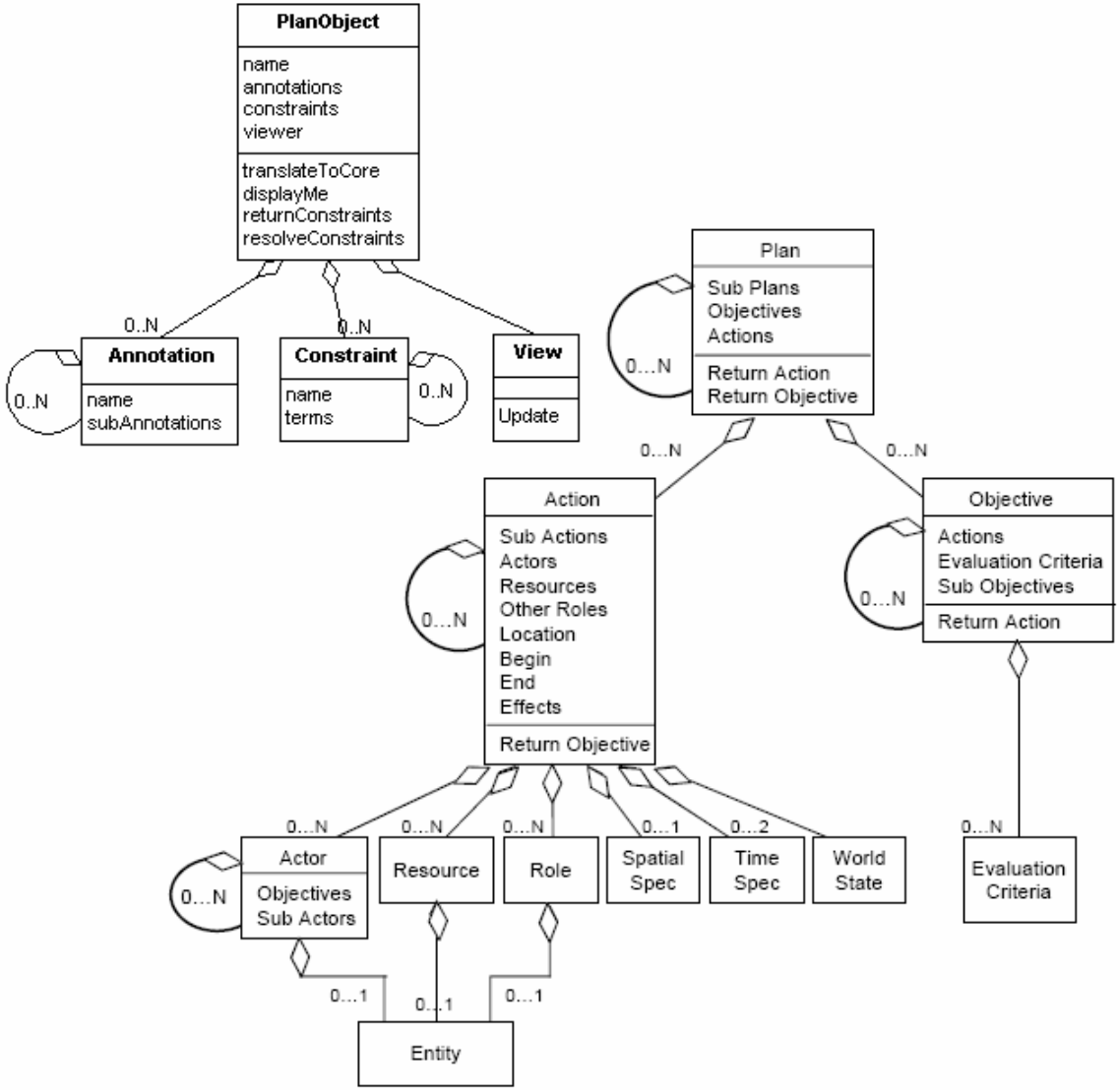
Questions?

Objective of the DEEP Project

- To provide a mixed-initiative planning environment where a human experience is:
  - captured
  - developed
  - adapted
- Augment human intuition and creativity
- To support the distributed planners in multiple cooperating command centers to conduct distributed and collaborative planning

Core Plan Representation

Original ARPI Version



The original ARPI-CPR

- Motivation
  - Plan interoperability
  - Object-oriented plan framework based on UML
- Recursive nature of CPR supports planning at all levels:

  Strategic Operational Tactical
- Most commonly shared set of objects:

  Objective Action

  Actor Resource