COA modeling with probabilistic ontologies

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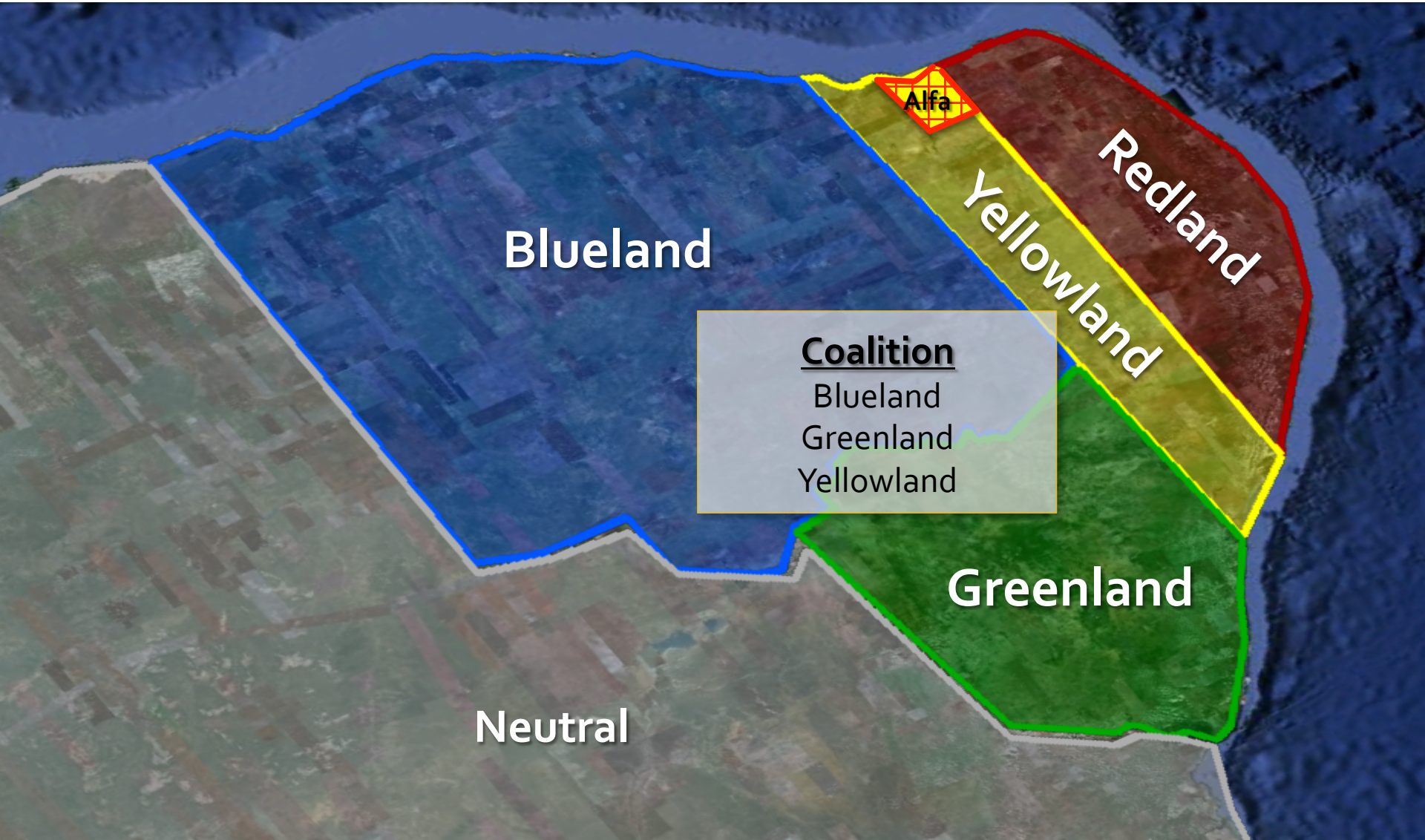
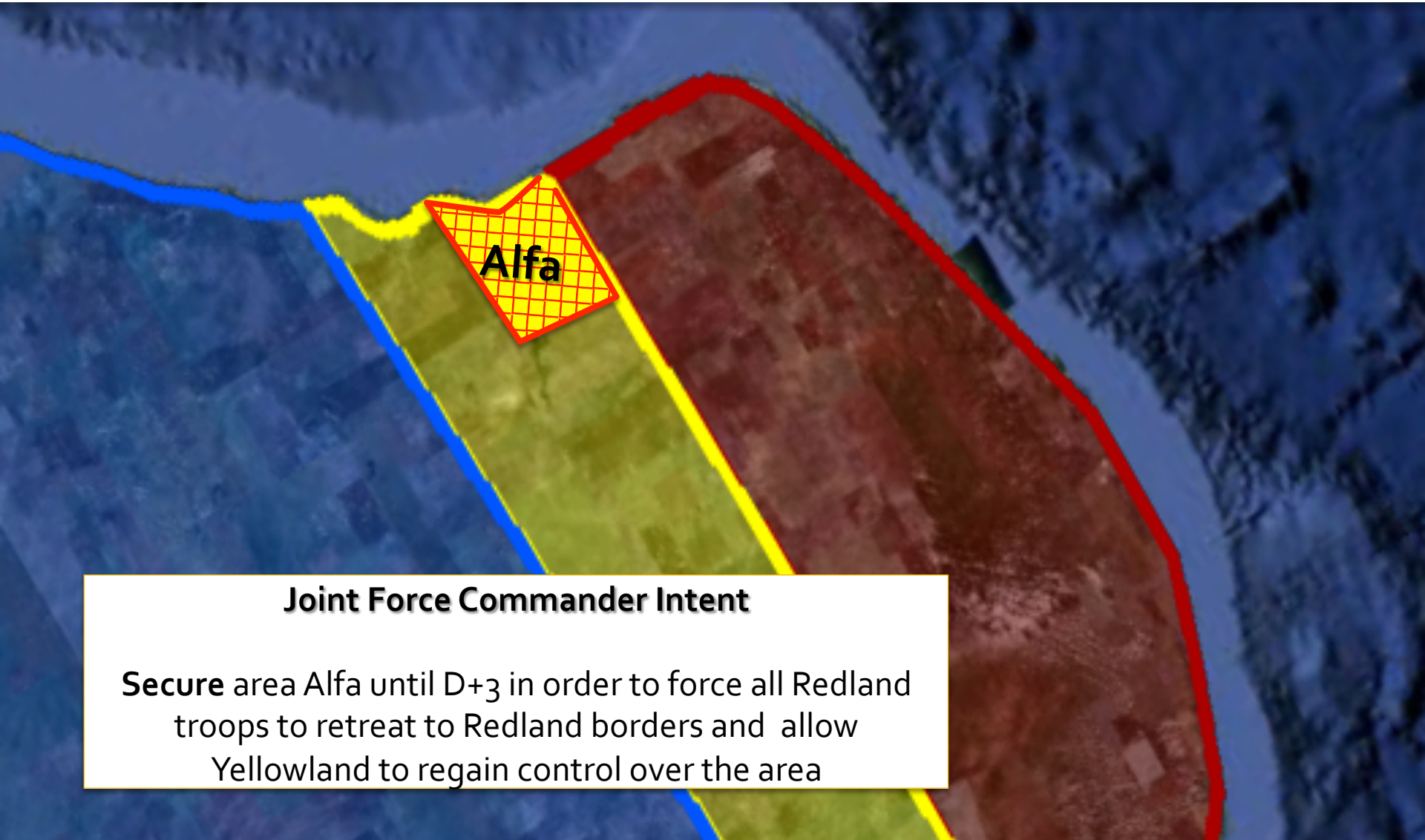
STIDS 2011

Introduction



Introduction



Joint Force Commander Intent

Secure area Alfa until D+3 in order to force all Redland troops to retreat to Redland borders and allow Yellowland to regain control over the area

Introduction

- **Secure**
  - May have different meanings depending on the coalition partner's doctrine and the operational domain (maritime, airspace or land) = **ambiguity**
  - As an effect, may be obtained through different actions
  - Must be coordinated in space and time (joint planning)

Introduction

- Battle Management Language (BML) - effort to reduce the ambiguity of the command intent description

Label 15 - force all Redland troops to retreat to Redland borders and allow Yellowland to regain control over the area
nlt – no later than

Secure	Alfa	nlt D+3	in order to accomplish Label15
WHAT	WHERE	WHEN	WHY

RESTRICTED SEMANTICS – There is no description on the relation between the effects and the actions that can contribute to reach the desired intent

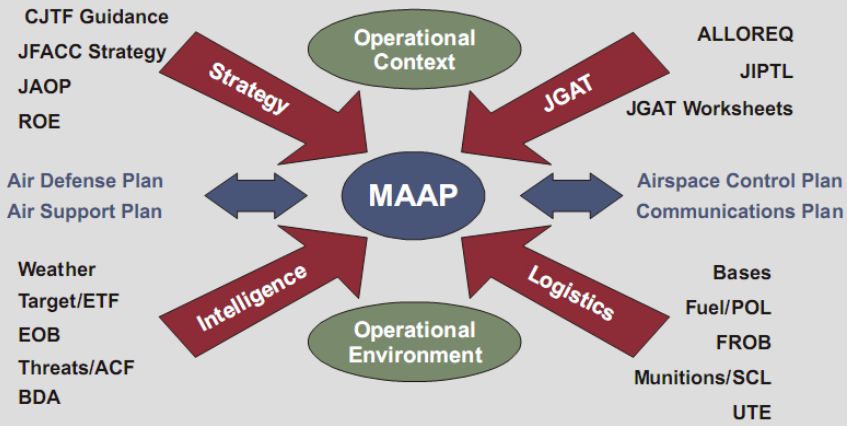
Introduction

SECURE ALFA		
Maritime	Land	Airspace
• Patrol Yellowland's north coast	• Attack Redland's 2nd Brigade on ALFA	• Support the other component's activities • Establish a NO-FLY zone over ALFA
Table 1 - Possible tasks to reach the Secure effect		

Which capabilities, tasks and resources?

- Master Air Attack Plan - MAAP

MASTER AIR ATTACK PLAN INPUTS



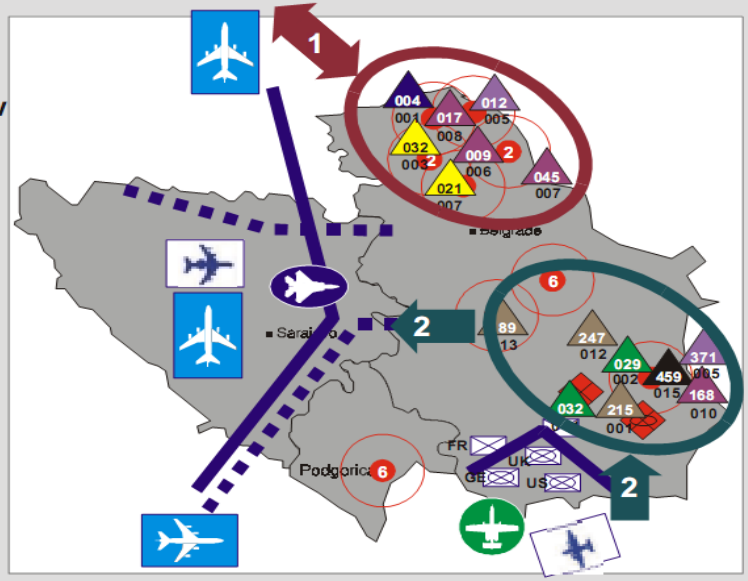
ACF: Air contingency force
ALLOREQ: Allocation request
BDA: Battle damage assessment
CJTF: Commander, joint task force
ETF: Electronic targeting folders
EOB: Enemy order of battle
FROB: Friendly order of battle
JAOP: Joint air operations plan
JFACC: Joint force air component commander
JGAT: Joint guidance, apportionment, and targeting
JIPTL: Joint integrated prioritized target list
MAAP: Master air attack plan
POL: Petroleum, oils, and lubricants
ROE: Rules of engagement
SCL: Standard conventional load
UTE: Utilization rate

DoD - Joint Publication 3-30 Command and Control for Joint Air Operations/ 2003

MASTER AIR ATTACK PLAN DEPICTION

24-Hour DCA CAP
10-Hour CAS Window
Two Packages

- Package 1 (HD/LD)
  - Belgrade/N. Serbia
  - Overlapping threats
  - Urban targets
  - Northern flow
- Package 2 (COMAO)
  - Nis/S. Serbia
  - Isolated threats
  - Diverse targets
  - Southern flow



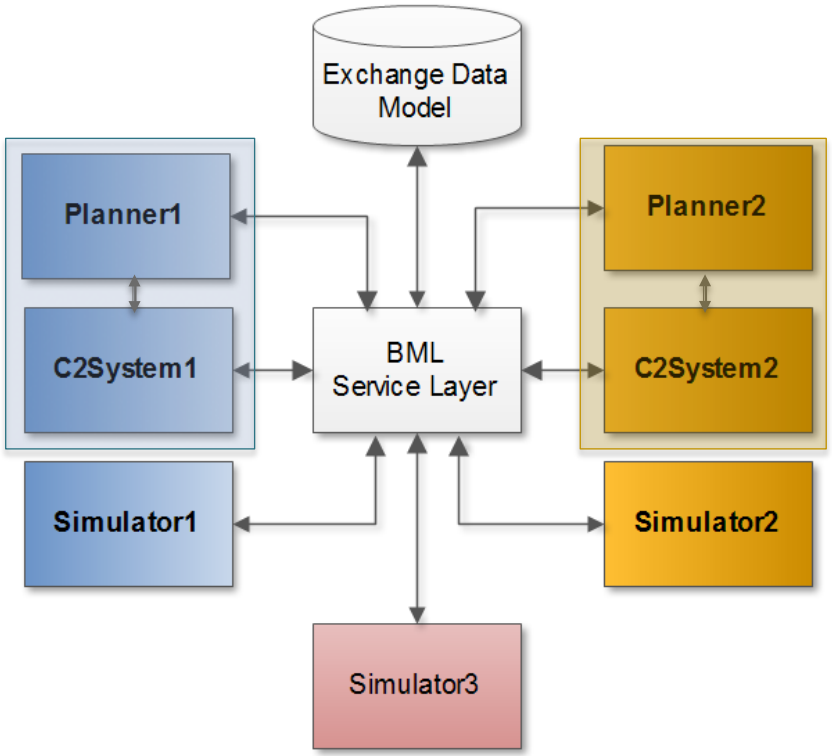
CAP: Combat air patrol
CAS: Close air support
COMAO: Composite air operations
DCA: Defensive counterair
HD/LD: High density/low density

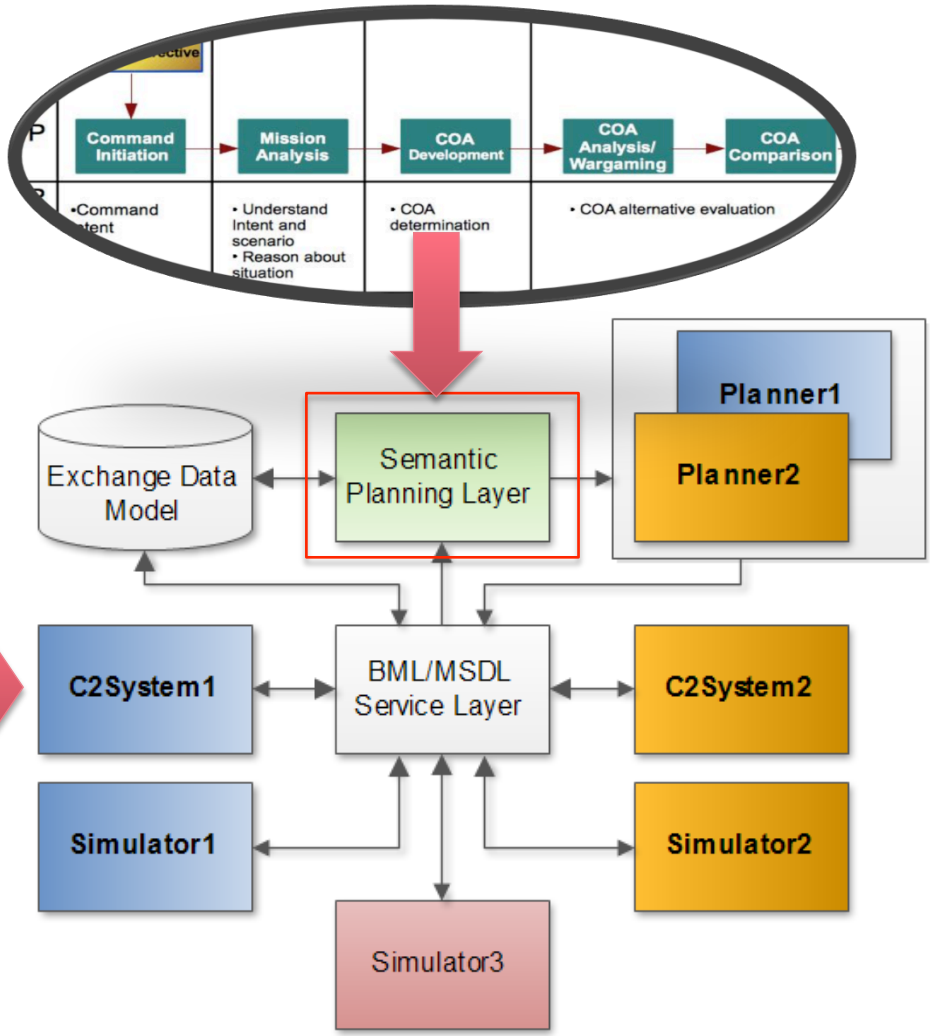
Tactical Level
JFACC

Introduction

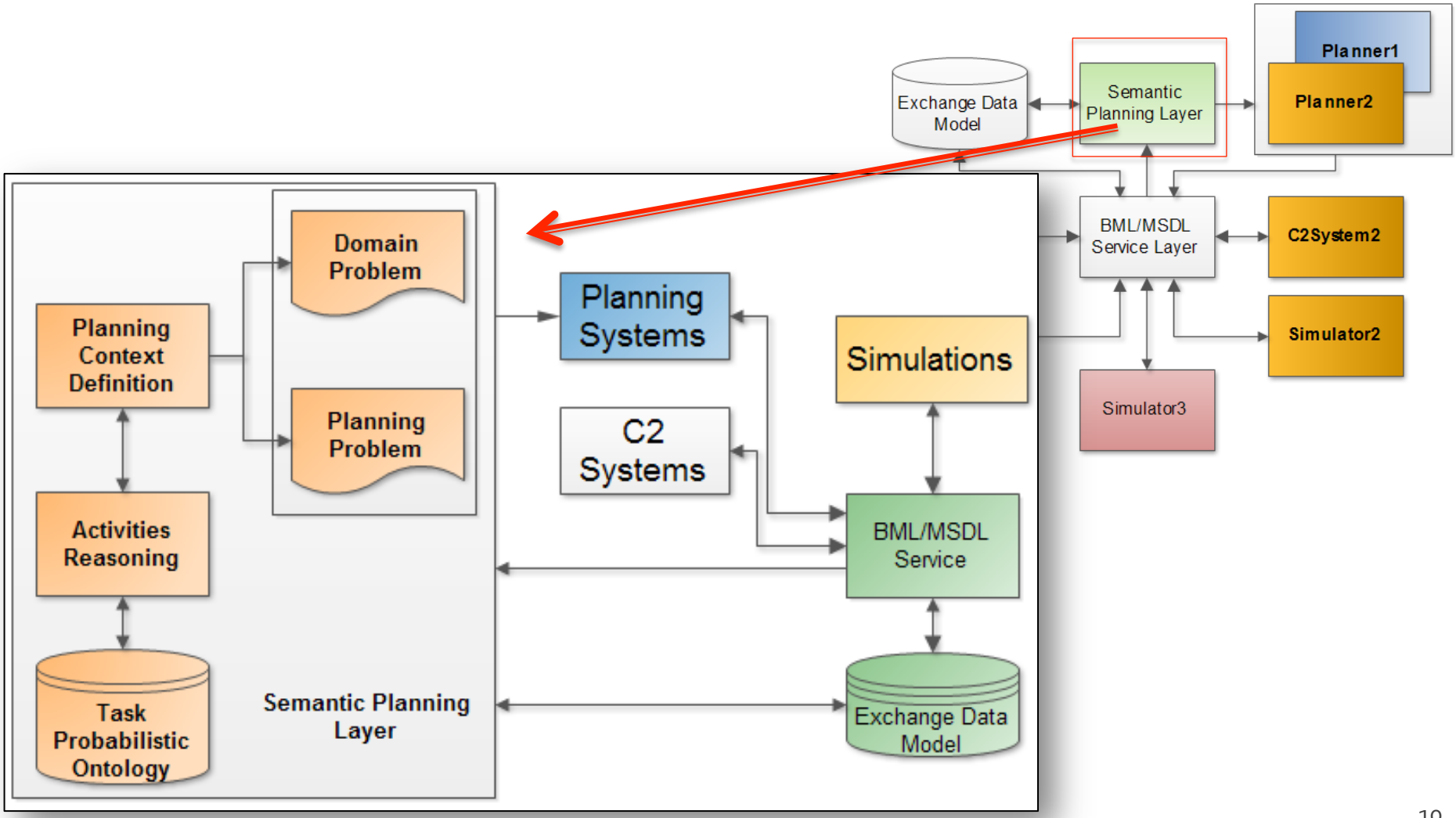
Proposed C2 Interoperability Planning Framework

Actual M&S Interoperability framework

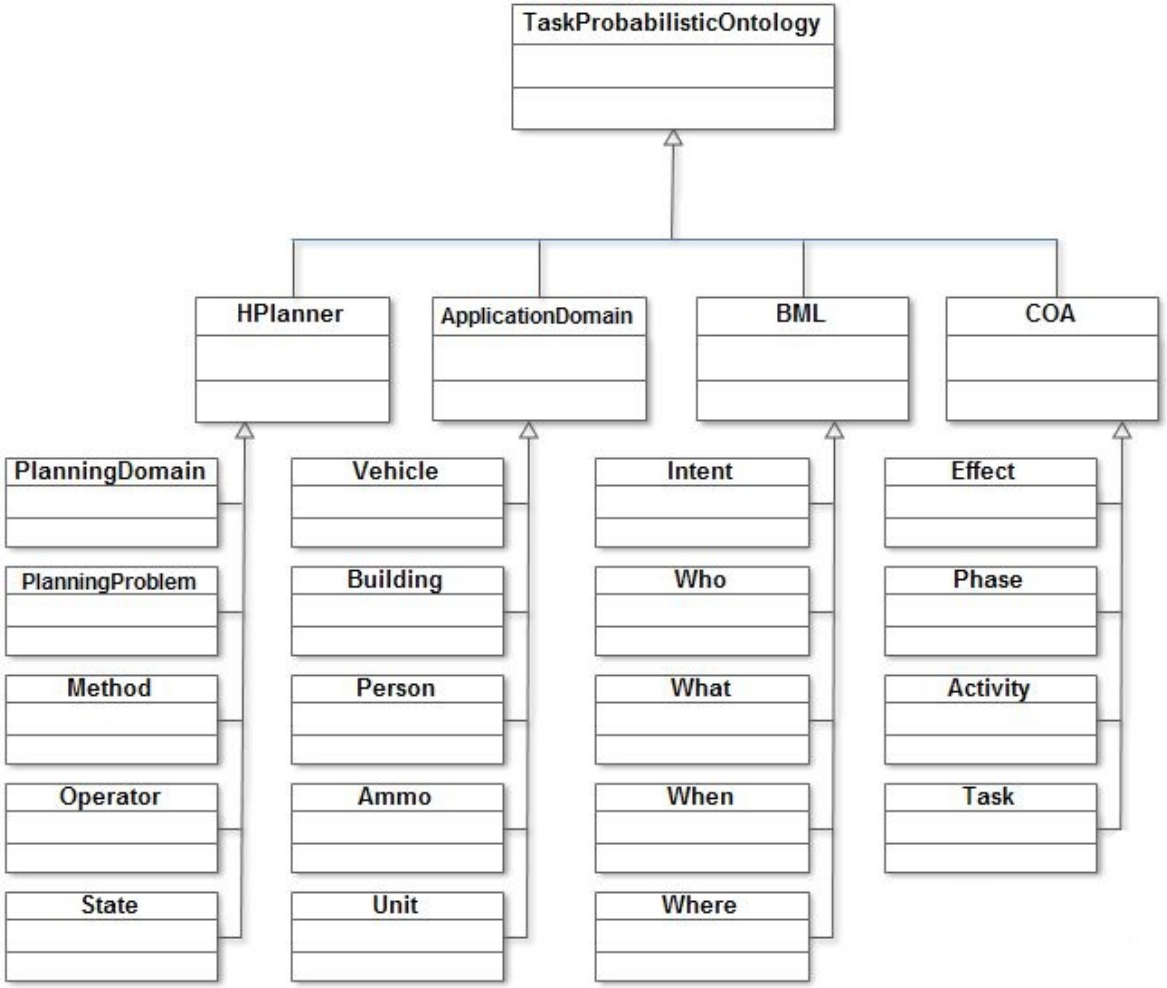




Semantic Planning Layer



Task Probabilistic Ontology



Partial Semantic Structure of the mid-level Task Probabilistic Ontology

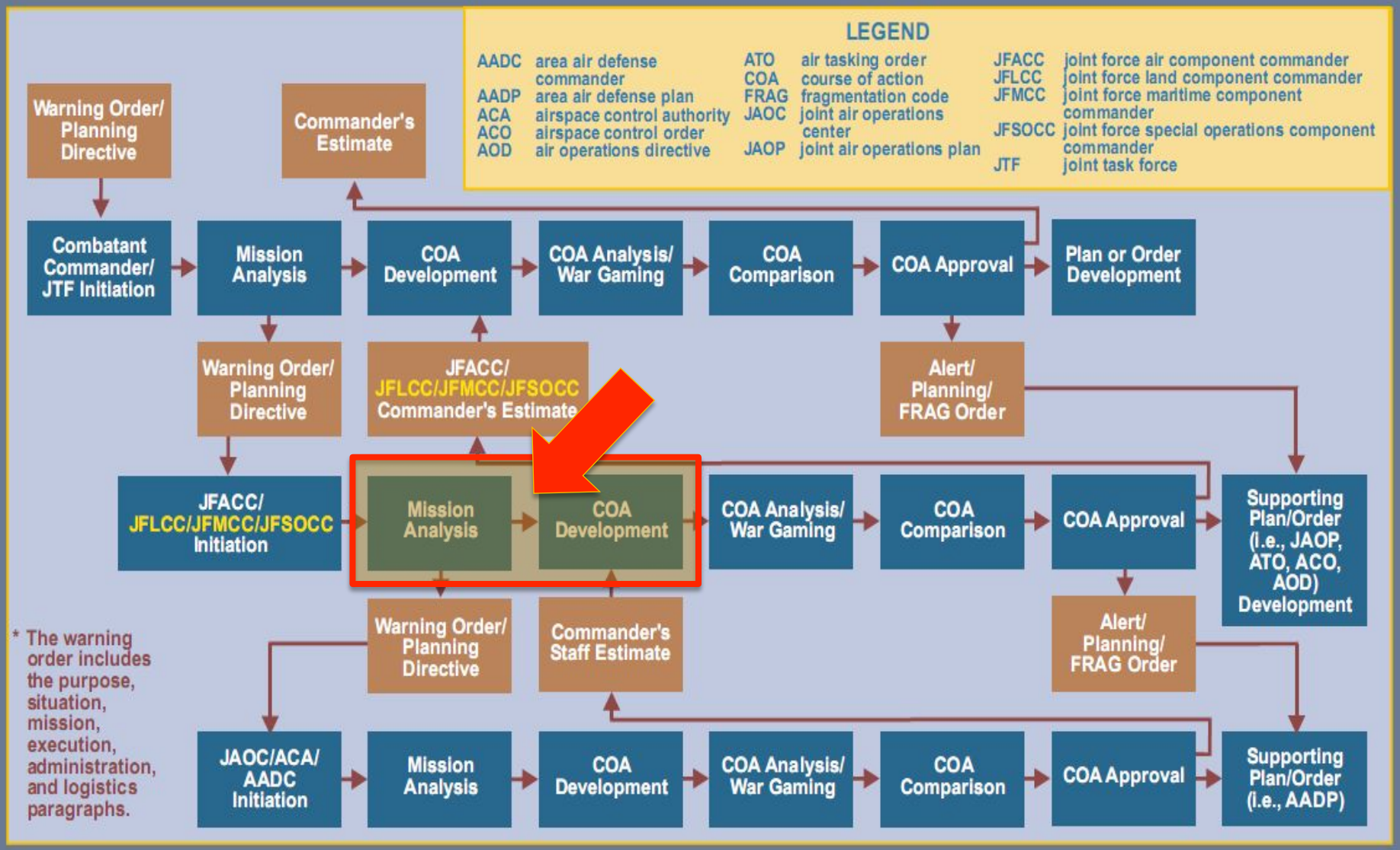
Introduction

- The main goal of this work is to generate Course of Action (COA) representation to improve planning automation
  - The key elements of the approach are:
    - To model the relationship between activities (high level tasks) and effects
    - To represent the decomposition from activities to tasks (atomic)
    - To infer about the uncertainty on the production of the desired effects, based on a set of tasks, in order to reach the end state

Agenda

- Joint Operation Planning Process
- COA Modeling
- COA Development
- Conclusion and Future Work

JOINT OPERATION PLANNING PROCESS



DoD - Joint Publication 3-30 Command and Control for Joint Air Operations/ 2010

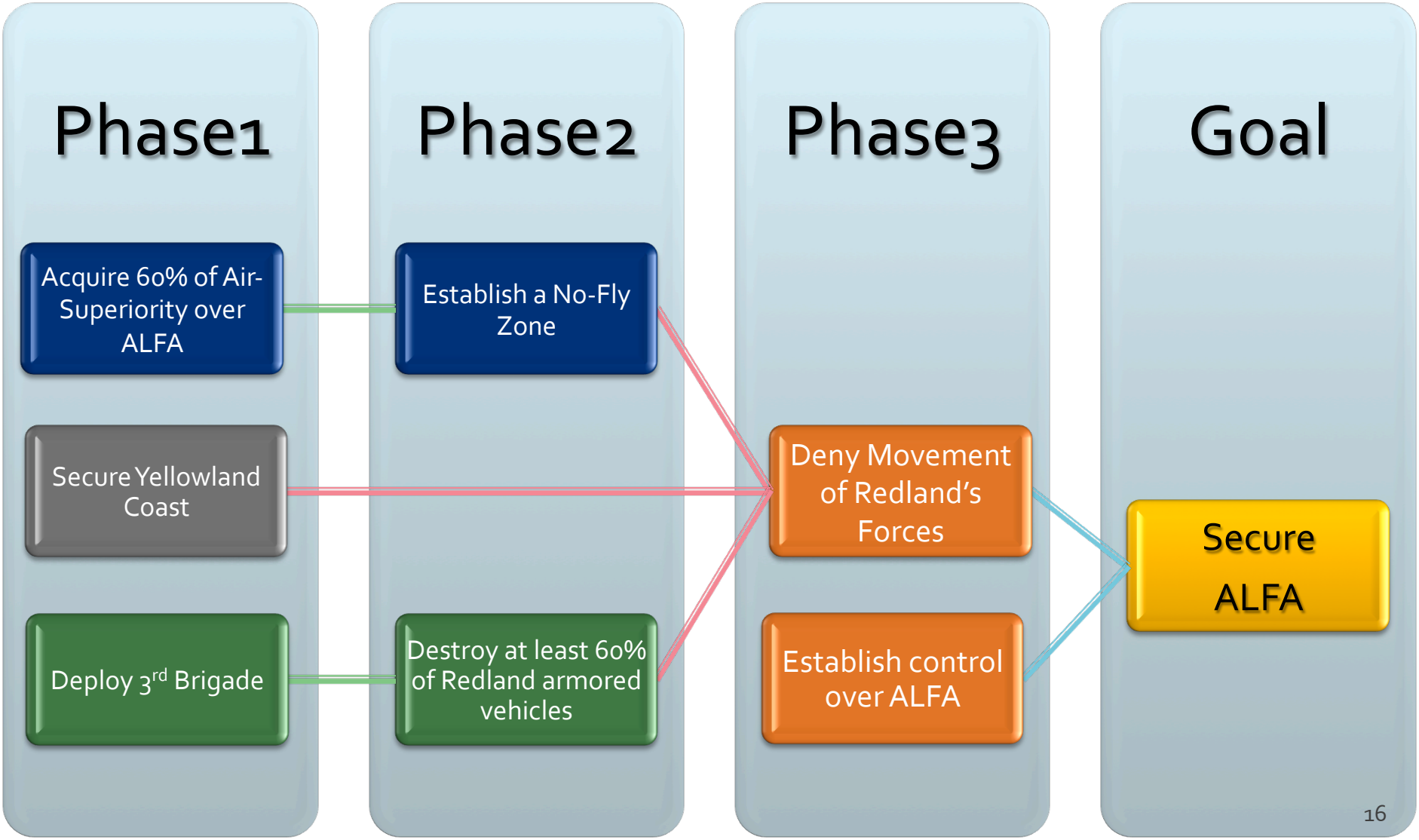
Joint Operation Planning Process – JOPP

DoD - Joint Publication 3-30 Command and Control for Joint Air Operations/ 2010

	1	2	3	4	5	6
JOPP	Warning Order/ Planning Directive → Command Initiation	Mission Analysis	COA Development	COA Analysis/ Wargaming → COA Comparison	COA Approval	Supporting Plan/Order
Role	•Command Intent	• Understand Intent and scenario • Reason about situation	• COA determination	• COA alternative evaluation	• Choose the best available COA	• Track changes in scenario
Task	• Represent Intent	• Generate causal relations	• Generate space states •Generate probabilities •Generate constraints •Problem solving methods	• Establish a war-game environment • Generate different scenarios • Compare results • Generate a scored list based on the established metrics for comparison	•Decision	•Update COA

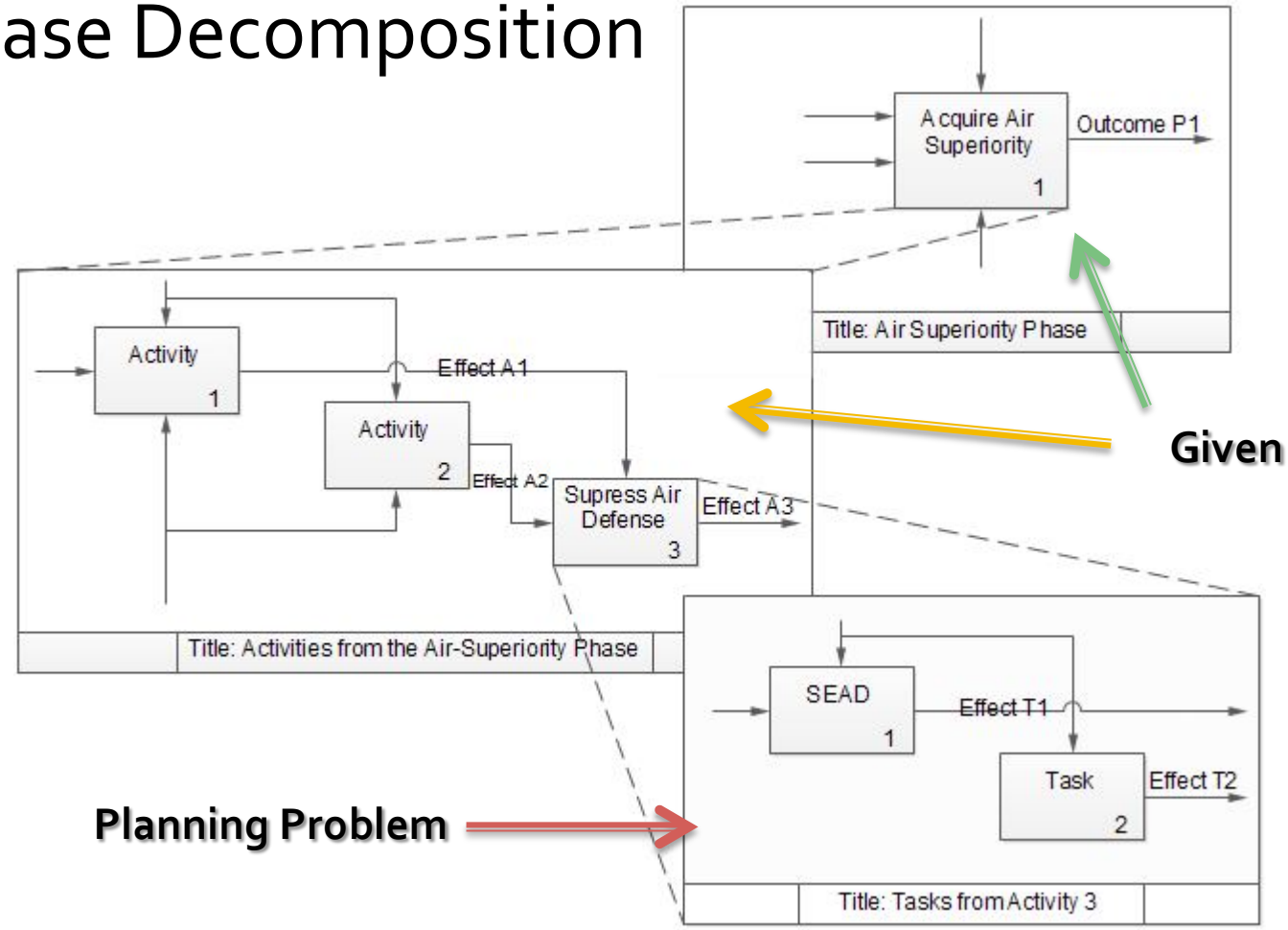
Joint Operation Planning Process divided into six steps [Marques 2011]

COA Modeling



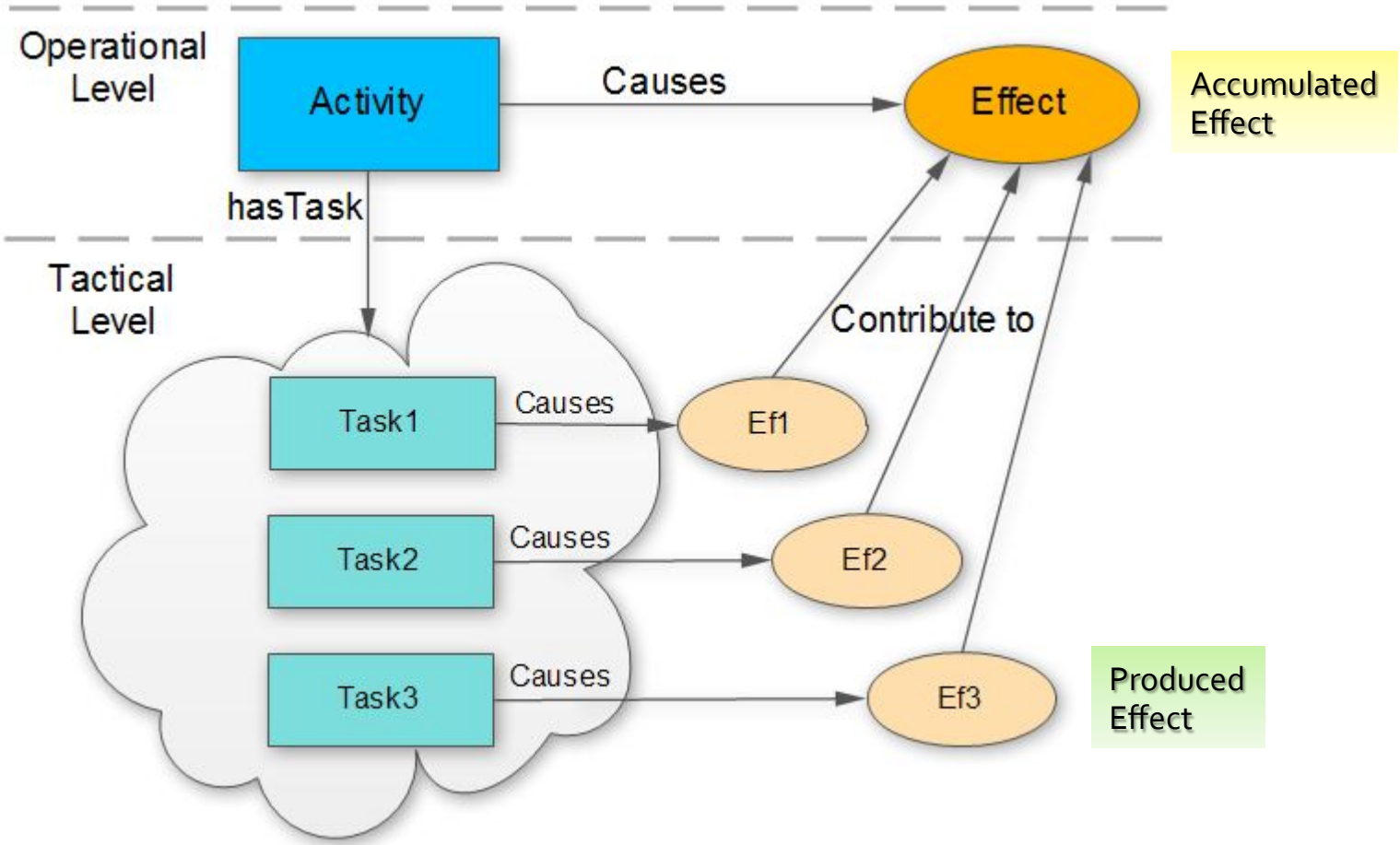
COA Modeling

- Phase Decomposition

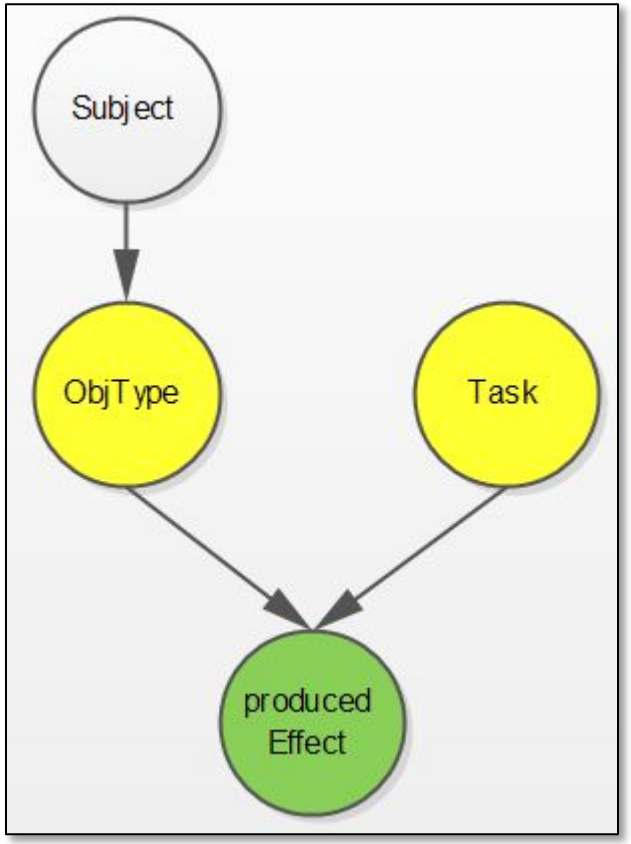


COA Modeling

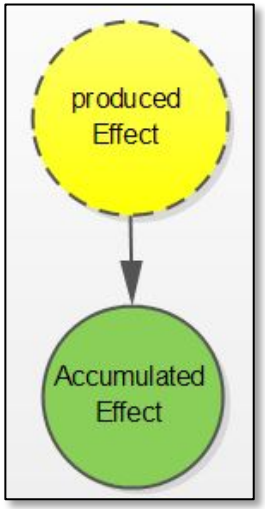
- Cumulative Effects Model



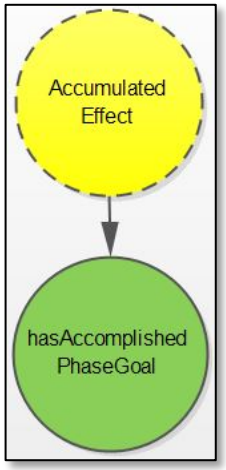
COA Modeling



Activity Fragment

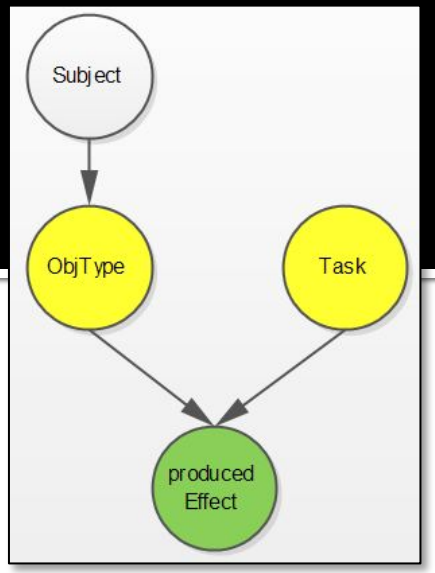


Effect Fragment



Phase Fragment

COA Modeling



- The model also has the local probability distribution tables (LPD) for the resident nodes of interest;

	Task								
producedEffect	*Reccon*	*Attack*	*SEAD*	*Reccon*	*Attack*	*SEAD*	*Reccon*	*Attack*	*SEAD*
High	.70	.60	.80	.60	.50	.55	.55	.20	.40
Medium	.20	.20	.10	.25	.30	.20	.30	.30	.35
Low	.05	.15	.05	.10	.15	.15	.10	.35	.20
None	.05	.05	.05	.05	.05	.10	.05	.15	.05
	Soft			*Medium*			*Hard*		
	ObjType								

The producedEffect's LPD

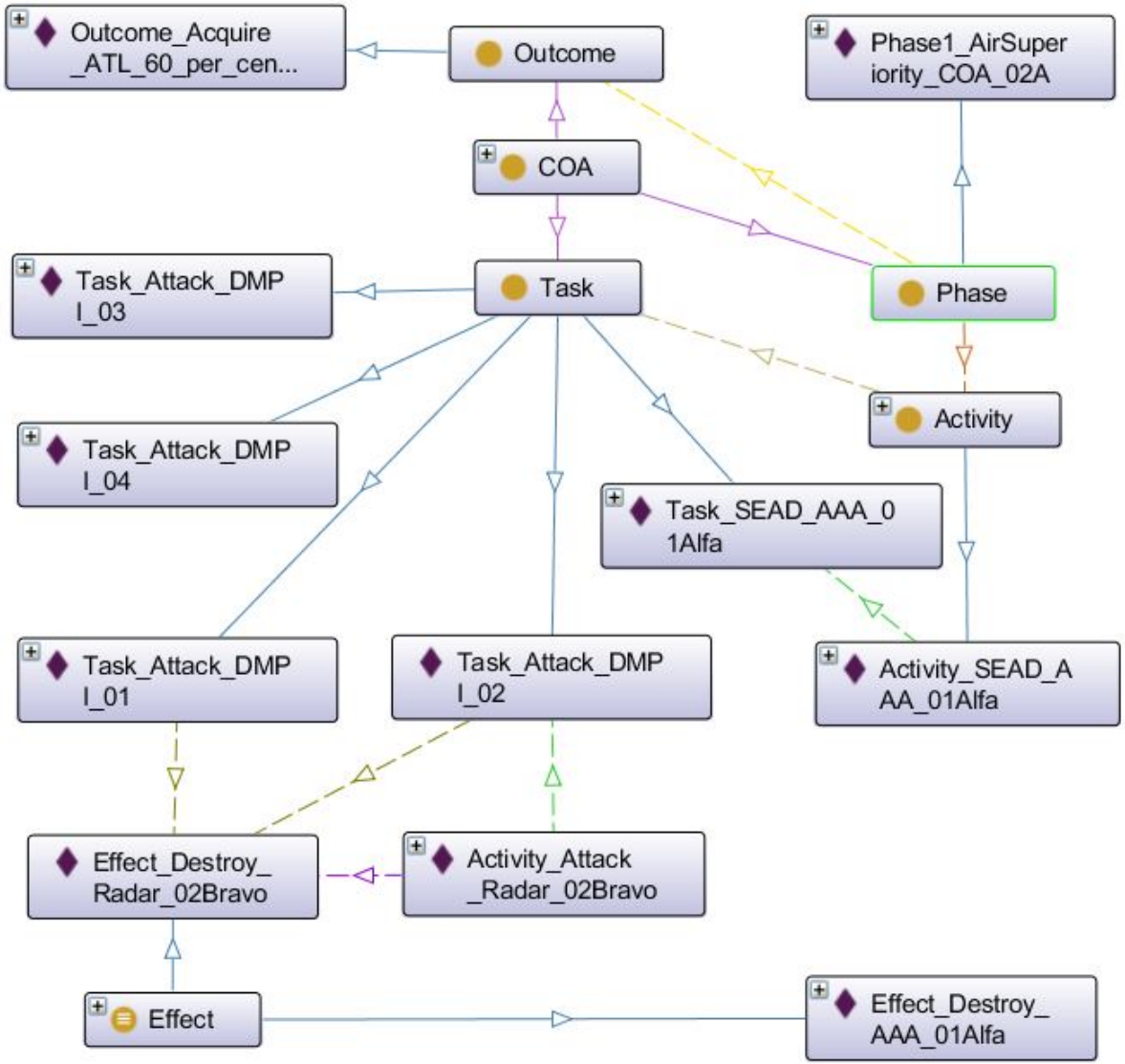
COA Development

- Phase 1 – Activity 1
  - Acquire at least 60% of Air Superiority

Phase - Air Superiority		
Outcome - Acquire at least 60% of Air Superiority		
Effect	**Activity**	**Task**
Destroy AAA	SEAD	SEAD
Destroy Radar	Attack Radar	Attack DMPI01 and DMPI02
Destroy C2 Comm	Attack C2 Comm	Attack DMPI03 and DMPI04

Table 1 –Tasks definition

COA Ontology

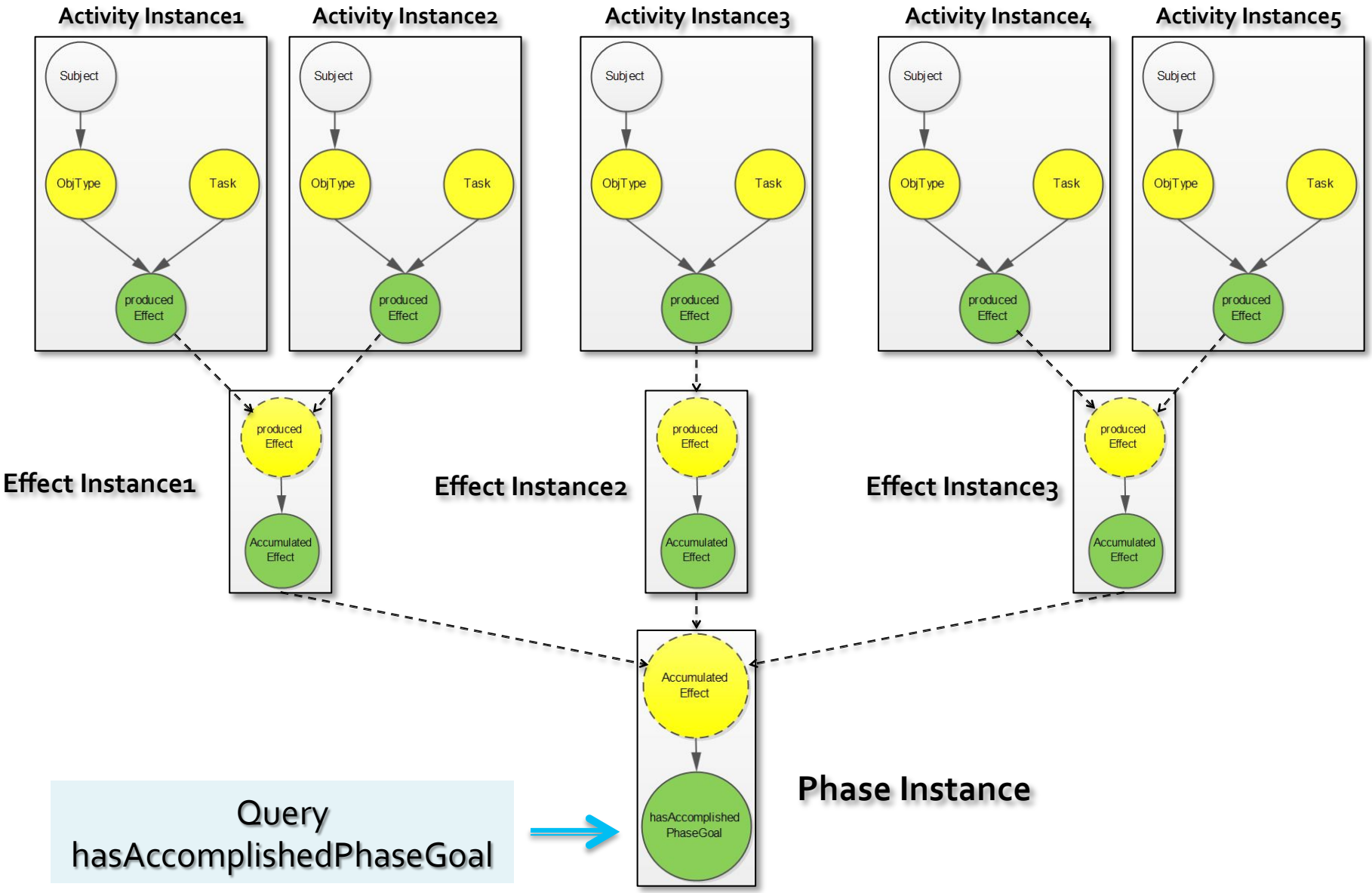


COA Development

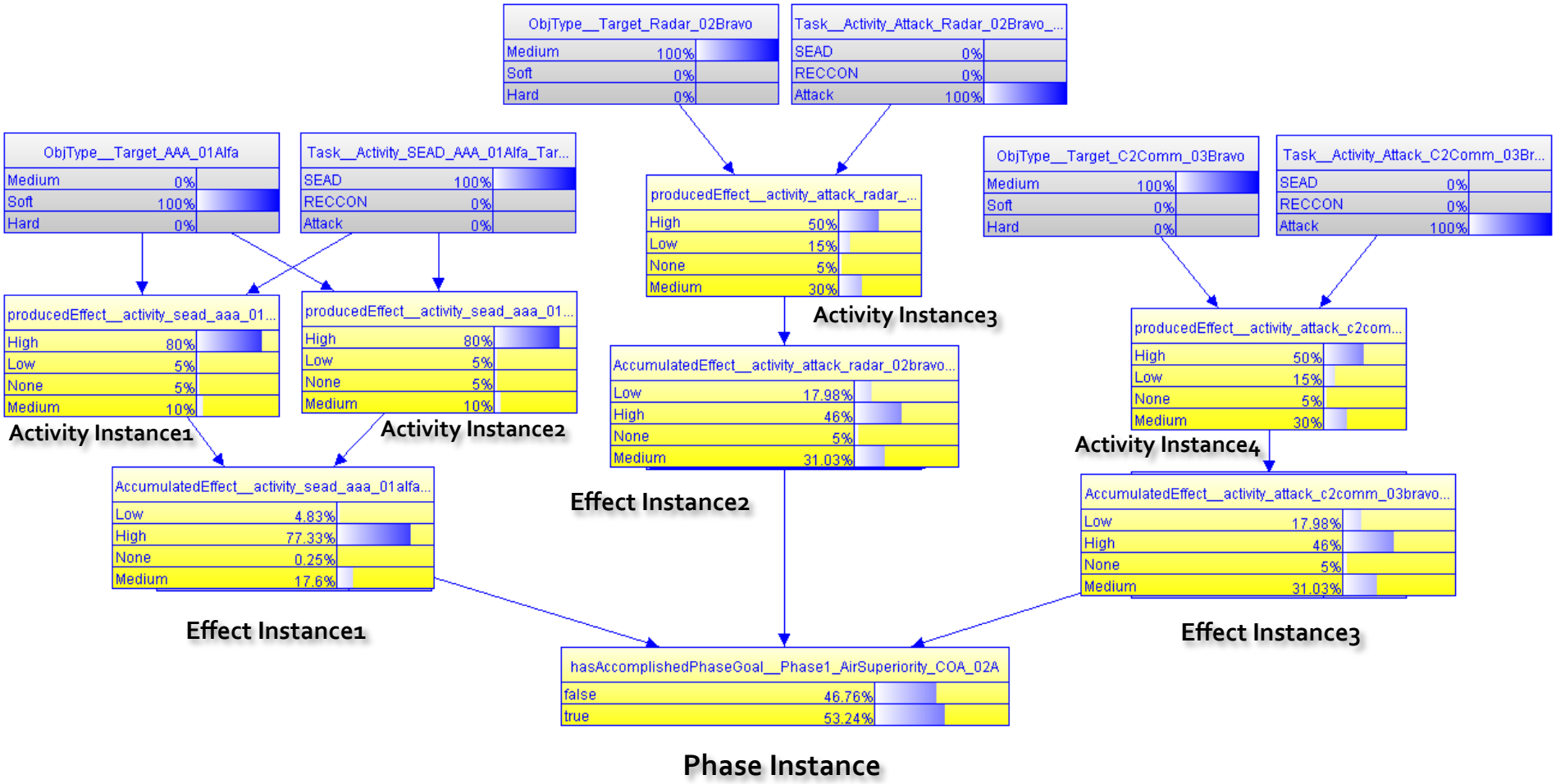
- After all instances and LPDs are included in the probabilistic ontology, a query can be posted to the model to assess a specific outcome;

- A Specific Situation Bayesian Network – SSBN is the result of a query on the planned outcome of the AirSuperiority phase *[hasAccomplishedPhaseGoal (Phase1_AirSuperiority_COA_02A)];*

- In the resulting SSBN, there are planned effects accumulated from Time *To* and *T1* for the activity *SEAD_AAA_01Alfa* to object *Target_AAA_01Alfa* and the activity *Attack_C2Comm_03Bravo* over object *Target_C2Comm_03Bravo*;


Activity Instance1
Activity Instance2
Activity Instance3
Activity Instance4
Activity Instance5
Subject
ObjType
Task
produced Effect
Effect Instance1
Effect Instance2
Effect Instance3
Accumulated Effect
hasAccomplished PhaseGoal
Phase Instance
Query hasAccomplishedPhaseGoal

COA Development



1st Query to support Phase Outcome inference

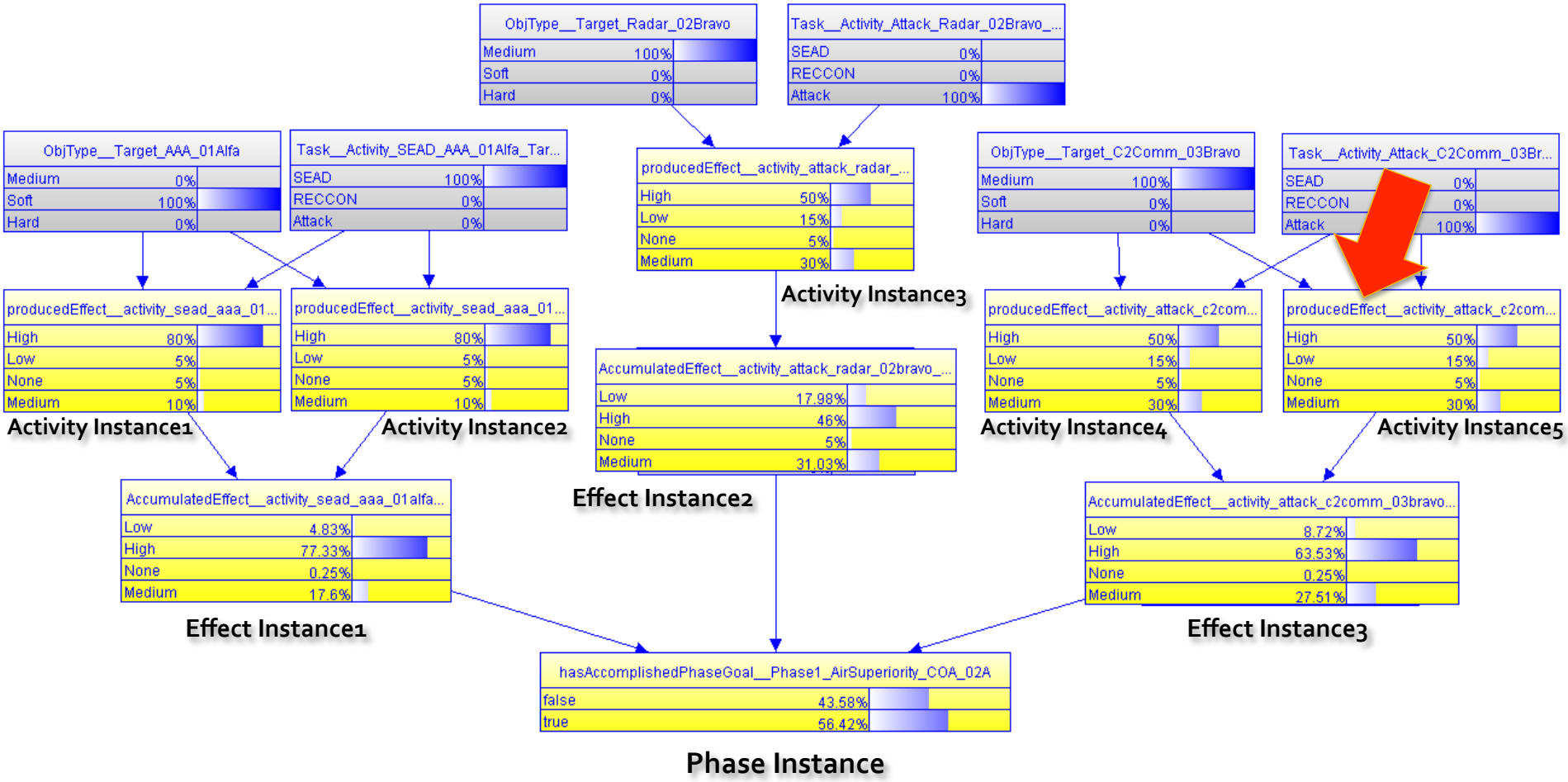
Task Inference

GenerateTaskList

Input: A knowledge base (kb), a Phase and it's defined threshold
Output: A list of tasks that contribute with the desired effect or NIL

```
Create an empty list of tasks called R;
Q1 = Query(Phase);
If  Phase's threshold  was already reached,  Return NIL;
Else get the activities TaskList from Phase;## previous planned activities for the phase
While not (EMPTY TaskList){
    A = TOP(TaskList);
    Generate a NewActivity based on A; ## external function
    Q2 = Query(Phase);
    If (Q2 > Q1)  R receives A;
    If (Q2 >= threshold)   Return R;
}EndWhile
Return R;
```

COA Development



2nd Query to support Phase Outcome inference after generating a new task

Conclusion

- The present research is a work in progress
- At this moment we have achieved:
  - An Activity-Effect relationship description with uncertainty
  - A reasoning model to support task analysis
- Our goal is to improve planning automation through

Future Work

- Improve the effects model showing also the secondary effects
- To model behavioral effects
- Improve reasoning with Decision Nodes and Utility Functions in the resulted SSBN
- Planning system integration
- Verification through simulations

COA modeling with probabilistic ontologies

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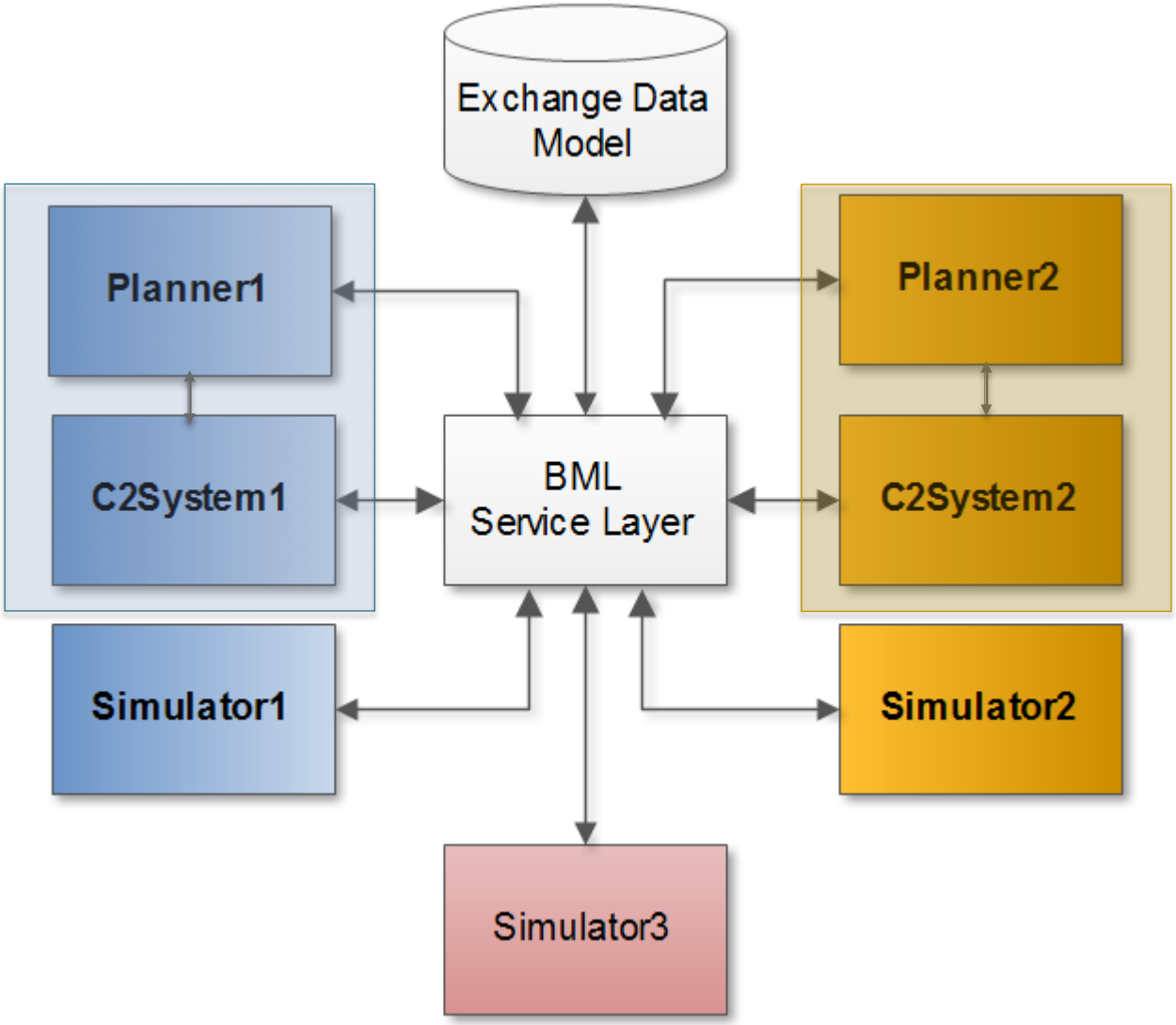
Planning Process - Interoperability

- COA Determination
  - Decision Support Systems – C^2 Systems
  - Planning system as a module
- Different Players may have different planning systems with different problem-solving methods
- How to describe COA to improve planning interoperability?

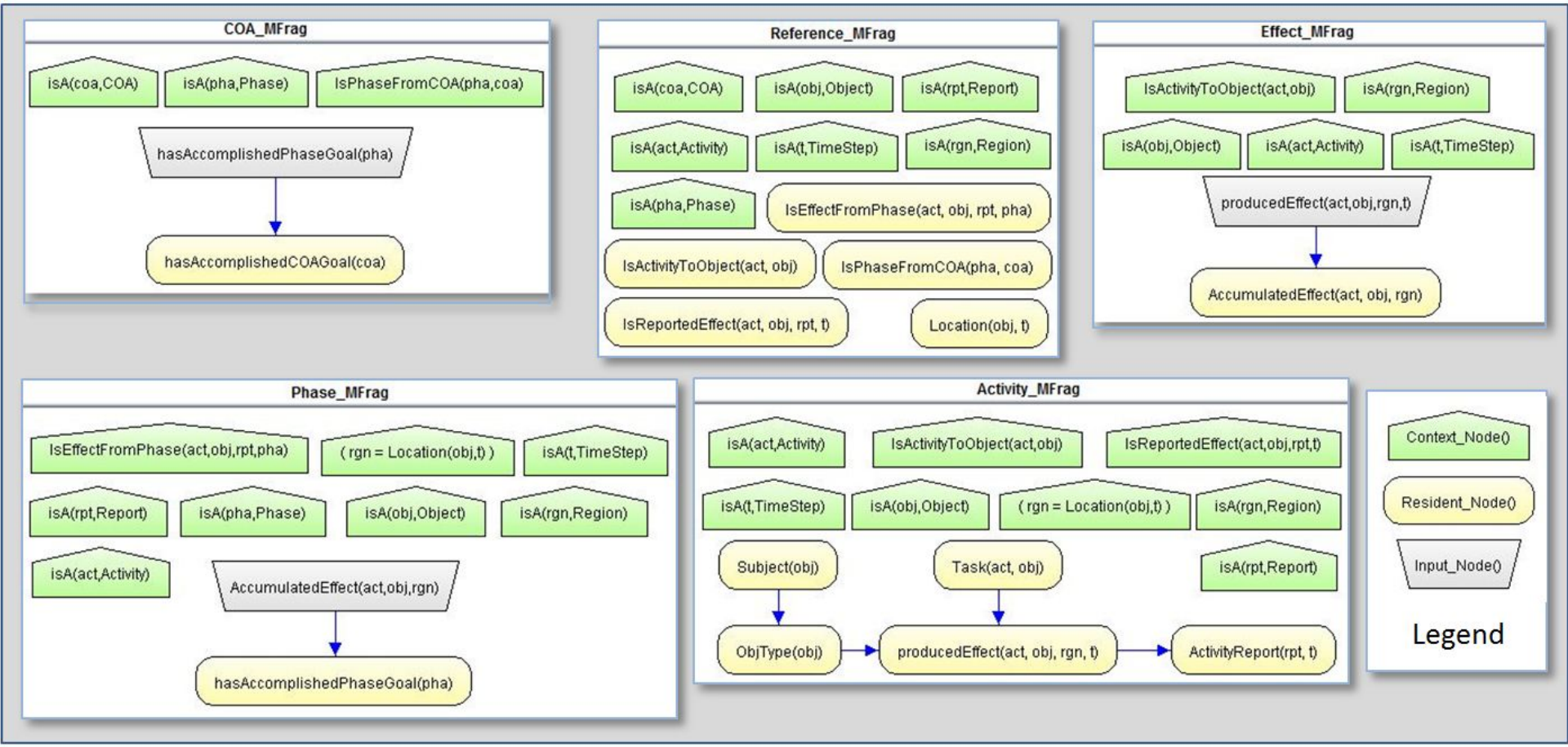
M&S Interoperability Framework



Task Probabilistic Ontology

- Probabilities described through PR-OWL, a probabilistic OWL language [Costa 2005 , Carvalho 2011]
- PR-OWL implements Multi-Entity Bayesian Networks (MEBN) inference [Laskey 2008]
- Describes the relations and properties as a deterministic ontology, but has the ability to also describe a Situation Specific Bayesian Network (SSBN) to support reasoning under uncertainty

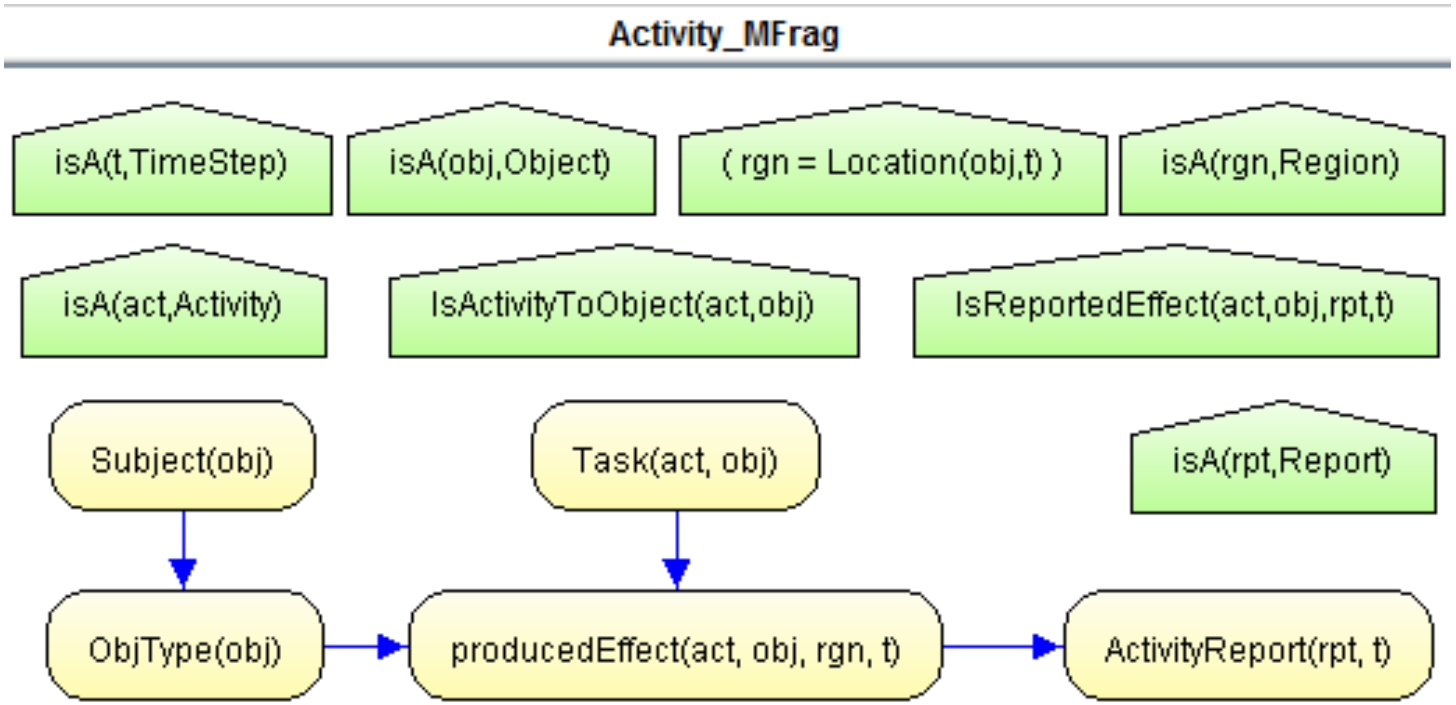
COA Probabilistic Ontology

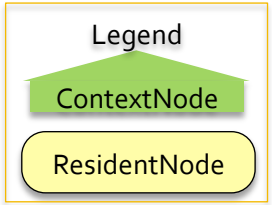


COA MTheory

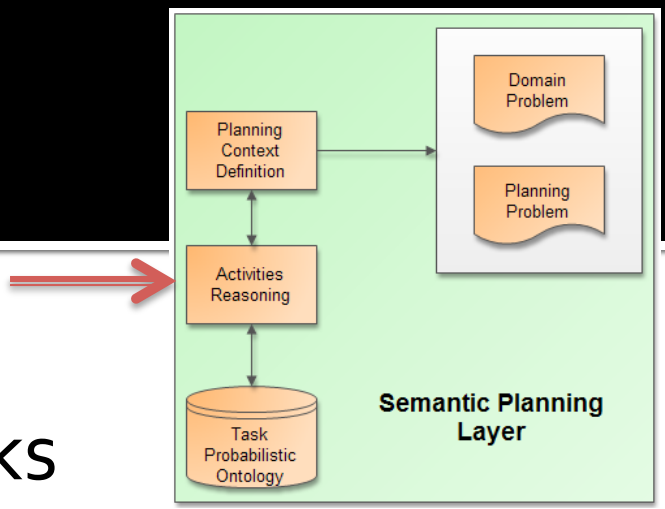
Activity Probabilistic Description

- Cumulative Effects Model in PR-OWL



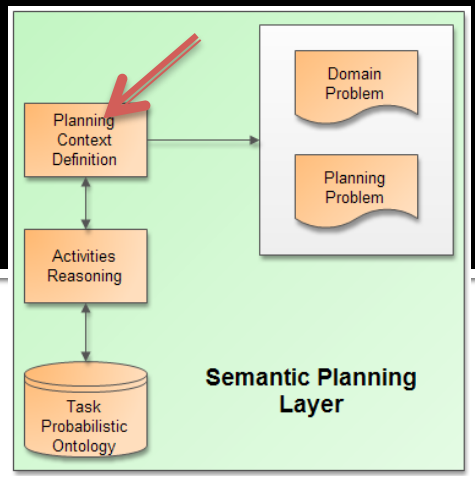


Activities Reasoning



- Pull BML/MSDL high level tasks
- Through the support of the probabilistic task ontology, identify activities to be pruned by analyst criteria (defined threshold for each phase and activity)
- Generate SSBN to support the activities inference
- Export a list of the activities to be described within the Planning Context Definition module

Planning Context Definition



- process to establish the problem context to be submitted to the domain-independent planning system
  - Planning Domain definition – identification of the methods that decomposes the activities and also the operators
  - Planning Problem definition – description of the tasks to be decomposed and the initial state declared on the MSDL message
  - PDDL files generation