# Multi-Modeling of Adversary Behaviors

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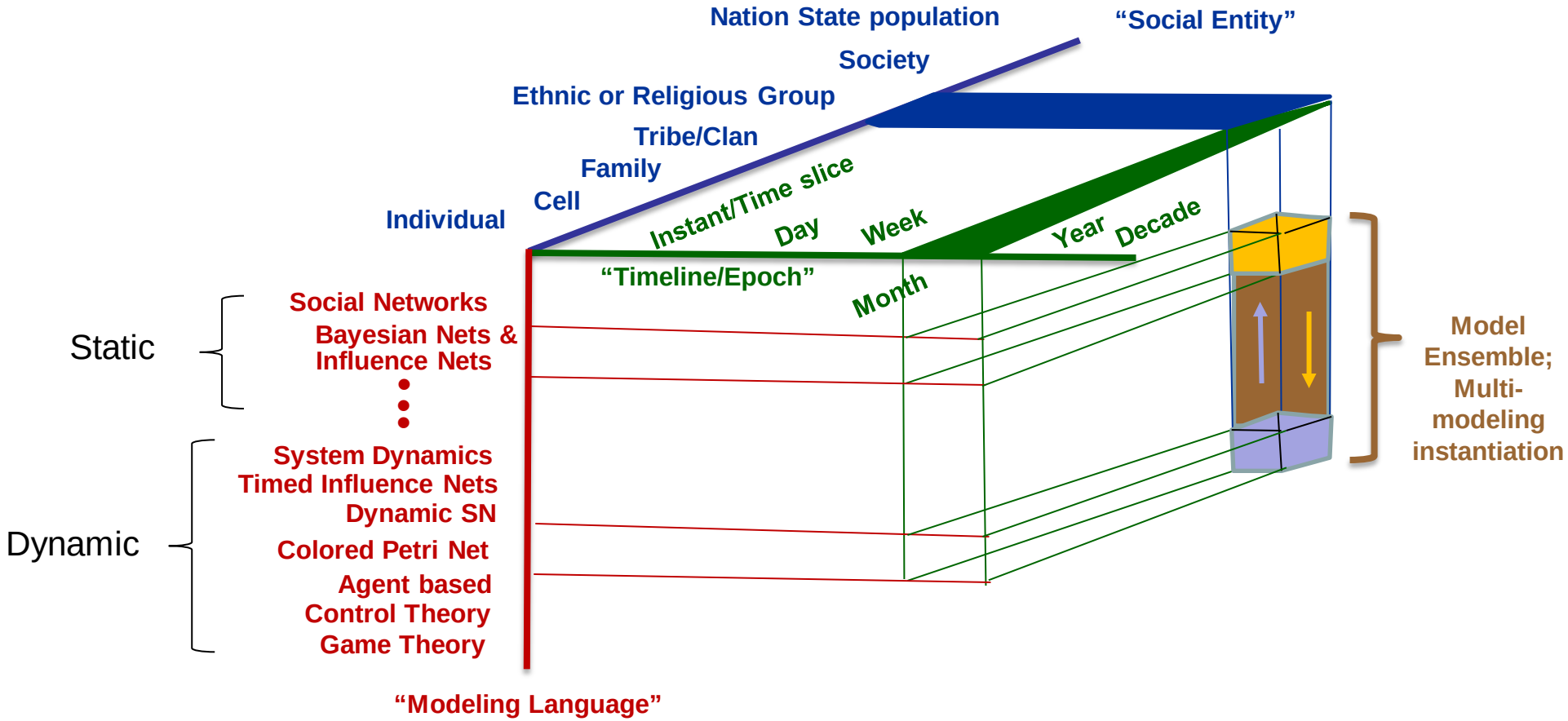
# Adversary Behavioral Modeling

- In considering this research area, we may try to develop a classification scheme that can place different problems in context.
- While the domain is very complex when observed from different perspectives, we can define three dimensions that are relevant to mathematical modeling

1. Mathematical modeling languages
2. Social Entity
3. Time.

- The Time Horizon of the decision problem is another attribute of the temporal dimension
- As the Time Horizon is increased, the sphere of influence (the social entity) is broadened
- Human decision making occurs at three distinct levels: strategic, operational, and tactical.

# Model Interoperation for Multi-Modeling Construct




- The linked cells in this diagram show that an ethnic or religious group has been modeled as an interoperable Bayesian Net and Colored Petri Net model to enable the study alternative Courses of Action

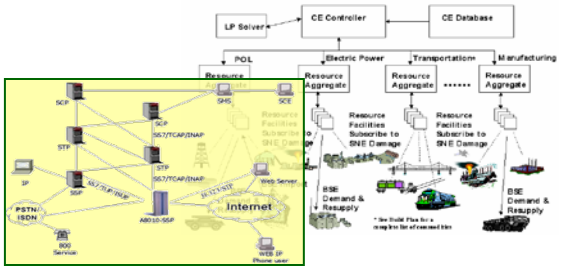
# Multi-Modeling Problem Statement

- **Given**
  - **Multiple Knowledge Representations**
  - **Multiple Reasoning/Computational Approaches**
  - **Complex human-centric scenarios**

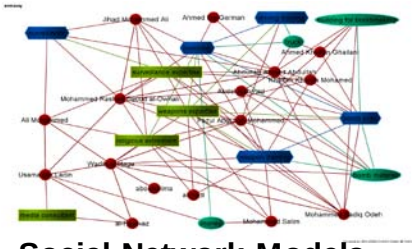
- **Nexus Between Models**
  - **What are valid *interconnections* between models?**
  - **Are there *overlaps* among the models?**
  - **Can the outputs of different models be *fused* together?**
  - **How do we identify *gaps*, *inconsistencies*, or *incompleteness* ?**

- **Workflow**
  - **Given an analysis objective, what is the workflow (i.e., sequence of/between models) that exploits multi-modeling in addressing the objectives?**

# Multi-Modeling Concept



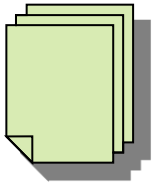

Engineering System Models e.g., Network Models, Vehicle models



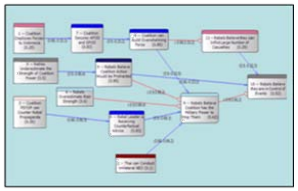
Social Network Models e.g., ORA

Modeling/Analysis Objective

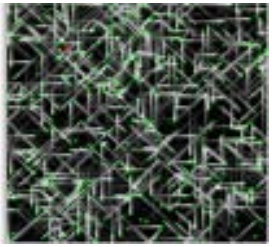
SME



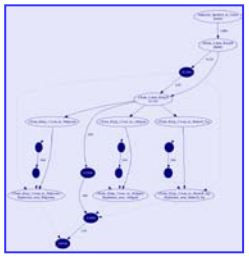
Data Set



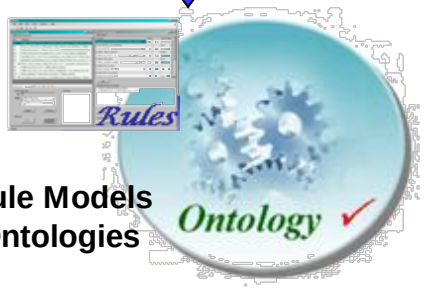
Situational Influence Models e.g., Timed Influence Net



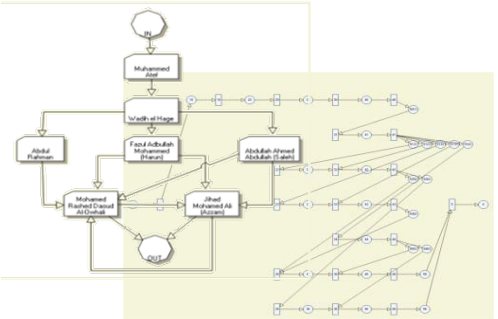
Multi-Agent Simulation Models, e.g., DyNet



Temporal Models

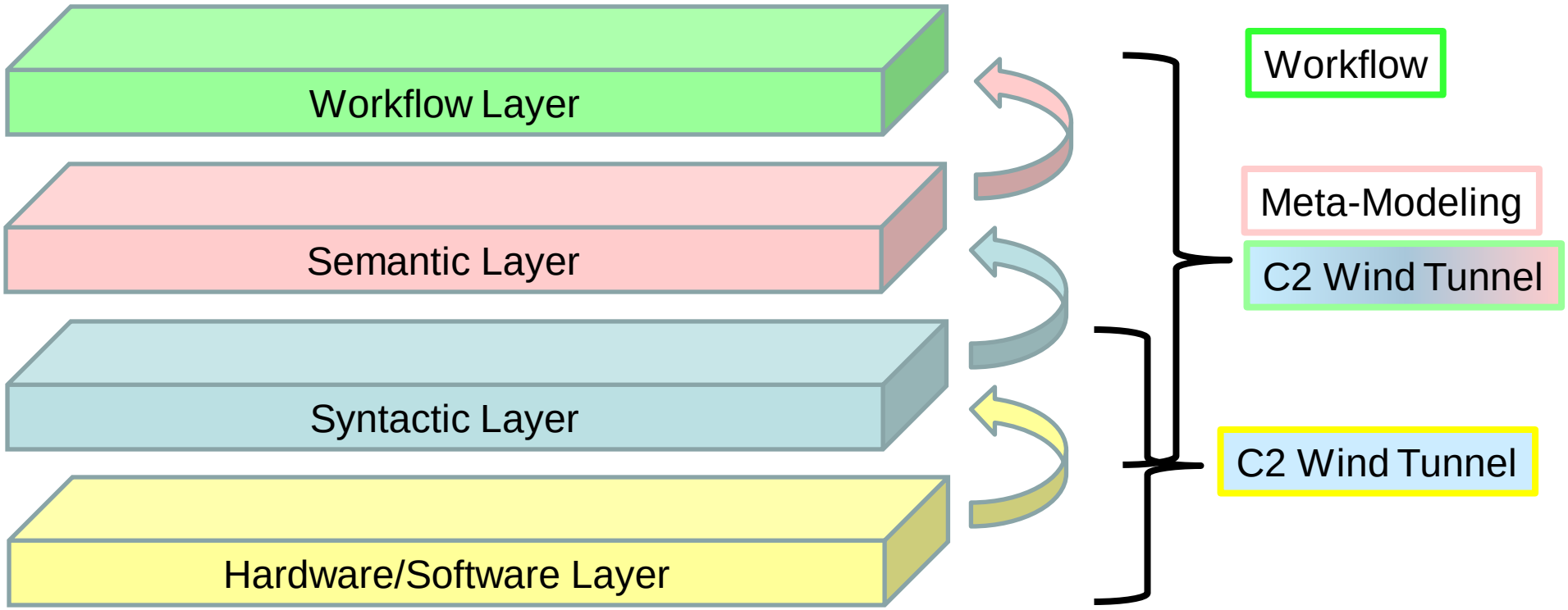



Rule Models Ontologies



Organization Models e.g, Petri Nets

# Multi-Modeling Layers



# Multi-Modeling: Hardware/Software and Syntactic Layers

- **Problem 1: Establish an infrastructure that enables:**
  - **The loose coupling of diverse modeling languages and simulation engines**
  - **The use of the <u>same data</u> by multiple models expressed in different modeling languages**
- **Problem 2: Develop a rapid system integration technology for empirical/computational studies**

**Approach: The C2 Wind Tunnel was developed by ISIS/Vanderbilt with UC-Berkeley and SAL/George Mason to address these two problems under an AFOSR grant**

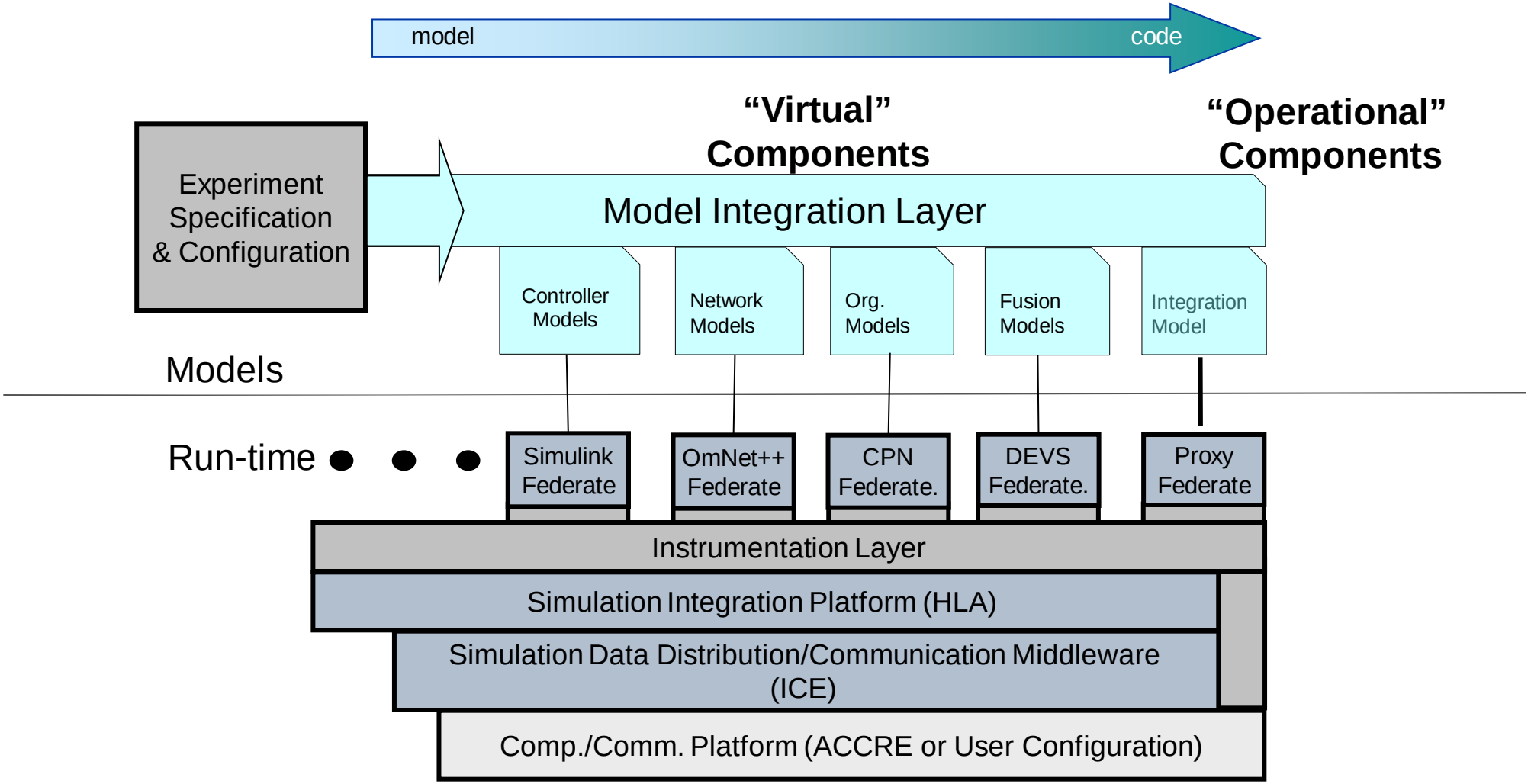
# Multi-Modeling: Semantic and Workflow Layers

- **Problem 3 - <u>Syntactic Layer</u>: This problem addresses the software infrastructure (or platform) on which multiple models will interoperate**
  - ***Meta-Modeling*** *is used to analyze different modeling languages in order to embed them in the C2 Wind Tunnel and enable model interoperation at the syntactic level*

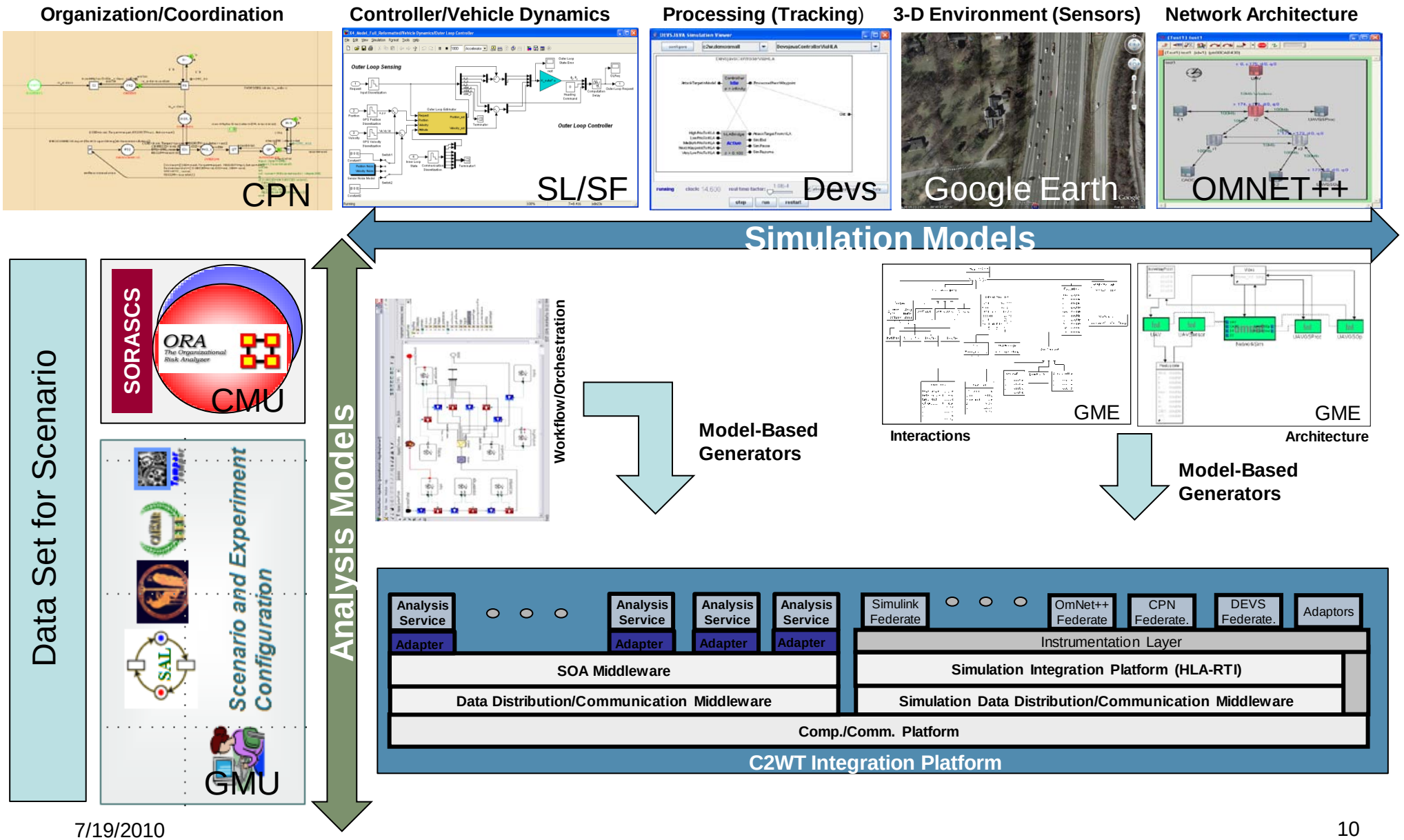
- **Problem 4 - <u>Semantic Layer</u>: This problem addresses the validity of using a set of interoperating models for a particular problem**
  - ***Meta-Modeling*** *is used to understand modeling language semantics so that multiple models can be used together validly to address a problem*

- **These two layers, when working properly together, enable valid Multi-Modeling**

# C2 Wind Tunnel Architecture

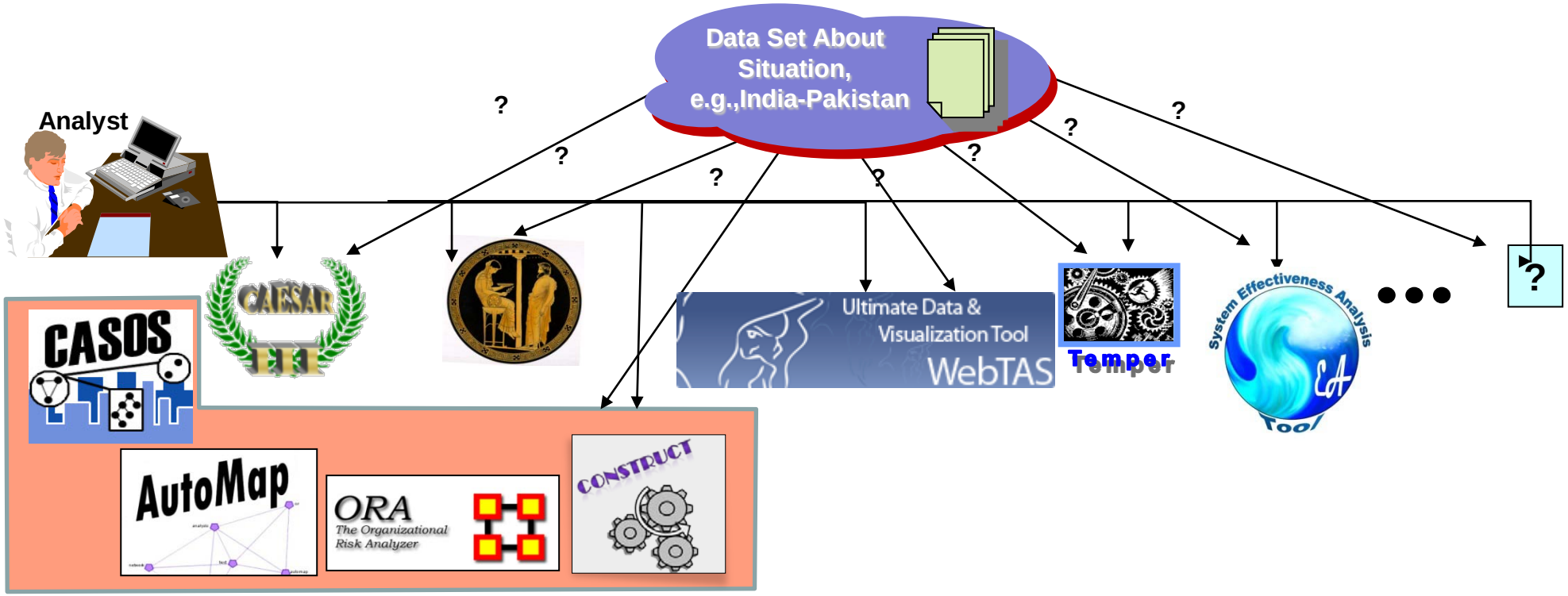


# C2WT Modeling Environment

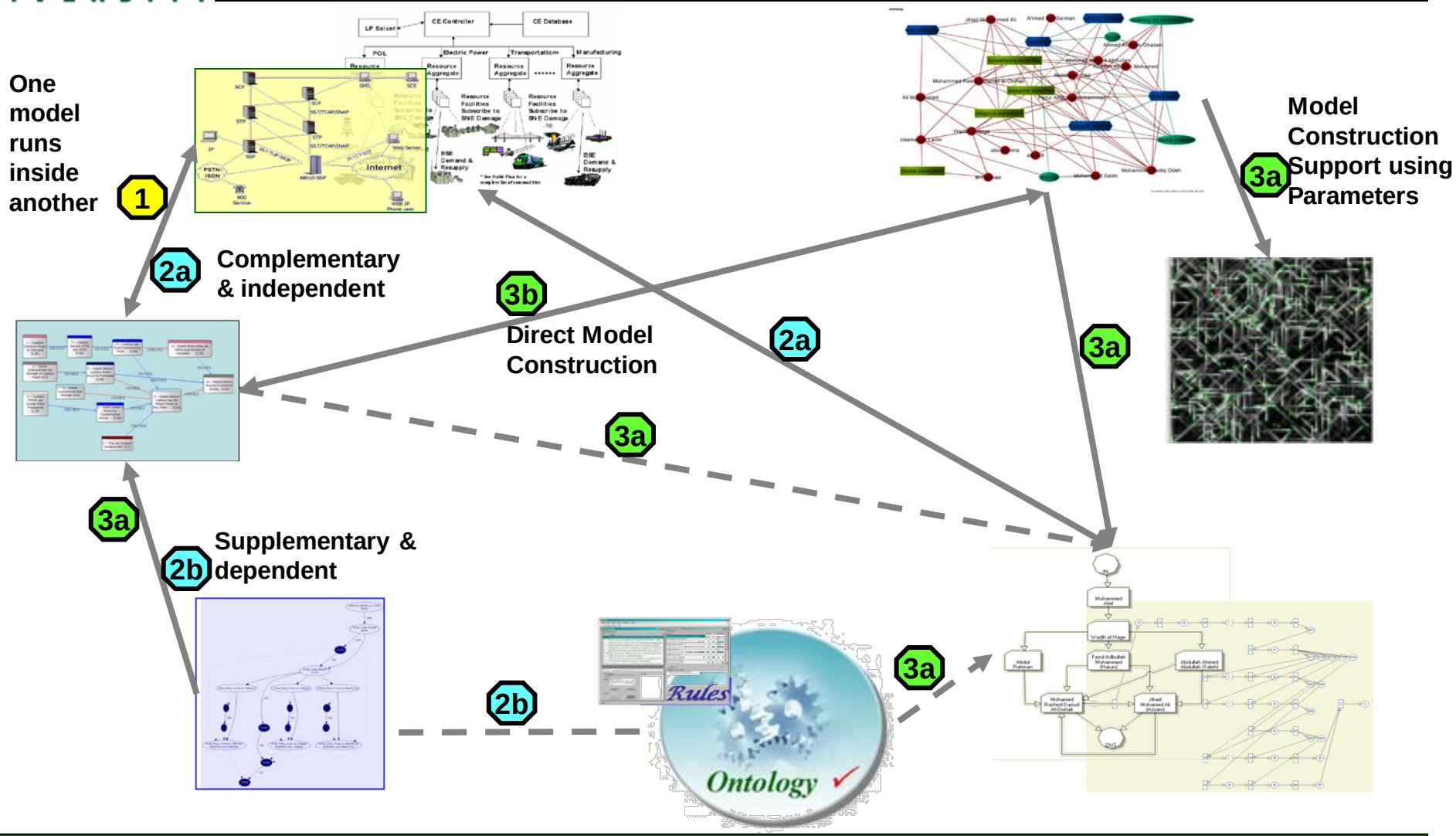


# Multi-Modeling: The Semantic Layer

- **Given a data set about a region, one or more adversaries, a set of third-party states, and international organizations, how can a common data set be used in different types of models to *synergistically* analyze the situation and enable Course of Action determination?**



# Progress to Date



# Interoperation Between Model Types

1. One model runs inside another (1)
2. Two models run side-by-side and Interoperate

   The interoperation can be both

   (2a) Complementary – the two run totally independent of each other supplying parts of the solution required to answer the questions

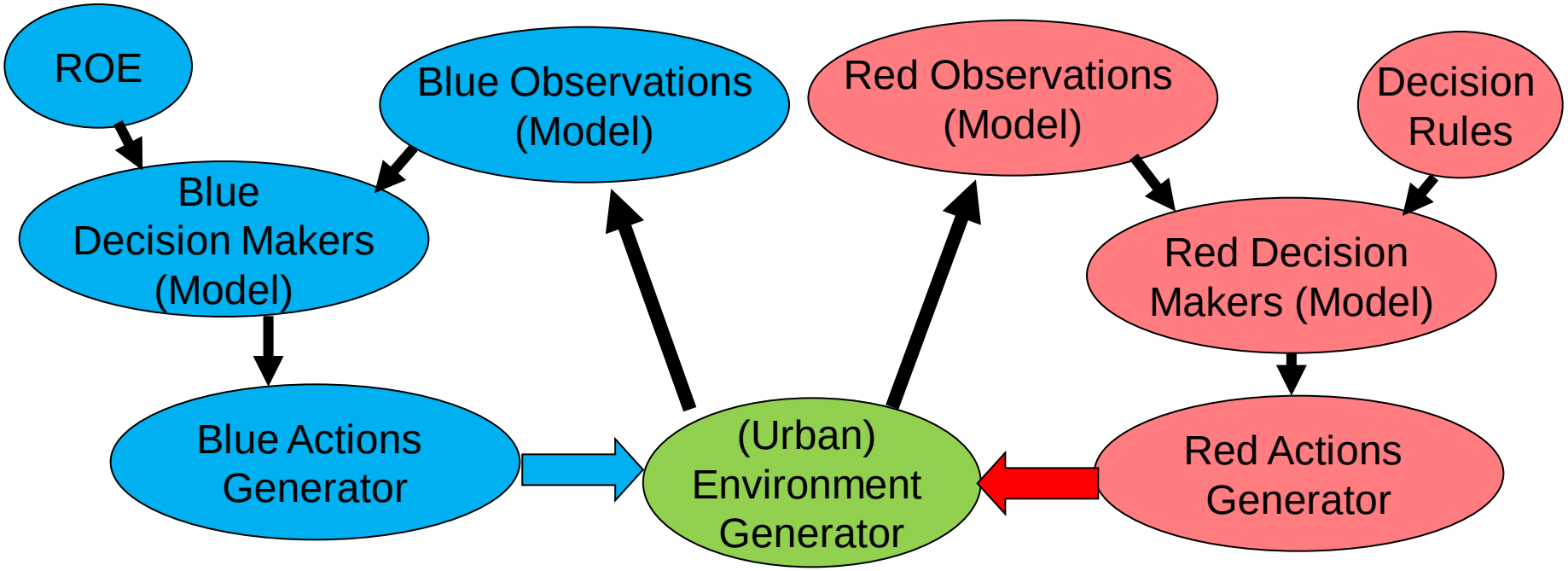
   (2b) Supplementary – the two supply (offline and/or online) each other with parameter values and/or functionality not available to an individual model

3. One model is run/used to construct another

   (3a) Provides design parameters/constraints

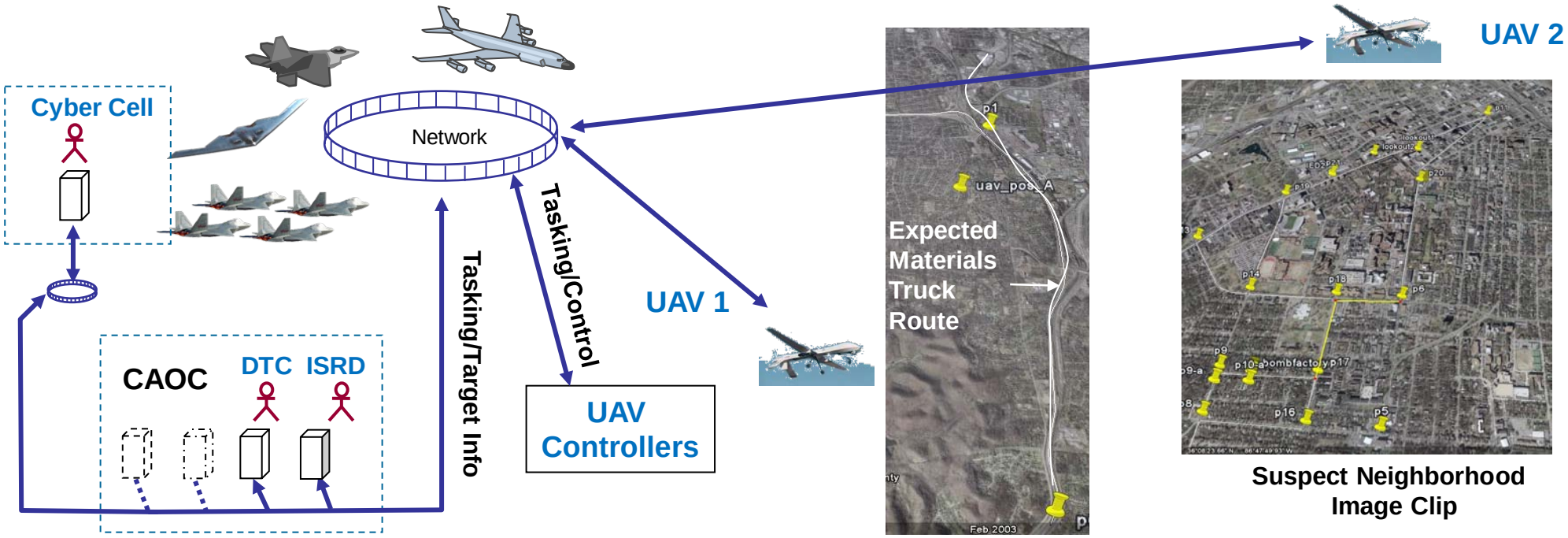
   (3b) Constructs whole/part of another model

# Example: Two-sided Concept




- **Two sided action in an urban environment**

# Blue Organization

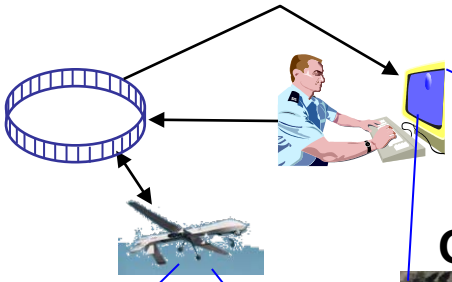



LCC

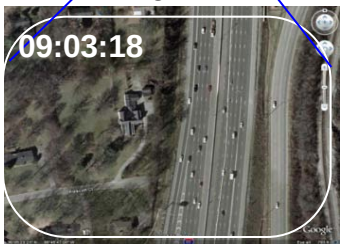
- CAOC
  - Commander
  - Dynamic Targeting Cell (DTC)
  - ISR Division (ISRD)
- Cyber Cell

- SIGINT
- UAV Operator Controllers
- Land Component (LCC)

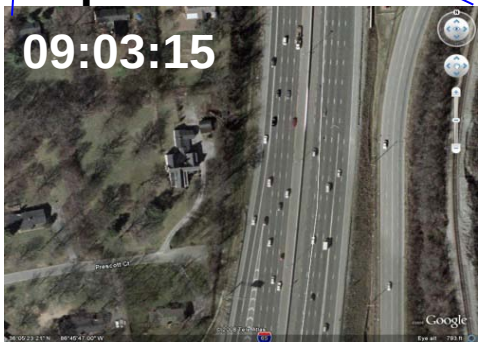
# What One Sees

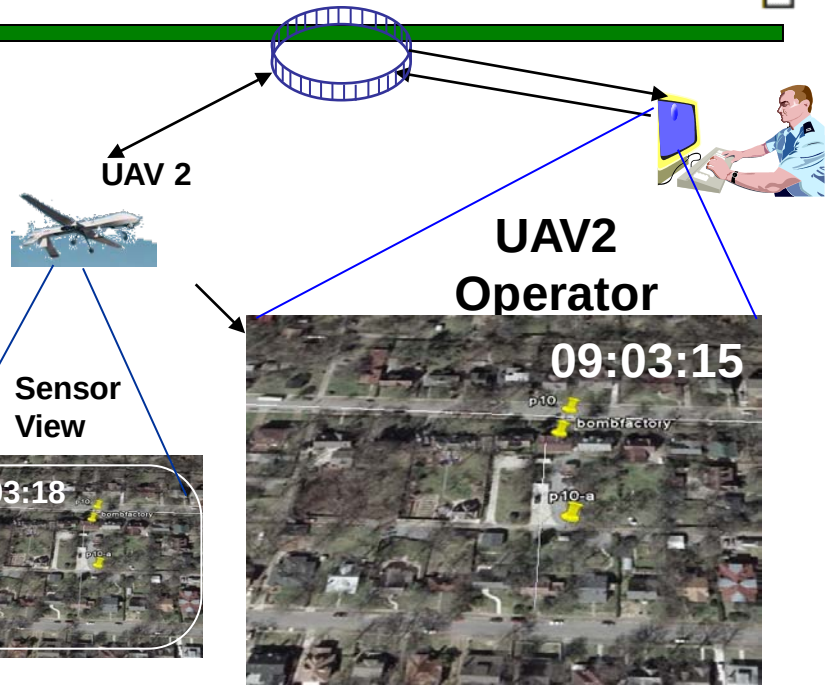


Sensor View

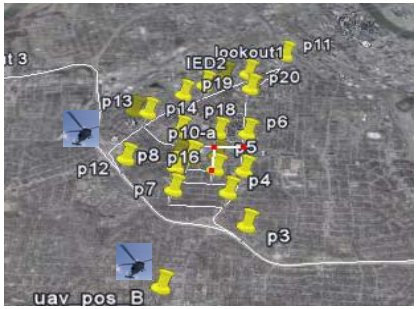



UAV1 Operator View



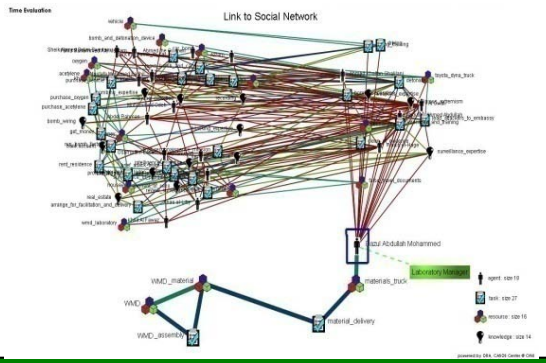

## Ground Truth




## Key Events/Messages Blue's View

Cell Phone Intercept
UAV 1 Tracking Vehicle
UAV 1 locates building
....

## ORA Social Network



# Conclusion

- No single model can capture the complexities of deterrence campaign planning
- The use of multiple interoperating models has posed a number of technical challenges at four Layers
  - Hardware/Software, Syntactic, Semantic, Workflow Layers
- New approaches have been developed to address these challenges
- Meta-modeling research to establish the validity of multi-modeling
- Complex scenarios are being developed and exercised to test these concepts