High Performance Computing for Command & Control Real-Time Decision Support

Real-Time Course of Action Analysis

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Outline

- Motivation
- Approach
- High Performance Computing (HPC) Real-Time Decision Support
  - Effects Based Simulation Behaviors
  - Automated Scenario Generation
  - Modeling Intelligent Adversaries
  - Parallel Course of Action (COA) Analysis Framework
  - Course of Action Simulation Analysis
- Conclusions / Challenges

Motivation

Current Course of Action Analysis Limitations

- **Dynamic Course of Action (COA)[1] vs enemy COA (eCOA) Analysis done on Paper, if at all**
  - **Manpower Intensive (Blue / Red Teaming)**
  - **Single COA Analysis, need the Ability to Assess Multiple COAs Simultaneously**
- **Automated Wargaming Technology**
  - **Static, don't Represent the Dynamic Behavior (Action / Reaction / Counteraction) of the Adversary or Friendly Force, many Decision Points**
    - **Adversary Actions are Pre-Scripted**
  - **Attrition Based, Force-on-Force – do not Address other Campaign Approaches, such as Effects Based Operations[2]**
- **Neither Approach can be Accomplished in Real-Time**

[1]The sequence of decisions and actions that are accomplished related to a mission. (JP 1-02)

[2]Effects Based Operations are actions taken against enemy systems designed to achieve specific effects that contribute directly to desired military and political outcomes. (AFDD 1)

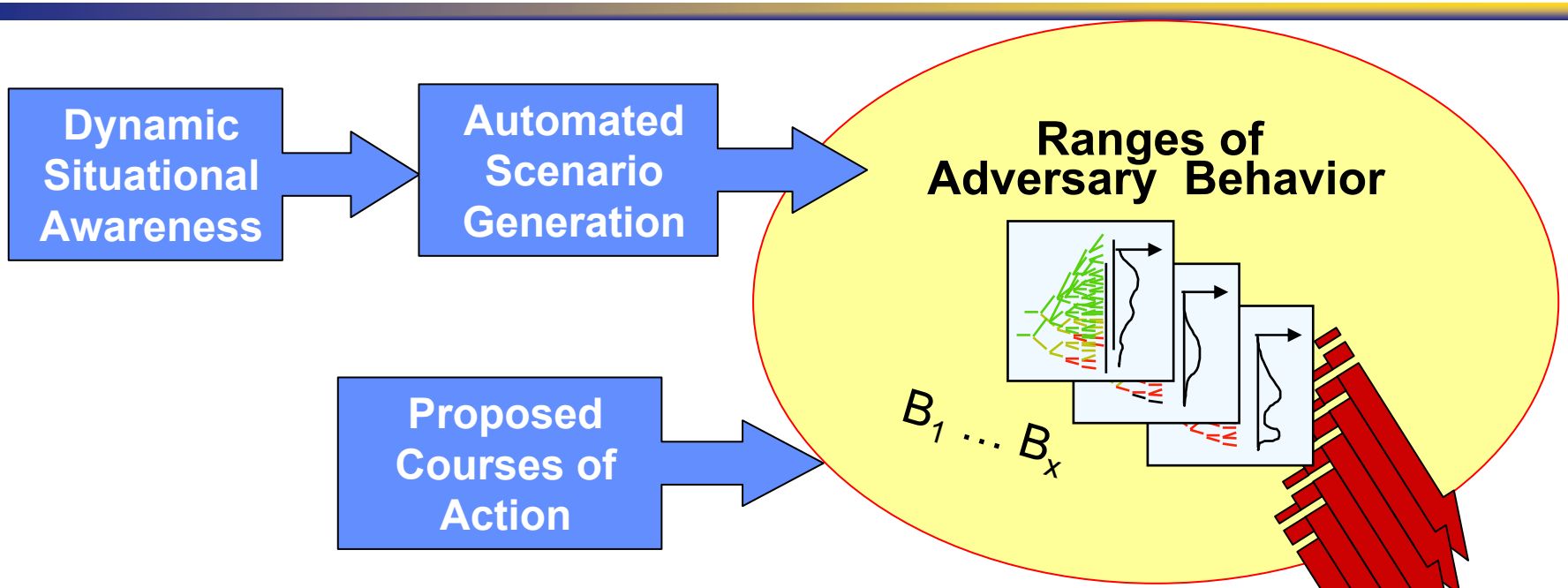
Approach

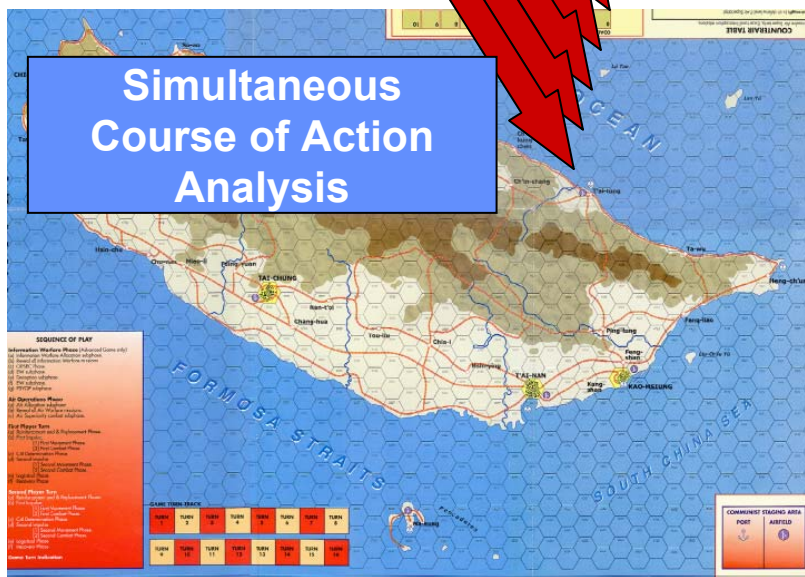
- Challenge
  - Simultaneous Real-Time Processing of Situational Data & Operational Plans in Generating Force Structure Simulations for Multiple Predictive Effects Based COA vs. eCOA Analysis
- Approach
  - Use High Performance Computing (HPC) Simulation Technology for Dynamic Decision Support for Command & Control
  - Develop In-house Force Structure Simulation R&D Testbed
  - Real-Time Analysis Framework to Provide Realistic Simulated Combat Behaviors to Exercise Developing R&D Applications

"Static" vs. "Dynamic" Simulation

- **"Static" Simulation: Traditional use of Simulation Technology**
  - **Use Wargaming Simulations to Study Scenarios well in Advance**
  - **Get General Idea of what Might Happen if Similar Scenario Actually Occurs**
- **"Dynamic" Simulation: Novel use of Simulation Technology**
  - **Use Wargaming Simulations to Assist Decision Makers** *While the Scenario is Happening*
  - **Quickly Simulate Ahead to Glimpse Possible Futures**
  - **Evaluate Possible COAs and Multiple Decision Points Within Each COA**
  - **Dynamic Situational Assessment During Combat Operations, Comparison Against Plans, Alerts on New Threats or Opportunities**

M&S-based COA Analysis
Challenges





Technological Challenges

- **Effects Based / Attrition Based Behaviors**
- **Techniques for Intelligent, Predictive Adversary Behavior**
- **Scenario Generation & Dynamic Update**
- **Scalable Simulation Framework**
- **Real-Time Analysis & Feedback**
- **Dynamic / Interactive HPC Environment**

HPC Real-Time Decision Support

Problem: ***Efficient Generation and Analysis of a Range of Course of Action (COA) Alternatives to Anticipate and Shape the Future Battlespace.***

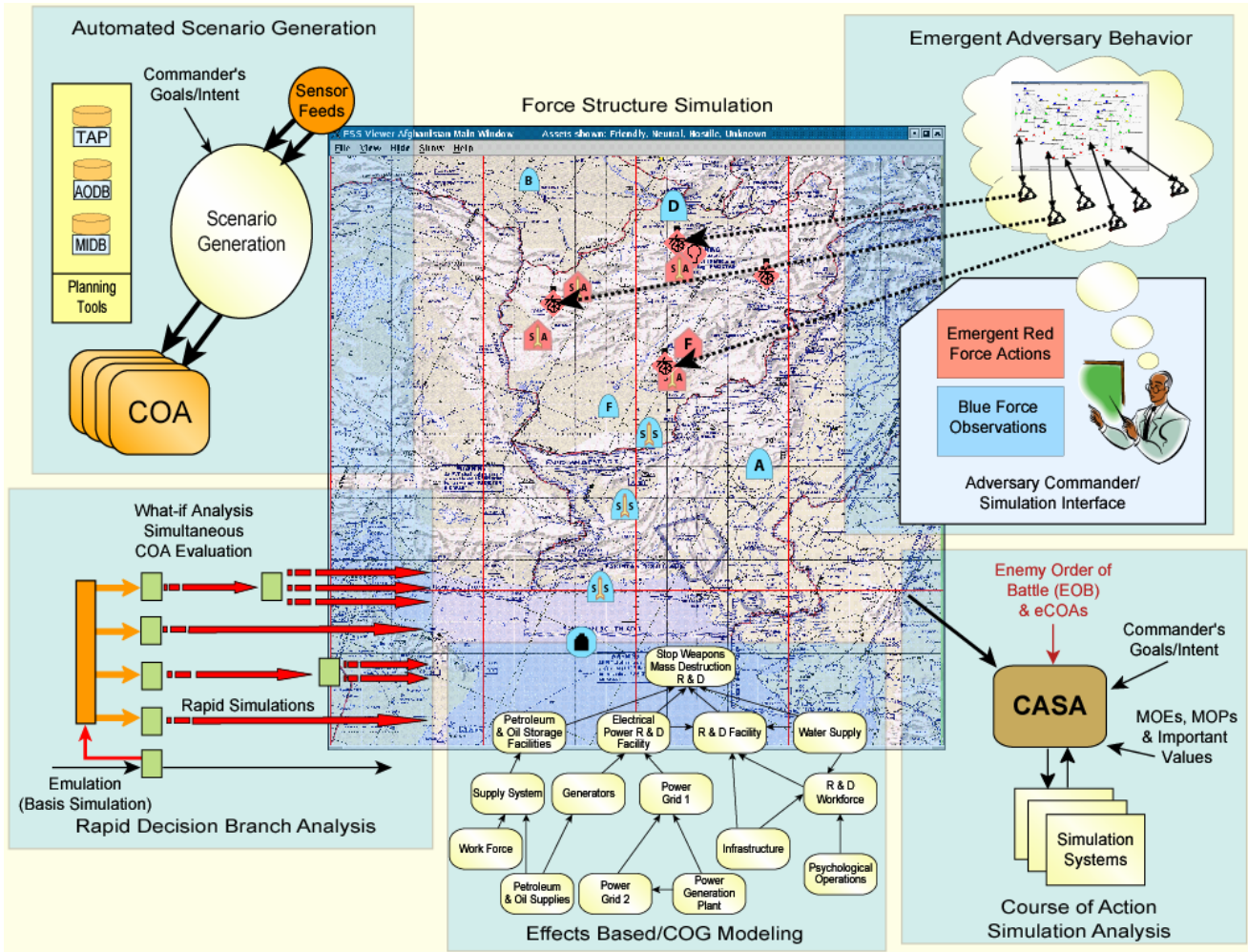
Objective: **Use HPC Simulation Technology for Dynamic Decision Support for Command & Control**

Challenges:

- **Intelligent Adversary Behavior Modeling**
- **Simulating Effects: Kinetic, Non-Kinetic, Indirect, Complex and Cascading**
- **Filtering Large COA Evaluation Space**
- **COA Grading/Evaluation**
- **Integration of Stored and Real-time Information**
- **Automating COA Generation Trigger Events**

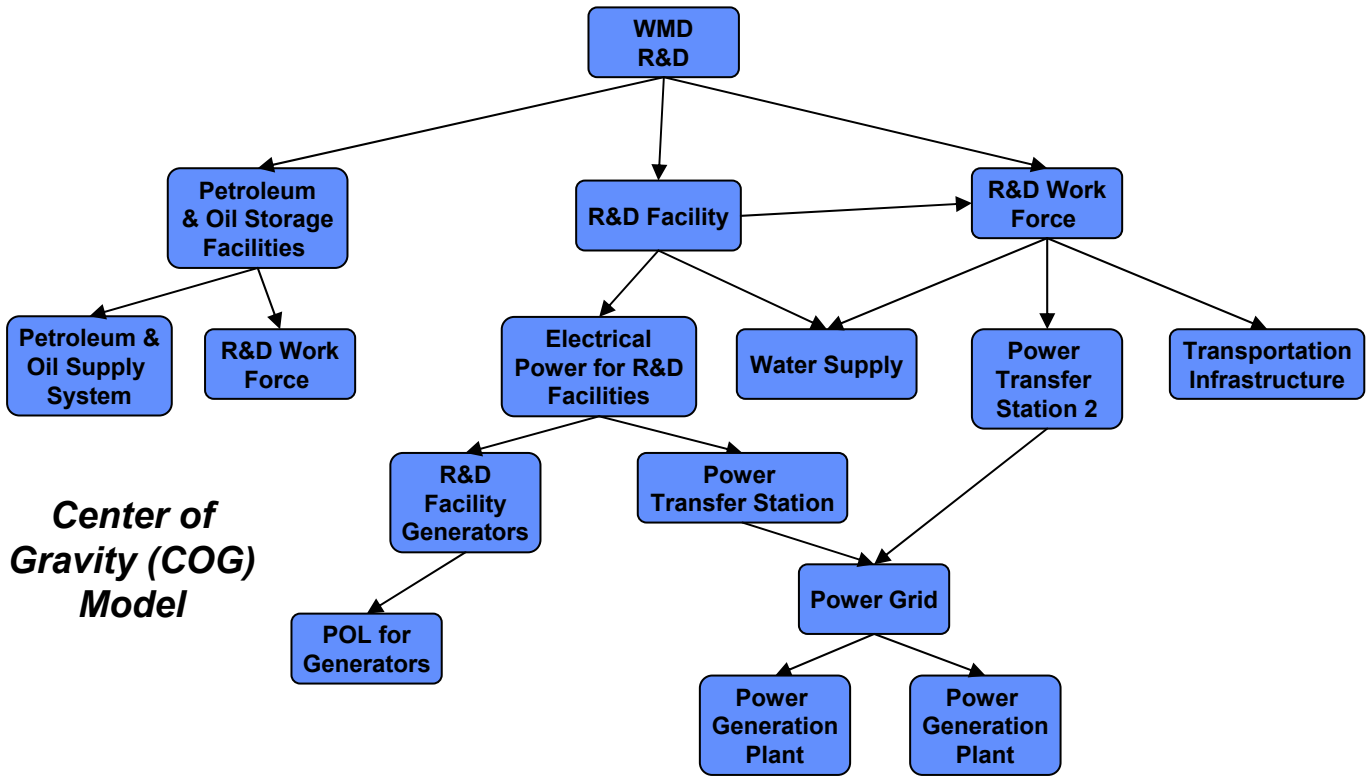
Accomplishments:

- **In-House Force Structure Simulation Testbed**
- **Simultaneous COA/eCOA Evaluation**
- **Automated Scenario Generation**
- **Generic EBO Modeling Capability**
- **EBO Simulation Capability**
- **COA Analysis/Grading**
- **Simulation Cloning**
- **Intelligent Adversary Response**

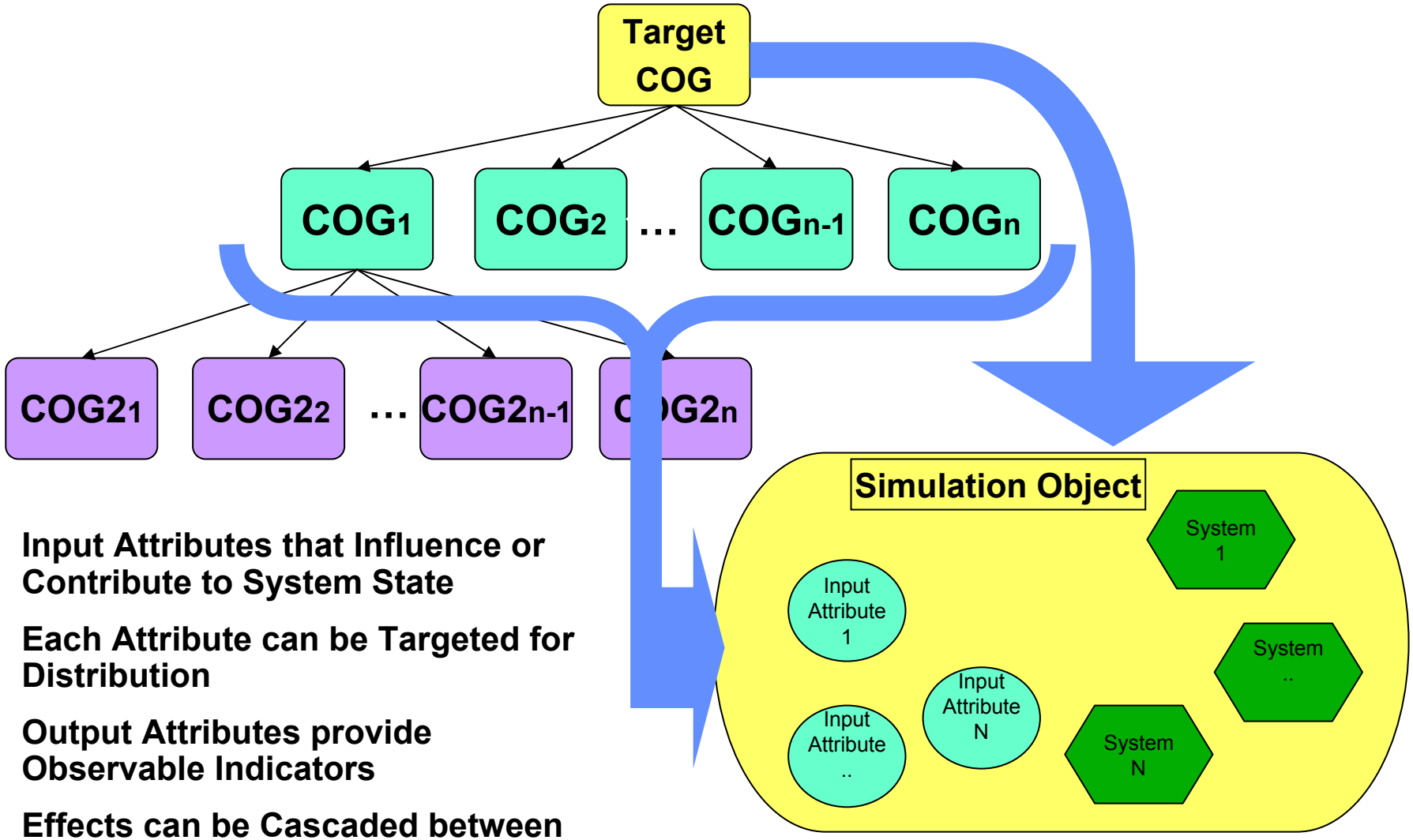


Effects Based Simulation Behaviors

- Expanding Wargaming Operational Concepts to Integrate EBO Effects for Campaign Assessment
  - Complex, Cascading, Recovery
- EBO Simulation Objects and Indirect Effects Analysis
- Generic EBO Simulation Modeling Methodology for Wargaming

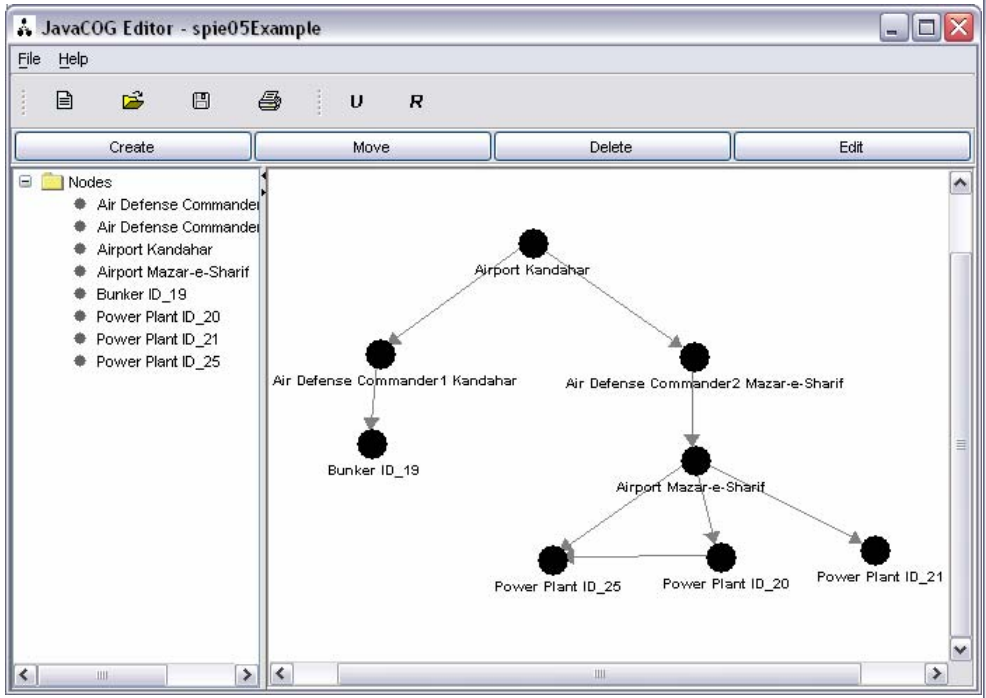


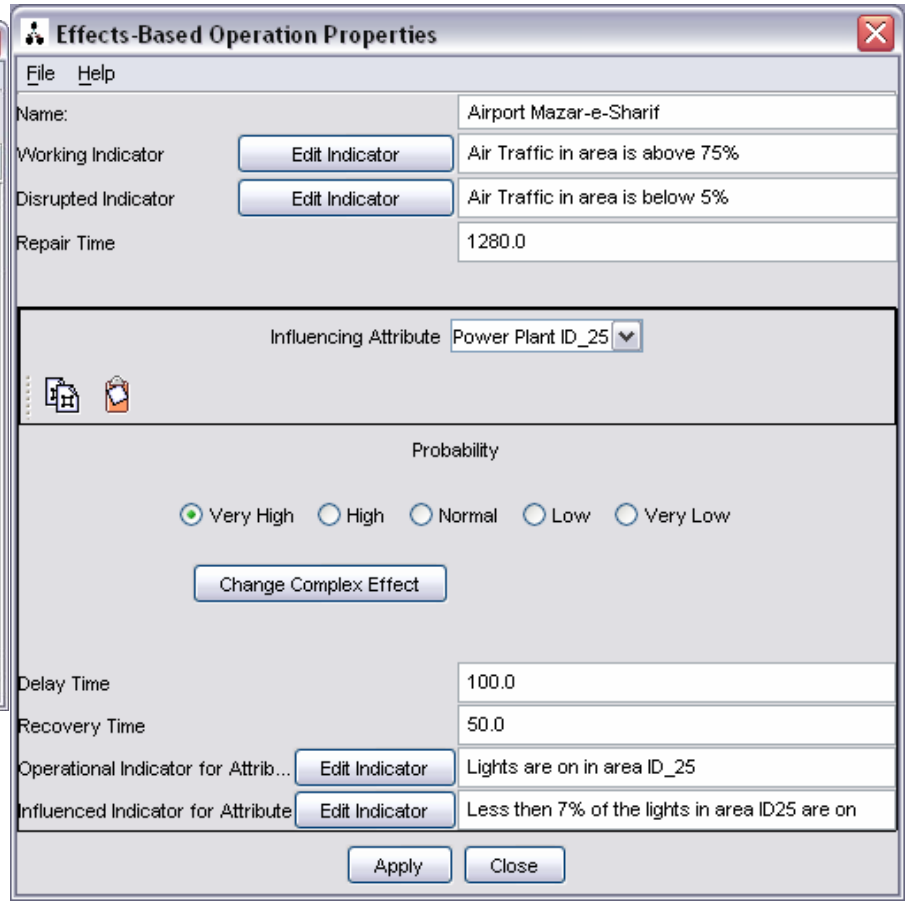
COG Representation in the EBO Object Model



- Input Attributes that Influence or Contribute to System State
- Each Attribute can be Targeted for Distribution
- Output Attributes provide Observable Indicators
- Effects can be Cascaded between Model Objects

JavaCOG

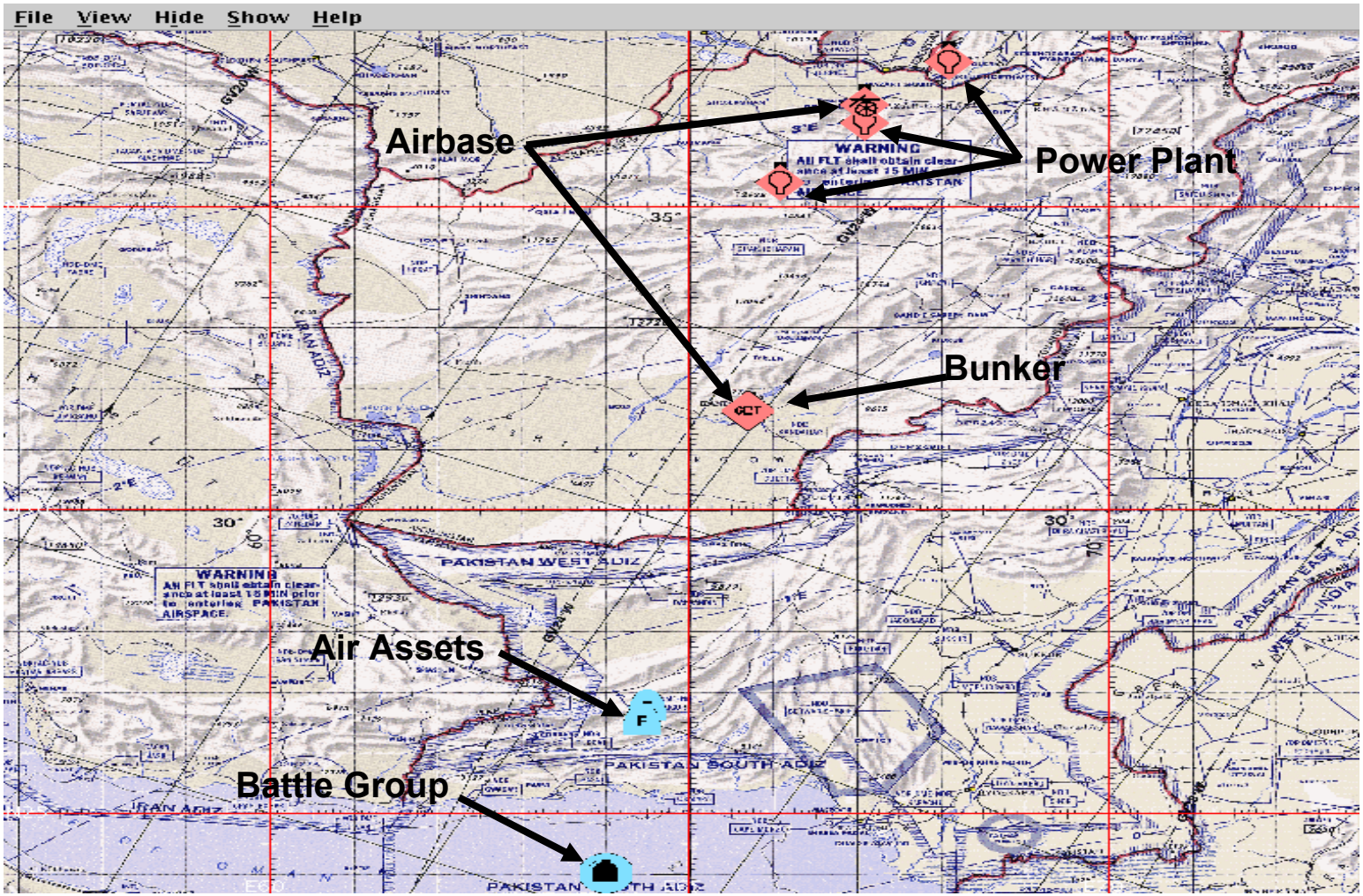

JavaCOG Editor - spie05Example
File
Help
U
R
Create
Move
Delete
Edit
Nodes
Air Defense Commander
Air Defense Commander
Airport Kandahar
Airport Mazar-e-Sharif
Bunker ID_19
Power Plant ID_20
Power Plant ID_21
Power Plant ID_25
Airport Kandahar
Air Defense Commander1 Kandahar
Air Defense Commander2 Mazar-e-Sharif
Bunker ID_19
Airport Mazar-e-Sharif
Power Plant ID_25
Power Plant ID_20
Power Plant ID_21


Effects-Based Operation Properties
File
Help
Name:
Airport Mazar-e-Sharif
Working Indicator
Edit Indicator
Air Traffic in area is above 75%
Disrupted Indicator
Edit Indicator
Air Traffic in area is below 5%
Repair Time
1280.0
Influencing Attribute
Power Plant ID_25
Probability
Very High
High
Normal
Low
Very Low
Change Complex Effect
Delay Time
100.0
Recovery Time
50.0
Operational Indicator for Attrib...
Edit Indicator
Lights are on in area ID_25
Influenced Indicator for Attribute
Edit Indicator
Less then 7% of the lights in area ID25 are on
Apply
Close

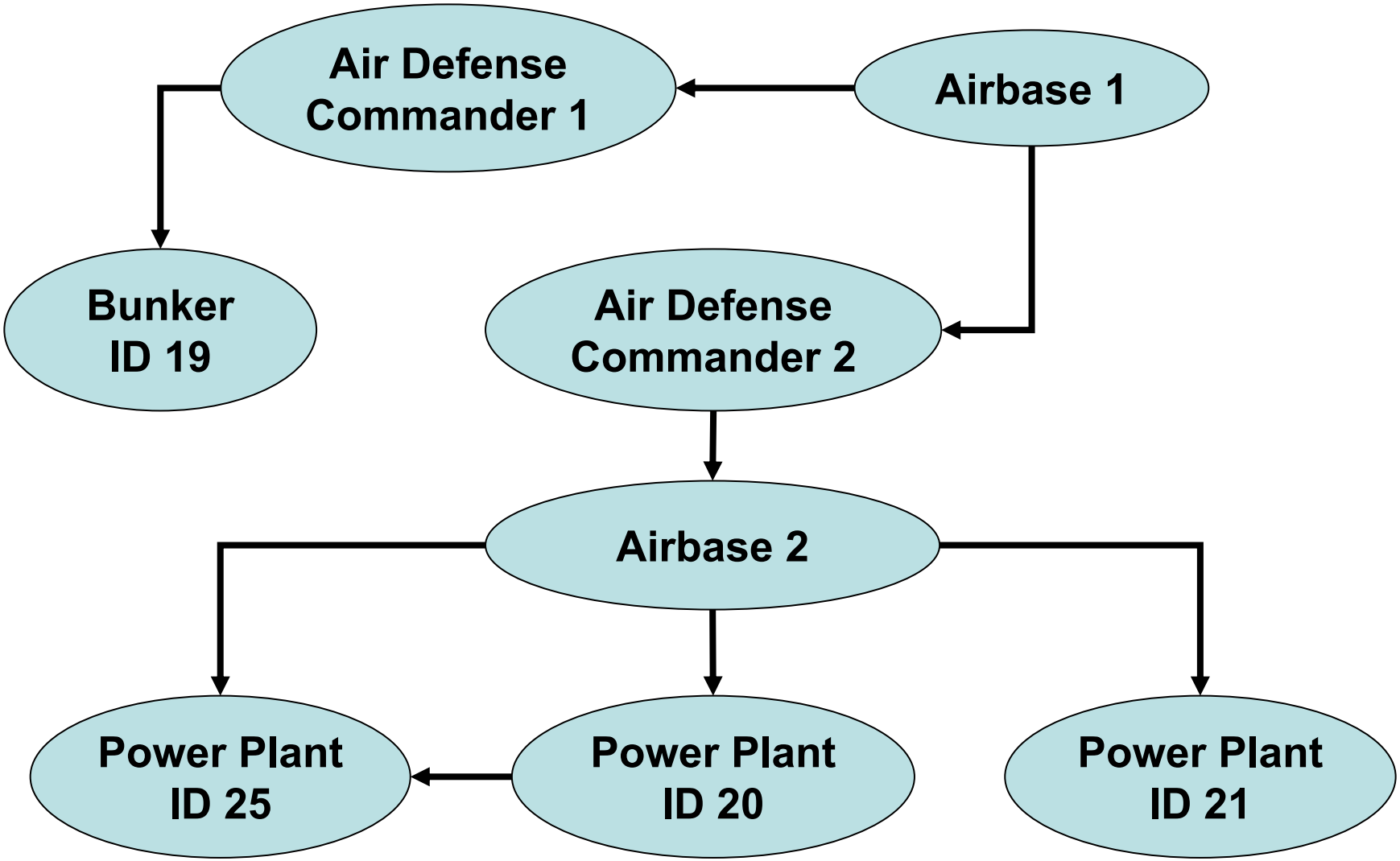
Simple, Fictional Example

- Demonstrates
  - Cascading Effects
  - Complex Effects
  - Recovery Events
    - Direct
    - Indirect
- Compare EBO Results to the Attrition Results

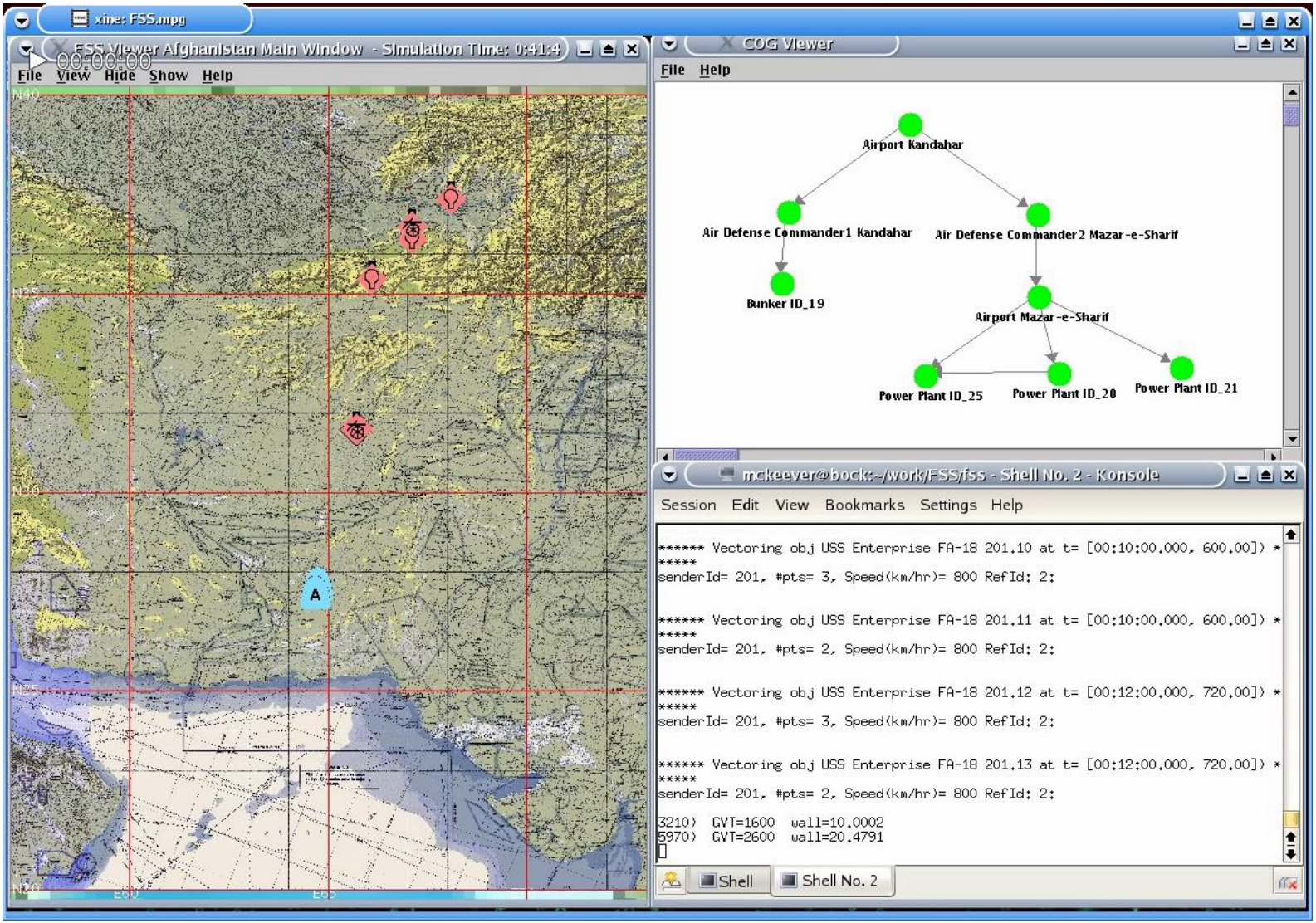
Simulation Example



Simple COG Model

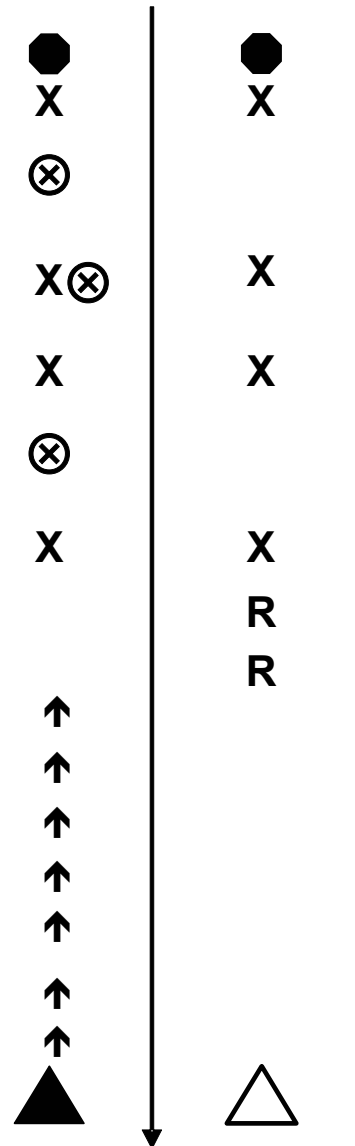


Simulation Playback



Simulation Results

TIME (sec)	Symbol	Event Description
625	●	Launch Aircraft
4625	X	Engage Bunker ID_19; Bunker Destroyed
4950	⊗	Disable Air Defense Commander 1 Cascading Event
6400	X	Engage Power Plant ID_25; Power Plant Destroyed
6400	⊗	Disable Power Plant 20 Cascading Event
7050	X	Engage Power Plant ID_21; Power Plant Destroyed
7200	⊗	Disable Airbase 2; Air Defense Commander 2; Airbase 1 Cascading Event
7850	X	Engage Power Plant ID_20; Power Plant Destroyed
8400	R	Deploy SAM
8450	R	Engage Aircraft; Kill 2
9150	↑	Recovery of Power Plant ID_25
9200	↑	Recovery of Airbase 2
9400	↑	Recovery of Air Defense Commander 2; Airbase 1
9450	↑	Recovery of Power Plant ID_20
9600	↑	Recovery of Power Plant ID_21
11850	↑	Recovery of Bunker ID_19
12150	↑	Recovery of Air Defense Commander 1
17500	▲	Land Battle Group; 2 return (with COG four return)

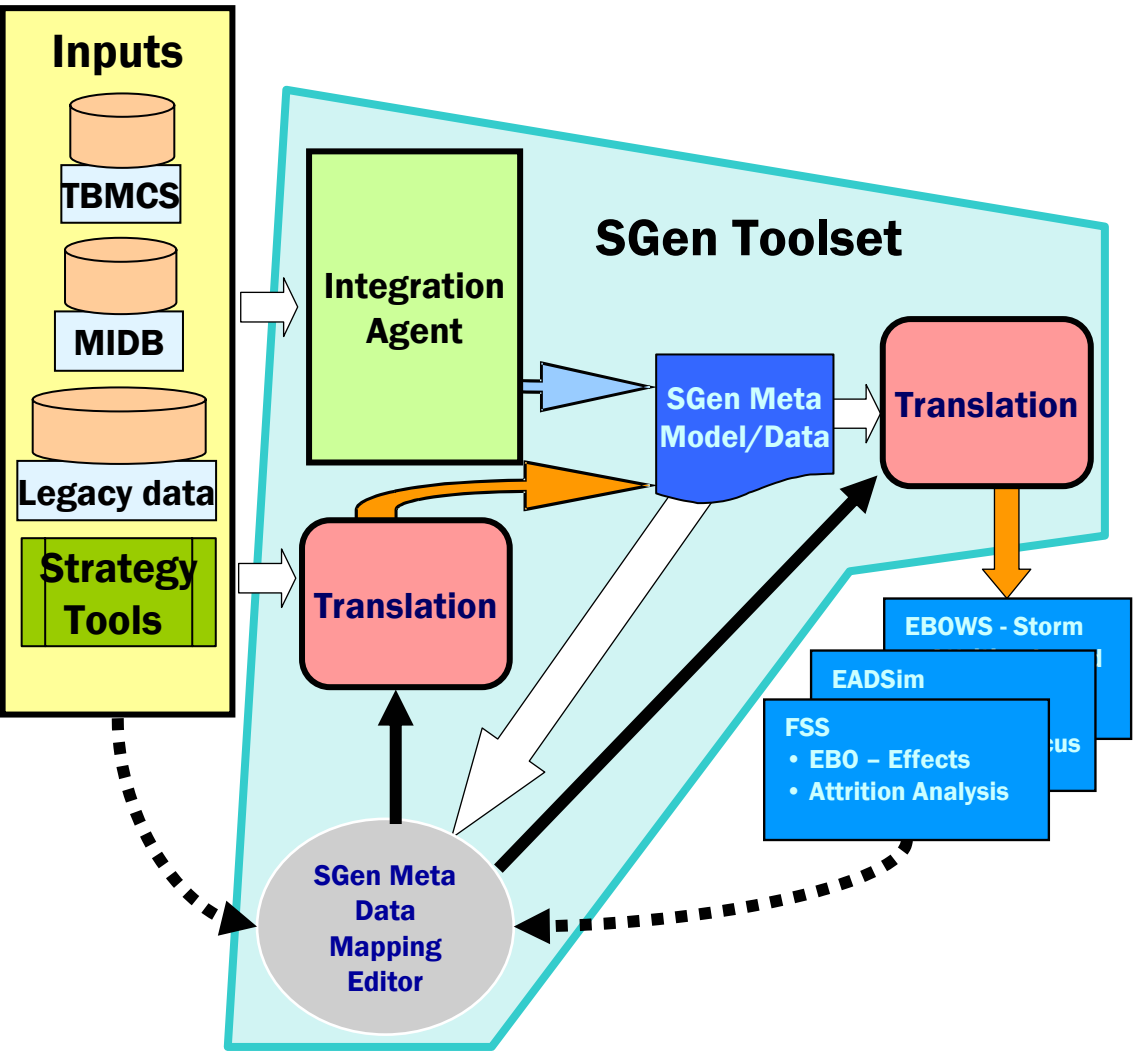


Current Scenario Generation

- Operational-Level Scenario Generation is not Automated
  - Process Time in Preparing a Simulated Exercise Measured in Days and Hours Rather than Minutes (or less)
- Can't support "what if" analysis to determine best COA
- Can't Support Real-Time Scenario Generation
  - Predictive Battlespace Awareness Requires the Ability to Automatically Generate Scenarios to Support Look Ahead
- Must Include an Effects Based Focus

Automated Scenario Generation

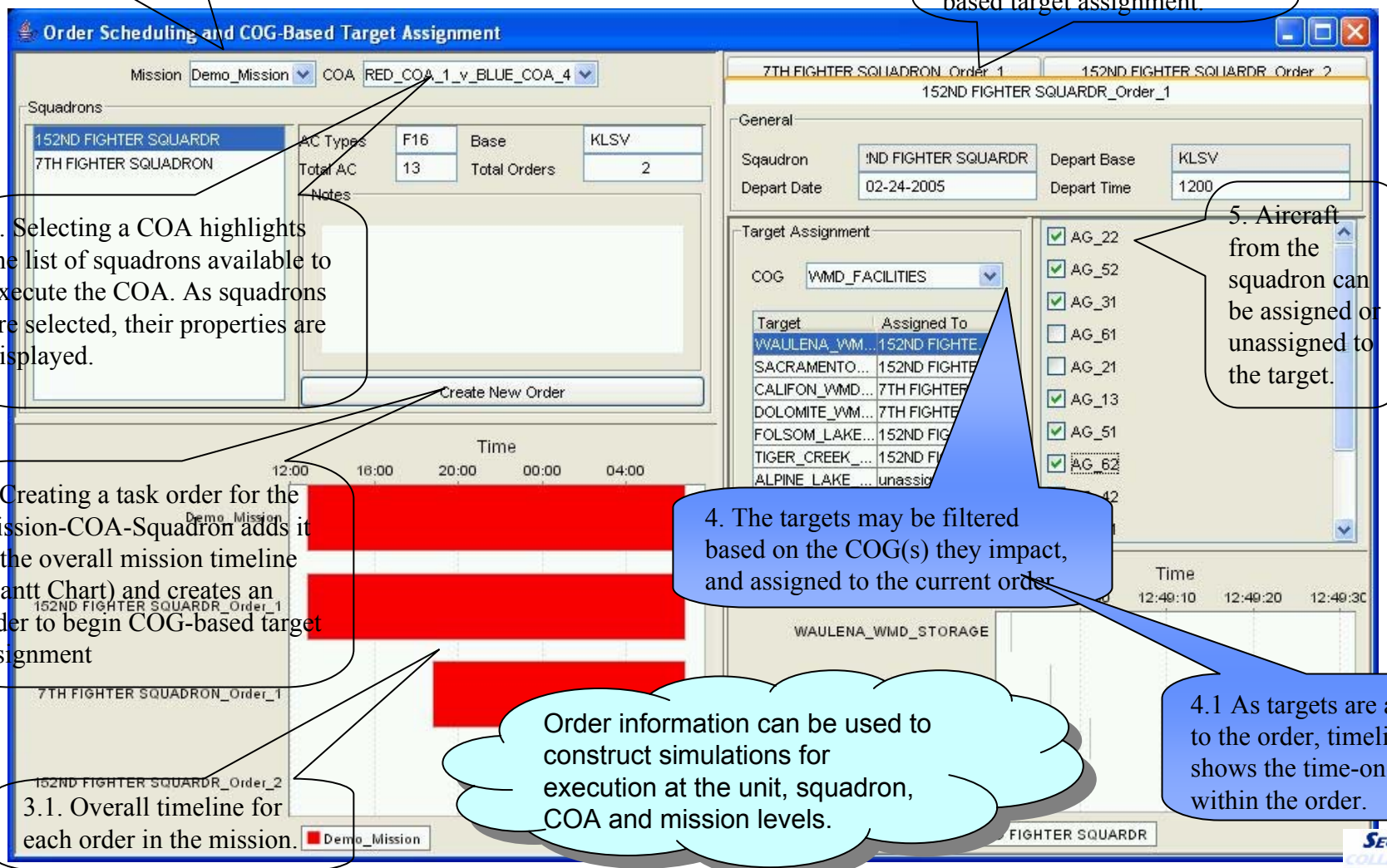
Simultaneous Data Feeds, both Stored and Real-Time, used to Generate Multiple Blue COAs



Technical Challenges :

- Semantic Mapping Information Elements
  - OWL Common Meta-Model
  - Domain SME Initial Mapping
  - Cognitive Semantic Mapping
- Syntactical Domain Translation
  - XSLT Import / Export
  - Investigating Alternative Methods
- OWL Inferencing Technology
  - Assess Consistency & Relevance
- Dynamic API for Real-Time Situation Feed
  - Experiment Update & Flow Through

SGen

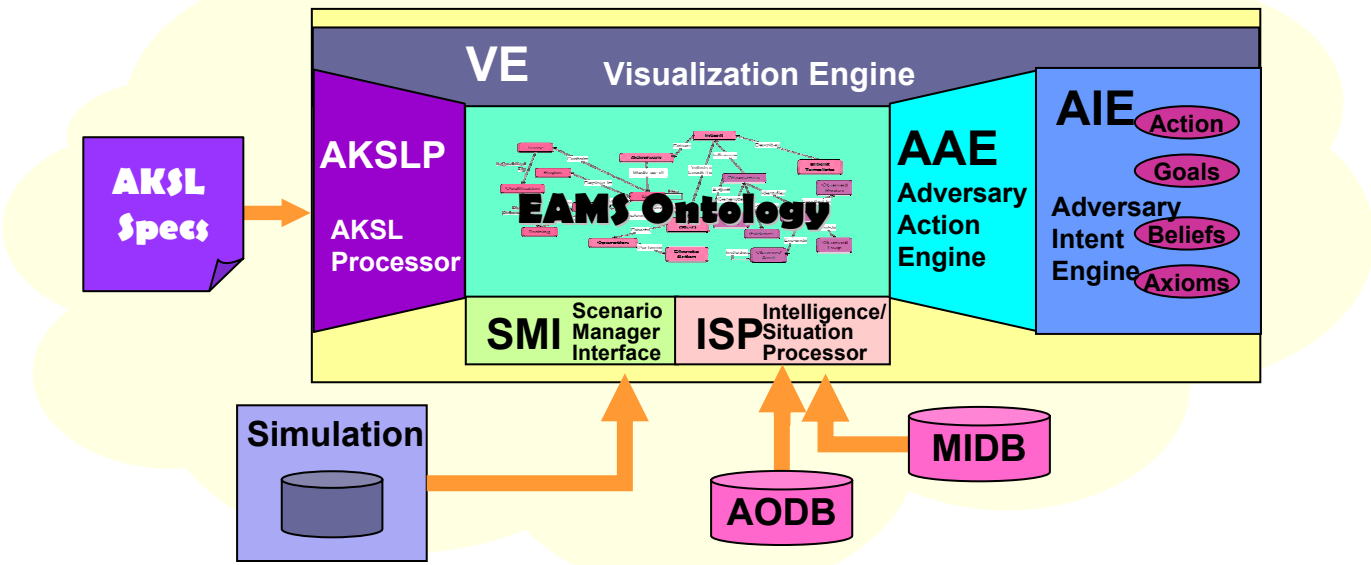

1. Current Mission and COAs that comprise its execution.
4. As orders for the squadron are created, they are added to the Tabbed Pane for COG-based target assignment.
Order Scheduling and COG-Based Target Assignment
Mission Demo_Mission
COA RED_COA_1_v_BLUE_COA_4
Squadrons
152ND FIGHTER SQUADRDR
7TH FIGHTER SQUADRON
AC Types F16
Base KLSV
Total AC 13
Total Orders 2
Notes
Create New Order
7TH FIGHTER SQUADRON_Order_1
152ND FIGHTER SQUADRDR_Order_2
152ND FIGHTER SQUADRDR_Order_1
General
Sqaudron ND FIGHTER SQUADRDR
Depart Base KLSV
Depart Date 02-24-2005
Depart Time 1200
Target Assignment
COG WMD_FACILITIES
Target
Assigned To
WAULENA_WM...
SACRAMENTO...
CALIFON_WMD...
DOLOMITE_WM...
FOLSOM_LAKE...
TIGER_CREEK_...
ALPINE_LAKE_...
AG_22
AG_52
AG_31
AG_61
AG_21
AG_13
AG_51
AG_62
Time
12:00
16:00
20:00
00:00
04:00
Demo_Mission
152ND FIGHTER SQUADRDR_Order_1
7TH FIGHTER SQUADRON_Order_1
152ND FIGHTER SQUADRDR_Order_2
Demo_Mission
12:49:10
12:49:20
12:49:30
WAULENA_WMD_STORAGE
FIGHTER SQUADRDR
2. Selecting a COA highlights the list of squadrons available to execute the COA. As squadrons are selected, their properties are displayed.
5. Aircraft from the squadron can be assigned or unassigned to the target.
3. Creating a task order for the Mission-COA-Squadron adds it to the overall mission timeline (Gantt Chart) and creates an order to begin COG-based target assignment
4. The targets may be filtered based on the COG(s) they impact, and assigned to the current order.
4.1 As targets are assigned to the order, timeline shows the time-on-target within the order.
3.1. Overall timeline for each order in the mission.
Order information can be used to construct simulations for execution at the unit, squadron, COA and mission levels.

Modeling Intelligent Adversary Behaviors

- Current Generation Wargaming Technologies Execute a Pre-Scripted Sequence of Events for an Adversary – Don't Survive beyond the first Campaign Action
- Provide a Dynamic Simulation Capability that Incorporates Potential Adversary Actions
  - Adversary COAs don't need to be predetermined
- Incorporate Sequential Action / Reaction Analysis Concept into Future Simulations
- More Robust COA Assessment
  - Multiple What-if Analysis
- Predictive Battlespace Awareness (PBA)

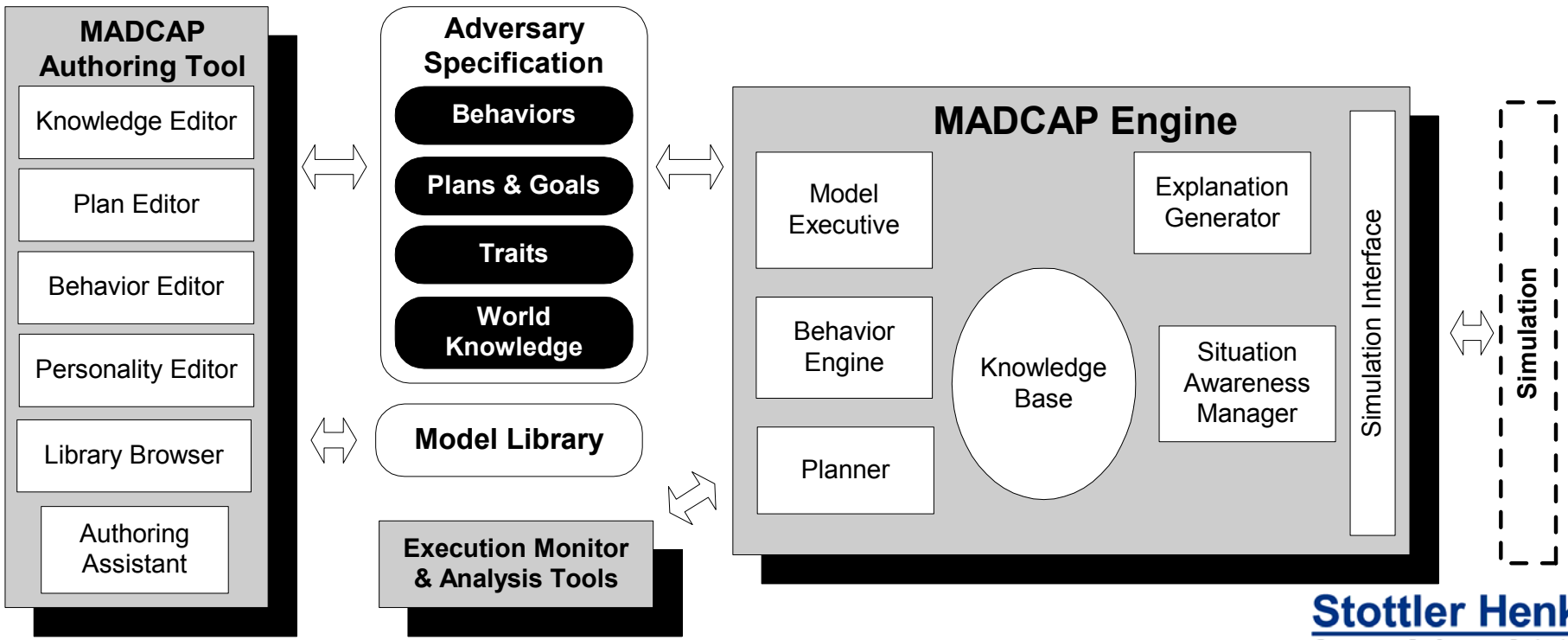
Emergent Adversarial Modeling System (EAMS)

- Inferencing System Framework Based on Bayesian Belief Networks
- Inferencing System Captures Adversary Behavior Attributes
  - Beliefs, Perceptions, Biases, Desired End-states
- Adversary Modeling System Inputs Observables from the Simulation System and Infers, in order of Likelihood, the Adversary Goals and Intents
- Adversary Behavior and Actions are Calculated and input to the Simulation System and Executed by the Adversary Force



Authorable Adversary Modeling for COA Assessment

- Utilizes Hierarchical Planning and Ruled-Based Techniques
- Adversary Models Based on Objectives, Actions, Predicates and Behaviors, including aspects of cultural and extra-cognitive factors
- Attributes Captured by a Model Execution Engine
- Execution Engine Dynamically Determines Adversary Actions based on the Adversary Model and the Current State of the Simulated World



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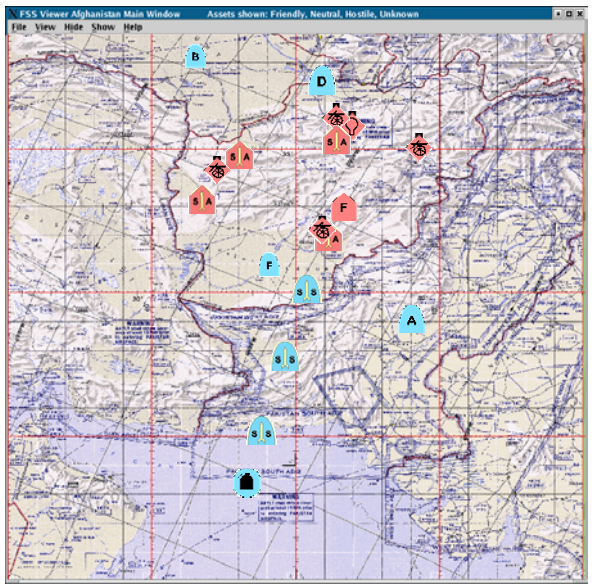
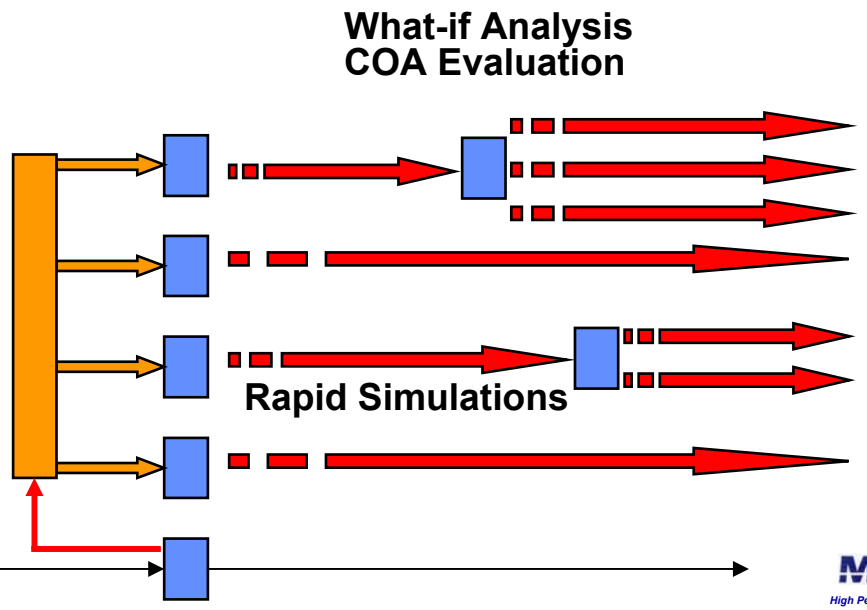
HPC COA Analysis Framework

- Simulation Framework for Faster than Real-Time Parallel COA Evaluations
- Utilize Parallel Event Simulation to Harness Computing Power of Many CPUs
- Continuously Emulate Common Operating Picture with Real-Time ISR Inputs
- Processing Mechanism to Clone Emulation State and Evaluate Alternative COAs Simultaneously or Predict Future Battlespace





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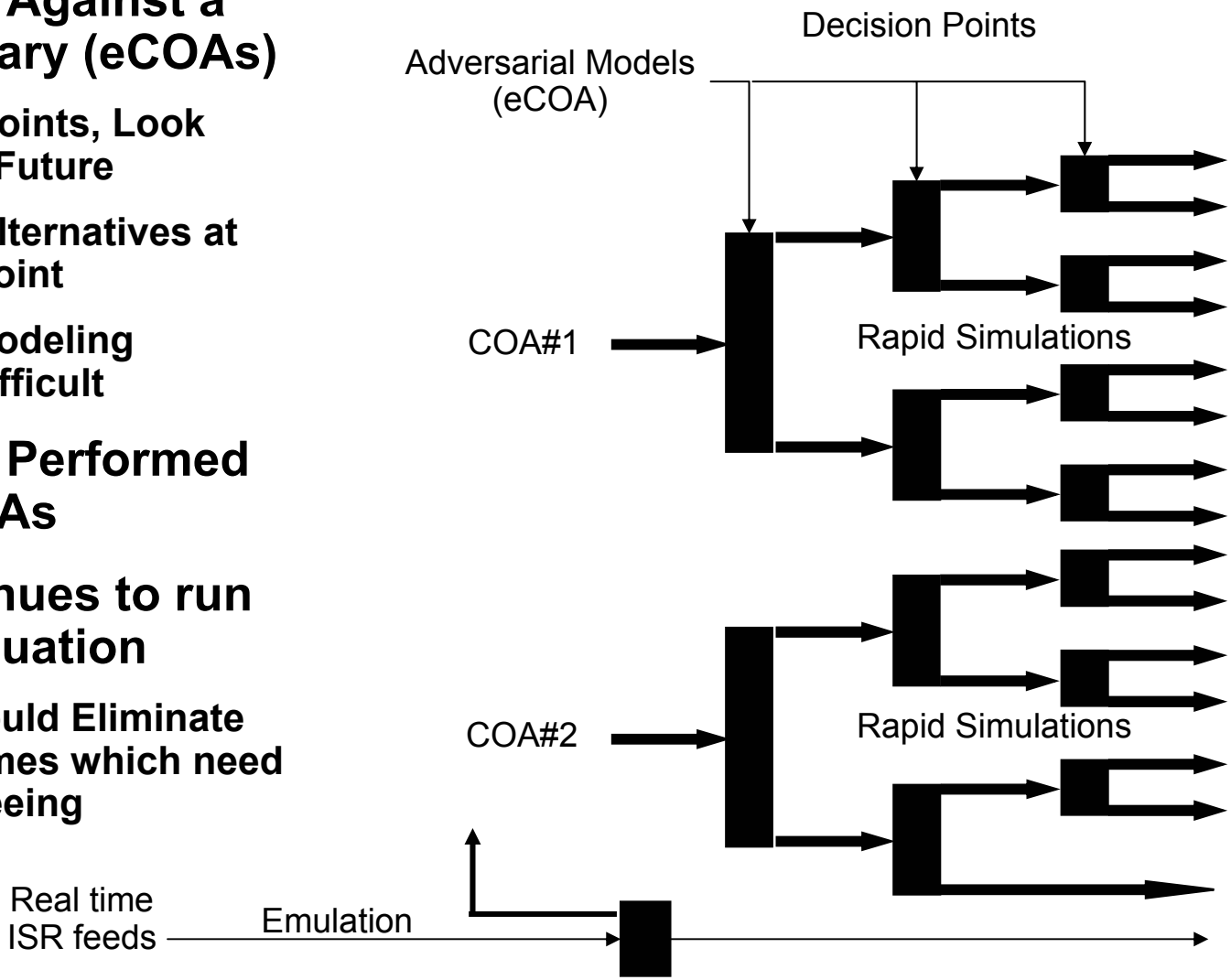
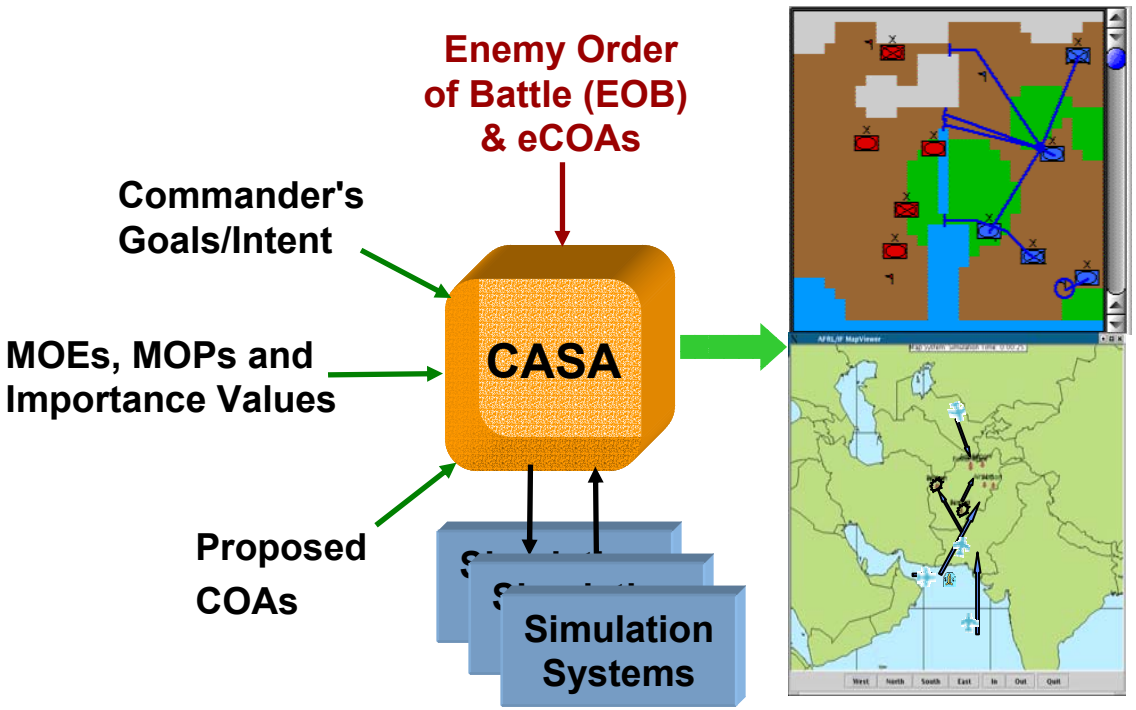
Simulation Cloning Example

- **Can Evaluate More Friendly COAs in Parallel Against a Dynamic Adversary (eCOAs)**
  - **More Decision Points, Look Further into the Future**
  - **Evaluate More Alternatives at each Decision Point**
    - **Adversary Modeling Extremely Difficult**
- **What-if Analysis Performed on Unlimited COAs**
- **Emulation Continues to run during COA Evaluation**
  - **New ISR Data could Eliminate Potential Outcomes which need to be Pruned Freeing Resources**



Course of Action Simulation Analysis (CASA)

- Define appropriate Measures of Effectiveness/ Measures of Performance (MOEs/MOPs) for COAs
- Identify a Very Low Level, Fundamental and Common set of Characteristics that, when Aggregated, can be used to Describe any MOP or MOE
- Provide a Means of Comparison for Disparate Approaches of Multiple COAs
- Metrics to Rate and Rank the Relative Merit of Evaluated COAs
- Develop Data Visualization Techniques



COA 1: Aggregate Score 92.3
+ *MOE 1-1: 78.2 ; Weighting: 3.0*
+ *MOE 1-2: 64.2 ; Weighting: 2.7*
  - *MOP 1: 83.4 ; Weighting: 1.7*
    - *Raw Data*
      - *Attrition: 4.7 %*
      - *Successful Missions: 87 %*
      - *Targets Destroyed: 419*
      - *…*
+ *MOE 1-3: 64.2 ; Weighting: 0.3*

COA 2: Aggregate Score 87.6
+ *MOE 2-1: 84.2 ; Weighting: 0.9*
+ *MOE 2-2: 52.3 ; Weighting: 1.2*
+ *MOE 2-3: 98.7 ; Weighting: 1.8*

…

High Performance Computing Real-Time Decision Support

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Objective: **Use HPC Simulation Technology for Dynamic Decision Support for Command & Control**

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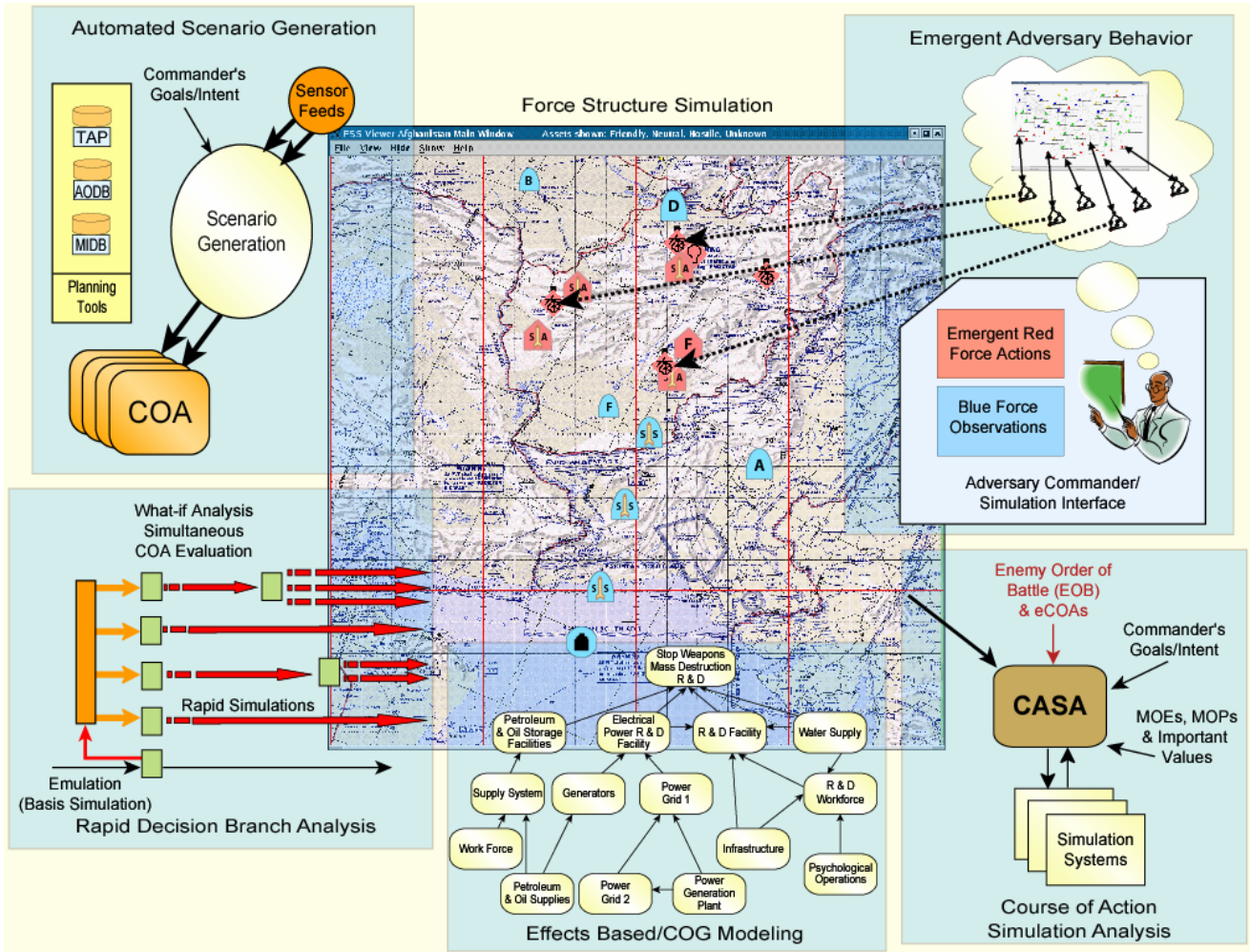

Some Challenges

- New Models of Computation for Human Behavior Modeling
  - Dynamic Model Generation
  - Ability to Reason About All Adversary Intentions
- Data Analysis
  - Mergence of Stored and Real-Time Information – Continuous Projection into the Future
  - Continuously Assess Engagement Results vs. Predictions
  - Automated COA Generation, Trigger Events
  - Modeling Data Uncertainty, Conflict
  - Common Operating Picture
- Continuous Situation Awareness / Decision Support Loop
- System of System Analysis
- COA Robustness

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