

**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 Operations²**
- **Neither Approach can be Accomplished in Real-Time**

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

²Effects 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**



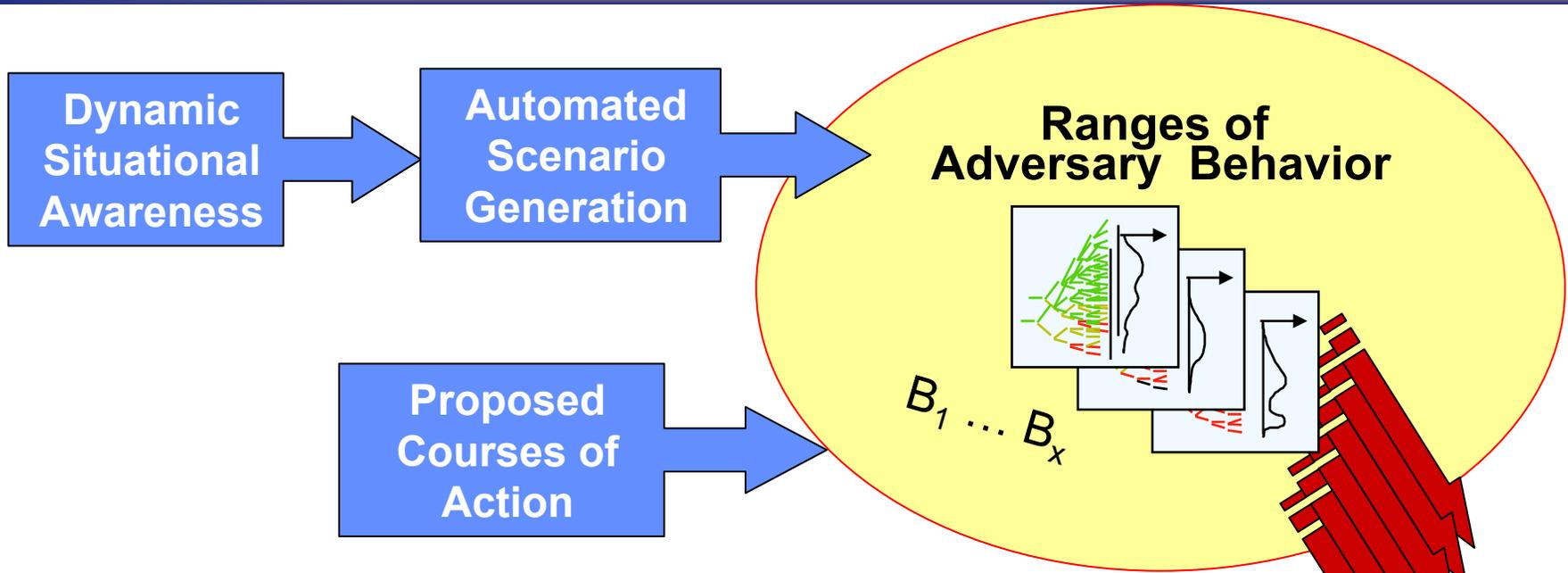
“Static” vs. “Dynamic” Simulation



- **“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

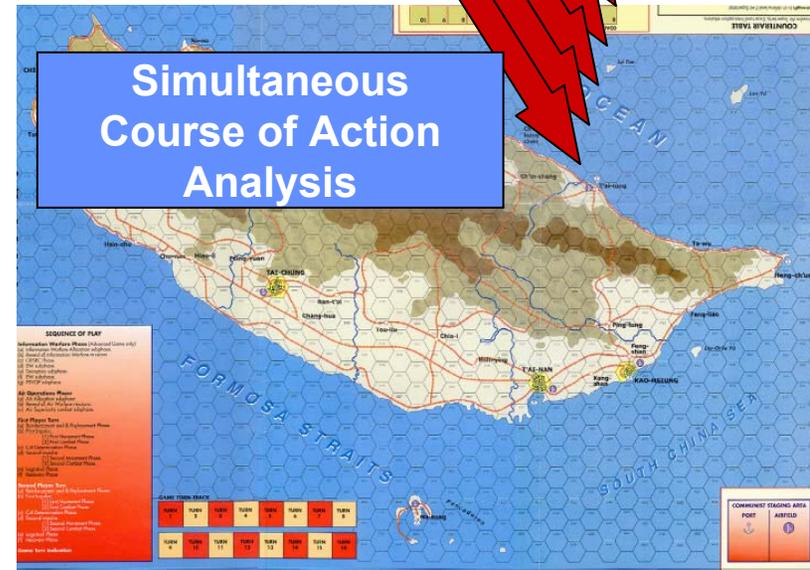


M&S-based COA Analysis Challenges



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.

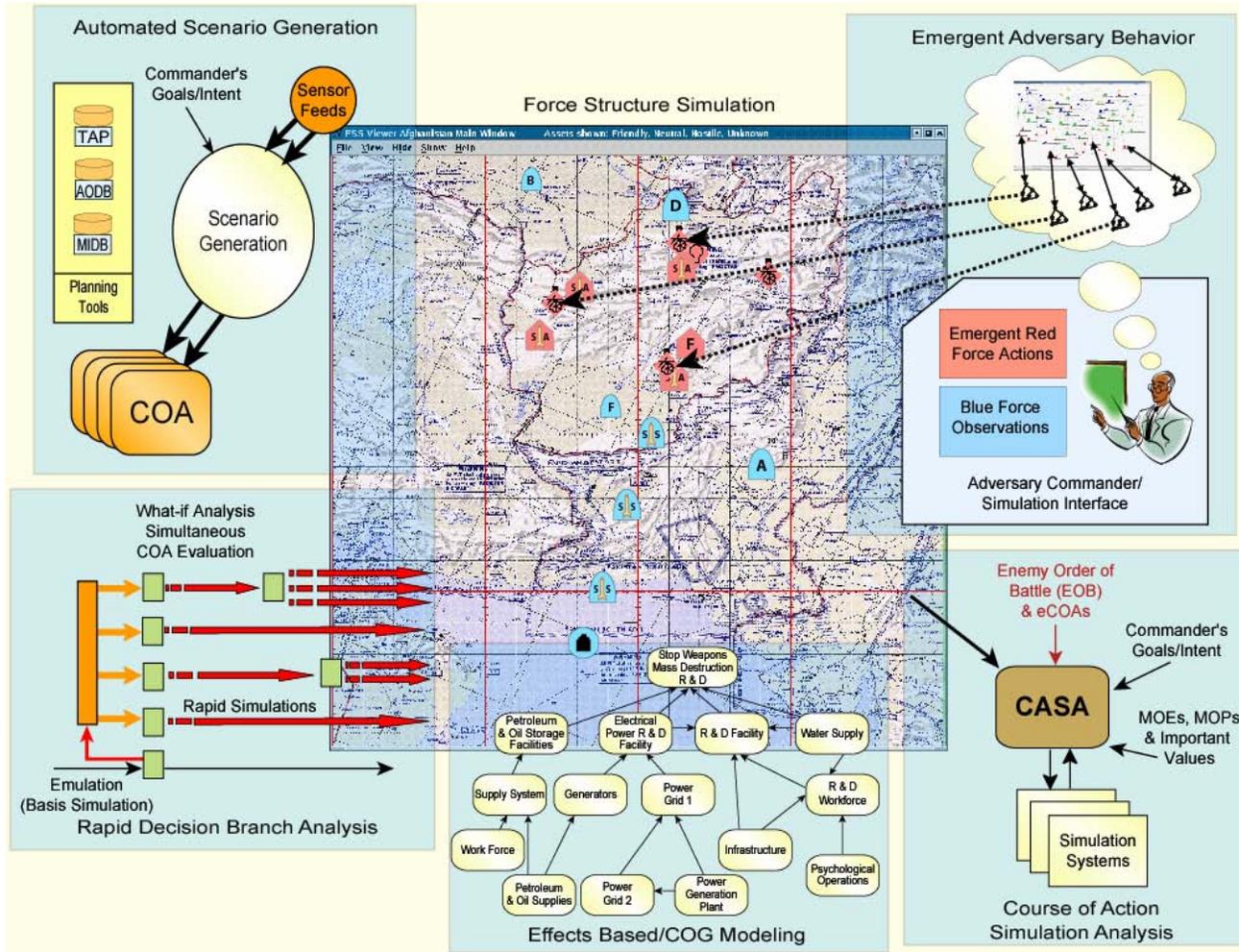
Objective: Use HPC Simulation Technology for Dynamic Decision Support for Command & Control

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

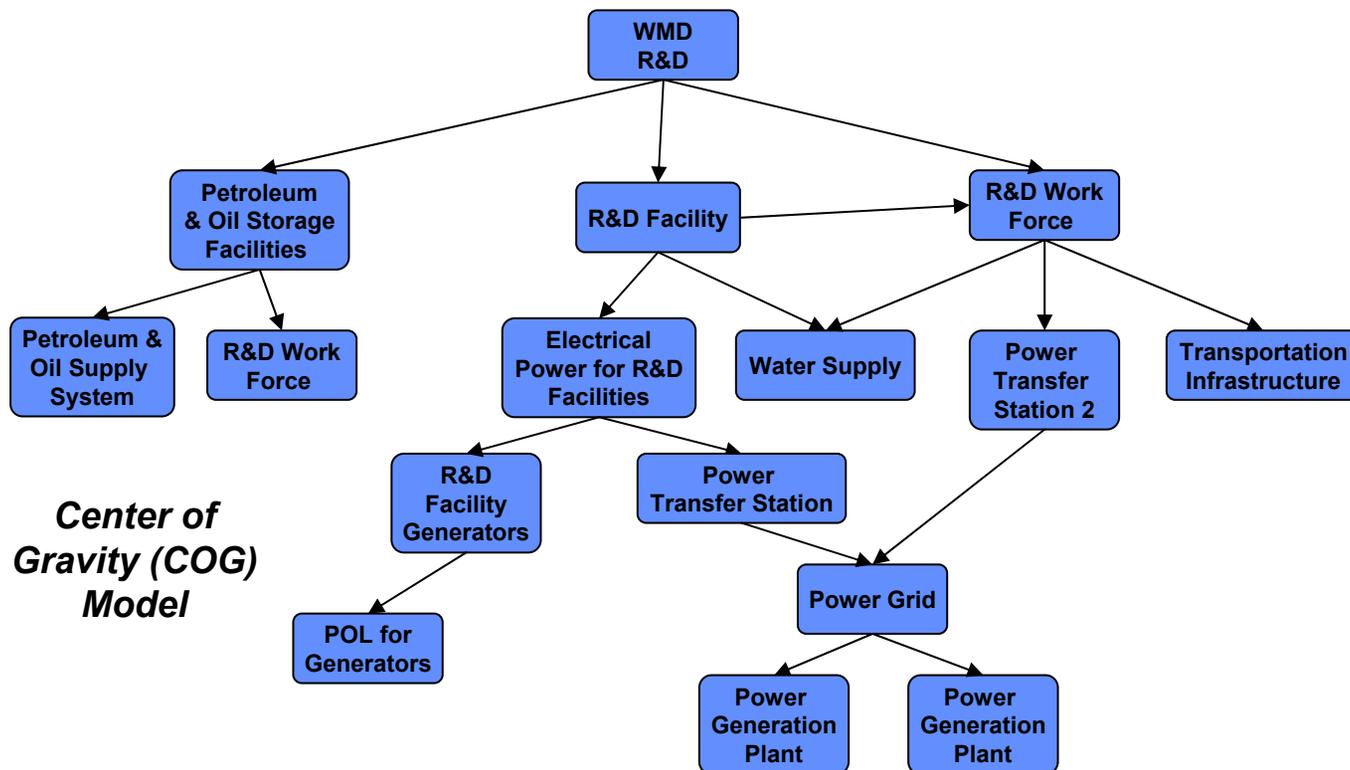




Effects Based Simulation Behaviors

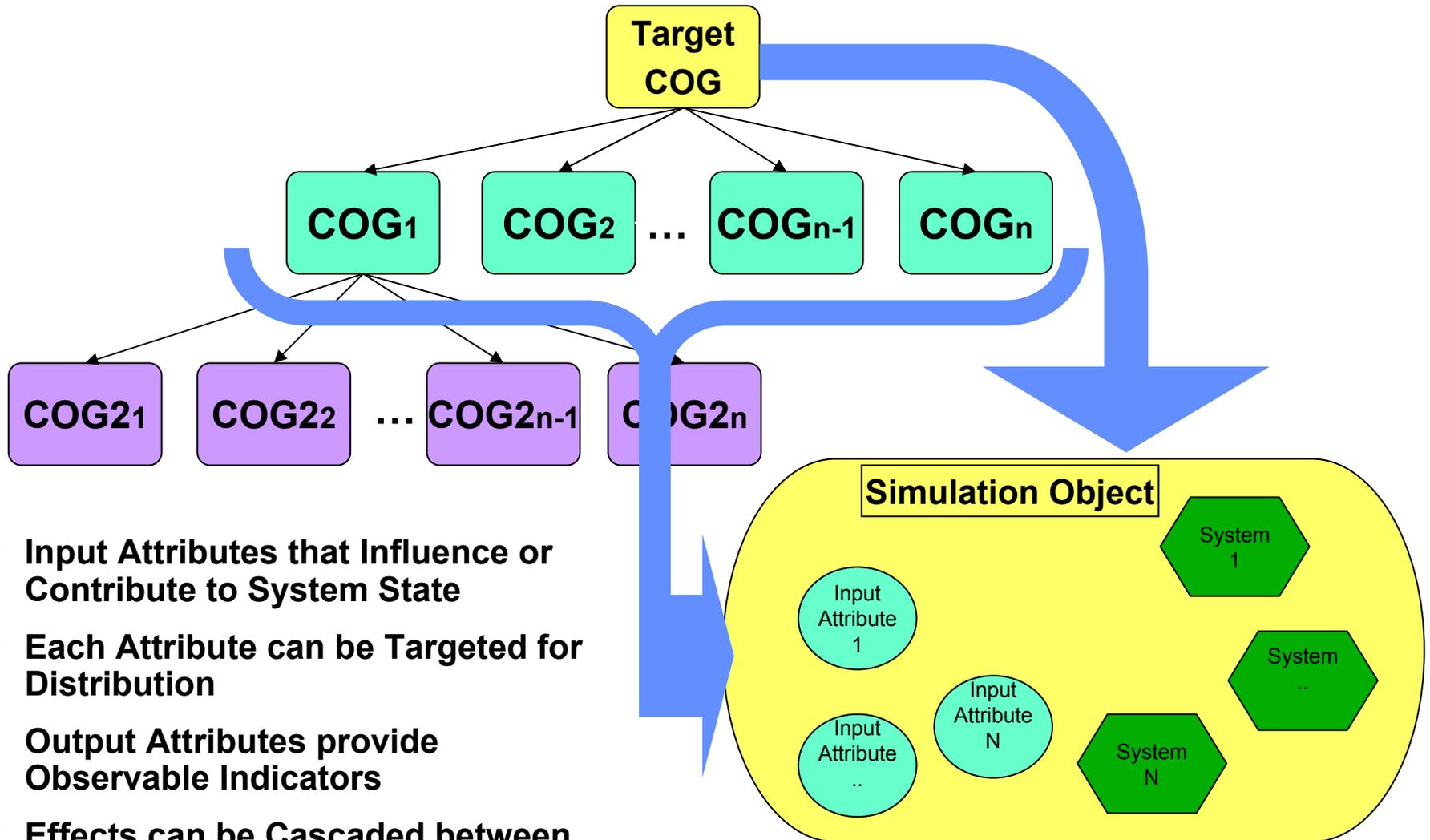


- Expanding Wargaming Operational Concepts to Integrate EBO Effects for Campaign Assessment
 - Complex, Cascading, Recovery
- EBO Simulation Objects and Indirect Effects Analysis
- Generic EBO Simulation Modeling Methodology for Wargaming





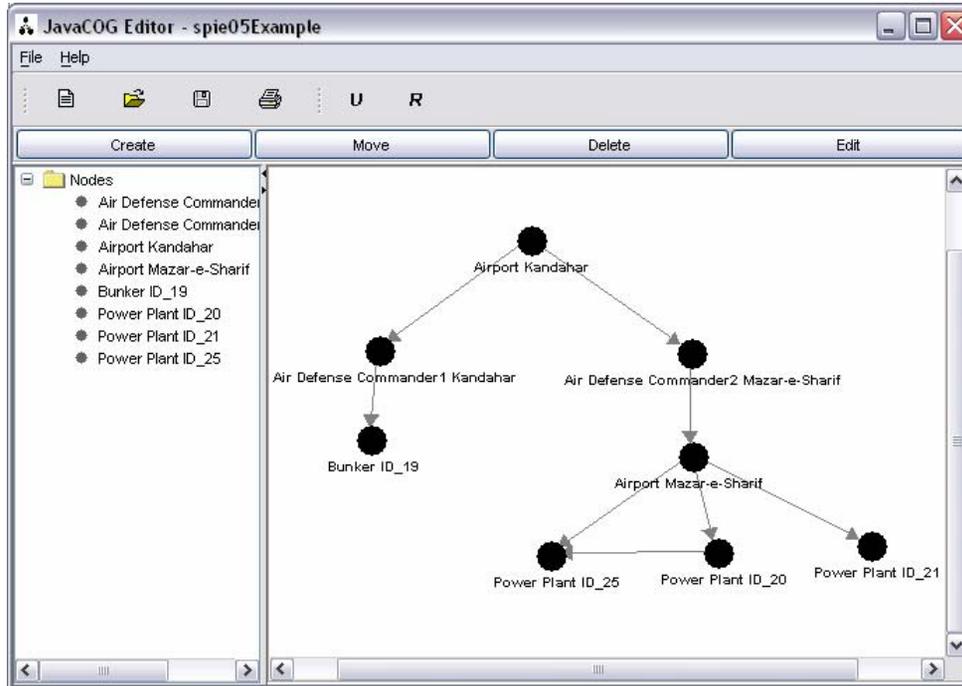
COG Representation in the EBO Object Model



- **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



Effects-Based Operation Properties

File Help

Name: Airport Mazar-e-Sharif

Working Indicator Air Traffic in area is above 75%

Disrupted 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

Delay Time 100.0

Recovery Time 50.0

Operational Indicator for Attrib... Lights are on in area ID_25

Influenced Indicator for Attribute Less then 7% of the lights in area ID25 are on



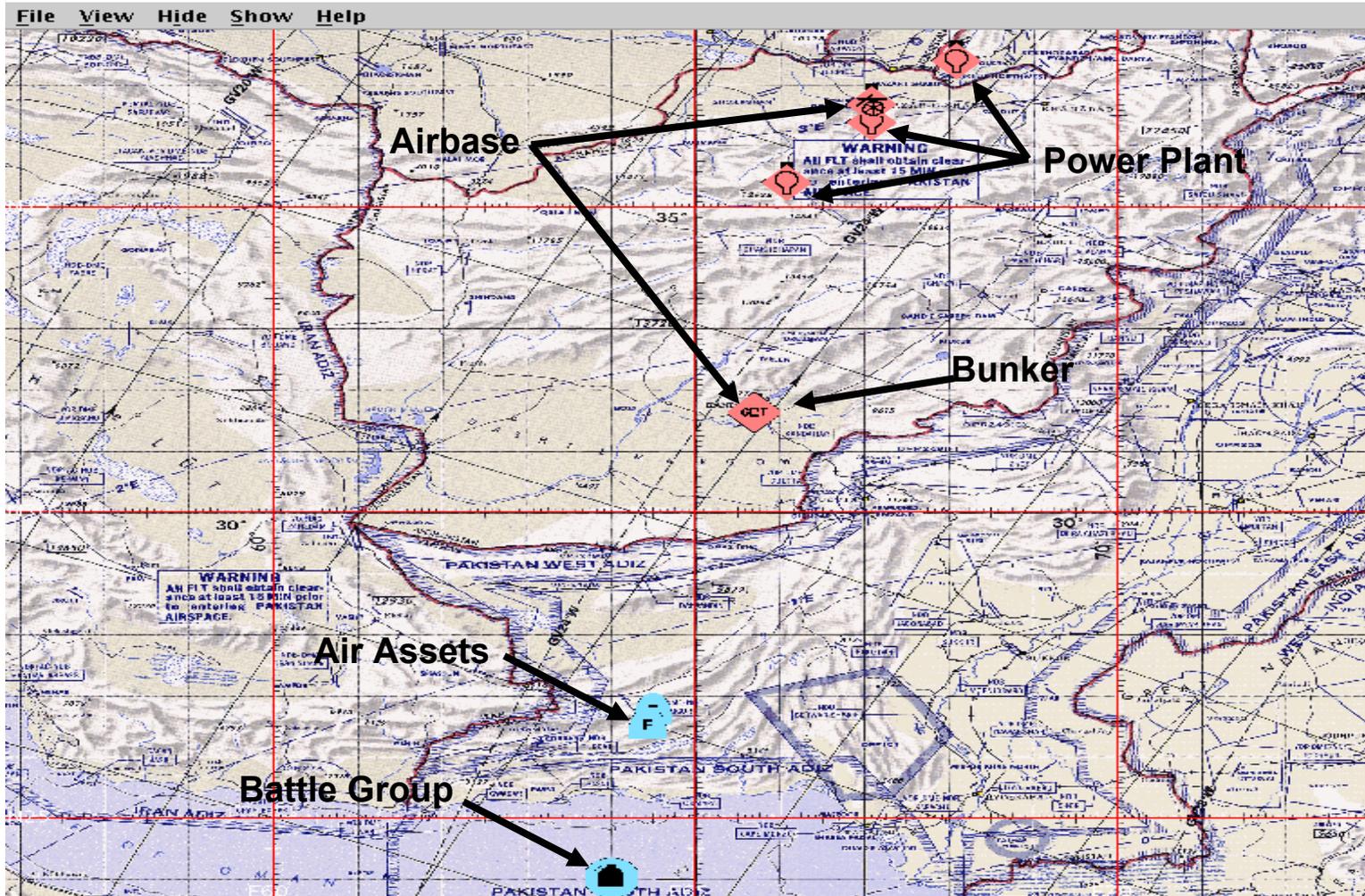
Simple, Fictional Example



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

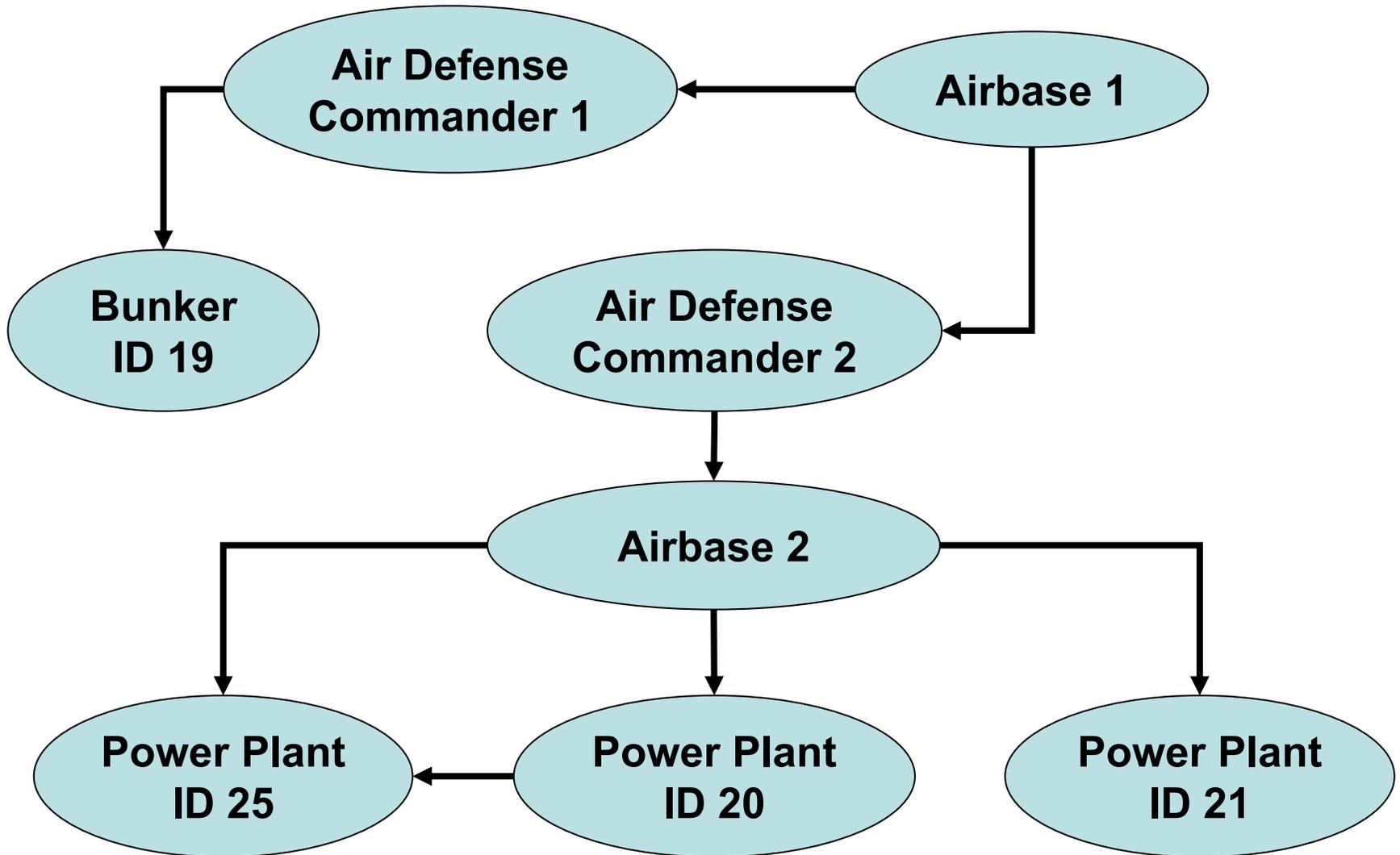


Simulation Example





Simple COG Model





Simulation Playback



The screenshot displays a simulation playback interface with three main components:

- FSS Viewer Afghanistan Main Window:** Shows a satellite-style map of Afghanistan with a red grid. Several red icons representing targets or threats are visible on the map. A blue label 'A' is present in the lower-left quadrant.
- COG Viewer:** Displays a network diagram with green nodes and arrows. The nodes are labeled: Airport Kandahar, Air Defense Commander 1 Kandahar, Air Defense Commander 2 Mazar-e-Sharif, Bunker ID_19, Airport Mazar-e-Sharif, Power Plant ID_25, Power Plant ID_20, and Power Plant ID_21.
- Console Window:** Shows log output for vectoring objects. The text includes:

```
***** Vectoring obj USS Enterprise FA-18 201,10 at t= [00:10:00.000, 600.00] *  
*****  
senderId= 201, #pts= 3, Speed(km/hr)= 800 RefId: 2;  
  
***** Vectoring obj USS Enterprise FA-18 201,11 at t= [00:10:00.000, 600.00] *  
*****  
senderId= 201, #pts= 2, Speed(km/hr)= 800 RefId: 2;  
  
***** Vectoring obj USS Enterprise FA-18 201,12 at t= [00:12:00.000, 720.00] *  
*****  
senderId= 201, #pts= 3, Speed(km/hr)= 800 RefId: 2;  
  
***** Vectoring obj USS Enterprise FA-18 201,13 at t= [00:12:00.000, 720.00] *  
*****  
senderId= 201, #pts= 2, Speed(km/hr)= 800 RefId: 2;  
  
3210) GVT=1600 wall=10.0002  
5970) GVT=2600 wall=20.4791
```



Simulation Results



| TIME (sec) | Symbol | Event Description | <u>With</u> | <u>Without</u> |
|------------|--------|---|-------------|----------------|
| 625 | ● | Launch Aircraft | ● | ● |
| 4625 | X | Engage Bunker ID_19; Bunker Destroyed | X | X |
| 4950 | ⊗ | Disable Air Defense Commander 1 Cascading Event | ⊗ | |
| 6400 | X | Engage Power Plant ID_25; Power Plant Destroyed | X | X |
| 6400 | ⊗ | Disable Power Plant 20 Cascading Event | X ⊗ | |
| 7050 | X | Engage Power Plant ID_21; Power Plant Destroyed | X | X |
| 7200 | ⊗ | Disable Airbase 2; Air Defense Commander 2; Airbase 1 Cascading Event | ⊗ | |
| 7850 | X | Engage Power Plant ID_20; Power Plant Destroyed | X | X |
| 8400 | R | Deploy SAM | | R |
| 8450 | R | Engage Aircraft; Kill 2 | | R |
| 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**



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.

2. Selecting a COA highlights the list of squadrons available to execute the COA. As squadrons are selected, their properties are displayed.

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

3.1. Overall timeline for each order in the mission.

4. The targets may be filtered based on the COG(s) they impact, and assigned to the current order

5. Aircraft from the squadron can be assigned or unassigned to the target.

4.1 As targets are assigned to the order, timeline shows the time-on-target within the order.

Order information can be used to construct simulations for execution at the unit, squadron, COA and mission levels.

The screenshot displays the 'Order Scheduling and COG-Based Target Assignment' window. At the top, it shows the current mission 'Demo_Mission' and COA 'RED_COA_1_v_BLUE_COA_4'. Below this, a 'Squadrons' list includes '152ND FIGHTER SQUADR' and '7TH FIGHTER SQUADR'. A table shows properties for the selected COA: AC Types (F16), Base (KLSV), Total AC (13), and Total Orders (2). The main area is a Gantt chart with a time axis from 12:00 to 04:00, showing red bars for mission orders. On the right, a 'Target Assignment' pane shows a list of targets (e.g., WAULENA, SACRAMENTO, CALIFON, DOLOMITE, FOLSOM_LAKE, TIGER_CREEK, ALPINE_LAKE) and a list of aircraft (AG_22, AG_52, AG_31, AG_61, AG_21, AG_13, AG_51, AG_62) with checkboxes for assignment. A 'COG' dropdown is set to 'WMD_FACILITIES'. The bottom of the window shows a timeline for 'Demo_Mission' with a 'FIGHTER SQUADR' label.



Modeling Intelligent Adversary Behaviors



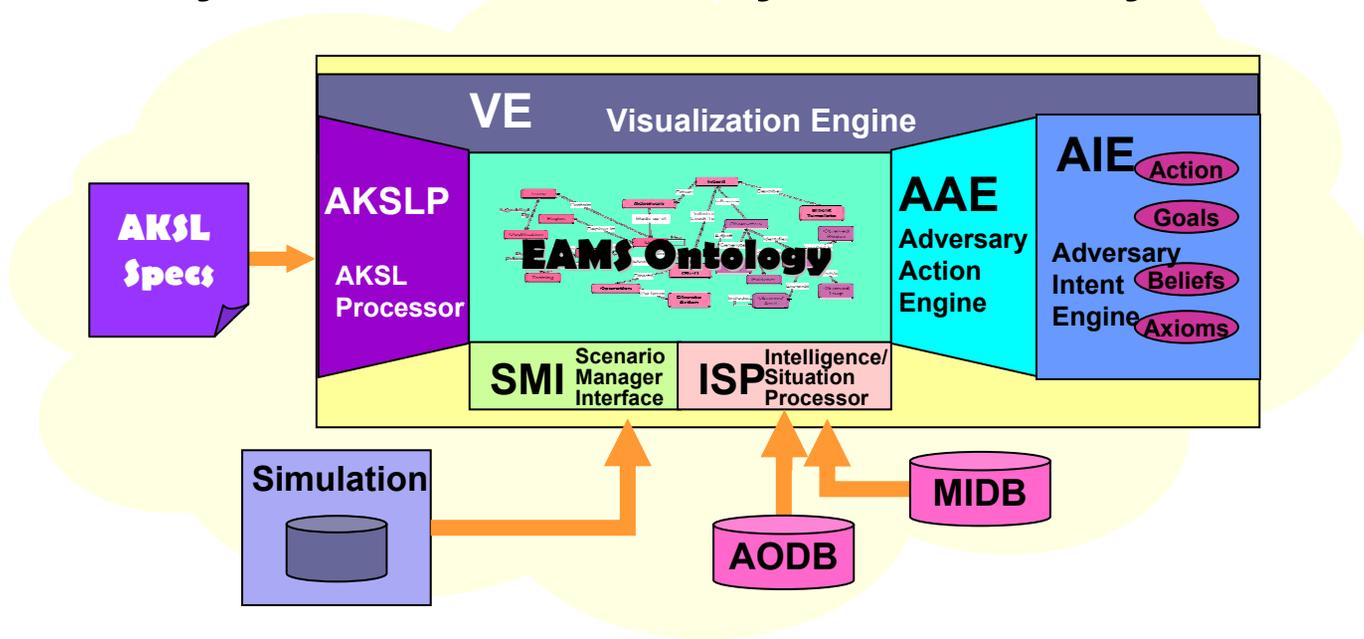
- **Current Generation Wargaming Technologies Execute a Pre-Scripted Sequence of Events for an Adversary – Don't Survive beyond the first Campaign Action**
- **Provide a Dynamic Simulation Capability that Incorporates Potential Adversary Actions**
 - **Adversary COAs don't need to be predetermined**
- **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 Intent
- Adversary Behavior and Actions are Calculated and input to the Simulation System and Executed by the Adversary Force

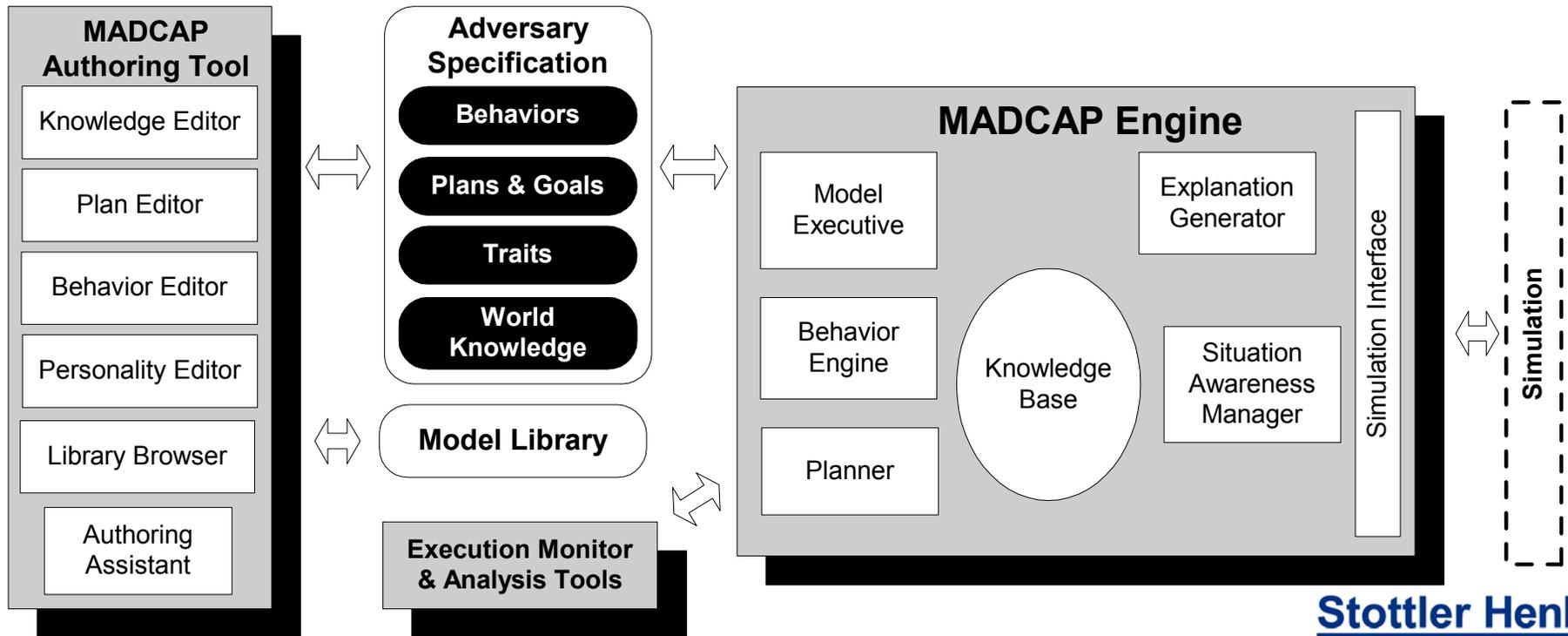




Authorable Adversary Modeling for COA Assessment



- 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

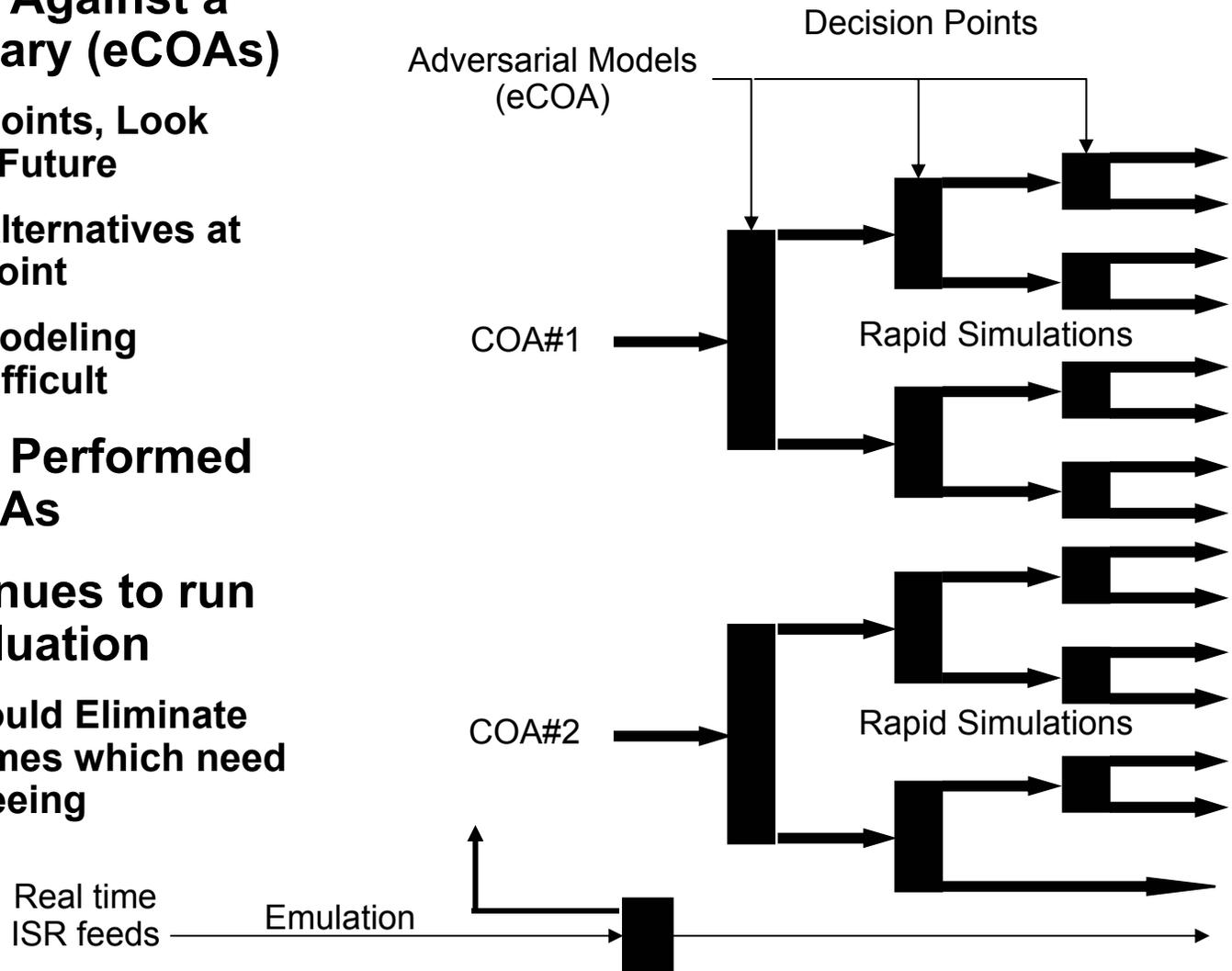




Simulation Cloning Example



- **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

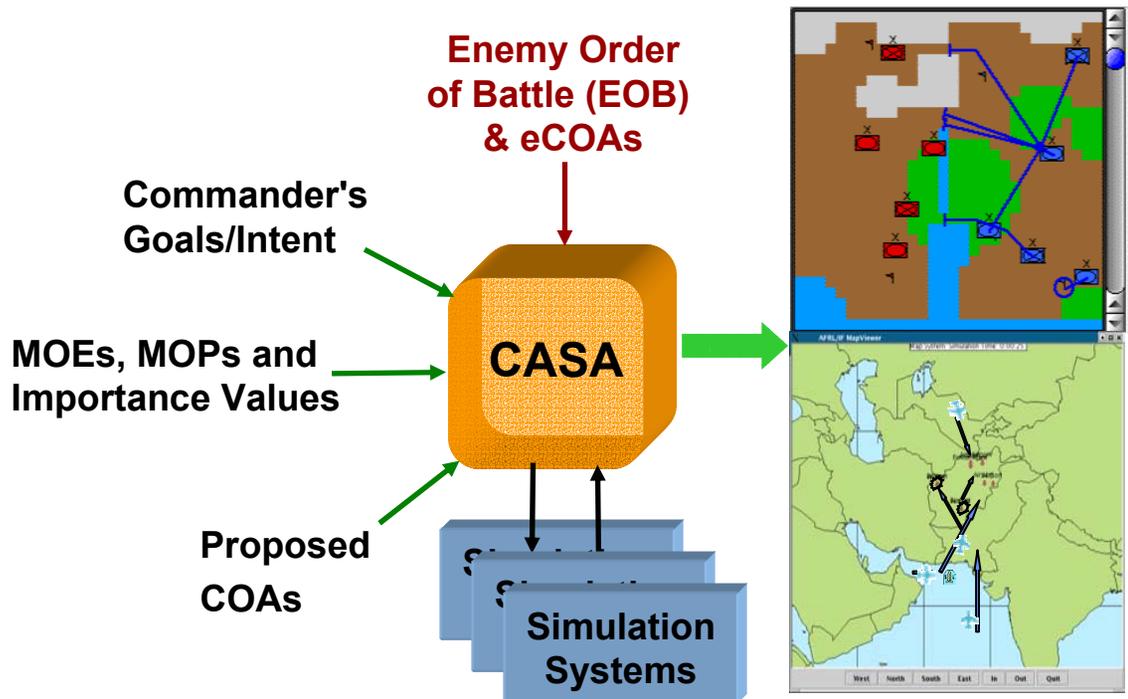




Course of Action Simulation Analysis (CASA)



- 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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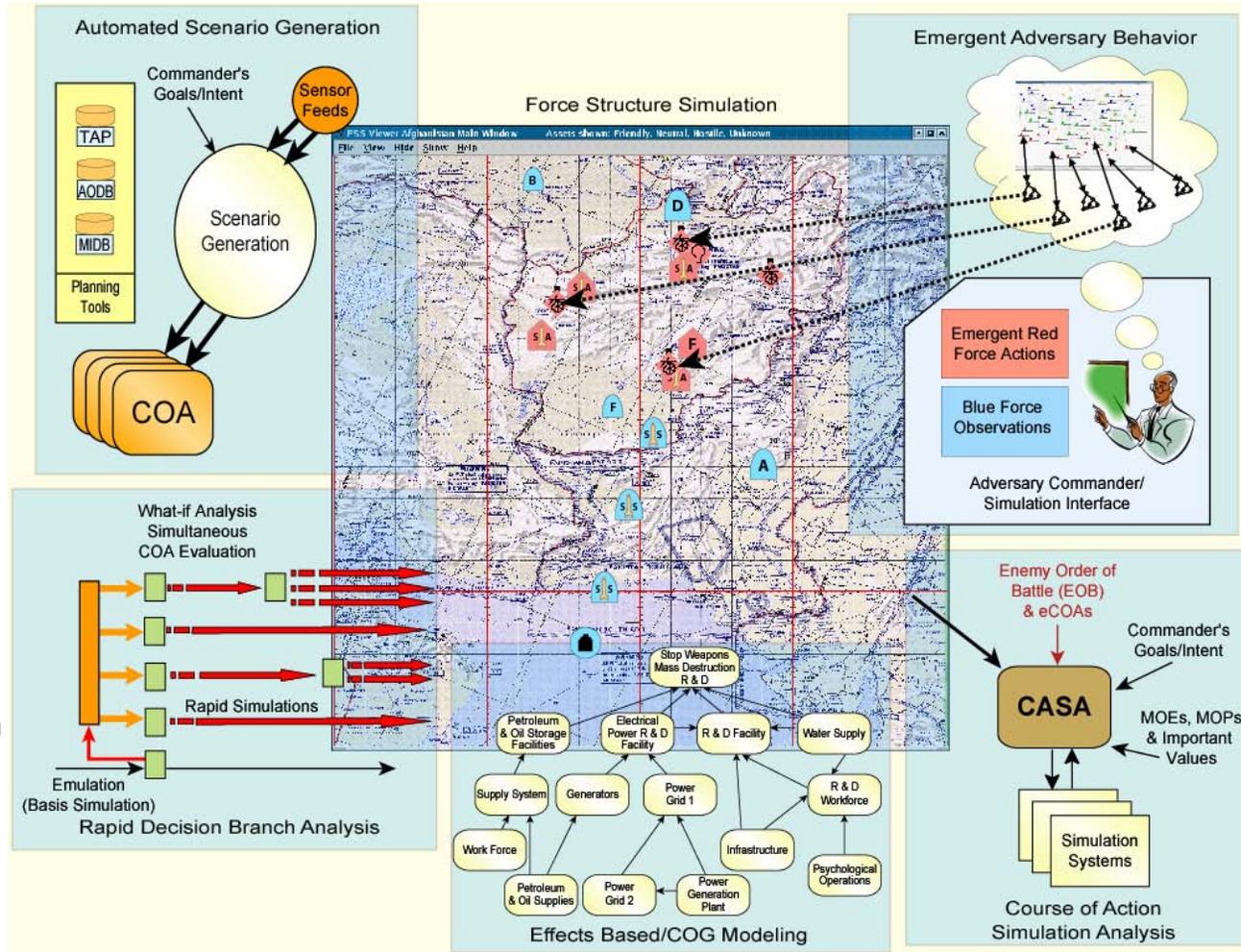
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- EBO Simulation Capability
- COA Analysis/Grading
- Simulation Cloning
- Intelligent Adversary Response





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**



References



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- **Krause, Lehman, Koziarz, *Automated Scenario Generation*, Enabling Technology for Simulation Science VII Conference, Orlando FL, April 2003**
- **McKeever, Gilmour, Hillman, *An Approach to Effects Based Modeling for Wargaming*, Enabling Technology for Simulation Science VIII Conference, Orlando FL, April 2004**
- **Gilmour, Hanna, Blank, *Dynamic Resource Allocation in an HPC Environment*, DOD HPC Modernization Program 2004 Users Group Conference, Williamsburg VA, June 2004**
- **Gilmour, Hanna, Koziarz, McKeever, Walter, *High-Performance Computing for Command and Control Real-Time Decision Support*, AFRL Tech Horizons, February 2005, <http://www.afrlhorizons.com>**