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Integrating Effects-Based and Attrition-Base Modeling

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OVERVIEW

- Purpose: Examine process and methods of interfacing high-level probabilistic Effects-Based models with higher fidelity attrition-based models and performing evaluations of alternative Courses of Action using the combination of these modeling techniques
- Outline:
  - Effects-Based Challenge
  - Case Study from Persian Gulf War
  - Conclusions

Network-Centric Effects-Based Operations (EBO) … Shaping the Adversary's Behavior

- **JFCOM defines EBO** as ***"a process for obtaining a strategic outcome or effect on the enemy through synergistic, multiplicative, and cumulative application of the full range of military and non-military capabilities at the tactical, operational, and strategic levels".***
- **Network-Centric Operations (NCO) enables EBO**
  - **NCW enabled by 4 technologies:**
    - **Sensors**
    - **IT and Network Architectures**
    - **Precision Weapons**
    - **Stealth Platforms**

EBO is the key to broadening the role of NCO beyond Attrition Warfare

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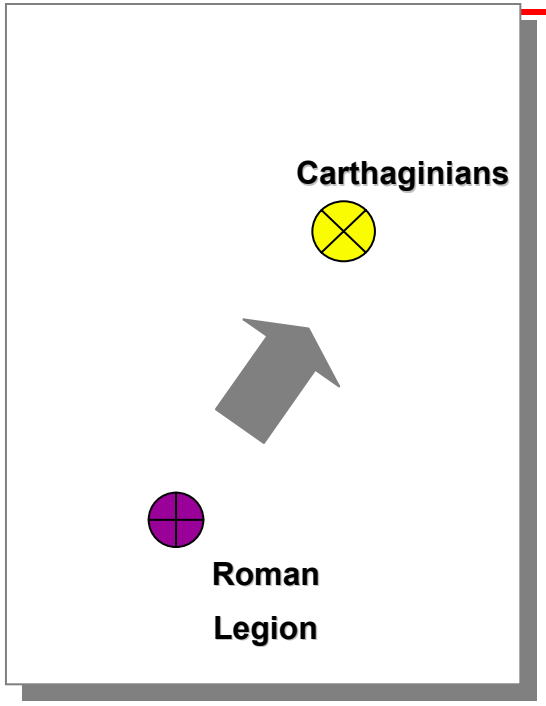
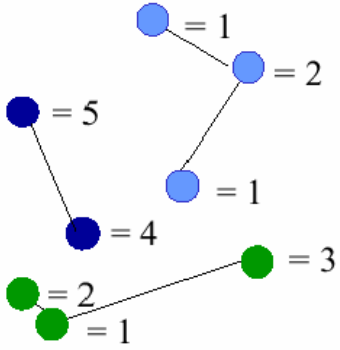
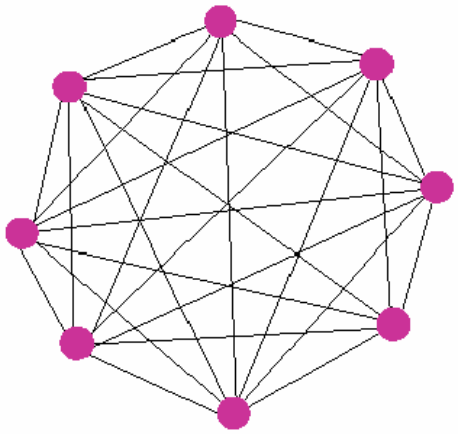
Evolution of Warfare* and Modeling & Simulation Approaches

** Measuring the Effects of Network Centric Warfare, Booz-Allen & Hamilton, 1999*





Total Force Value = 19
(N+N+N+N+N+N+N+N)



Total Force Value = 64
(N^2)

Single Dimension Warfare	Platform-Centric Warfare	Network-Centric Warfare
Force N on M	PCW ⇨ $\sum N_i$	NCW ⇨ $(N)^n$
Lanchester's Equations: Attrition Modeling	Physics-Based Force-on-Force Attrition Modeling (Campaign, Engagement)	Paradigm Shift to EBO** requires modeling Physical + Belief + Reason Domains

** BGEN Deptula, USAF, 2001, on *"EBO: Change in the Nature of War"*

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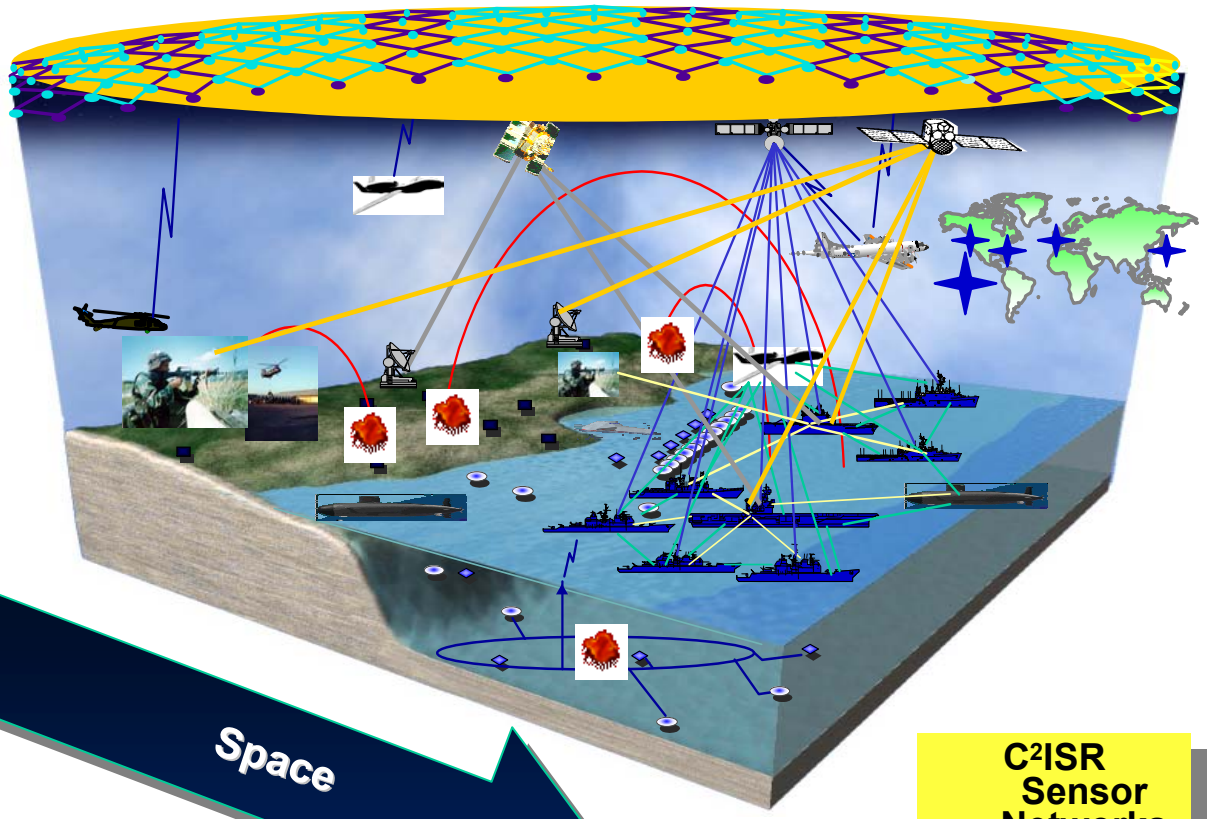
Dimensions of Network Centric Warfare (NCW)*

* *Measuring the Effects of Network Centric Warfare, Booz-Allen & Hamilton, 1999*

Information/Knowledge Grid

(Nanoseconds)

Network & Info Technology



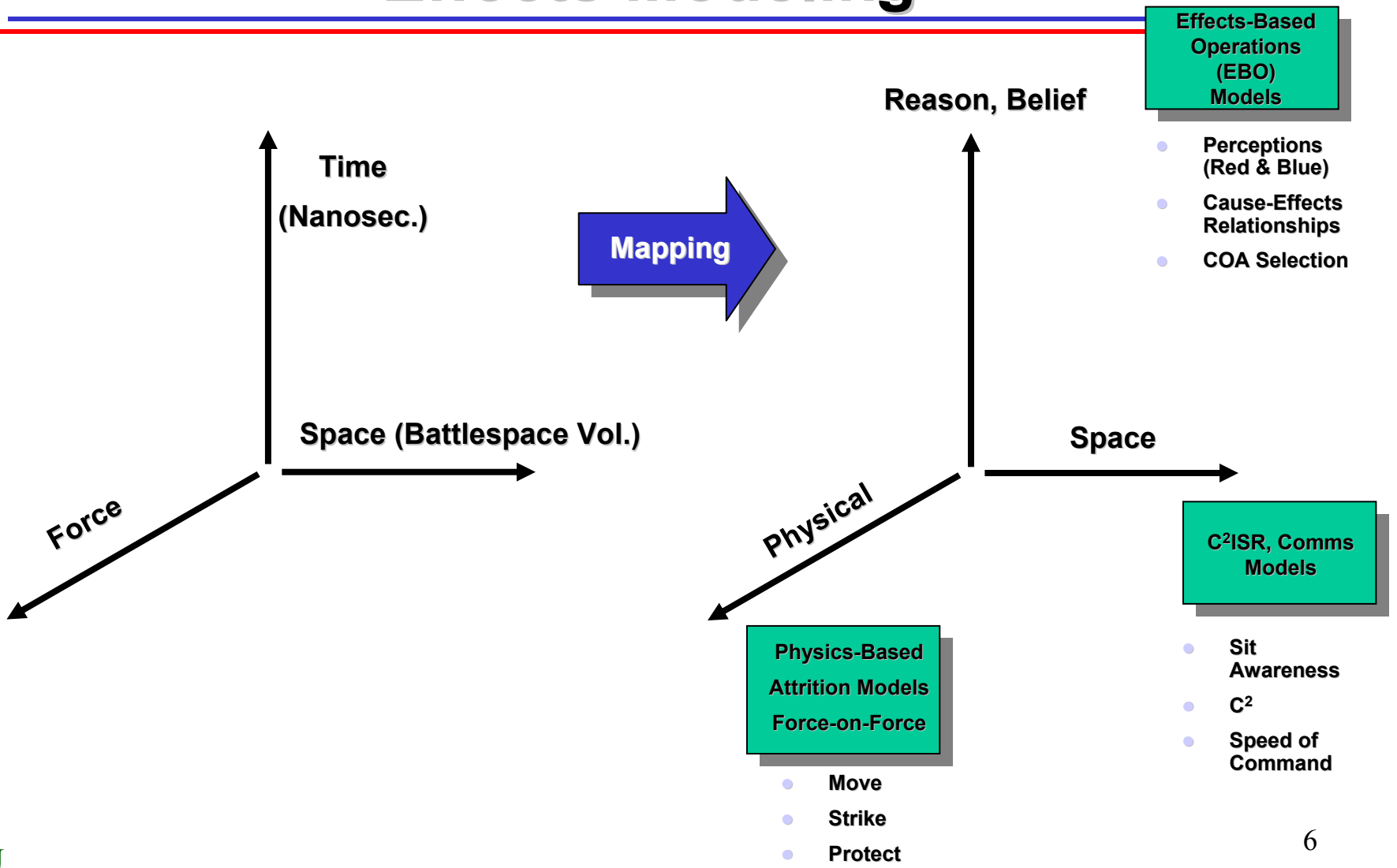
C²ISR Sensor Networks

Stealth Platforms, Precision Weapons

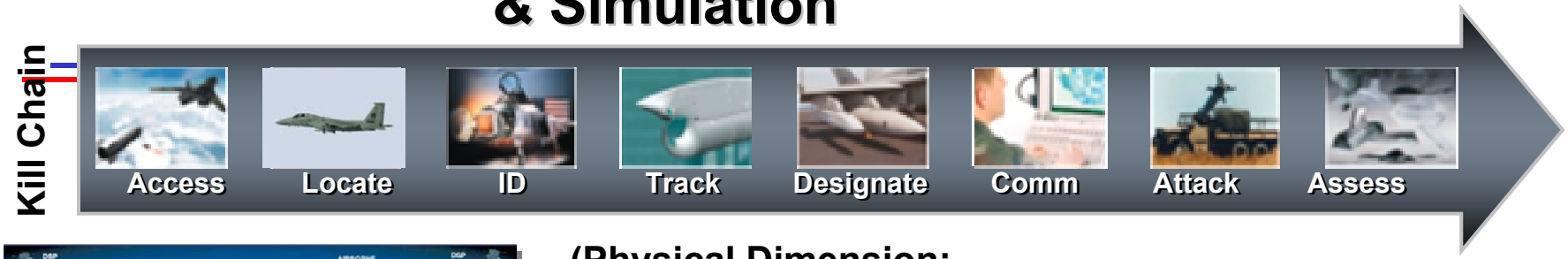
Sensor Grid

(1000s - 1,000,000s m.)

Integrate Physical & Cognitive Effects Modeling



EBO Modeling Linked to Attrition-Based Modeling & Simulation



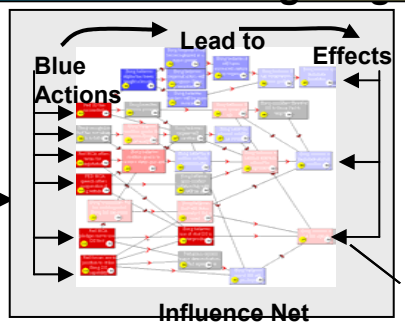
(Physical Dimension: Force, Space, Time Domain)

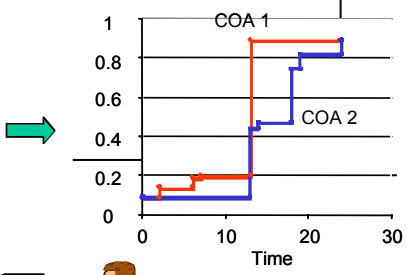
+

EBO NCW Operational System

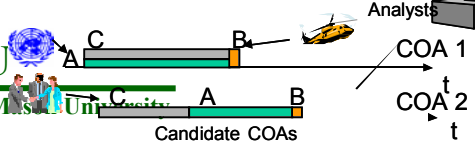
Intel + Planning + Execution Assessment

Campaign Plan





(Reason & Belief Domain)



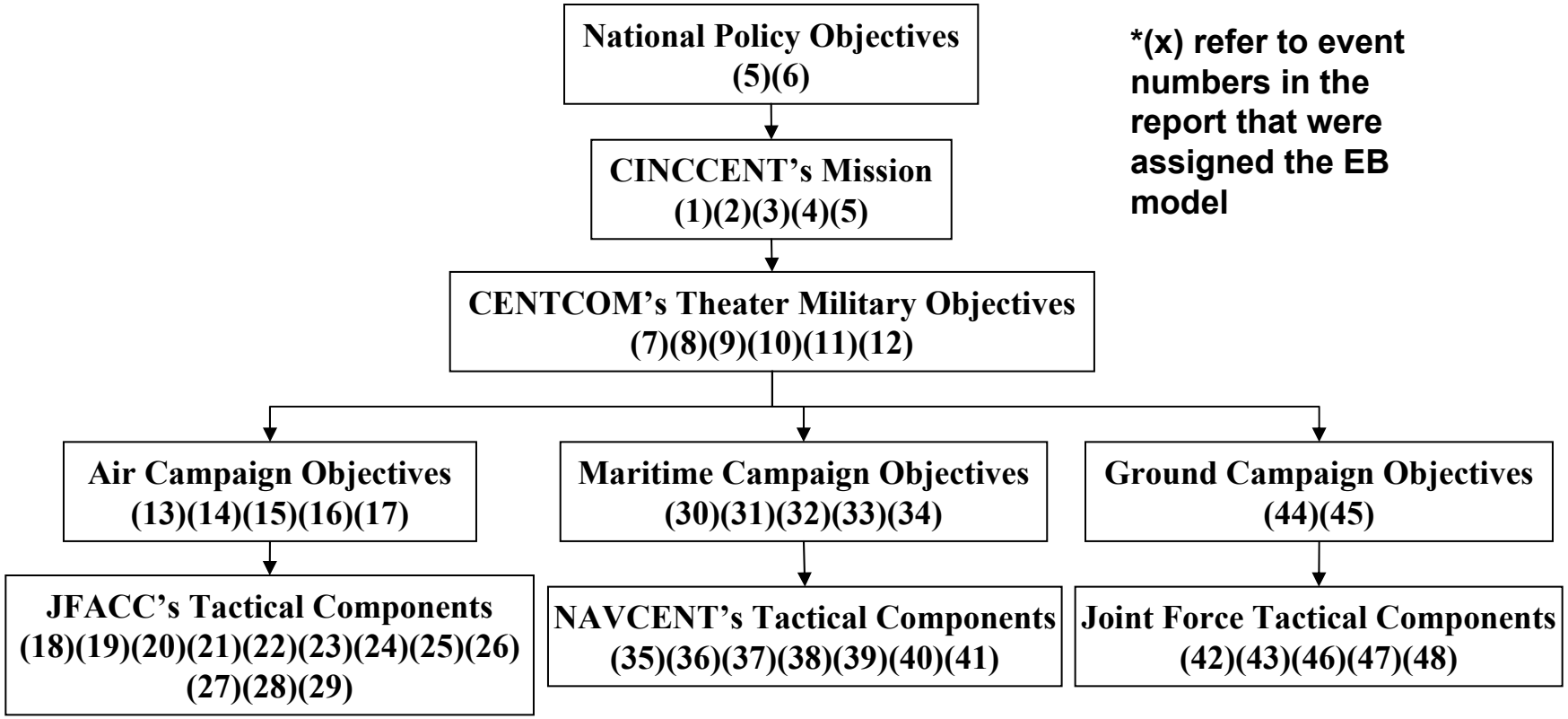
** EBO are coordinated sets of actions – including diplomatic, economic, information operations, psychological operations, and lethal/non-lethal warfare—directed at shaping the behavior of friends, foes and neutrals in military operations*

CASE STUDY APPROACH

- Persian Gulf War *(Desert Storm*) well documented; much unclassified information published. Many of the situations encountered there are still significant today.
- We first used documentation* from Desert Storm to create a high level EBO model
  - Model behavior was "validated" using the Final Report
- We attempted to discover how the higher level model can foster the development and analysis of the lower level model and how, in turn, the lower level model results can impact the higher level model.
- By using a known situation it was possible to validate model results and to test the postulated interfaces between the models that were developed
- Specific results then are generalized

"*Conduct of the Persian Gulf War: Final Report to Congress*" [DoD, 1992]

FLOW DOWN OF PERSIAN GULF WAR OBJECTIVES



*(x) refer to event numbers in the report that were assigned the EB model

Desert Storm War Scenario

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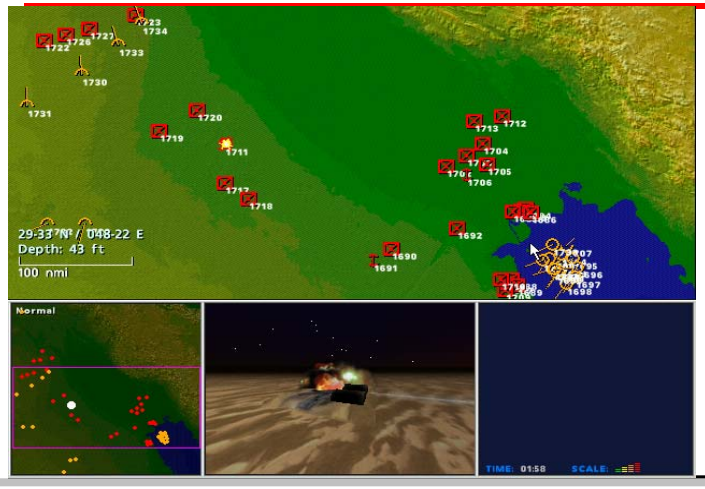
Fleet Command Naval Warfare Simulation…
3D Real-Time Modeling, Simulation & Visualization



Adapted by Raytheon for use on DARPA / NAVSEA Submarine Payloads & Sensors Program. Developed HLA-compatible interface to Raytheon Hi-Fi Missile Server. Can be run in Monte Carlo mode (turn off graphics).

✓Tested sensitivity to various Mission / System Concepts within context of Scenarios

✓Conducted Operational Utility Analysis to Quantify Military Value:

- »Notional Korea-China Scenario, (UNCLASS ver.)
- »Persian Gulf Scenario (UNLCASS ver.)

***Fleet Command* functionality:**

- **Set up Geo-scenario using Mission Editor GUI**
- **Modify Platform/Sensor/Weapon Parameters with Database GUI**
- **"Drag and Drop": Lay-down Red/Blue Forces (Lat/Long) on Geographic Map Window**
- **Simulation can be run in different ways:**
  - **Computer (Blue) vs Computer (Red)**
  - **Human (Blue) vs. Computer (Red)**
  - **Human (Blue) vs Human (Red)**

Features:

- Geographically accurate 3D environment
  - –Bathymetric Data (display depth with mouse)
  - –1000 meter resolution Terrain (Standard)
    - »Integrated DTED Level 1 (100 m resolution)
- Complete Jane's Order Of Battle for 16 countries; countries can be added
- Sim Objects include Submarines, UUVs, Surface Ships, Aircraft, UAVs, Missiles, Tanks, TELs, Land Vehicles, undersea mines and some ground installations; can customize sim objects
- Multiple views of unfolding scenario

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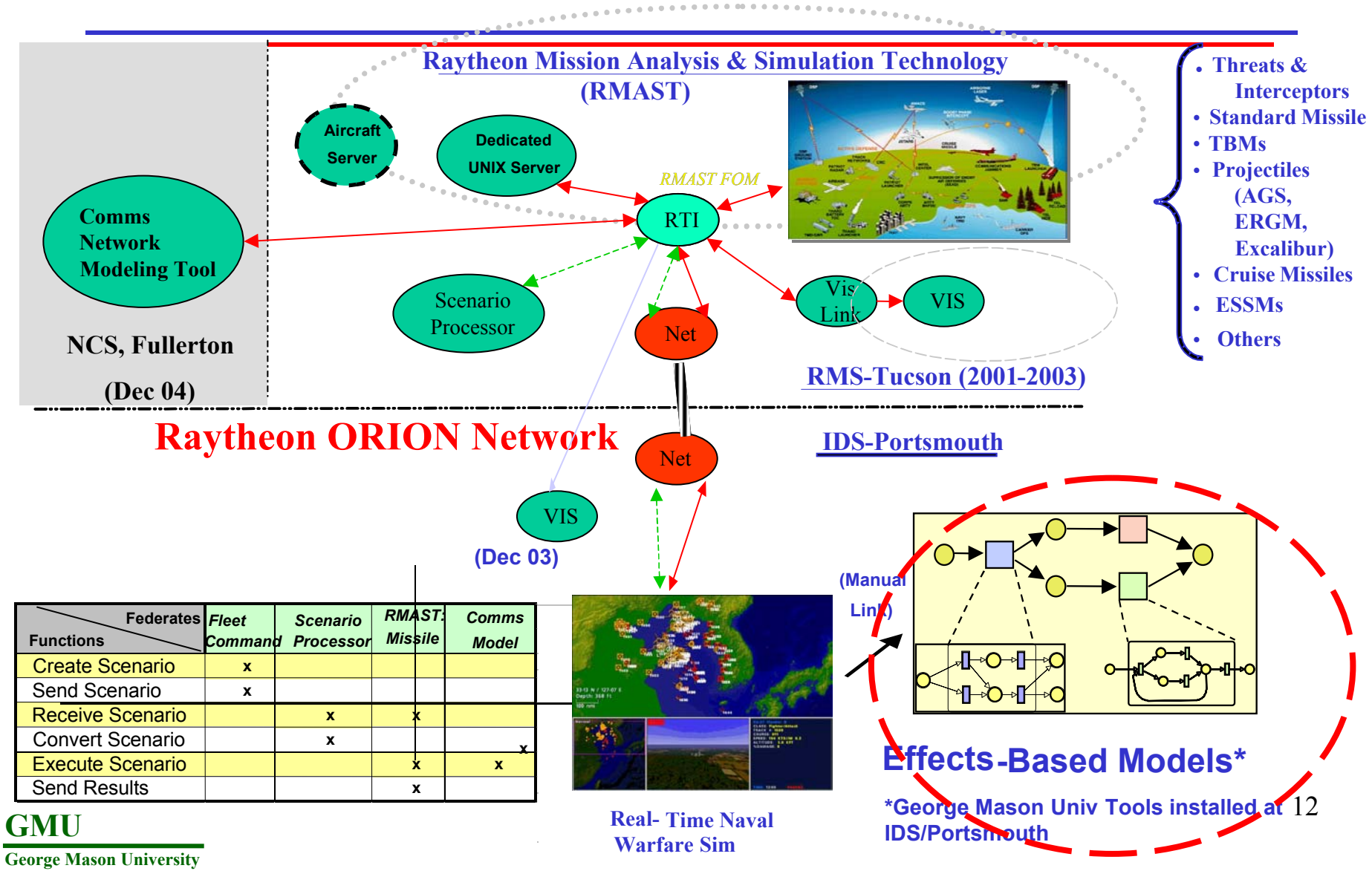
HLA Architecture Supports Distributed Scenario Generation, Req'mnts Analysis & Concept Development



Functions \ Federates	Fleet Command	Scenario Processor	RMAST: Missile	Comms Model
Create Scenario	x			
Send Scenario	x			
Receive Scenario		x	x	
Convert Scenario		x		x
Execute Scenario			x	x
Send Results			x	

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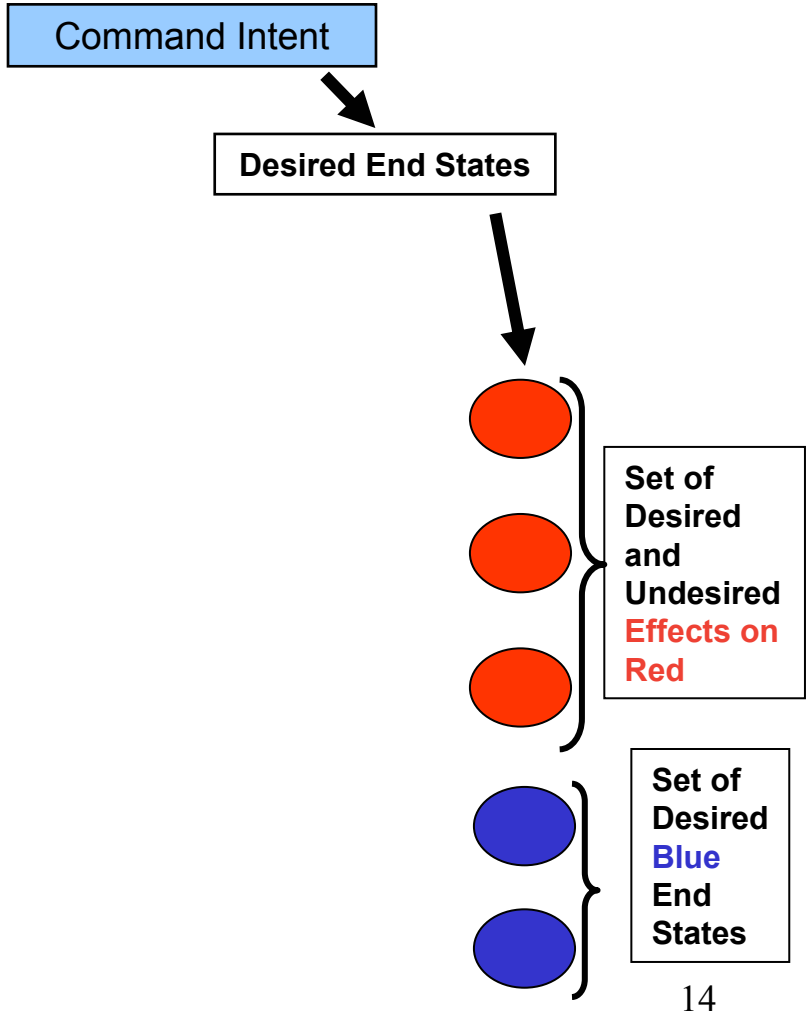
COURSES OF ACTION FOR EBO

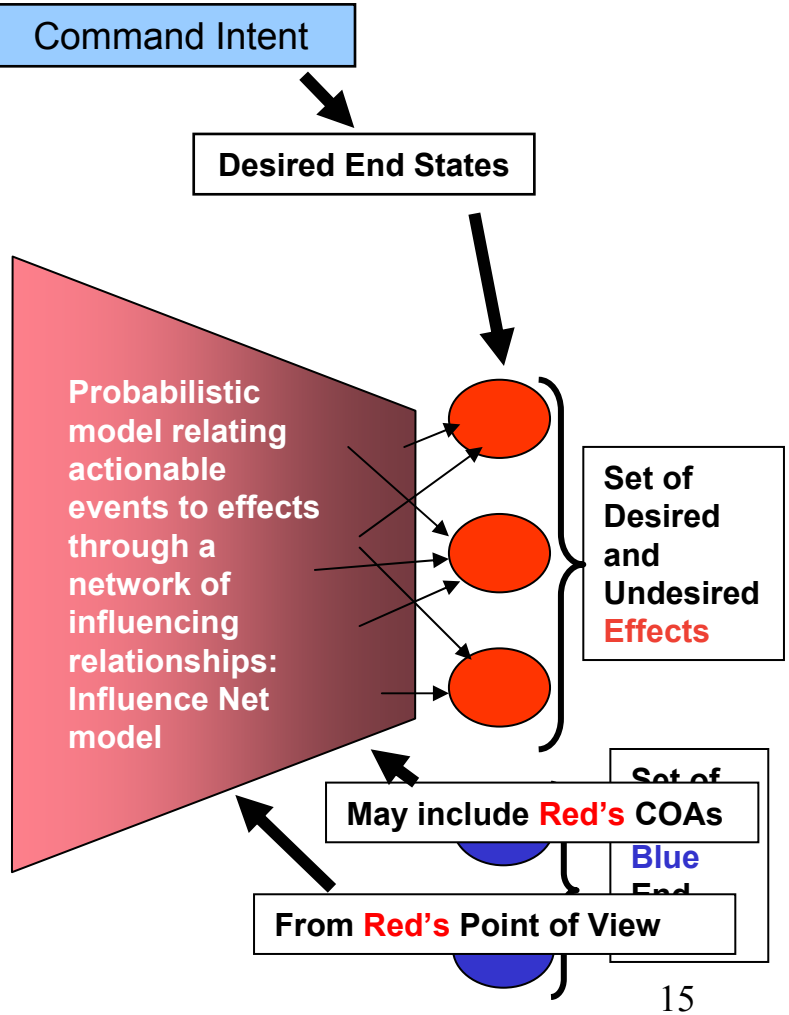
- An effects-based way of thinking has been evolving for some time. Objectives can be obtained by achieving effects. Effects can be achieved by actions that comprise COAs
- Needed is an approach that captures the rationale for COAs that explain how actions can achieve effects
- Different levels of detail impact the type of analysis that can be done
  - Detailed Engineering and physics knowledge can allow engineering models to show the behavior of systems to actions
    - How to disrupt electric power, POL, an IADS are examples
    - If we have the knowledge and the models they can give very precise results
  - Qualitative knowledge about system or the reasoning belief and decision make aspects require a more abstract approach
    - Probabilistic modeling techniques may be helpful

Effects Based Modeling for COA Development

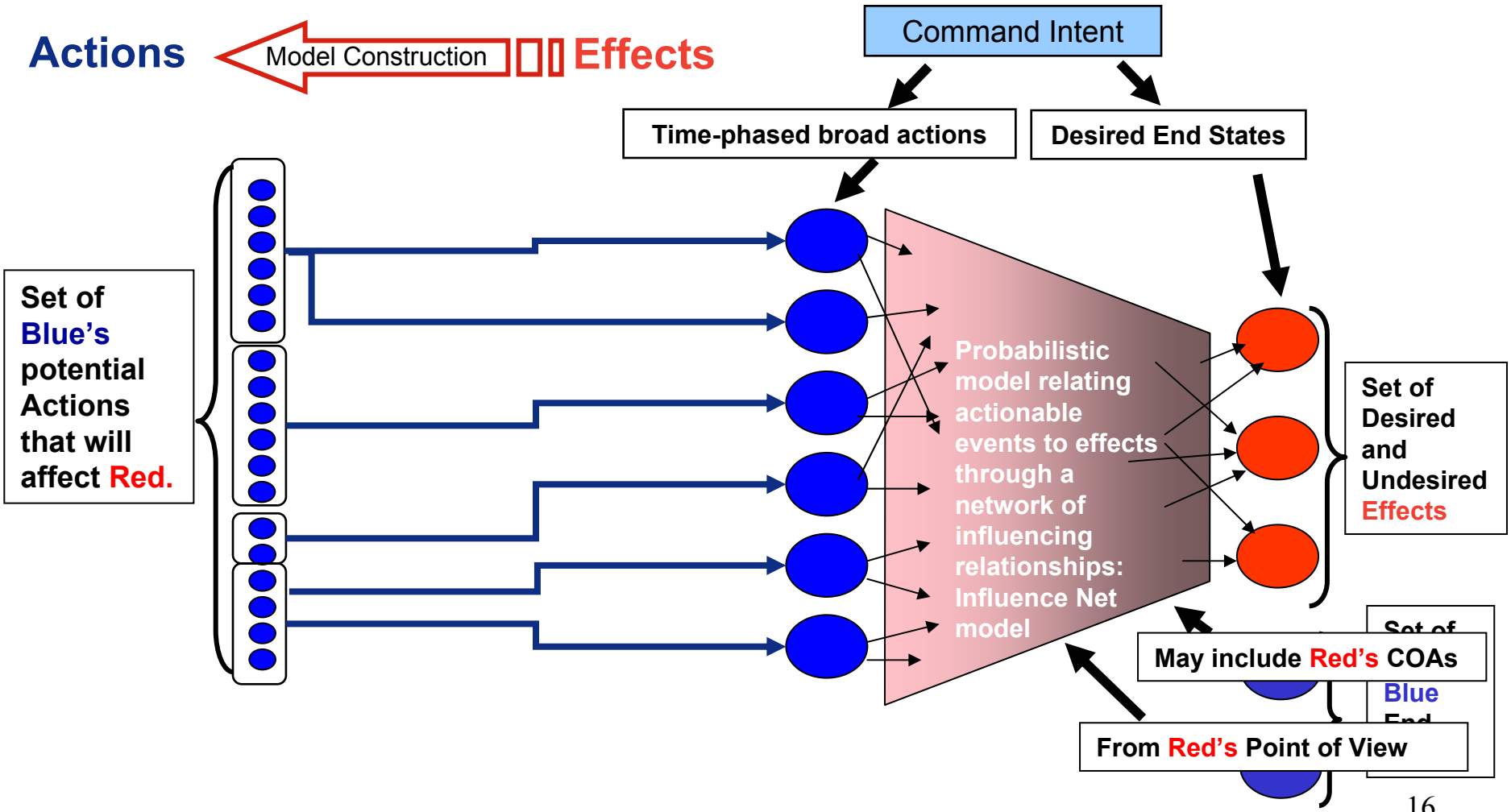


Effects Based Modeling for COA Development

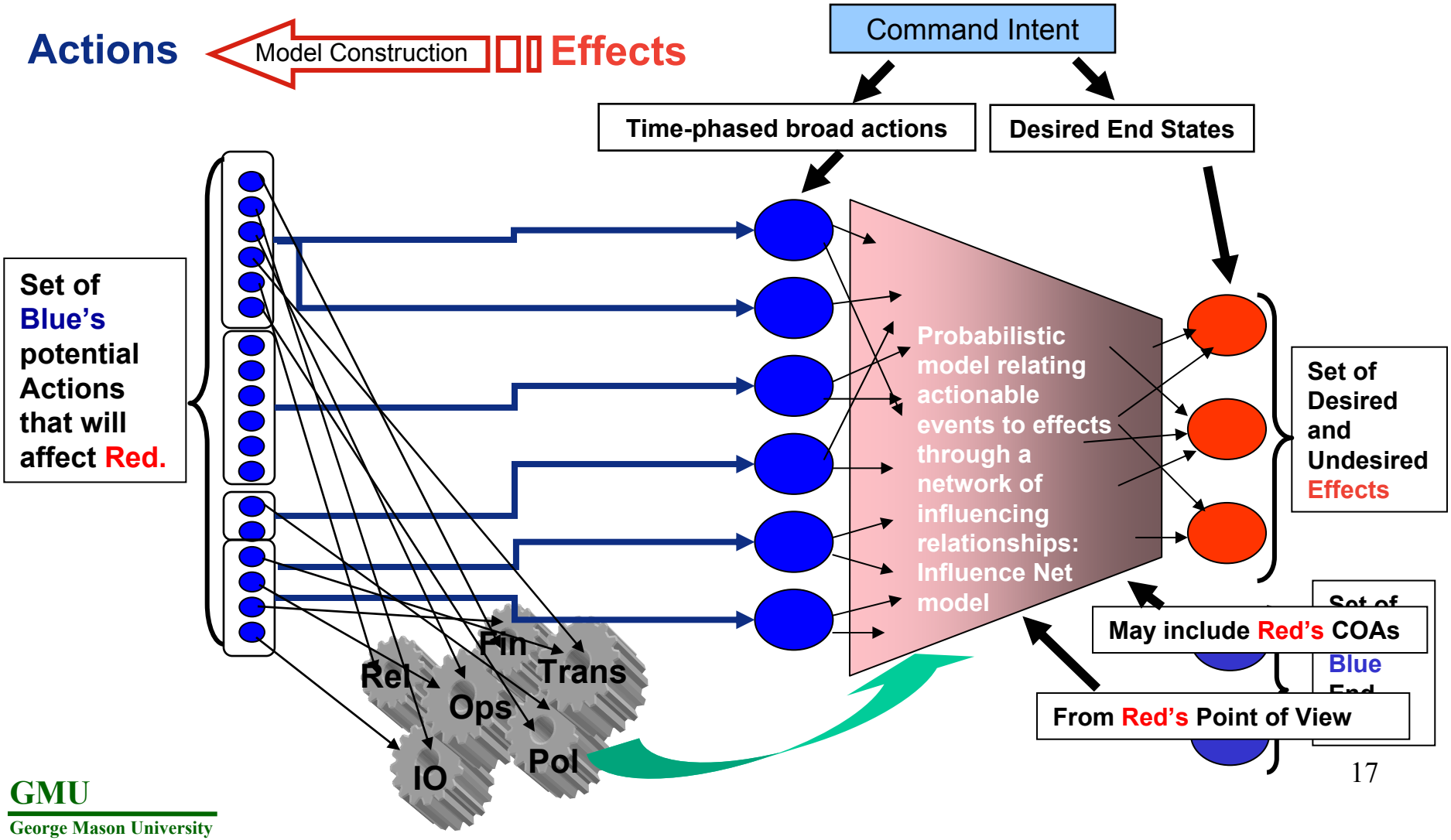
Actions ← Model Construction → **Effects**



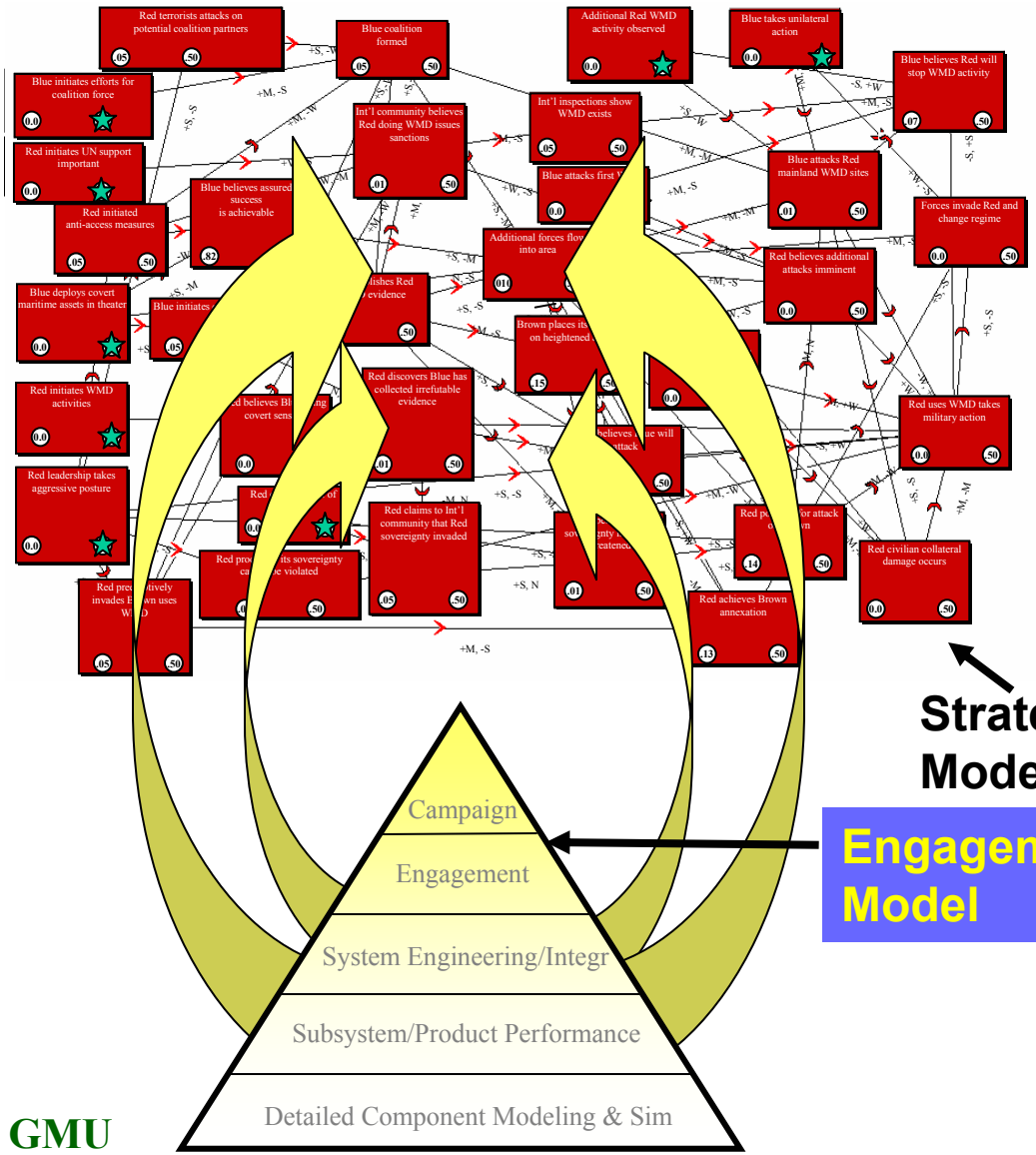
Effects Based Modeling for COA Development



Effects Based Modeling for COA Development



AN INTEGRATE MODELING APPROACH



Strategic Model

Engagement Model

Objective: Codify belief structure of Adversary to establish cause and effect relations and impact of actions

Identify
- Intent/outcome
- Beliefs
- Initial events
- Actions

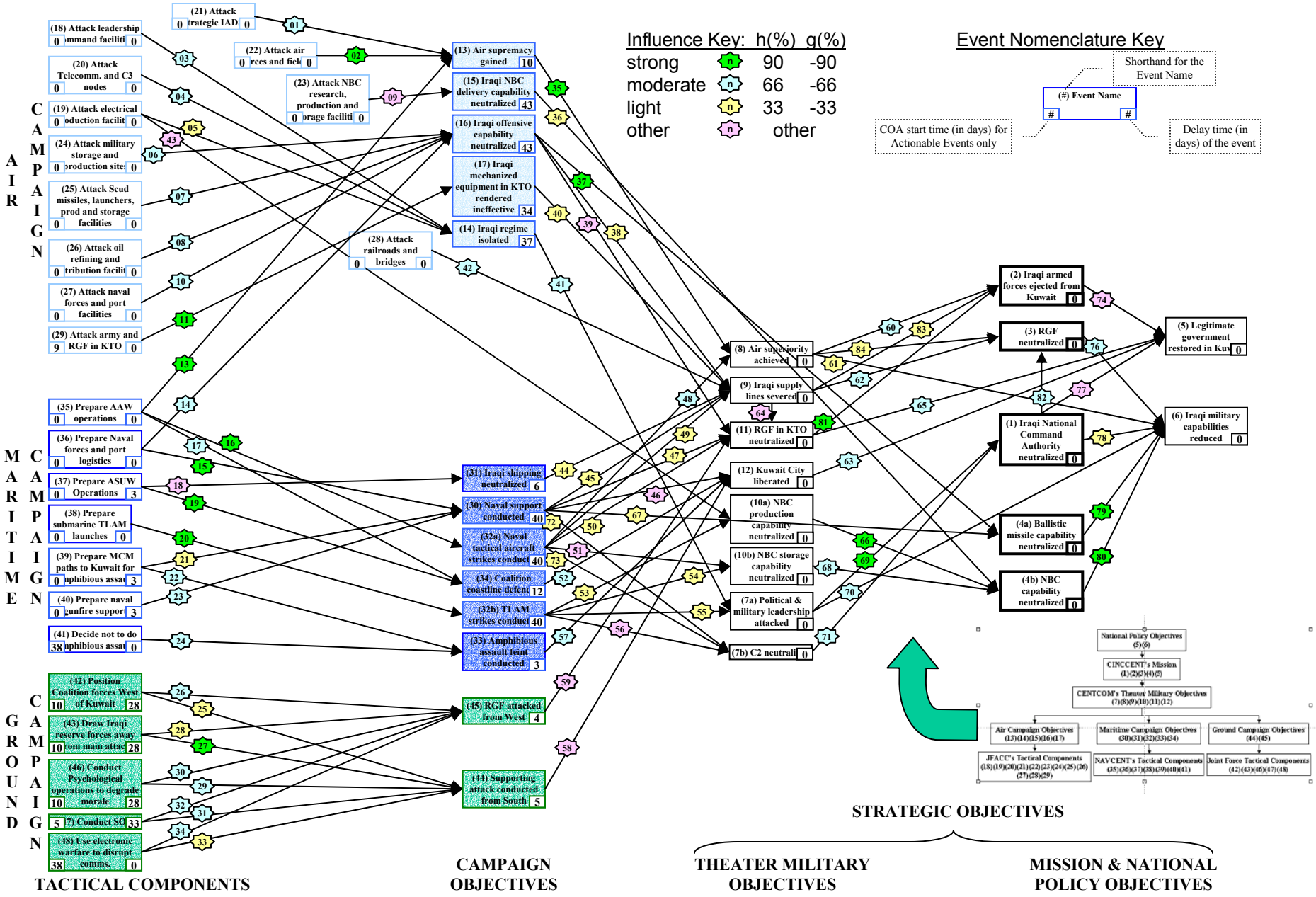
Establish
- Cause and effect relationships
- Probability estimates
- Times (when, how long)

Link with Engagement Models
- Quantity appropriate action for increased fidelity

HYPOTHESES

- Use of more detailed modeling improves the derivation of the elements of the higher-level EBO model
  - High fidelity simulations can provide more accurate values for the conditional probability values and the time delay information that the higher-level models use as input.
- High fidelity simulations can be useful in providing a more detailed look at actionable events that are created in the high level EBO model

Gulf War Model Rev 16b



HIGH LEVEL MODEL VALIDATION

- Concentrated on the overall behavior given the choice of values for the influence strength parameters, since the structure and timing more were directly derived from the Final Report to Congress.
- Examined *static* behavior by examining how changes in input actionable events result in reasonable changes throughout the net as well as changes at the overall effect nodes (Mission and National Policy Objectives).
- Compared *dynamic* behavior with timelines in Final Report.

Actionable Event Group			Probability of Effect						
Air	Maritime	Ground	(5) Legitimate government restored in Kuwait	(6) Iraqi military capabilities reduced	(2) Iraqi armed forces ejected from Kuwait	(3) RGF neutralized	(1) Iraqi National Command Authority neutralized	(4a) Ballistic missile capability neutralized	(4b) NBC capability neutralized
no	no	no	0.01	0.02	0.01	0.01	0.15	0.04	0.12
no	no	yes	0.04	0.02	0.05	0.01	0.15	0.04	0.12
no	yes	no	0.05	0.11	0.05	0.29	0.35	0.09	0.28
yes	no	no	0.04	0.78	0.20	0.71	0.64	0.91	0.34
no	yes	yes	0.35	0.11	0.30	0.29	0.35	0.09	0.28
yes	no	yes	0.52	0.78	0.86	0.71	0.64	0.91	0.34
yes	yes	no	0.33	0.95	0.55	0.90	0.84	0.96	0.65
yes	yes	yes	0.94	0.95	0.98	0.90	0.84	0.96	0.65

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DYNAMIC BEHAVIOR - INITIAL HI LEVEL MODEL

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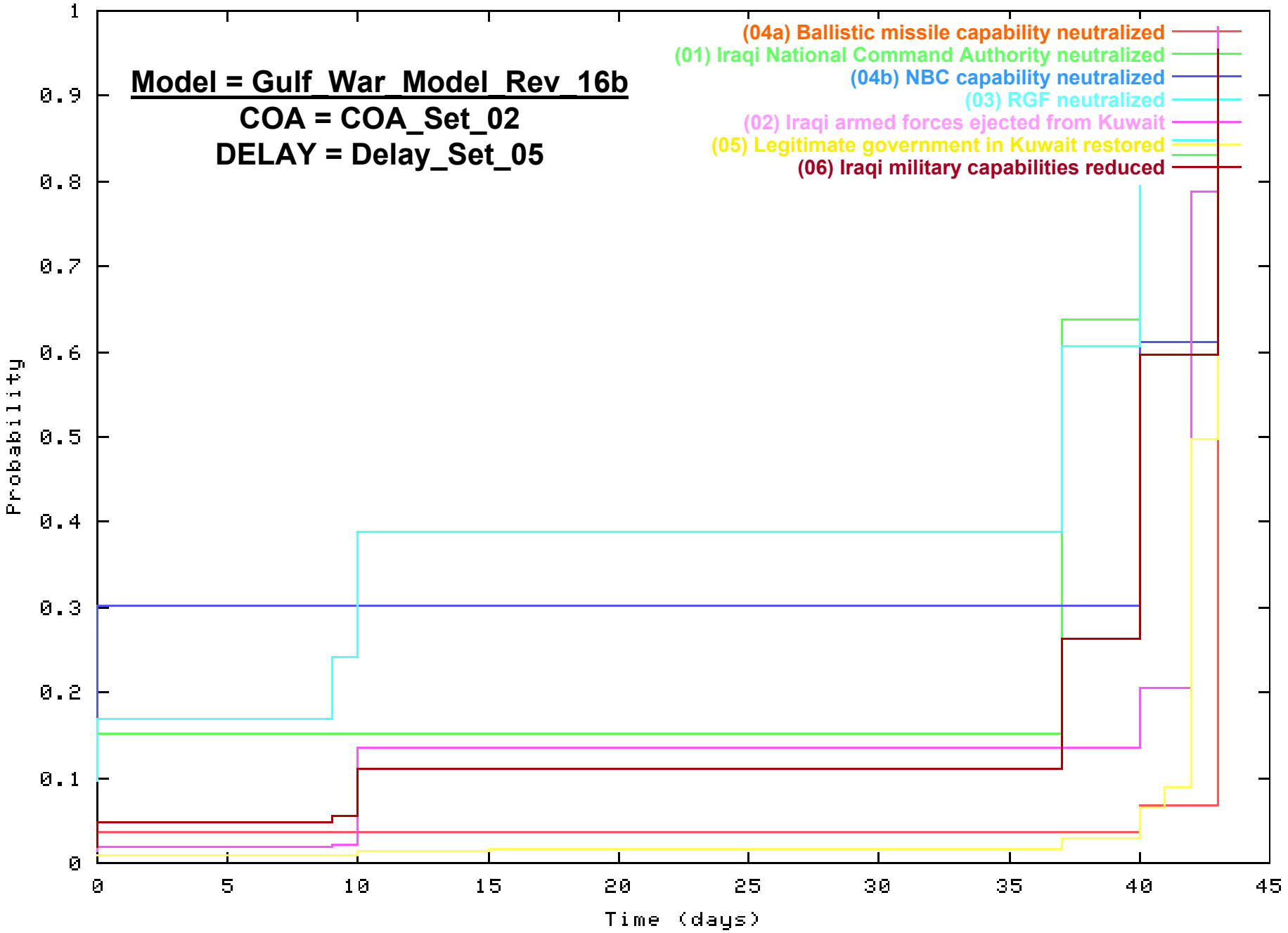
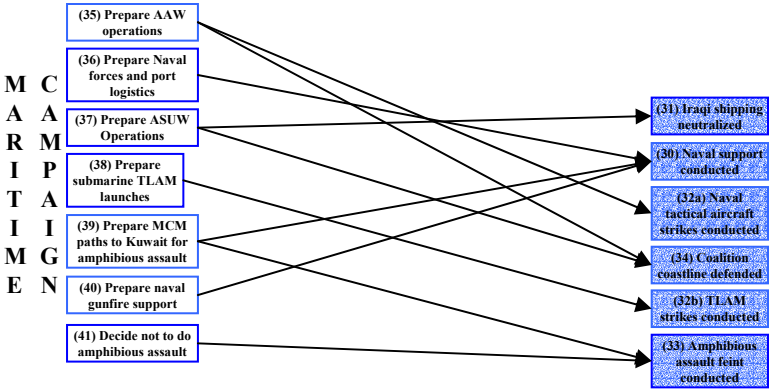
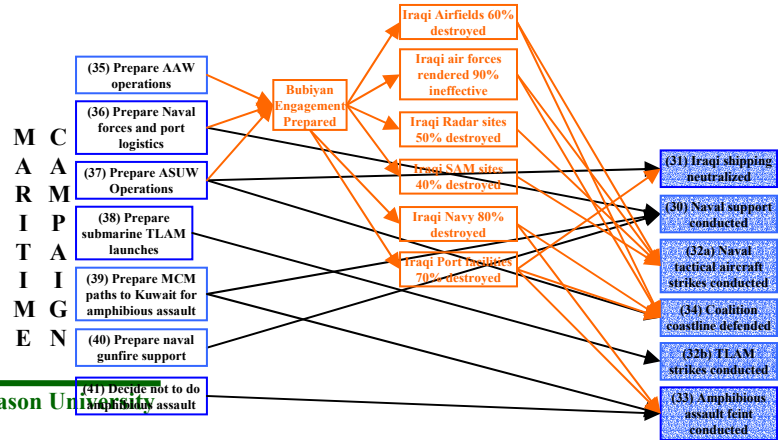
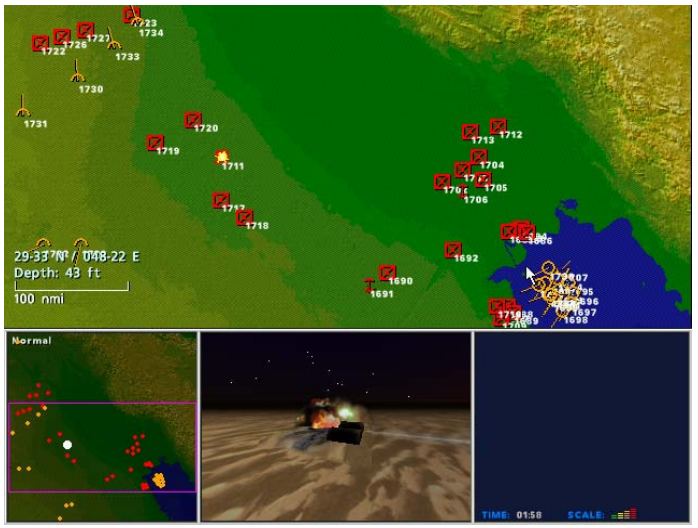


INTEGRATING ATTRITION MODEL

- Identified specific tactical engagements within the campaigns (from the Final Report to Congress) for modeling with physics-based simulations
- Used a modified version of *Jane's® Fleet Command*™ [modified by Raytheon]







INTEGRATING ATTRITION MODEL

- The attrition-based model provides quantitative measures of effectiveness (% killed) of the engagement participants versus time.
  - Thus, the effect(s) of the attrition model are events that reflect achievement in progress for the neutralization of adversarial participants.
- Such events became the vehicle for interfacing information from the lower level to the Hi Level EB model
- Several engagements were run in the attrition-based model and used to enhance the Hi Level EB Model
  - Additional structure added
  - Time delays refined
- The enhancements to the Hi Level model did not effect its basic behavior, but provided a more detailed description of intermediate events that could be examined

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ENHANCED HI LEVEL MODEL

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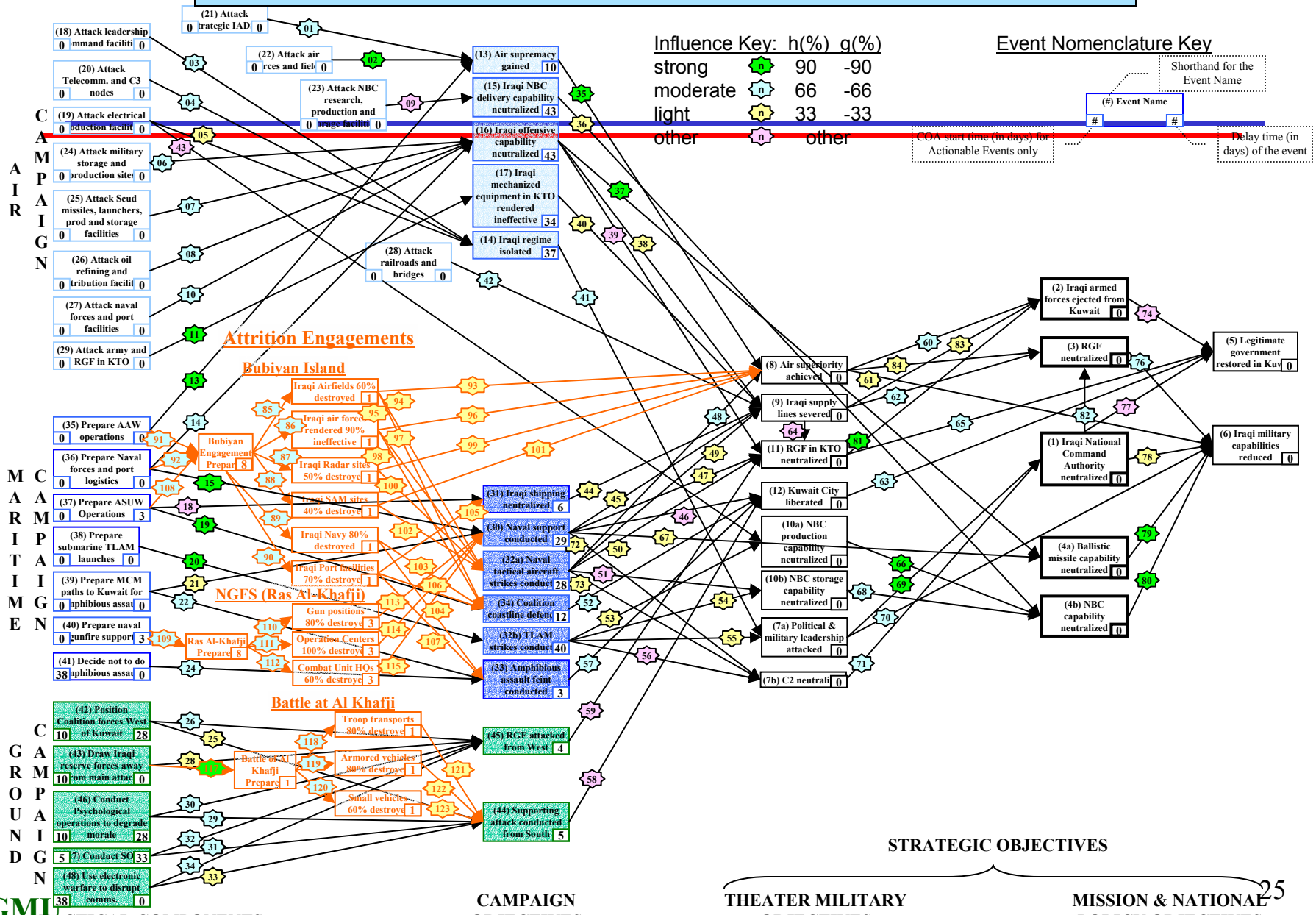

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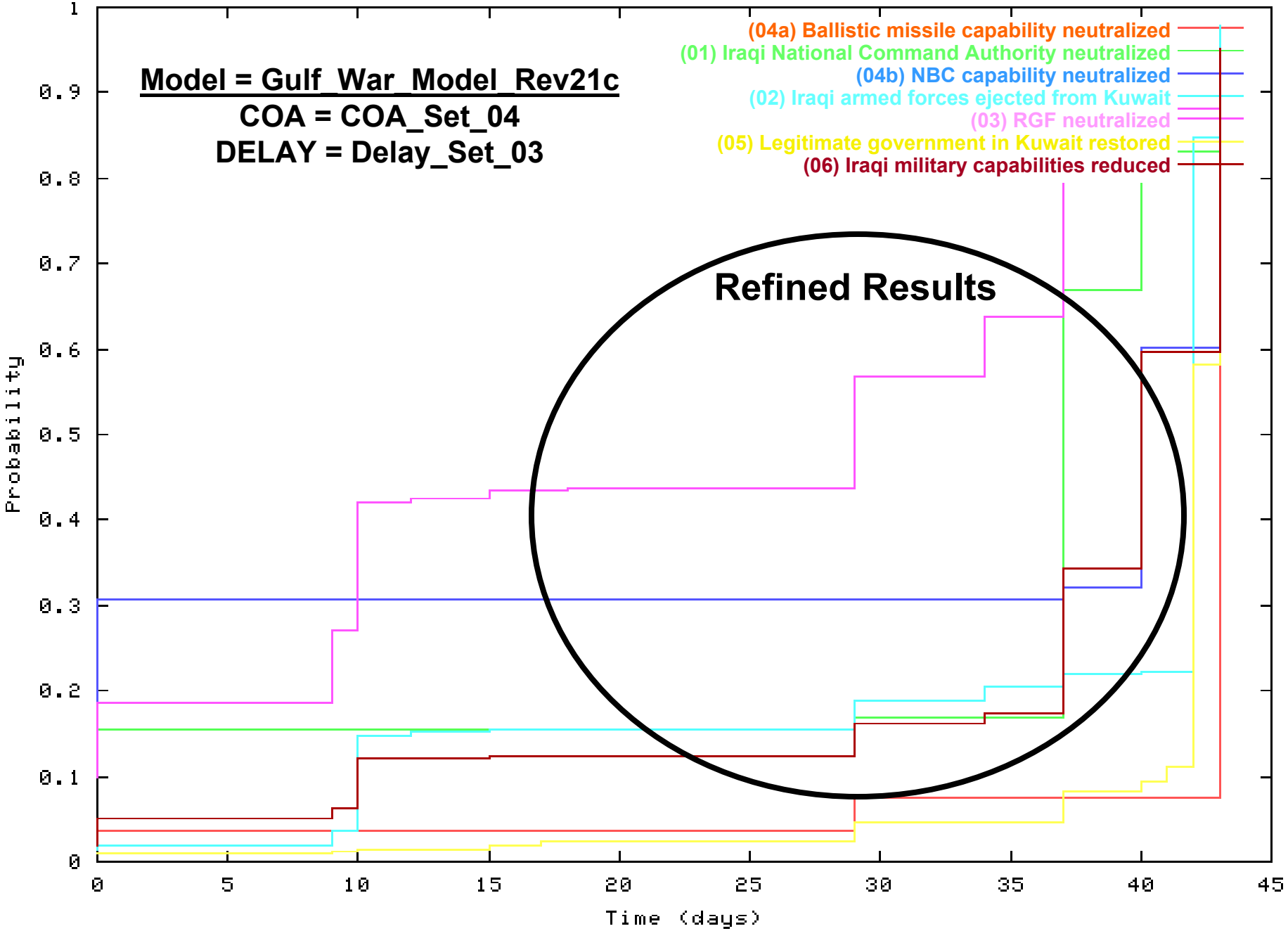
Model = Gulf_War_Model_Rev21c
COA = COA_Set_04
DELAY = Delay_Set_03
(04a) Ballistic missile capability neutralized
(01) Iraqi National Command Authority neutralized
(04b) NBC capability neutralized
(02) Iraqi armed forces ejected from Kuwait
(03) RGF neutralized
(05) Legitimate government in Kuwait restored
(06) Iraqi military capabilities reduced
Refined Results
Probability
Time (days)
0
0.1
0.2
0.3
0.4
0.5
0.6
0.7
0.8
0.9
1
0
5
10
15
20
25
30
35
40
45

CONCLUSIONS

- Using a case study approach we explored a process for relating a high-level effects-based model with detailed attrition-based models
  - Attrition models can provide a more detailed look at actionable events that are created in the high-level EBO model and can help planners refine the courses of action selected from analysis of the EBO model
  - Attrition models can help refine the structure and the conditional probability and time parameters EB model (increases the confidence in the EB model)
- Creating the interfaces was labor intensive; no "automated" technique for linking the two types of models was discovered
- Some preliminary "rules of thumb" were postulated for creating new structure in the EB model as a result of the analysis of the attrition model
- More research should yield a more efficient approach to establishing the ties between hi level effects based models and the higher fidelity attrition models