New Effects-Based Operations Models in War Games

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OVERVIEW

- Purpose: to describe new approaches for using an effects based modeling tool (CAESAR II/EB) for supporting Effects Based Operations
- CAESAR II/EB (Effects Based) Basics
  - Process
  - Influence nets
  - Colored Petri Nets
- Four modeling techniques explored
  - A model of Chem/Bio attack
  - A model to test the backward propagation capability
  - An indications and warning model
  - Model support to assessment
- Lessons and conclusions being evaluated
- Future Directions and Conclusions

PROBLEM STATEMENT

- In order to carry out effects-based operations, we need:
  - To identify desired effects
  - To identify actionable events and relate them to the effects (establish a cause-effect relationship)
  - To develop strategies that maximize the probability of achieving the desired affects over time
  - To be able to measure the degree to which we are achieving the desired effects as we execute our plans

- The integration of four key methodologies
  - Influence nets, a form of Bayesian nets
  - Colored Petri Nets (Discrete event dynamical models)
  - Temporal Logic
  - Modeling and Simulation

  provides a feasible approach

EBO PROBLEMS

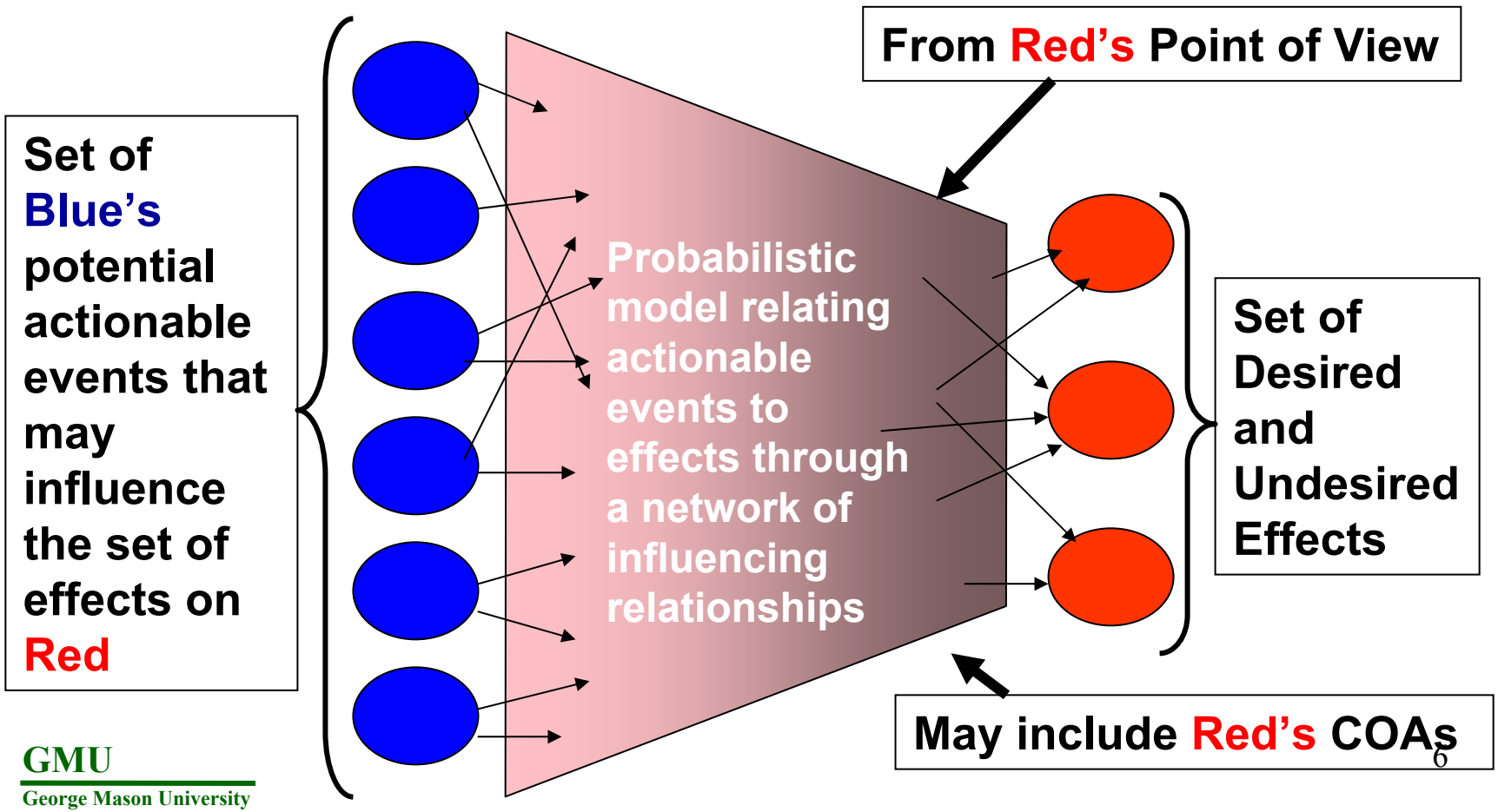
- **EBO Problem**: Relating Effects (desired and un-desired) to Actionable Events through cause-effect relationships
- **COA Problem**: Selecting, sequencing, and timing actions that will achieve the desired effects and suppress the un-desired effects in a timely manner
- **ISR Problem**: Determining the indicators of effects and determining what and when to look for those indicators
- **Evaluation Problem**: Determining metrics by which MOPs and MOEs can be formulated so that COAs can be compared
- **Execution Assessment Problem**: As plans that implement selected COAs unfold and ISR provides status of indicators, calculate the degree of success and determine if changes should be made to COAs

TECHNICAL APPROACH

- CAESAR II/EB is a research tool for developing and evaluating Courses of Action (COAs) by creating dynamic models of situations
  - It is based on the integration of two modeling formalisms
    - Influence nets, a form of Bayesian networks
    - Colored Petri Nets (Discrete event dynamical models)
  - It allows evaluation of sets of actions and how they impact desired effects and undesired consequences
  - It provides visualization of the impact of the timing and synchronization of actions on outcomes
- How to incorporate this type of tool in existing C2 processes to support EBO is an active area of research being address by experimentation in war games

INFLUENCE NET MODELS

- Relate actionable events by Blue to effects from the point of view of Red



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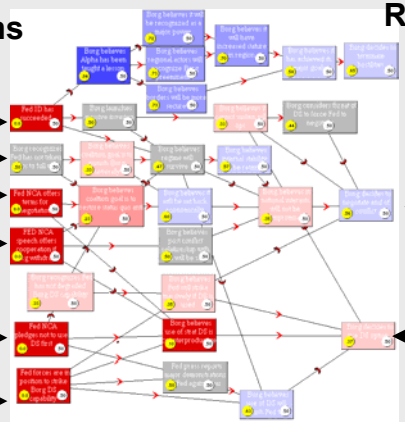
CAEASR II/EB PROCEDURE

STATIC ANALYSIS

Lead to

Blue Actions

Red Decisions

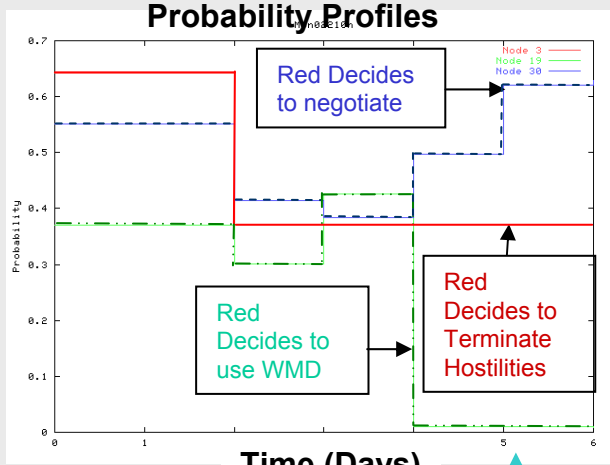


Influence Net

Text file

Best Set of Actions

TEMPORAL ANLYSIS

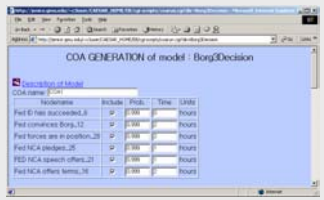


Sequence and Timing of Actions

When to task ISR

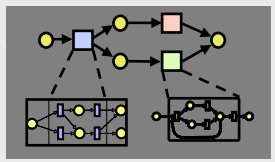
When effects may occur

Time windows of Risk

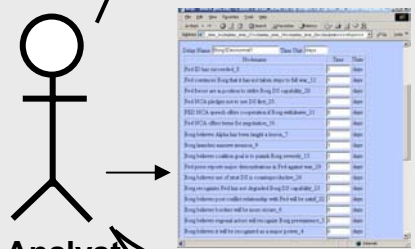


COAs (actions with times)

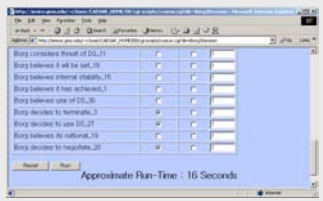
EXECUTABLE



Stored Probability Profile for COAs



Analyst



Time Delays

Nodes for Display of Probability profile

COA Comparison Probability profiles

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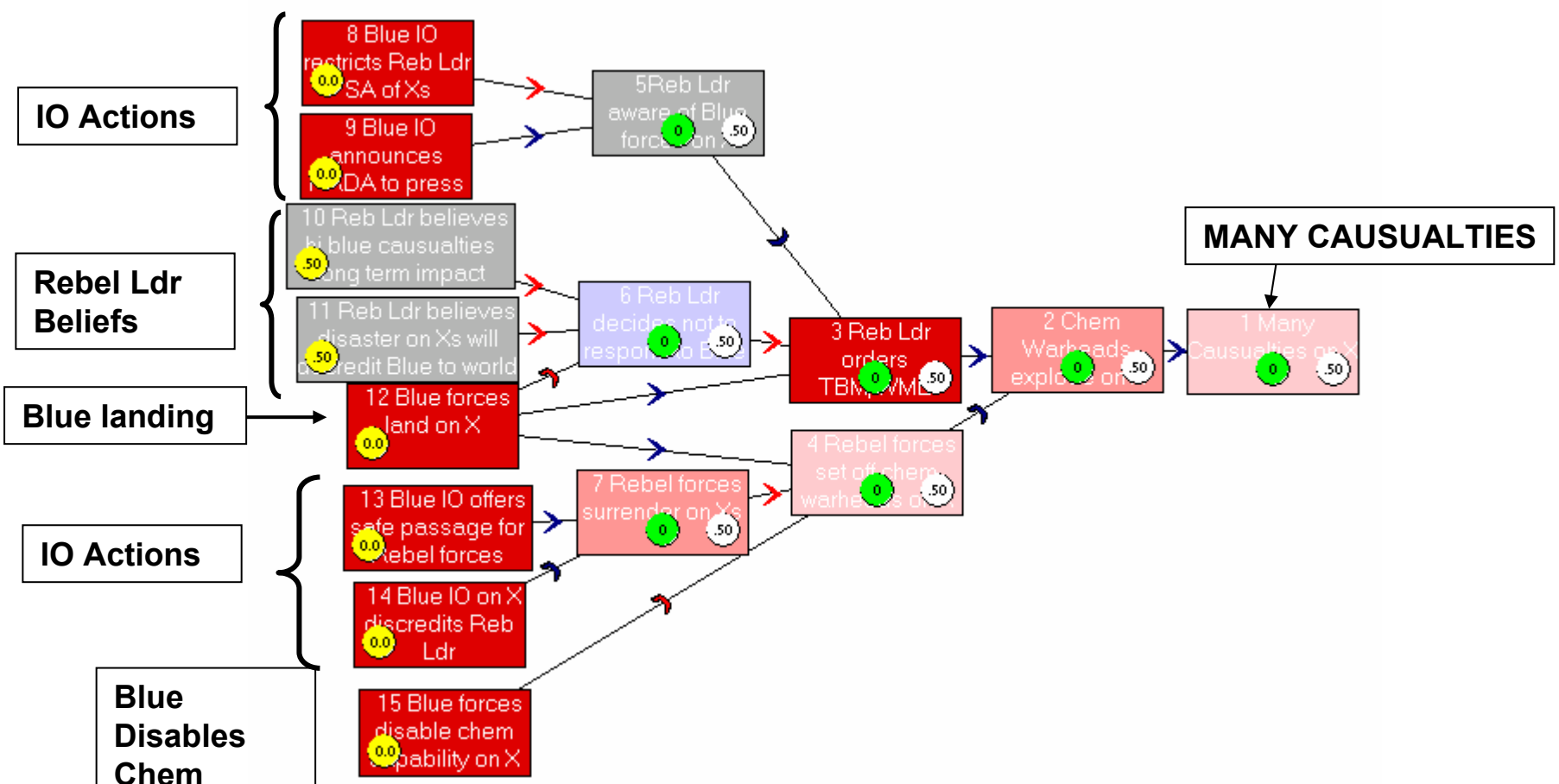
CASE STUDY 1: CHEMICAL WMD

- Scenario
  - Rebel force occupy a territory, may possess WMD
  - Blue mission is to land forces and cause rebels to surrender
  - Rebel leader may authorize the use of WMD
    - Believes he can cause high blue casualties
    - May be willing to cause many civilian casualties
- Model assumptions
  - If chemical weapons are set off, the potential for many civilian and military casualties is high
  - Two ways for chemical discharge: TBM with Chem launch by Rebels and release of Chem agents by Rebel forces on islands
    - Rebel leader must be aware of the activities on the islands including the landing of Blue and decide it is in his best interest to launch
    - Rebel forces could decide to set off or release chem agents if Blue force land on the island and if they have not decided to surrender.
  - Overall effect: There are many casualties (need to keep probability low)
  - Actionable events include IO and landing operations

CAESAR II/EB INFLUENCE NET



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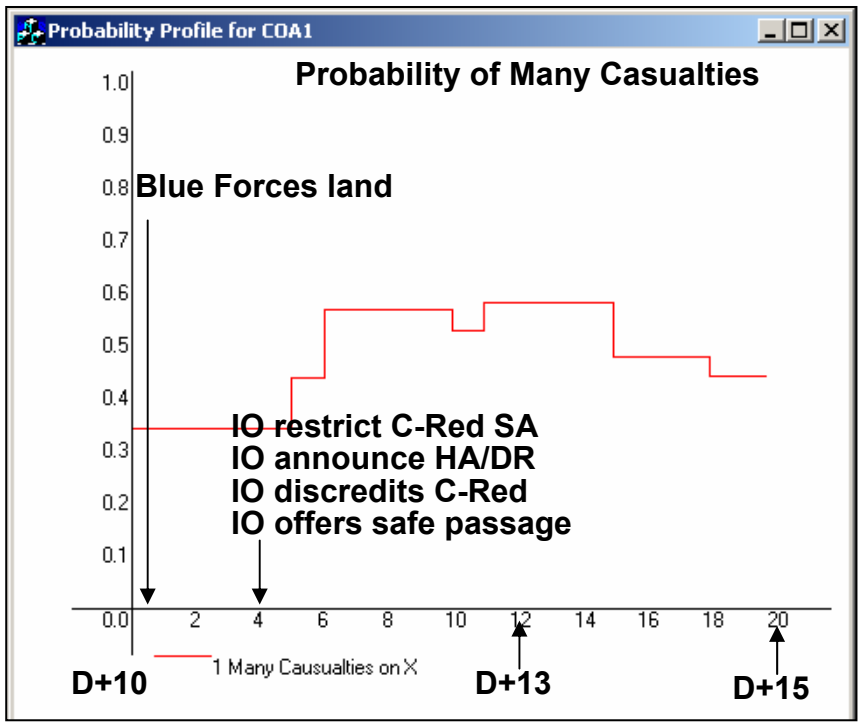
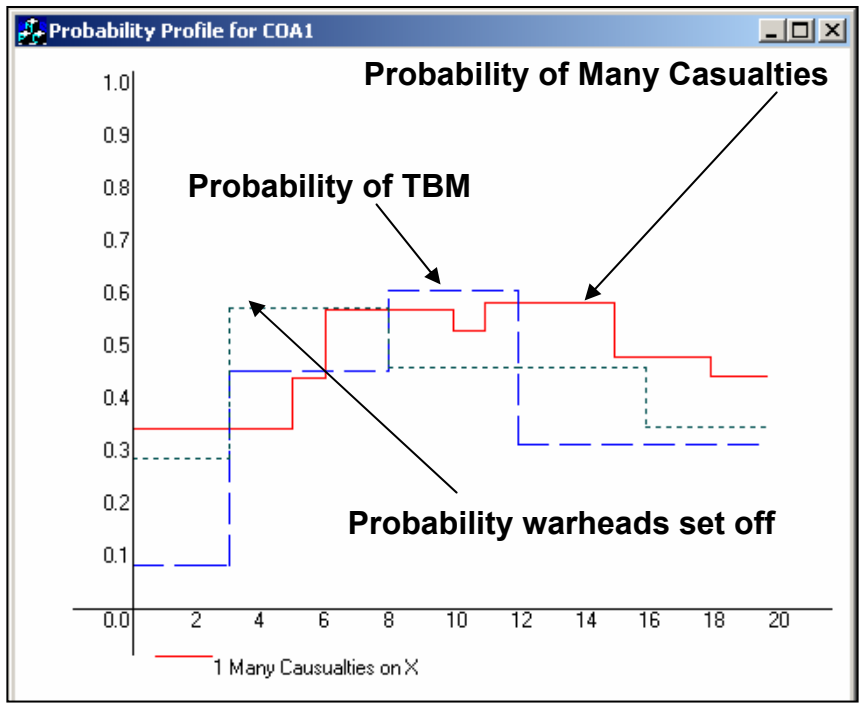
TEMPORAL ANALYSIS OF COAs

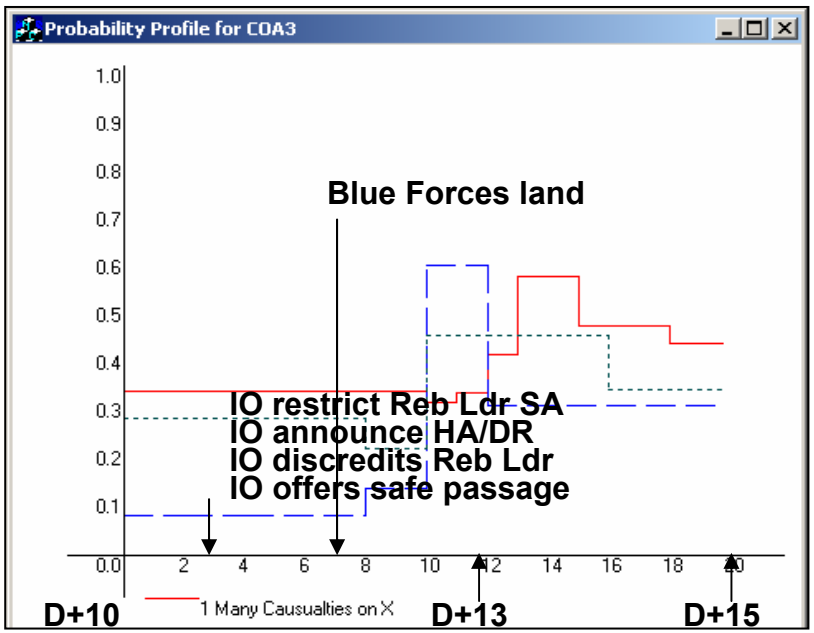
- Five timed sequences of the actionable events (COAs) were analyzed to see the impact of the timing on the probability of the effects.
- COA 1 was based on the Blue Force landing taking place on D+10 and the IO actions taking place simultaneously on D+11
  - Results in a 3 day time window of high probability of casualties due to chem release
- COA 2, 3, and 4 delay the landing until D+ 11, 12, and 13 which reduces the time window of vulnerability
- Best COA contains the early use of IO to restrict the Rebel leader's situational awareness and discredit him with his forces while it delays the announcement of the HA/DR (that may tip off the rebels) until just before the landing at D+13. Result is elimination of the window of vulnerability
- Further analysis shows that Blue must react quickly once it lands to disable the chem systems to minimize the time they are available for release by the Rebel forces.

ANALYSIS OF COA 1

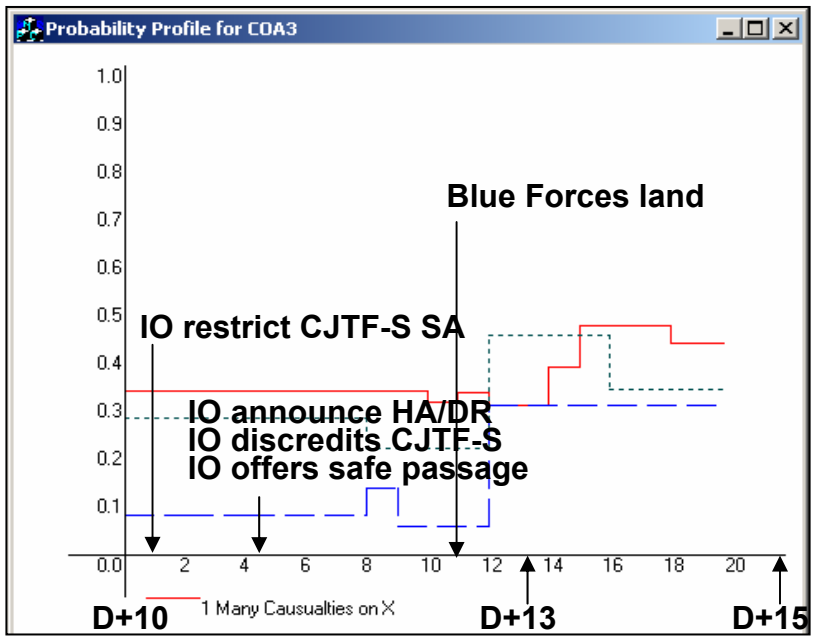




COAs 3 AND 4
EARLY SA RESTRICTION; DELAYED LANDING

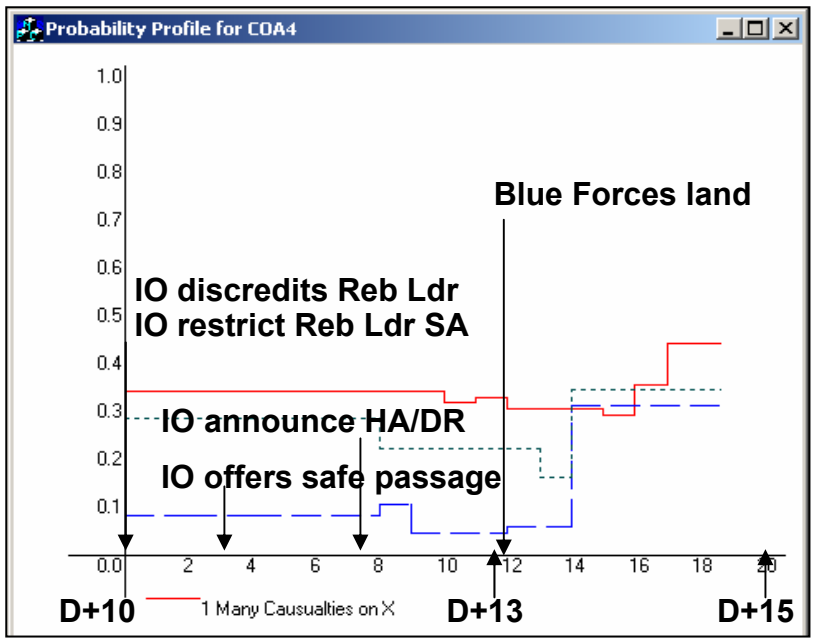


COA 3



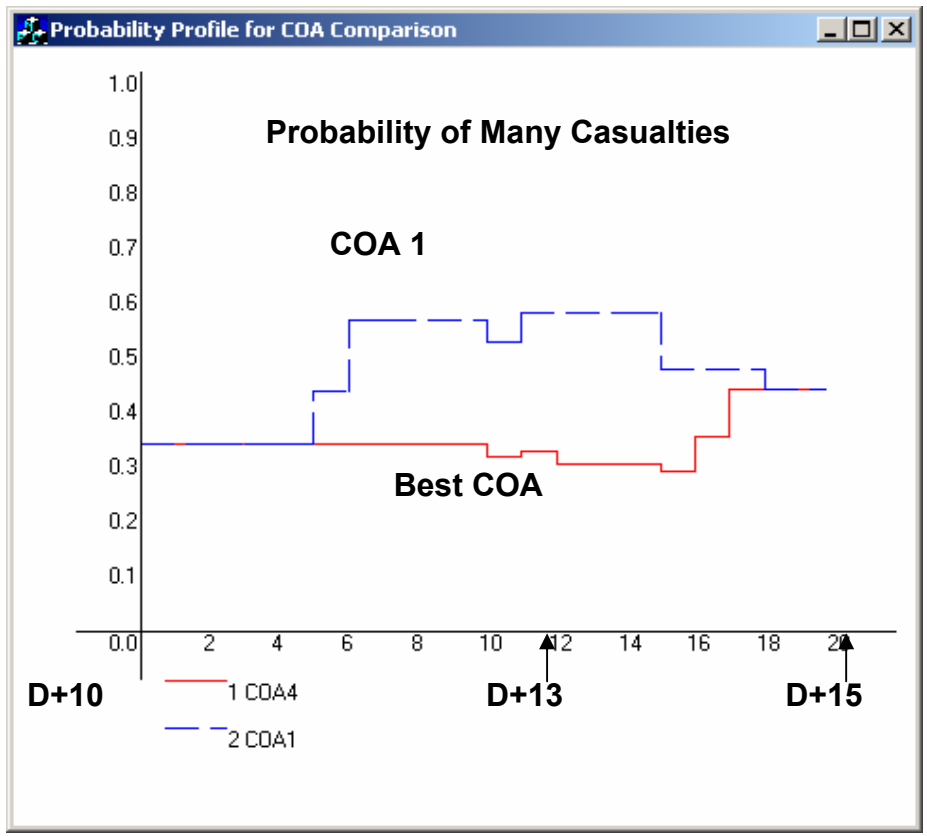
COA 4

"BEST" COA (5)
(Delay HA/DR Announcement, Landing at D+13)



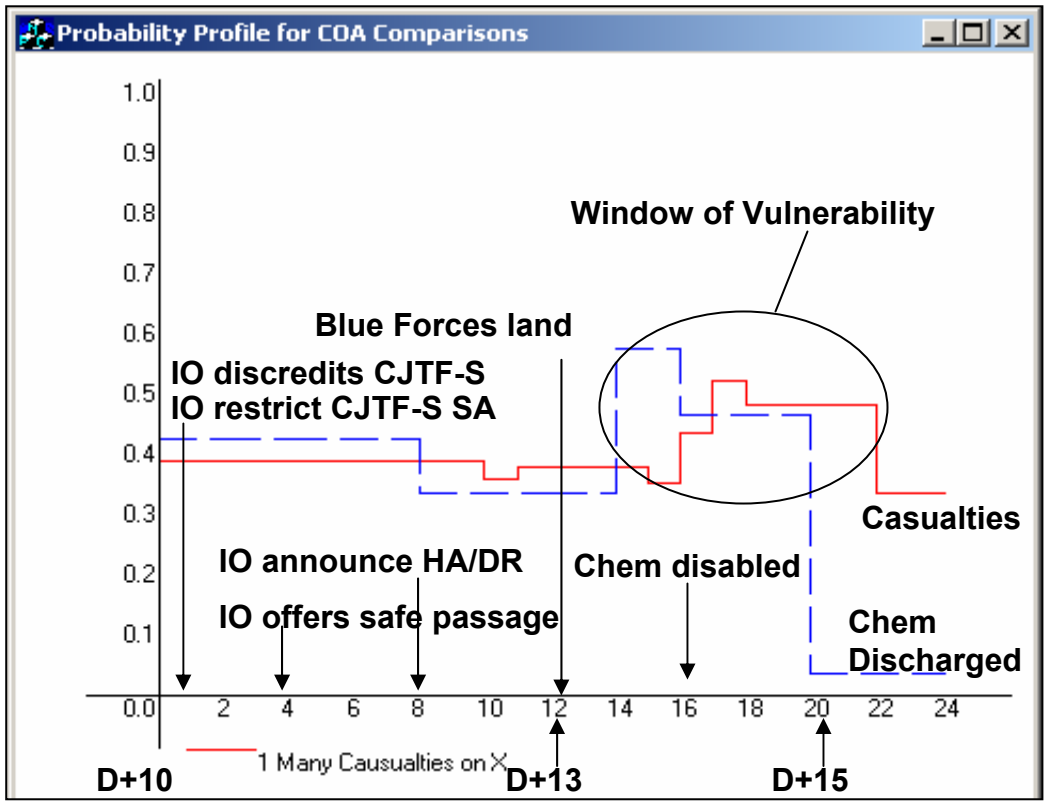
- COA timing reduces probability of TBM attack and dispersal of chem by forces on islands (no significant window of vulnerability
- Actions to disarm chem on islands should be undertaken

COMPARISON OF COA 1 TO BEST



Best COA eliminates window of vulnerability

COA 5 with Chem Disablement



Assuming it takes 24 hours from the time Blue lands on the island until the chem is disabled, there is a short window of vulnerability

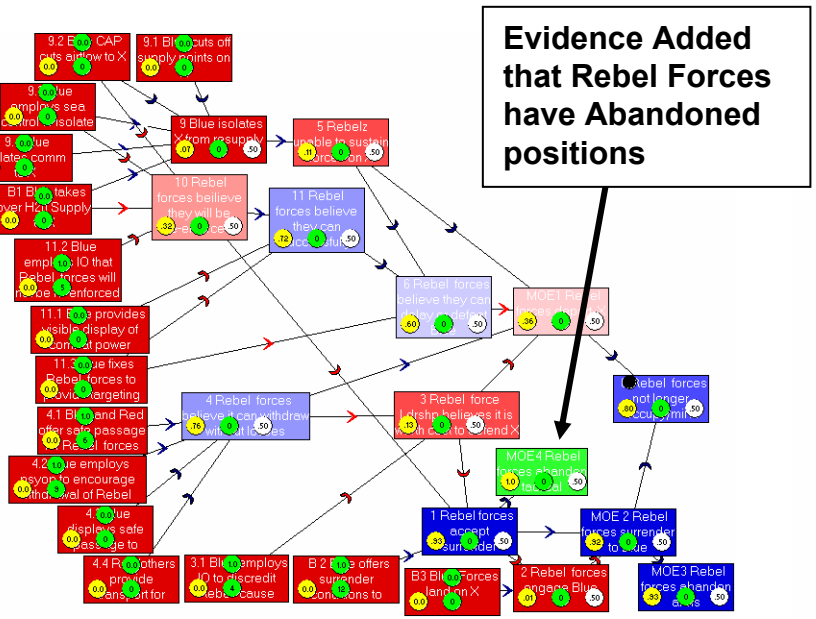
Shortening this time reduces the window

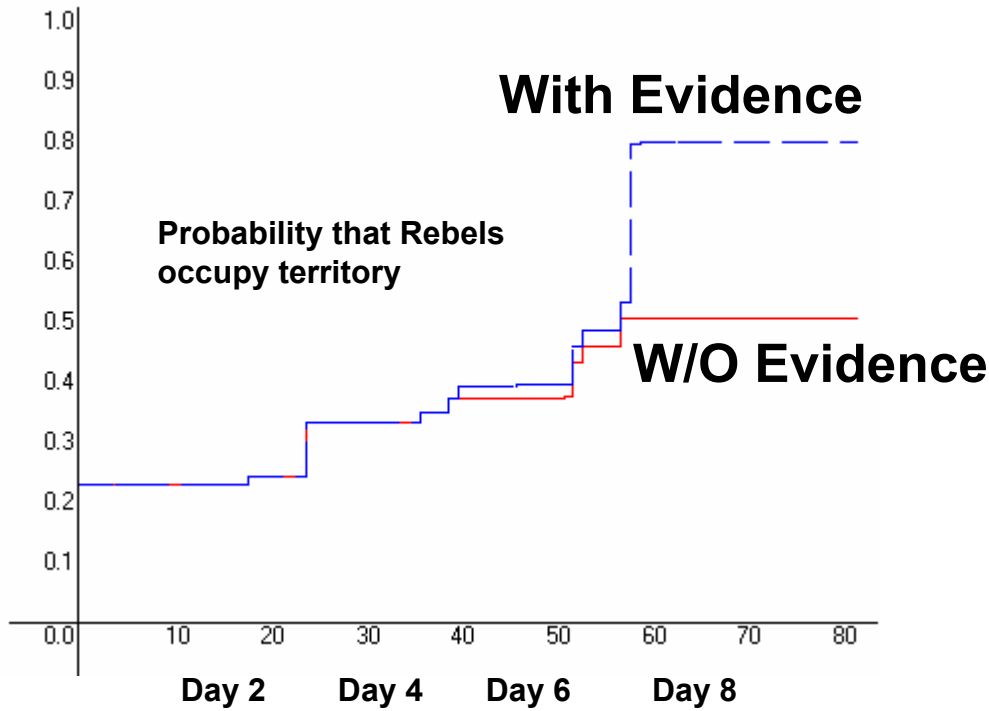
CASE 2: Incorporating Evidence from ISR

- Given that a plan exists and it is being executed:
  - Blue begins to receive observations from the battlespace
    - Observations: Evidence on pre-conceived direct indicators
    - Observations: Evidence on indirect indicators
- What does this evidence tells us about the changing probabilities of achieving the desired events?
  - Static view of the problem
  - Dynamic view of the problem
- Critical issues:
  - Multiple parents of a node
  - Temporal unfolding (or roll back)
- Requires a forward and backward propagation algorithm to infer updated probabilities of occurrence of upstream nodes (parents) *and the times they occurred* and propagates forward to re-evaluate probability of achieving effects

CASE 2: Adding Evidence

- **Backward Propagation Test**
  - **Partial COA executed**

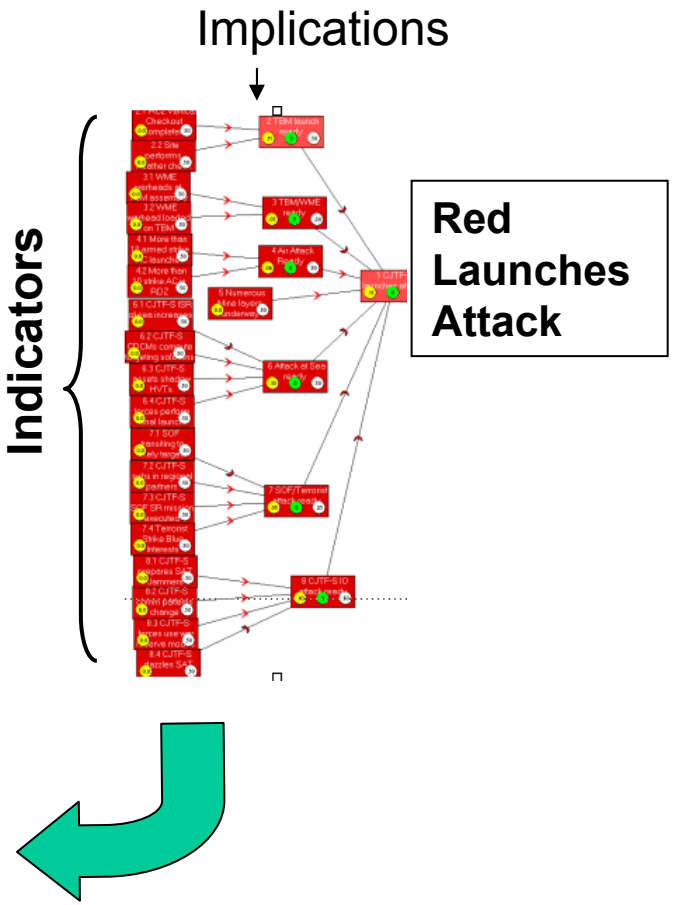


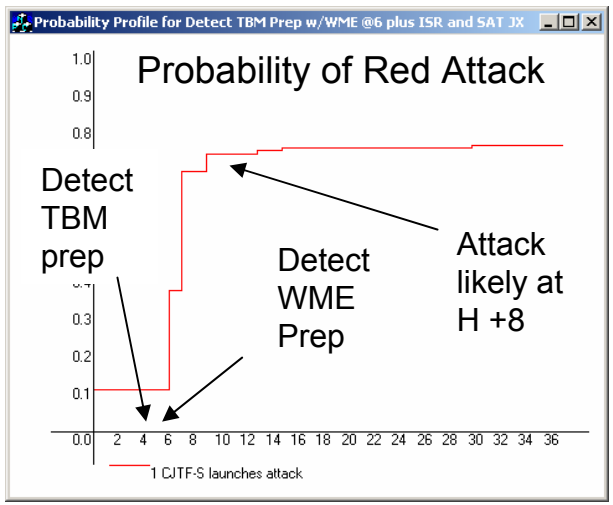


- **Evidence indicates that COA is succeeding**
- **May not need to carryout all actions of COA**

CASE 3: Indications and Warning Approach

- **Build influence net model that relates indicators to probability of (red) attack.**
- **Add time delay estimates from time of indication to the time of (red) attack.**
- **Position ISR to look for indicators**
- **Indication can be input to the model**
  - **Temporal analysis gives estimate of time of attack**





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CASE 3: Indications and Warning

- Figure 1: Initial indirect indications occur between hours 2 and 10; probability of attack increasing
- Figure 2: New indicator at time = 12 further increases likelihood of attack to 50% by time = 18
- Figure 3: Critical indicator at time = 13 warns that probability of attack by time = 17 is high

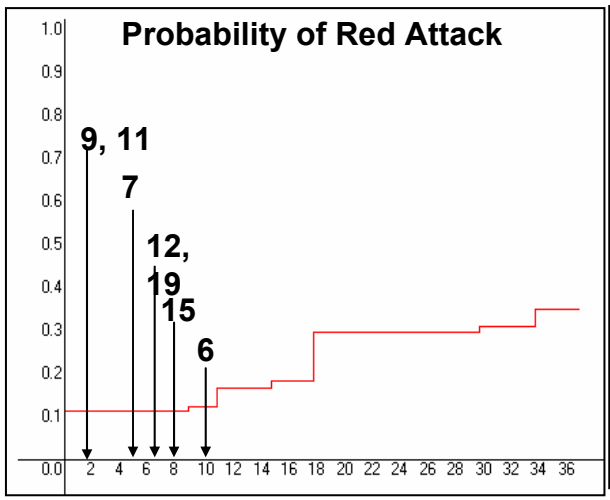

Figure 1: t = 10

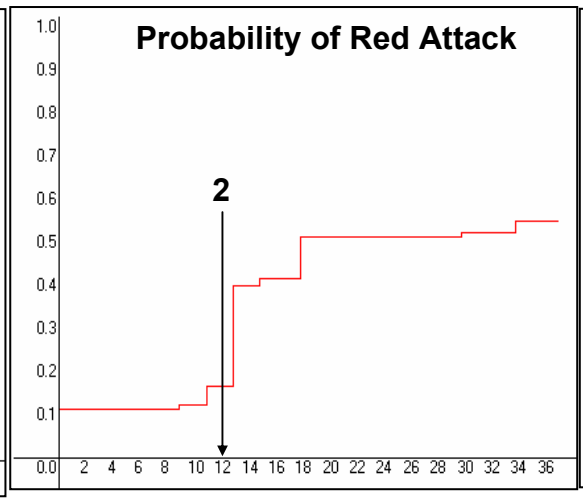

Figure 2: t = 12

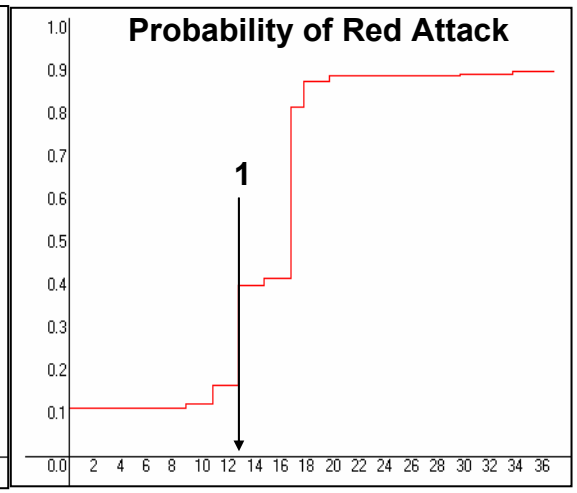

Figure 3: t = 13

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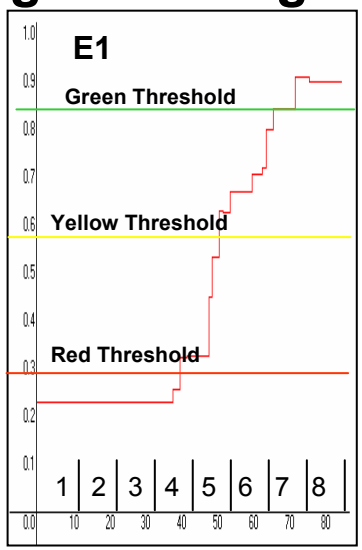
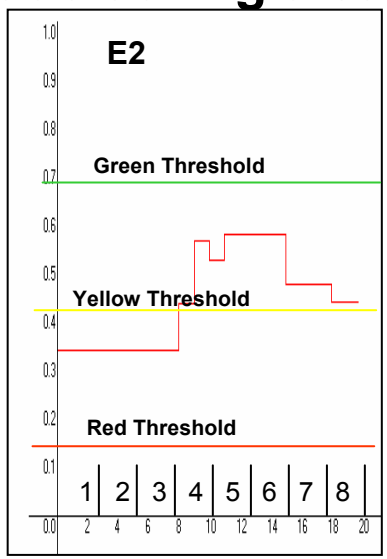
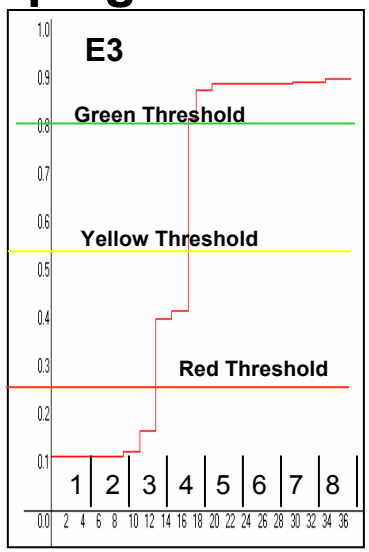
CASE 4: EBO Model Driven Assessment

- Forward Look is a key desire of Commanders
- Effects Based Models could be used to provide a visualization of the potential progress being made during a campaign
- Thresholds applied to Effect Based Models for each effect
- Summary of Campaign provided in Matrix







MODELS

Summary Matrix

Effect	Trend	1	2	3	4	5	6	7	8
E1 Rebels no longer occupy X	↑	●	●	●	X	X	X	X	X
E2 WMD has been secured	↔	●	●	●	X	X	X	X	X
E3 Effect 3	↑	●	●	●	X	X	X	X	X

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CONCLUSIONS

- Participation in Wargames and Experiments has provided a valuable opportunity to discover new uses of EBO technology in realistic environments
- The uses we have described in this paper span the spectrum from indications and warning, COA development and selection, the inclusion of evidence from ISR to reduce uncertainty in the COA model, to overall assessment of multiple effects.
- Perhaps the largest challenge ahead is to develop a cadre of analysts within the operational community who can quickly create these types of models. Members of that cadre should be made available at multiple echelons of the command and control structure. These cadre could continuously coordinate the develop and maintenance of there models as they support the planning, execution and assessment process.