



Pythia

WEB ENABLED TIMED INFLUENCE NET MODELING TOOL

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Adversary Behavioral Modeling
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- *Pythia* 1.5 (what is it?)
- Background
- Influence Net Description
- Process for Course of Action Analysis
- *Pythia* capabilities
- Conclusion

- Timed Influence Net Modeling and Analysis tool
- Developed with support from ONR, AFOSR, and AFRL (and initially with support from AFIWC)
- Enables analysts to create executable (probabilistic) models that link potential actions (elements of a COA) to effects based on knowledge about the environment
- Captures **the rationale** for COAs that explain how actions can achieve effects
 - Given a set of actionable events, determine the Courses of Action that maximize the achievement of desired effects as a function of time
- Pythia 1.5 has been created in both a stand-alone and a server based versions



- Visual Studio .NET platform
- C# as the programming language.
- The front end of the tool is designed with the help of AddFlow™, a Commercial-Off-The-Shelf (COTS) API.



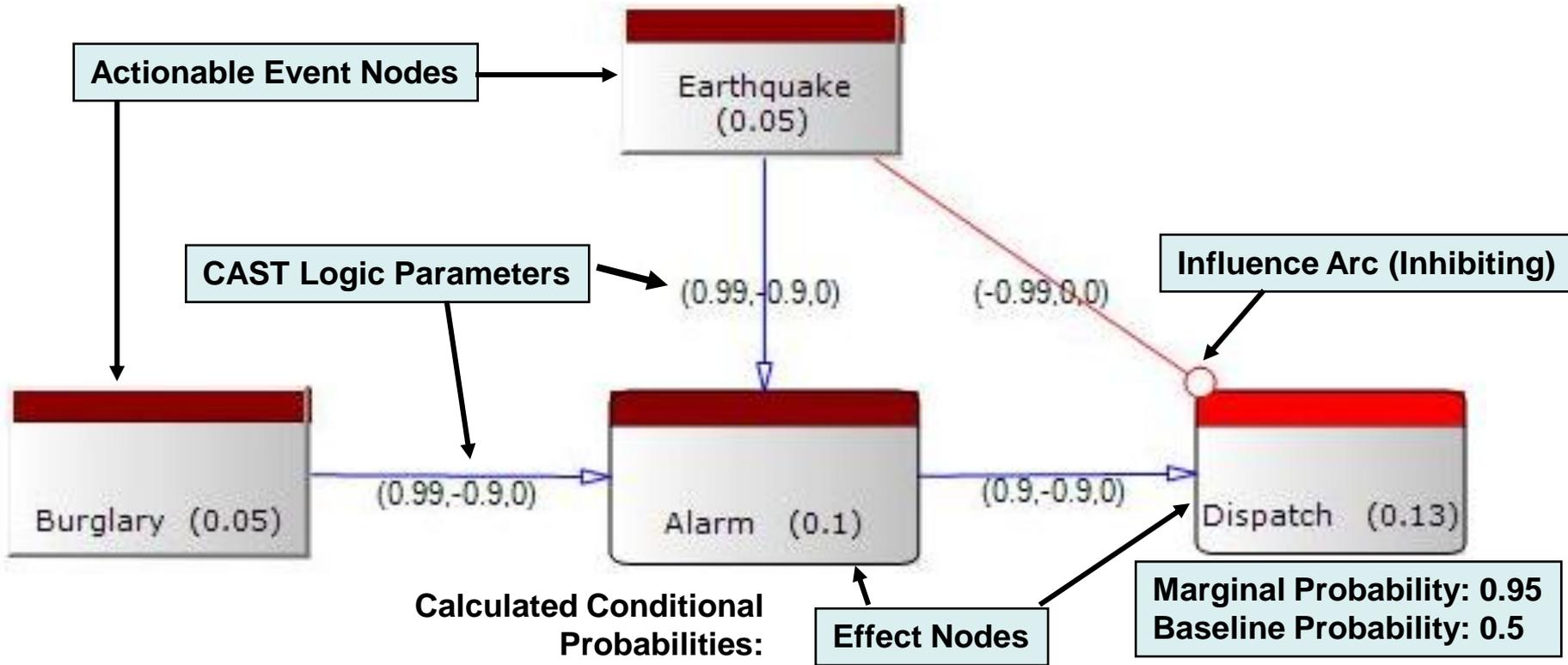
- After the first Gulf war, the Intelligence community needed modeling tools and techniques to determine approaches for influencing leaders such as Saddam Hussein, Milosevic, and others
- This gave rise (1994) to Influence net modeling, a variant of Bayesian nets. SAIC, supported by GMU, developed SIAM (Situational Influence Analysis Model) for DARPA; this has been used extensively by the Intelligence community as well as others
- SIAM is a static model that enables the representation of influences (causes) on a person's or organization's behavior. By stimulating selected influences, one tries to modify that entity's behavior
- The static influence net technology has evolved to an approach using a *dynamic model* that includes temporal information to determine Courses of Action for Effects-based Operations



- **Purpose: assess socio-political influence strategies**
- **Objective: extract empirical expertise and knowledge about adversaries and place it in an analytical framework.**
- **Tool designed toward five requirements**
 - **Model Based**
 - **Support Collaboration amongst domain experts**
 - **Support mathematically rigorous analysis such that actions could be compared against the effects those actions could influence**
 - **Be usable by analysts without the need to understand complex Bayesian mathematics or require large quantities of conditional probability values that may be difficult to obtain**
 - **Provide an intuitive understanding of the complex interaction of cause and effect relationships to decision makers who would compare and select courses of action based on the analysis**



- **Influence Nets (INs), an instance of the Bayesian framework, were proposed a decade ago to overcome the intractability issues present in BNs. They employ:**
 - **A non-probabilistic knowledge acquisition interface, termed as the CAST logic [Chang et al., 1994; Rosen and Smith, 1996].**
 - **an approximation inference algorithm**
- **The modeling of the causal relationships is accomplished by connecting a set of actionable events and a set of desired effects through chains of cause and effect relationships.**
 - **The strength of such relationships is specified using the CAST logic parameters instead of the probabilities. The required probabilities are internally generated by the CAST logic with the help of user-defined parameters.**



Calculated Conditional Probabilities:
 $P(A|\neg E, \neg B) = 0.005$
 $P(A|\neg E, B) = 0.950$
 $P(A|E, \neg B) = 0.950$
 $P(A|E, B) = 0.990$

- The marginal probability value of each effects node is computed with the help of its Conditional Probability Table (CPT) and the prior probabilities of its parents

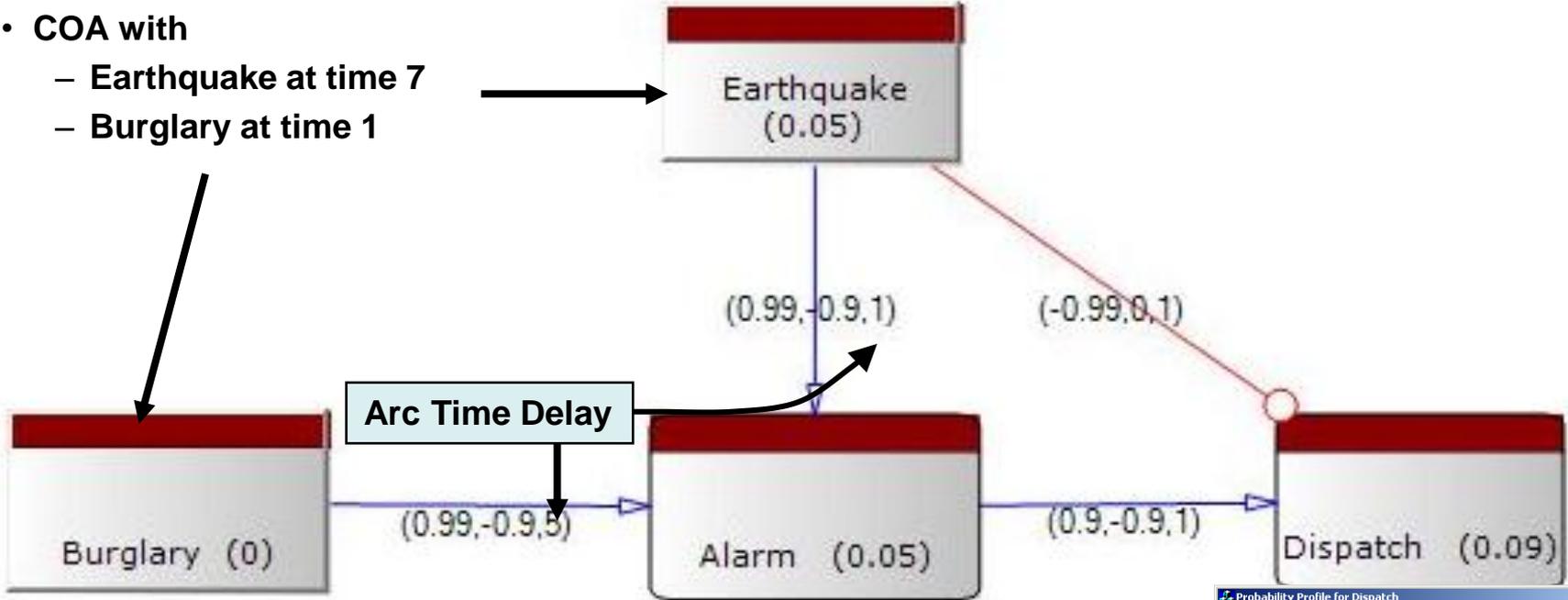


- **Extension of basic static influence net**
- **Models situations where the impact of events (actions or effects) takes some time to reach and be processed by the affected events or conditions**
- **The temporal constructs allow a system modeler to specify delays associated with nodes and arcs.**
 - **These delays may represent the information processing and communication delays present in a given situation.**
- **Time Stamps become associated with each node including the “input” nodes that represent potential actions (and when they will happen) within a course of action**
- **Any particular COA triggers a timed sequence of changes in the probability values of the effect nodes. The result can be represented graphically with what is called a probability profile.**

Timed Influence Nets

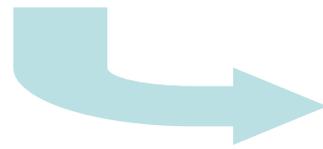
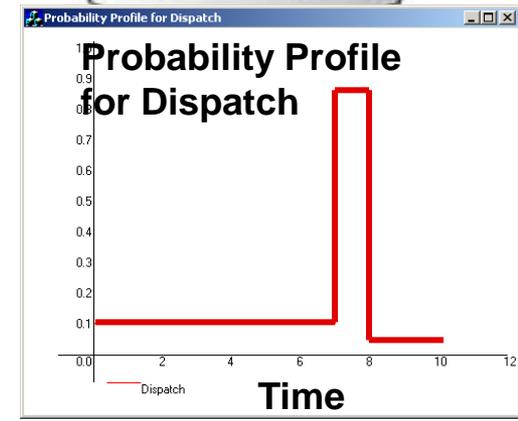


- COA with
 - Earthquake at time 7
 - Burglary at time 1



Arc Time Delay

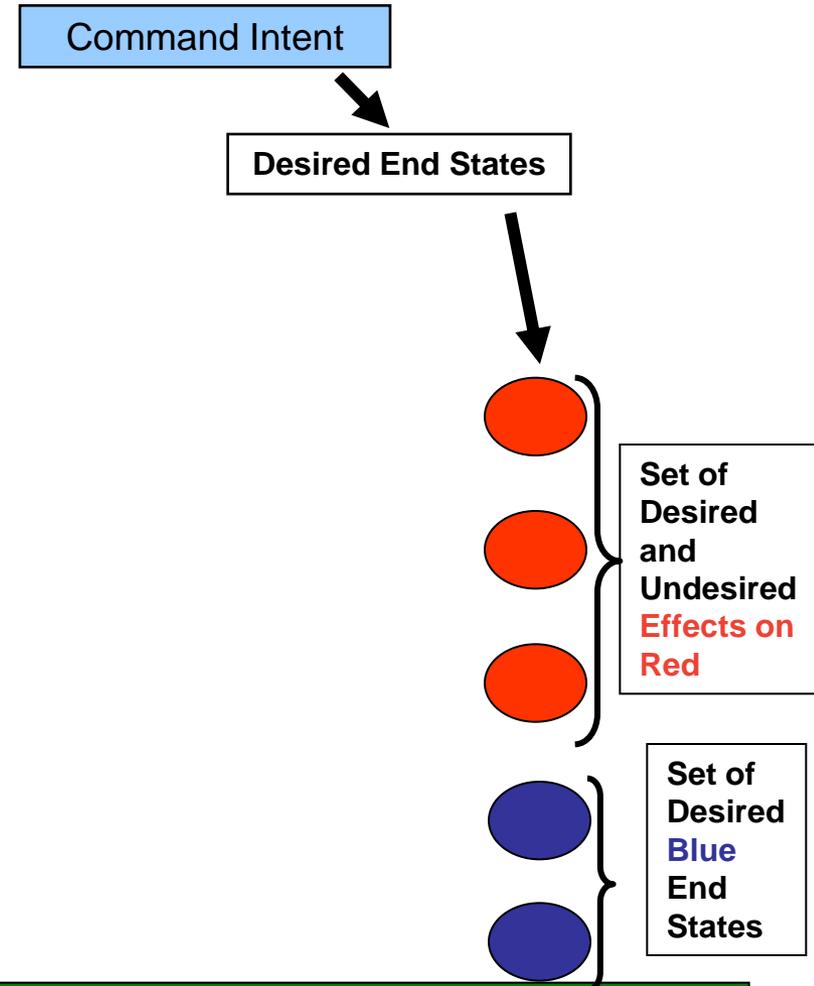
Node Time Delay = 0



Effects Based Modeling for COA Development



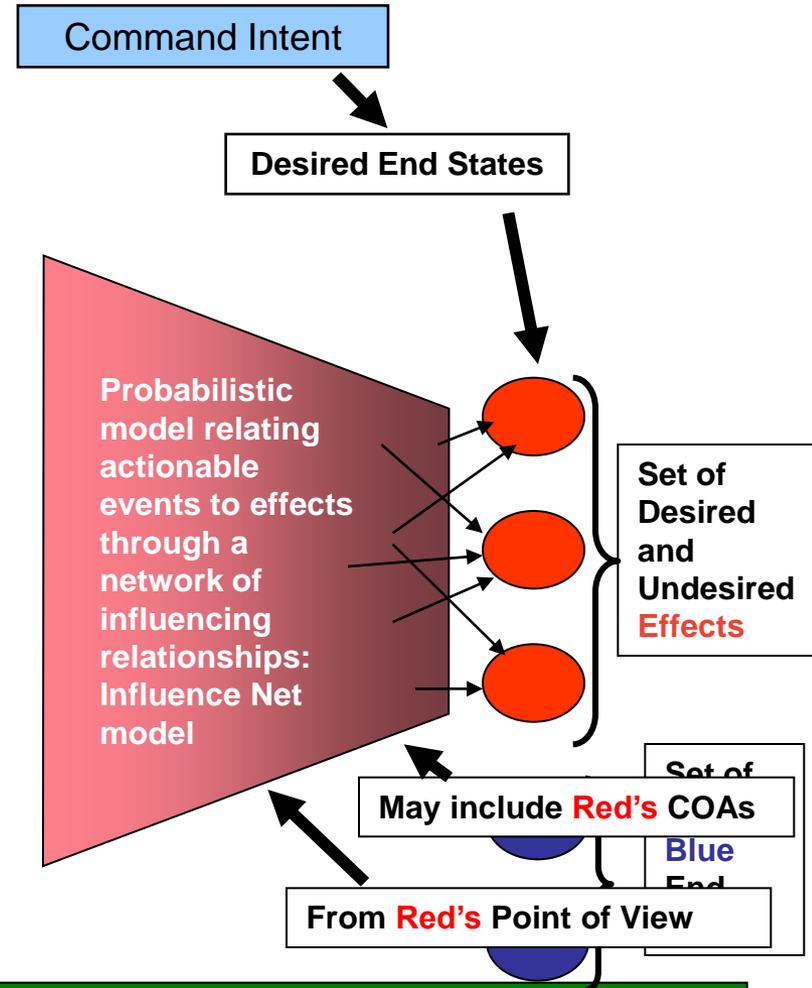
Actions ← **Model Construction** □ □ **Effects**



Effects Based Modeling for COA Development



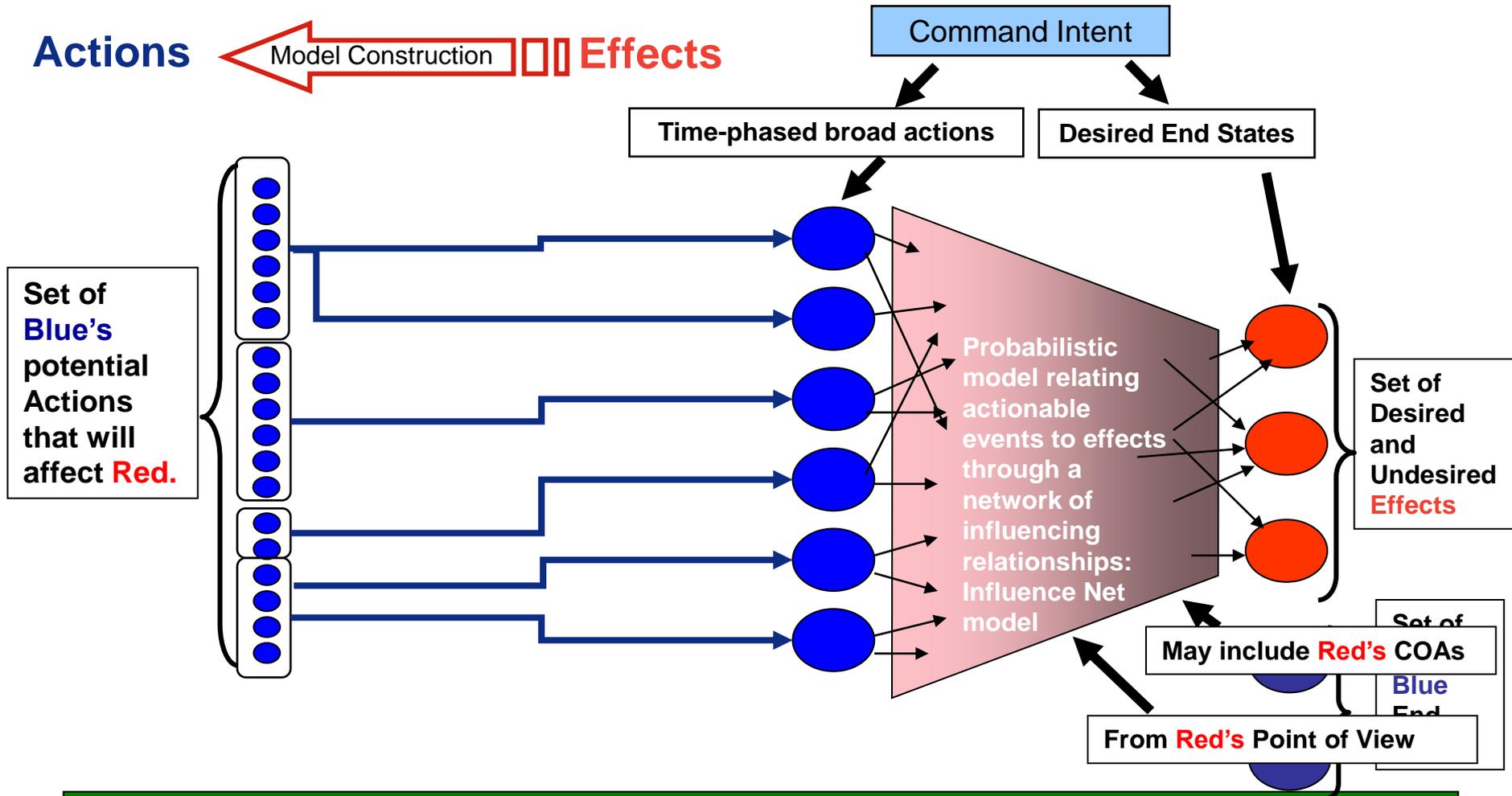
Actions



Effects Based Modeling for COA Development



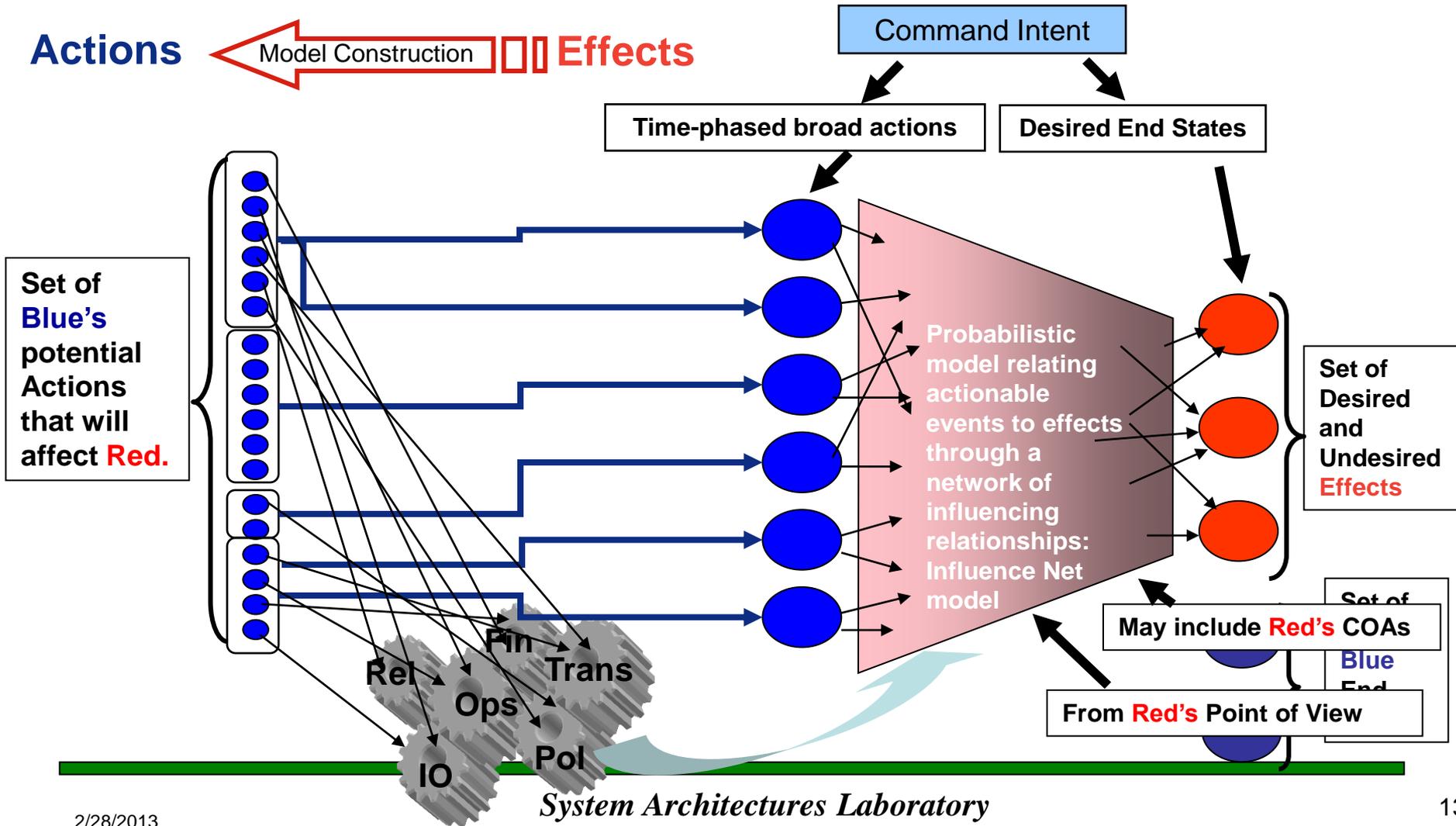
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Effects Based Modeling for COA Development



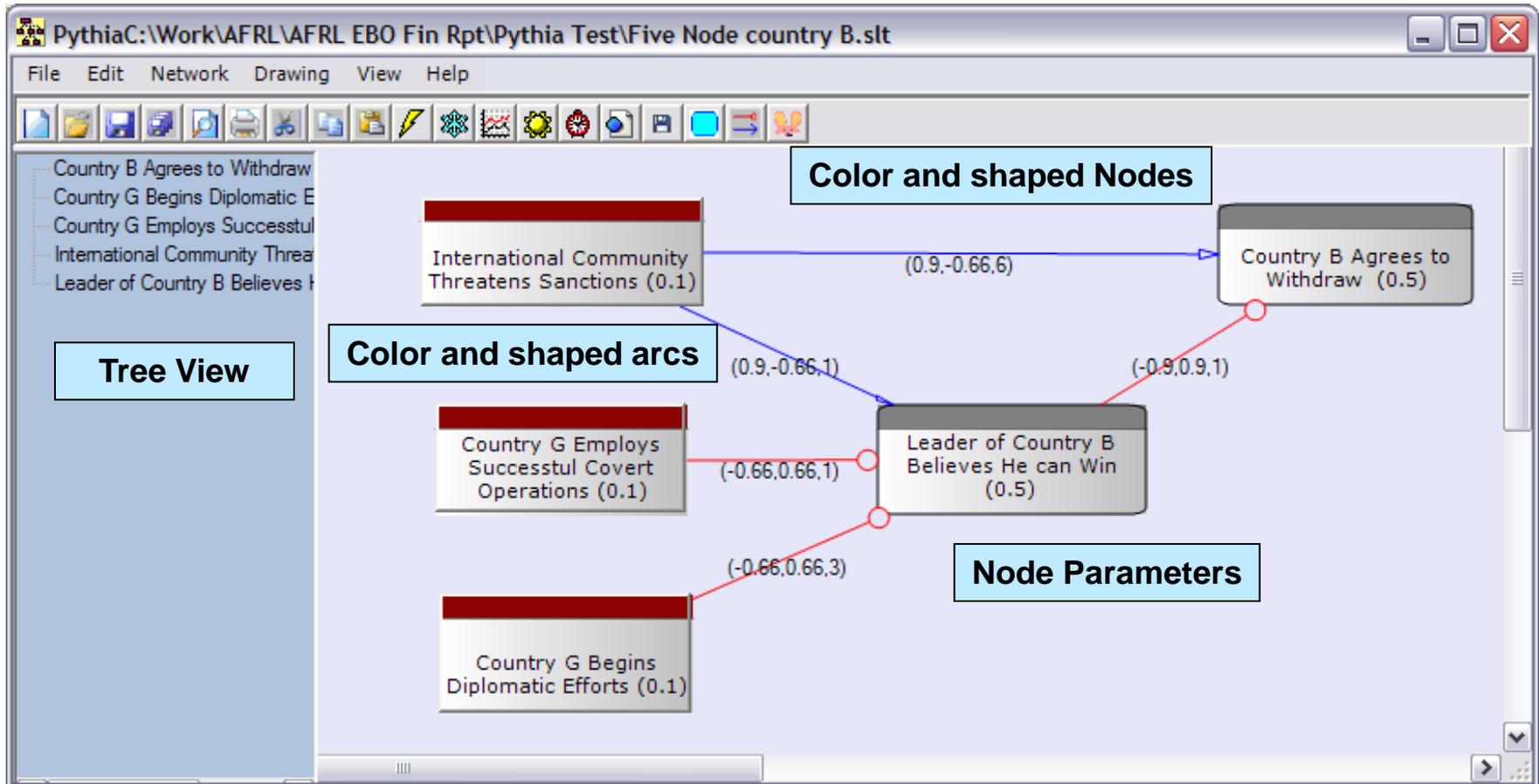
Actions



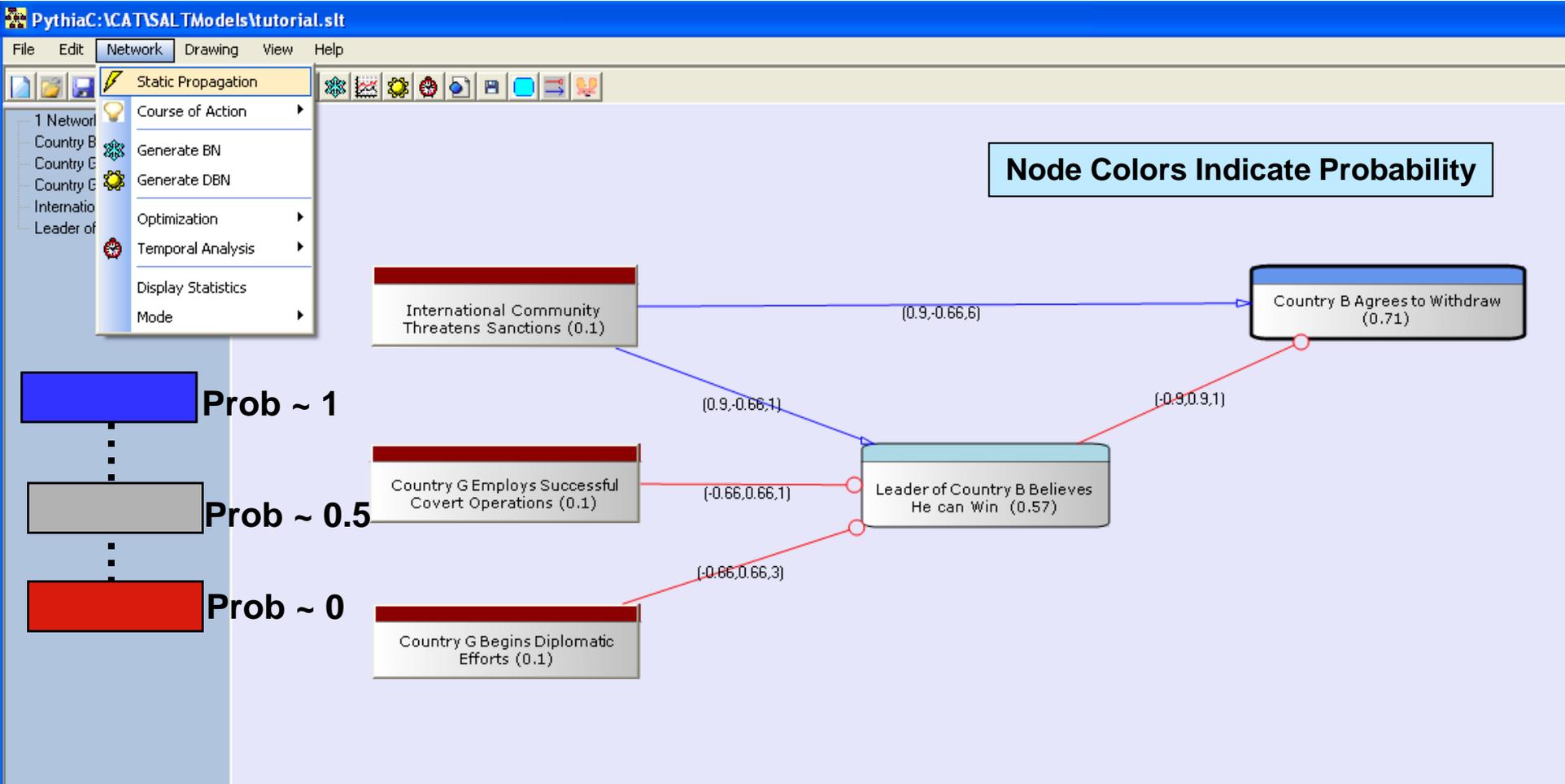
Effects Based Operations Modeling Approach



- The Effects Based Operations modeling approach starts with the definition of desirable Effects on the Adversary (Red) and *the desired end state of Blue*
- Then we work backwards (from right to left) to the Centers of Gravity of Red that influence the desired Effects – the arrows show the “Cause to Effect” relationships (left to right)
- Then we identify the Operational Functions of Red that affect the COGs, which in turn influence the Effect(s)
- We continue “unfolding” backwards in a “Cause to Effect” chain till we arrive at Actionable Events that can be carried out by Blue
- Finally, we include other external events, not controlled by Blue, that influence the achievement of the desired Effects on Red
- There are also “Cause to Effect” relationships that affect the *strength* of the influences (e.g., selected Information Operations)



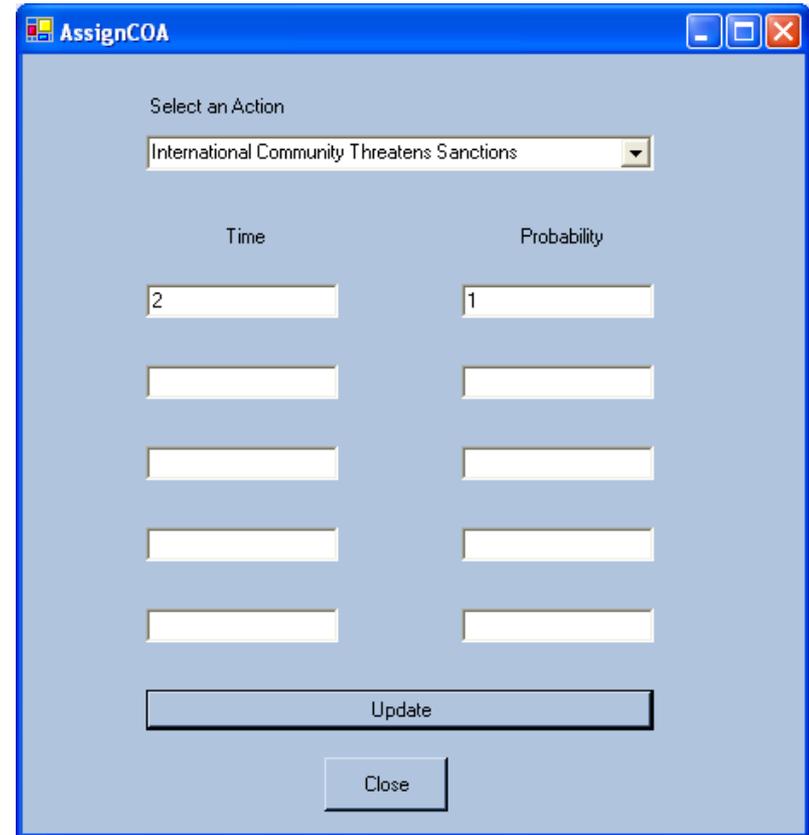
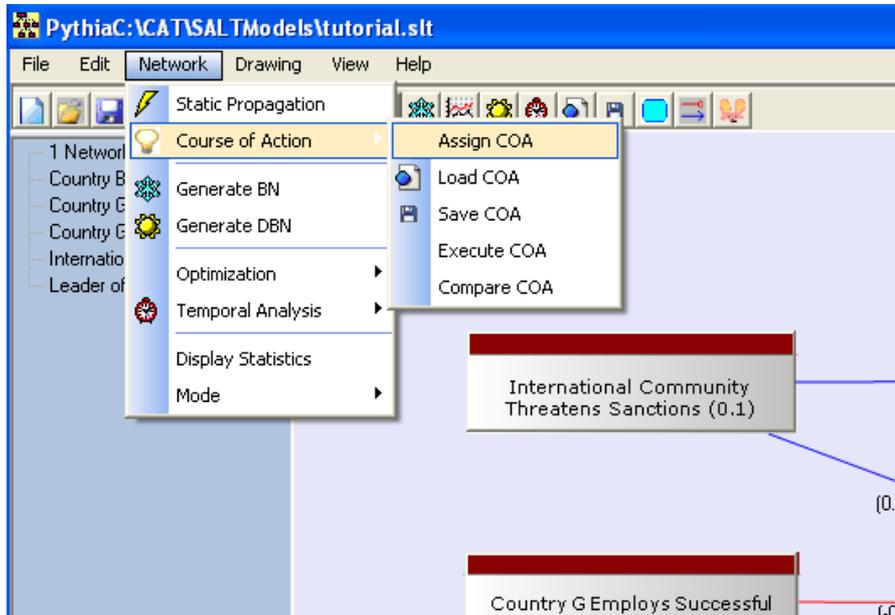
- Given the marginal probability of the nodes with no parents, the probability of the other nodes is...



Creating and Saving a COA

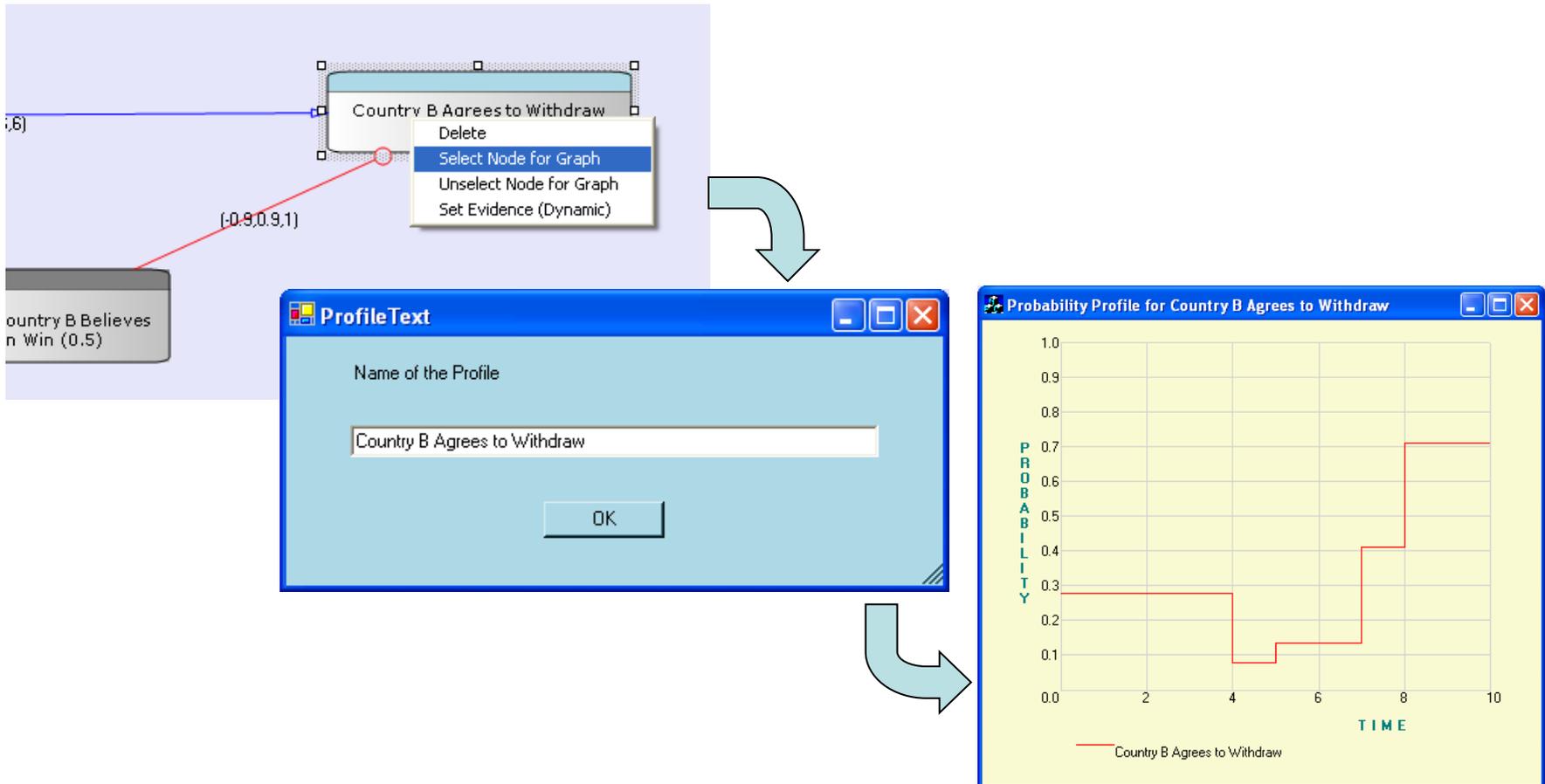


- Once an Influence Net has been upgraded to a Timed Influence Net by assigning positive values to some or all of the arc and node time delays, COAs can be created and analyzed



Notions of persistence of actions can be captured in the COA

- Once COA has been created, it can be evaluated by selecting the nodes for which probability profiles will be generated



- **Creating Influence Nets and Timed Influence Nets**
 - **Static Probability Propagation**
 - **Sensitivity Analysis**
 - **Set of Actions Finder (SAF)**
 - **Course of Action creation and saving**
 - **Probability Profile Generation**
 - **Course of Action Probability Profile Comparison**
 - **Evolutionary Algorithm for COA “optimization”**
 - **Temporal Analysis (Queries on what caused a change and what if analysis)**
 - **Conversion to Time-Sliced Bayesian Net for incorporation of evidence**
 - **Dynamic Influence Nets to model two types of Persistence.**
- Influence Net Analysis**
- Timed Influence Net Analysis**



- The EBO modeling approach is robust when considering the “Attack” aspects of a campaign – how to affect the adversary
- But, the current EBO modeling approach needs substantial further development to address the “Defend” aspects of a campaign:
 - How to prevent the adversary from achieving his effects and
 - *How to achieve Blue’s end state*
- Furthermore, since the EBO approach starts by considering the effects on the adversary, it is imperative that we model the adversary correctly
- This leads to the *Cultural Modeling of the Adversary* if we are to represent the cause to effect relationships reasonably correctly
- Consequently, personality and cultural modeling are becoming increasingly important



- **The Timed Influence Net technology and the Pythia tool for Course of Action Analysis provide a mechanism for modeling and analysis of the effects of actions on an adversary that is embedded in a society**
- **Such models represent knowledge created by humans using data and information contained the various sources and data bases to generate knowledge about the situation**
- **Pythia has been converted to a server version with a client so that it can be run remotely and be interfaced with other tools**
- **Recent research has relaxed the independence assumption without requiring more data input by the analyst**
- **The research issue is how these different tools (AutoMap, ORA, Dynet, Pythia, etc.) can be used in combination by analysts to provide better insight into the effects actions will have in an area of operation where the social and cultural factors have a major influence on outcomes**