

Capturing Adversarial Intent for Behavior Analysis

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Overview

- Say “Hello!”
- About Adversarial Modeling
- Adversary Intent
- Capturing Information – Bayesian Knowledge Bases
- An Intent Driven Approach
- Tools and Applications
- Conclusion

Adversarial Modeling

- Required in a multitude of domains when opponent actions/reactions/counteractions matter
 - Financial/Business Competition
 - Politics/Elections
 - Sports
 - Warfare/Conflict
 - Planning and Execution
 - Wargaming

Increased Demands on the Planning Paradigm

- Traditionally, Blue COAs are wargamed against the “**most likely / dangerous**” adversary COAs
 - Often a pre-scripted sequence of events independent of Blue actions
- Non-conventional adversaries seldom have capabilities that rival U.S. forces
 - Asymmetry of capabilities means differences in **intent**
- Assessment / re-assessment of friendly courses of action is currently limited by human capacity
- Need to model dynamic adversary behaviors that integrate with various intelligence and mission data sources (Modernized Integrated Database (MIDB), Air Operations Database (AODB), IPB Products, etc.)

Drivers of Adversarial Modeling

- Increasing limited conflict warfare necessitates **computational** adversarial modeling
 - Existing historical adversarial models not enough
- Effects based operations (EBO) and predictive battlespace awareness (PBA) require **understanding of adversary intent**
- Modern elements of military intelligence and decision making require forecasts/predictions of adversary force **actions and reactions** to provide a complete and realistic viewpoint

Goals for Using Adversarial Models

- Generate alternative futures in performing COA analysis
- Performing “what if” analysis of actions and reactions designed to visualize the flow of the battle and evaluate each COA
- Reduce the man-power intensive nature of modern planning and strategy assessment

Essential Adversary Characteristics

- Adversary dynamically changes and adapts
 - E.g., new capabilities are acquired/discovered while existing capabilities maybe interdicted/destroyed
- Little is known about the adversary before hand
 - **Uncertainty** and **incomplete information** about the adversary
 - Information about the adversary “unfolds”
- Understanding these high-level characteristics allows us to account for “pop-up” adversaries

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“If you know the enemy and know yourself, you need not fear the result of a hundred battles”

- *Sun Tzu circa 400 B.C.*

What do you need to know about the adversary?

- Things like:
 - Histories of responses and actions in different situations?
 - Social/Economic/Military/Political/Religious doctrine?
 - Infrastructure and reliability of leadership or command and control?
 - Perceptions about us (our force) or other groups?
 - Political and cultural factors?
- Might provide clues on their propensity for future actions?
- What do we really need?

What is Intent?

- **Intent inferencing**, or **user intent inferencing**, involves deducing an entity's goals based on observations of that entity's actions (Geddes, 1986)
 - Deduction involves the construction of one or more behavioral models that have been optimized to the entity's behavior patterns
 - Data/knowledge representing observations of an entity, the entity's actions, or the entity's environment (collectively called **observables**) are collected and delivered to the model(s)
 - Models attempt to match observables against patterns of behavior and derive inferred intent from those patterns
- Useful for generation of advice, definition of future information requirements, proactive aiding, or a host of other benefits (Bell et al., 2002; Santos, 2003)

What is Adversary Intent?

- What's the context of a Red action?
- What is the rationale behind the Red action?
- What are the causes and effects of the intended Red goal?
- What is the motivation behind a Red behaviour?
- What will happen next?
- Why did this behaviour occur?
- What does Red believe?

Accounting for Human Factors in Capturing Adversary's Intent

- Assymmetric adversaries – they are not like us; we do not think like them
- “What is rational” is not the same between different individuals or groups especially with different backgrounds.
- Differences in decision-making and behavior come from differences in background
 - Social
 - Cultural
 - Economic
 - Political
 - Psychological

Adversary Intent

- Intent is not just the plan or enemy course of action
- Not just “The enemy commander *intends* to launch his SAMs” or “The organization *intends* to undertake a suicide bombing”, but also **why??**
- **Intent** is the highest-level goal(s) the adversary is pursuing + the support for that goal + the plan to achieve it
- Need intent to **understand** and **anticipate** Red behavior
- Must model adversary based on their **perceptions** of the world

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Knowledge Representation

- What does knowledge look like?
- What are the semantics of knowledge?
- How do I work (reason) with it?
- Examples of knowledge?
 - A causes B
 - B occurred with probability p
 - A influences D and E
 - B was likely observed
 - C is the belief that A is a likely effect of B when B may have been observed to be the cause of D.

Objects and States

- Identify principle objects/components
- Determine object attributes
- Define attribute state/values
- Enforce state mutual exclusion

Semantics of Relationships

- How are objects related to each other?
 - Cause and Effect relationships
 - Capture only local relationships
 - Avoid extended indirect relationships
 - Don't interconnect everything!!

Interacting Relationships

- For example,
 - If A, then C is likely.
 - If B, then C is likely.
 - If A *and* B, then C is *very* likely.
- Localizing relationships implies that we must be able to derive indirect relationships
- Typically source of **anomalous** inferences

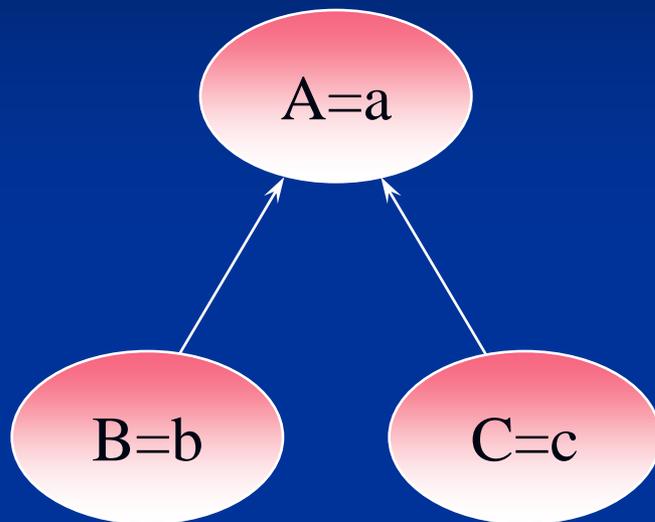
Uncertainty

- Arises from
 - Imprecise information
 - Incomplete information
 - Exceptions
 - Uncertainties in the domain

Graph-Based Modeling

- **Nodes** represent different discrete object/event states
- **Arcs** between two nodes represent *direct* relationships
 - Semantics: Relationships are cause and effect
 - Source node *causes* sink node

Capturing Uncertainty

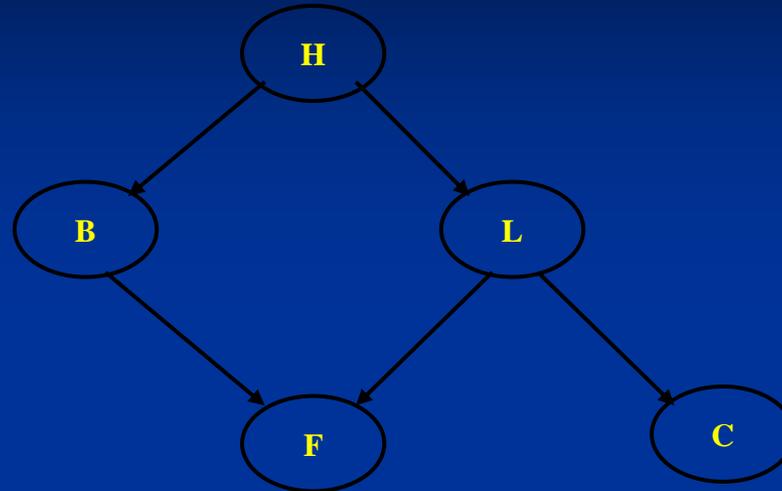


- Model dependence
- Treat as conditional probability
- If $B = b$ and $C = c$, then $A = a$ with probability $P(A = a | B = b, C = c)$

Bayesian Networks

- **Random variables (r.v.s)** represent discrete object state information
- Cause and effect relationships modeled as probabilistic **conditional dependencies**
- Strong semantic foundations

Bayesian Networks



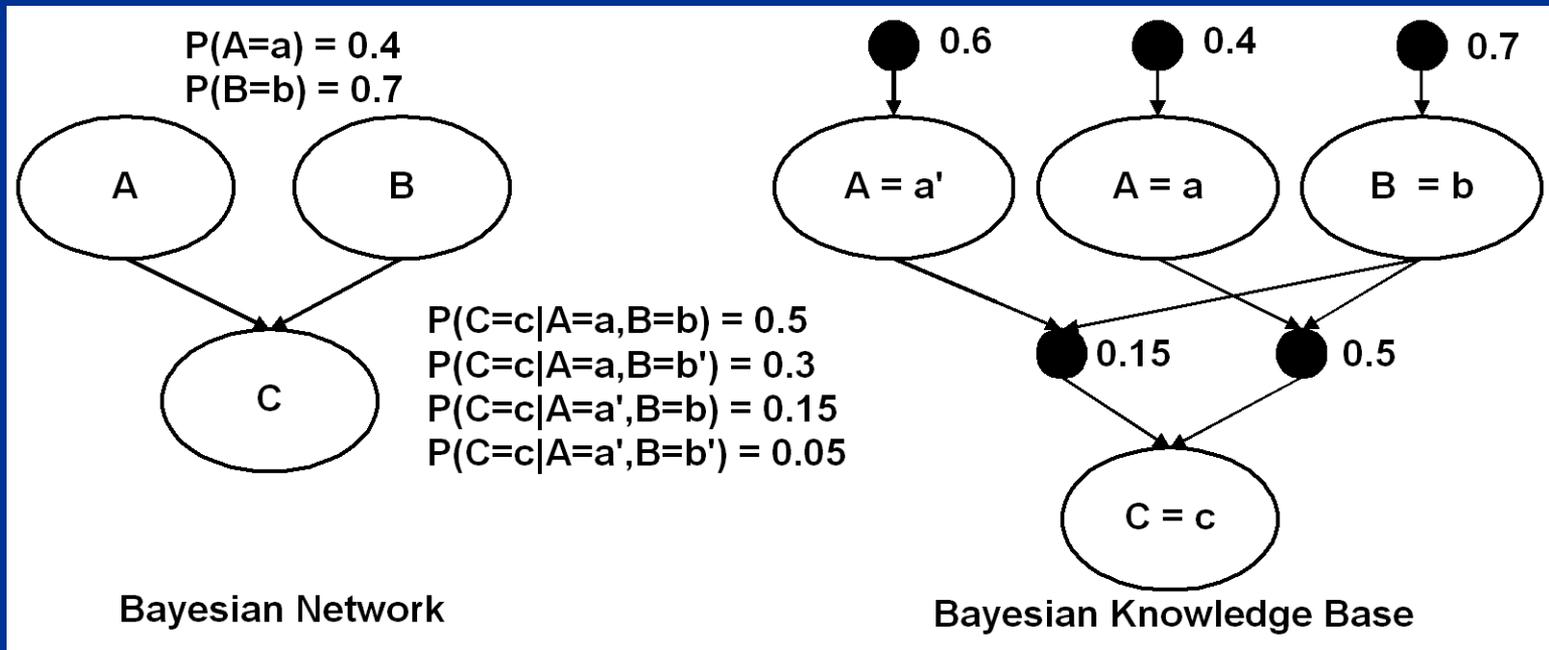
A Bayesian network for the diagnosis of lung cancer
[Neapolitan, 2003]

feature	meaning
H (h_1, h_2)	History of smoking
B (b_1, b_2)	Bronchitis
L (l_1, l_2)	Lung Cancer
F (f_1, f_2)	Fatigue
C (c_1, c_2)	Chest X-ray

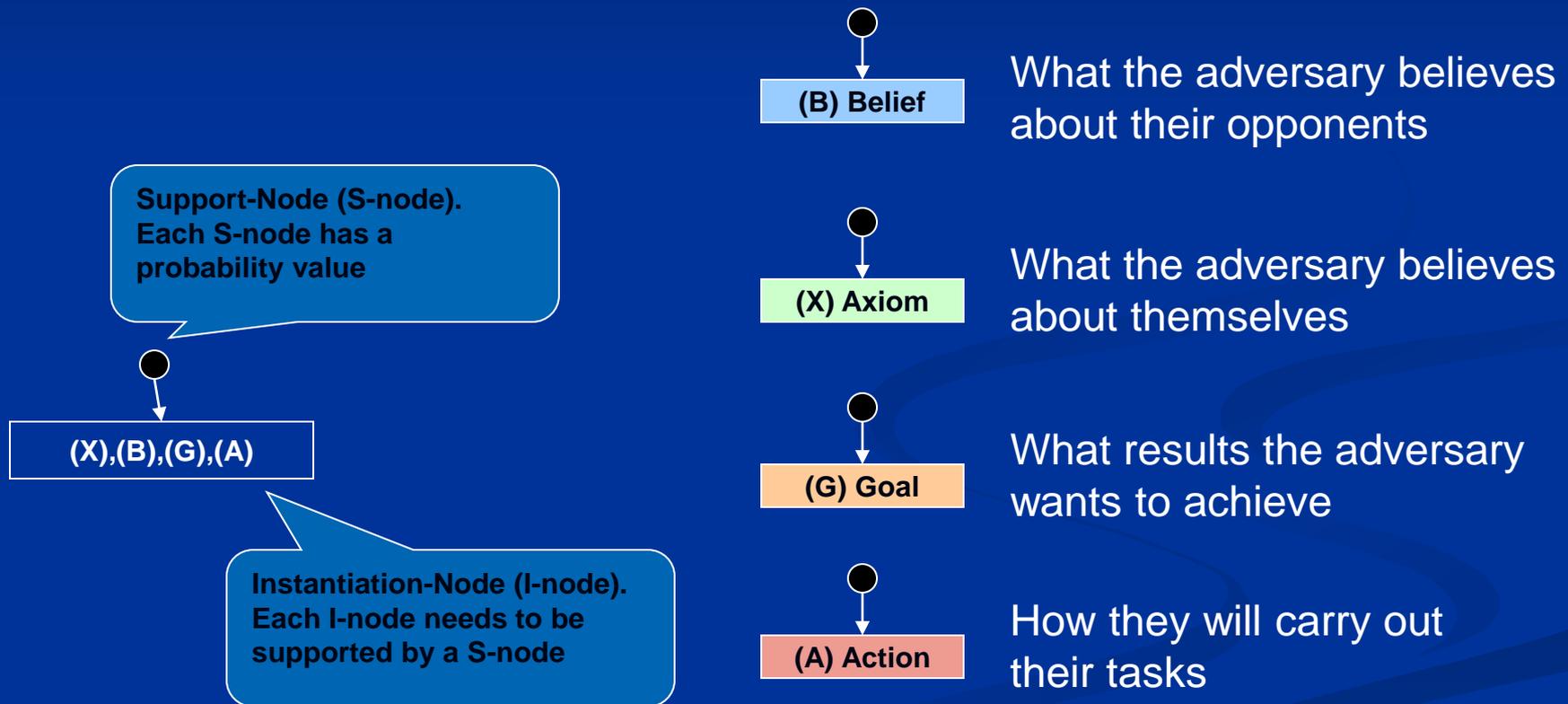
Bayesian Knowledge Base

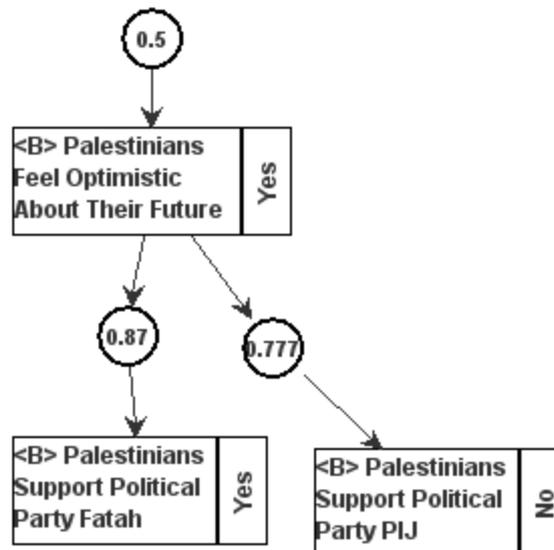
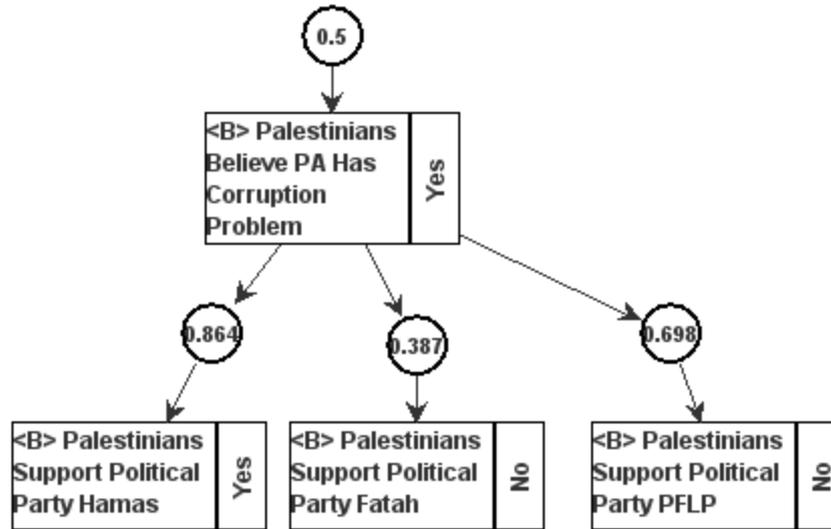
- Generalization of the Bayesian Network Representation
- Directed Graph
 - Allows certain types of cycles
 - **Allows incompleteness**
- Composed of two distinct types of nodes
 - Instantiation Nodes (I-Nodes)
 - Represent random variable states
 - Support Nodes (S-Nodes)
 - Specify a logical AND relationship between parent nodes
- Theoretically sound model for reasoning

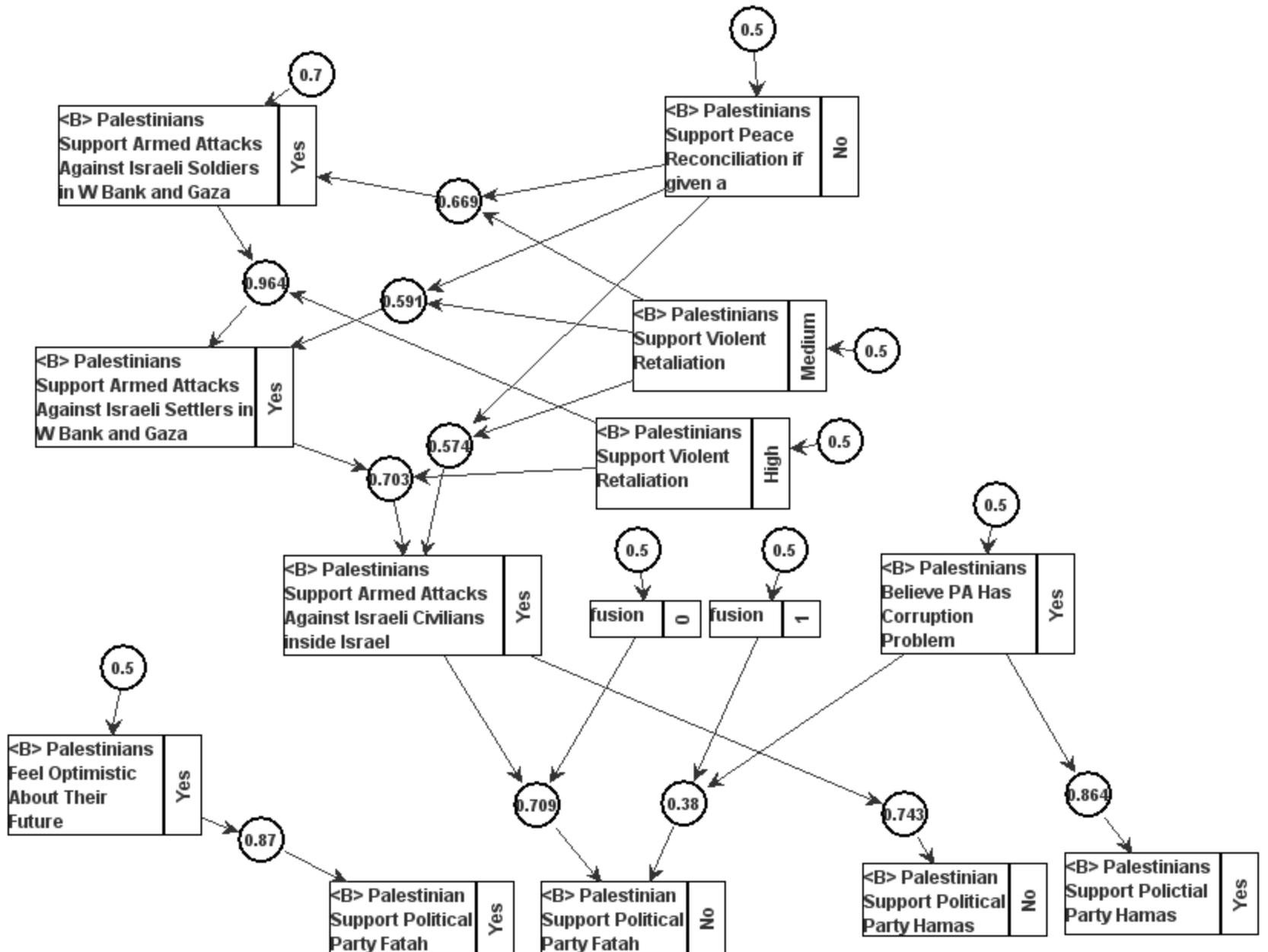
BN and BKB



Basics for BKB fragments and Adversary Intent Inferencing Model







Plug for Tomorrow

- Mr. Richard Detsch will talk in more detail about Bayesian Knowledge Bases and how to make and use them

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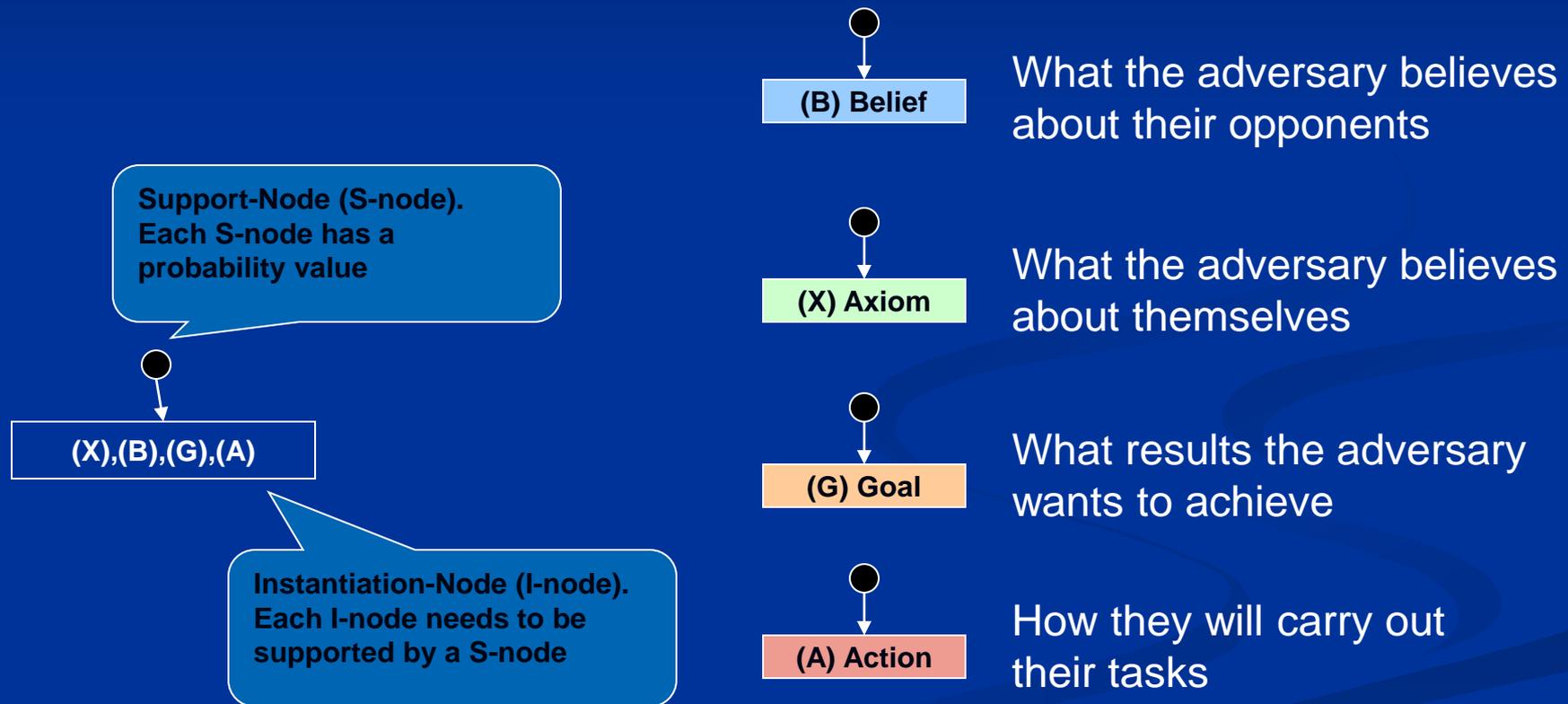
Modeling and Perception

- Approach: Model of enemy based from enemies perception or point of view
 - How does red view the world?
 - What can red observe about blue?
 - Explanation of red behavior grounded in terms of red's world-view
 - *Avoids accidentally imposing blue beliefs on red*
- Observables and evidence passed to the adversarial model is based on the above questions
 - Obviously, red does not see everything
 - Allows for modeling of deception

Intent Driven Approach

- **Model adversary through 3 formative components:**
 - **Goals/Foci:** A prioritized (by probability) list of short and long term goals representing adversary intents, objectives or foci. The goal component captures *what* the adversary is doing.
 - **Rationale Network:** A probabilistic network representing the influences of the adversary's beliefs, both about themselves and their opposition, on their goals and on high level actions associated with those goals. The rationale component infers *why* the adversary is behaving in a certain fashion.
 - **Actions Network:** A probabilistic network representing the detailed relationships between adversary goals and possible actions to realize those goals. The action component captures *how* an adversary might act.

Basics for BKB fragments and Adversary Intent Inferencing Model



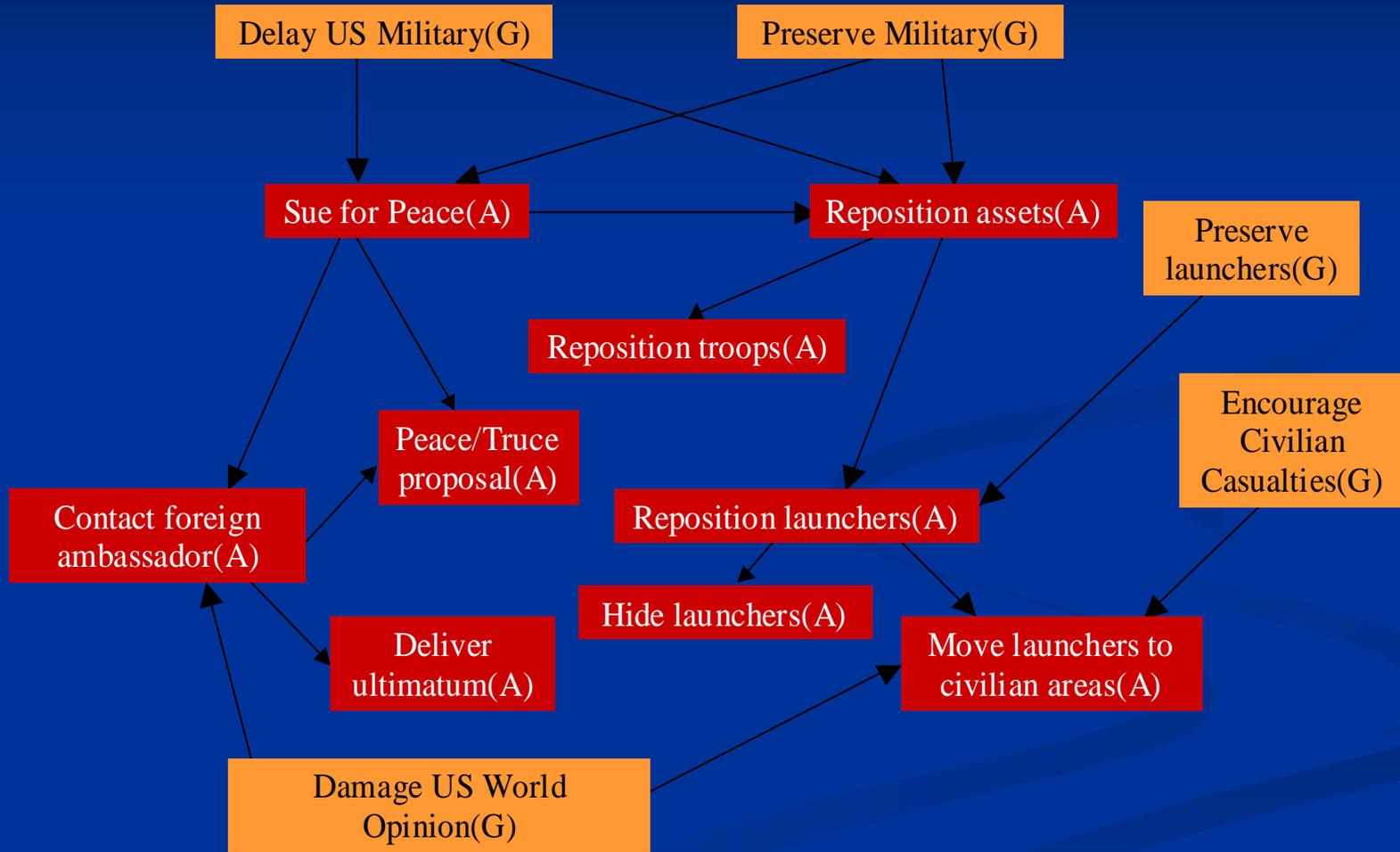
Capturing Adversary Intent

- **Adversary axioms (X)** – represent the underlying beliefs of the adversary about themselves (vs. beliefs about Blue forces). Axioms typically serve as inputs or explanations to the other RVs, such as adversary goals.
- **Adversary beliefs (B)** – represent the adversary's beliefs regarding Blue forces (e.g., an adversary may believe that U.S. forces will not destroy religious sites or shrines).
- **Adversary goals (G)** – represent the goals or desired end-states of the adversary (e.g., preserving launchers, damage world opinion of U.S. action, defeat U.S. foreign policy, etc.).
- **Adversary actions (A)** – represent the actions of the adversary that can typically be observed by Blue forces.
- **Avoids infinite regression**
 - Modeling from red's perspective

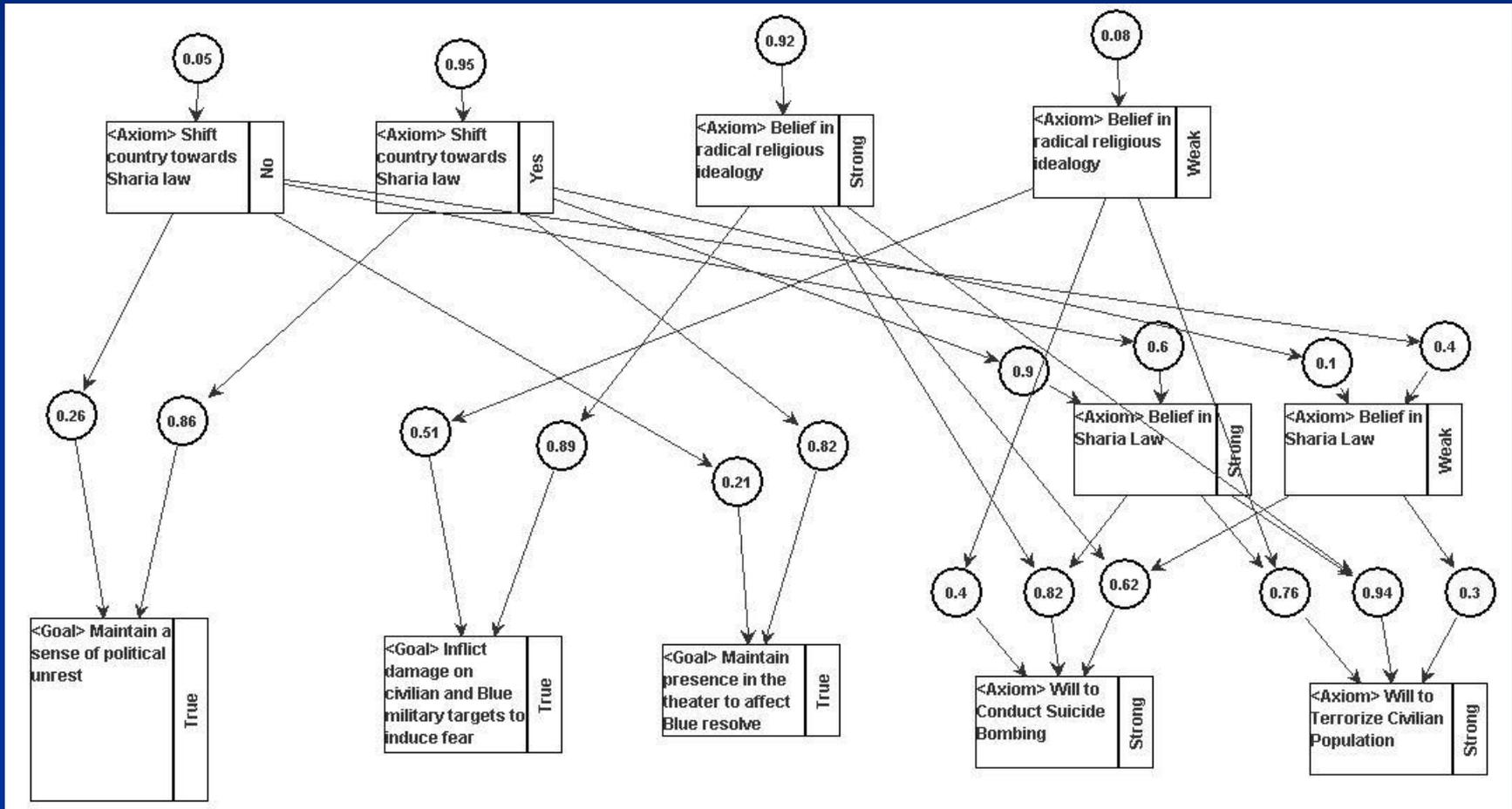
Rationale Network



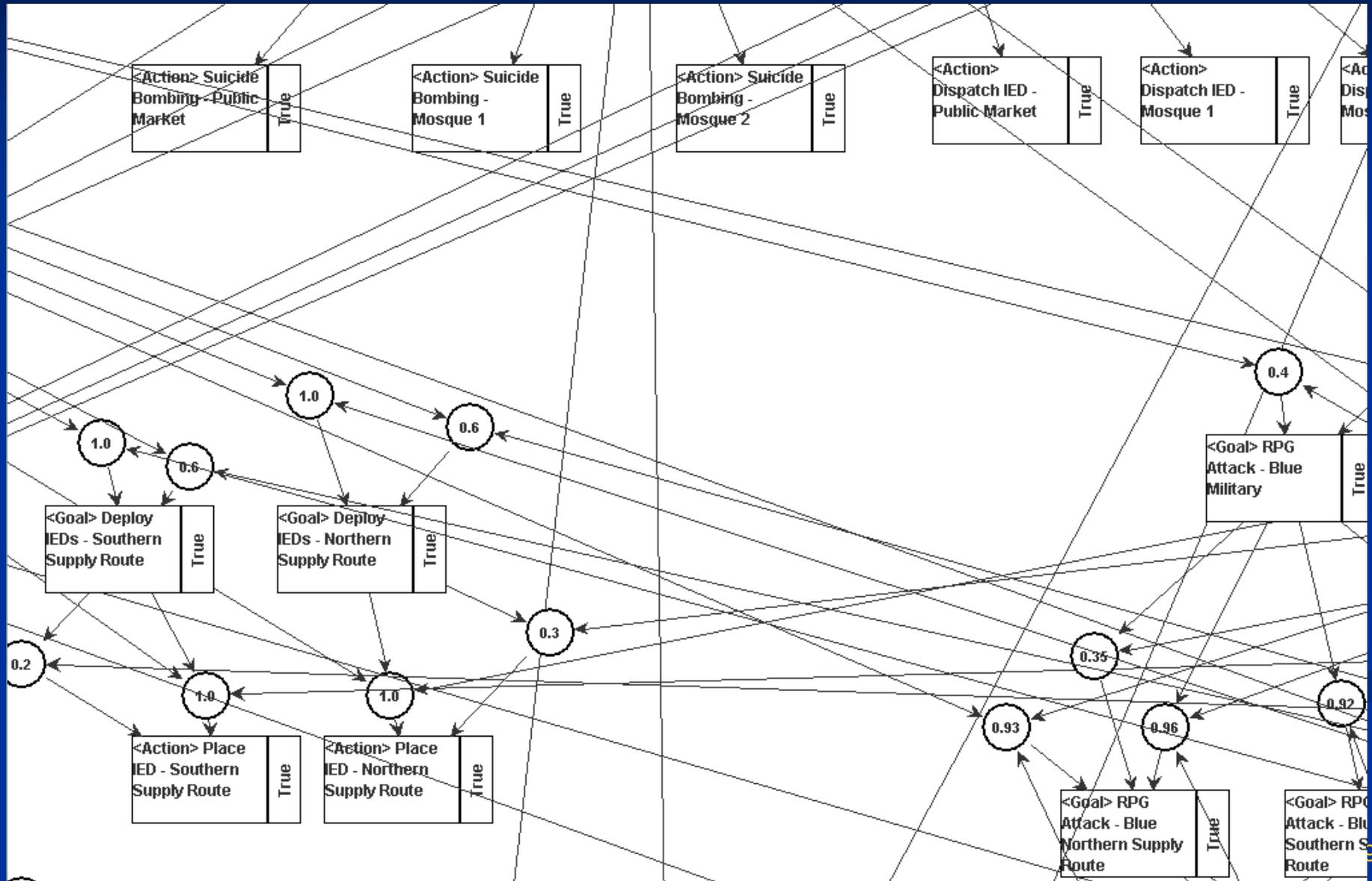
Action Network



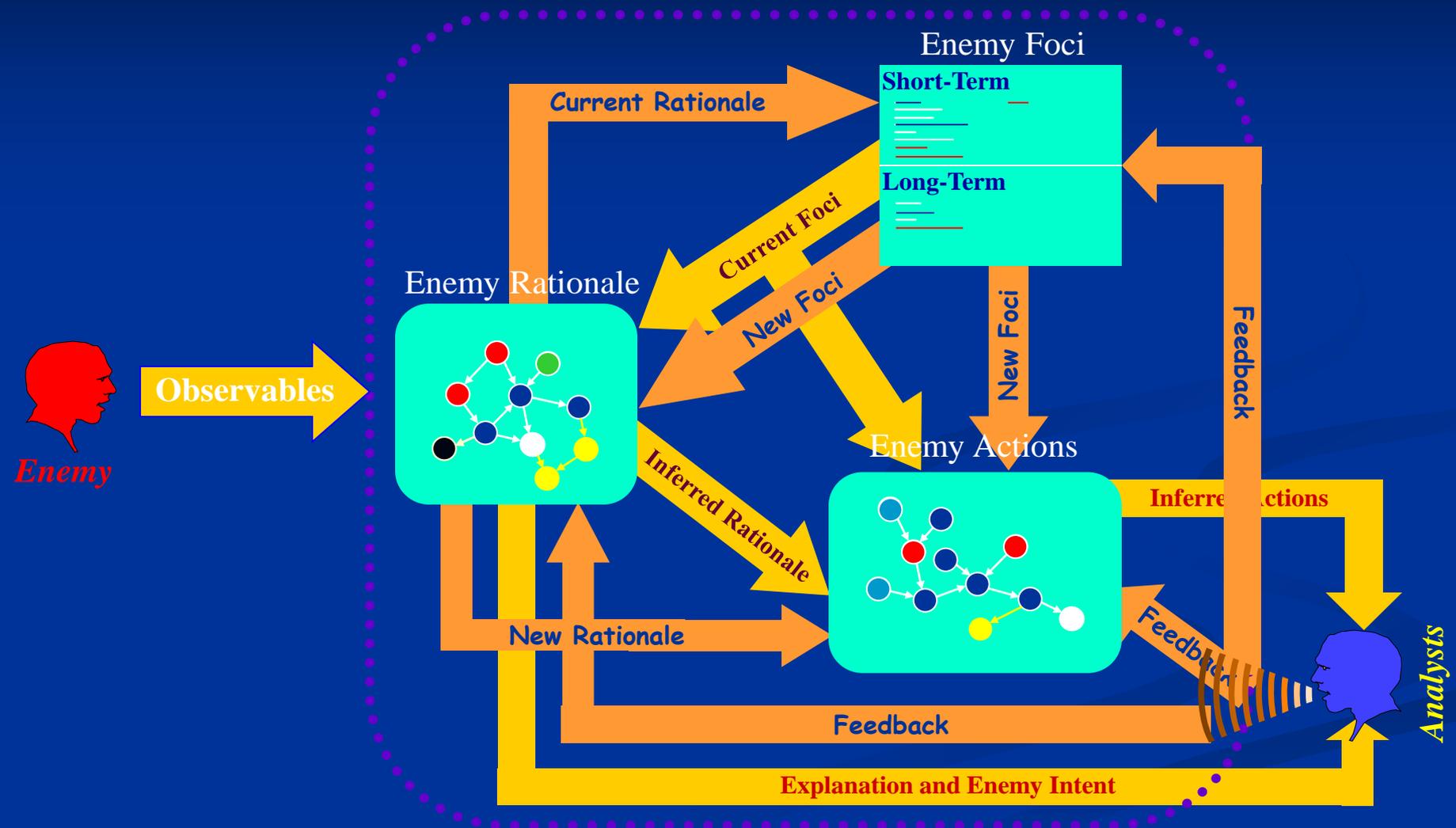
Rationale Network



Action Network



Processing for Enemy Intent



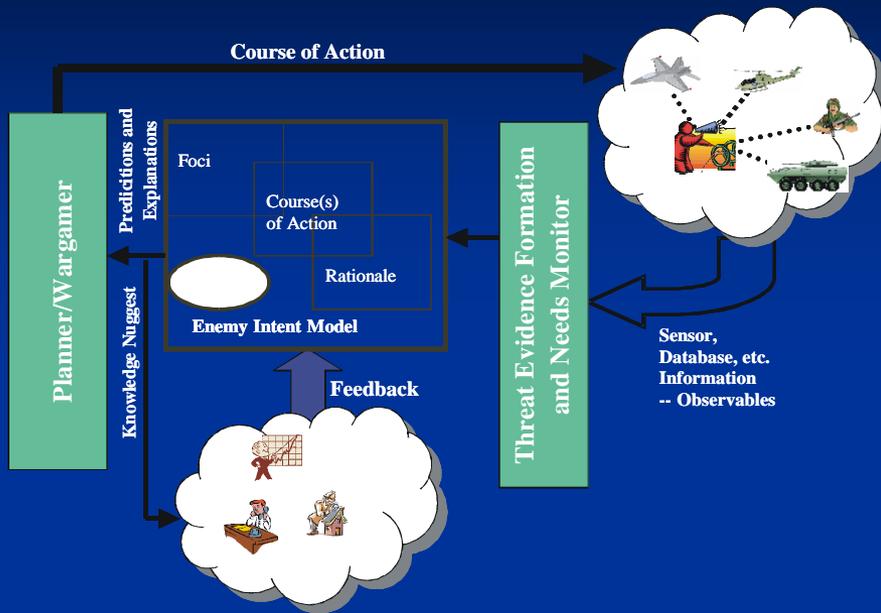
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Simulations and Tools

- AII – Adversary Intent Inferencing Project
 - Battle of al Khafji Simulation
- AII & Force Structure Simulation (FSS)
- EAMS – Emergent Adversarial Modeling System
- Social, Political, and Cultural Factors in Adversarial Behavior
- DAGA – Dynamic Adversarial Gaming Algorithm

Adversary Intent Inference for Predictive Battlespace Awareness



Objective: Design and develop computational framework for adversarial modelling and intent inferencing for decision support

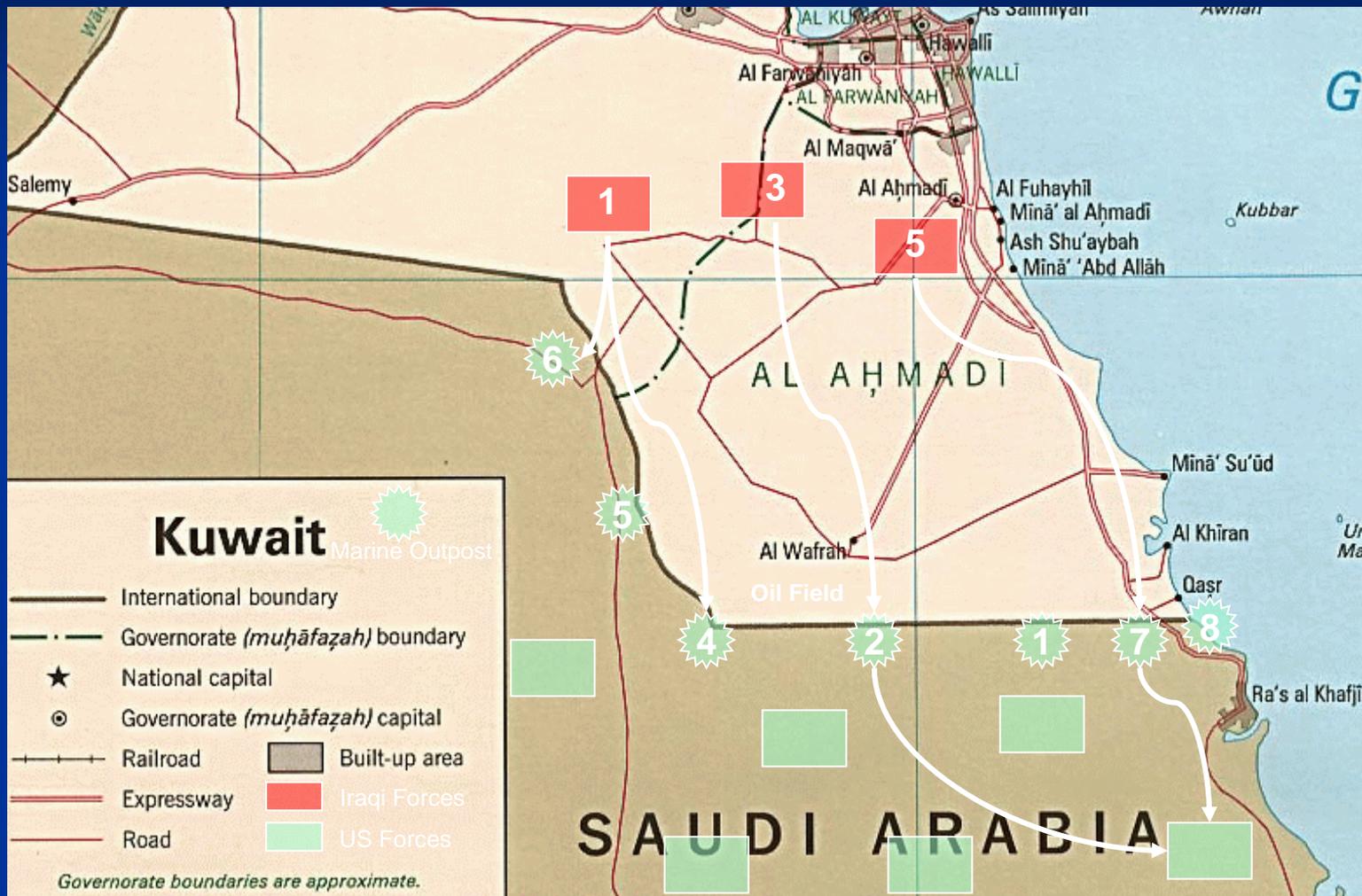
Approach: Dynamically capture and identify enemy interests, goals, rationale, and courses of action under uncertainty through Bayesian Knowledge-Bases

Accomplishments: (1) Designed and implemented core Adversary Intent Inferencing module for wintel and Unix platforms. (2) Prototype All deployed into IF wargaming system (Hillman & Surman). (3) All module also integrated into prototype system for modelling and anticipating the adversary based on the Battle of al Khafji scenario (LM ATL – Gigli & Vetesi).

Team: UConn (Santos) and LM ATL (Bell, Gigli, and Vetesi)

Sponsor: AFRL Information Institute Research Program (Graniero/Hillman) – 6.1/6.2 Enabling technology for EBO ATD [FY 02 – FY 04]

Battle of al Khafji Prototype



Battle of al Khafji

- Only organized Iraqi offensive during first Gulf War
- al Khafji, small abandoned town in Saudi Arabia near Kuwait border
- Coalition attention and sensors (Joint STARS, etc.) focused on western Iraqi border in support of SCUD suppression and bombardment of Republican Guard
- Southern Iraqi offensive thought to be unlikely
- Intentions of offensive (overrunning of Marine outposts and loss of al Khafji) were unknown or incorrectly assessed
- AII prototype simulation intended to model Iraqi commander and infer enemy intent
- Based on coalition reports, AII model initialized with enemy intent of NOT conducting an offensive
- As scenario unfolded with observables as input to AII, model evolved to correct enemy intent and anticipation of enemy actions
- Prototype provided analysts with ability to “look into” enemy intentions and explain actions consistent with observables.

Al Khafji Simulation Screenshot

The screenshot displays a simulation interface for the Al Khafji operation. The window title is "(8) Adversary Intent Inferring Demo November 06, 2002 (ATL/UCONN)".

Short Term Goal List:

- T=01 0.769 No->Go_IraqiUseChemBio
- T=01 0.745 No->Go_IraqiSurrender
- T=01 0.709 Yes->Go_SurpriseCoalitionOutposts
- T=01 0.704 Yes->Go_AttackCoalitionOutposts

Long Term Goal List:

(Empty)

Ranked Actions List:

- T=01 Rank(00) 1.000 Yes->Ac_IraqiActivityAlongSaudiBorder
- T=01 Rank(01) 0.706 Yes->Ac_IraqiForcesMassing
- T=01 Rank(02) 0.695 Yes->Ac_IraqiCommandoAttackAlMis
- T=01 Rank(03) 0.676 Yes->Ac_IraqiForcesCrossingBorder

Evidence:

- T=01 Yes->Ac_IraqiActivityAlongSaudiBorder

Battlespace Sensor Reports:

- Jan 22 1991 20:32:07 GMT+3 GMTI: Ac_IraqiActivityAlong

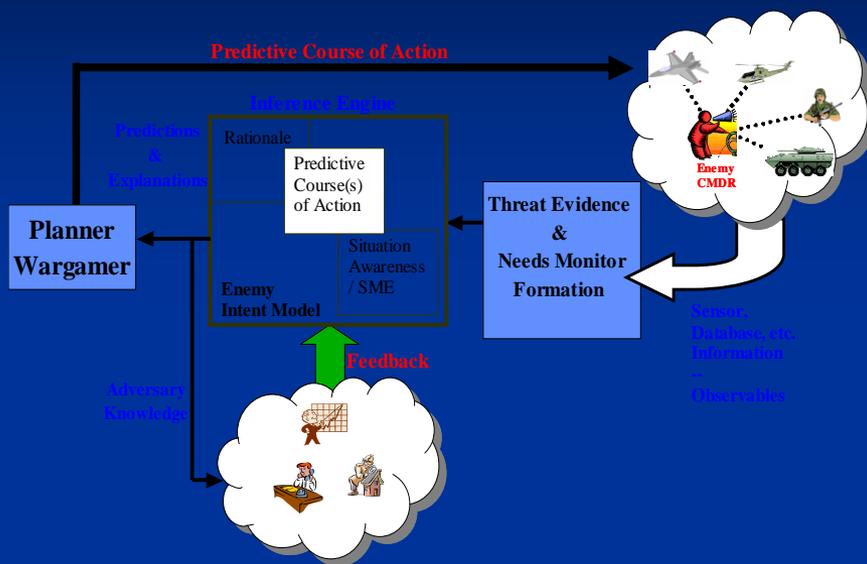
Map: Kuwait-Saudi Border. The map shows the region of Al Ahmadi, Saudi Arabia, with various locations marked including Al Fuhayh, Mina' al Ahmadi, Ash Shu'aybah, Mina' 'Abd Allah, Al Maqwa, Al Wafrah, Al Khiran, and Dahr. A blue box highlights the action "Ac_IraqiActivityAlongSaudiBorder = Yes".

IMINT **COMINT** **ELINT**

Parameters **Modify Evidence** **Update Model** **Advance Clock** **Exit**

Scenario Time [Jan 22 1991 20:32:07 GMT+3] Time Step [1]

Adversary Intent Inferencing and Force Structure Simulation



Objective: Can Inferencing be Utilized within Wargaming to:

- Dynamically Modify an Enemy Course of Action ?
- Provide Emergent Behavior In an Intelligent Manner ?

Accomplishments: (1) Established an Understanding of Adversary Inferencing Concepts Related to Enemy COA Generation. (2) Analysis Results Affirmed Our Original Hypothesis of Utilizing Adversary Inferencing and Answered The Question. (3) Developed Concepts To Integrate ECOA Generation Into Wargaming.

Team: AFRL/IFTC (Hillman, Surman), UConn (Santos)

Sponsor: AFRL/IFTC Internal Project [FY 03]

Experimental Assessment Goals

- Can The Inferencing System Could be Easily Modified And External Interfaces Created ?
- Can An Interface Be Established to Link Wargaming Behavior to AII ?
- Developed Experimental Scenarios to Investigate Dynamic Behavior With Multiple Use Cases
 - Adversarial Inferencing Models
 - Blue Force Courses of Action
- Utilize Analysis Environment To Answer
Can Inferencing be Utilized for ECOA Wargaming ?

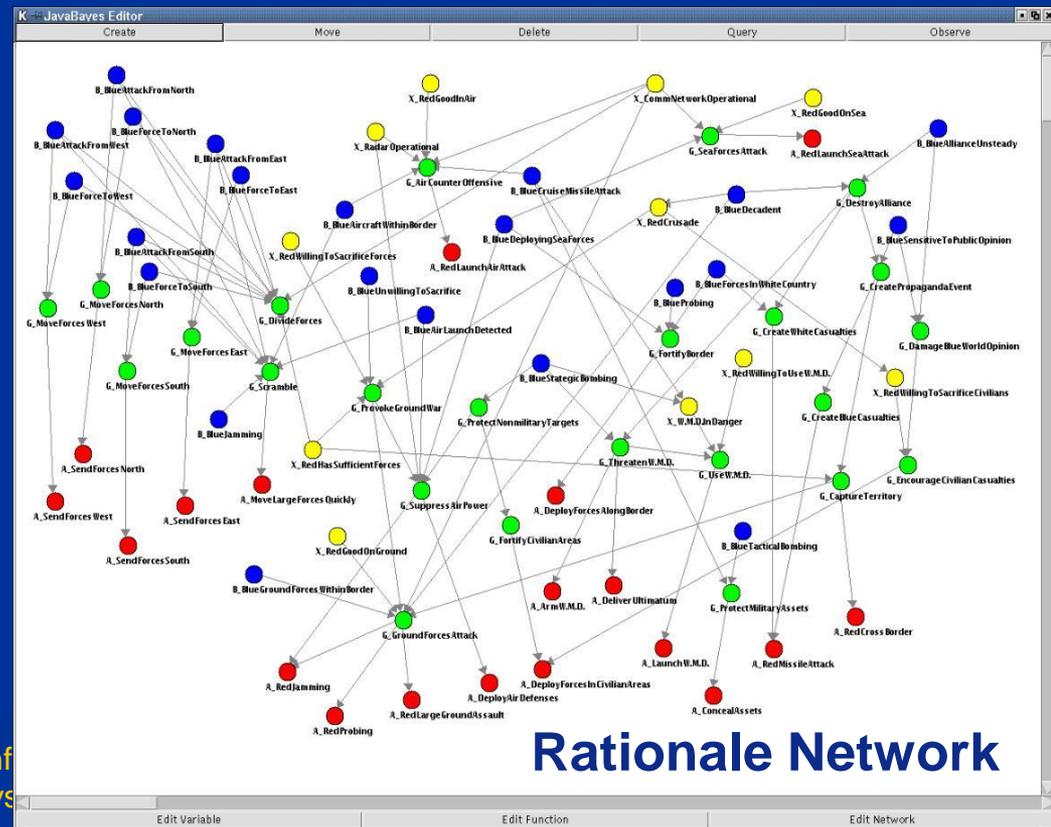
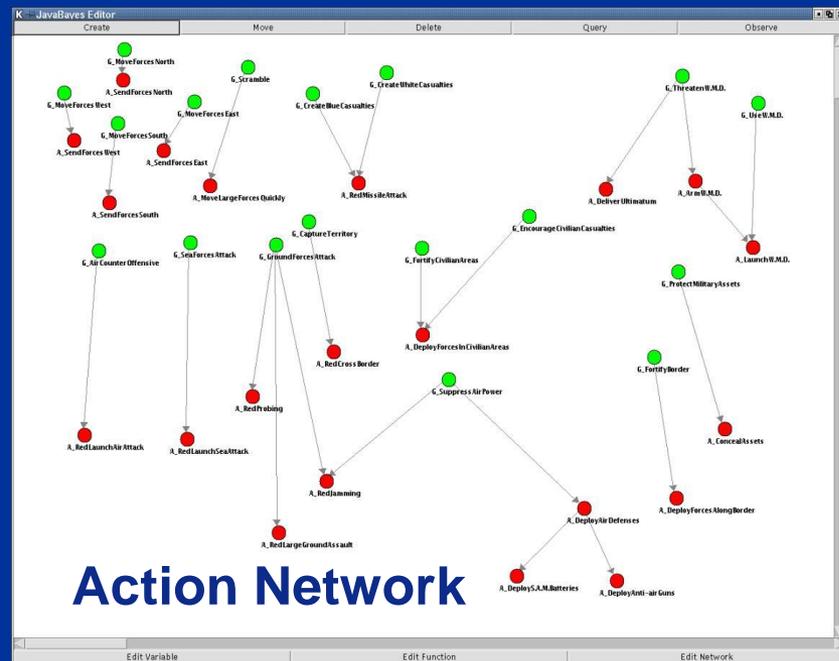
Bayesian Network Complex

Graphical Tool Required for Static AII

1) Edit Bayesian Net 2) Visualize & Comprehend Model

- Obtained JAVA Bayesian Editor (CMU)
- JAVA Modified To Annotate Bayesian Nodes For Inferencing Concepts
- Format Converter Integrated (E. Santos)

 AXIOM  BELIEF  GOAL  ACTION



Sample Analysis Matrix

- Developed Experimental Scenarios (2 x 2 Matrix)
 - Two Adversarial Belief Models
 - Two Blue Force COA Data Sets

	Adversary A	Adversary B
COA Input set 1	Deliver Ultimatum Launch Air Attack Send Forces South Arm Weapons Of Mass Destruction Launch Weapons Of Mass Destruction	Launch Ground Assault Send Forces South Enemy Recon Probing Forces Cross Border Deploy Forces In Civilian Areas
COA Input set 2	Deploy Forces In Civilian Areas Deliver Ultimatum Deploy Forces Along Border Arm Weapons Of Mass Destruction Conceal Assets Launch Weapons Of Mass Destruction	Deploy Forces In Civilian Areas Launch Ground Assault Send Forces West Send Forces North Enemy Recon Probing Forces Cross Border Deploy Forces Along Border Conceal Assets

Inferencing GUI Demo

Time Step 1

Observation

Short Term Goals

Forecasted Actions

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Distrib

The screenshot displays the 'Adversary Intent Inferencing' window, which is divided into three main sections: Observations, Goals, and Top Ranked Actions.

Observations: This section lists two active observations, both with a relative ranking of 92.4 and a status of {true}.
- **<Radar Operational>** is {true} with relative ranking of 92.4
- **<Comm Network Operational>** is {true} with relative ranking of 92.4

Goals: This section is divided into Short Term Goals and Long Term Goals. The Short Term Goals list 8 actions with their relative rankings and timesteps.
- Short Term Goals:
- Relative ranking **<Damage Blue World Opinion>** is {true} = 86.4065. Timesteps: 0
- Relative ranking **<Destroy Alliance>** is {true} = 90.4146. Timesteps: 0
- Relative ranking **<Create Propaganda Event>** is {true} = 87.4051. Timesteps: 0
- Relative ranking **<Threaten W. M. D.>** is {true} = 90.0967. Timesteps: 0
- Relative ranking **<Suppress Air Power>** is {true} = 86.1982. Timesteps: 0
- Relative ranking **<Scramble>** is {true} = 87.3063. Timesteps: 0
- Relative ranking **<Fortify Border>** is {true} = 86.9625. Timesteps: 0
- Relative ranking **<Use W. M. D.>** is {true} = 85.4543. Timesteps: 0
- LongTermGoals:

Top Ranked Actions: This section lists 17 actions, each with a relative ranking and a status of {true}.
- Action #1: 90.4534 Relative ranking **<Deliver Ultimatum>**={true}
- Action #2: 89.2005 Relative ranking **<Move Large Forces Quickly>**={true}
- Action #3: 89.0462 Relative ranking **<Deploy Forces Along Border>**={true}
- Action #4: 83.675 Relative ranking **<Red Missile Attack>**={true}
- Action #5: 83.55 Relative ranking **<Red Jamming>**={true}
- Action #6: 83.175 Relative ranking **<Deploy Forces in Civilian Areas>**={true}
- Action #7: 82.5301 Relative ranking **<Deploy Anti-air Guns>**={true}
- Action #8: 82.5301 Relative ranking **<Deploy S. A. M Batteries>**={true}
- Action #9: 72.7 Relative ranking **<Red Large Ground Assault>**={true}
- Action #10: 72.45 Relative ranking **<Send Forces West>**={true}
- Action #11: 72.45 Relative ranking **<Send Forces North>**={true}
- Action #12: 72.45 Relative ranking **<Red Launch Air Attack>**={true}
- Action #13: 72.45 Relative ranking **<Send Forces South>**={true}
- Action #14: 72.45 Relative ranking **<Red Launch Sea Attack>**={true}
- Action #15: 72.45 Relative ranking **<Red Probing>**={true}
- Action #16: 72.45 Relative ranking **<Red Cross Border>**={true}
- Action #17: 72.45 Relative ranking **<Denlay Air Defenses>**={true}

Inferencing GUI

Demo

Time Step 2

Additional
Observations

Updated
Short Term Goals

Updated
Forecasted Actions

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Adversary Intent Inferencing

Observations

<Radar Operational> is {true} with relative ranking of 92.4
<Comm Network Operational> is {true} with relative ranking of 92.4
<Blue Force To South> is {true} with relative ranking of 86.5
<Blue Deploying Sea Forces> is {true} with relative ranking of 82.7
<Blue Forces In White Country> is {true} with relative ranking of 87.7
<Deploy Forces Along Border> is {true} with relative ranking of 89.3

Goals

Short Term Goals:

Relative ranking <Damage Blue World Opinion> is {true} = 92.0081. Timesteps: 1
Relative ranking <Destroy Alliance> is {true} = 94.8143. Timesteps: 1
Relative ranking <Create Propaganda Event> is {true} = 92.7758. Timesteps: 1
Relative ranking <Threaten W. M. D.> is {true} = 94.6359. Timesteps: 1
Relative ranking <Suppress Air Power> is {true} = 91.8915. Timesteps: 1
Relative ranking <Scramble> is {true} = 92.6181. Timesteps: 1
Relative ranking <Fortify Border> is {true} = 93.1338. Timesteps: 1
Relative ranking <Use W. M. D.> is {true} = 91.4673. Timesteps: 1
Relative ranking <Create Blue Casualties> is {true} = 85.17. Timesteps: 0
Relative ranking <Create White Casualties> is {true} = 86.0509. Timesteps: 0
Relative ranking <Move Forces South> is {true} = 90.2685. Timesteps: 0

LongTermGoals:

Top Ranked Actions

```
-- Action #1 -- 98.5475 Relative ranking <Deploy Forces Along Border>={true}
-- Action #2 -- 93.9712 Relative ranking <Red Missile Attack>={true}
-- Action #3 -- 91.9118 Relative ranking <Red Jamming>={true}
-- Action #4 -- 90.5305 Relative ranking <Send Forces South>={true}
-- Action #5 -- 90.4534 Relative ranking <Deliver Ultimatum>={true}
-- Action #6 -- 89.8276 Relative ranking <Deploy Anti-air Guns>={true}
-- Action #7 -- 89.8276 Relative ranking <Deploy S. A. M Batteries>={true}
-- Action #8 -- 89.2005 Relative ranking <Move Large Forces Quickly>={true}
-- Action #9 -- 88.703 Relative ranking <Deploy Air Defenses>={true}
-- Action #10 -- 86.9162 Relative ranking <Arm W. M. D.>={true}
-- Action #11 -- 83.175 Relative ranking <Deploy Forces In Civilian Areas>={true}
-- Action #12 -- 79.118 Relative ranking <Launch W. M. D.>={true}
-- Action #13 -- 72.7 Relative ranking <Red Large Ground Assault>={true}
-- Action #14 -- 72.45 Relative ranking <Send Forces West>={true}
-- Action #15 -- 72.45 Relative ranking <Send Forces North>={true}
-- Action #16 -- 72.45 Relative ranking <Red Launch Air Attack>={true}
-- Action #17 -- 72.45 Relative ranking <Red Launch Sea Attack>={true}
```

Inferencing GUI

Demo

Time Step 3

Modified
Observations

Updated
Short Term Goals

Long Term Goals

Updated
Forecasted Actions

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Adversary Intent Inferencing

Observations

```
<Radar Operational> is {true} with relative ranking of 92.4
<Comm Network Operational> is {true} with relative ranking of 92.4
<Blue Force To South> is {true} with relative ranking of 86.5
<Blue Deploying Sea Forces> is {true} with relative ranking of 82.7
<Blue Forces In White Country> is {true} with relative ranking of 87.7
<Deploy Forces Along Border> is {true} with relative ranking of 89.3
<Blue Cruise Missile Attack> is {true} with relative ranking of 95.4
<Blue Jamming> is {true} with relative ranking of 84.5
<Red Missile Attack> is {true} with relative ranking of 88.3
<Move Large Forces Quickly> is {true} with relative ranking of 82.6
```

Goals

Short Term Goals:

```
Relative ranking <Create Blue Casualties> is {true} = 95.581. Timesteps: 2
Relative ranking <Create White Casualties> is {true} = 95.8765. Timesteps: 2
Relative ranking <Move Forces South> is {true} = 97.28. Timesteps: 2
Relative ranking <Protect Military Assets> is {true} = 94.5345. Timesteps: 1
Relative ranking <Air Counter Offensive> is {true} = 92.4229. Timesteps: 1
Relative ranking <Ground Forces Attack> is {true} = 85.244. Timesteps: 0
```

LongTermGoals:

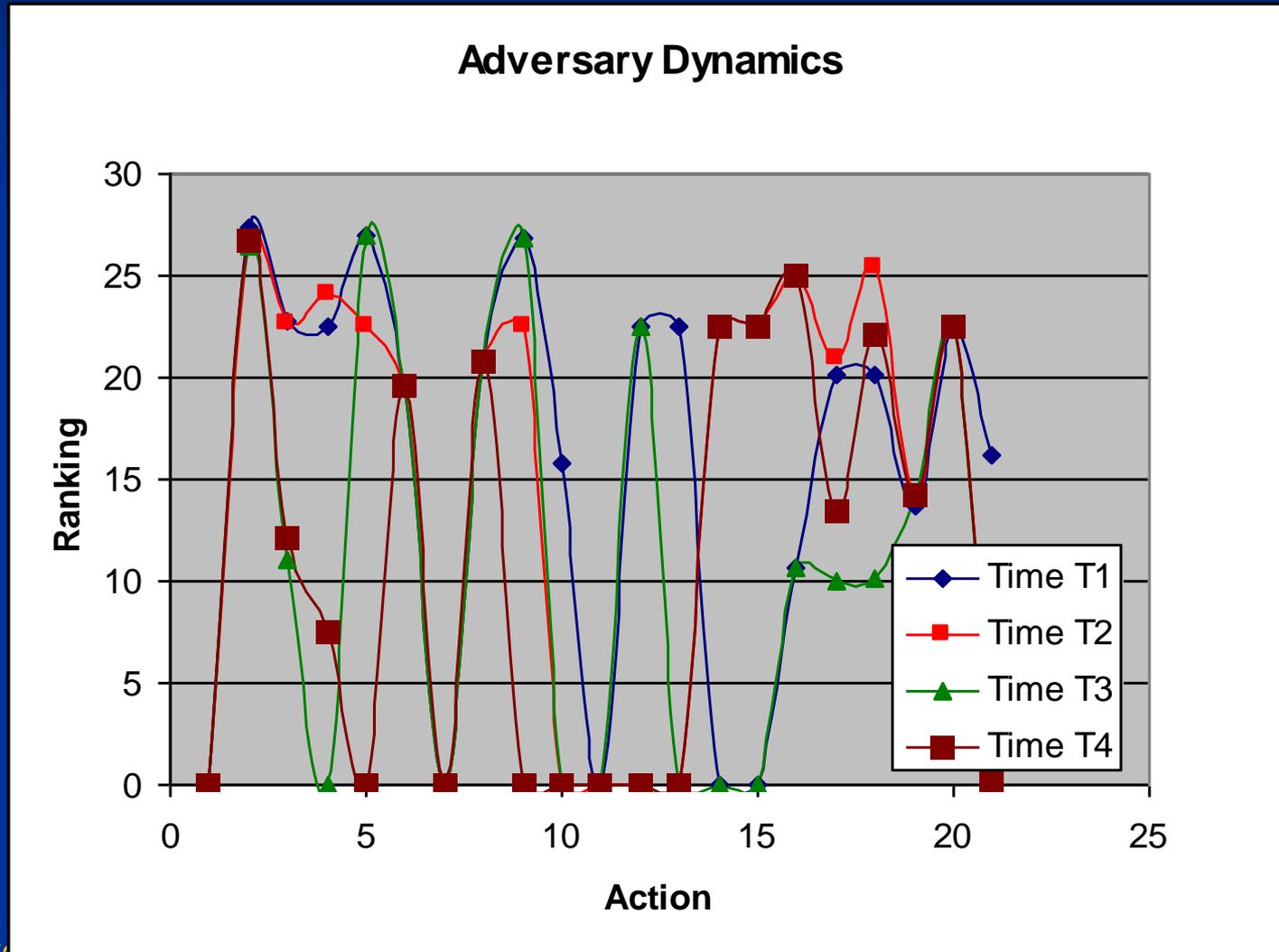
```
Relative ranking <Damage Blue World Opinion> is {true} = 98.002. Timesteps: 3
Relative ranking <Destroy Alliance> is {true} = 98.7036. Timesteps: 3
Relative ranking <Create Propaganda Event> is {true} = 98.1939. Timesteps: 3
Relative ranking <Threaten W. M. D.> is {true} = 98.659. Timesteps: 3
Relative ranking <Suppress Air Power> is {true} = 97.9729. Timesteps: 3
Relative ranking <Scramble> is {true} = 98.1545. Timesteps: 3
```

Top Ranked Actions

```
-- Action #1 -- 99.3602 Relative ranking <Deploy Forces Along Border>={true}
-- Action #2 -- 99.293 Relative ranking <Red Missile Attack>={true}
-- Action #3 -- 98.8806 Relative ranking <Move Large Forces Quickly>={true}
-- Action #4 -- 95.241 Relative ranking <Red Jamming>={true}
-- Action #5 -- 94.9 Relative ranking <Deliver Ultimatum>={true}
-- Action #6 -- 94.9 Relative ranking <Red Launch Air Attack>={true}
-- Action #7 -- 94.9 Relative ranking <Send Forces South>={true}
-- Action #8 -- 94.9 Relative ranking <Deploy Air Defenses>={true}
-- Action #9 -- 93.2 Relative ranking <Arm W. M. D.>={true}
-- Action #10 -- 92.6101 Relative ranking <Deploy Anti-air Guns>={true}
-- Action #11 -- 92.6101 Relative ranking <Deploy S. A. M Batteries>={true}
-- Action #12 -- 92.1 Relative ranking <Conceal Assets>={true}
-- Action #13 -- 88.7008 Relative ranking <Red Large Ground Assault>={true}
-- Action #14 -- 88.2746 Relative ranking <Red Probing>={true}
-- Action #15 -- 86.6276 Relative ranking <Launch W. M. D.>={true}
-- Action #16 -- 83.175 Relative ranking <Deploy Forces In Civilian Areas>={true}
-- Action #17 -- 72.45 Relative ranking <Send Forces West>={true}
```

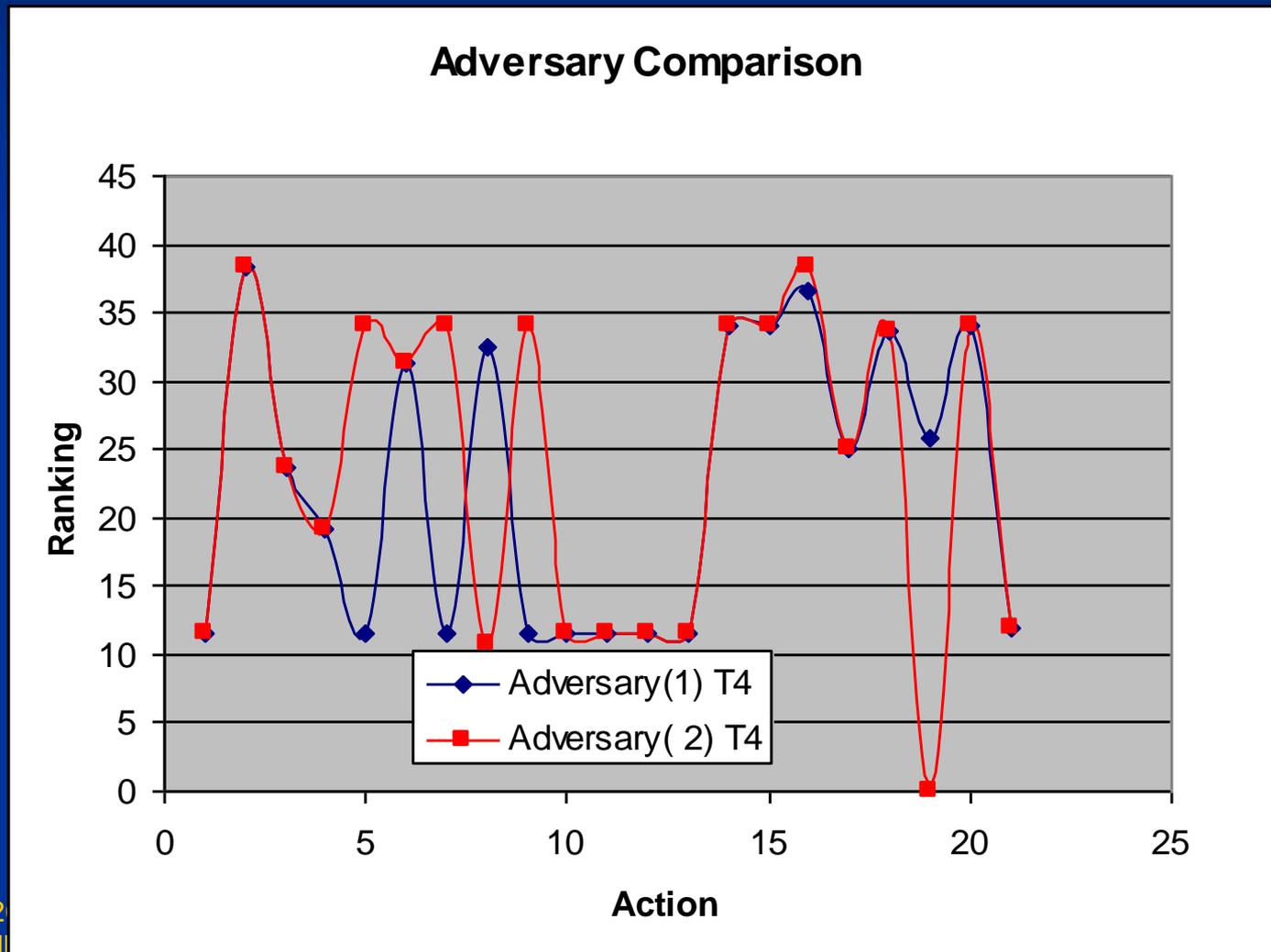
Illustration of Adversary Dynamics

Dynamics Of Adversary(1) Across Time Steps

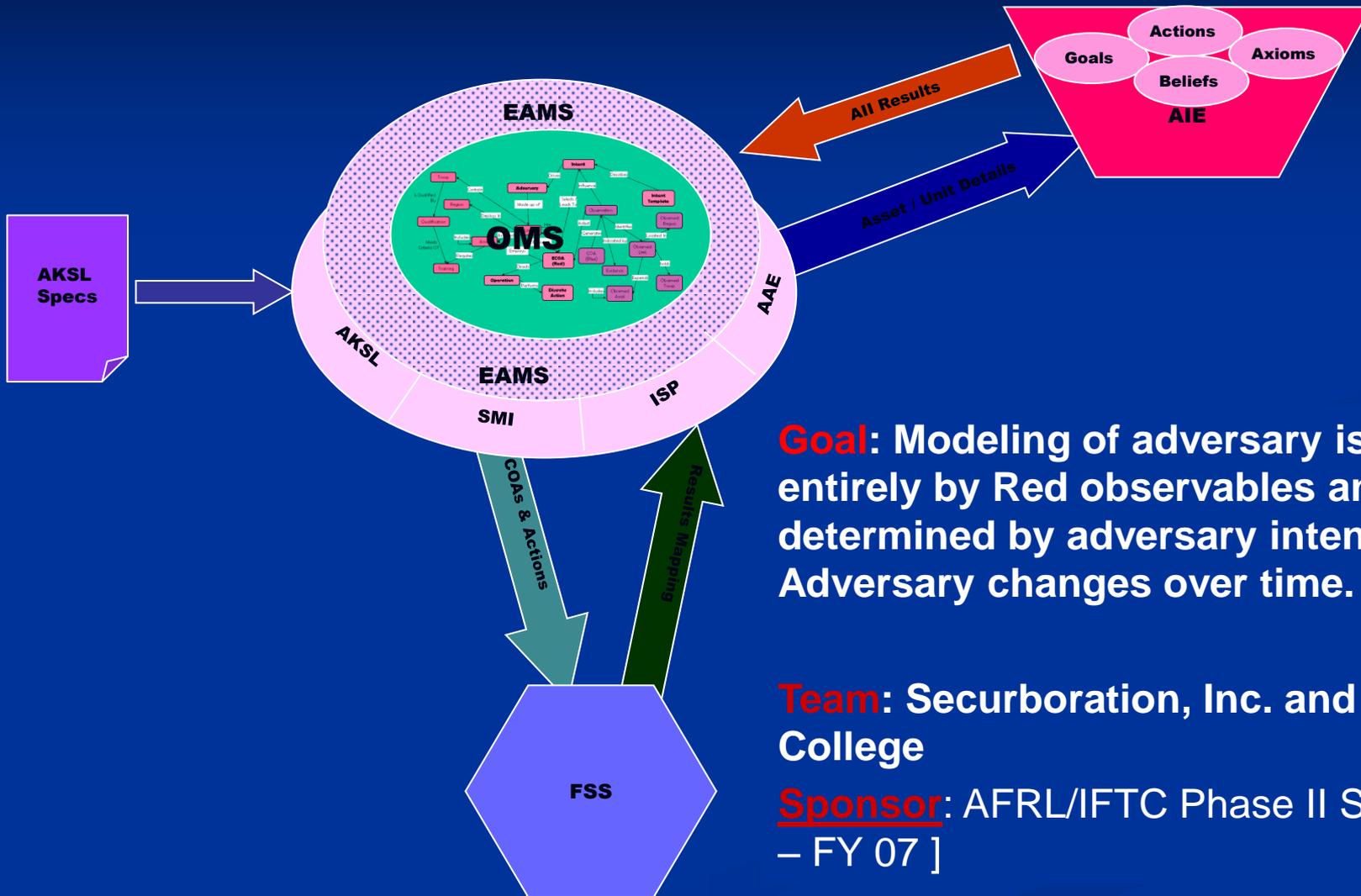


Differences in Adversary Ranking

Comparison Of Adversary(1) and Adversary(2) at Time Step 4



Emergent Adversarial Modeling System (EAMS)



Goal: Modeling of adversary is driven entirely by Red observables and actions determined by adversary intent. Adversary changes over time.

Team: Securboration, Inc. and Dartmouth College

Sponsor: AFRL/IFTC Phase II SBIR [FY 05 – FY 07]

Plug for Demos

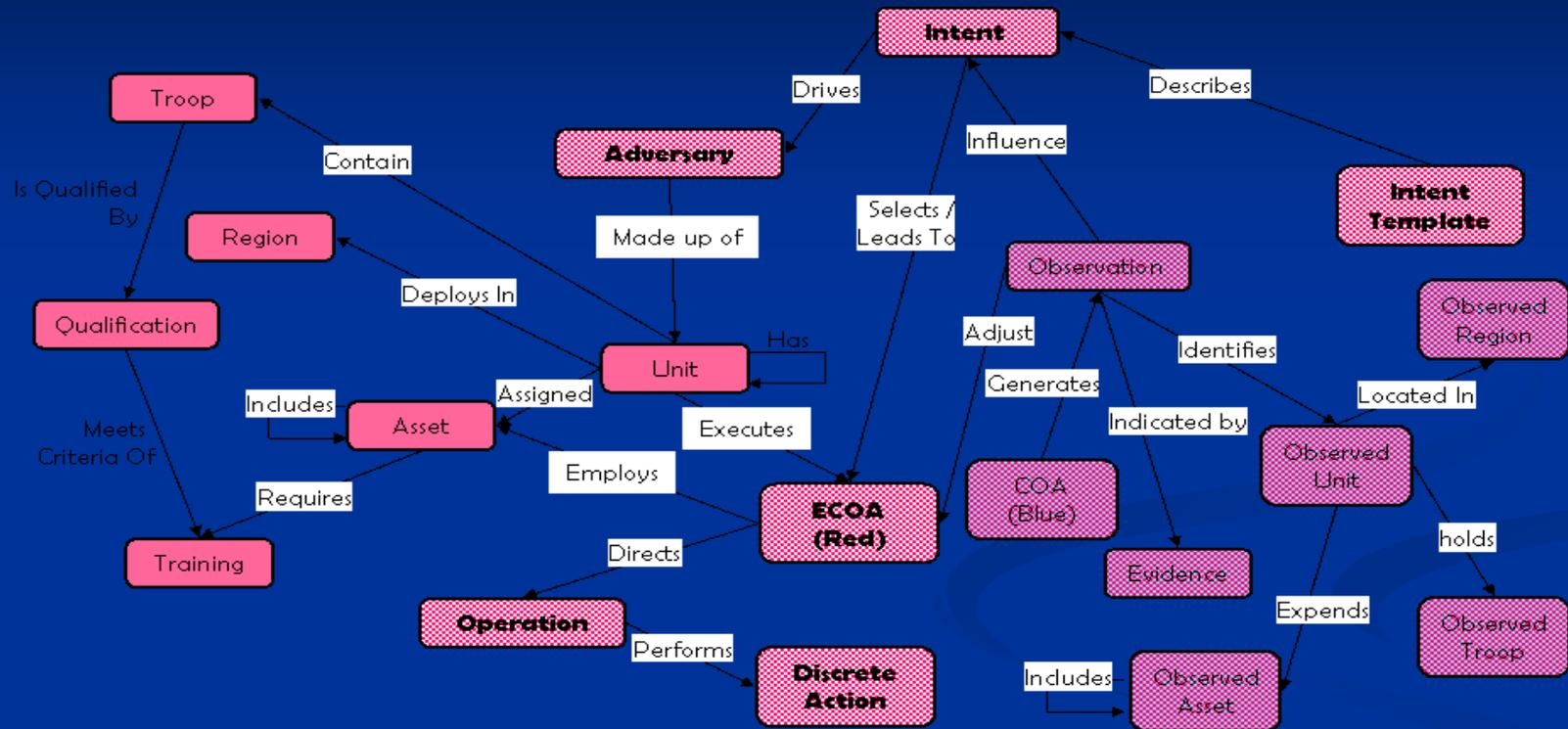
- Dr. Qunhua Zhao will demo tomorrow!

Emergent Adversarial Behavior

What is the concept of Emergent Adversarial Behavior

- Emergent behavior refers to intelligent dynamic adversarial actions generated at the operational level in response to the execution of the friendly force within the simulation
- Red Force reacts to Blue Force actions (from their perspective)
 - Monitor and understand battle-space *observables* and how they relate to *adversary* intent
 - Form a mission or missions (*reacting*) based on the *observables*
- Red Force intent drives their actions
 - **Missions differ based on differing intent**
- Predictive adversary modeling is one of the key requirements for EBO, where the adversary is addressed as a system.

EAMS Ontology



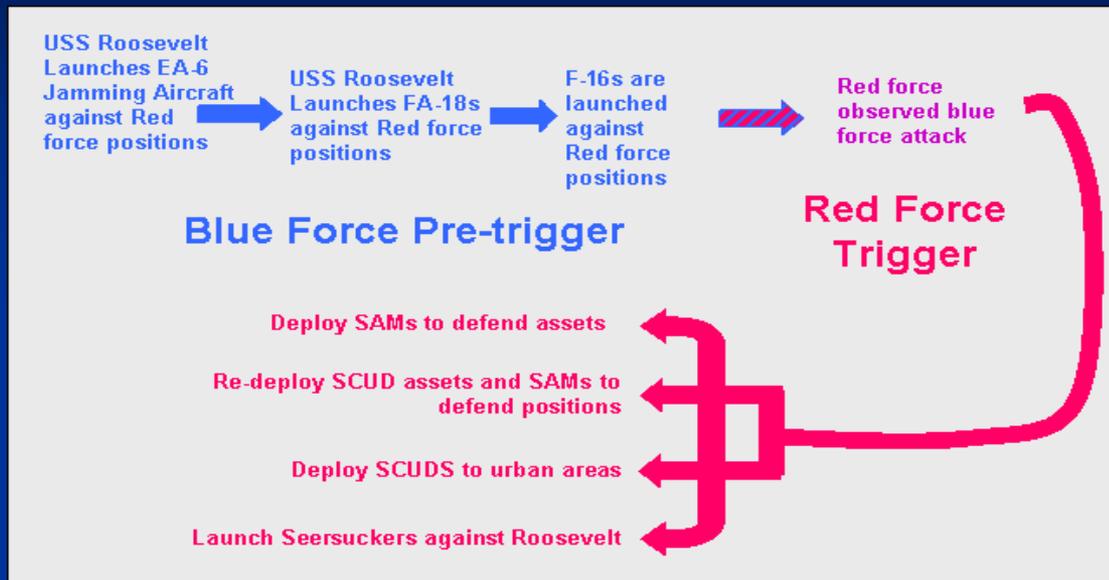
Legend

Red Force Asset and Unit Characteristics represented in EAMS Ontology

Red Force Intent and Operation in All

Red Force Observations about Blue Force Actions and Assets in EAMS Ontology

Deny Force Scenario



Additional Info (TBD)

- Grid
- Weapons Systems Operating Envelopes
- Observation Criteria

Scenario Timeline



Demo Scenario 1

Significant Observable Events

- Meadows Detects Enemy
- Meadows Experiences Destruction
- Twenty Nine Palms Detects Enemy

Commander Intent - **Aggressive**

- **Defend Initial Attack**
 - Move GOA's into Meadows from Pendleton
- **React To Destruction**
 - Launch SeerSucker at USSTR from Vandenberg
- **Continue To Defend**
 - Move GOA's into Twenty Nine Palms from Pendleton

Demo Scenario 2

Significant Observable Events

- Meadows Detects Enemy
- Meadows Experiences Destruction
- Twenty Nine Palms Detects Enemy

Commander Intent - **Passive**

- Defend Initial Attack
 - Move GOA's into Meadows from Pendleton
- Continue To Defend
 - Move GOA's into Twenty Nine Palms from Pendleton
- Defend With Authority
 - Operate All SA-2's

Observation Initiating AII

```
Cygwin
c++: <Reflect> ClassName=FixedAsset, ObjectName=CommandPost, FullName=MEADOWS EW
W SITE CommandPost, ObjectType=104, ObjectId=17, ObjectAlliance=0, ObjectRef=11,
Status=100, CommanderId=-555, DiscoverRate=1, EnemyInArea=1, Jammed=0
java: update: [className=FixedAsset][new=false][dirty=true][ObjectName=CommandPo
st][FullName=MEADOWS EW SITE CommandPost][ObjectType=104][ObjectId=17][ObjectAll
iance=0][Status=100][CommanderId=-555][DiscoverRate=1][EnemyInArea=1][Jammed=fal
se]

END OF WHILE, Going again
Before sendObservableViaFile
Entering AiiProxy.sendObservablesViaFile
update adversary model
Max Table Size - 16          CPU Seconds - 1.81
XXXXXXXXXXXXXXXX 0
Max Table Size - 16          CPU Seconds - 1.96
Max Table Size - 2          CPU Seconds - 1.97

-----
Marginal Evidence Set -
-----
<Ax_Behavior> ---- [ A = 1 ] [ N = 0 ] [ P = 0 ]
<Be_M> ---- [ Yes = 1 ] [ No = 0 ]
<Ax_Detect_FA18_at_MeadowsEW> ---- [ Yes = 1 ] [ No = 0 ]
<Ax_Detect_F16CG_at_29Palms> ---- [ Yes = 0 ] [ No = 1 ]

-----
-- Short Term Goals Update
Short Term Goals: <rv name> = <rv state> ! <weight> ! <duration>

-----
Ranked actions:
#0 [ 0.474328 ] <Ac_Move_GOA_to_MeadowsEW> = <Yes>
#1 [ 0.465112 ] <Ac_Attack_USSTR_by_Seersucker_from_Vandenberg> = <Yes>
#2 [ 0.45669 ] <Ac_Operate_SA2_at_MeadowsEW> = <Yes>
#3 [ 0.453765 ] <Ac_Launch_Seersucker_from_Vandenberg_to_USSTR> = <Yes>
#4 [ 0.448331 ] <Ac_Move_SA2_to_MeadowsEW> = <Yes>
#5 [ 0.4376 ] <Ac_Move_GOA_to_29Palms> = <Yes>
#6 [ 0.42316 ] <Ac_Operate_GOA_at_MeadowsEW> = <Yes>
#7 [ 0.421819 ] <Ac_Operate_GOA_at_29Palms> = <Yes>
#8 [ 0.41753 ] <Ac_Move_SA2_to_29Palms> = <Yes>
#9 [ 0.416038 ] <Ac_Move_GOA_from_Pendleton> = <Yes>
#10 [ 0.40977 ] <Ac_Operate_SA2_at_29Palms> = <Yes>

After _aii.process(dfin5_1)
Action:Ac_Move_GOA_to_MeadowsEW=0.474328
Action:Ac_Attack_USSTR_by_Seersucker_from_Vandenberg=0.465112
Action:Ac_Operate_SA2_at_MeadowsEW=0.45669
Action:Ac_Launch_Seersucker_from_Vandenberg_to_USSTR=0.453765
4128,15 62%
```

Ranked Action To Sim Mission

```
Select Cygwin
Ranked actions:
#0 [ 0.613991 ] <Ac_Move_GOA_to_MeadowsEW> = <Yes>
#1 [ 0.602873 ] <Ac_Move_SA2_to_MeadowsEW> = <Yes>
#2 [ 0.580711 ] <Ac_Move_GOA_from_Pendleton> = <Yes>
#3 [ 0.465112 ] <Ac_Attack_USSTR_by_Seersucker_from_Uandenberg> = <Yes>
#4 [ 0.453765 ] <Ac_Launch_Seersucker_from_Uandenberg_to_USSTR> = <Yes>
#5 [ 0.4376 ] <Ac_Move_GOA_to_29Palms> = <Yes>
#6 [ 0.41753 ] <Ac_Move_SA2_to_29Palms> = <Yes>
#7 [ 0.40977 ] <Ac_Operate_SA2_at_29Palms> = <Yes>
#8 [ 0.279958 ] <Ac_Operate_GOA_at_29Palms> = <Yes>
#9 [ 0.252792 ] <Ac_Operate_SA2_at_MeadowsEW> = <Yes>
#10 [ 0.237212 ] <Ac_Operate_GOA_at_MeadowsEW> = <Yes>

After _aii.process(dfin5_2)
Action:Ac_Move_GOA_to_MeadowsEW=0.613991
Action:Ac_Move_SA2_to_MeadowsEW=0.602873
Action:Ac_Move_GOA_from_Pendleton=0.580711
Action:Ac_Attack_USSTR_by_Seersucker_from_Uandenberg=0.465112
Action:Ac_Launch_Seersucker_from_Uandenberg_to_USSTR=0.453765
Action:Ac_Move_GOA_to_29Palms=0.4376
Action:Ac_Move_SA2_to_29Palms=0.41753
Action:Ac_Operate_SA2_at_29Palms=0.40977
Action:Ac_Operate_GOA_at_29Palms=0.279958
Action:Ac_Operate_SA2_at_MeadowsEW=0.252792
Action:Ac_Operate_GOA_at_MeadowsEW=0.237212
After FssXlator.importAiiActions
Entering AiiProxy.getTopAction
Processing 22Actions
After getTopAction
CHECKING ACTION NAME:Ac_Move_GOA_to_MeadowsEW
Setting Mission ID:3
Mission ID:3 is set
RANKED ACTION:Ac_Move_GOA_to_MeadowsEW
After sendObservableViaFile
AII Thread $leeping...
READY TO CALL SendMissionCommands
MISSION ID:3
c++: In SendMissionCommands...

c++: time_step=100
TIME:Time = <1200, 0, 0, 0>
NEW MISSION TIME:1405
c++: Mission 3
-- StateCommand - Command: 14 MC AssetType 506.94 Time = <1405, 2, 0, 0, 0> R
etask 0
Time till Next Command: D: Time = <0, 0, 0, 0, 0> S: -1
-- MotionCommand - Command: 2 move AssetType 506.94 Time = <1405, 0, 0, 0, 0>
Retask 2
Speed: 35 R: 0 D: 0 NumPts: 2
-- StateCommand - Command: 8 operate AssetType 506.94 Time = <1405, 1,
0, 0, 0> Retask 0
Time till Next Command: D: Time = <0, 0, 0, 0, 0> S: -1
PLAN Sequence 3 commands in the Plan.
-- MotionCommand - Command: 2 move AssetType 506.94 Time = <1405, 0, 0, 0, 0>
Retask 2
Speed: 35 R: 0 D: 0 NumPts: 2
-- StateCommand - Command: 8 operate AssetType 506.94 Time = <1405, 1,
0, 0, 0> Retask 0
Time till Next Command: D: Time = <0, 0, 0, 0, 0> S: -1
```

FSS Executing Mission

```
Select Cygwin
[00:29:00.639, 1740.64] ASSET: USS Roosevelt FA-18.39 the CurrentCommand is n
ow: 558
--- Target Sequence: FA-18 Range=6.75168
Missile::FireWeapon at t= 1740.64, randDraw= 0.34632, Pk= 0.9
Missile::FireWeapon at t= 1740.64, randDraw= 0.923344, Pk= 0.9
Weapon MISSED.
--- End Engagement ---

[00:29:00.639, 1740.64] ASSET: USS Roosevelt FA-18.39 the CurrentCommand is n
ow: 557

***** Vectoring obj USS Roosevelt FA-18 201.39 at t= [00:29:00.639, 1740.64] *
*****
senderId= 201, #pts= 2, Speed(km/hr)= 800 RefId: 2:

***** S_Asset::ProcessWeaponHit *****
t= 1747.39: MEADOWS EW SITE CommandPost hit by weaponType= 1111
Damage= 0; Intact= 0

10020> GUT=1800 wall=20.0016
Commander ::: VANDENBERG AFLD Air Defense Commander8 receiving a message of 345
2 bytes at Time = <1800, 0, 0, 0>
--- MotionCommand - Objectype: 305 Command: 2 move Assetype 305.133 Time =
<1905, 0, 0, 0> Retask 2
Speed: 120 R: 0 D: 0 NumPts: 2
[lat, lng, alt] = [34.5, -120.3, 1] degrees
[lat, lng, alt] = [34.33, -120, 0] degrees
--- InteractionCommand - Objectype: 305 Command: 3 engage Assetype 305.133
Time = <1905, 1, 0, 0> Retask 0
Targetype: 401 ID: 2 D-time: Time = <0, 0, 0, 0>
--- StateCommand - Objectype: 305 Command: 14 MC Assetype 305.133 Time = <1
905, 2, 0, 0> Retask 0
Time till Next Command: D: Time = <0, 0, 0, 0> Subsystem: COMPLETE
SYSTEM
WARNING: Cancel event ignored.
Event to cancel is in the past.
Event to cancel: Time = <0, 0, 0, 0>
Cancel request: Time = <1800, 0, 0, 0>
[00:30:21.138, 1821.14] ASSET: USS Roosevelt FA-18.35 the CurrentCommand is n
ow: 558
--- Target Sequence: FA-18 Range=3.64364
Missile::FireWeapon at t= 1821.14, randDraw= 0.434465, Pk= 0.9
Missile::FireWeapon at t= 1821.14, randDraw= 0.256188, Pk= 0.9
--- End Engagement ---

[00:30:21.138, 1821.14] ASSET: USS Roosevelt FA-18.35 the CurrentCommand is n
ow: 557

***** Vectoring obj USS Roosevelt FA-18 201.35 at t= [00:30:21.138, 1821.14] *
*****
senderId= 201, #pts= 2, Speed(km/hr)= 800 RefId: 2:

***** S_Asset::ProcessWeaponHit *****
t= 1824.78: CARRERAS TRANSFORMER STATION Power Plant hit by weaponType= 1111
Damage= 54; Intact= 46

1183,2 63%
```

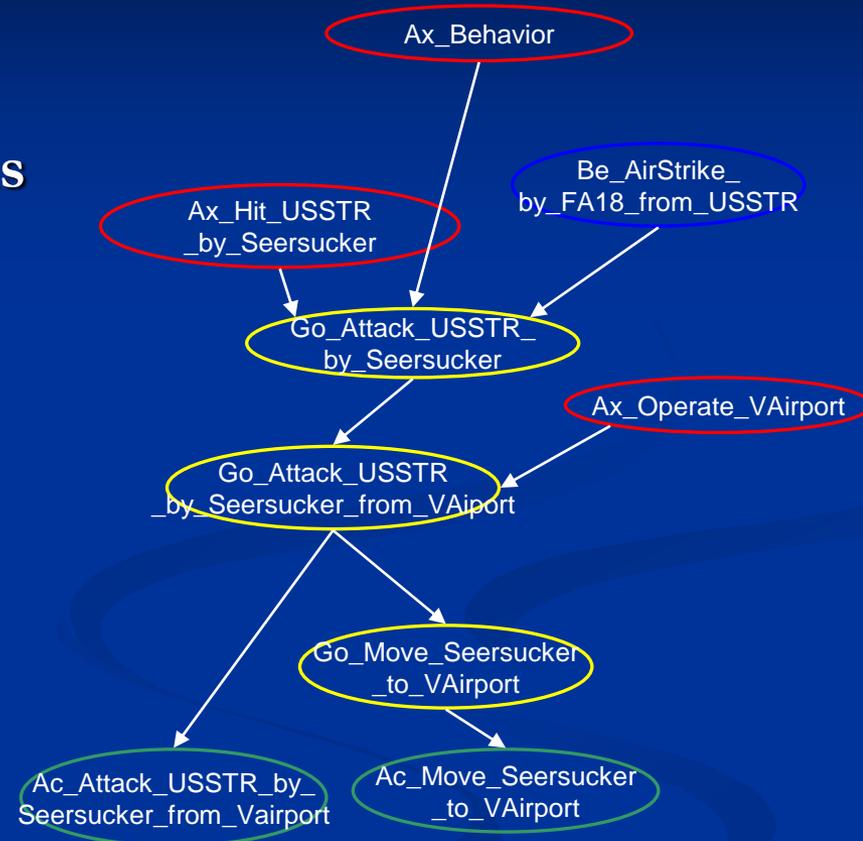
An example of BKF generation

- According to the scenarios, there is a goal to attack USS TR with sunburn, which is a new asset not in the working network.

- Assets include: USS TR, sunburn, VAirport, ...

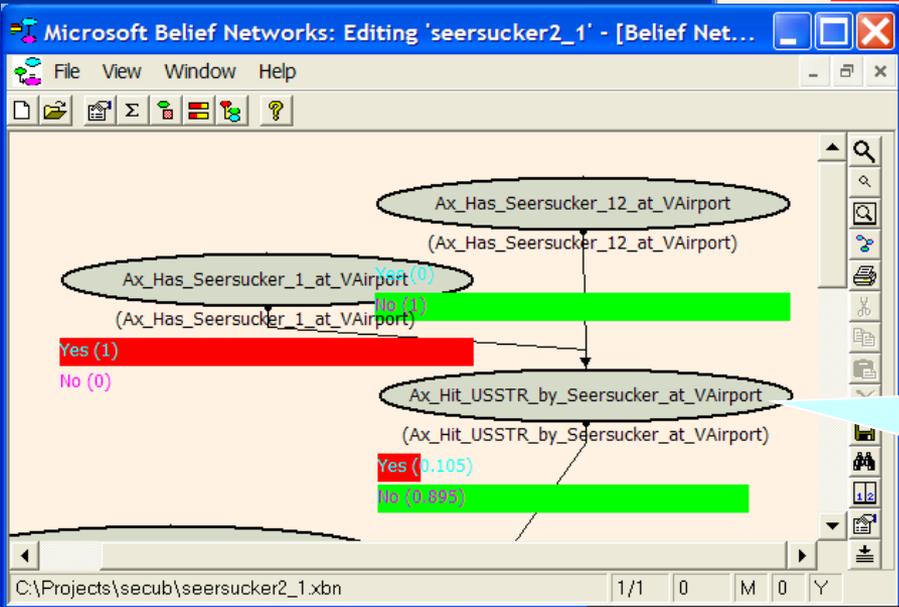
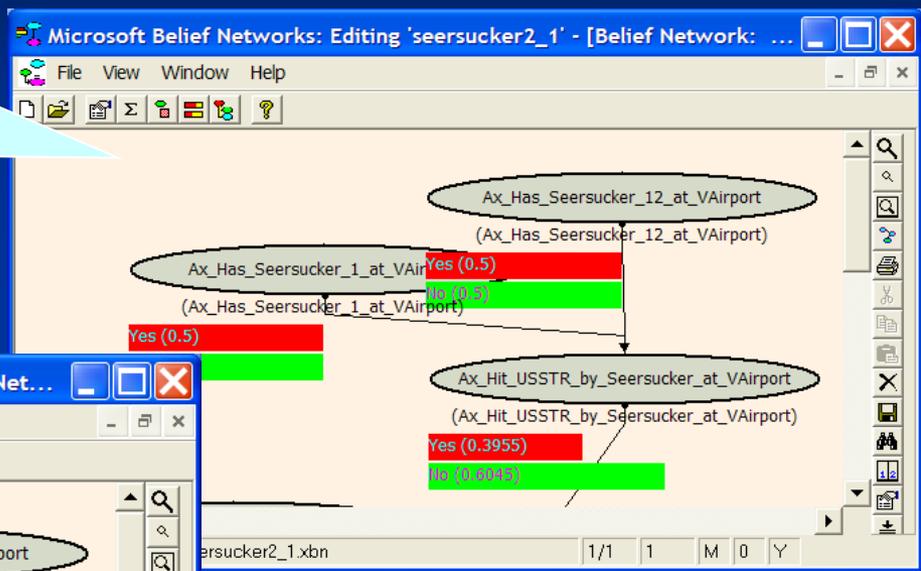
- Search in the library retrieves one fragment (shown next)

- Include, USS TR, VAirport, seersucker.
- Also the goals, axioms, and beliefs are very similar



Represent numbers of assets dynamically

Red possibly has 1 or 12 seersuckers from 2 different reports. Hit $p(\text{yes} = 0.3955, \text{no} = 0.6045)$

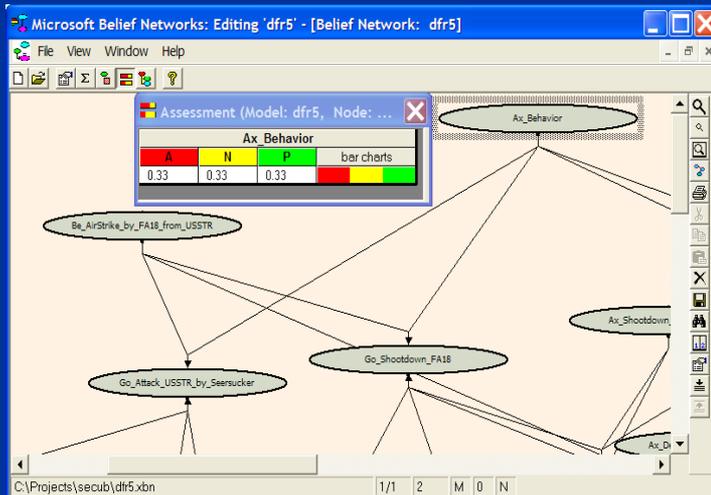


Now confirmed, they only have 1 seersucker. Hit $p(\text{yes} = 0.105, \text{no} = 0.895)$

Behavior and Affects

Ax_Behavior represents a soft factor of red (commander).

Three states:
Aggressive,
Neutral,
Passive



Assessment (Model: dfr5, Node: Go_Shutdown_FA18)

Ax_ShootDown_FA18	Parent Node(s)	Ax_Behavior	Go_Shutdown_FA18		bar charts
			Yes	No	
Yes	Yes	A	0.766	0.234	
		N	0.649	0.351	
		P	0.433	0.567	
	No	A	0.649	0.351	
		N	0.474	0.526	
		P	0.316	0.684	
No	Yes	A	0.474	0.526	
		N	0.211	0.789	
		P	0.141	0.859	
	No	A	0.374	0.626	
		N	0.061	0.939	
		P	0.041	0.959	

Assume the probability for the neutral states (N) is p_n ,
The Probability for aggressive states (A) is: $p_n + 0.33 * (1.0 - p_n)$
The Probability for passive states (P) is: $(1 - 0.33) * p_n$

Social, Political, and Cultural Factors in Adversarial Behavior

- Soft factors are those factors that influence adversarial intent in their decision making process, which include social, cultural, religious, political, economic and psychological issues.
- **Team:** Dartmouth, IHMC, Virginia Tech, and UConn
- **Sponsor:** AFOSR [FY 06 – FY 09]

Objectives

- Design and develop a computational model for *inferring adversarial intent and behavior*
- Build and employ social, cultural, and political data-driven models to *explore and explain* (in addition to modeling) adversarial attitudes and behaviors

Our study: Terror attacks

- To maximize data availability use recent Palestinian-Israeli conflict.
- Unambiguous measures: E.g., No. of attacks, No. casualties for 5 factions (PIJ, Hamas, PLFP, Fateh, Al-Aqsa Martyr's Brigade).
- Monthly sums January, 1999- Dec. 2005
- Four independent sources for each datum → test intersource reliability.

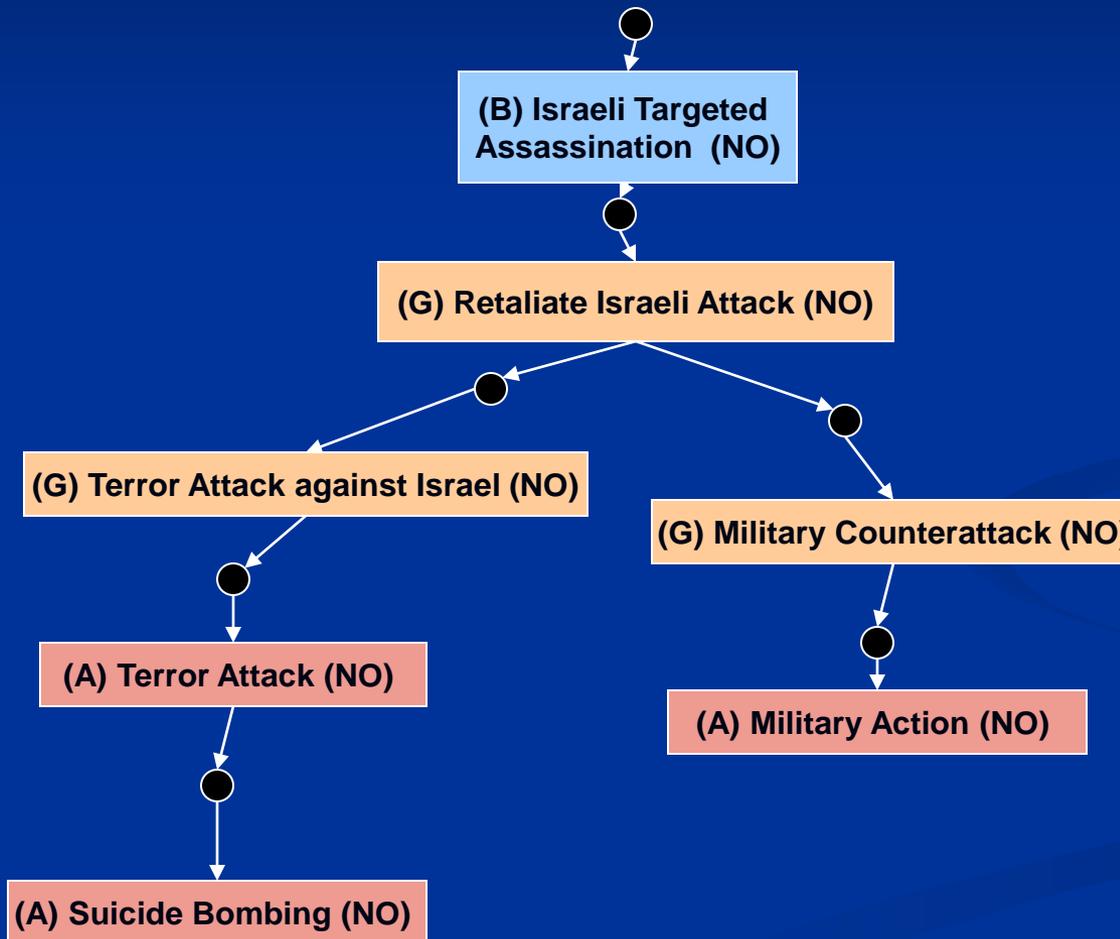
Our study: Context variables

- Data on popular Palestinian political attitudes, including support of each faction, suspicion/trust in Palestinian Authority and “peace process,” and justification of terrorism.
- Actions by Israeli Defense Forces (IDF: not completely reported to date).

Sample preliminary Results: Palestinian & Israeli Politics

- Casualties by IDF decrease Palestinian support for peace process and increase support for attacks against Israeli civilians.
- Increased Palestinian popular support for attacks increases the likelihood of attacks by smaller factions (PFLP, PIJ) but not for larger factions (Hamas, Fateh).
- Perceived corruption in PA relates to support for Hamas and attacks by Hamas.

Constructing BKB Fragments from Terrorism Attack Scenario



“Arafat convinced Hamas to suspend military actions after Sept. 11, 2001 on the condition that Israeli targeted assassination stop.”

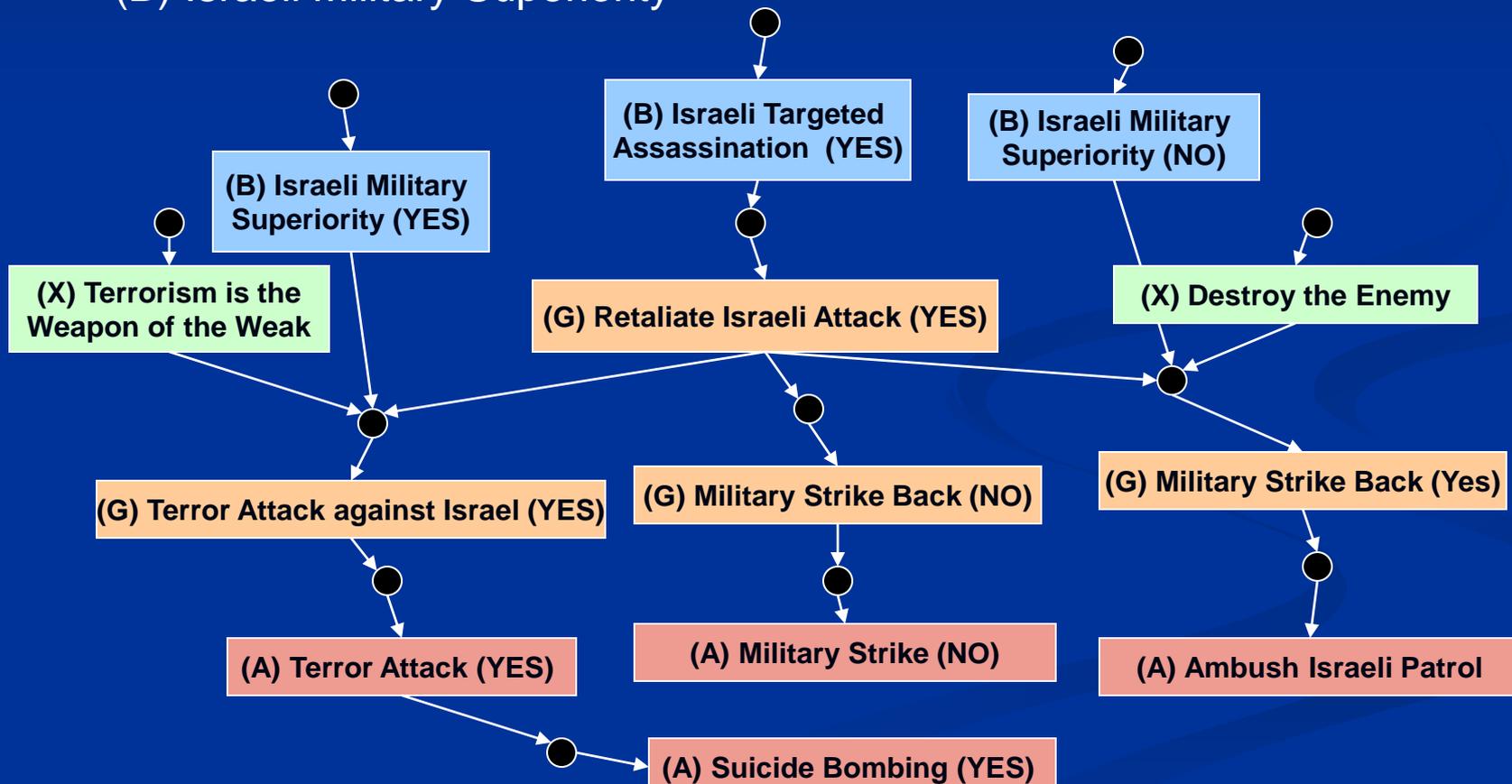
Mia Bloom (2005)
“Dying to Kill, the allure of suicide terror”

An explanation follows from the logic that violence is often retaliatory; “The al Ibrahimi Mosque massacre opened the doors of revenge in Palestinian like never before” (Mazin Hammad, cited in “Dying to Kill”).

Also:

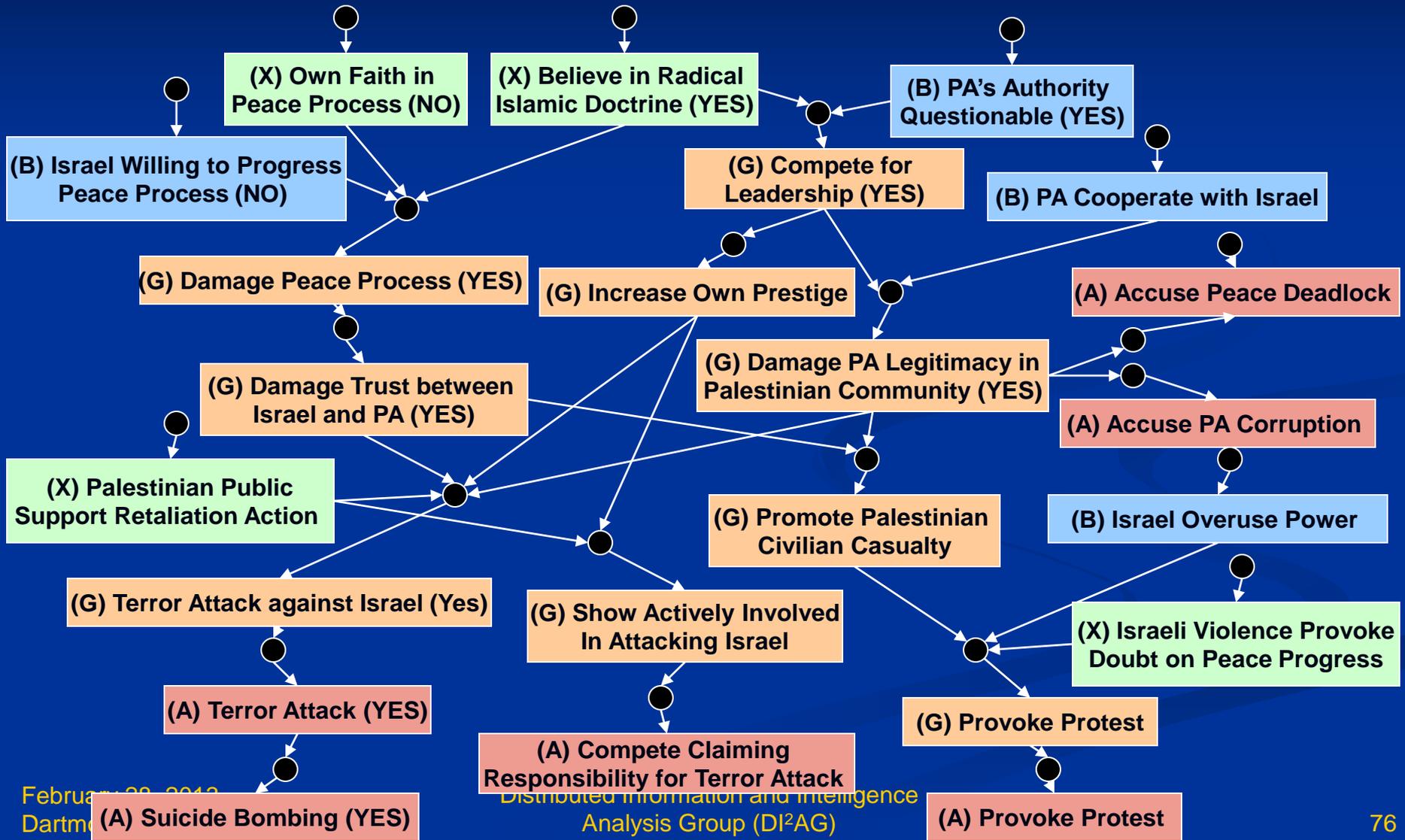
(X) Terrorism is the weapon of the weak

(B) Israeli Military Superiority



Another view of the reason behind suicide bombing: Competing for the leadership in Palestinian community, when public has no hope in peace and supports violence for revenge.

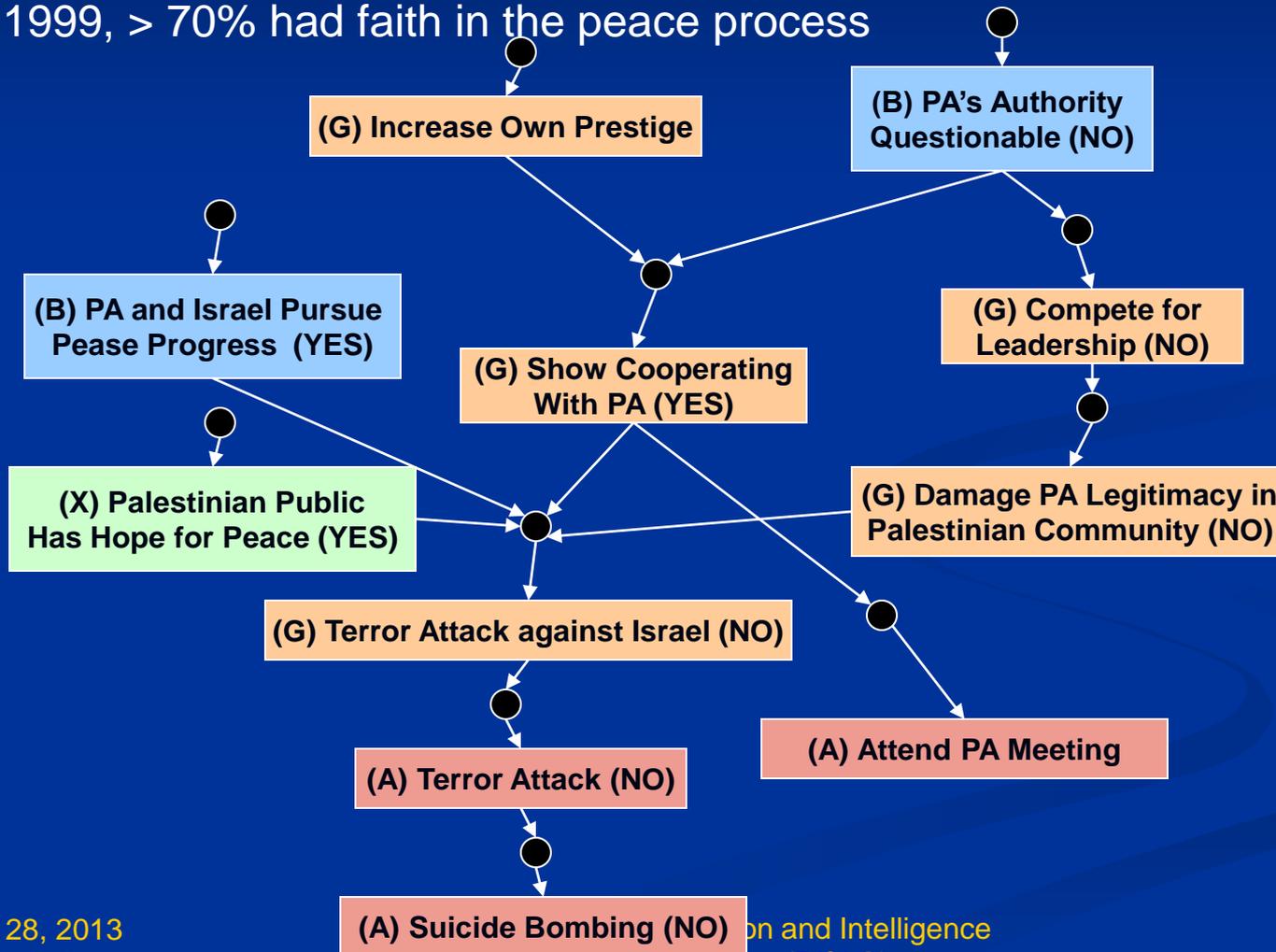
(1) Increasing own profile; (2) damage PA's authority; and (3) damage peace process



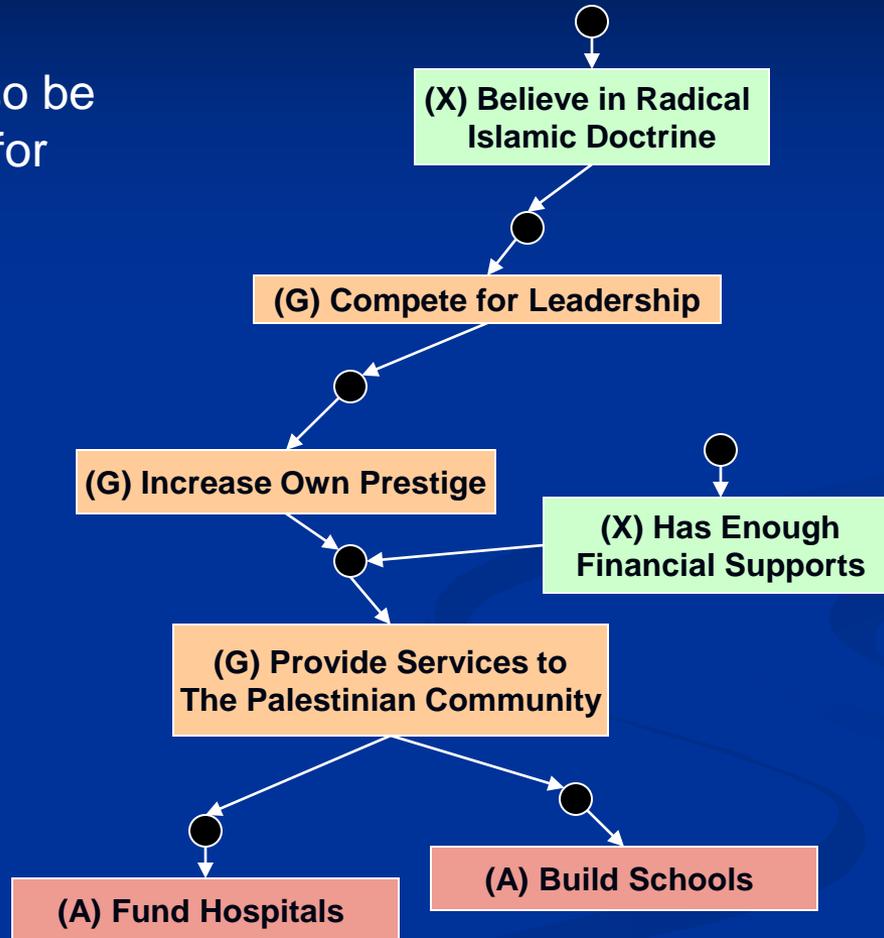
- **PA document:** suicide bombing was much more a purely political matter ...
- **Andrew Kydd and Barbara F. Walter:** Violence plays a spoiler role to the peace process. It weakens the moderates (PA) and makes the other side (Israel) become more uncertain.
- **James Bennet:** Having seen peace initiatives melt before in previous waves of violence, Israelis, like Palestinians, were already deeply skeptical of the new plan.
- **Sheikh Ahmed Yassin and Dr. Abdel Aziz Rantisi (Hamas leaders):** Suicide bombings were intended to both undermine the legitimacy of the PA and negatively affect the peace process.
- ...
- (cited in “Dying to Kill”).

One observation: When Palestinian public has hope for the peace process and PA's Authority is unchallengeable, then stop violent action and show cooperation with PA.

In Nov. 1998, 75% Palestinians ceased to support suicide operation;
 In 1999, > 70% had faith in the peace process

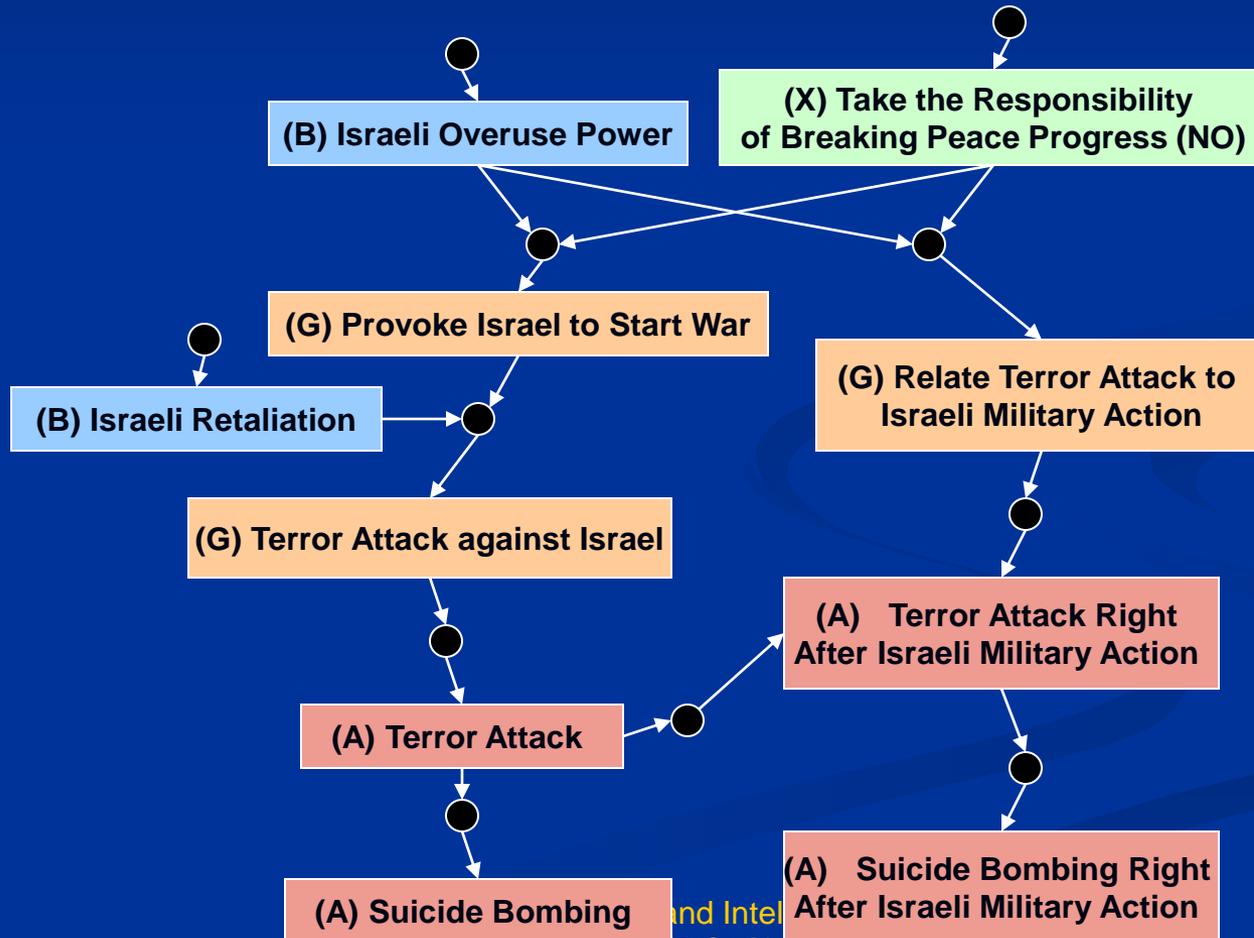


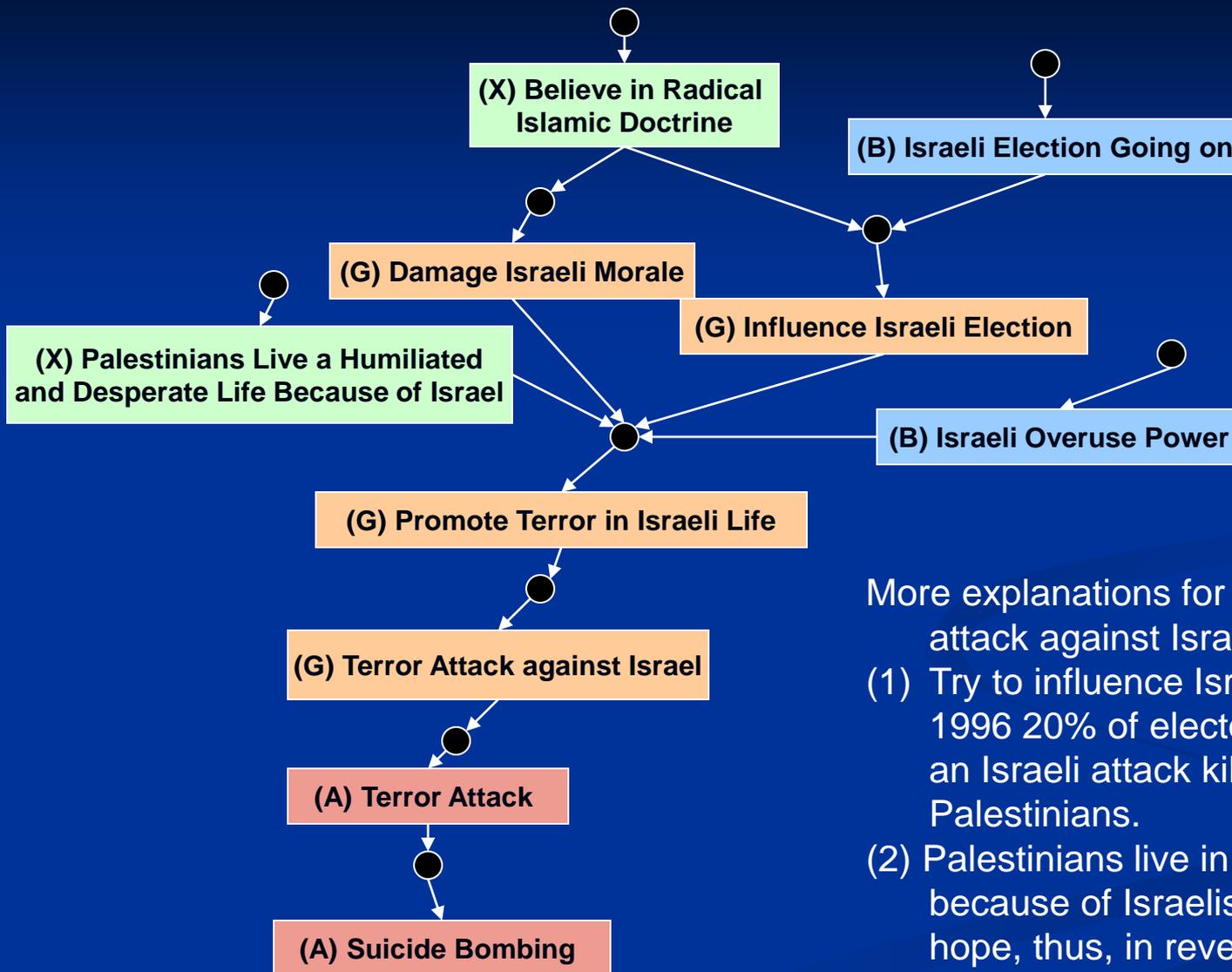
Other actions can also be taken in competition for leadership.



More reasons for using terrorism attacks against Israel:
 Do not want to take the responsibility of breaking peace progress
 but try to have Israel start the war.

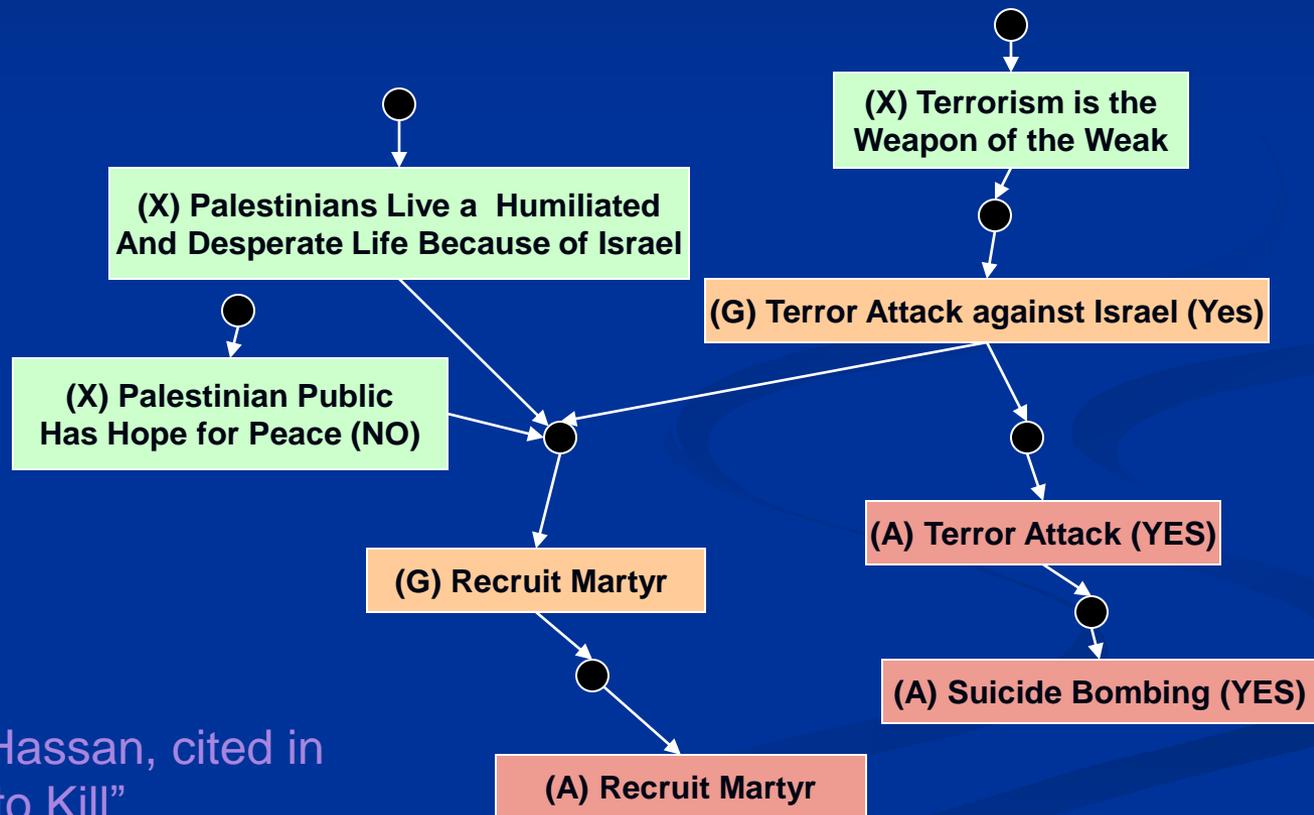
Richard Lebow's, "justification of hostility" (cited in "Dying to Kill")





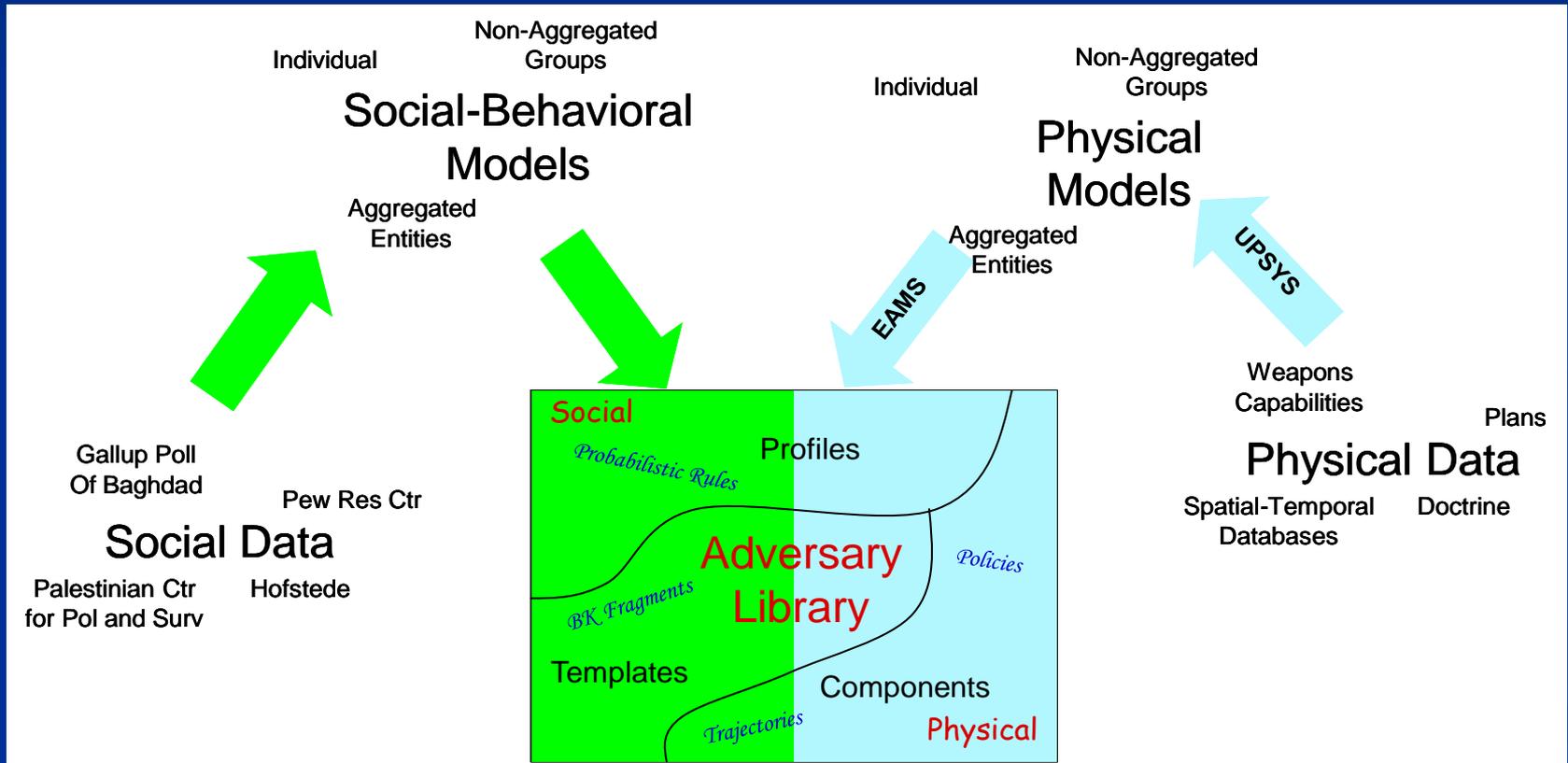
- More explanations for using terrorism attack against Israel:
- (1) Try to influence Israeli election; 1996 20% of electorate boycotted after an Israeli attack killed 102 Palestinians.
 - (2) Palestinians live in desperation because of Israelis, and there is no hope, thus, in revenge, want to provoke terror in Israeli life too.

Some factors that influence Palestinian individuals to be recruited as martyrs



Nasra Hassan, cited in
"Dying to Kill"

Adversary Library

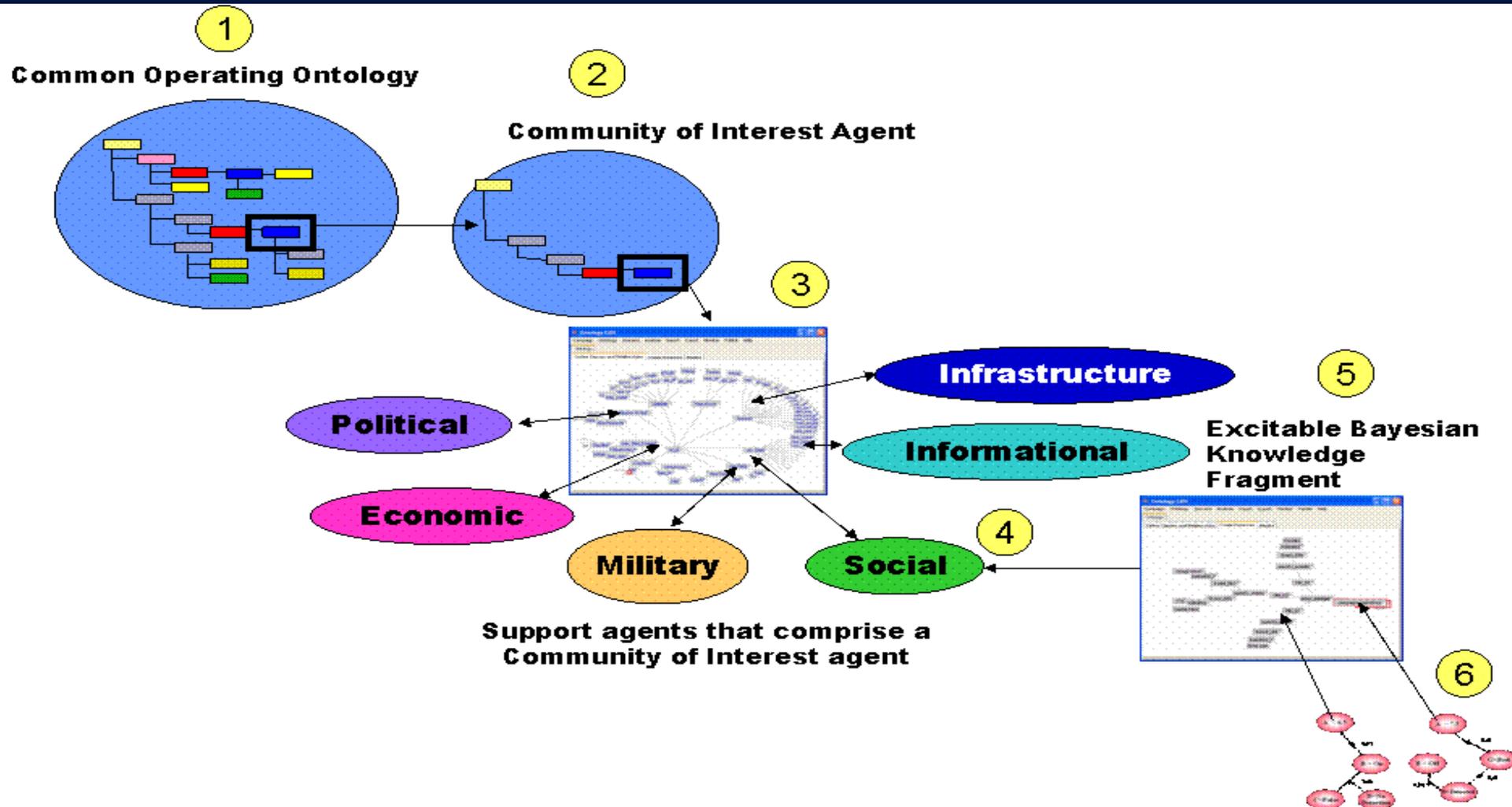


Properties of BKF Approach for Intent Modeling

- Intuitive and straightforward to employ
 - Automated fusion – dynamic construction
- Allows explanations with explicit indication of expert source
- Resolves conflict and loopy problems as well as others
 - Competing theories, SME conflict
- Theoretically sound – satisfies probability theory

- Provide “easy” methodology for analysts/SMEs to input knowledge to model and infer intent
- Library of Fragments aims to permit reuse and domain transportability

Dynamic Adversarial Gaming Algorithm (DAGA)



Team: Securboration, Inc. and Dartmouth College

Sponsor: AFOSR Phase II STTR [FY 06 - 08]

February 28, 2013
Dartmouth College

Distributed Information and Intelligence
Analysis Group (DI²AG)

Overall Goal

- Develop algorithmic techniques to accurately model and forecast Community of Interest (COI) response to social, cultural, political and economic actions.
 - Enable forecasts based not only on current situation and adversary capabilities, but also on adversary's cultural dimensions and 'soft-factors'.
 - Provides adaptive strategy selection in multi-cultural adversarial games and related simulations within the context of an agent-based dynamic adversarial environment.

Communities of Interest: Details COI Individual-Religious | Details COI Groups-Religious | Details COI Individuals-General | Details COI Groups-Secular

Coalition Actions

- Coalition Raid, Cause Civilian Casualties and Destruction
- Clear Evidence

- Coalition Allies Facing Pressure of Withdrawing
- Clear Evidence

- Coalition Assassinate Insurgency Leader
- Clear Evidence

- Religious Leader Condemns Heathenry
- Clear Evidence

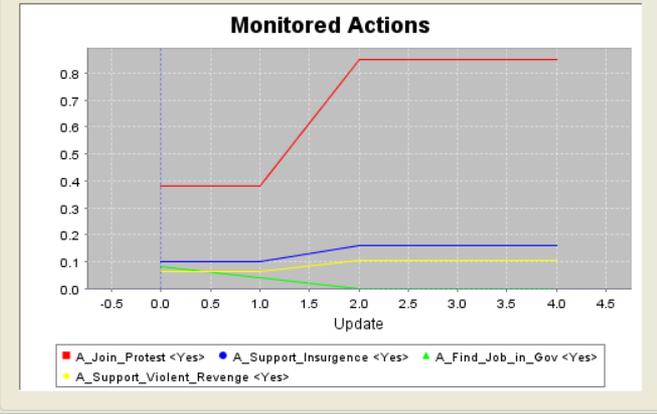
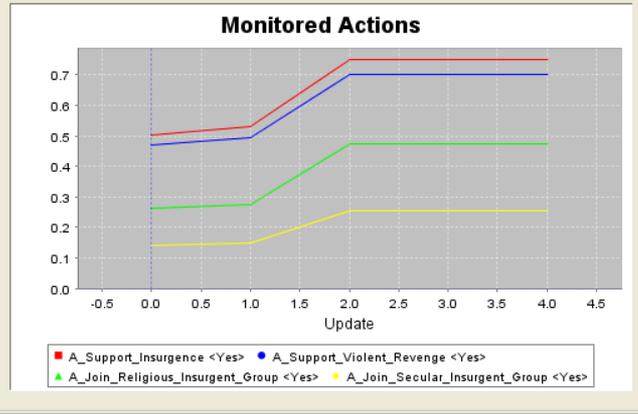
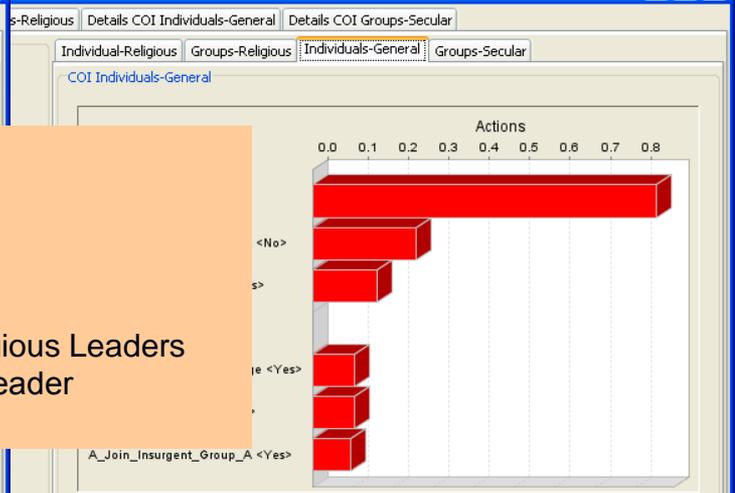
- Coalition Distribute Supplies
- Clear Evidence

- Coalition Meet Religious Leaders, and Religious Leaders Call for Peace
- Clear Evidence

- Coalition Assign Withdraw Timetable
- Clear Evidence

Update

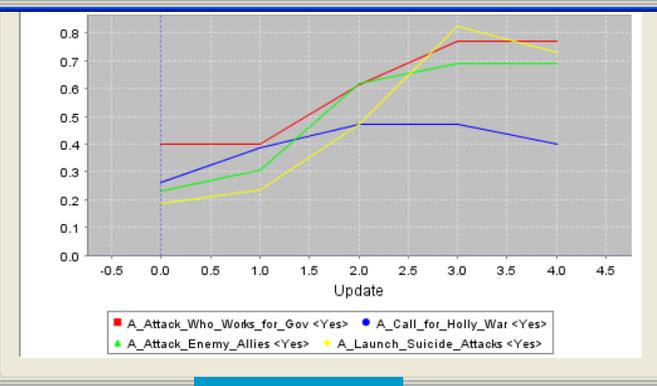
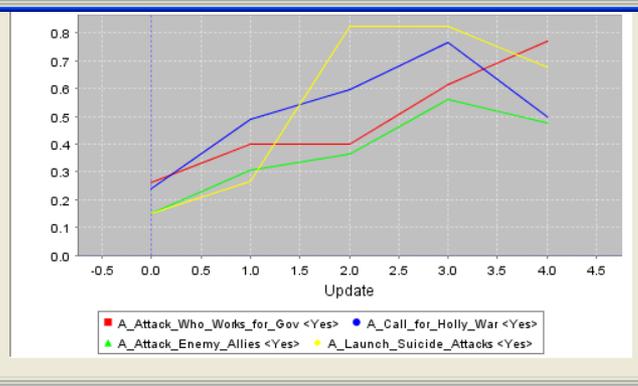
- ### Sequence 3
1. Coalition Raid
 2. Coalition Assassinate Insurgent Leaders
 3. Religious Leader Condemns Heathenry
 4. Coalition Distribute Supplies
 5. Coalition Meet Religious Leaders, and Religious Leaders Call for Peace (Clear Evidence 'Religious Leader Condemns')



- Coalition Meet Religious Leaders, and Religious Leaders Call for Peace
- Clear Evidence

- Coalition Assign Withdraw Timetable
- Clear Evidence

Update



Conclusion

- Adversarial modeling is actually fun!

Active Collaborators

- Securboration, Inc. (L. Krause, L. Lehman, B. McQueary, T. Stritzinger)
 - Institute for Human Machine Cognition (Dr. J. Bradshaw, Dr. P. Feltovich, Dr. R. Hoffman)
 - Virginia Tech (Dr. E. Santos)
 - University of Connecticut (Dr. F. Pratto)
 - Indasea, Inc.
-
- Dr. Qunhua Zhao will demo DAGA and EAMS tomorrow

Related Work

- Modeling Deception and Deception Intent
- User Modeling, Decision Making, and Perception
- Modeling Analysts and Analytic Process
 - Enhancing Collaboration Among Analysts
 - Intelligent Information Retrieval
 - Multi-Document Summarization
- Culturally Infused Adversarial Social Networks
- Adversarial Modeling Work
 - See Chapter 1 in *Adversarial Reasoning: Computational Approaches to Reading the Opponents Mind* (Eds. A Kott and W. McEneaney), CRC Press, 2006.