



# Can a Bayesian Approach Add Value to Deterrence Planning?

---

Marc Warburton

SAIC

USSTRATCOM/J525

Deterrence Assessment Branch

4 February 2008

# Agenda

---



- Modeling a Decision Calculus
- Implementation in Software
- Integrating US Actions
- COA Evaluation
- Sensitivities
- Pros/Cons

*Note:*

*All data, scenarios, actions, and relationships are strictly notional, represent no real situation, and are used here for illustrative purposes only.*

# Simplified Adversary Decision Scenario

---



- Decision maker intends to invade neighbor, whose defense relies on reinforcements from a distant, nuclear-armed ally
- Overall strategic objectives:
  - Achieve war aims (i.e, defeat and occupy neighbor); and,
  - Not get killed in the process
- Decision maker's nuclear weapons question: "To Use, or Not to Use"
- Calculus involves cost, benefits, consequences of restraint, and uncertainties.

# Nominal “Deterrence Framework” Approach



| <b>Should I Use Nuclear Weapons?</b>       | <b>Value</b> | <b>Probability</b> |
|--|--------------|--------------------|
| B1: Reduce Enemy A/C Sortie Rate           | H            | H                  |
| B2: Enemy's Allies Deny Basing             | H            | M                  |
| B3: Enemy Capitulates                      | VH           | VL                 |
| C1: Enemy Destroys Us with Nuclear Weapons | VH           | L                  |
| C2: Enemy Hangs Me as War Criminal         | VH           | H                  |
| CR1: We Are Defeated and Occupied          | VH           | M                  |
| BR1: Maintain Neutrality of Our Ally       | M            | VH                 |

Probability: What is the probability I will achieve that cost or benefit?  
Value: How important is the cost or benefit to my objectives?  
Uncertainty: Contained in the “squishiness” of VH, H, M....sort of.

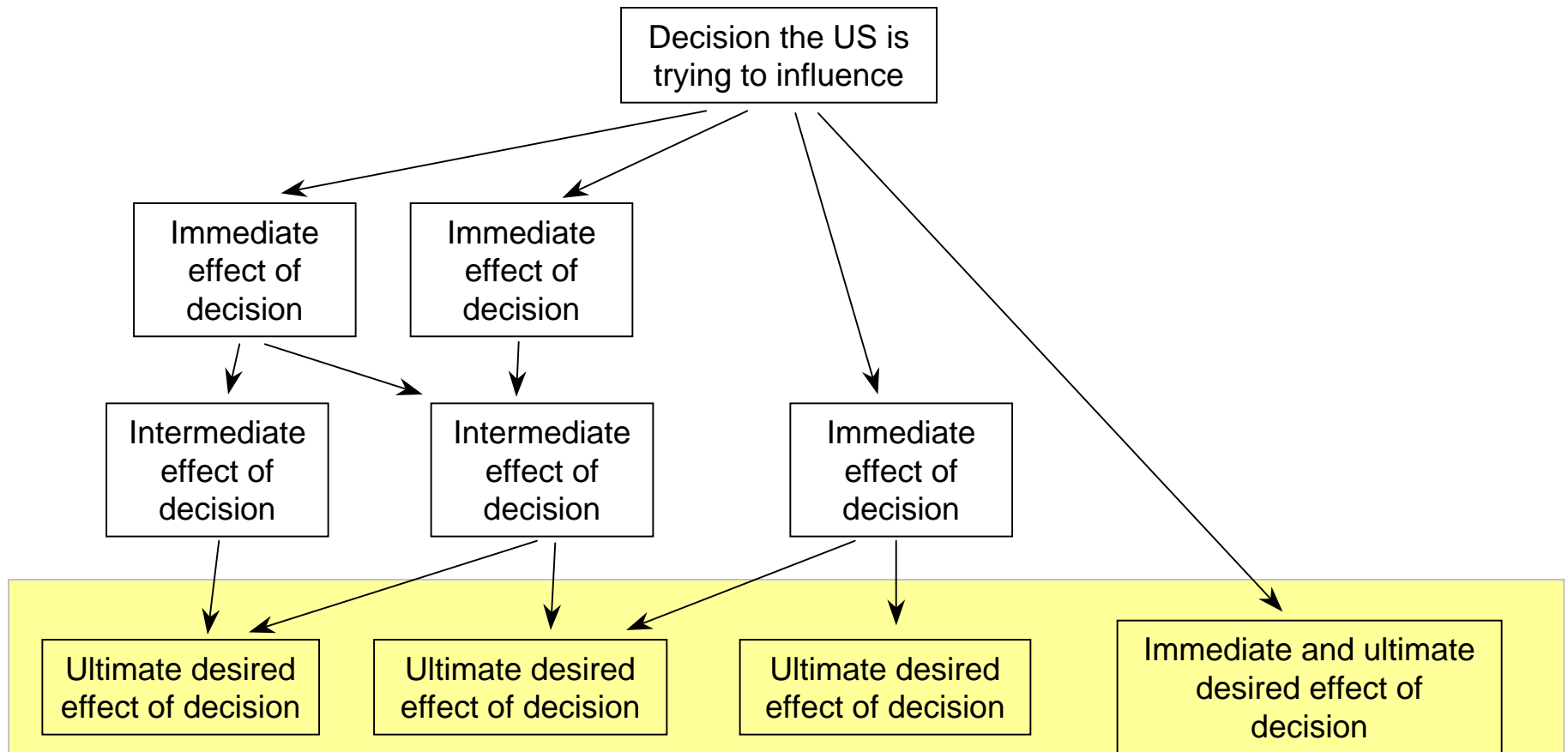
# Issues with this Approach

---



- Where do the probability ratings H, M, VL... come from?
  - The mind of a good analyst steeped in the adversary profile
- Where do the Value ratings come from?
  - The analyst's judgment of the impact of the parameter on the adversary's war aims
    - ✓ This aspect of SDAL methodology is unstructured
- Can Bayes help?

# Modeling Decision Drivers

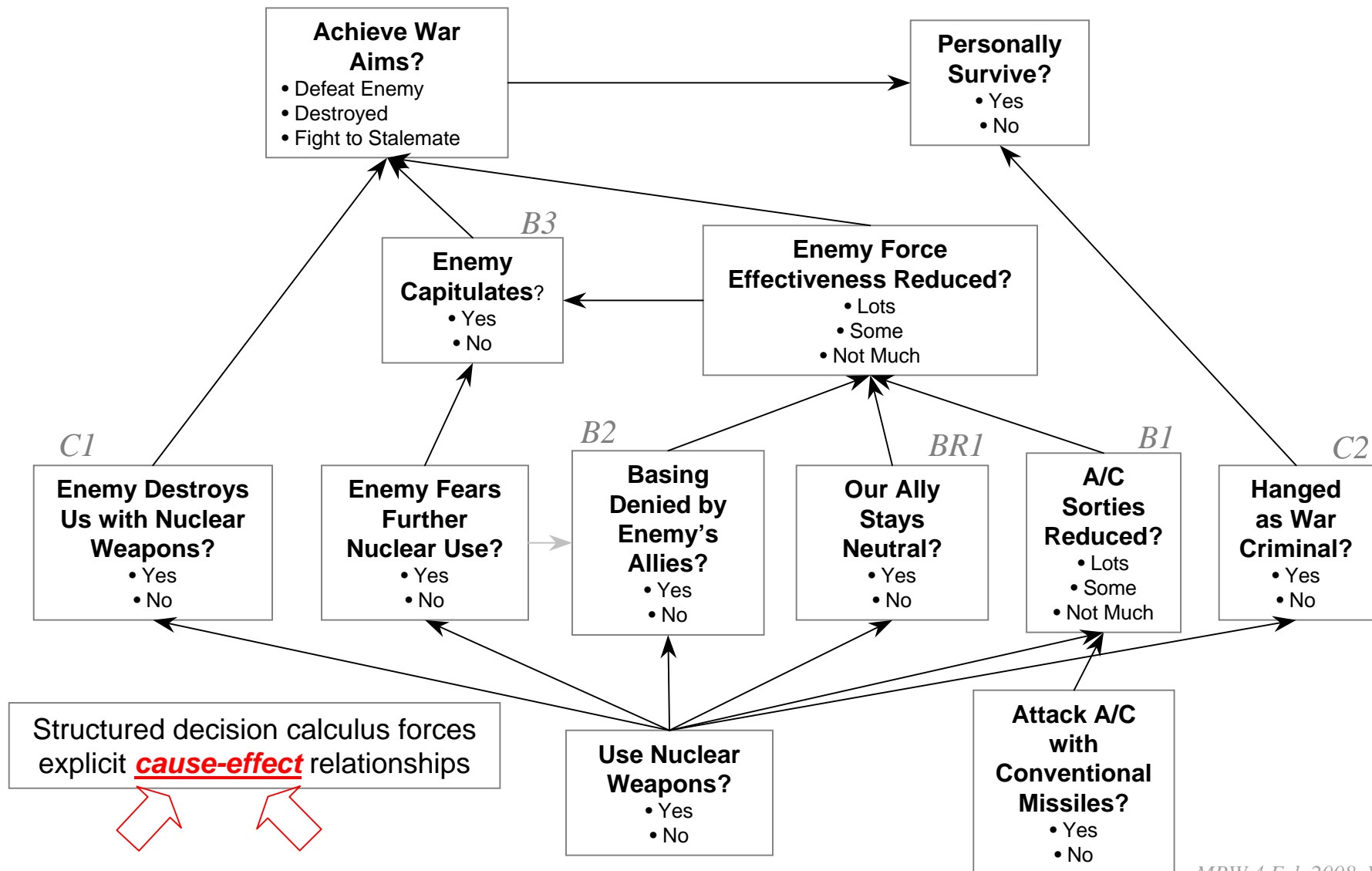


*Ultimate desired effects may be of differing importance to the decision maker*

*Cost, benefits, and consequences of restraint are given their importance by how much they contribute to ultimate effects*

*Decision is made (or not) based on its contribution to the effects at this “ultimate impact” level – which can be negative!*

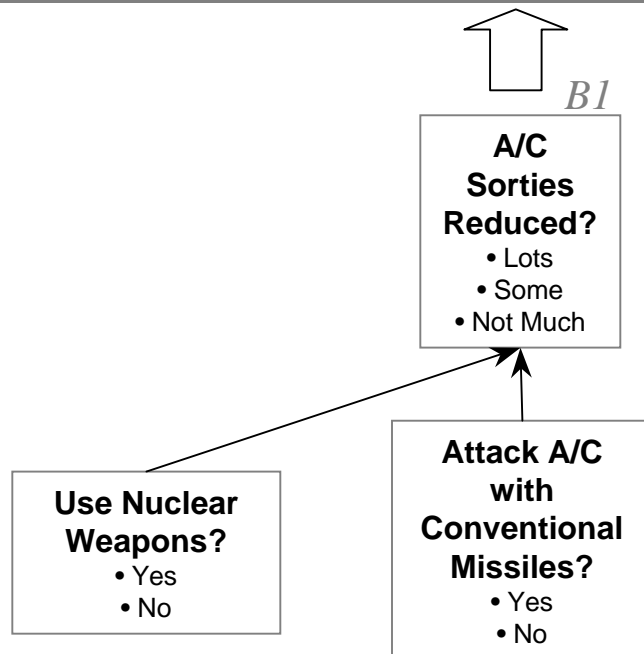
# Beginning Decision Calculus Structure



# Conditional Probability Tables



| Use Nuclear Weapons? | Attack A/C with Conventional Missiles? | A/C Sorties Reduced? |      |          |
|----------------------|--|----------------------|------|----------|
|                      |  | Lots                 | Some | Not Much |
| Yes                  | Yes                                    | 0.9                  | 0.1  | 0        |
| Yes                  | No                                     | 0.8                  | 0.2  | 0        |
| No                   | Yes                                    | 0.3                  | 0.3  | 0.4      |
| No                   | No                                     | 0                    | 0    | 1        |



# Conditional Probability Tables



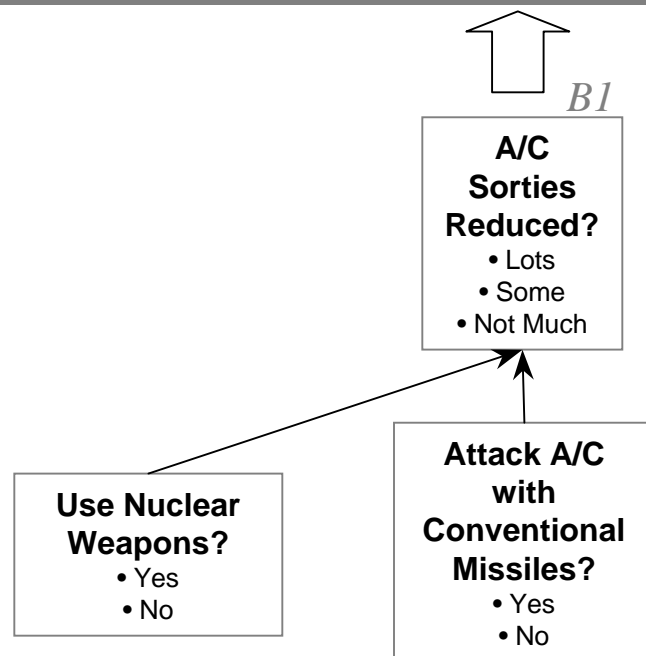
| Use Nuclear Weapons? | Attack A/C with Conventional Missiles? | A/C Sorties Reduced? |      |          |
|----------------------|--|----------------------|------|----------|
|                      |  | Lots                 | Some | Not Much |
| Yes                  | Yes                                    | 0.9                  | 0.1  | 0        |
| Yes                  | No                                     | 0.8                  | 0.2  | 0        |
| No                   | Yes                                    | 0.3                  | 0.3  | 0.4      |
| No                   | No                                     | 0                    | 0    | 1        |

- Uncertainty explicitly included
- Restraint is automatically included

*Benefit of using nuclear weapons ( $B1$ )*

*Cost of restraint ( $\neq \bar{B1}$ )*

*Both depend on whether conventional missiles used or not!*



These numbers can come from an adversary-perspective assessment of their attack effectiveness. This is an intel or analysis requirement.

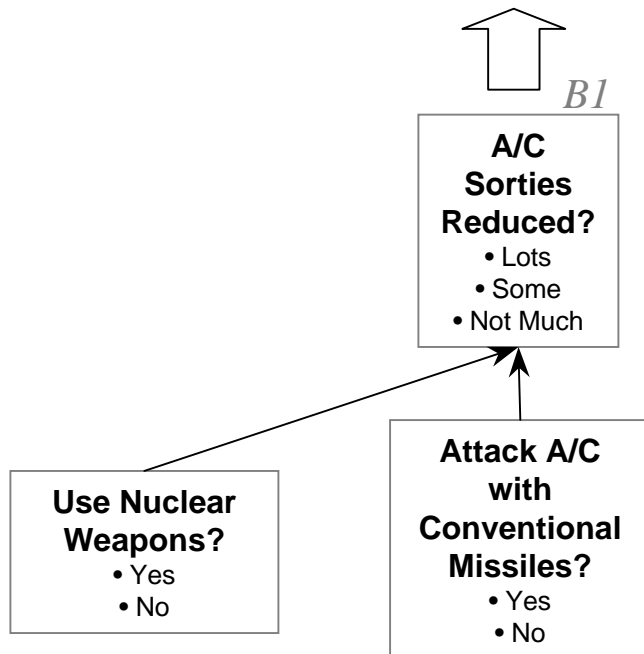
# Conditional Probability Tables



| Use Nuclear Weapons? | Attack A/C with Conventional Missiles? | A/C Sorties Reduced? |      |          |
|----------------------|--|----------------------|------|----------|
|                      |  | Lots                 | Some | Not Much |
| Yes                  | Yes                                    | 0.9                  | 0.1  | 0        |
| Yes                  | No                                     | 0.8                  | 0.2  | 0        |
| No                   | Yes                                    | 0.3                  | 0.3  | 0.4      |
| No                   | No                                     | 0                    | 0    | 1        |

*Benefit of using nuclear weapons (B1)*

*Cost of restraint ( $\neq \bar{B1}$ )*

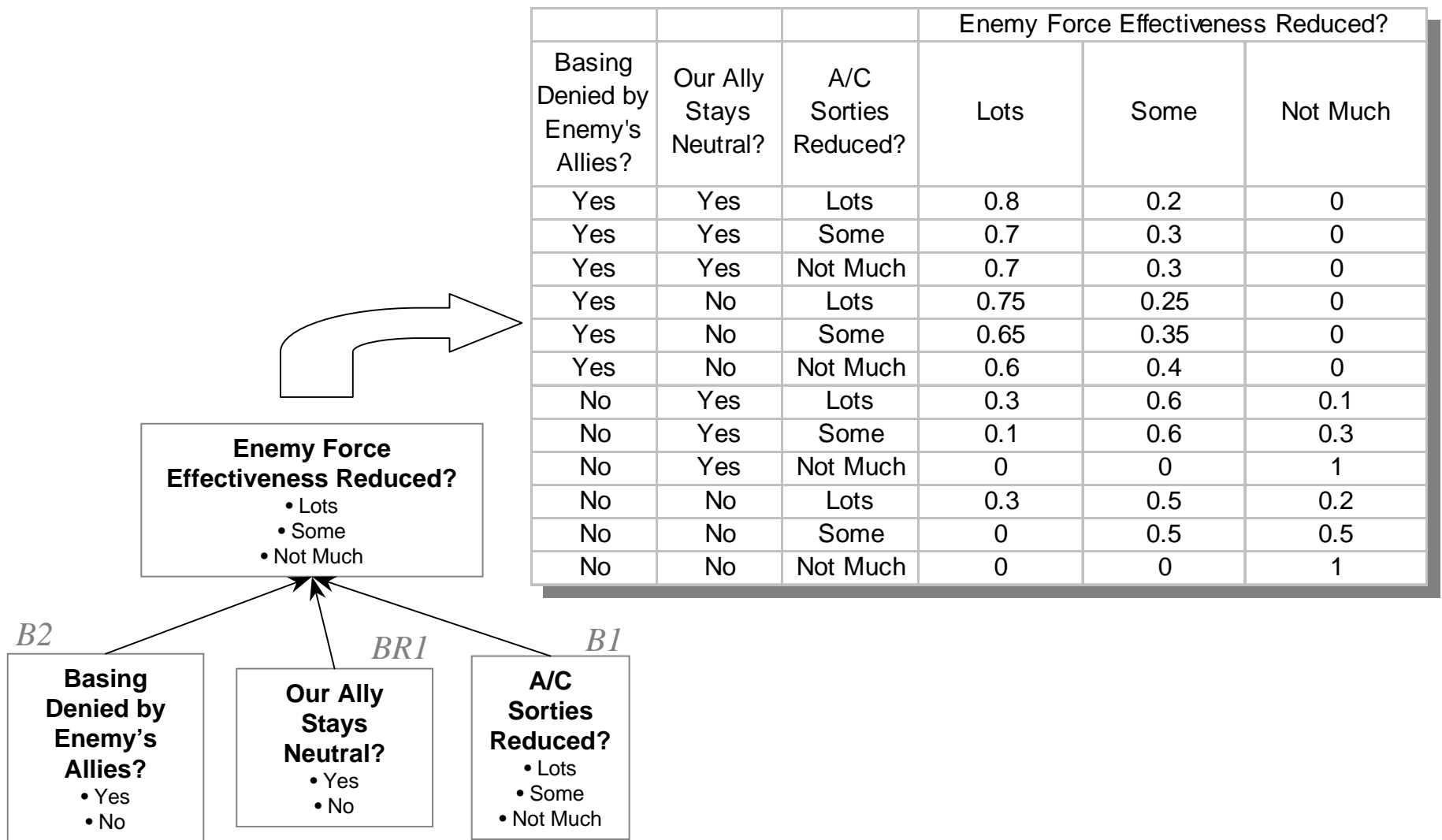


*Deterrence framework Value, somewhat removed...*

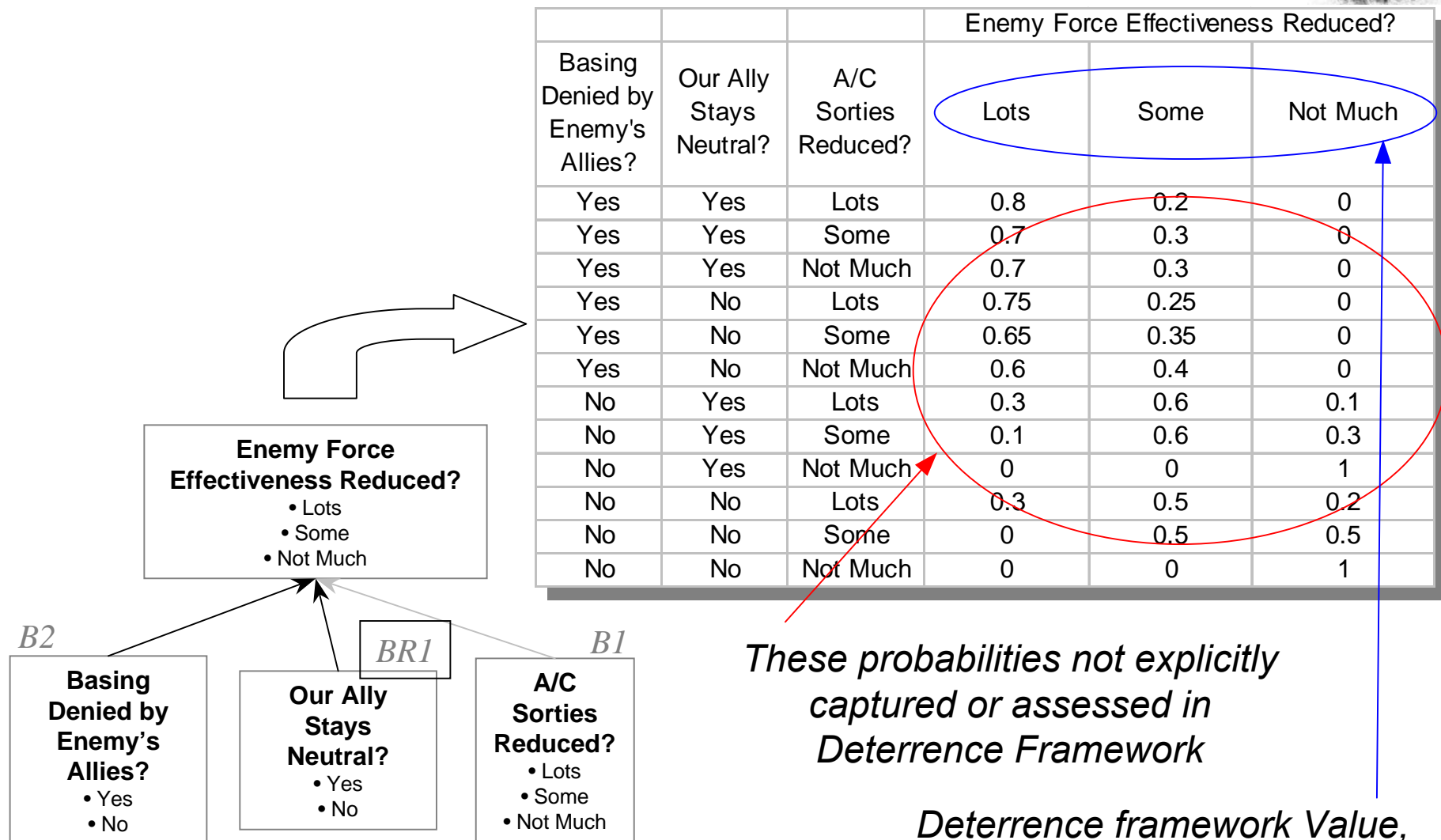
*Deterrence framework Probability*

*Conditional effects and uncertainty not included in SDAL methodology*

# Intermediate Probability Tables



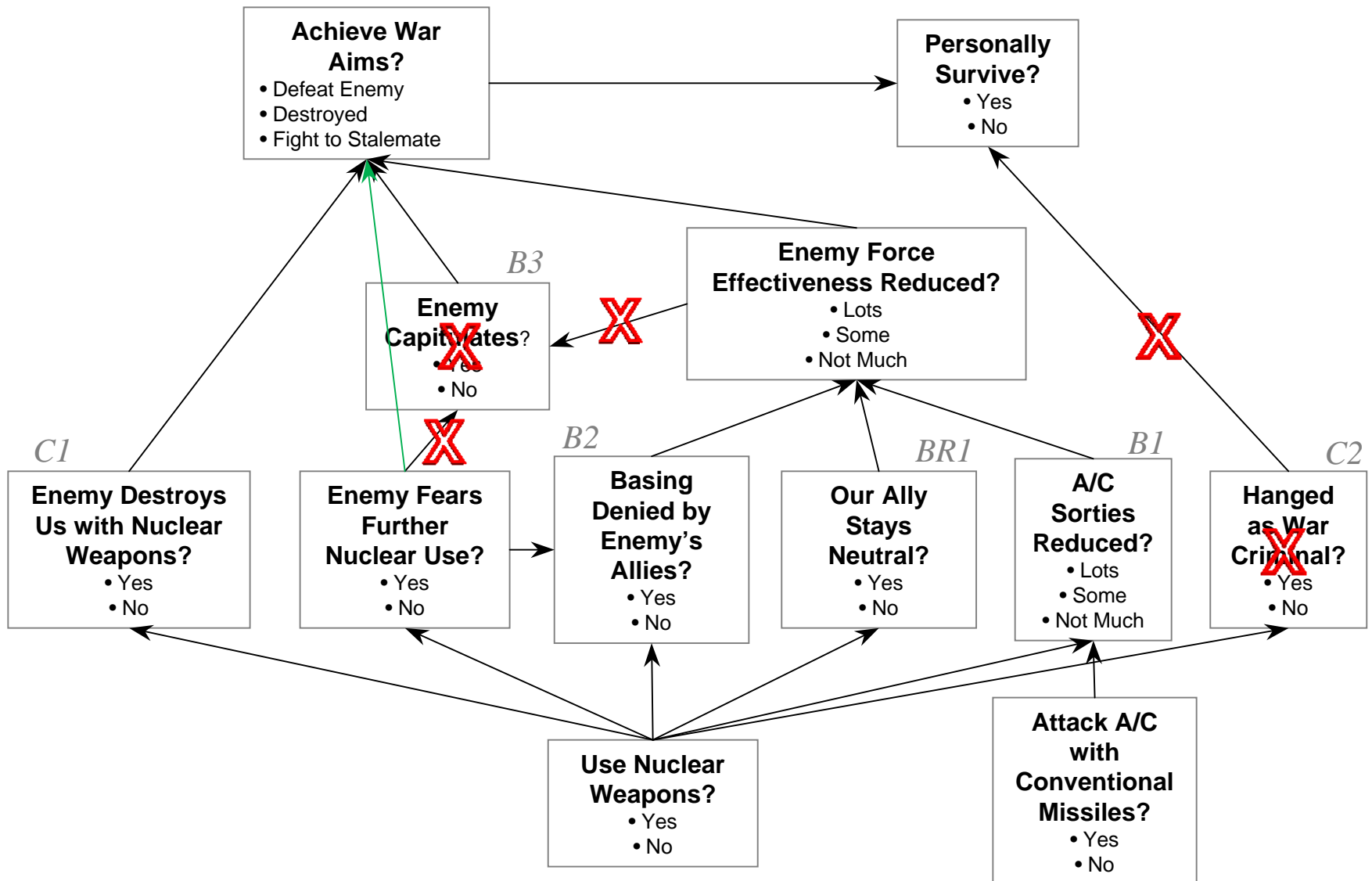
# Intermediate Probability Tables



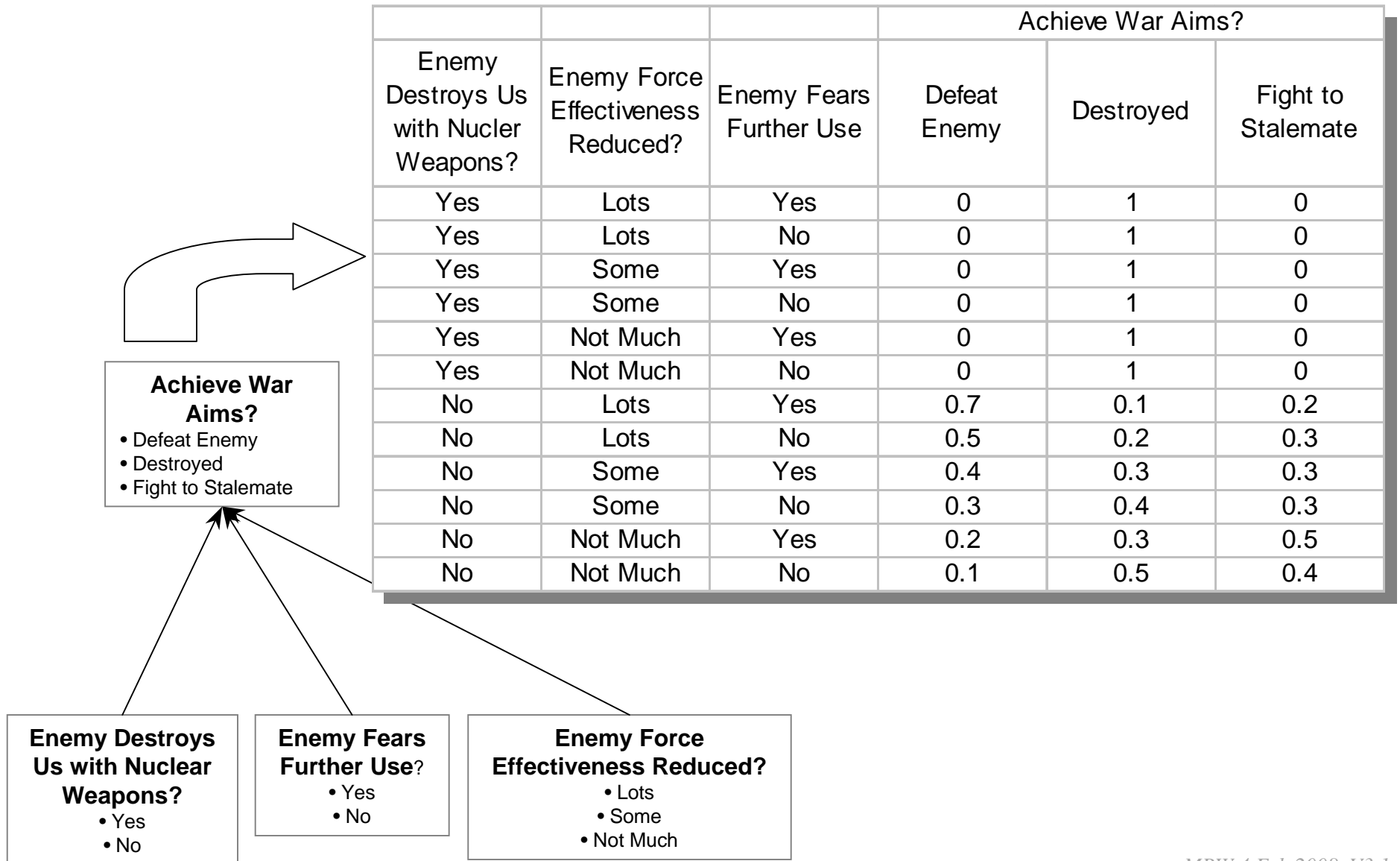
*These probabilities not explicitly captured or assessed in Deterrence Framework*

*Deterrence framework Value, getting closer to bottom line...*

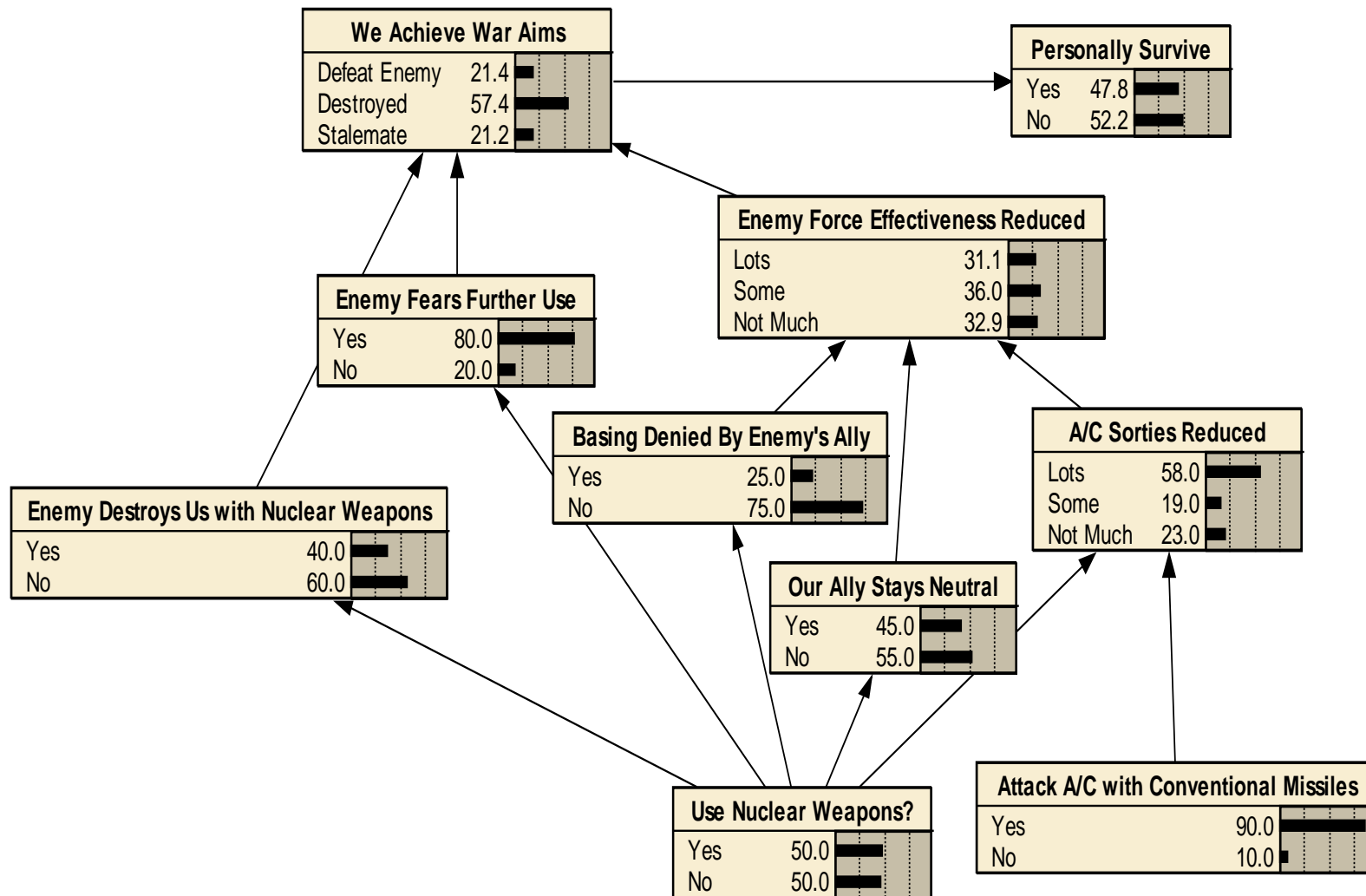
# Problem – This Model Doesn't Work



# Fixed It....



# Netica Implementation

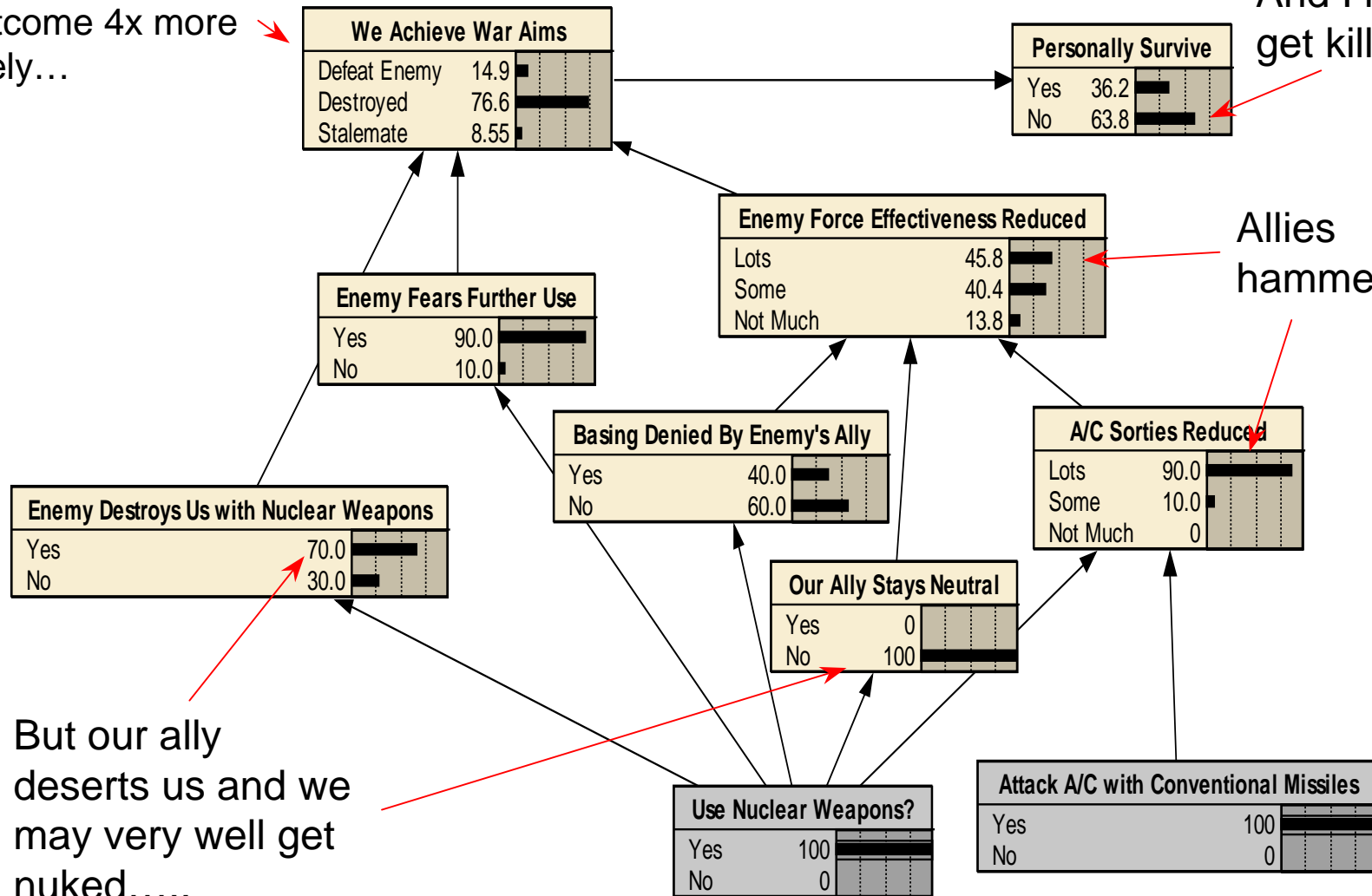


# What if I Use Nuclear Weapons?



Bottomline: Bad outcome 4x more likely...

And I might get killed...



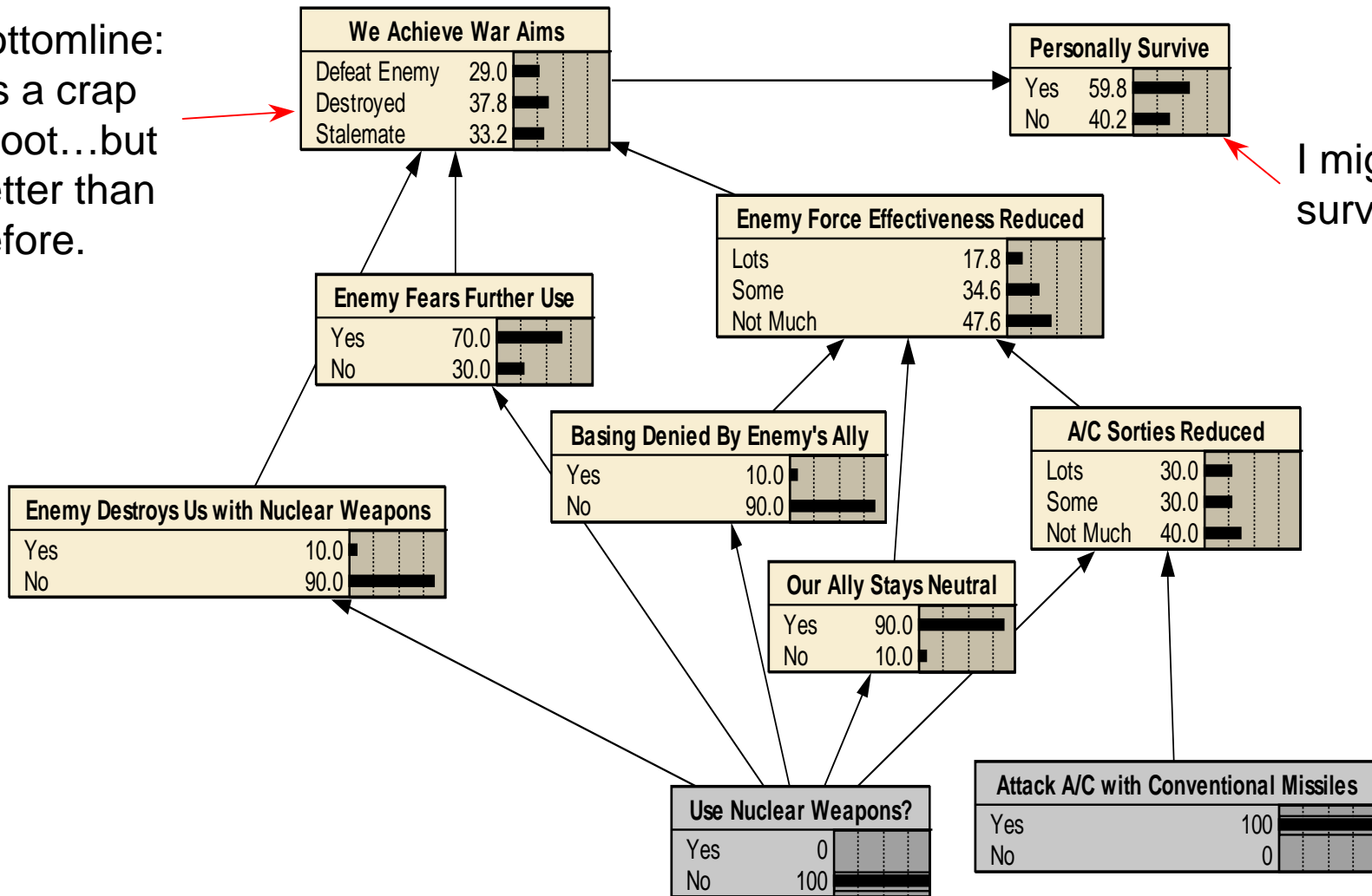
But our ally deserts us and we may very well get nuked.....

Allies hammered....

# What if I Don't?



Bottomline:  
It's a crap  
shoot...but  
better than  
before.

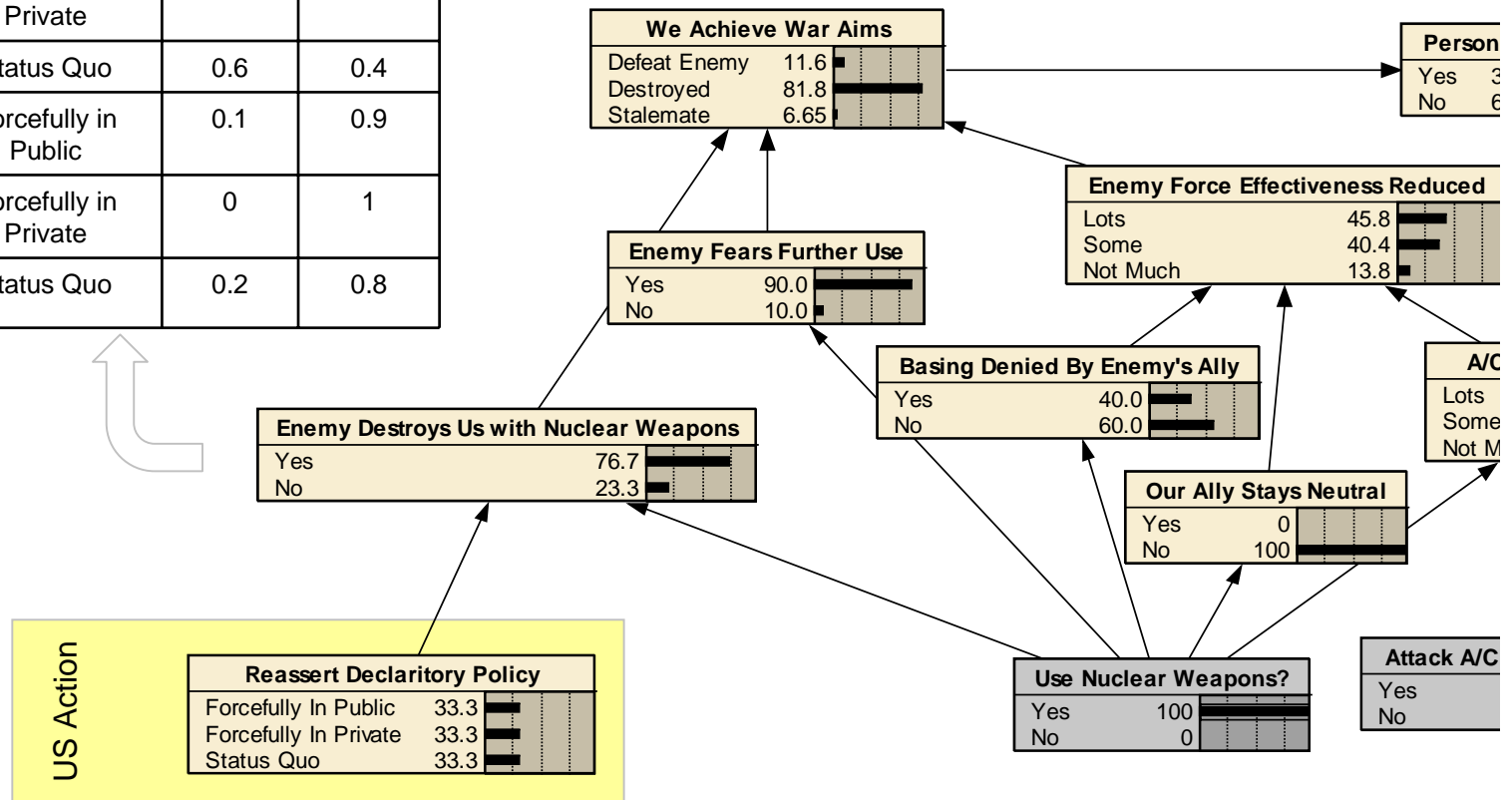


I might  
survive...

# Integrating US Actions....



| Use Nuclear Weapons | Reassert Declaratory Policy | Enemy Will Destroy Us |     |
|---------------------|-----------------------------|-----------------------|-----|
|                     |                             | Yes                   | No  |
| Yes                 | Forcefully in Public        | 0.8                   | 0.2 |
| Yes                 | Forcefully in Private       | 0.9                   | 0.1 |
| Yes                 | Status Quo                  | 0.6                   | 0.4 |
| No                  | Forcefully in Public        | 0.1                   | 0.9 |
| No                  | Forcefully in Private       | 0                     | 1   |
| No                  | Status Quo                  | 0.2                   | 0.8 |



# Noted Illustrative Rationale



Meaning, "If you use nuclear weapons we will nuke you." (E.g., a pledge to retaliate)

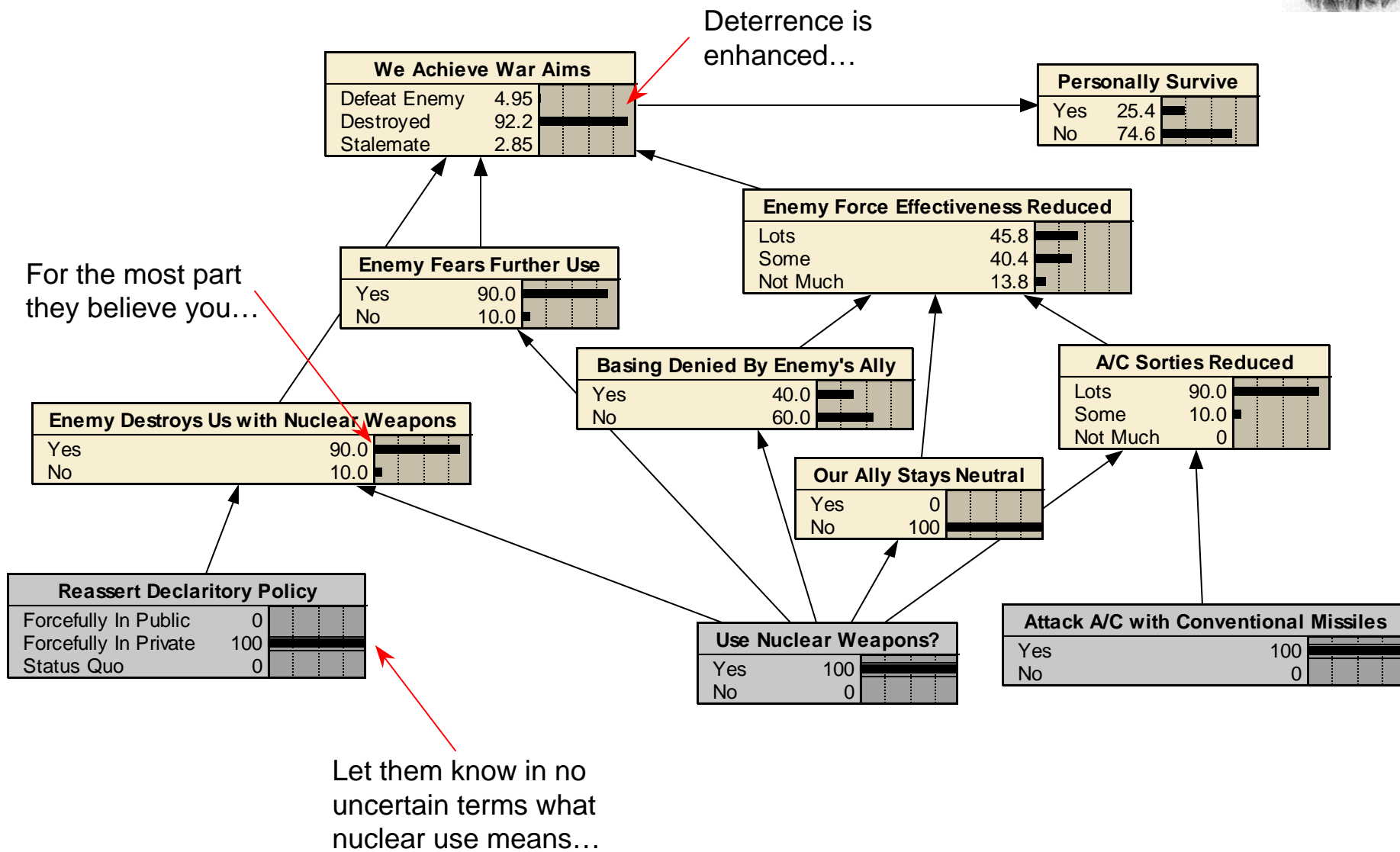
| Use Nuclear Weapons | Reassert Declaratory Policy | Enemy Will Destroy Us |     |
|---------------------|-----------------------------|-----------------------|-----|
|                     |                             | Yes                   | No  |
| Yes                 | Forcefully in Public        | 0.8                   | 0.2 |
| Yes                 | Forcefully in Private       | 0.9                   | 0.1 |
| Yes                 | Status Quo                  | 0.6                   | 0.4 |
| No                  | Forcefully in Public        | 0.1                   | 0.9 |
| No                  | Forcefully in Private       | 0                     | 1   |
| No                  | Status Quo                  | 0.2                   | 0.8 |

## Rationale

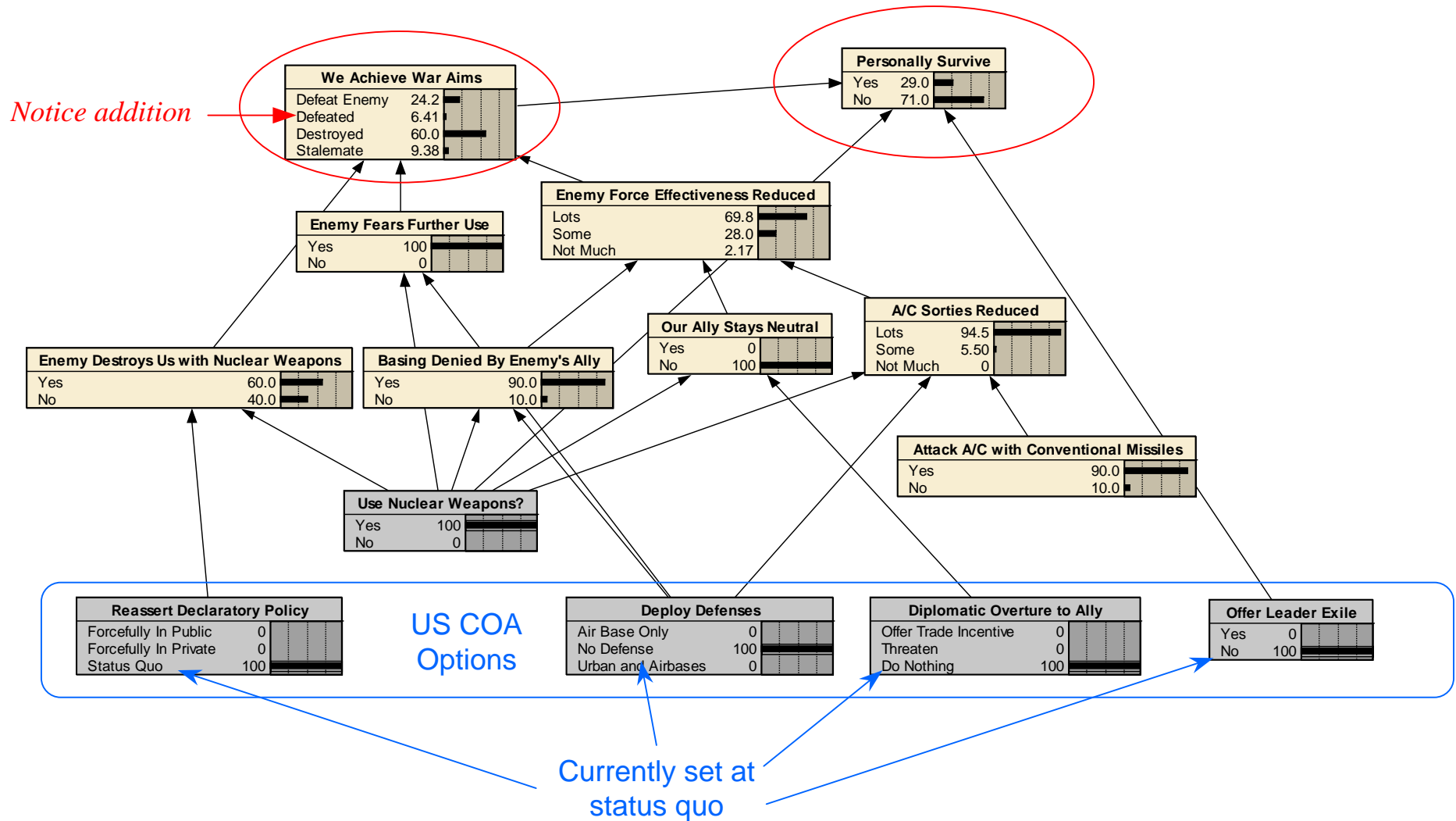
- Crazy Americans might do it
- Boy, sounds like they really will
- Significant chance they will chicken out
- Someone may convince the president to nuke us
- They promised and I believe them
- They probably won't do it

Meaning, "If you don't use nuclear weapons we won't nuke you." (E.g., a no-first use pledge)

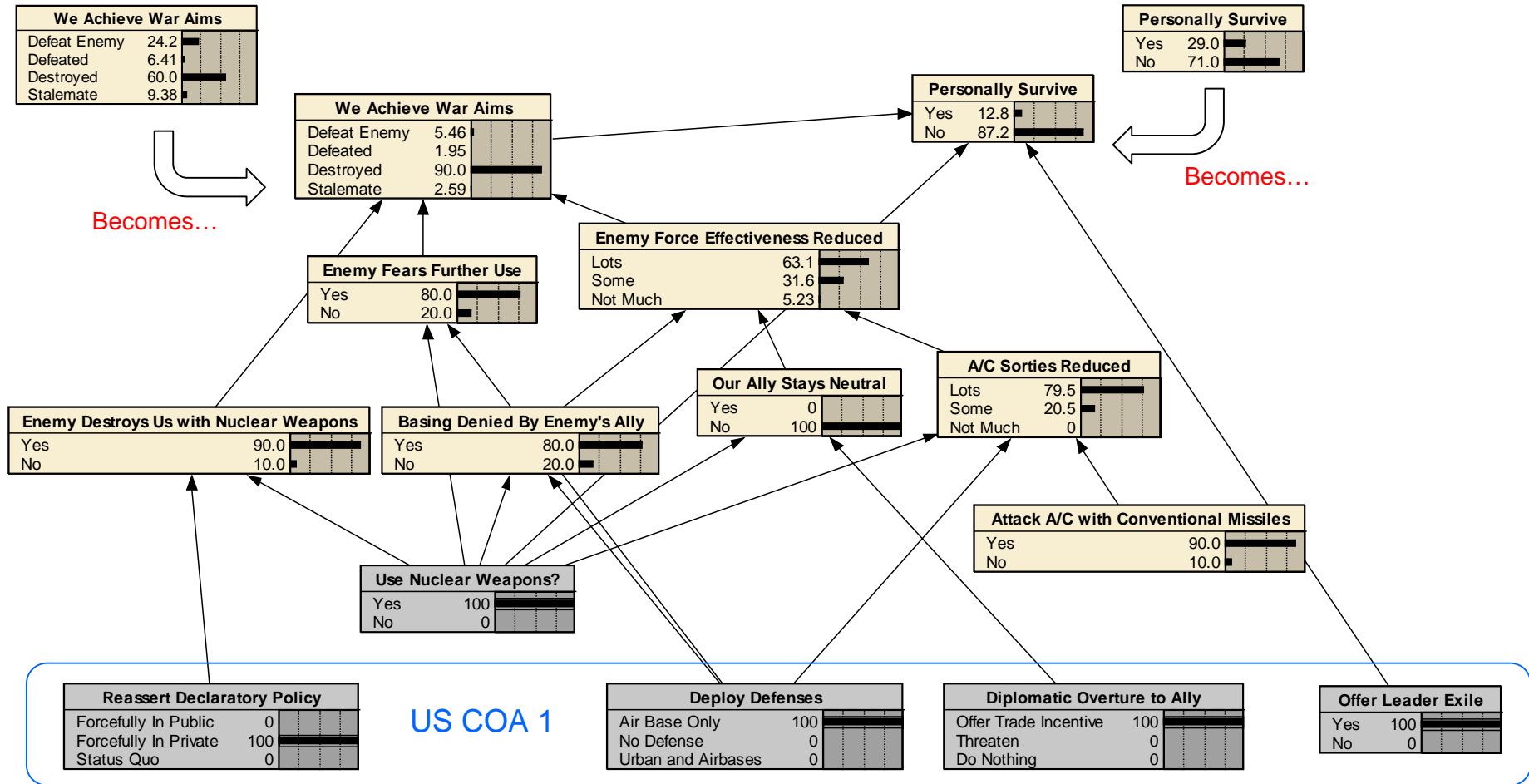
# Impact of US Actions....



# Developing a COA “Package”



# COA 1 Applied



# US COA Evaluation in the Adversary's Frame of Mind



| Adversary's Probability of End-State Given US COAs (%) | Status Quo | COA1 (Softer)  | COA 2 (Harder)   |
|--|------------|--|--|
|  |            | <ul style="list-style-type: none"> <li>• Current Declaratory Policy</li> <li>• No Defenses</li> <li>• No Overture</li> <li>• No Exile</li> </ul> | <ul style="list-style-type: none"> <li>• Private Declaratory Policy</li> <li>• Defend AFB</li> <li>• Trade Incentive</li> <li>• Offer Exile</li> </ul> |
| If Use Nuclear Weapons:                                |            |  |  |
| Defeat Enemy   | 24         | 6  | 10   |
| Defeated   | 6          | 2  | 4  |
| Destroyed  | 60         | 90   | 80   |
| Stalemate  | 10         | 2  | 6  |
| Leader Survives  | 29         | 13   | 13   |
| Leader Killed:   | 71         | 87   | 87   |
| If Don't Use Nuclear Weapons:                          |            |  |  |
| Defeat Enemy   | 32         | 34   | 23   |
| Defeated   | 22         | 31   | 32   |
| Destroyed  | 20         | 0  | 10   |
| Stalemate  | 26         | 35   | 35   |
| Leader Survives  | 56         | 83   | 56   |
| Leader Killed  | 44         | 17   | 44   |

# Sensitivities

---



Sensitivity of 'Survive' due to a finding at another node:

| <u>Node</u>         | <u>Entropy Reduction</u> |
|---------------------|--------------------------|
| War_Aims            | 0.38836                  |
| Destroyed           | 0.34824                  |
| Use_Nukes           | 0.20404                  |
| Sorties_Reduced     | 0.10507                  |
| Ally_Neutral        | 0.05150                  |
| Basing_Denied       | 0.04396                  |
| Effectiveness       | 0.03387                  |
| Offer_Exile         | 0.01905                  |
| Fears_Use           | 0.00856                  |
| Reassert_Policy     | 0.00414                  |
| Deploy_Defenses     | 0.00017                  |
| Missile_Attack      | 0.00002                  |
| Diplomatic_Overture | 0.00000                  |

Entropy Reduction: a relative measure of a node's ability to reduce the uncertainty of the "Survive" node; i.e., drive it towards Yes or No.

# Sensitivities



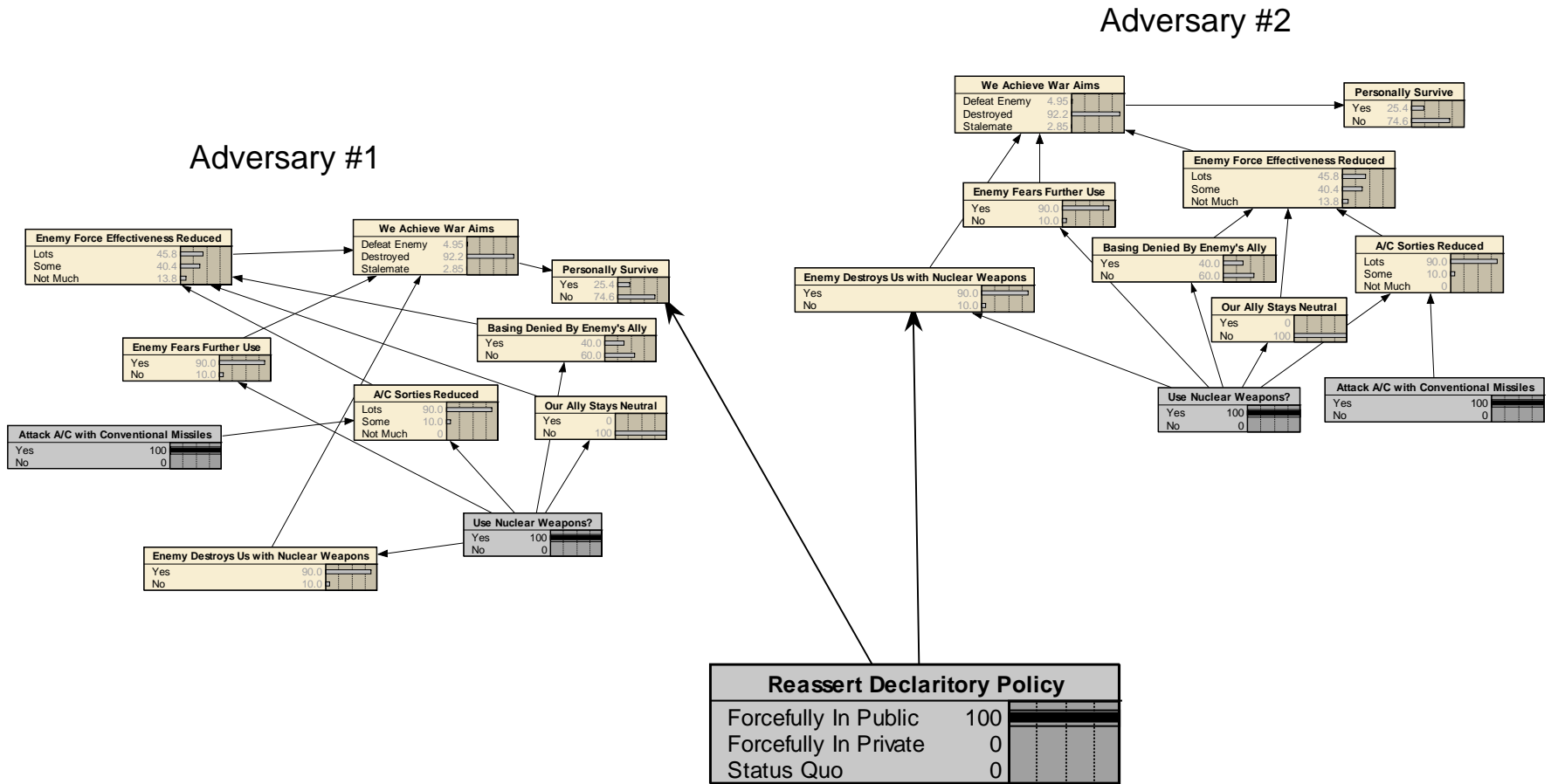
Sensitivity of 'Survive' due to a finding at another node:

| <u>Node</u>         | <u>Entropy Reduction</u> |  |
|---------------------|--------------------------|--|
| War_Aims            | 0.38836                  | ← Survival driven by how war turns out...          |
| Destroyed           | 0.34824                  | ← Which is influenced by us getting nuked....      |
| Use_Nukes           | 0.20404                  | ← And that depends on whether we use nukes or not. |
| Sorties_Reduced     | 0.10507                  |  |
| Ally_Neutral        | 0.05150                  |  |
| Basing_Denied       | 0.04396                  |  |
| Effectiveness       | 0.03387                  |  |
| Offer_Exile         | 0.01905                  | ← Most US effective action...                      |
| Fears_Use           | 0.00856                  |  |
| Reassert_Policy     | 0.00414                  |  |
| Deploy_Defenses     | 0.00017                  |  |
| Missile_Attack      | 0.00002                  |  |
| Diplomatic_Overture | 0.00000                  |  |

**Our Decisions**

**US Actions**

# Actions Across AOR's....



# What Might Bayes Tell You?

---



- Quantifies adversary's decision calculus:
  - Estimates probability he will achieve his goals
  - Estimates impact on this probability if we change his perception of a cost or benefit via an action
- Sensitivity analysis shows most influential cost, benefits, and actions
- Impacts of actions across adversaries can be estimated

# Bayes Approach: Pros

---



- Forces explicit, documented, repeatable, and transferable model of the adversary's decision structure
- Benefits, costs, and consequences are arrayed and related in a natural way via cause and effect
- Uncertainty is explicitly included and modeled
- Quantifies adversary's decision calculus:
  - Estimates probability he will achieve his goals
  - Estimates impact on this probability if we change his perception of a cost or benefit via an action
- Intelligence requirements and their priority are explicit and well-defined
- New factors easily added and integrated into model
- Sensitivity analysis shows most influential cost, benefits, and actions
- Link to  $N^{\text{th}}$ -order problem is straight forward via the addition of factors and modification of probability tables

# Bayes Approach: Cons

---



- Assessment is only as good as the model it's based on.
  - Is this how the adversary *really* thinks?
- Must avoid tendency to over-analyze how the adversary thinks by including too many factors
  - They don't create a Bayesian net!
- Setting up a mathematically-meaningful decision model is non-trivial
  - Options must be mutually exclusive and exhaustive
  - Cause and effect – and intermediate effects – must be thought out
- Spectacular, non-linear insights unlikely to jump out of analysis
  - This is only my impression, unverified by experiment
  - If you don't model a critical factor, it won't show up (duh)
- Lots of information required for the probability tables
  - Issue of complex tables mitigated somewhat if bullet #2 is minded
  - A fair amount of the data is probably amenable to adversary-perspective modeling and intel analysis