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Thoughts on Risk Analysis Methods and Deterrence

Methodological Considerations

Jason Reinhardt (jcreinh@sandia.gov)

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U.S. DEPARTMENT OF ENERGY

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Defining Terms

Protagonist

An actor wishing to prevent specific future actions from being taken by another

Antagonist

An actor considering a specific future action that works against the protagonist's wishes

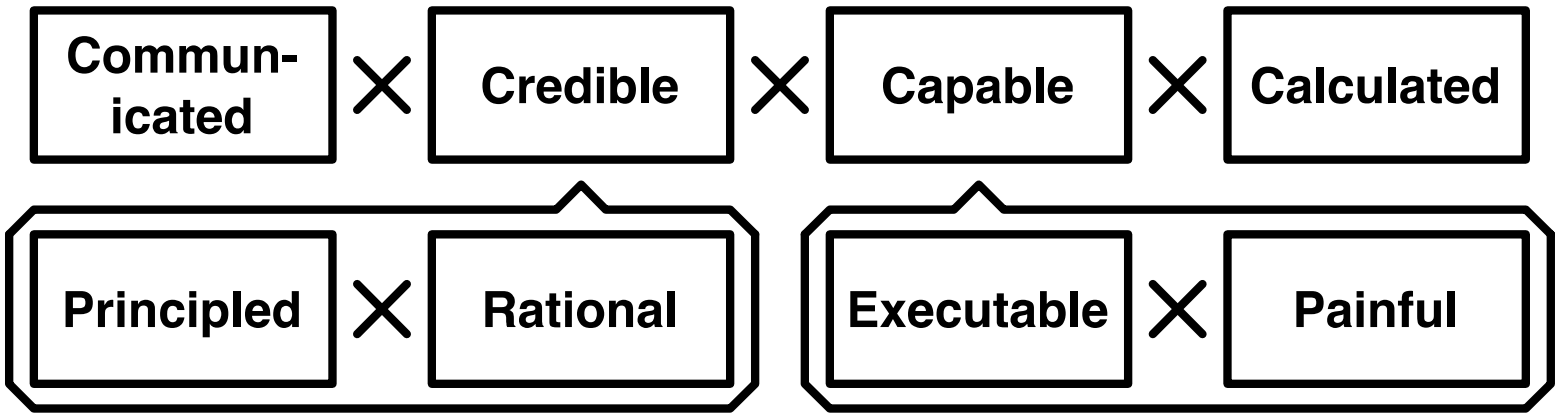
Deterrent Threat

The threat that the protagonist makes in an effort to influence the antagonists to not take an action (e.g., 'don't do that or you will be attacked')

Deterrence Failure

An antagonist, through calculation, miscalculation, or misperception takes an action counter to the protagonist's interests in spite of a protagonist's deterrent threat

A Framework for Deterrence Effectiveness



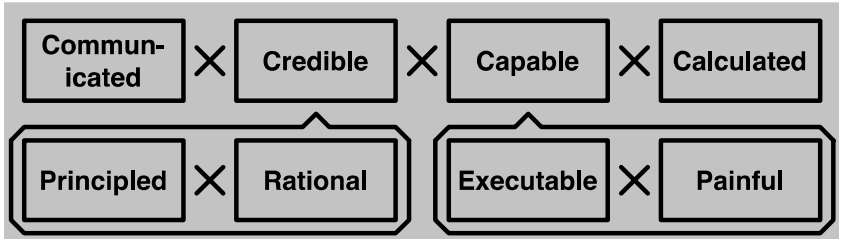
Communicated	The protagonist must issue a deterrent threat, and the antagonist must receive, and understand that threat.
Credible	The deterrent threat must align with the protagonist's principles, and must be rational to carry out.
Capable	The protagonist must be able to execute deterrent threat, and it must inflict pain on the antagonist if executed.
Calculated	The antagonist must consider the deterrent threat and its implications when choosing a course of action.

Deterrence Failure Risk vs. Deterrent Risk

Deterrence Failure Risk

What deterrent threats (actions, policies, and capabilities) will motivate behaviors the protagonist wishes to see in the antagonist?

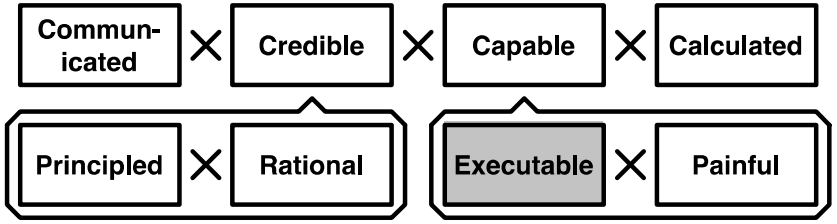
Antagonist decisions & actions, stability, escalation



Deterrent Risk

What capabilities ensure that the protagonist can effectively carry out actions specified in a deterrent threat?

Weapon effects, safety, security, & reliability



Antagonist Behavior Considerations

A core challenge in risk analysis is addressing how one captures the behavior and actions of other decision makers who can influence the outcomes, including antagonists.

Behavior of Groups

- Aggregate behaviors can be better described (e.g. polling, statistics)
- Markets, crime, politics, organizations
- "What is the probability that SOME person will…?"

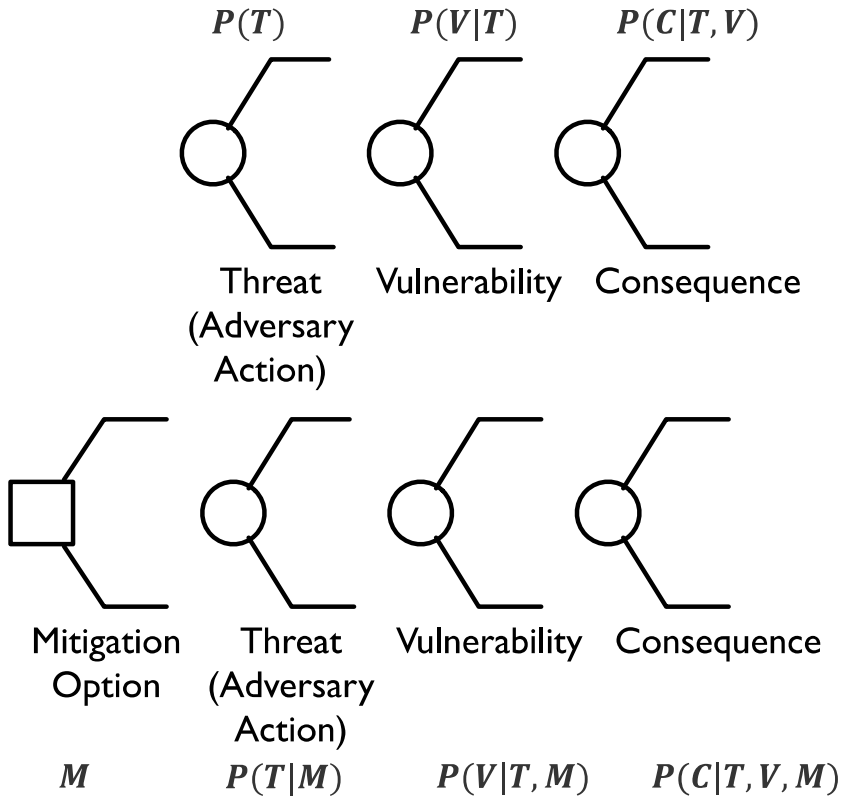
Behavior of Individuals

- Individual behaviors are much harder describe accurately
- National leaders, terrorists
- "What is the probability that THIS person will…?"

Complications in Antagonist Modeling

The inclusion of intelligent adversaries in risk analysis creates a unique set of methodological and philosophical issues. How do we consider the role of adversary actions in risk?

- ***Normative*** vs. ***Descriptive*** Modeling
  - Biases and shortcomings
  - Information asymmetries
  - Idiosyncratic behaviors
- Intelligent and ***Adaptive*** vs. ***Random***
  - Adversary observations
  - Threat Shifting
- ***Inadequate Understanding*** of Adversaries
  - Large epistemic uncertainties
  - Multiple adversary types
- Several proposals to avoid these problems often include disregarding the threat component of risk altogether
  - Prioritize conditional risks (i.e., assume the attack WILL happen…)
  - Prioritize protection of highest value assets
- Most proposals still make implicit assumptions about adversary choices (i.e., rules that model behavior!)



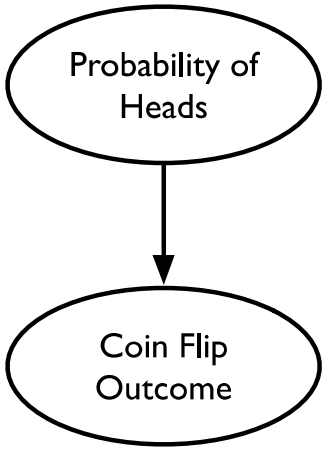
Uncertainty in Risk Analysis with Antagonists

In order to think about uncertain adversary actions, we must think about the models we use to describe the adversaries, and the uncertainty over which is most correct.

It is possible to have multiple models of a coin:

- Fair (50/50)
- Biased tails (30/70)
- Biased heads (60/40)
- Double heads (100/0)
- …

Each model provides a different likelihood of various outcomes.

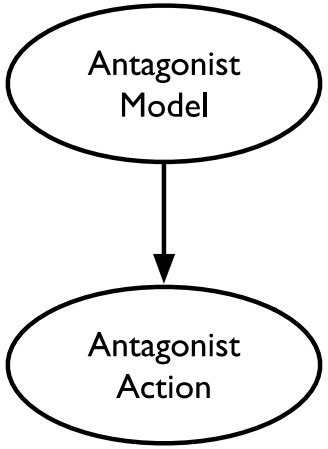


Despite having many models, we can consider the probability of the coin flip outcome "heads" given each of them, and consider the aggregate probability of heads.

It is possible to have multiple models of an adversary:

- Rational
- Boundedly Rational
- Expert Based
- Satisficing
- …

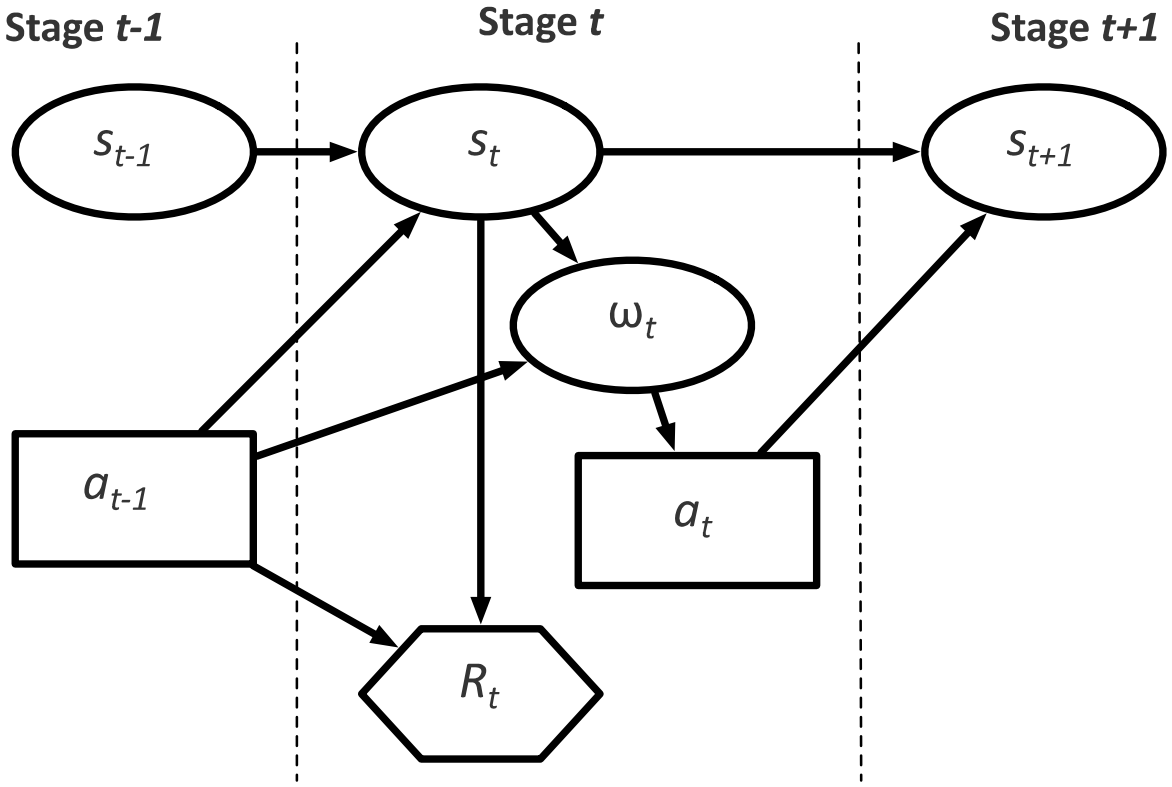
Each model provides a different predicted decision, or distribution over decisions.



Despite having many models, we consider the antagonist choices implied or predicted by each possible model, and consider the aggregate probability of various actions.

One Approach to Modeling Deterrence Failure

Partially Observable Markov Decision Processes are specified by *states (s), observations (w), actions (a), rewards (R)*, and *probability distributions* that describe their evolutions from stage to stage.



Conflict Model Example

$\boldsymbol{s_t}$ =(Peace, Crisis, Low Level Conflict,…)

$\boldsymbol{\omega_t}$ =(Intelligence, Battle Outcomes, Political Status,…)

$\boldsymbol{a_t}$ =(Do Nothing, Engage, Use Weapon,…)

$\boldsymbol{R_t}$ =(Gains and Losses)

Solutions to POMDPs are behavior models that specify optimal actions based on observations ($\boldsymbol{\omega_t} \rightarrow \boldsymbol{a_t}$).

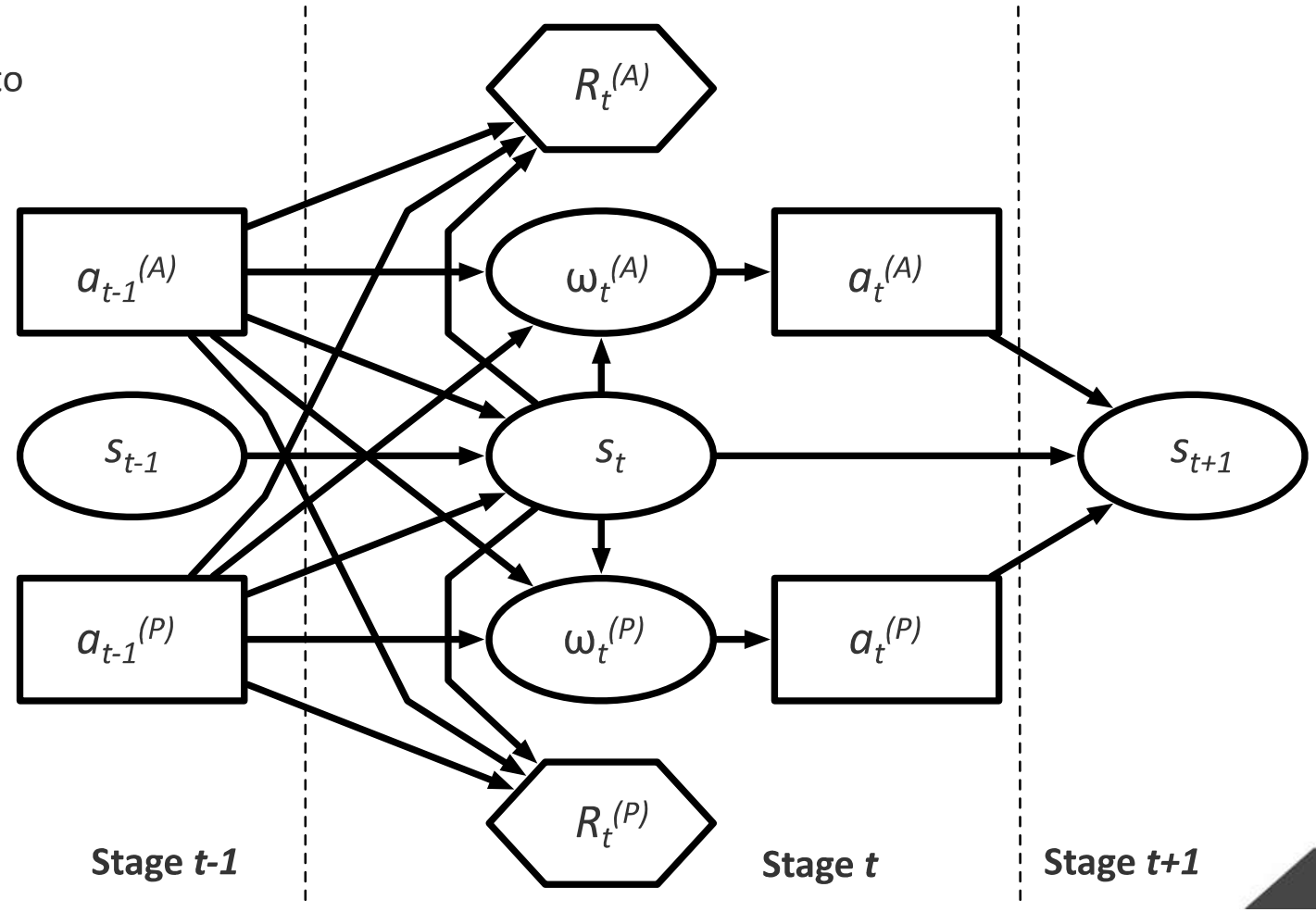
Note: This work was done as part of thesis research at Stanford University.

Interactive Partially Observable Markov Decision Processes

Superscript ***(P)*** or ***(A)*** to refer to protagonist and antagonist decisions and variables, respectively

Antagonist may only make imperfect observations ($\boldsymbol{\omega_t^{(A)}}$), just like protagonist

Solutions to IPOMDPs are behavior models that specify optimal actions based on observations ($\boldsymbol{\omega_t \rightarrow a_t}$) for both the protagonist and antagonist.



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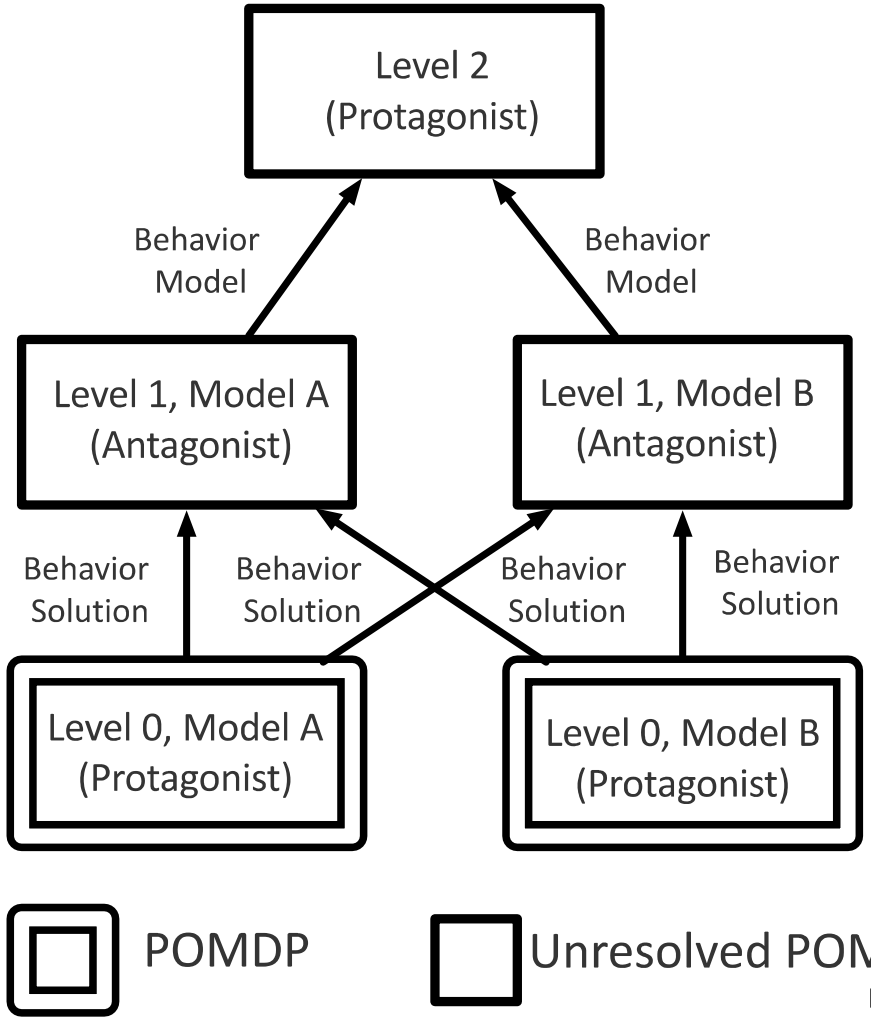
Solving A Deterrence Failure Risk Model



Solve each level, starting from the bottom

Pass behavior solution up to next higher level

Level 0 Agents are modeled as POMDPs

Level 1+ actors are modeled as POMDPs that roll in the behavior models from lower levels

Similar to "k-level" game approach

Each side is uncertain about adversary

- What do they want?
- What do the know?
- What can they do?

Final behavior solutions are simulated to determine the probability of deterrence failure

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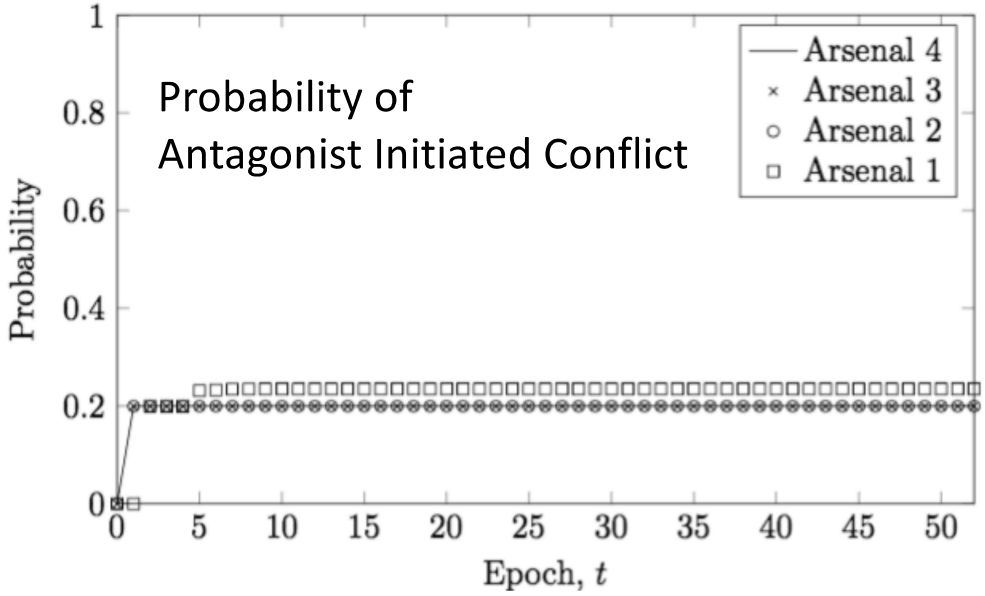
Example: Protagonist's Arsenal Impacts on Deterrence Effectiveness

Consider a scenario with two nuclear armed nations in an escalatory conflict. How do different protagonist arsenals (qualitative and quantitative) change the probabilities of deterrent failure?

Slight increase in the Antagonist conflict initiation probability



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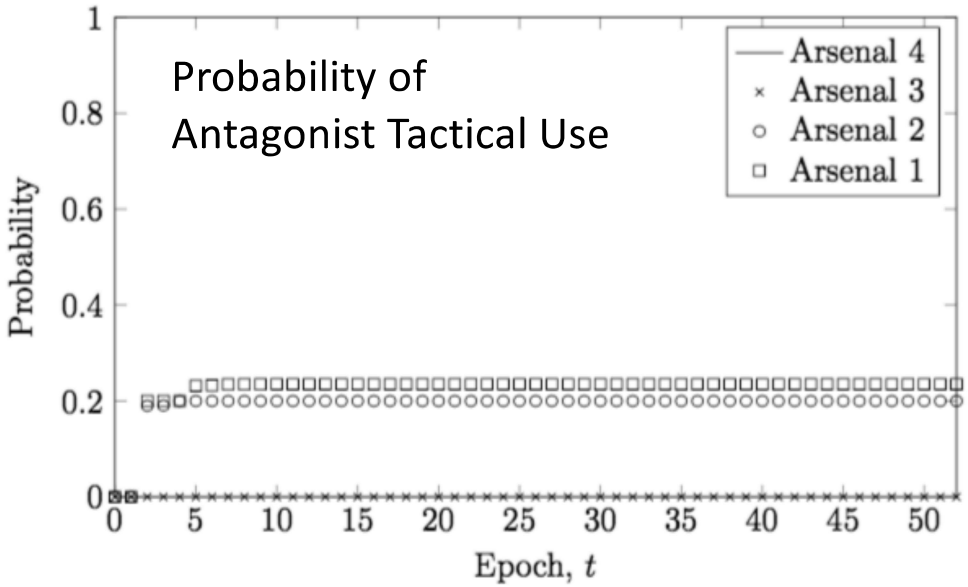

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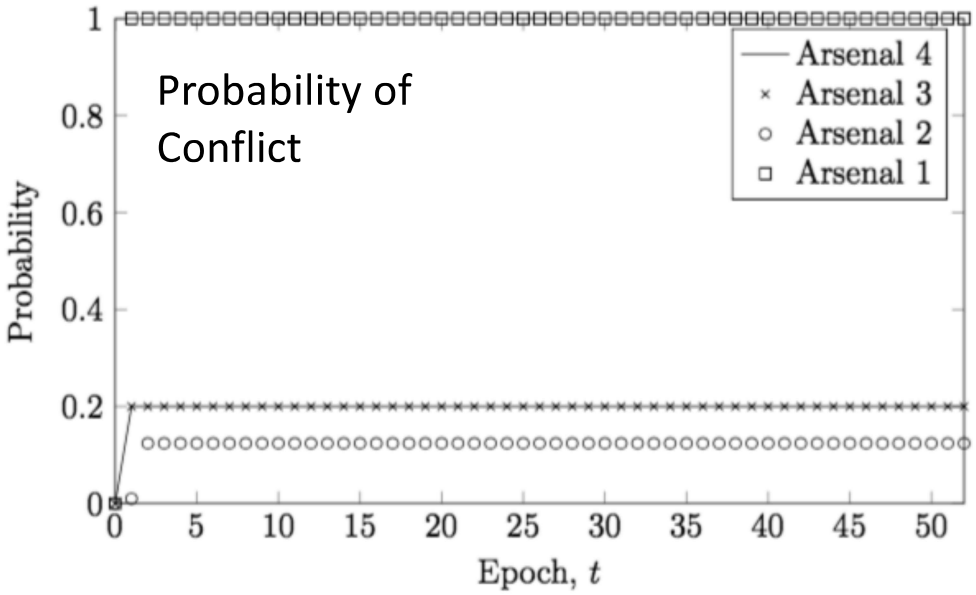
Protagonist motivated to initiate conflict with smaller arsenals



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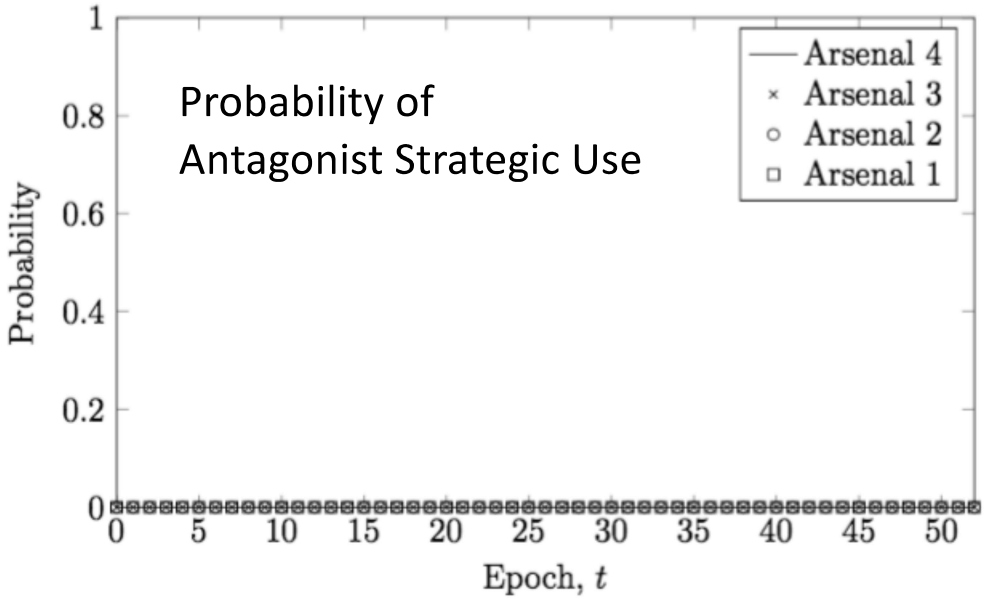

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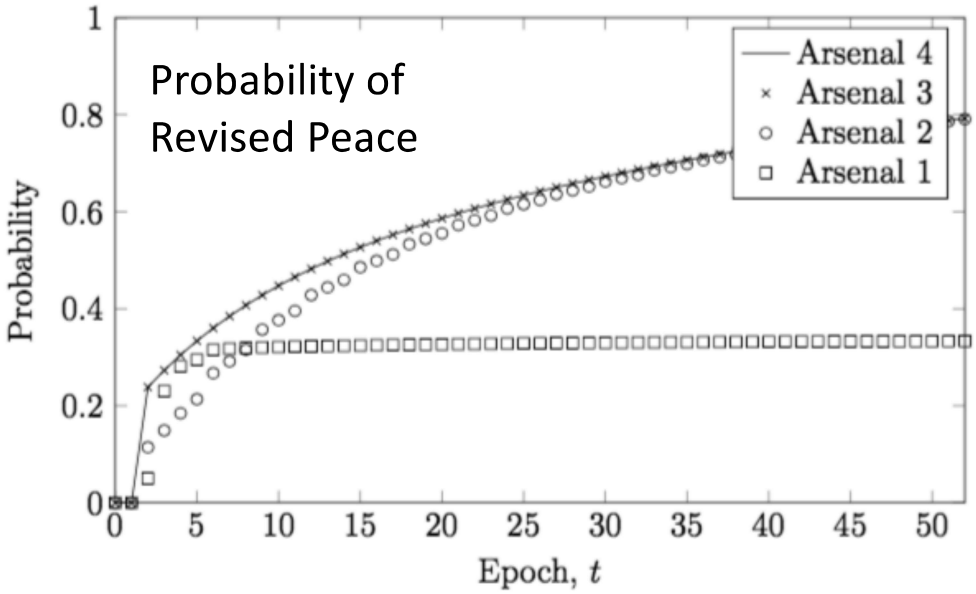
Strategic nuclear deterrence holds

Reducing Protagonist arsenal size reduces the Revised Peace probability

Puts Protagonist in a position to act more aggressively to protect interests due to more aggressive antagonist



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Conclusions

Probabilistic risk analytic methods can be used to assess deterrence failure risks.

Using probabilistic methods for examining deterrence failure risk can:

- Enable cross-domain comparisons beyond nuclear
- Integrate data and assessments from technical analysis and intelligence analysis
- Make logic of analysis and trade-offs explicit
- Provide a mechanism to test alternative assumptions and incorporate new information

Generally, method isn't the challenge – agreeing on the assumptions, scenarios, metrics of interest is.

Interpretation and acceptance of results will depend on much more than the analysis itself.

Thank you!

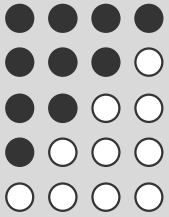
Uncertainty in Risk Problems

There are two types of uncertainty that must be addressed in risk assessment: *epistemic uncertainty* and *aleatory uncertainty*, which describe different aspects of what we know.

Epistemic Uncertainty

Based in a lack of knowledge because of information available in the present.

Urn A has some mix of black and white marbles in it, 4 total. If you draw a white marble, I give you a dollar. If you draw a black marble, you give me a dollar.



Urn A has five possible models of the marbles

A **B**

Which do you prefer?

Aleatory Uncertainty

Inherent uncertainty and "randomness" due to probabilistic variability.

Urn B has 2 black and 2 white marbles in it. If you draw a white marble, I give you a dollar. If you draw a black marble, you give me a dollar.

Urn B has one possible model of the marbles

People usually behave as though Epistemic Uncertainty > Aleatory Uncertainty.
In reality, you have the **same chances** in both cases (see Ellsberg Paradox).
Epistemic uncertainty and ***aleatory uncertainty*** should not be handled differently.