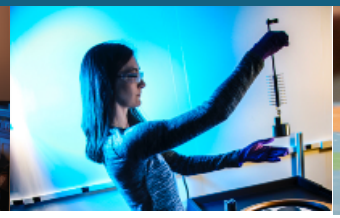
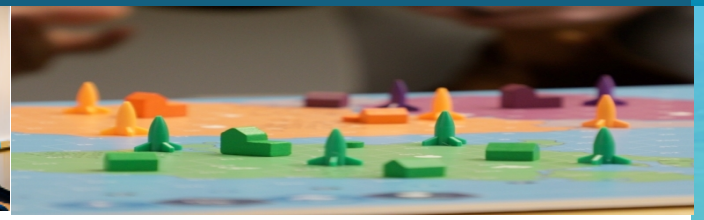
SAND2023-00050C

PEGASIS
PROGRAM for EXPERIMENTAL GAMING & ANALYSIS of STRATEGIC INTERACTION SCENARIOS

Sandia National Laboratories

Experimental Wargaming and Simulations





PRESENTED BY

Kiran Lakkaraju

U.S. DEPARTMENT OF ENERGY | NNSA

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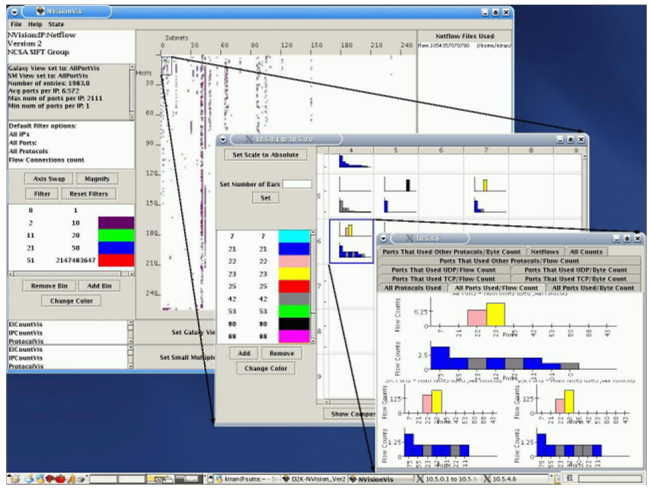
Who Am I?

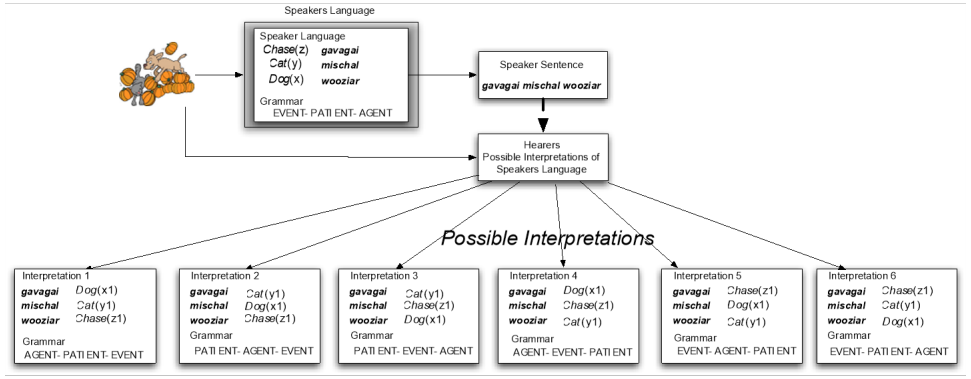
ILLINOIS

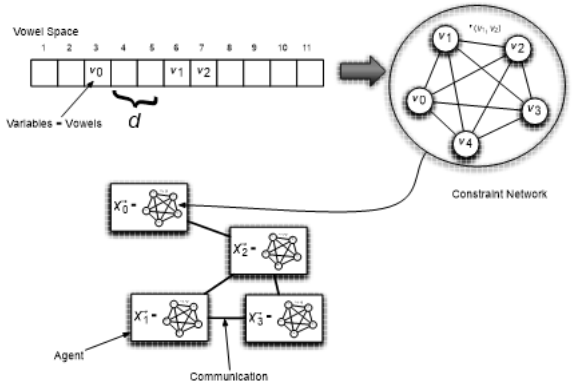
- Ph. D. in Computer Science
  - Artificial Intelligence/Machine Learning.
  - M.S. thesis used Neural Networks to study bird songs.
  - I was interested in Neural Networks well before they became cool.
- Ph.D. work focused on modeling and simulation & network security visualization.
- Language evolution and diffusion: How do languages change and spread through social interaction?
  - Developing abstract models of language evolution, consensus and diffusion informed by sociolinguistics and computer science



NVisionIP

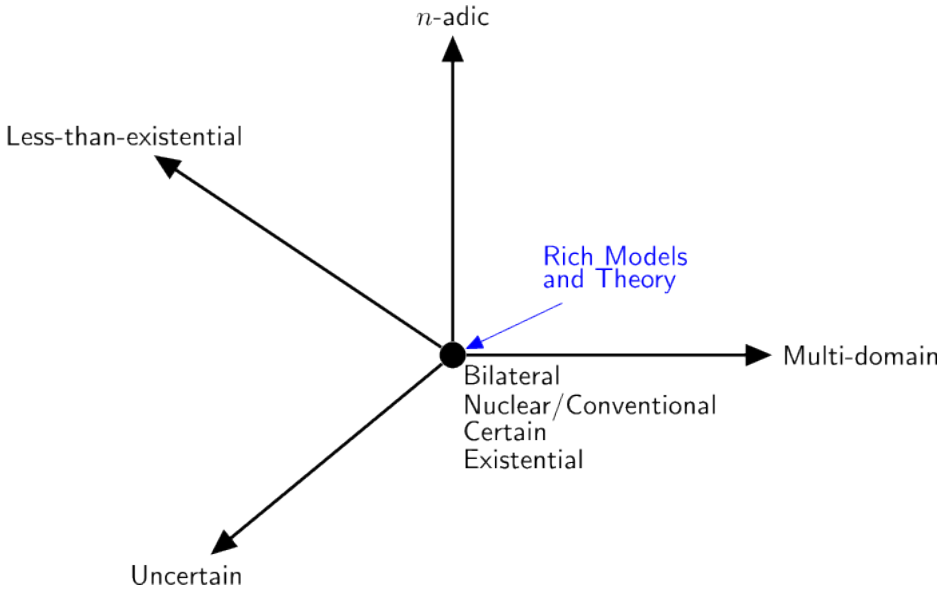
K. Lakkaraju, W. Yurcik, A. J. Lee, R. Bearavolu, Y. Li, and X. Yin. NVisionIP: NetFlow Visualizations of System State for Security Situational Awareness. In Proceedings of the CCS Workshop on Visualization and Data Mining for Computer Security (VizSec/DMSEC), 2004.

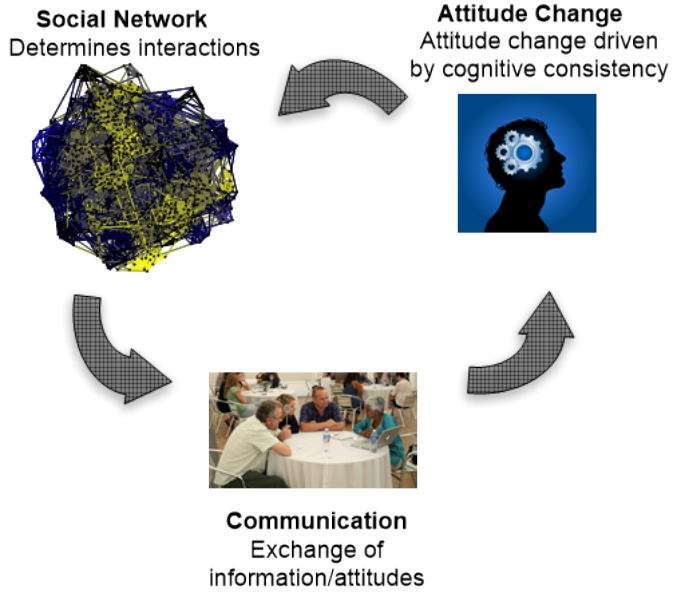


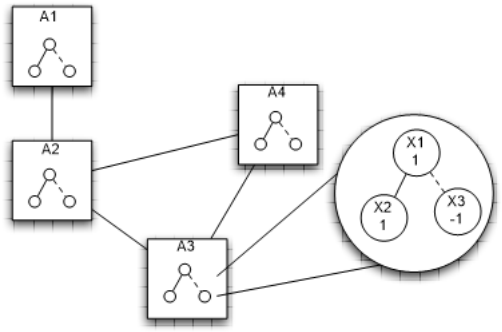


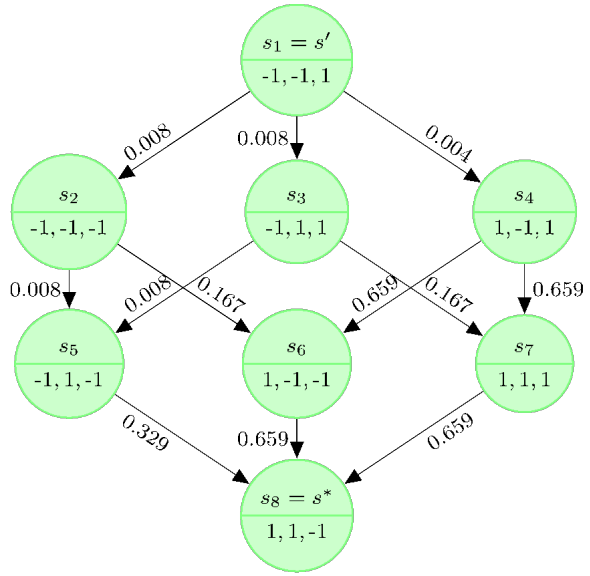
K. Lakkaraju, S. Swarup, and L. Gasser. Consensus under Constraints: Modeling the Great English Vowel Shift. In Proceedings of the 2012 Social-Computing, Behavioral-Cultural Modeling, and Prediction Conference, 2012.

What I mean by models and simulations.





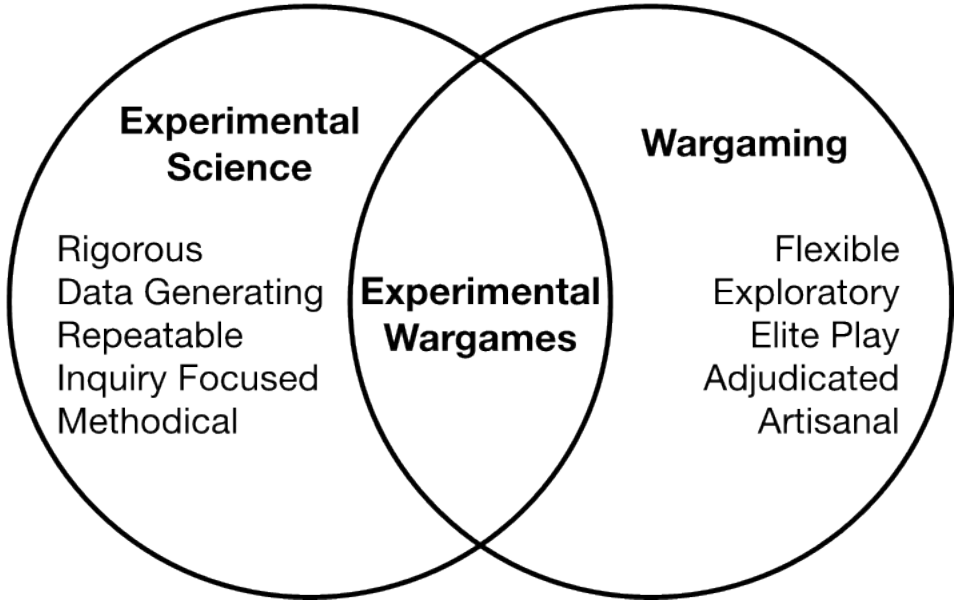


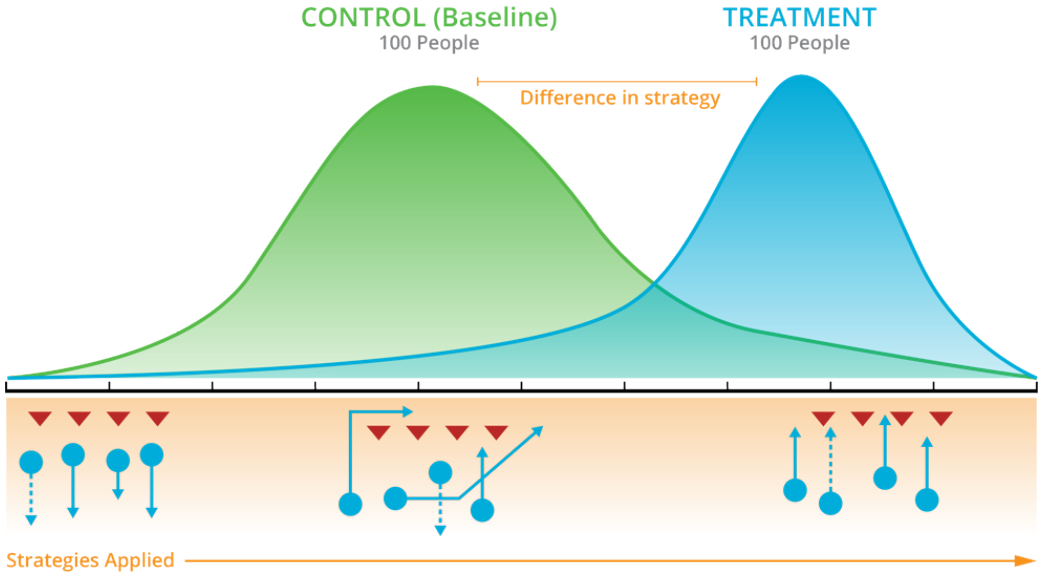


K. Lakkaraju. Modeling attitude diffusion and agenda setting: the MAMA model. Social Network Analysis and Mining, 6(1):1–13, 2016.

What are experimental wargames?

Experimental Wargames are games designed to quantitatively study national security scenarios of interest where the situation, potential responses, and abstraction are driven by research question(s) of interest

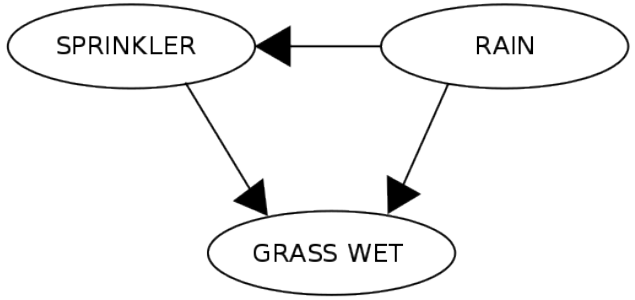




How can experimental wargaming inform simulation?

- Test hypotheses.
  - Underlying every model & simulation are causal assumptions that should be verified.
- Validation
- Calibration

RAIN	SPRINKLER T	SPRINKLER F
F	0.4	0.6
T	0.01	0.99



RAIN T	RAIN F
0.2	0.8

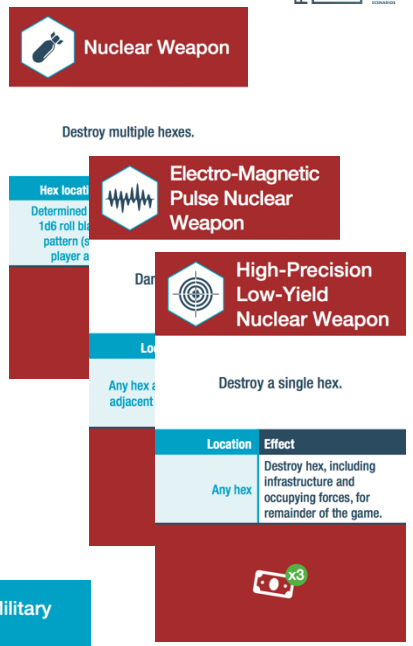
SPRINKLER	RAIN	GRASS WET T	GRASS WET F
F	F	0.0	1.0
F	T	0.8	0.2
T	F	0.9	0.1
T	T	0.99	0.01


PROJECT ON
NUCLEAR GAMING


SIGNAL

SIGNAL is an experiment, and created using experimental design principles.

How do tailored nuclear capabilities alter the threshold for nuclear use in a wargaming context?



- Two factor, between subjects design.
  - **Tailored Effect Condition (TE):** Purple and Green players are given Traditional NW, HPLY and EMP capabilities.
  - **Traditional Condition (Trad):** Purple and Green are given only Traditional NW.
- Key elements of game design:
  - **Abstract Environment.**
  - **Minimal Stochasticity**
  - **Multiple Avenues for Winning**
  - **No white cell/adjudicator**

- Tailored & Traditional NW
- Conventional Forces Only
- Cyber
- Defensive

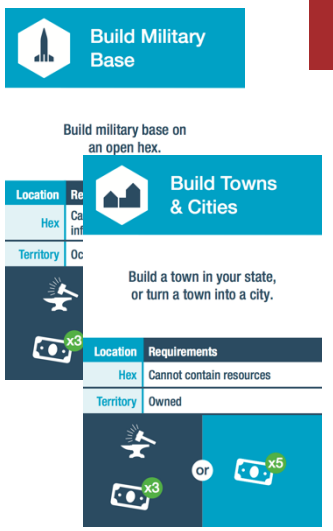


Table 3: Logit regression models measuring the probability of nuclear use using the game as the unit of analysis

	Dependent variable:			
	Nuclear use			
	(1)	(2)	(3)	(4)
Treatment	0.039	0.038	0.024	0.022
	(0.218)	(0.218)	(0.219)	(0.219)
Female		−0.059		−0.055
		(0.120)		(0.130)
College Degree		0.004		−0.014
		(0.127)		(0.140)
Age >29		−0.073		−0.089
		(0.122)		(0.124)
National Security			0.076	0.097
			(0.143)	(0.150)
More Right			0.058	0.069
			(0.117)	(0.122)
Reported Knowledge			−0.062	−0.074
			(0.127)	(0.139)
Constant	0.963***	1.120***	0.915***	1.099***
	(0.154)	(0.308)	(0.256)	(0.396)
Observations	426	426	426	426
Log Likelihood	−249.421	−249.144	−249.027	−248.602
Note:				*p<0.1; **p<0.05; ***p<0.01

There is **no statistically significant difference** in nuclear use with tailored-output nuclear weapons in the arsenal within the SIGNAL environment.

		Player 2 Nuclear Capabilities	
		HY (H)	*+Tailored (T)*
Player 1 Nuclear Capabilities	*High-Yield (H)*	H, H (**Control**) *209 games*	H, T
	+Tailored (T)	T, H	L, L (**Treatment**) *216 games*

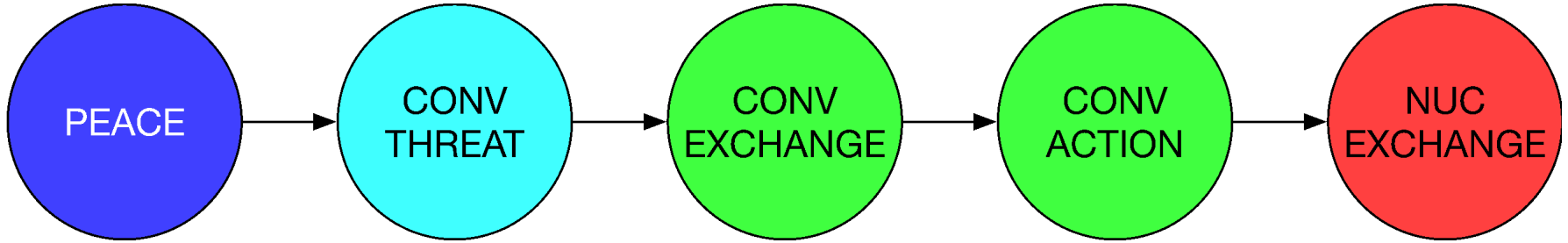
SIGNAL Collects Player Action and Behavior Data

The raw data set from the game is a large collection of process data in the form of event messages and periodic summaries of actions taken. This set must be transformed and reduced to facilitate analysis, in a way that moves beyond outcome data.

- Conflict Classes (More Flexible)
  - Categorizes rounds (made up of multiple moves by all actors) based on the combination of actions that were taken
  - Can be defined according to a wide range of analytic questions (e.g., how quickly did nuclear use occur?)
  - Tracks round-to-round conflict evolution and identifies macro trends
  - Can obscure fine detail of action-retaliation, dyad dynamics, deterrence success and failure

Action-Dyad Simulation (More Powerful)

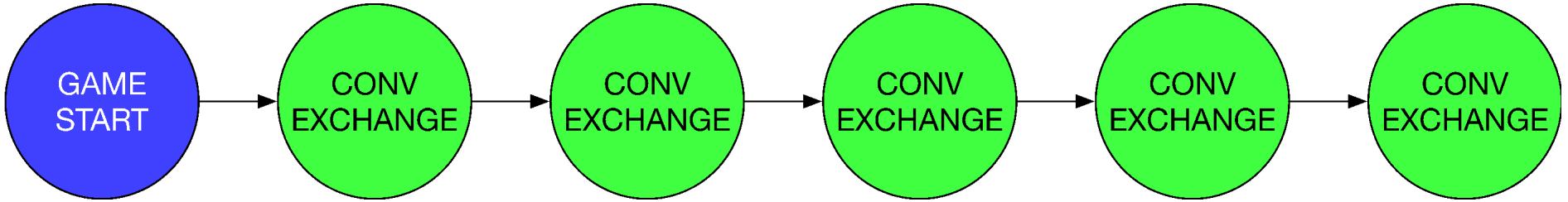
- Simulates the game at a blow-by-blow level allowing for event detection and nuanced analysis
- Can examine correlations between preceding actions, detect the attempt to deter, and the success/failure of deterrence attempts
- Provides a coded set of specific event indicators that can be used in standard data science techniques (Random Forests, Clustering, PCA, etc…)
- Potentially less generalizable to other data sets



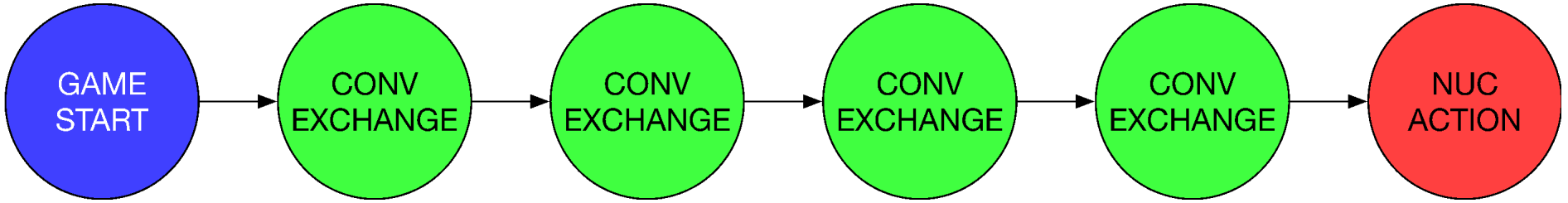
We can identify most likely escalation paths within SIGNAL.

- Coded data was rendered into transition probability matrices, conditioned on player actions, game state, round number, etc., which facilitated survival and next action/state analyses
- Provides a foundation for probabilistic ML methods, such as Interactive Partially Observable Markov Decision Processes, which can be powerful tools for examining strategies and optimal conflict management policies.

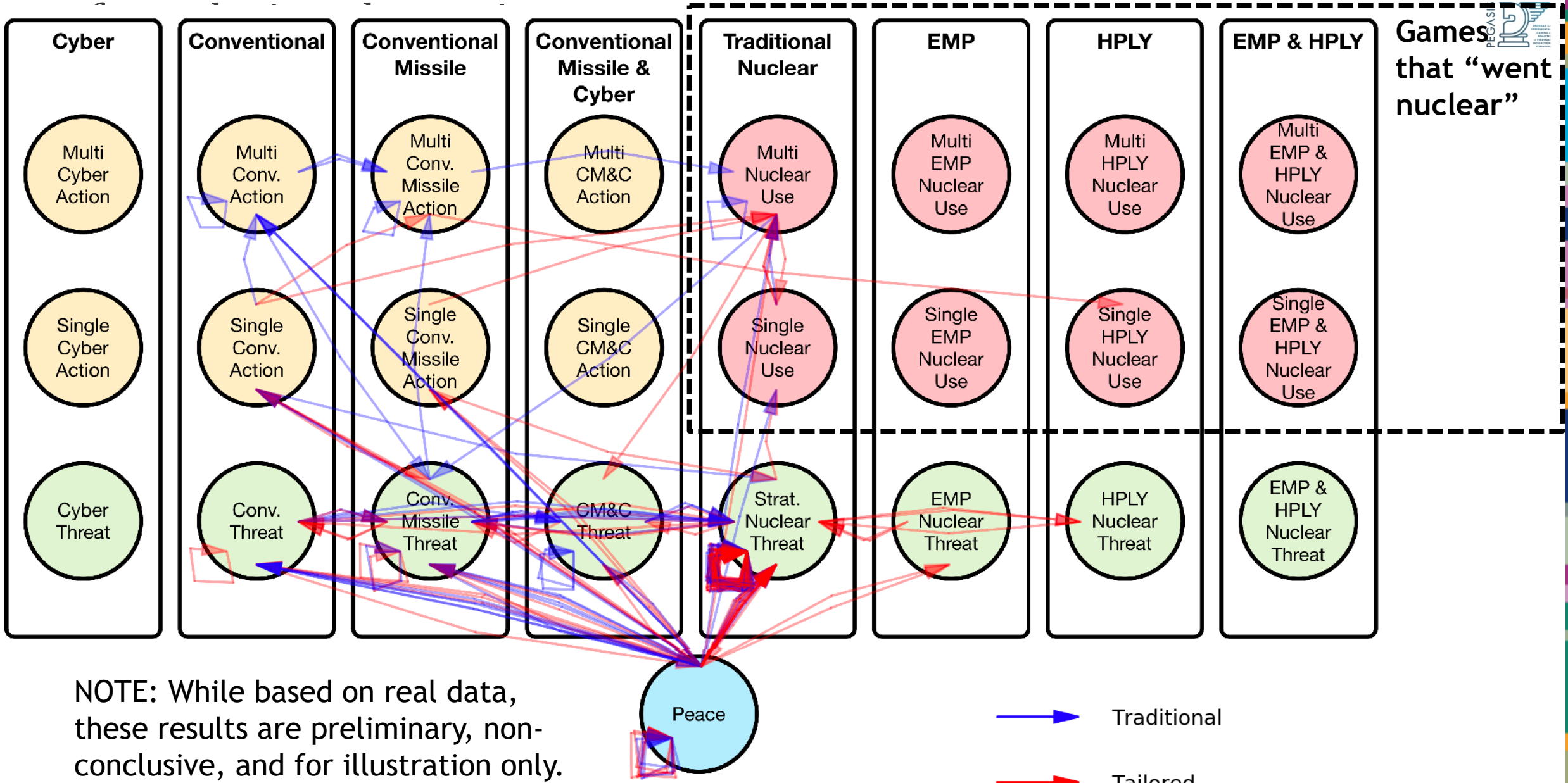
Traditional Effect Games Most Likely Escalation Path



Tailored Effect Games Most Likely Escalation Path

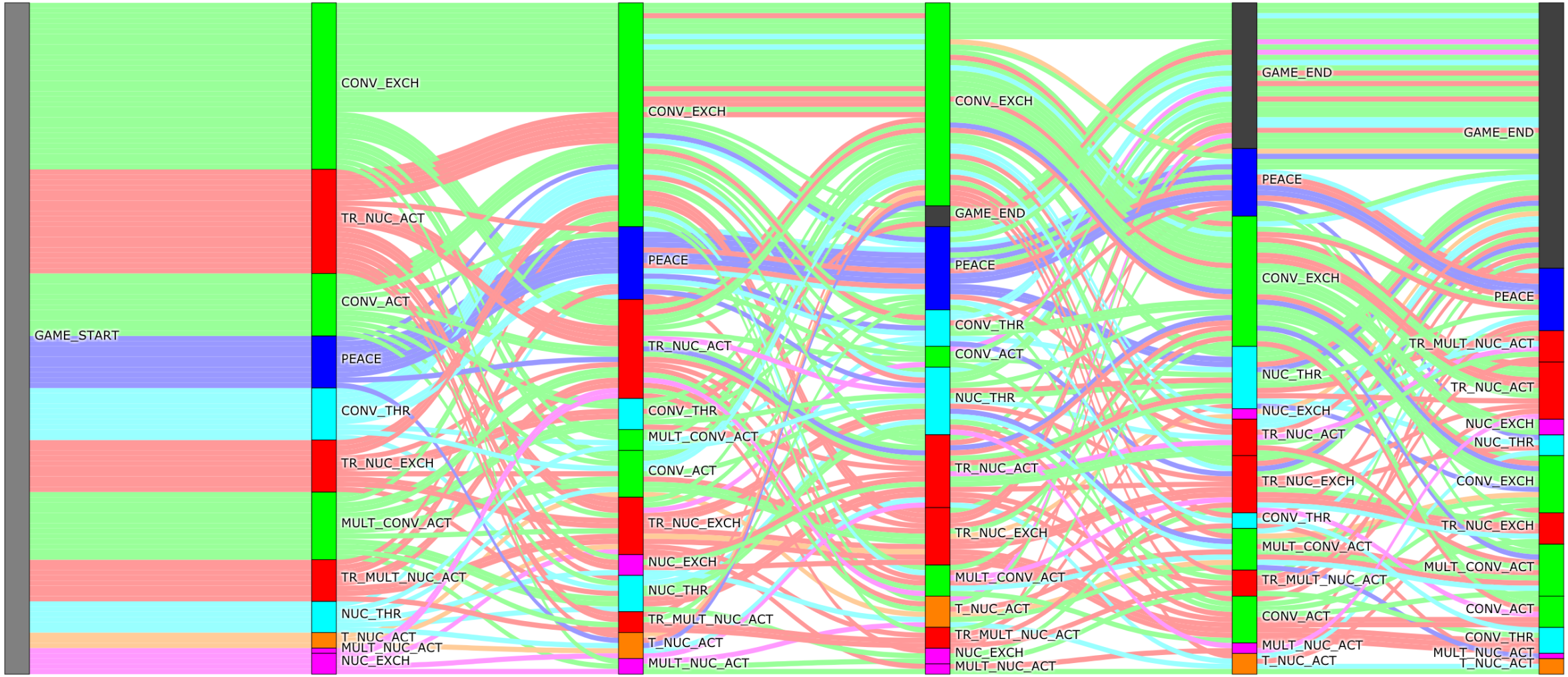


Establishing Conflict Classes from raw data enables analysis



NOTE: While based on real data, these results are preliminary, non-conclusive, and for illustration only.

Conflict Data Visualization



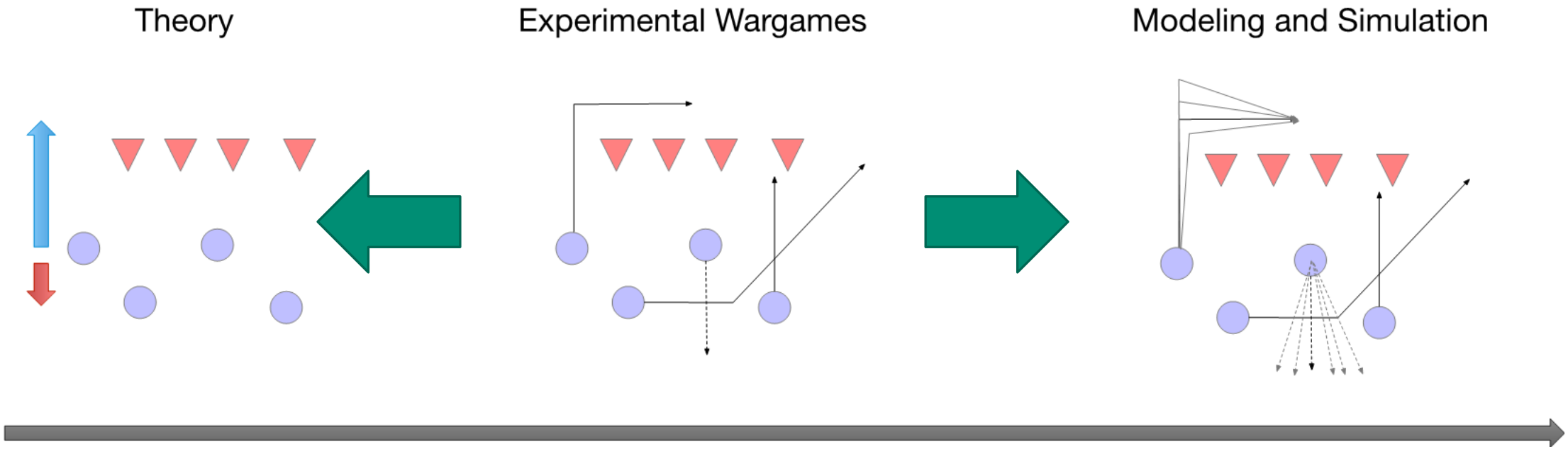
Once coded to a conflict class schema, the data set can be visualized as trajectories through the conflict class space, round by round.

Experimental wargaming can inform theory development and modeling & simulation.

Theory provides broad generalizations.

Experimental Wargames provide a rich, quantitative exploration of strategies within a scenario.

Modeling and Simulation can explore the impact of small changes to strategies.



Thank You!

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