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NUCLEAR NONPROLIFERATION ANALYSIS USING AGENT BASED MODELING IN AN ENTROPY EMPOWERED INTELLIGENT AGENT BAYESIAN FRAMEWORK

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ABSTRACT

For decades, scholars have studied the proliferation of nuclear weapons by states. There have traditionally been two theories of proliferation: (1) the demand side in which proliferation is driven by the national security demand for the weapons and (2) the supply side in which proliferation is driven by the ready supply of nuclear materials and technology. We hypothesize that neither theory is strictly correct and that instead there is a crucial and dynamic interplay between the national security motivations of a state and the facilitation that ready access to supplies provides. In this work, we sought to determine if this interplay can be correctly simulated using Agent Based Modeling (ABM). The modular Bayesian ABM Nonproliferation Enterprise (BANE) tool has been developed at Texas A&M University for considering intelligent agents and dynamic nonproliferation scenario analysis. Using BANE we showed that the ABM can accurately model historical cases of proliferation as long as agent rules are properly defined. We also provided data that supports the hypothesize that nuclear proliferation is influenced by a dynamic balance between demand and supply drivers and political and military constraints. Future work explores a range of weapons of mass effect (WME) cross domain decision implications.

1 INTRODUCTION

Demand side justifications for obtaining nuclear weapons remain largely unchanged since 1945, and focus primarily on security, economics, and prestige. Nuclear and dual use technology advancements are a supply side proliferation reality, and will remain so for the foreseeable future. Evolving global networks of suppliers and increasing global technical competence offer new, or harder to detect, technical opportunities with nuclear proliferation applications. Implementing a dynamic tool to more accurately model proliferation is important to go beyond existing, static nonproliferation assessment methods.

2 BANE OVERVIEW

ABM and Bayesian methods are integrated into BANE. Realistically, no two proliferating or defensive entities are exactly identical; ABM is a computational methodology addressing the uniqueness of those facilitating or preventing the spread of nuclear weapons. Bayesian inference has been employed in fields such as intelligence, where information limits are ever present. Correlating incomplete evidence for pattern recognition in BANE using Bayesian inference draws upon technical supply side proliferation linkages grounded in physics. Potential or current proliferator security, economic trajectory, or other factors modify demand drivers for undertaking proliferation. With Bayesian inference the coupled demand and supply proliferation drivers are connected to create feedback interactions. Bayesian analysis supports linking crucial knowledge and technology requirements into relationship networks. With a Bayesian network, gaining information on proliferator actions in one proliferation field informs counter proliferation agents where to expend limited resources impeding capabilities.

3 PHYSICS AND SOCIAL SCIENCE CONSTRAINED DECISION MAKING

The BANE Bayesian inference network approach for managing agent technical progress is based on physics defined proliferation constraints. Social science plays into agents making decisions considering their perceptions for achieving supply side technical success meeting their demand side objectives. Proliferation pathways evolve as aggregated agent decisions introduce more data indicating proliferation intentions and corresponding key technology investments. The additional information reduces the entropy associated with a particular agent goal being achieved. The probability and statistics basis of entropy meshes well with the BANE Bayesian inference framework for guiding agent technical success choices. Entropy and mutual information are integral to empowering BANE agents making intelligent proliferation and counter proliferation decisions. From a BANE technical perspective, a major entropy reduction advantage is its consistency for positive or negative correlations. At each time step the uncertainty effects build, leading to greater fluctuation in technical success.

4 BANE VERIFICATION AND VALIDATION

Verification and some validation for BANE is performed using historical case studies and extrapolated scenarios based on actual proliferation events. Using BANE to analyze how proliferation networks from the Soviet Union to Iraq evolved demonstrates its flexibility and applicability. Modeling complex proliferation situations with BANE by including empowered proliferating, defensive, and neutral agents helps bound the range of socially and technically valid outcomes. Through BANE, the framework exists for expanding beyond the nuclear field into exploring broader WME proliferation.

5 CONCLUSION AND FUTURE BANE RESEARCH

Intelligent learning and contingency planning arises in the real world as multiple entities vie to achieve their proliferation or counter proliferation objectives. BANE captures the continuously active and interrelated aspect of global proliferation occurrences to a greater extent than existing static proliferation models. A range of economic, technical, and outside non-detection constraints in BANE force states and non-state actors to prefer different pathways. Similar to nuclear proliferation, pursuing other WME capabilities requires diverting significant resource allocations away from other economic and security sectors. Knowledge and infrastructure thresholds in key areas must be reached. Counter WME defensive organizations are dynamically attempting to thwart WME outside assistance and indigenous development.

Additional BANE modules are continuously implemented to better capture nuclear proliferation aspects, such as greater agent decision making uncertainty and alterations in affinities affecting cooperation between agents. Allowing proliferating agents more decision pathway, including conventional weapon selection, will aid simulation realism. Expanding BANE to consider WME and conventional weapon options will increase policy maker understandings about the trade-offs states make in securing their national interests.

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