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A CHEMICAL ROMANCE: HOW ALLIANCES AND CONFLICT AFFECT CHEMICAL WEAPON ADOPTION AMONG VIOLENT NON-STATE ACTORS

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THESIS

A CHEMICAL ROMANCE: HOW ALLIANCES AND CONFLICT AFFECT CHEMICAL WEAPON ADOPTION AMONG VIOLENT NON-STATE ACTORS

by

Aaron M. Green and Christopher M. Price

December 2019

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With an ongoing pivot toward great power competition, there may be a temptation to reduce counter-proliferation efforts against violent non-state actors (VNSA) to a peripheral mission for U.S. Special Operations Command (USSOCOM). However, the current and emerging threats of weapons of mass destruction (WMD) acquisition and use by VNSA are increasing through the ubiquity of various technologies, materials, and internet access. This research analyzes the use of chemical weapons (CW) by VNSA and the unique challenges of detecting and combating CW at the strategic, operational, and tactical levels. This research first implements regression models using chemical incident data from 1995–2017 to identify which strategic and operational environments are associated with VNSA CW adoption, and uses the outcomes to create a template for predictive intelligence methods for chemical threats. Next, the researchers conduct social network analysis to investigate commonalities among VNSA with chemical programs, and to determine if these CW tactics are geographically migrating. Then, lessons learned from the case study involving al-Qaeda in Iraq yield a proposed disruption model tested in a plausible, near-future scenario. Finally, policy recommendations are provided for USSOCOM and other relevant entities to improve counter-WMD efforts as they relate to the prediction and disruption of the chemical programs of VNSA.

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ABSTRACT

With an ongoing pivot toward great power competition, there may be a temptation to reduce counter-proliferation efforts against violent non-state actors (VNSA) to a peripheral mission for U.S. Special Operations Command (USSOCOM). However, the current and emerging threats of weapons of mass destruction (WMD) acquisition and use by VNSA are increasing through the ubiquity of various technologies, materials, and internet access. This research analyzes the use of chemical weapons (CW) by VNSA and the unique challenges of detecting and combating CW at the strategic, operational, and tactical levels. This research first implements regression models using chemical incident data from 1995–2017 to identify which strategic and operational environments are associated with VNSA CW adoption, and uses the outcomes to create a template for predictive intelligence methods for chemical threats. Next, the researchers conduct social network analysis to investigate commonalities among VNSA with chemical programs, and to determine if these CW tactics are geographically migrating. Then, lessons learned from the case study involving al-Qaeda in Iraq yield a proposed disruption model tested in a plausible, near-future scenario. Finally, policy recommendations are provided for USSOCOM and other relevant entities to improve counter-WMD efforts as they relate to the prediction and disruption of the chemical programs of VNSA.

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LIST OF ACRONYMS AND ABBREVIATIONS

ABM	actor-based model
AIC	Akaike Information Criterion
AQ	al-Qaeda
BAAD	Big Allied and Dangerous
CP	counter-proliferation
CT	counter-terrorism
CBRN	chemical, biological, radiological, nuclear
CW	chemical weapon
CWC	Chemical Weapons Convention
CWMD	counter-weapons of mass destruction
DoD	Department of Defense
DTMF	Dual Tone Multiple Frequency
EOD	explosive ordnance disposal
ETA	Basque Fatherland and Freedom
GED	Georeferenced Event Dataset
GTD	Global Terrorism Database
HUMINT	human intelligence
IED	improvised explosive device
IO	information operations
IC	intelligence community
IPOE	intelligence preparation of the operational environment
IS	Islamic State
IV	Independent Variable
MAR	minorities at Risk
MASINT	measurement and signature intelligence
MAV	Myanmar-Affiliated VNSA
MDF	Multidivisional Form
MISO	military information support operations
MYR	Myanmar
NGO	non-governmental organization

NP	non-proliferation
OCO	offensive cyber operations
OPCW	Organisation for the Prohibition of Chemical Weapons
POICN	Profiles of Incidents Involving CBRN Use by Non-state Actors
PSYOPS	psychological operations
SIGINT	signals intelligence
SNA	social network analysis
SOCPAC	Special Operations Command, Pacific
SOF	special operations forces
START	Study of Terrorism and Responses to Terrorism
TAM	technology adoption model
TRAC	Terrorism Research and Analysis Consortium
TTP	tactics, techniques, and procedures
USINDOPACOM	United States Indo-Pacific Command
UCDP	Uppsala Conflict Data Program
USSOCOM	United States Special Operations Command
VNSA	violent non-state actor
WMD	weapons of mass destruction

EXECUTIVE SUMMARY

In 2016, U.S. Special Operations Command (USSOCOM) assumed the role as the U.S. Department of Defense (DoD) Counter-Weapons of Mass Destruction (CWMD) synchronizer, prompting renewed effort to investigate the DoD's CWMD role, how USSOCOM can orchestrate it, and how to better define what DoD's place is among the various U.S. CWMD stakeholders. A particular topic within this discussion that should be better explored involves chemical weapon (CW) adoption and use by violent non-state actors (VNSA). Enhancing awareness of the environmental factors that contribute to a VNSA's decision and ability to adopt CW could aid USSOCOM's ability to develop appropriate methods and policies to counter and prepare for potential CW use.

This paper's methods include modeling how conflict influences CW use over time and social network analysis (SNA) on VNSA inter-organizational alliance networks to discern patterns of how CW may migrate from one organization to another.

The modeling portion suggests there is a statistically significant and positive relationship between an increase in the severity (number of deaths) of conflict and CW use among VNSA. This suggests VNSA will more often adopt CW in high-intensity conflict compared to low-intensity conflict. The SNA portion suggests CW migration from one VNSA to another requires a highly active (connected) VNSA to be successful.

The results from the modeling and SNA are used to inform a notional agent-based model (ABM) using a contemporary inter-organizational alliance network in Myanmar that provides a means of predictive analysis based on running the model multiple times. The results from the ABM suggest, in a minimally developed theater, kinetic operations are initially more effective than information operations (IO) but overtaken by IO effectiveness over longer time periods.

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I. INTRODUCTION

A. FRAMING THE PROBLEM

The Washington Post published an article in January, 2019 describing Iraqi geologist Suleiman al-Afari's experience as the Islamic State (IS) made its way through Mosul, Iraq in 2014.[1] Upon finding al-Afari, IS militants offered him a position to help them develop CW. Despite limited knowledge of CW, al-Afari accepted the position and commenced a 15-month endeavor to develop a supply chain for lethal chemical agents such as Sulfur mustard ($C_4H_8Cl_2S$), commonly known as mustard gas. Al-Afari reflected it was clear how important it was for the IS to make something that could terrify the masses. When asked if he regretted his role, he replied "They had become the government and we now worked for them. We wanted to work so we could get paid."[2] Once the paychecks from the Iraqi government ceased, there were many like al-Afari who had to choose between working with the new terrorist regime or being left behind with nothing. From this situation, we see the value in identifying and exploring how CW tactics proliferate across organizations, and this thesis aims to assess why some inter-organizational networks enable CW proliferation and others do not, as well as compare different disruption techniques at the intersection of the operational and strategic levels of warfare. Thus, what environmental factors drive CW proliferation from one organization to another and what indicators may be developed to identify that potential migration?

Al-Afari's story speaks to the importance of acquiring and leveraging expertise for terrorist organizations to develop CW. Even while under considerable external duress from coalition forces, the IS attained unprecedented access to university laboratories, industrial

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[1] Joby Warrick, "Exclusive: Iraqi Scientist Says He Helped ISIS Make Chemical Weapons," *The Washington Post*, January 21, 2019, https://www.washingtonpost.com/world/national-security/exclusive-iraqi-scientist-says-he-helped-isis-make-chemical-weapons/2019/01/21/617cb8f0-0d35-11e9-831f-3aa2c2be4cbd_story.html?noredirect=on&utm_term=.218437ddc229.

[2] Ibid.

complexes, and to a workforce with few options in Mosul.[3] What resulted was a mix of crudely weaponized Chlorine and low-grade mustard gas combined with various delivery systems like mortars and rockets. In response, the United States initiated a campaign targeting suspected IS chemists and chemical production centers in Mosul and Hit, Iraq.[4] The strikes against chemical production centers, coupled with IS territorial losses, severely hindered its ability to develop a CW capability.[5] As Herbert Tinsley et al. conclude, the IS's tactical application of CW and the chemical agents themselves remained unsophisticated.[6] Following their analysis, Tinsley et al. suggested that the IS may have used its limited CW capability as a means to target uninformed adversaries who may not have fully understood the lack of toxic potency or how CW works; they also pointed out that contrary to conventional wisdom, the group did not use propaganda to capitalize on its CW use.[7] Such analysis leads one to conclude that the IS viewed CW as a military-versus-military weapon rather than an appropriate method to conduct terror attacks. Thus, a weapon considered a Weapon of Mass Destruction (WMD) in the most recent guidance within the National Strategy for Countering WMD Terrorism 2018 was used more tactically than strategically.[8]

Not only do uncertainties remain surrounding the IS's perception of CW utility and how it applies to its overall strategic plan, but CW use also brings back the nearly two-decade-old question prompted by the Aum Shinrikyo chemical attacks in Japan during the

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[3] Ibid.

[4] Ibid.

[5] Ibid.

[6] Herbert Tinsley et al., "Islamic State Chemical and Biological Weapons Behavior Profile" (College Park, MD: START, 2017), 15.

[7] Ibid.

[8] White House, *National Strategy for Countering Weapons of Mass Destruction Terrorism* (Washington, DC: White House Office, 2018), https://www.hsdl.org/?view&did=819382.

mid 1990s: Are CW becoming more acceptable and obtainable by Violent Non State Actors (VNSA)?[9]

The answer, as the historical record indicates, likely consists of a more conservative conclusion suggesting that the successful adoption and implementation of a CW capability must take into account a series of complex methods, a dedication of resources, and an educated pool of personnel to draw upon which makes developing CW weapons a conscience and costly decision.[10] Thus far, only the IS and Aum Shinrikyo were able to develop a modest CW capability and did so under unique circumstances. However, the record also shows that a steady number of VNSA from various backgrounds are increasingly turning to chemical agents as a suitable weapon, demonstrating that the issue of how and where to conduct counter-proliferation (CP) efforts is likewise increasingly necessary.

B. BACKGROUND

In 2016, U.S. Special Operations Command (USSOCOM) assumed the role as the U.S. Department of Defense (DoD) Counter-Weapons of Mass Destruction (CWMD) synchronizer, prompting a renewed effort to investigate what the DoD's CWMD role is, how USSOCOM can orchestrate it, and how to better define what DoD's place is among the various U.S. CWMD stakeholders. A particular topic within this discussion that should be better explored involves chemical weapon (CW) adoption and use by VNSA. Enhancing awareness of the environmental factors that contribute to a VNSA's decision and ability to

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[9] Brian A. Jackson, "Technology Acquisition by Terrorist Groups: Threat Assessment Informed by Lessons from Private Sector Technology Adoption," *Studies in Conflict & Terrorism* 24, no. 3 (2001): 204, https://doi.org/10.1080/10576100151130270.

[10] Stephanie E. Meulenbelt and Maarten S. Nieuwenhuizen, "Non-State Actors' Pursuit of CBRN Weapons: From Motivation to Potential Humanitarian Consequences," *International Review of the Red Cross* 97, no. 899 (2015): 831–58, https://doi.org/10.1017/S1816383116000011.

adopt CW could aid USSOCOM's ability to develop appropriate methods and policies to counter and prepare for potential CW use.[11]

This suggestion may be considered in concert with the Worldwide Threat Assessment of the U.S. Intelligence Community released in January 2019 which projects "the overall threat from WMD [will continue to] grow during 2019, and we note in particular the threat posed by chemical warfare following the most significant and sustained use of chemical weapons to date."[12] The assessment goes on to suggest the continued use of CW weakens the international norms against its use and shifts the cost-benefit analysis in such a manner that may entice more actors to consider their development and use.

Furthermore, to advance the CWMD mission, the White House's National Security Strategy for Countering WMD Terrorism 2018 identified the following objectives:

- The agents, precursors, and materials needed to acquire WMD are placed beyond the reach of terrorists and other malicious non-state actors, and the global quantity of WMD and related materials is reduced.
- States and individuals are deterred from providing support to would-be WMD terrorists.
- An effective architecture is in place to detect and defeat terrorist WMD networks.
- United States defenses against WMD terrorism are strengthened, and state, local, tribal, and territorial preparedness to contend with WMD threats is enhanced.
- The United States is able to identify and respond to technological trends that may enable terrorist development, acquisition, or use of WMD.[13]

Likewise, the National Security Strategy 2017 provides overarching guidance that contends counter-terrorism (CT) operations include those conducted against WMD

[11] "Statement of General Raymond A. Thomas III, U.S. Army Commander United States Special Operations Command Before the Senate Armed Services Committee," § Senate Armed Services Committee (2017), https://www.socom.mil/pages/posture-statement-sasc.aspx.

[12] Daniel R. Coats, "Worldwide Threat Assessment of the U.S. Intelligence Community" (Office of the Director of National Security, January 29, 2019), 8.

[13] White House, *National Strategy for Countering Weapons of Mass Destruction Terrorism* (Washington, DC: White House Office, 2018), https://www.hsdl.org/?view&did=819382.

specialists, financiers, administrators, and facilitators.[14] From the National Security Strategy and the National Strategy for Countering WMD Terrorism, it may be presumed VNSA CW use is a priority, but what can USSOCOM do to advance CP efforts against VNSA CW use to better meet its lines of effort? Furthermore, are the lines of effort even effective at stopping VNSA CW use?

C. RESEARCH QUESTION

1. Significance

Ultimately, this study aims to support USSOCOM and associated stakeholders involved in CP and CT within the CWMD mission with an improved understanding of how CW migrates among VNSA to provide indications that can support better intelligence collection efforts and minimize uncertainty when considering kinetic and information operations. To accomplish this, we first examine how a conflict's character affects the probability a VNSA would adopt CW. Second, we examine how a CW capability may migrate through the inter-organizational VNSA alliance structure to identify potential new opportunities to disrupt the flow of knowledge and material from one organization to another. Using the results from these two approaches, we analyze potential disruption methods that leverage USSOCOM's core competencies, such as direct action and information operations (IO) by using the VNSA alliance network within Myanmar.

Instead of taking common approaches found in previous scholarly work such as case studies or intra-organizational methods that analyze internal motivators for CW development, this research takes an inter-organizational approach of social network analysis (SNA) and applies it to a contemporary VNSA network.[15] We aim to discern which alliances could potentially influence a VNSA's ability to develop CW. Here,

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[14] White House, *National Security Strategy of the United States of America* (Washington, DC: White House Office, December 2017), 8, https://www.whitehouse.gov/wp-content/uploads/2017/12/NSS-Final-12-18-2017-0905-2.pdf.

[15] Meulenbelt and Nieuwenhuizen, "Non-State Actors' Pursuit of CBRN Weapons," 2; Gary A. Ackerman et al., "Profiling the CB Adversary: Motivation, Psychology and Decision" (College Park, MD: START, 2017).

alliances consist of recorded relationships like a pledged allegiance and cooperative training and operations. The questions of concern here are:

How does the nature of conflict affect a VNSA's ability to innovate and adopt a CW capability?

How does an alliance network of VNSA, at the organization level, support the migration of CW use?

Does a VNSA's position within the alliance network, and the centrality of a group provide some indication that CW tactics will migrate to other groups within that alliance network?

Are kinetic operations or IO efforts more effective if the strategic objective is to contain the spread of a tactic or technological attribute?

D. RESEARCH FINDINGS

By taking an external view of the VNSA CW proliferation problem, the research conducted here determined a number of findings that may benefit policy development as USSOCOM further engages itself as the DoD's CWMD synchronizing entity:

- The lethality (death-rate) of state-based conflict acts as a better predictor of CW use than the intensity (number of events) of state-based conflict in a country-year.
- Wealthier, more populated, and more democratic states have a higher probability of experiencing a VNSA CW attack.
- There is a non-linear association between the lethality of conflict and the probability a VNSA uses CW. While there is a slight decline of CW probability at lower lethality levels, there is a relatively dramatic increase in probability at higher levels.
- Since 1995, VNSA have increasingly turned to using chemical agents, making the probability of a CW attack more likely today than in the past two decades.
- An alliance network's topology is the strongest factor in determining how quickly a technology can migrate across multiple organizations.

- If a particular organization already has a CW capability, that organization's power (by virtue of its brokerage or centrality measures) has a significant effect on whether the CW capability will migrate throughout the network.
- With lower diffusion rates of CW technologies in an inter-organizational network, coercive disruption (which includes kinetic and non-kinetic action degrading/disrupting a VNSA's CW capability) performs better initially, but over longer timeframes, IO disruption (which targets the lines of communication between VNSA in physical or information domains) is more effective in countering CW technology migration.
- With higher diffusion rates, IO disruption performs slightly better than coercion initially, but over longer timeframes both strategies produce similar results.
- It could benefit CWMD practitioners to incorporate relevant assets (Medical, EOD, Engineers, and other CBRN response entities) into non-kinetic targeting and planning, so that the various strategies under consideration have a full-spectrum CWMD perspective ranging from coercive actions to IO.

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II. LITERATURE REVIEW

Before addressing this thesis' methods, conclusions, and potential policy implications geared towards VNSA CP efforts, a review of relevant literature is necessary to identify where the VNSA CW debate currently resides. Although this research looks at a specific issue among the larger VNSA and debate, it nevertheless touches on several academic fields of study. This review attempts to address those debates identified as relevant by examining theories associated with WMD categorization, deterrence, counter-proliferation efforts, and how organizations adopt new technologies.

Our review first discusses the misuse of state-centric proliferation analysis along with the small, but growing, literature aimed directly at understanding the unique complexities inherent in VNSA CW development. Second, deterrence theory and its applicability to VNSA and WMD proliferation will be addressed. Third, conclusions across the overarching proliferation literature will be covered to highlight the current consensus that offers the foundation for current counter-proliferation efforts. Fourth, the debate surrounding the validity of the perceived threat VNSA pose regarding chemical weapon development and use is covered. Lastly, a discussion is presented regarding the technology adoption model (TAM) framework, which describes factors affecting a VNSA's ability to adopt new technologies, along with migration and contagion theories to substantiate the foundation this research resides upon.[16]

The conclusions derived from this review suggest CW counter-proliferation efforts targeting VNSA could be modified to not exclusively focus on supply-chain mitigation, but to identify those VNSA that are susceptible to incorporating a CW capability based on

[16] Jackson, "Technology Acquisition by Terrorist Groups: Threat Assessment Informed by Lessons from Private Sector Technology Adoption"; Gary A. Ackerman et al., "Profiling the CB Adversary: Motivation, Psychology and Decision" (College Park, MD: START, 2017); Gary A. Ackerman et al., "Anatomizing Chemical and Biological Non-State Adversaries: Identifying the Adversary," Project on Advanced Systems and Concepts for Countering WMD (PASCC), Center on Contemporary Conflict, Naval Postgraduate School (College Park, MD: National Consortium for the Study of Terrorism and Responses to Terrorism, January 2014).

external pressures and are well-placed within an inter-organizational alliance network to receive requisite knowledge, materials, and tactics.

A. A GAP IN COUNTER-PROLIFERATION EFFORTS?

Both non- and counter-proliferation policy recommendations provided by some of the literature regarding VNSA CW programs and associated illicit supply networks are often considered through a lens perhaps more aptly suited for state- and international-level WMD affairs. From this vantage, VNSA involvement in the CW realm remains relegated to witting and unwitting supply-chain enablers for illicit state-level programs or that a VNSA's own capability to conduct a mass CW attack is severely limited and requires little counter-proliferation attention or resources.[17] Although useful in their own right, these conclusions are based on a perception that the utility CW provides is reserved for strategic effects and fail to realize that CW, in the hands of VNSA (and states for that matter), are predominately used to meet tactical ends. As David Rapoport and John Parachini accurately surmise, the threat of a VNSA CW attack on a scale capable of killing or

[17] Brian A. Jackson, "Technology Acquisition by Terrorist Groups: Threat Assessment Informed by Lessons from Private Sector Technology Adoption" 204; Daniel Salisbury, "Why Do Entities Get Involved in Proliferation? Exploring the Criminology of Illicit WMD-Related Trade," *The Nonproliferation Review* 24, no. 3–4 (2017): 297, https://doi.org/10.1080/10736700.2018.1423718; Jonathan B. Tucker, "The Future of Chemical Weapons," *The New Atlantis*, no. 26 (Fall /Winter 2010 2009): 3, 12–13, 22–28; David C. Rapoport, "Terrorism and Weapons of the Apocalypse," in *Twenty-First Century Weapons Proliferation*, ed. James M. Ludes and Henry Sokolski, 1st ed. (London: Routledge, 2014), 25–26; John Parachini, "Putting WMD Terrorism into Perspective," *Washington Quarterly* 26, no. 4 (2003): 38, https://doi.org/10.1162/016366003322387091; Jerrold M. Post, "The Psychology of WMD Terrorism," *International Studies Review*, Nonstate Actors, Terrorism, and Weapons of Mass Destruction, 7 (2005) 148; Aaron Arnold, "A Resilience Framework for Understanding Illicit Nuclear Procurement Networks," *Strategic Trade Review* 3, no. 4 (Spring 2017): 3.

incapacitating on a massive scale is low, however, that does not mean VNSA are shying away from adopting CW agents.[18]

To this point, Gary Ackerman concludes "There is sufficient evidence to conclude that a variety of terrorist groups and individuals espousing different ideologies have either considered using CBRN [Chemical, Biological, Radiological, and Nuclear] weapons or have attempted to acquire CBRN weapons capability."[19] Thus, without direct analysis considering VNSA and CW proliferation, resulting conclusions and policy suggestions may not reveal all potential options that could enhance counter-proliferation efforts.[20] At best, this limited scope may only lead to extending the time it would take for a VNSA to acquire CW rather than stopping or preventing development altogether.

The gap in policy consideration associated with the relationship between VNSA and CW may stem from the overarching term, "WMD," often found in many media reports and official policies, which may erroneously suggest that the components under its umbrella—CBRN—are similar, or at least share important commonalities. Despite those who acknowledge that there are more differences than similarities among the WMD family, this bias often reveals itself in much of the literature that continually suggests attention to WMD supply-chains and supply-chain entities is of paramount importance—that WMD

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[18] David C. Rapoport, "Terrorism and Weapons of the Apocalypse," in *Twenty-First Century Weapons Proliferation*, ed. James M. Ludes and Henry Sokolski, 1st ed. (London: Routledge, 2014), 25–26; John Parachini, "Putting WMD Terrorism into Perspective," *Washington Quarterly* 26, no. 4 (2003): 38, https://doi.org/10.1162/016366003322387091; James Revill, "Past as Prologue? The Risk of Adoption of Chemical and Biological Weapons by Non-State Actors in the EU," *European Journal of Risk Regulation* 8 (2017): 641; William Morgan Alley and Jessica L. Jones, "An Analysis of the Threat of Malicious Chemical Use by Nonstate Actors: Questioning the State-Based Approach to Chemical Nonproliferation," *The Nonproliferation Review* 22, no. 3–4 (2015): 310, https://doi.org/10.1080/10736700.2016.1159373.

[19] Gary Ackerman, "Defining Knowledge Gaps within CBRN Terrorism Research," in *Unconventional Weapons and International Terrorism: Challenges and New Approaches*, 1st ed. (Routledge, 2009), 14 .

[20] Horowitz and Narang, "Poor Man's Atomic Bomb? Exploring the Relationship between 'Weapons of Mass Destruction,' 515.

proliferation is a supply-chain issue.[21] As such, non- and counter-proliferation policy recommendations run the gamut of modifying industry normative behavior; universalizing supply-chain restrictions; securing surplus WMD-related material; enhancing illicit supply-chain detection mechanisms; and deterring transnational criminal organizations.[22] Although useful, these conclusions leave the CW counter-proliferation effort focused on large-scale WMD programs and the daunting task of identifying a handful of needles in the global commerce haystack, which is made exponentially more difficult when considering the infinitesimal indications suggesting a VNSA is pursuing CW and is often satisfied with unsophisticated chemical agents and delivery mechanisms.[23] As Morgan Jones and Jessica Alley contend, it is not that current programs to inhibit CW proliferation by state actors are wrong, but that those same efforts are ill-suited to counter VNSA.[24]

To diverge from the WMD generalization, VNSA CW proliferation must be considered as a problem in-and-of itself and not just a part of the greater WMD non- and counter-proliferation effort. The limited, but growing, amount of literature focused on this field suggests a necessity to view VNSA CW proliferation on its own due to three fundamental characteristics: 1) VNSA CW use does not necessarily meet the WMD model upon which current non- and counter-proliferation policies are founded; 2) CW supply-chains do not hold similar characteristics as supply chains for other WMD; and 3) non-

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[21] Gary A. Ackerman et al., "Anatomizing Chemical and Biological Non-State Adversaries: Identifying the Adversary," Project on Advanced Systems and Concepts for Countering WMD (PASCC), Center on Contemporary Conflict, Naval Postgraduate School (College Park, MD: National Consortium for the Study of Terrorism and Responses to Terrorism, January 2014), 17.

[22] James J. Wirtz, "Counter-Terrorism via Counter-Proliferation," *Terrorism and Political Violence* 14, no. 3 (Autumn 2002): 129–140; David Albright, Paul Brannan, and Andrea Stricker, "Detecting and Disrupting Illicit Nuclear Trade after A. Q. Khan," *The Washington Quarterly* 33, no. 2 (2010): 85–106, https://doi.org/10.1080/01636601003673857; Auerswald, "Deterring Nonstate WMD Attacks," 543–568; Daniel Salisbury, "Why Do Entities Get Involved in Proliferation? Exploring the Criminology of Illicit WMD-Related Trade," *The Nonproliferation Review* 24, no. 3–4 (2017): 297–314, https://doi.org/10.1080/10736700.2018.1423718.

[23] Alley and Jones, "An Analysis of the Threat of Malicious Chemical Use by Nonstate Actors: Questioning the State-Based Approach to Chemical Nonproliferation, 310."

[24] Ibid., 310.

state actors are not beholden to the same international norms or pressures as most state actors.[25]

First, as scholars such as Gary Ackerman, Michelle Jacome, Thomas Graham Jr, Keith Hansen, Thomas McNaugher, James Revill, and Ashton Carter contend, labeling all CBRN weapons as WMD is fundamentally inaccurate.[26] Essentially, all WMD consist of CBRN, but not all CBRN should be considered WMD. While McNaugher warns against overstating CW effectiveness or elevating CW to the WMD status, as this may entice states to acquire them. Graham and Hansen contend CW may be best categorized as "weapons of mass casualties," or "disruption" as coined by Stephanie Meulenbelt and Maarten Nieuwenhuizen, rather than weapons of mass destruction.[27] Carter suggests CW is more synonymous with conventional weapons, but Ackerman and Jacome provide a more nuanced approach by advising the amount, nature, and sophistication of the chemical and delivery mechanism should play a factor when labeling use of a CW as WMD or as an attack using a chemical agent.[28] From this aspect, Ackerman and Jacome state VNSA have

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[25] Gary Ackerman and Michelle Jacome, "WMD Terrorism: The Once and Future Threat," *Prism* 7, no. 3 (May 15, 2018): 23; Breiger and Pinson, "A New Approach for Identification of Multiple Threat Scenarios to Counter CBRN Networks," 157; Paul K. Davis and Brian Michael Jenkins, "Deterrence & Influence in Counterterrorism: A Component in the War on Al Qaeda" (RAND Corporation, 2002), XVIII; Thomas L. McNaugher, "Ballistic Missiles and Chemical Weapons: The Legacy of the Iran-Iraq War," *International Security* 15, no. 2 (Fall 1990): 5–34.

[26] Gary Ackerman and Michelle Jacome, "WMD Terrorism: The Once and Future Threat," 23; Thomas Graham Jr. and Keith A. Hansen, *Preventing Catastrophe: The Use and Misuse of Intelligence in Efforts to Halt the Proliferation of Weapons of Mass Destruction* (Stanford: Stanford University Press, 2009), loc 72 of 3995, Kindle; Thomas L. McNaugher, "Ballistic Missiles and Chemical Weapons: The Legacy of the Iran-Iraq War," *International Security* 15, no. 2 (Fall 1990): 5–34; Revill, "Past as Prologue? The Risk of Adoption of Chemical and Biological Weapons by Non-State Actors in the EU," 631; Ashton Carter, "How to Counter WMD," *Council on Foreign Relations* 83, no. 5 (n.d.), 73.

[27] McNaugher, "Ballistic Missiles and Chemical Weapons: The Legacy of the Iran-Iraq War," 8; Graham Jr. and Hansen, Preventing Catastrophe: The Use and Misuse of Intelligence in Efforts to Halt the Proliferation of Weapons of Mass Destruction, loc 72 of 3995, Kindle; Meulenbelt and Nieuwenhuizen, "Non-State Actors' Pursuit of CBRN Weapons: From Motivation to Potential Humanitarian Consequences," 858.

[28] Graham Jr. and Hansen, *Preventing Catastrophe: The Use and Misuse of Intelligence in Efforts to Halt the Proliferation of Weapons of Mass Destruction*, loc 170 of 3995, Kindle; Gary Ackerman and Michelle Jacome, "WMD Terrorism: The Once and Future Threat," *Prism* 7, no. 3 (May 15, 2018): 23; Ashton Carter, "How to Counter WMD," *Council on Foreign Relations* 83, no. 5 (n.d.), 73.

conducted CW attacks, but none have met the "WMD" threshold.[29] Although the "threshold" is left ambiguous, it may be discerned through the historical record that VNSA have not yet met the level of chemical agent and delivery mechanism sophistication equating to a strategic-level weapon, but have typically conducted operations with, as Revill terms, "scruffy" or crude chemical agents.[30] Ted Gurr seconds this assessment highlighting that he is "…not aware of WMD use by any of the 300 politically significant minorities that have been tracked since the 1980s by the Minorities at Risk (MAR) project…"[31] To further complicate the issue, Revill points out, CW has been used for purposes other than killing, suggesting that not only is CW not necessarily a WMD, but that it can be used for temporary purposes.[32] These distinctions prove relevant to counter-proliferation efforts when such activities are predominately aimed towards proliferation on a "grander" scale as they may lose efficacy at the granular—non-state—level.

Second, as David Albright, Andrea Stricker, Graham, and Hansen argue, where nuclear weapon development has certain "tells" derived from highly specific materials, technology, and facilities that make the supply-chain exceptionally worthy of attention, CW production by VNSA may be produced without tipping off monitoring and enforcement agencies.[33] Apart from the more advanced chemical agents (e.g., VX and Sarin), precursor chemicals and necessary equipment are readily available in the open and

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[29] Ackerman and Jacome, "WMD Terrorism," 24.

[30] Revill, "Past as Prologue? The Risk of Adoption of Chemical and Biological Weapons by Non-State Actors in the EU," 627.

[31] Ted Robert Gurr, "Which Minorities Might Use Weapons of Mass Destruction?," *International Studies Review*, Nonstate Actors, Terrorism, and Weapons of Mass Destruction, 7 (2005), 143.

[32] Revill, "Past as Prologue? The Risk of Adoption of Chemical and Biological Weapons by Non-State Actors in the EU," 631.

[33] Graham Jr. and Hansen, *Preventing Catastrophe: The Use and Misuse of Intelligence in Efforts to Halt the Proliferation of Weapons of Mass Destruction*, loc 32 of 3995, Kindle; David Albright and Andrea Stricker, "The World of Illicit Nuclear Trade: Present and Future," in *Preventing Black-Market Trade in Nuclear Technology* (New York: Cambridge University Press, 2018), 47.

little-monitored market and have been used arguably to effectively meet tactical goals.[34] Adding to this point, Ackerman and Jacome address newer technologies like chemical microreactors that may be used to subvert nearly any export control measure.[35] Although continuous monitoring and export control functions remain a necessary component to support countering VNSA CW proliferation, it may be beneficial for counter-proliferation practitioners to reconsider the notion that VNSA CW proliferation is simply another WMD issue and instead develop a framework that considers how externalities affect the level of demand a VNSA has in developing a CW capability. Instead of focusing on the supply-side of CW development, in the case of VNSA, it may be more beneficial to identify which VNSA exhibits a higher demand signal.

Despite some effort to support a doctrinal shift to counter VNSA CW proliferation, particularly embodied by 2018 National Strategy for Countering Weapons of Mass Destruction Terrorism, the analytical basis necessary to operationalize such doctrine is either misappropriated or remains in its infancy.[36] This lack of attention may stem from the practice, as Ersel Aydinli argues, that appears to regulate VNSA analysis to a sub-area of terrorism and criminal studies, thus leaving VNSA outside the realm of analysis typically focused on state-to-state interactions (e.g., proliferation and international relations).[37] As well, Brian Jackson observes, prior to the mid-1990s, most scholarly research concluded WMD adoption remained outside the terrorist desired goals and are ultimately incompatible, leaving further research something of a moot point.[38] Jackson continues with identifying the 1995 Aum Shinrikyo chemical attack in Japan as a pivotal

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[34] Alley and Jones, “An Analysis of the Threat of Malicious Chemical Use by Nonstate Actors: Questioning the State-Based Approach to Chemical Nonproliferation.”

[35] Ackerman and Jacome, “WMD Terrorism,” 31.

[36] White House, *National Strategy for Countering Weapons of Mass Destruction Terrorism* (Washington, DC: White House Office, 2018), https://www.hsdl.org/?view&did=819382.

[37] Ersel Aydinli, Violent Non-State Actors: From Anarchists to Jihadists (New York: Rutledge, 2016).

[38] Jackson, “Technology Acquisition by Terrorist Groups: Threat Assessment Informed by Lessons from Private Sector Technology Adoption, 204.”

moment that swung the scholarly debate to conclude terrorist groups will quickly adopt CW from any number of sources.[39] However, this conclusion is as erroneous as its predecessor and lacks the appropriate scholarly rigor seen in state-level affairs. Although there exists some high-level policy concerns regarding potential VNSA launching chemical attacks, little has been done to understand "…the motivations, psychology and decision-making of the potential perpetrators themselves."[40] As the pendulum swings between accounts based upon VNSA chemical abstinence on one end and universal chemical adoption on the other, careful research may help the pendulum find its proper placement.

B. DETERRENCE AND THE VNSA QUAGMIRE

There remains an unresolved question as to whether deterrence theory can be aptly applied to VNSA as they operate below the state level. Scholars such as Emmanuel Adler and T.V. Paul highlight the notion that deterrence against asymmetric adversaries (e.g., terrorist groups and insurgencies) takes the theory out of the arena is was designed for—state-to-state interaction.[41] With this in mind, a debate certainly exists within the literature as to whether or not deterrence is a viable strategy against asymmetric adversaries.[42] To this point, Lawrence Freedman and David Auerswald suggest VNSA may be deterred, but the overarching classical, generalized deterrence requires modification.[43] Such modification, as Matthew Kroenig and Barry Pavel cite, was holistically adopted in the 2006 Quadrennial Defense Review, which promoted the Pentagon's shift to tailored

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[39] Ibid., 204.

[40] Gary A. Ackerman et al., "Profiling the CB Adversary: Motivation, Psychology and Decision" (College Park, MD: START, 2017), 3.

[41] T.V. Paul, "Complex Deterrence," in *Complex Deterrence Strategy in the Global Age* (Chicago: The University of Chicago Press, 2009), 15; Emanuel Adler, "Complex Deterrence in the Asymmetric-Warfare Era," in *Complex Deterrence in the Global Age* (Chicago: The University of Chicago Press, 2009), 85.

[42] For examples see: Robert F. Trager and Dissislava P. Zagorcheva, "Deterring Terrorism: It Can Be Done," *International Security* 30, no. 6 (Winter 2005): 87–123; Robert A. Pape, *Dying to Win: The Strategic Logic of Suicide Terrorism* (New York: Random House, 2005).

[43] Auerswald, "Deterring Nonstate WMD Attacks," *Academy of Political Science* 121, no. 4 (Winter 2006 / 2007): 543–568; Lawrence Freedman, *Deterrence* (Malden, MA: Polity Press, 2008).

deterrence strategies designed for revisionist or rogue powers, VNSA, and for near-peer competitors.[44] The Pentagon's shift appears to diminish the once conventional thought terrorists are irrational and undeterrable.

Deterrence, a concept central to strategic discourse during the Cold War between the United States and the Soviet Union, has experienced episodes of the highest importance, disdain, rejection, and modification.[45] At its core, Freedman contends deterrence is a practice of coercion, where a deterring state threatens actual or potential punishment in an attempt to stop another state from taking or continuing an unwanted action.[46] This classical deterrence is based on three principals, as Paul illustrates: 1) the deterring state must have adequate capacity to carry out the threat conveyed, 2) the threat must be credible, in that it must be severe enough to stop the target state's action but not so severe that actually carrying out the threat is perceived unlikely, 3) and last, the deterring state must be able to communicate the threat to the target state unambiguously.[47] As well, traditional deterrence theory assumes the belligerents are unitary, rational, and fully informed actors.[48] Deterrence, therefore, achieves success when the target state makes the rational decision to abstain from conducting the unwanted activity out of fear of reprisal. Thus, classical deterrence theory relies firmly on a rational calculation that proposed punishments would increase the cost should a state conduct an action to the point any benefit the state wanted to gain would be negated.

Those suggesting deterrence is not a viable strategy find issue with the principles and assumptions on which the theory is founded. From this camp, a general assumption exists that VNSA may not be deterrable when using a threat of punishment politically

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[44] Matthew Kroenig and Barry Pavel, "How to Deter Terrorism," *The Washington Quarterly* 35, no. 2 (April 2012): 22, https://doi.org/10.1080/0163660X.2012.665339.

[45] Freedman, *Deterrence*.

[46] Ibid., 26.

[47] T.V. Paul, "Complex Deterrence," in *Complex Deterrence Strategy in the Global Age* (Chicago: The University of Chicago Press, 2009), 2.

[48] Ibid., 3.

feasible to the deterring state.[49] Apart from the threat itself, there are hurdles the deterring state must surpass to convey a threat has even been made. For instance, a study released in 2001 by DFI International concludes VNSA are difficult to deter because they are revisionist by their nature and assume a different risk calculus than states; VNSA will seek out violence rather than refrain from it because violence gains them greater notoriety.[50] As well, the assumption of rationality becomes problematic when applied to the VNSA (as well as states), because there are a variety of views and motivations that make rationality non-universal—different actors consider what is valuable, differently.[51] As well, David Auerswald acknowledges there is a lack of direct communication between the state actor and VNSA leading to indirect communication that results in ambiguity.[52] Similarly, there is an apparent lack of common "deterrent culture" shared between the state and VNSA that would otherwise promote a common normative language that could lead to alternative actions other than violence.[53] Furthermore, it is suggested a state's use of deterrence may even invigorate a VNSA's actions rather than prevent further violence. This may partly be because to the more commonly states use deterrence policies, the more likely VNSA will develop counter methods to create situations where the VNSA can gain notoriety or some other benefit.[54] This maneuvering devolves into a situation where the state actor is left with no good options, what Adler refers to as a "deterrence trap," to counter a VNSA's activity other than through prolonged war.[55] To counter such a trap, the previously mentioned DFI study suggests deterrence strategies involving the denial of VNSA's objectives represent the most effective role for the U.S. military and further suggests

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[49] Ibid., 15.

[50] "Non-Nuclear Strategic Deterrence of State and Non-State Adversaries: Potential Approaches and Prospects for Success," Final Report (Washington, DC: DFI Government Practice, October 2001), 12.

[51] Freedman, *Deterrence,* 10.

[52] Auerswald, "Deterring Nonstate WMD Attacks, 551."

[53] Adler, "Complex Deterrence in the Asymmetric-Warfare Era, 96."; Freedman, *Deterrence*, 67.

[54] Adler, "Complex Deterrence in the Asymmetric-Warfare Era," 85.

[55] Ibid., 85–88.

interdiction operations, enhanced defenses, and an effective consequence management apparatus are key endeavors to denying VNSA from gaining benefits (objectives) from conducting attacks.[56] Suffice to say, deterring VNSA by threatening punishment is a difficult and uncertain endeavor.[57]

Despite the previous arguments which target the assumptions deterrence theory resides upon, there remain proponents of deterrence applicability against asymmetric VNSA. Many proponents have turned to criminological literature, which has made great strides in modifying deterrence theory into something perhaps more useful when considering VNSA. Overall, Daniel Nagin and Greg Pogarksy surmise there is a general agreement within criminal justice discourse regarding deterrence that the certainty of punishment provides a deterrent affect over that of the severity of punishment.[58] Within a framework devoted to addressing criminal activity, a body of literature exists to identify ways to convey the costs associated with apprehension and punishment, at the individual and organization level, as an option to overwhelm any potential profit.[59] Criminal deterrence is conveyed in two forms, with both attempting to make clear that “crime does not pay.” General deterrence seeks to educate and influence the population as a whole, while specific deterrence is targeted at the offender to deter them from further criminal acts.[60] Regardless of the aforementioned consensus, critics question the efficacy, or at least the level of analysis as yet produced, of deterrence claims in this form, stating there are limited and conflicting understandings regarding human behavior (e.g., personal values

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56 “Non-Nuclear Strategic Deterrence of State and Non-State Adversaries: Potential Approaches and Prospects for Success,” 23. The study considers denial of operations, of coercion, and of objectives with each being possible, but the denial of objectives as the most feasible.

57 David P. Auerswald, “Deterring Nonstate WMD Attacks,” 546.

58 Daniel S. Nagin and Greg Pogarsky, “Integrating Celerity, Impulsivity, and Extra-Legal Sanction Threats into a Model of General Deterrence: Theory and Evidence,” *Criminology* 39, no. 4 (2001), 865.

59 Eugene McLaughlin and John Muncie, eds., *The Sage Dictionary of Criminology* (Thousand Oaks, CA: SAGE Publications, 2001), 88.

60 Ibid.

and norms).[61] Just as well, studies regarding the severity as well as the swiftness of punishment have suggested they too have an effect but remain "highly ambiguous."[62]

Terrorism and proliferation research has taken criminal deterrence findings to advance their claims. However, as Kroenig and Pavel articulate, deterrence is inadequately understood and underutilized in counterterrorism efforts, but it has great potential to stop future terrorist attacks.[63] Attempting to unpack some of the deterrence mystery, Daniel Salisbury highlights potential sub-state deterrent methods targeting both individuals and organizations as a way to mitigate WMD-related illicit trade.[64] Paul Davis and Brian Jenkins proposed reconsidering a VNSA organization as a whole and instead consider it as a complex system made of many parts that create and support it.[65] Additionally, addressing the life-cycle of the terrorist process, from recruitment to assignment, may also impact the ability of the organization to continue.[66] Looking at the individuals and their motivations within a terrorist network affords new deterrent options (a system of influences) that will potentially whittle away the terrorist organization's ability to exist.[67] As Davis and Jenkins

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[61] Michael Tonry, "Learning from the Limitations of Deterrence Research," *Crime and Justice* 37, no. 1 (2008): 280. For example, A recent study suggested offenders may modify behaviors to decrease the likelihood of apprehension when deterrence measures are systematic, mitigating the temporal and spatial deterrent effects. See: Barak Ariel and Henry Patridge, "Predictable Policing: Measuring the Crime Control Benefits of Hotspots Policing at Bus Stops," *Journal of Quantitative Criminology* 33, no. 4 (December 2017): 809–33.

[62] Daniel S. Nagin and Greg Pogarsky, "Integrating Celerity, Impulsivity, and Extra-Legal Sanction Threats into a Model of General Deterrence: Theory and Evidence," *Criminology* 39, no. 4 (2001); Michael Tonry, "Learning from the Limitations of Deterrence Research," *Crime and Justice* 37, no. 1 (2008); Daniel Salisbury, "Why Do Entities Get Involved in Proliferation? Exploring the Criminology of Illicit WMD-Related Trade," *The Nonproliferation Review* 24, no. 3–4 (2017): 306, https://doi.org/10.1080/10736700.2018.1423718.

[63] Kroenig and Pavel, "How to Deter Terrorism," 22.

[64] Salisbury, "Why Do Entities Get Involved in Proliferation? Exploring the Criminology of Illicit WMD-Related Trade, 297–314."

[65] Paul K. Davis and Brian Michael Jenkins, "Deterrence & Influence in Counterterrorism: A Component in the War on Al Qaeda" (RAND Corporation, 2002), 9.

[66] Ibid., 19.

[67] Ibid., 15.

ask, “Can al Qaeda be deterred? Of course not. But wait, what do we mean by that? If we ask, instead, whether the elements of the al Qaeda *system* [sic] can be deterred from doing specific things, the answer is ‘Yes.’”[68] Thus, when faced with an asymmetric adversary, deterring a form of warfare may be a more productive endeavor than deterring the conflict altogether.

However, even proponents of VNSA deterrence acknowledge there are limits to its effectiveness and lament it is unlikely all individuals can be successfully deterred. Davis and Jenkins generally categorize terrorist actors as either Type A or Type B.[69] Type A terrorists include fanatics and pirates that are driven by violence itself. It is this type that the authors suggest must be eradicated. Echoing this, T.V. Paul acknowledges cataclysmic groups may not be deterrable at all.[70] Type B terrorists describe those actors generally more pragmatic with political goals. They may act destructively but will revert to normal behavior once they achieved their goals. This type should be suppressed, but their concerns should be subsequently addressed.[71] Although categorizing VNSA is useful for developing strategies to counter them, it is difficult to accept the premise there are actors only motivated by violence itself and the notions of suppressing and then addressing concerns is very compatible. Nevertheless, Kroenig and Barry suggest as long as some terrorism can be deterred, deterrence must be a part of a counterterrorism strategy.[72]

Proliferation literature has taken criminal deterrence findings and applied them predominately to individuals and organizations along the supply-chain that wittingly or unwittingly support WMD proliferation. Similar to terrorism conclusions, non- and counter-proliferation literature categorizes individuals and entities into varying degrees of complicity. One such model by I.J. Stewart and Daniel Salisbury offers the “4 I’s:” 1)

[68] Ibid., 22.

[69] Ibid., 11–12.

[70] Paul, “Complex Deterrence," 15.

[71] Davis and Jenkins, “Deterrence & Influence in Counterterrorism” 11-12.

[72] Kroenig and Pavel, “How to Deter Terrorism,” 22, 24.

Innocent—those actors that are unaware they have done anything wrong, 2) Ignorant—those actors that do not understand controls regulating WMD-related material trade, 3) Indifferent—those actors that know they have done something wrong, but do not care, and 4) Ideological—those actors that clearly know what they are doing is wrong either legally or morally and this fact may even drive them to act in this way.[73] The model further identifies which type of deterrence method may be effective based on the individual's or organization's supposed "I." The methods range from educating the innocent and ignorant, while the only method that may be available to deter the ideological is through denial of required technology, materials, and knowledge to develop WMD.[74] Again, similar to terrorism conclusions, proliferation contends that there may be certain types of actors immune to any deterrent strategy, and suggests imprisonment or denial of export privileges as solutions.[75]

Thus, the deterrence theory debate provides a wide swath of possibilities when applied to VNSA, both explored and untouched. While the application of classic deterrence appears limited, there is potential when considering a tailored approach that can penetrate the target organization at the individual or sub-component level. The notion that certainty of punishment has a deterrent effect in the criminological literature is notable, except CW, as with most proliferation, is normally conducted covertly making the ability to punish difficult.[76] Likewise, the concept of punishment, certain or not, as a deterrence may not be overly relevant when targeting the determined terrorist or terrorist organization that already decided to pursue CW. Thus, there is a quagmire of questionable efficacy in completely deterring a terrorist organization or an individual terrorist as they may remain outside the reach of current deterrence efforts. What may be an alternative, is identifying useful

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[73] I. J. Stewart and D. B. Salisbury, "Non-State Actors as Proliferators: Preventing Their Involvement," *Strategic Trade Review* 2, no. 3 (n.d.): 14.

[74] Ibid., 15.

[75] Ibid., 26.

[76] Victor Jupp, Pamela Davies, and Peter Francis, "The Features of Invisible Crime," in *Invisible Crimes: Their Victims and Their Regulation* (London: Palgrave Macmillan, 1999), 5.

indicators that suggest a VNSA is primed to adopt CW and focus intelligence collection and counter-proliferation efforts to negate the VNSA's ability to successfully do so.

C. PUTTING THE VNSA CW THREAT INTO PERSPECTIVE

Apart from the debate surrounding the effectiveness and utility CW possess at the state level, a separate debate surrounds whether the threat posed by a VNSA's CW adoption and use is real or exaggerated. As Revill surmises, terrorists using CW in Syria and Iraq are a reality, but predicting VNSA adoption of catastrophic-level CW ignores several factors that influence the decision to adopt, much less to use them.[77] Along this same vein, Philipp Bleek stated in a seminar one of his major concerns is not a VNSA using military-grade CW, but a single actor attacking a victim by splashing acid across their face.[78] Thus, it may not necessarily be whether the threat is real, but at what scale should a VNSA CW attack be expected?

This discussion, as previously mentioned, turned a corner following the Aum Shinrikyo CW attacks in the mid-1990s.[79] As both Ackerman and Jackson acknowledge, the literature suggested VNSA would rush to incorporate CW now that the precedent was set.[80] To exemplify this swing towards the perceived existential threat, Gregory Koblentz highlights that in 2008 Commission on the Prevention of Weapons of Mass Destruction Proliferation and Terrorism predicted, "…it is more likely than not that a weapon of mass

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[77] Revill, "Past as Prologue? The Risk of Adoption of Chemical and Biological Weapons by Non-State Actors in the EU," 627.

[78] Philipp Bleek from the Middlebury Institute of International Studies during a guest lecture at the Naval Postgraduate School on February 8th, 2019.

[79] For a review of literature focused on this discussion, see: Ackerman et al., "Anatomizing Chemical and Biological Non-State Adversaries: Identifying the Adversary," 6–15.

[80] Ackerman et al., "Anatomizing Chemical and Biological Non-State Adversaries: Identifying the Adversary," 7; Jackson, "Technology Acquisition by Terrorist Groups: Threat Assessment Informed by Lessons from Private Sector Technology Adoption," 204. For examples see: Brad Roberts, "Terrorism and Weapons of Mass Destruction: Has the Taboo Been Broken?," *Politics and the Life Sciences* 15, no. 2 (September 1996): 216–17."; Gavin Cameron, "WMD Terrorism in the United States: The Threat and Possible Countermeasures," *The Nonproliferation Review* 7, no. 1 (2000): 162–79, https://doi.org/10.1080/10736700008436803."

destruction will be used in a terrorist attack somewhere in the world by the end of 2013."[81] However, as hindsight informs us, this prediction may appear to be something of a knee-jerk reaction that attempted to generalize and provide broad conclusions founded on a handful of incidents that were unique to the Aum Shinrikyo case. As such, Meulenbelt and Nieuwenhizen observe that there has not been any substantial increase in VNSA CBRN incidents in recent decades.[82]

In addressing various biases that may influence VNSA CBRN threat assessments, Gregory Koblentz aptly categorizes the schools of thought concerning the threat posed by VNSA acquiring WMD as either optimists, pessimists, or pragmatists.[83] Koblentz goes on to state that each of the schools of thought drew their conclusions from the same CBRN terrorism data, but each developed their own conclusions. The optimists suggest CBRN terrorism is a "very low probability, very low consequence" threat; VNSA are not seeking a CBRN capability because they are not required to meet their objectives and will continue to prefer using conventional weapons.[84] Koblentz suggests scholars that fall within this camp include Brain Michael Jenkins, Ehud Spriznak, and Milton Leitenberg. The pessimists consider CBRN terrorism is a "low (but growing) probability, high consequence" threat; the CBRN threat is growing due to VNSA changing intentions and increasing capabilities based on the democratization of science and technology.[85] Scholars Koblentz suggests that fall within this camp include Richard Falkenrath, Ashton Carter, and Graham Allison. The pragmatists state CBRN terrorism is a "low probability, low consequence" threat; there is concern VNSA are showing a greater interest in mass casualty

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81 Gregory D. Koblentz, "Predicting Peril or the Peril of Prediction? Assessing the Risk of CBRN Terrorism," *Terrorism and Political Violence* 23, no. 4 (2011): 501.

82 Meulenbelt and Nieuwenhuizen, "Non-State Actors' Pursuit of CBRN Weapons: From Motivation to Potential Humanitarian Consequences," 833.

83 Koblentz, "Predicting Peril or the Peril of Prediction? Assessing the Risk of CBRN Terrorism," 502.

84 Ibid., 503.

85 Ibid.

events and acquiring CBRN, but these cases are rare.[86] Scholars Koblentz suggests fall within this camp include John Parachini, Jonathon Tucker, and Jean Pascal Zanders.[87] What is left unanswered is what each of the probabilities and consequences actually correspond to other than the scholar's own interpretation. Despite using statistical jargon, there is no quantitative analysis providing a contextual backdrop. This missing information is not necessarily an omission made by Koblentz, but a result of the lack of data Koblentz could draw from. Much of the literature has thus far treated the relationship between VNSA and CBRN as if it were a similar issue as the relationship between states and nuclear proliferation.

Just as well, regardless of which of Koblentz's schools of thought appears to have a greater or lesser argument, that cases of VNSA exploring and using CW continue to materialize suggests the necessity of better analysis to inform policymakers and counterproliferation stakeholders on methods to deter and interdict those organizations seeking CW. As Ackerman, Bruce Hoffman, Christina Hellmich, and Amanda Redig argue, assessing the VNSA's motivations, thought and decision-making process, and intentions to carry out attacks using CW must be done prior to assessing the true threat a VNSA poses.[88] That is, analysis of the proclivity and capability a VNSA has must be conducted to inform probability and consequence conclusions.

D. INTERNATIONAL RESPONSES AND STANDING GUIDANCE

As stated previously, the proliferation literature predominately focuses on methods to restrict states and VNSA ability to obtain WMD-related materials and technology from a supply side perspective. Such nonproliferation efforts based on monitoring and

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[86] Koblentz, "Predicting Peril or the Peril of Prediction? Assessing the Risk of CBRN Terrorism," 504.

[87] Ibid., 513.

[88] Ackerman et al., "Anatomizing Chemical and Biological Non-State Adversaries: Identifying the Adversary," 17; Christina Hellmich and Amanda J. Redig, "The Question Is When: The Ideology of Al Qaeda and the Reality of Bioterrorism," *Studies in Conflict & Terrorism* 30, no. 5 (n.d.): 384, https://doi.org/10.1080/10576100701258593; Bruce Hoffman, "Forward," in *Research on Terrorism: Trends, Achievements and Failures*, ed. Andrew Silke (Portland, OR: Frank Cass, 2004), xviii.

investigating have been taken on by entities like the Organisation for the Prohibition of Chemical Weapons (OPCW), which is charged with implementing the Chemical Weapons Convention (CWC), a United Nations framework adopted in 1992.[89] The OPCW is mandated to "…eliminate an entire category of weapons of mass destruction by prohibiting the development, production, acquisition, stockpiling, retention, transfer or use of chemical weapons by States Parties."[90] Operating in concert with the OPCW, the Australian Group acts as a multilateral export control regime, dedicated to publishing controlled chemical and biological weapon precursors and associated dual-use equipment lists and monitoring exports and imports of chemical shipments.[91]

The international community's dedication to restricting the flow of CW and associated components has substantially impacted the availability of such material to aspiring CW developers, both states and VNSA.[92] However, as Alley and Jones point out, the current nonproliferation regime remains focused on restricting those agents associated with traditional—military-grade—CW, which fails to control agents most utilized by VNSA.[93] Despite these massive efforts, there remain indications terrorist organizations continue to plan operations using CW.[94] In 2000, Matt Valiquette argued a counter-proliferation strategy has become increasingly necessary and must be further developed

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89 For more information regarding the OPCW, see: https://www.opcw.org/. For the CWC, see: https://www.opcw.org/chemical-weapons-convention

90 Ibid.

91 For more information on the Australian Group see: https://australiagroup.net/en/.

92 Matt J. Valiquette, "Assessing the U.S. Counter Proliferation Initiative: Considerations for Military Operations Other than War" (Naval Postgraduate School, 2000), xii.

93 Alley and Jones, "An Analysis of the Threat of Malicious Chemical Use by Nonstate Actors: Questioning the State-Based Approach to Chemical Nonproliferation," 310.

94 Ackerman et al., "Anatomizing Chemical and Biological Non-State Adversaries: Identifying the Adversary, 7."; Ackerman, Gary. "Defining Knowledge Gaps within CBRN Terrorism Research." In *Unconventional Weapons and International Terrorism: Challenges and New Approaches*, 1st ed. Routledge, 2009, 14.

and actualized.[95] Such a statement remains relevant more than 19 years later. Yet, with few exceptions, the literature finds the best way forward is to emphasize the vulnerability among the legitimate and illicit supply-chain networks and to promote the criminalization of its activity. Simply, James Wirtz posits, “Counter-proliferation addresses the ‘supply-side’ of the WMD issue by reducing the availability of nuclear, chemical, and biological weapons that might find their way into the hands of terrorists.”[96]

In countering the supply-side of WMD, there appears a general consensus that illicit trade is the key factor in WMD development and more must be done to stop it. As David Albright et al. argue (regarding nuclear proliferation, but contend is relevant for all WMD), “The first line of defense is not currently adequate at deterring, catching, or prosecuting traffickers in dangerous nuclear goods.”[97] Albright et al. continue with, “The international community must make countering illicit nuclear trade a bedrock of international nonproliferation efforts.”[98] In their conclusion, they suggest making export controls universal, protecting facilities, improving illicit trade detection, increasing international organization investigatory capabilities, and expanding government and industry cooperation.[99]

To complement the previous suggestions, in reference to the above 4 I’s, it is suggested continued efforts devoted to regulatory education and shaping international normative culture, through further chemical trade controls and improving ethical standards among chemists, could further restrict WMD material availability from entering illicit

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[95] Matt J. Valiquette, “Assessing the U.S. Counter Proliferation Initiative: Considerations for Military Operations Other than War,” (Naval Postgraduate School, 2000), xii.

[96] James J. Wirtz, “Counter-Terrorism via Counter-Proliferation,” *Terrorism and Political Violence* 14, no. 3 (Autumn 2002): 131–132.

[97] David Albright, Paul Brannan, and Andrea Stricker, “Detecting and Disrupting Illicit Nuclear Trade after A. Q. Khan,” *The Washington Quarterly* 33, no. 2 (2010): 104, https://doi.org/10.1080/01636601003673857.

[98] Albright, Brannan, and Stricker, “Detecting and Disrupting Illicit Nuclear Trade after A. Q. Khan,” 104.

[99] Ibid., 95–101.

supply networks.[100] Other policy options include increasing law and regulatory enforcement to deny those deemed undeterrable.[101] Salisbury additionally contends there remains a need to "raise illicit WMD-related trade from the realms of 'invisible crime'…" and further research into the illicit trade is required.[102]

This sentiment is echoed by David Auerswald who acknowledged there are limits to deterring VNSA (as end-users) from WMD proliferation and suggests focusing on deterring, through denial or punishment, transnational organized crime groups (as likely intermediaries between legitimate trade and illegitimate end-users) as an option to restricting illicit trade supporting VNSA.[103] Along a similar vein, Matthew Bunn and William Potter state that (nuclear) illicit trade "requires a whole-of-government approach combining intelligence, law enforcement, export controls, interdiction, customs, and financial controls."[104] Likewise in reference to nuclear WMD proliferation, Wyatt Hoffman and Tristan Volpe address the challenges posed by additive manufacturing technologies and suggest that additional regulations and monitoring may eventually be necessary to control the flow of dual-use or nuclear weapon component build packages.[105]

Much of the work done aimed at further educating employees, increasing export controls, modifying acceptable normative behavior, and increasing cooperation among the various non- and counter-proliferation stakeholders continues to shed light on a topic that

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[100] Stewart and Salisbury, "Non-State Actors as Proliferators: Preventing Their Involvement," 15.; Sydnes, Leiv K. "How to Curb Production of Chemical Weapons," *Nature* 556 (April 2018).

[101] Ibid.

[102] Salisbury, "Why Do Entities Get Involved in Proliferation? Exploring the Criminology of Illicit WMD-Related Trade," 297.

[103] Auerswald, "Deterring Nonstate WMD Attacks," 545–548.

[104] Matthew Bunn and William C. Potter, "Introduction: The Problem of Black-Market Nuclear Technology Networks," in *Preventing Black-Market Trade in Nuclear Technology* (New York: Cambridge University Press, 2018), 3.

[105] Wyatt Hoffman and Tristan A. Volpe, "Internet of Nuclear Things: Managing the Proliferation Risks of 3-D Printing Technology," *Bulletin of the Atomic Scientists* 74, no. 2 (2018): 110, https://doi.org/10.1080/00963402.2018.1436811.

justly requires it. However, actions targeting the supply-chain will likely not be enough to stop determined VNSA from acquiring a CW capability.[106] In the meantime, the "democratization of technical information, methodological approaches, and physical technology are making advanced science and engineering more accessible to non-specialist individuals."[107] Increasing access coupled with advances in dual-use technology and simplified methods, will make supply-chain monitoring and regulation increasingly challenging.[108] This begs for a concerted effort to evaluate where the supply is headed and how it will be used. As Gary Ackerman and Markus Binder identify, appropriate planning to enhance counter-proliferation efforts cannot be accomplished if the threat environment is not understood.[109] Without understanding what the threat is, how can the effects (regulation, deterrence, education, or norms development) of supply-chain policy be appropriately measured?

Although there have been recent endeavors by Ackerman et al. to identify indications that can discern the likelihood a VNSA would adopt and use a chemical weapon, little research (although growing) exists that provides actionable direction to counter them.[110]

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106 Bunn and Potter, "Introduction: The Problem of Black-Market Nuclear Technology Networks," 12–13.

107 Gary A. Ackerman and Markus K. Binder, "Chemical and Biological Threats: The Emerging Landscape" (Baltimore, MD, 2017).

108 William M. Evans and Bret B. Hays, "Dual-Use Technology in The Context of the Non-Proliferation Regime," History and Technology 22, no. 1 (n.d.), https://doi.org/10.1080/07341510500517850.

109 Ackerman and Binder, "Chemical and Biological Threats: The Emerging Landscape" (Baltimore, MD, 2017).

110 Ackerman et al., "Anatomizing Chemical and Biological Non-State Adversaries: Identifying the Adversary, 1." For examples of recent work on VNSA propensity to adopt chemical weapons, see: Gary A. Ackerman et al., "Profiling the CB Adversary: Motivation, Psychology and Decision" (College Park, MD: START, 2017).

E. ADOPTION, MIGRATION, AND CONTAGION

The foundation for this research takes into consideration three fundamental concepts: technology adoption, tactics migration, and contagion. Taking a page from the Technology Adoption Model (TAM) often seen in the commercial advertising and acquisition literature, Brian Jackson highlighted factors that could lead to VNSA successfully adopting new weapons.[111] The factors are divided into two stages, with the first addressing those that influence decisions to innovate. Stage one factors include:

- Technological awareness
- Openness to new ideas
- Attitudes toward risk*
- The nature of the environment*[112]

While the first two factors involve the psychological and philosophical nature of an organization and its key actors, the second two (with asterisk) can affect the demand to adopt based on various external pressures. External pressures could influence a VNSA's ability to communicate, share material, and reconsider the appropriate level of risk.

Stage two focuses on those factors that influence the successful adoption of technology, once the decision to innovate (Stage one) is made. Stage two factors include:

- The nature of the technology
- External communication links and the characteristics of technology sources*
- The environment of the terrorist group*
- Availability of financial and human resources*
- Group longevity[113]

Again, Stage two considers the environment along with other factors that are influenced by external pressure and how connected the organization is to the outside world. Thus, it is characterizing externalities that support CW adoption, a topic found in both

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[111] Jackson, "Technology Acquisition by Terrorist Groups: Threat Assessment Informed by Lessons from Private Sector Technology Adoption."

112 Ibid., 189-195.

113 Ibid., 195-202.

stages, that this research seeks to accomplish. In Jackson's analysis of the impacts the environment has, he states VNSA contend with "pressures that lack an analogue in legitimate organizations. For example, the impact of law enforcement and counterterrorist forces, in addition to affecting operations that are underway, can have a significant effect on a group's technology adoption process."[114] Although the stated external pressures may make it increasingly difficult for a VNSA to find the time and space necessary to fully develop new and effective weapons, could such pressures nevertheless prompt VNSA to try? Will pressure force a VNSA to develop a chemical capability in a similar fashion as witnessed by that same pressure forcing them to adjust tactics, techniques, and procedures regarding more conventional weapons?

In concert with TAM, tactics migration theory literature such as Adam Dolnik's book "Understanding Terrorist Innovation," contends that many consider Aum Shinrikyo as "the most innovative terrorist organization of all time," contributing that status primarily to the group's psychological aspects such as an unyielding fascination for non-bloody—but nevertheless terrifying—methods for causing mass casualties.[115] However, there generally exist common external factors that affect a VNSA's ability to innovate given a constant set of internal factors. As well, state sponsorship is sometimes attributed to an organization's ability to innovate due to the two obvious advantages that come with such an alliance: increased ability to raise funds, and higher probability of access to critical information for technological or tactic development. Looking at the Revolutionary Armed Forces of Colombia (FARC), we see a well-funded organization provided by their narcotics business, which also leveraged expertise from the Colombian Navy and universities to design and build seaworthy semi-submersibles sometimes through financial incentive and other times through coercion.[116] This ability to seek sources of knowledge outside their

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[114] Ibid., 195.

[115] Adam Dolnik, Understanding Terrorist Innovation: Technology, Tactics and Global Trends. (London; New York: Routledge, 2013), 21.

[116] Michelle Jacome Jaramillo, "The Revolutionary Armed Forces of Colombia (FARC) and the Development of Narco-Submarines." *Journal of Strategic Security* 9, no. 1 (2016): 49-69. http://dx.doi.org/10.5038/1944-0472.9.1.1509

organization helped them raise funds and therefore increased their operational effectiveness, however CW did not migrate through its alliance network of other VNSA.

A VNSA's cooperation with other organizations, as opposed to merely individuals with expertise, has shown to be a promising contributor to the organization's probability of success in developing new technologies and tactics. For example, Al-Qaeda (AQ) training its affiliated groups such as Jemaah Islamiya (JI) has shown to migrate improvised explosive device (IED) tactics. Based on the researchers' operational experience, this tactics migration included the utilization of multiple IEDs in tandem for maximizing casualties, as well as devices specifically designed to target first responders such as Explosive Ordnance Disposal (EOD) personnel, where a complex and compound initiation device does not detonate until certain neutralization procedures are attempted. The migration of mobile devices for sophisticated IEDs, such as dual-tone multi-frequency (DTMF) signaling that makes decoding signals more difficult without advanced electronic equipment, is yet another example of a migrating tactic resulting from VNSA alliances.

These evolutions in tactics and technology are mostly incremental, which is the most prevalent scale of innovation in terrorist groups, despite academic researchers' tendencies to focus on radical leaps of innovation.[117] CW should be considered a radical leap considering that Aum Shinrikyo spent $30 million, of its estimated $1 billion in resources, solely to develop a Sarin capability on its own with negligible external collaboration.[118]

Complementing the communication and technological awareness concepts provided by TAM and tactics migration theory, among social network analysis (SNA), contagion theory delves more specifically into how actors influence others within the same network. Contagion theory seeks to explain "organizational members' knowledge, attitudes, and behavior on the basis of information, attitudes, and behavior of others in the

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[117] Nicole Tishler, "Trends in Terrorists' Weapons Adoption and the Study Thereof." *International Studies Review* 20, no. 3 (Carleton University, 2017), 390.

[118] Adam Dolnik, Understanding Terrorist Innovation: Technology, Tactics and Global Trends. (London; New York: Routledge, 2013), 46–47.

network to whom they are linked."[119] It posits that one actor's behavior influences another's behavior to the degree that both actors have comparable relations to all the other actors within the network. Essentially, the measure of influence between actors is directly proportional to how similarly they are connected to the network.[120]

Moving specifically to an organizational level of analysis, Palmer et al. contended during a study of U.S. corporations' adoption of a multidivisional form (MDF) that, from an embeddedness perspective, "organizations are situated in networks of social relationships and adopt structures irrespective of efficiency considerations."[121] A conclusion suggested a corporation is more likely to adopt the MDF when they have ties with other firms that have already adopted MDF. Considering this finding with the overarching contagion theory, it is proposed that not only do tied organizations influence one another, but when it comes to the migration of a new technology, process, or, in our case, CW adoption, throughout an organizational network, a central organization must adopt it.

Thus, for a new technology to successfully migrate in a dark network—a covert and illegal network—it may be important for a centrally placed actor within the network to adopt and act as a sponsor, though it does not necessarily need to be the first to do so.122 Without the influence the centrally placed actor has, the new information and know-how will likely not be successfully distributed. This is particularly true among dark networks, which contend with pressures that inhibit a free flow of communication and a necessity to weigh operational security with the potential of interdiction by CT operations.

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[119] Peter R. Monge and Noshir S. Contractor, *Theories of Communication Networks* (New York: Oxford University Press, 2003), 174.

[120] Ibid., 176.

[121] Donald A. Palmer, P. Devereaux Jennings, and Eueguang Zhou, "Late Adoption of the Multidivisional Form by Large U.S. Corporations: Institutional, Political, and Economic Accounts," *Administrative Science Quarterly* 38 (1993): 100, https://doi.org/0001-8392/93/3801-00100.

[122] Daniel Cunningham, Sean Everton, and Philip Murphy, *Understanding Dark Networks: A Strategic Framework for the Use of Social Network Analysis* (Lanham, MD: Rowman & Littlefield Publishers, Inc., n.d.), xvii.

Therefore, considering the tenets provided by the TAM model and taking a demand-side approach at potential counter-proliferation efforts, it is surmised by analyzing the intensity of conflict—the environment—in concert with the inter-organizational alliance structure—the opportunity to proliferate—the results may reveal insights as to which VNSA are more likely to successfully adopt CW and which VNSA are better positioned to proliferate CW.

III. CONFLICT AND VNSA CW ADOPTION

A. METHODOLOGY

The data used to identify the impact conflict has on the likelihood a VNSA would adopt CW was collected from five pre-existing datasets: the Global Terrorism Database (GTD); the Profiles of Incidents Involving CBRN Use by Non-state Actors (POICN); the Uppsala Conflict Data Program Georeferenced Event Dataset Global version 18.1 (UCDP GED); the POLITY IV Project Political Regime Characteristics and Transitions, 1800–2017; and the World Bank's World Development Indicators.[123]

The GTD and POICN datasets were used to discern whether a VNSA CW attack was conducted in a particular country in a given year. Each dataset considers a CW event as a single observation and was thus transformed to discern whether CW was used in that country, in that year, providing a binomial dependent variable. Although GTD covers the years from 1970 to 2017, the years considered for this analysis were between 1995–2017 because of the Aum Shinrikyo events, which propelled the idea VNSA may actually consider CW as a viable weapon. Prior to 1995, there were very few occurrences of VNSA use which could suggest it was either not readily reported in open sources or VNSA generally had not used them.

Both GTD and POICN were used as references to ensure as much reporting on CW events were covered as possible. Although both were developed by the National Consortium for the Study of Terrorism and Responses to Terrorism (START), each database fulfilled a particular requirement, thus leaving some disparities in their

[123] "National Consortium for the Study of Terrorism and the Responses to Terrorism (START) Global Terrorism Database" (University of Maryland, 2018), https://www.start.umd.edu/gtd; "National Consortium for the Study of Terrorism and the Responses to Terrorism (START) POICN Database: CBRN Event Variables and Traits. Version 8.71" (University of Maryland, December 31, 2017); Mihai Croicu and Ralph Sundberg, "UCDP GED Codebook Version 18.1" (Department of Peace and Conflict Research, Uppsala University, 2017); "Croicu, Mihai and Ralph Sundberg, 2017, 'UCDP GED Codebook Version 18.1', Department of Peace and Conflict Research, Uppsala University," n.d.; Monty G. Marshall, Ted Robert Gurr, and Keith Jaggers, "POLITYtm IV PROJECT: Political Regime Characteristics and Transitions, 1800–2017 Dataset" (Center for Systemic Peace, October 24, 2018), http://www.systemicpeace.org/index.html; The World Bank, "World Development Indicators," n.d.

observations. While GTD collected reported VNSA attacks, regardless of weapon used, POICN covered 1990–2017 and specifically looked at reporting for VNSA chemical and other WMD-type weapon events. However, POICN not only tracked CW use, but also included reports consisting of plots to use, threats to use, or failed use, for example. Therefore, this analysis only considered those events that actually occurred in POICN. Although most GTD and POICN events overlapped, there were a number that were reported in one and not the other. Therefore, a subsequent dataset was developed that merged GTD with POICN's actual CW events, and removed any duplicated reports to create a streamlined dataset.

The UCDP GED dataset was used to measure conflict and the estimated deaths resulting from that conflict. The UCDP GED unit of observation is "the 'event', i.e., an individual incident (phenomenon) of lethal violence occurring at a given time and place."[124] By tallying the type of violence and the resulting deaths in a country given a particular year, the resulting sum of the number of conflict events of a particular type provided a general conflict-centric intensity measurement, while the death sum provided a measure of lethality. The UCDP GED dataset divides the type of conflict into three nominal categories: 1) State-Based Conflict, 2) Non-State Conflict, and 3) One-Sided Violence.[125] UCDP GED defines State-Based Conflict as conflict involving a governing regime of a state against either another governing regime or an organized armed group (e.g., a terrorist organization).[126] A Non-State Conflict is defined as "'the use of armed force between two organized armed groups, neither of which is the government of a state, which results in at least 25 battle related deaths in a year.'"[127] One-Sided Violence is defined as "the use of armed force by the government of a state or by a formally organized group against civilians

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[124] Mihai Croicu and Ralph Sundberg, "UCDP GED Codebook Version 18.1," (Department of Peace and Conflict Research, Uppsala University), 2.

[125] Ibid., 2–3.

[126] Ibid.

[127] Marie Allanson and Mihai Croicu, "UCDP Non-State Conflict Codebook Version 18.1" (Department of Peace and Conflict Research, Uppsala University, 2017), 2.

which results in at least 25 deaths."[128] Also tallied was the count of years that a country did not experience conflict. Thus, a total of seven independent variables, based on a country-year unit of analysis were derived from the UCDP GED dataset.

Last, the revised combined Polity Score, POLITY2, tracked by the POLITY IV PROJECT Political Regime Characteristics and Transitions, 1800–2017 dataset and the World Development Indicators tracking populations and GDP per capita (current US$) were used as control variables. The POLITY2 measure uses an ordinal scale between -10, depicting a full autocracy regime, and a +10, depicting a fully democratic regime.[129]

Given the necessity to merge five separate datasets into a coherent and useful format, the open-source R Studio software was utilized to both combine and transform the data in a reproducible format.[130] Each dataset was reduced to a sum of country-year occurrences to develop a common unit of analysis. As stated previously, the dependent variable, the occurrence of a VNSA CW event, was dichotomized to indicate a yes or no, or "1" or "0." The independent variables consisted of the sum of events the particular dataset measured. To minimize the presence of extreme values, the UCDP GED conflict and death sums as well as the WDI variables were natural log transformed.

In an effort to examine a cause and effect relationship, the independent variables derived from the UCDP GED dataset were lagged by one year. For example, the sum of conflicts in Brazil in 2001 were compared to the presence of a VNSA CW event in 2002. By offsetting the independent variable (sum of conflict) by one year, CW migration or adoption by VNSA may be better depicted as a result of conflict. Once the data was merged and transformed, this study used logistic regression to compare the dependent variable with the independent variables to assess potentially relevant associations. Additionally, for each of the independent variables, quadratic forms (and cubic for years of peace) were

[128] Ibid.

[129] Marshall, Gurr, and Jaggers, "POLITY™ IV PROJECT: Political Regime Characteristics and Transitions, 1800–2017 Dataset," 17.

[130] R Core Team, "R: A Language and Environment for Statistical Computing" (R Foundation for Statistical Computing, 2013), http://www.R-project.org/.

considered to allow for non-linear relationships. The resulting independent variables are depicted in Table 1.

Table 1. Dependent and Independent Variables

Dependent Variable	Independent Variable
Chemical Weapon Use?	Country/Year (lag) Non-State Conflict (log)
	Country/Year (lag) State-Based Conflict (log)
	Country/Year (lag) One-Sided Violence (log)
	Country/Year (lag) Non-State Resulting Deaths (log)
	Country/Year (lag) State-Based Resulting Deaths (log)
	Country/Year (lag) One-Sided Violence Resulting Deaths (log)
	Country/Year Polity2 Score (measure of democracy)
	Country/Year Population (log)
	Country/Year GDP per capita (current US$) (log)
	Country/Year Count of Peace Years and quadratic and cubic

B. MODEL RESULTS

Six models were developed using the variables depicted in Table 1 with the results identified in Table 2. The first model incorporates all variables to provide an initial reference to compare with the subsequent models. Models 2 through 6 differentiated the lethality and the intensity of conflict while incorporating the conflict's character (state-based, one-sided, and non-state based). Variables shown to be insignificant (e.g., non-state-based conflict) were removed in follow-on models to ascertain the strength of those variables showing a measure of significance.

Table 2. Model Results[131]

	VNSA Chemical Weapon Use?					
	(Model 1)	(Model 2)	(Model 3)	(Model 4)	(Model 5)	(Model 6)
Years of Peace	0.103 (0.148)	0.079 (0.146)	0.099 (0.148)	0.089 (0.147)	-0.050 (0.150)	-0.050 (0.150)
Years of Peace^2	-0.004 (0.019)	-0.002 (0.019)	-0.004 (0.019)	-0.003 (0.019)	0.010 (0.020)	0.010 (0.020)
Years of Peace^3	-0.0002 (0.001)	-0.0002 (0.001)	-0.0002 (0.001)	-0.0002 (0.001)	-0.001 (0.001)	-0.001 (0.001)
Democracy	0.088*** (0.031)	0.084*** (0.031)	0.088*** (0.031)	0.089*** (0.031)	0.085*** (0.031)	0.078** (0.031)
Democracy^2	-0.009* (0.005)	-0.010* (0.005)	-0.009* (0.005)	-0.009* (0.005)	-0.010* (0.006)	-0.011* (0.006)
State-Based Conflict	0.134 (0.230)	0.195** (0.085)				-0.648*** (0.219)
State-Based Conflict^2						0.146*** (0.035)
Deaths from State-Based Conflict	0.053 (0.171)		0.147** (0.060)	0.142** (0.060)	-0.408** (0.159)	
Deaths from State-Based Conflict^2					0.073*** (0.019)	
One-Sided Violence	-0.044 (0.203)	0.198* (0.115)				0.340 (0.282)
One-Sided Violence^2						-0.034 (0.051)
Deaths from One-Sided Violence	0.194 (0.136)		0.167** (0.078)	0.184** (0.074)	0.109 (0.176)	
Deaths from One-Sided Violence^2					0.008 (0.023)	
Non-State Conflict	-0.147 (0.276)	0.067 (0.094)				
Deaths from Non-State Conflict	0.125 (0.168)		0.037 (0.058)			
GDP per capita	0.470*** (0.094)	0.467*** (0.092)	0.476*** (0.092)	0.464*** (0.089)	0.493*** (0.093)	0.475*** (0.094)
State Population	0.528*** (0.080)	0.516*** (0.078)	0.531*** (0.078)	0.537*** (0.077)	0.545*** (0.077)	0.508*** (0.078)
Constant	-16.778*** (1.563)	-16.378*** (1.513)	-16.838*** (1.519)	-16.824*** (1.513)	-16.768*** (1.527)	-15.855*** (1.524)
Observations	3,494	3,494	3,494	3,494	3,494	3,494
Log Likelihood	-404.296	-406.449	-404.554	-404.752	-396.173	-397.458
Akaike Inf. Crit.	836.591	834.898	831.107	829.503	816.346	818.915
Note:	*p**p***p<0.01					

131 Table 2 produced using: Marek Hlavac, "Stargazer: Well-Formatted Regression and Summary Statistics Tables. R Package Version 5.2.2," 2018, https://CRAN.R-project.org/package=stargazer.

As can be seen in Table 2, the effect of each control variable (democracy, population, GDP per capita, and years of peace) remained relatively unchanged across each model. Across these specifications, Model 5 presents the lowest Akaike Information Criterion (AIC) score at 816.346. Since the AIC score is useful in comparing the models, with the lowest score indicating the best fit, Model 5's AIC score proposes the lowest rate of prediction errors. As such, Model 5 suggests there is a statistically significant quadratic relationship between deaths from state-based conflicts and the probability of VNSA CW use, with a p-value of less than 0.01. This indicates there is a non-linear relationship between deaths resulting from state-based conflict and the probability of VNSA CW use, where there is a decreasing probability of VNSA CW at low levels of lethality and an increasing probability at higher levels of lethality. The inflection point appears at approximately 19 deaths in a country-year with a 1% probability of a VNSA CW attack. Therefore, low-lethality conflict shows a moderate mitigating effect on CW use while high-lethality conflict significantly intensifies the likelihood of CW use.

In comparison, Model 6 presents an AIC score of 818.915, yet measures the number of state-based conflict events (intensity) instead of the number of deaths (lethality) that Model 5 measures. Because Model 5's AIC score suggests it is a better predictive model than Model 6, the number of deaths vice the number of conflict events is likely a better indicator when considering the probability of VNSA CW use. Thus, it may be the effects of conflict rather than the conflict itself that provides a useful indicator.

Figures 1 and 2 display the coefficients for Model 1 (all tested variables) and Model 5, the best fit. Figure 1 showcases the control variables and Figure 2 shows the key independent variables. In each figure, the dots set along the bars represent the model's coefficients and the thicker bars represent the standard error. The longer, thinner bars show the 95% confidence interval. The shorter the bar, the more certain the coefficient. The bars that cross 0 indicate an insignificant relationship at the 5% level.

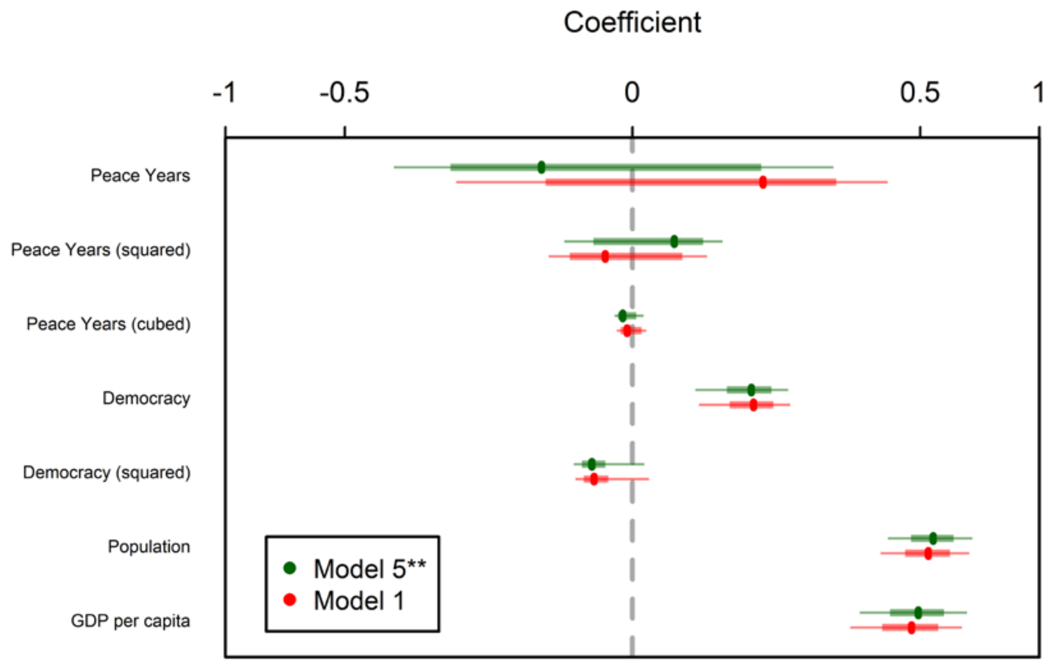

Figure 1. Control Variable Regression Coefficients

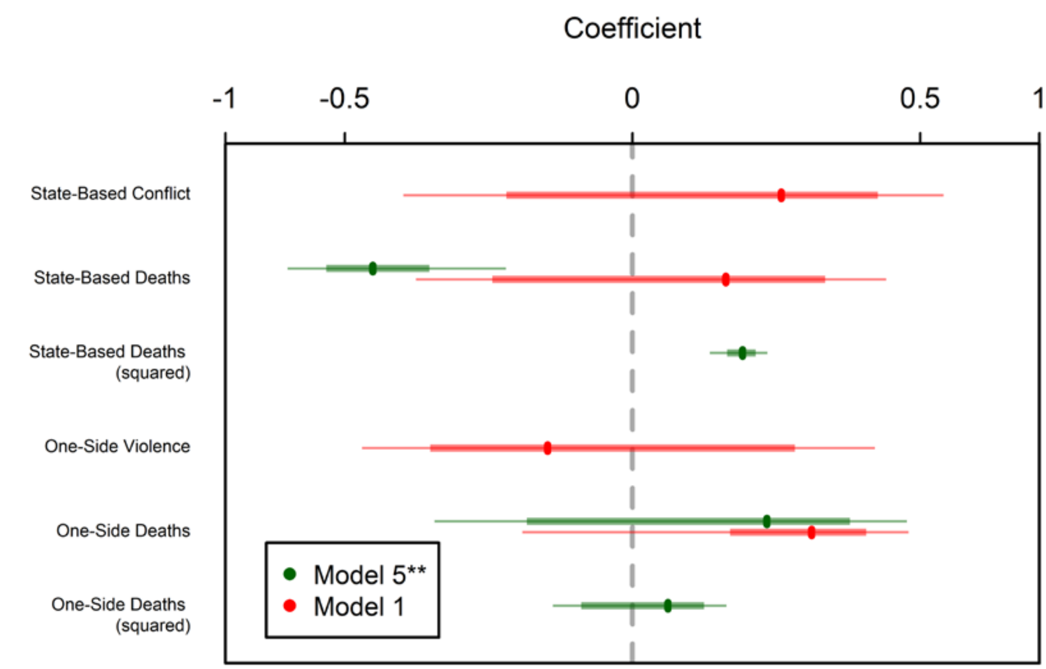

Figure 2. Test Variable Regression Coefficients

As noted previously, Figure 1 shows the control variable coefficients were relatively unchanged across models. However, Figure 2 shows Model 5's (in green) coefficients have a narrower 95% confidence interval, with State-Based Conflict Deaths^2 particularly narrow. The double asterisks indicate that Model 5 had the best fit with observed data.

Figure 3 provides a visual representation for Model 5, particularly indicating the increasing probability of a VNSA CW attack at higher levels of lethality. The Y-axis reflects the probability of CW use by a VNSA. The X-axis depicts the independent variable, the lethality of conflict. The solid lines in the figures indicate the expected value of the dependent variable and the shaded areas around the lines depict the 95% confidence intervals.

Figure 3. VNSA Probability of CW Use: Deaths from State-Based Conflict

As displayed in Figure 3, there is a minimal, slightly negative effect on the probability of VNSA CW use at the lowest levels of conflict lethality, as measured by deaths resulting from state-based conflict. This shifts to a slightly positive relationship at middle ranges of lethality (at approximately 19 deaths), then rises more rapidly for logged values higher than 8, which corresponds to approximately 2,980 deaths in a country-year.

Further analysis conducted on the effects that a state's wealth, population, and democracy also provide revealing and provocative results. To summarize, a wealthier, more populated, and more democratic state—in conflict—is more at risk of a VNSA CW attack than a poorer, less populated, and more autocratic state. Figure 4 is provided as a graphic representation of the effect a state's wealth has on the probability of a VNSA CW event.

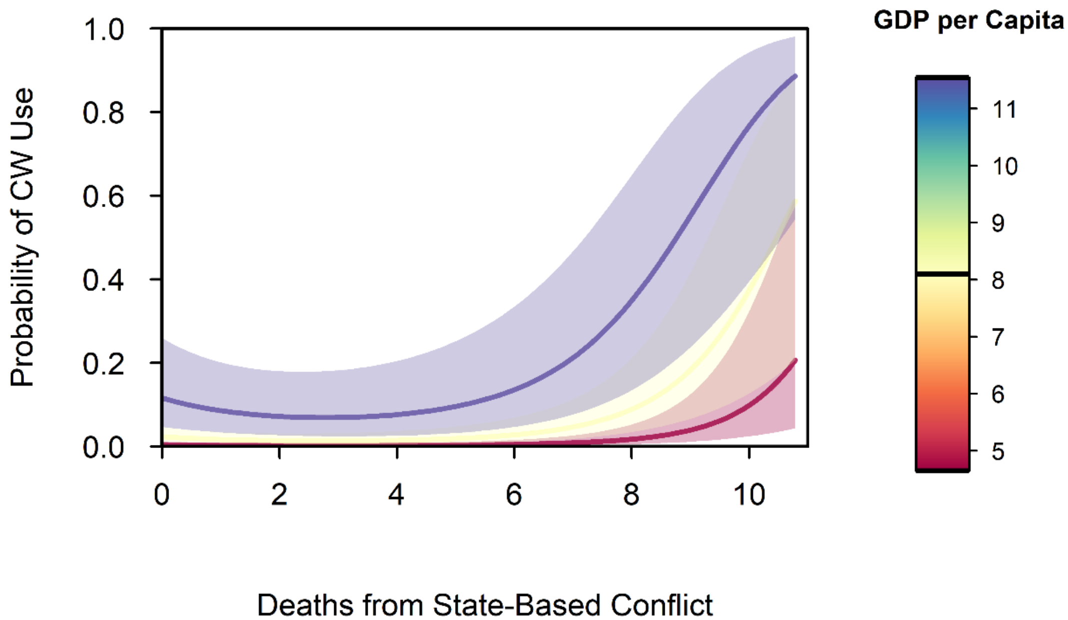

Figure 4. VNSA Probability of CW Use: Deaths from State-Based Conflict versus Wealth

In a similar non-linear fashion as presented in Figure 3, Figure 4 presents a slightly negative slope in the lower levels of conflict lethality which pivots to a positive slope at the middle ranges equating to approximately 17 deaths. At 17 deaths, the probability shows of CW use is 0.2% at the lowest level of GDP per capita, while at the highest level of GDP per capita, the probability is 7%. As well, the wealthier states see a faster increase in probability than those at the lowest levels of wealth. Again, where the lethality value equates to a logged value of 8, the probability of CW use for countries at the lowest level of GDP per capita sits at approximately 1.8%, yet at the highest level of GDP per capita, the probability is approximately 36%. These findings could result from the increased pressure a VNSA contends with to find capabilities to counter a military and policing force that is more likely better equipped based on the resources such a state possesses. However, further analysis on the relationships conveyed by these independent variables is warranted.

C. INCORPORATING TIME-PHASED ANALYSIS

The models thus far assumed CW migration from one environment to another remained constant from 1995 to 2017. This assumption would conclude the probability of a CW event based on a particular number of conflict events or deaths would remain constant regardless if it were 1995, 2017, or 2025. To depart from this assumption, a second set of models was constructed dividing up the years considered into four-year time periods (except for the last model, which included only the years 2015 to 2017). Using the same series of independent variables, Figure 5 provides the probability of a VNSA CW attack in each time period.

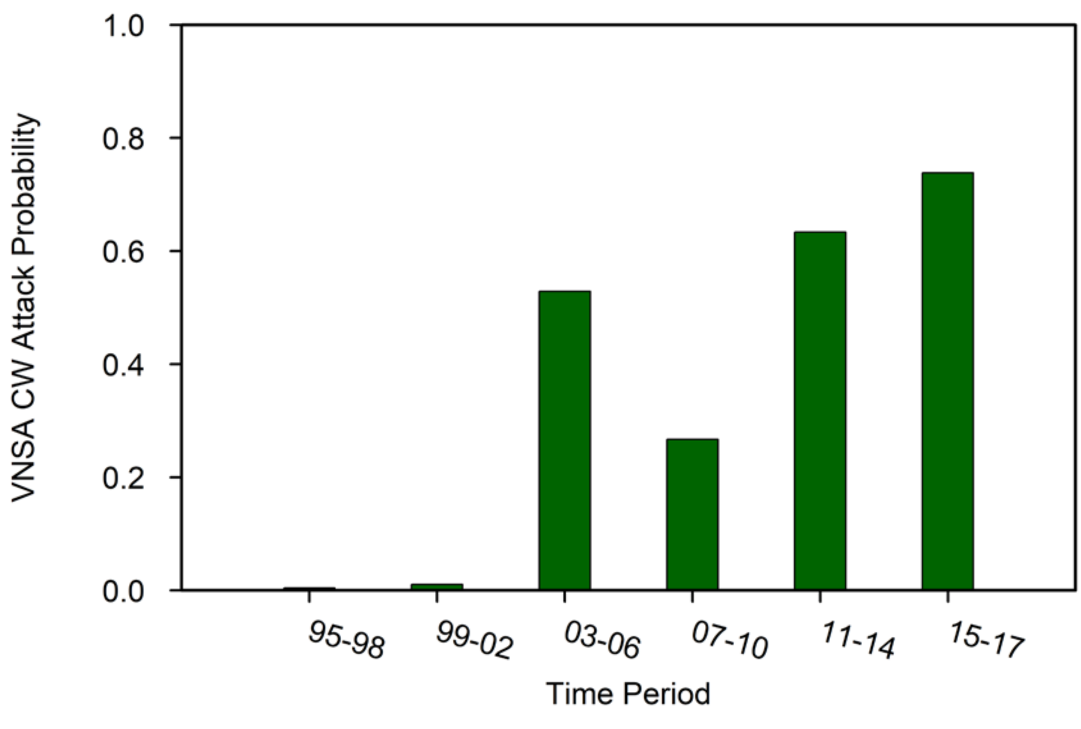

Figure 5. VNSA CW Attack Probability in Four-Year Periods

Although this does not provide the perfect trend line, there is some evidence of an increase in probability over time, with all things being equal, which suggests that VNSA are now more inclined to turn towards incorporating a CW capability than they were in the past. This speaks to the importance investigating environmental pressures and demand signals when considering counter-proliferation policies targeting VNSA.

D. ANALYSIS

Based on the models, the analysis suggests state-based conflict and its effects impact the probability of VNSA CW use, with lethality presenting as a better indicator than intensity. This study proposes that there is a statistically significant and non-linear relationship between VNSA CW use and state-based deaths with an apparent threshold of approximately 19 deaths. Additionally, the analysis suggests a wealthier, higher populated, and democratic state has a higher probability of a VNSA CW attack than its opposite across all levels of lethality. Such findings may seem contrary to conventional thinking, especially considering the nearly two decades of conflict in Iraq and Afghanistan. Further research is needed to better understand this phenomenon.

Referring to the TAM model, this study appears to provide a telling variable that can usefully augment others when attempting to describe the environment that may induce a VNSA to consider CW use. It is suggested that a permissive environment may not be as necessary for a VNSA to develop a chemical capability, but the presence of conflict could adjust motivations to innovate and adopt new measures to continue fighting. A potential take-away proposes VNSA will adjust tactics out of necessity as its adversary adapts to the VNSA's operational model. In other words, conflict forces innovation more so than peace. Such findings could be useful if adopted by U.S. counter-proliferation stakeholders and military planners. As conflict intensifies and results in a series of deaths, the necessity to adapt intelligence collection efforts towards identifying chemical agents within the battlespace may be prudent. This is particularly necessary given the evidence that suggests CW adoption is increasing over time. Such guidance could further support SOCOM's counter-proliferation synchronization efforts, by ensuring DoD entities coordinate accordingly and are not left unprepared.

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IV. SOCIAL NETWORK ANALYSIS AND DISRUPTION

With a fundamental understanding of how certain environmental factors derived from a strategic context affect a VNSA's likelihood of adopting and using CW, we now turn to how these tactics and technologies may transfer from one organization to another. Once we can estimate the likelihood that a single organization within an inter-organizational alliance network would adopt CW, we can assess different strategies to disrupt potential migration through two types of operations: coercive direct action and information operations (IO).

Relying on the mathematical and statistical models of social network analysis (SNA), analysts can map and identify methods to disrupt networks. This concept has been used to study illicit networks, gangs, drug cartels, and other "dark networks" among the same ilk. Following Sean Everton's adopted definition, dark networks are those that operate covertly and illegally, "namely, any group that seeks to conceal itself and its activities from authorities."[132] Therefore, the analysis of alliances among terrorist organizations, and the organizations' use of CW, falls neatly within dark network SNA.

A. SOCIAL NETWORK ANALYSIS THEORY

SNA may not itself be a prescriptive theory; it more closely resembles a set of tools resulting from a collection of theories and processes that can be used to provide insight into how networks consisting of individuals—or groups of individuals—interact and share information and materials.[133] Through measuring a network's topography and an actor's perceived power or prestige within a network, conclusions can be derived as to where power, influence, strengths, and vulnerabilities lie within a network. One can exploit such conclusions to increase the productivity or robustness of an organization, or in our case, disrupt it.

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[132] Sean F. Everton, *Disrupting Dark Networks*, Structural Analysis in the Social Sciences (New York: Cambridge University Press, 2012), xxv.

[133] Ibid., 5.

As with other analytical approaches, SNA relies on a set of assumptions which Everton compiled in a single list:[134]

- Actors and their actions are interdependent vice independent of other actors
- Ties between actors serve as avenues for the transfer of information and goods
- Social structures are seen as enduring ties between actors
- Continuous interaction among actors develop social formations which develop its own character that is both dependent and separate from the individual actors within the formation
- An actor's position in a network can influence that actor's beliefs and actions
- Social networks are not static, but change as actors join or leave the network

Thus, SNA suggests that various relationships among actors can provide measurable avenues of influence, information, and goods while considering an actor's location within a network as a determinant to the level of influence or access that actor has or can provide. In this and the next chapter, SNA will be used in conjunction with the Technology Adoption Model (TAM), tactics migration theory, and contagion theory discussed in Chapter II to provide a predictive intelligence tool for intelligence analysts supporting CP and other missions under special operations.

B. TERMINOLOGY

Among SNA researchers and practitioners, terminology can vary significantly with critical effects. Algorithms used to calculate various parameters to quantitatively describe a network can differ so much that the same term can have contradictory implications in disruption strategies. Therefore, we use terminology in *Understanding Dark Networks*

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134 Sean F. Everton, *Disrupting Dark Networks*, Structural Analysis in the Social Sciences (New York: Cambridge University Press, 2012), 14–15.

(Cunningham, Everton, and Murphy, 2016). The below offers an overview of network analysis statistics used in the following analyses.

Average Distance is the average length of all of the shortest paths between all actors in the network. All things being equal, dark networks with relatively shorter average path distances may be able to diffuse information or materiel quicker than networks with longer average paths.[135]

Diameter is the longest of all the short paths. A large diameter usually indicates that the network is decentralized, but it also implies that it takes longer for information to get from one node to the other.[136]

Variance is the average of the squared differences between each actor's centrality score and the mean average centrality score, which illustrates how centralized the dark network is. We use the normalized degree variance to compare differently sized networks. Furthermore, a high variance on degree centrality may mean that nodes have relatively high levels of access to each another, which would inhibit disruption.[137]

Degree centralization shows the degree to which a network is centralized or decentralized. A high centralization score means that one or a few actors are relatively active (have a lot of ties) while other have very few ties.[138]

Meanwhile, Degree Standard Deviation is the square root of the variance, consistent with standard statistical methods. This could also be interpreted as identifying how many actors are active in contrast to those that have fewer ties.[139] For example, as we will see with the ETA network, a group of 5 actors all tied to one another is the likely culprit of

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[135] Daniel Cunningham, Sean Everton, & Philip Murphy, *Understanding Dark Networks* (London: Roman & Littlefield, 2016), 86.

[136] Ibid., 86.

[137] Ibid., 87.

[138] Ibid.

[139] Ibid.

driving up the standard deviation score due to the degree standard deviation algorithm; this is an artifact that analysts should be wary of since the analyst could unintentionally provide false impressions of higher centralization to the customer, thus altering the recommended disruption strategy.

Normalized density also allows comparing networks of varied sizes to assess the total number of observed ties in a network divided by the total of possible ties, showing the level of interconnectivity for a dark network.[140]

Average Degree is the measure formally defined as the sum of ties in a network divided by the number of actors in the network. This demonstrates how interconnected the network is, shedding light into potential trade-offs the network may have to make.[141] Compactness is a measure that identifies how interconnected actors are within a network on a scale from 0 to 1.[142] When all actors are connected to all other actors, the network's compactness is 1 and when no actors are connected, the measure is 0.

A normalized clustering coefficient is the sum of each actor's ties divided by the number of actors within the network, and it also indicates how interconnected a network is while highlighting potential trades a network may have to make.[143]

Degree centrality counts the number of ties an actor has and could indicate how active the actor is, showing direct influence or power, or the ability to be influenced by others.[144]

Closeness centrality is the average geodesic distance from an actor to every other actor, and can indicate how accessible other actors are and to the materials or goods.[145]

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[140] Daniel Cunningham, Sean Everton, & Philip Murphy, *Understanding Dark Networks*, 87.

[141] Ibid.

[142] Ibid.

[143] Ibid., 88.

[144] Ibid.,144.

[145] Ibid.

Betweenness centrality is how often each actor lies on the shortest path between all other pairs which indicates potential brokerage—gatekeepers.[146]

Finally, eigenvector centrality weighs an actor's centrality by the centrality scores of its neighbors, showing the level of indirect influence or power—potential social capital.[147]

C. DATASETS

To apply the theories laid out in the previous section to CW adoption at the interorganizational level, we assimilated data for this study from the same datasets as in Chapter III: the Global Terrorism Database (GTD); the Profiles of Incidents Involving CBRN Use by Non-state Actors (POICN). In addition, this chapter uses the Big Allied and Dangerous (BAAD) Database 1 to provide the alliance network data necessary to conduct SNA.[148] In Chapter V, we introduce our network, the Myanmar-Affiliated VNSA (MAV) network, which we built using the open source Terrorism Research and Analysis Consortium (TRAC) database.

The BAAD 1 database is an established network depicting 394 VNSA as nodes (sometimes referred to as vertices in graph theory) and a variety of relationships referred to as edges, links, or ties. We filtered the database to include alliances between 1998 and 2005. The relationships–or edges–spanned from positive familial ties to negative or competitive ties. For this study, we only consider positive ties between VNSA.

The GTD and POICN datasets helped discern which of the VNSA from the BAAD network used CW. Reported CW use by a VNSA in the BAAD network serves as an attribute for that node. Although the BAAD data only covered 1998–2005, GTD and

[146] Ibid., 145.

[147] Daniel Cunningham, Sean Everton, & Philip Murphy, *Understanding Dark Networks*, 144.

[148] Victor Asal, R. Karl Rethemeyer, and Ian Anderson, "National Consortium for the Study of Terrorism and Responses to Terrorism (START) Big Allied And Dangerous Database I" (University of Maryland, August 2009); "National Consortium for the Study of Terrorism and the Responses to Terrorism (START) Global Terrorism Database"; "National Consortium for the Study of Terrorism and the Responses to Terrorism (START) POICN Database: CBRN Event Variables and Traits. Version 8.71."

POICN referenced years 1995–2008 to discern which of the VNSA used CW. The additional three years on both ends of the BAAD timeframe rests on our assumption that CW adoption could transcend a set of alliances depicted by a finite timeframe. In other words, a network of alliances in 2005 would likely affect CW adoption in 2006. The only VNSA added for this analysis was the Haqqani Network; justified by the fact that it was active during 1998–2005, used CW, and aligned itself with al-Qaeda.

The BAAD dataset supplied two unique inter-organizational alliance networks useful for comparative analysis. The first, the al-Qaeda (AQ) alliance network, illustrated a migration of CW TTP while the second, the Basque Fatherland and Freedom (ETA) alliance network, had only one group use CW and presented no migration. Next, we assess topographic and centrality measures for each alliance network.

D. INTER-ORGANIZATIONAL ANALYSIS

1. Topology

Using ORA software to conduct SNA, we isolate the AQ alliance network from the rest of the BAAD dataset and color nodes with the CW attribute red, as shown in Figure 6. Table 3 illustrates important topological characteristics of the AQ alliance network.

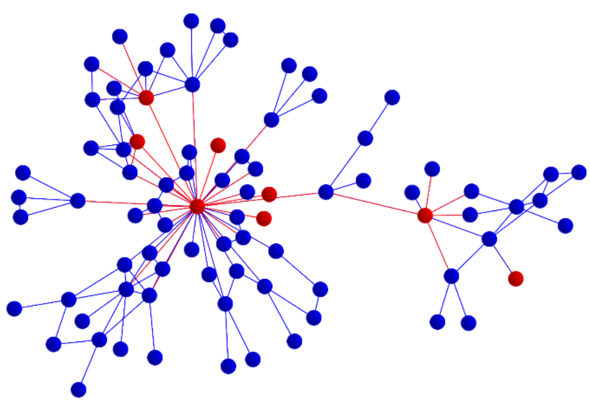

Figure 6. AQ Alliance Network (VNSA that have used CW are red)

Table 3 illustrates important topological characteristics of the AQ alliance network to include centralization and density measures. We then repeat this process for the ETA alliance network in Figure 7 and Table 4.

Table 3. Topographic Measurements

Centralization Measures

AQ Alliance Network	Network Size	Average Distance	Diameter	Normalized Variance	Degree Centralization	Standard Deviation
	84	3.584	9	6.023	.20	2.454

Density Measures

AQ Alliance Network	Average Degree	Compactness	Normalized Clustering Coefficient
	2.476	0.258	0.113

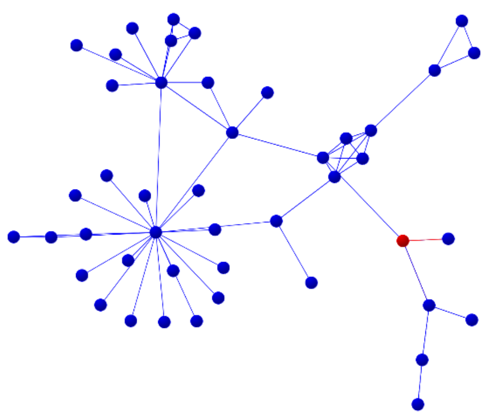

Figure 7. ETA Alliance Network (VNSA that have used CW are red)

Table 4. Topographic Measurements

Centralization Measures

ETA Alliance Network	Network Size	Average Distance	Diameter	Normalized Variance	Degree Centralization	Standard Deviation
	45	3.748	9	13.38	.21	3.658

Density Measures

ETA Alliance Network	Average Degree	Compactness	Normalized Clustering Coefficient
	2.067	0.207	0.161

Although the AQ alliance network is nearly twice the size of ETA's, the topographic measurements are fairly similar. This is due to how nodes in each network connect. The most significant difference between the two networks is normalized variance. This measurement, as explained previously, depicts how accessible actors are to others. What may be doubling the normalized variance in the ETA alliance network are the five organizations that all share an alliance in a five-node clique, a feature that the AQ alliance network lacks.

2. Centrality Measures

In Tables 5 and 6, we compare centrality of AQ and ETA alliance networks. We list degree, closeness, betweenness, and eigenvector centrality scores. Because each measure illustrates similar trends with these two networks, we only display the sociograms in Figures 8 and 9 by sizing each node according to its individual degree centrality score, where a higher score (number of ties) increases the node size proportionally.

Table 5. Top 10 Organizations' Centrality Measurements in the AQ Alliance Network

Degree	Closeness	Betweenness	Eigenvector
al-Qaeda 0.422	al-Qaeda 0.519	al-Qaeda 0.886	al-Qaeda 0.897
al-Qaeda Two Rivers 0.108	Hezbollah 0.403	Hezbollah 0.358	al-Qaeda Two Rivers 0.309
Lashkar-e-Taiba (LeT) 0.096	al-Qaeda Two Rivers 0.372	Hamas 0.294	Ansar al-Sunnah Army 0.264
Hamas 0.084	Lashkar-e-Taiba (LeT) 0.369	al-Qaeda Two Rivers 0.105	Ansar al-Islam 0.264
Hizbul Mujahideen (HM) 0.084	Hizbul Mujahideen (HM) 0.367	Popular Resistance Committees 0.096	Jaish al-Taifa al-Mansoura 0.227
al-Fatah 0.072	Ansar al-Sunnah Army 0.366	Hizbul Mujahideen (HM) 0.092	Tawhid and Jihad 0.212
Ansar al-Sunnah Army 0.072	Jaish al-Taifa al-Mansoura 0.362	Lashkar-e-Taiba (LeT) 0.092	Lashkar-e-Taiba (LeT) 0.206
Jaish-e-Mohammad (JeM) 0.060	Ansar al-Islam 0.359	Riyad us-Saliheyn Martyrs' Brigade 0.071	Armed Islamic Group 0.206
Lashkar-e-Jhangvi (LeJ) 0.060	Jaish-e-Mohammad (JeM) 0.356	Pattani United Liberation Organization (PULO) 0.071	Harakat ul-Mudjahidin (HuM) 0.200
Popular Resistance Committees 0.060	Tawhid and Jihad 0.356	Ansar al-Sunnah Army 0.051	Hizbul Mujahideen (HM) 0.194

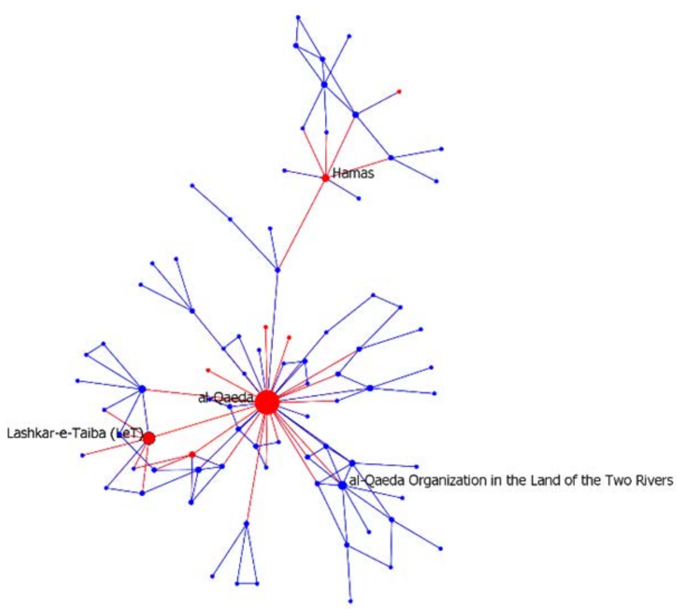

Figure 8. AQ Alliance Network, Nodes Sized by Degree Centrality

Table 6. Top 10 Organizations' Centrality Measurements in the ETA Alliance Network

Degree	Closeness	Betweenness	Eigenvector
Revolutionary Organization 17 November (RO-N17) 0.432	Revolutionary Organization 17 November (RO-N17) 0.463	Revolutionary Organization 17 November (RO-N17) 0.654	Revolutionary Organization 17 November (RO-N17) 0.825
Kurdistan Workers' Party (PKK) 0.227	DHKP-C 0.444	DHKP-C 0.375	Kurdistan Workers' Party (PKK) 0.495
International Solidarity 0.136	Kurdistan Workers' Party (PKK) 0.411	International Solidarity 0.375	DHKP-C 0.385
Cooperative of Hand-Made Fire and Related Items 0.114	International Solidarity 0.386	Kurdistan Workers' Party (PKK) 0.303	International Solidarity 0.241
DHKP-C 0.114	Black Star 0.383	Basque Fatherland and Freedom (ETA) 0.210	Black Star 0.227
July 20th Brigade 0.114	Cooperative of Hand-Made Fire & Related Items 0.341	Irish Republican Army (IRA) 0.132	Cooperative of Hand-Made Fire & Related Items 0.204
Five C's 0.091	TKP/ML-TIKKO 0.328	July 20th Brigade 0.130	Popular Revolutionary Action 0.191
Informal Anarchist Federation 0.091	Popular Revolutionary Action 0.324	Black Star 0.126	Revolutionary Struggle 0.191
Apo's Revenge Hawks 0.068	Revolutionary Struggle 0.324	Group of Carlo Giuliani 0.089	TKP/ML-TIKKO 0.185
Apo's Youth Revenge Brigades 0.068	Anti-State Action 0.319	Cooperative of Hand-Made Fire & Related Items 0.085	Apo's Revenge Hawks 0.180

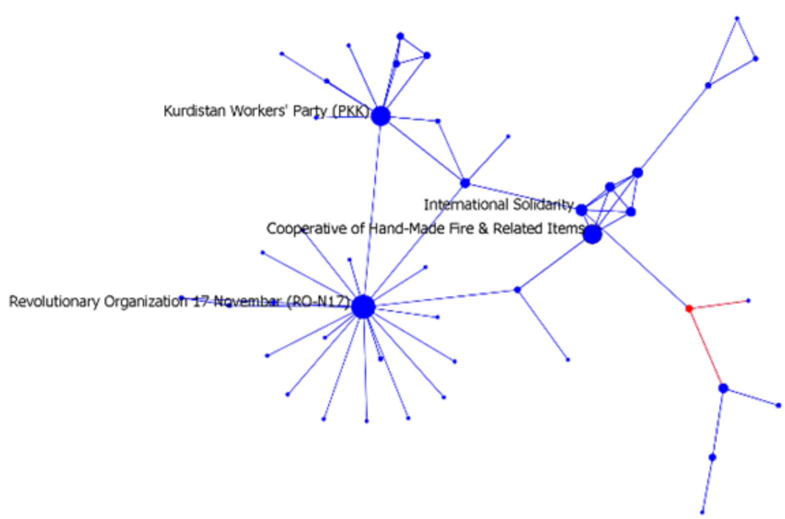

Figure 9. ETA Alliance Network, Nodes Sized by Degree Centrality

Across the centrality measures conducted in this analysis, AQ is clearly the most central organization, and thus has a prominent level of power within its network. Conversely, the ETA alliance network's most central and powerful organization is the Revolutionary Organization 17 November (RO-N17) and the ETA only rates fifth among the top organizations in betweenness. This suggests ETA is in a potential (but moderate) brokerage position but is not among the most powerful when considering these centrality measures. This offers a potentially powerful insight as to why CW use did not migrate in ETA's alliance network while it did in AQ's. Deriving from this analysis, a greater threat may have developed had RO-N17 adopted CW, for example.

3. Brokerage

ETA's potential as a broker due to its moderate betweenness score warrants analysis of an additional measurement concerning brokerage. Below, Figure 10 depicts the brokerage potential each organization plays in their respective alliance network. This analysis measurement attempts to identify those nodes that are positioned within a network that bridge gaps between the network topography and may be best suited to assume brokerage potential.[149] There are many ways to measure for brokerage potential, but we use the Burt's Constraint here. This can measure a node's "brokerage" ability in undirected networks by assessing how the overall network fractures when the node's ties are severed; therefore, higher brokerage scores correspond to low Burt's Constraint scores.[150] Since we are considering organizations—rather than individuals—as actors, it may be difficult to presume an organization's reach among a dark network would surpass much beyond the actors it is directly connected with. This means they can act as choke points for passing information and goods. It also means they may play key roles in fragmenting the network should they either be removed or cut relations with either side the actor connects. These features of the Burt's Constraint will assist in analyzing effectiveness of simulated IO disruption later on.

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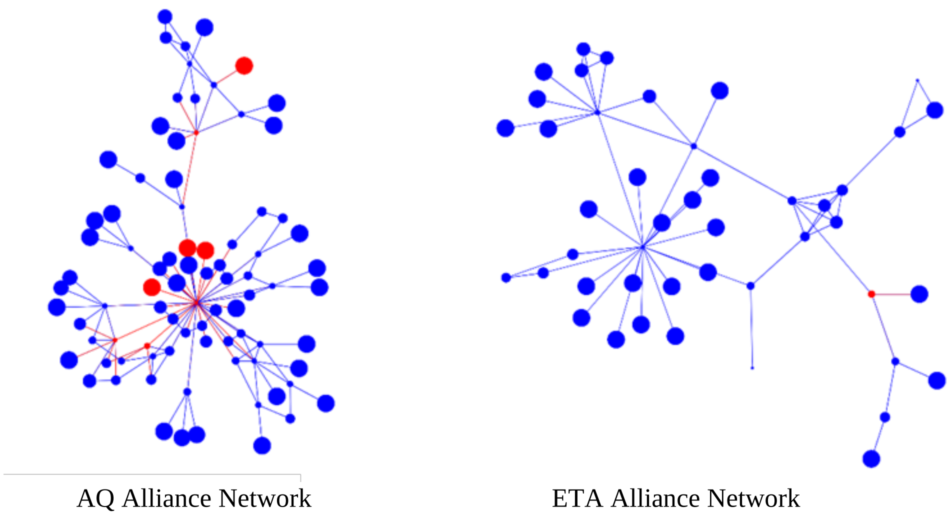
149 Daniel Cunningham, Sean Everton, and Philip Murphy, *Understanding Dark Networks: A Strategic Framework for the Use of Social Network Analysis* (Lanham, MD: Rowman & Littlefield Publishers, Inc., n.d.), 170–183.

150 Ibid., 182.

The graphics in Figure 10 show the smallest nodes as the least constrained, which are better positioned as a broker because they fill gaps within the network and connect different subgroups together. The larger nodes are more constrained and less capable of passing information or materiel across the network. As with the previous graphics, those organizations that have used CW are depicted in red.



Larger nodes indicate higher Burt's Constraint scores; Smaller nodes indicate higher Brokerage scores.

Figure 10. Burt's Constraint (Brokerage) Measurements

As depicted in Figure 10, both AQ and ETA appear as relatively unconstrained, but AQ is less constrained than ETA. Thus, each organization is in a better position to perform as brokers within their respective alliance networks. Within the AQ alliance network, those organizations that adopted CW follow a path from AQ through other organizations that also act as brokers. This suggests AQ's position within the alliance network, as a central node and well situated as a broker, supported CW migration.

To the contrary, even with ETA presenting a relatively strong brokerage score, CW TTP did not migrate. This is likely due to its peripheral location within the alliance network. Although it may support concern that CW use could migrate towards the network's periphery along those actors associated with ETA, the fact that ETA is not a central organization and is thus presented as less aggressively pursuing alliances makes CW migration. These conclusions are in line with the psychological components of the TAM's Stage One, which considers an organization's technological awareness, openness to new ideas. Furthermore, one could argue that because AQ is objectively seen as a well-known, influential actor (by those in and out of its alliance network), some of its adjacent nodes may have followed AQ's lead in pursuing CW TTP if they were adequately tied to it (had access to requisite knowledge and resources) because they saw their prestigious "mentor" organization do so.

E. DISRUPTION MODEL

There are numerous ways to evaluate different disruption strategies without having to conduct actual operations on a real-world network. In this chapter, we implement a basic Actor-Based Model (ABM) for the AQ network with simple, turn-based decision points using a list of assumptions to simplify the model for feasibility of implementation on a small scale. In Chapter V, we automate parts of the model and refine it for a specific case study. In this chapter, the basic model's friendly actors will initially know limited information about the network; but, as the model progresses and each actor conducts its unique actions, knowledge of the network will grow as will the CW tactics attribute throughout AQ's affiliates.

1. Actor-Based Model

In this ABM, the adversarial "actors" (and network nodes) are the VNSA, which we assume to be a terrorist organization that are either CW-capable or not, indicated by red and blue nodes. Black nodes are organizations which friendly forces do not yet know if they are CW-capable are not. We assume that the CW capability will spread from AQ (the most central node with well-developed CW capability from a decades-old program) by approximately 5% for each turn. We select this diffusion rate based on time-series data from GTD and POICN of CW diffusion throughout Middle Eastern, South Asian, and South-East Asian regions. By tallying up the number of unique organizations in these regions from the combined GTD and POICN database, we plot the cumulative number of

CW-capable organizations and see a linear trend from 2008–2017 with an R-squared value of 0.9804. Figure 11 and Table 7 illustrate approximately 5% diffusion, which we will use in the ABM.

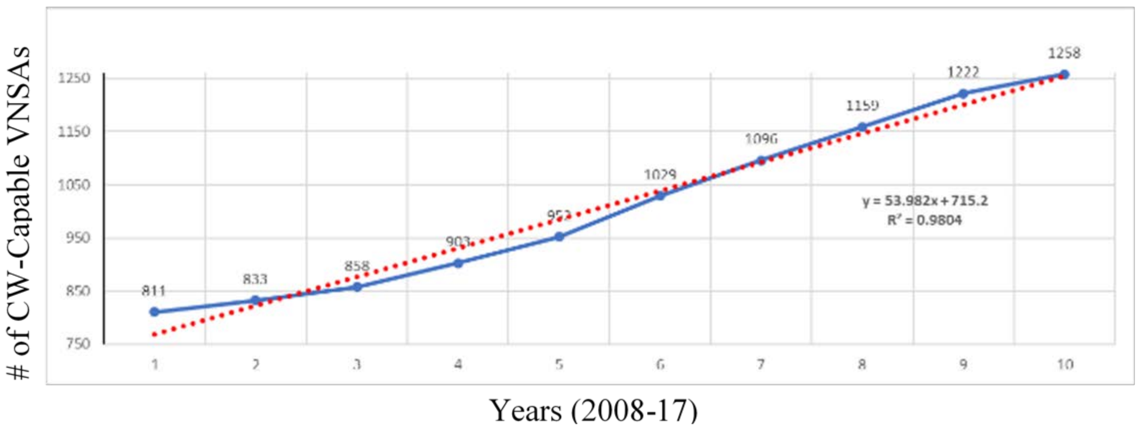


Figure 11. CW-Capable VNSA in Middle East, South Asia, and Southeast Asia: 2008–2017

Table 7. Year-Over-Year Increase of CW-Capable Organizations in Central and South Asia: 2008–2017 (GTD, POICN Databases)

2008	3.71%
2009	2.71%
2010	3.00%
2011	5.24%
2012	5.43%
2013	8.09%
2014	6.51%
2015	5.75%
2016	5.44%
2017	2.95%
Average	**4.88%**

This diffusion rate could correspond to a network's node with 20 ties, which would have 1 adjacent node that gains CW capability after each turn. Using a uniformly distributed pseudorandom number generator in MATLAB® Version R2019(a) with the random (`rand`) function, we choose the node to gain the CW capability (attribute). If a node chosen by the function happens to already exhibit the CW attribute, then the same process is conducted for that second-tier node at a diffusion rate of 5% for its adjacent nodes. If the second-tier node has less than 10 edges, then no further tactics migration occurs. For example, with the 33 nodes surrounding AQ, about 1.6 adjacent nodes (rounded up to 2) will gain the CW attribute. One of those secondary nodes has 12 adjacent nodes tied to it. If the `rand` function used on the next time-step choses a secondary node, one node (12 x 5% = 0.6, rounds up to 1) chosen at random will gain the CW attribute. The node(s) chosen to gain the CW attribute will be also based on the same random function by assigning each adjacent node an integer, and multiplying the result of the pseudorandom function by the maximum value (i.e. 33), the product (rounded to the nearest integer) from which will correspond to the node chosen to gain the CW attribute.

Another type of actor is the counter-proliferation (CP) force. For this model, CP forces include any operational unit of action (conventional, SOF, or Cyber/IO) tasked with (or to support) a CWMD mission in accordance with higher headquarters' guidance. In pursuit of inhibiting CW diffusion, CP forces are able to carry out either:

(a) **Coercive operations**, which disrupts TTP migration in the network by removing the CW attribute from a VNSA (node), or

(b) **Information Operations**, which breaks a tie between two or more nodes.

Coercive CP actions can include physical destruction (via conventional or SOF assets) of precursor agents or CW, or even a diplomatic, public affairs, economic, PSYOP, or any other activity that deters the VNSA from using CW. On the other hand, an IO CP action involves cutting ties by conducting offensive cyber operations (OCO) targeting the lines of communication between two or more actors, physical destruction of communications infrastructure, disinformation propagation, instilling distrust between allies, or other IO capabilities. In the case of coercion, the CP force will target the node(s) with highest degree centrality. For IO, CP forces target the tie(s) connected to nodes with the highest brokerage scores (lowest Burt constraint scores).

The third actor type is Intelligence assets (INTEL), which are only able to "monitor" three VNSA at a time within the AQ network due to "budgetary constraints and limited personnel resources" for CT and CP missions against non-state actors. Monitoring a node assumes that approximately 50% of its directly affiliated terrorist groups (adjacent nodes) with unknown CW capability status will be discovered after each time-step (where "discovered" will be indicated by turning a black node either blue or red, depending on its CW status after tactics migrated from the previous step). The fortunate caveat for INTEL is that they are able to monitor one more tie for each IO disruption, if the tie is between one known and one unknown VNSA. This assumes that when Cyber assets conduct an OCO, or IO forces spread disinformation, INTEL then has the ability to collect Signals Intelligence (SIGINT) from that tie between two nodes to "listen in" or to track the disinformation diffusion. Finally, if INTEL is monitoring every tie coming out of a node, then they are able to detect whether the VNSA is CW-capable or not, otherwise each turn yields the standard 50% probability of determining such information based on the number of ties leading to still-unknown nodes. The limitations of this model include the fact that the VNSA network is not really adapting to INTEL or CP actions, although the probability of CW tactics migrating to certain nodes does increase as ties are cut, which could infer second- or third-order effects detrimental to CWMD efforts. The INTEL mechanism will only be used in this chapter, and not the case study in Chapter V.

The objective in this simulation straddles the operational and strategic levels of irregular and information warfare. In our case, the objective is to utilize coercive direct action (kinetic or non-kinetic) and IO to disrupt the AQ network's CW TTP migration, in order to deter Hizbul Mujahideen (HM) from adopting CW. In one model we will only use IO (cutting ties) and in the other we will only use coercive direct action (turning red nodes to blue), within the context of the previously described ABM.

2. Model Time-Steps: IO Disruption

In Figures 12 and 13, on the left side, the full network and the CW-capability attributes are shown in blue and red. On the right side for each time-step of the model, we see what INTEL and CP "sees:" black nodes for VNSA with an unknown CW-capability status, blue with those that are not CW-capable and red with those that are. The text on the far right indicates which actions each actor takes for the next time-step based on the above assumptions. Initially, we are only aware of two organizations' CW capability statuses, HAMAS (left red node) and AQ (right red node). Because it is extremely difficult to effectively conduct CP on organizations as large as AQ, and politically sensitive as HAMAS, the first turn's actions only consist of IO and (as for every turn) intelligence collection. In an attempt to reflect the OPS/INTEL coordination cycle, the actors' action descriptions will appear in order of INTEL, Operations, and finally the adversary's CW tactics migration. The order would affect probabilities for each dependent variable within the model. Because each individual outcome is probabilistic, this model demonstration lacks robustness to provide stochastic results. Chapter V's case study will introduce these features to the model, but here we only look at one possible model trajectory. If the model was implemented again with the same parameters, there would likely be a slightly different outcome in terms of which VNSA adopt CW and which are surveilled by INTEL. Nevertheless, the example presented here demonstrates a framework with which CWMD OPS/INTEL fusion centers can work together using these analytical methodologies in support of CP.

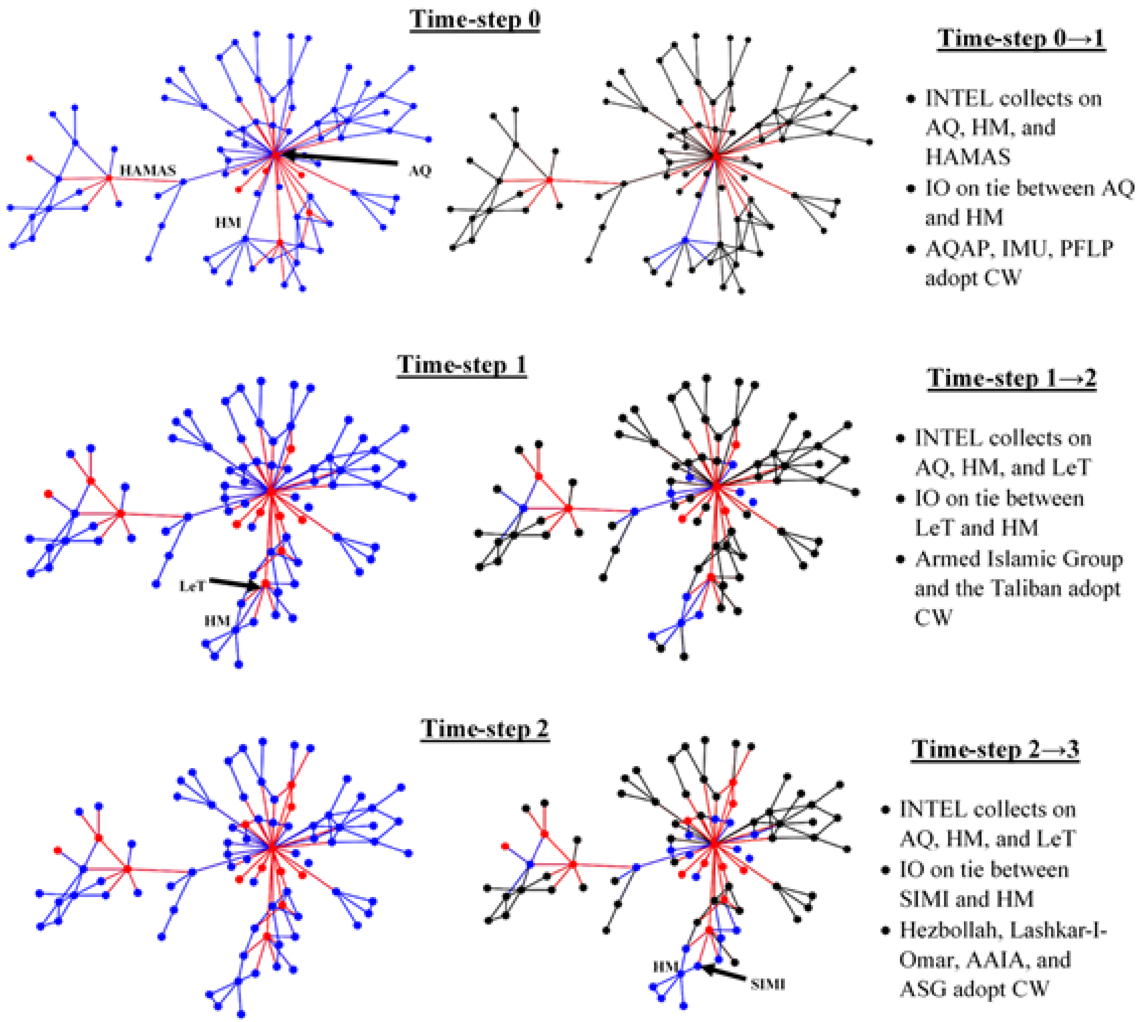


Figure 12. Model Time-Steps 0-2: IO Disruption

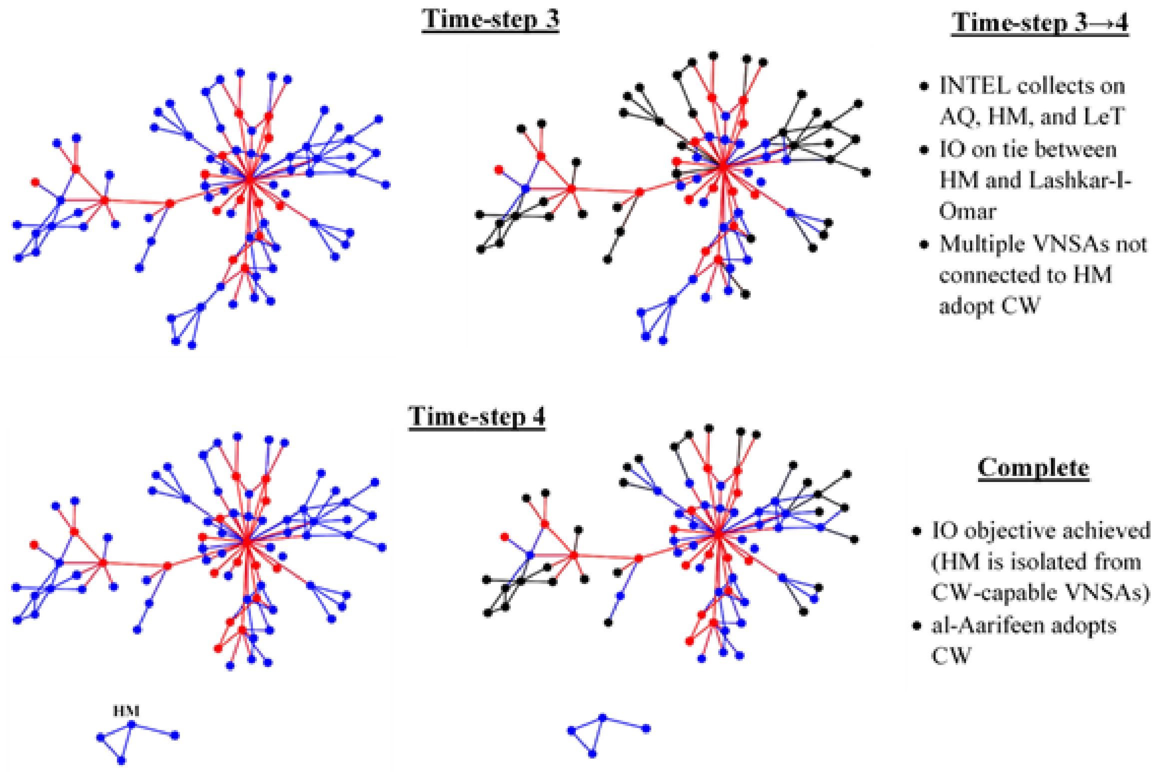


Figure 13. Model Time-Steps 3-4: IO Disruption

Here, we saw HM became isolated after four time-steps using only IO where we removed ties as intelligence was gathered on the inter-organizational network, and CW tactics migrated from those VNSA that were initially CW-capable. Next, we compare these results to coercive operations using the same intelligence capabilities and CW diffusion rates.

3. Model Time-Steps: Coercive Disruption

In Figure 14, the sociograms show time-steps and actions that reflect network changes as the CP assets (SOF, in this case) conduct coercion operations to remove a CW program as an attribute of an individual VNSA. This would correspond to direct action on a crucial facility or scientist, disposal of critical precursor or manufacturing materials, EOD operations on chemical munitions inbound to the VNSA, or economic sanctions on the VNSA's critical state sponsor resulting in effective deterrence. It could also include HUMINT source operations in which an organization's agent is tasked to sabotage the CW program in some way. Coercive disruption also includes conventional operations involving standoff munitions eliminating a critical facility or individual, or cyber operations that directly attacks the node (renders a CW program ineffective) as opposed to the tie between nodes.

We begin the simulation with the same parameters and probabilities as the IO simulation, and because it would be unrealistic to completely remove AQ's CW capability, the first coercive disruption action will be on the other organization initially known to be CW-capable: HAMAS.

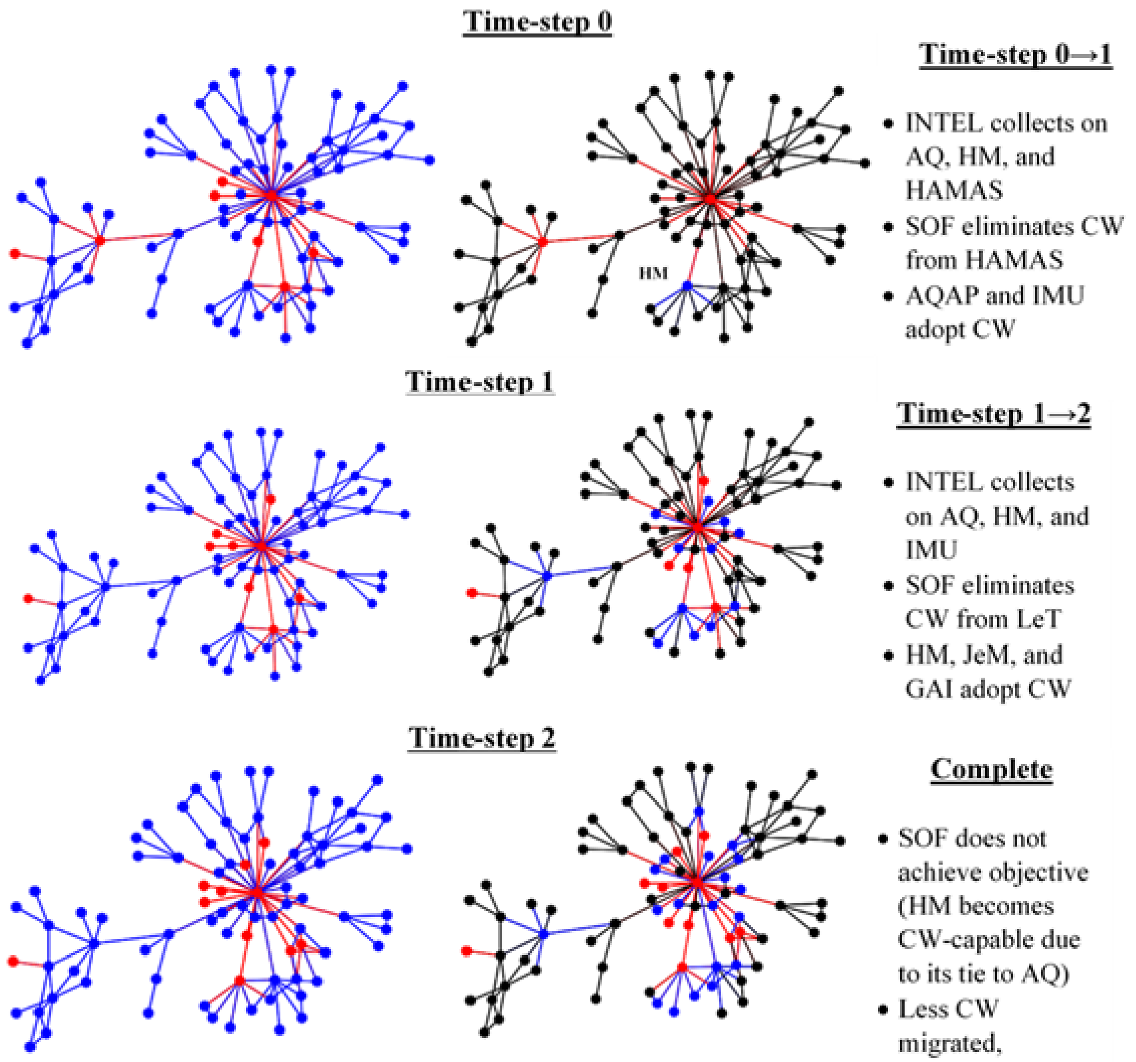


Figure 14. Model Time-Steps: Coercive Disruption

Because some critical ties between AQ and other nodes with high brokerage remained intact, it was only a matter of time before HM adopted CW tactics from the highly central node. Therefore, CP efforts failed after only two turns in deterring HM. It is important to note that CW tactics did not spread throughout the nodes in vicinity of HAMAS due to its early elimination, as well as those nodes around LeT. One can conclude from intuition and this simulation that it is effective to contain tactics migration to just a few nodes by eliminating the threatening attribute from the most central of nodes carrying that attribute. However, to prevent a specific node from gaining that attribute, it is more effective to reduce the ties to that target node. This disparity between IO and coercive direct action highlights the necessity to emphasize Commander's Intent when deciding strategies and certain combinations of CP tactics.

Running the pseudorandom number generator 1,000 times in a basic Monte Carlo simulation (see Appendix A for MATLAB Code), we obtain a histogram in Figure 15 that shows the distribution of the frequencies of 3 adjacent nodes obtaining CW tactics based on the prescribed diffusion rate of 5%. This process was repeated for 5% diffusion to secondary nodes, and 50% diffusion for intelligence collection. In future works, regression analysis could better fine tune these values to improve the actor-based model. The histograms in Figure 15 also illustrate the Monte Carlo simulations for how many times CW migrated to AQ's adjacent nodes using no, coercive, and IO disruption, respectively. In coercive disruption, one-third of AQ's adjacent nodes were effectively "coerced" (stayed zero regardless of AQ's efforts), and in IO disruption, one-third of AQ's ties were "disabled" (one-third less probability of CW diffusion).

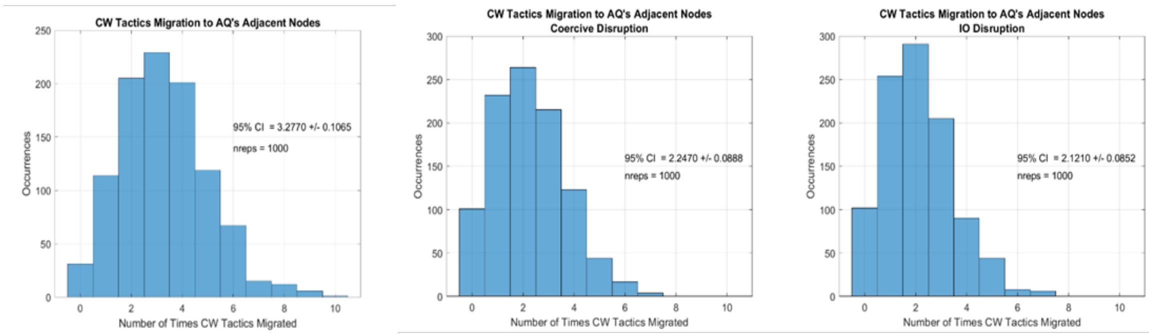


Figure 15. Number of Times CW Migrated to AQ's Adjacent Nodes for No Disruption (left), Coercive Disruption (center), and IO Disruption (right)

From these histograms, we see that at these diffusion rates, IO is slightly more effective than coercion (CW migrated 2.121 times on average under IO influence versus 2.247 times under coercion, although they do each lie just outside their margins of error). IO practitioners and CP operators understand that using coercive methods to completely remove the CW capability (often through kinetic action) or intent (often through non-kinetic action) is much more difficult than using (at least certain forms of) IO disruption to sever communications between two actors. Therefore, to effectively coerce one-third of AQ's allies with certainty that they either cannot or will not adopt or use CW is not very realistic. Instead, we assess the model's results from the same network with its CW diffusion characteristics as before, but this time only effectively coercing two nodes tied to AQ. For comparison's sake, we run IO disruption cutting only 2 of AQ's 33 ties and show the results in histogram format in Figure 16. The histograms from this scenario show that IO is again slightly more effective, although this time it lies within each plot's margin of error. Nevertheless, given that IO actions are often easier to use against a wide net of targets than coercive actions in the scope of CP of chemical programs, it is more useful to compare approximately two nodes coercively deterred against approximately one-third ties disrupted using IO.

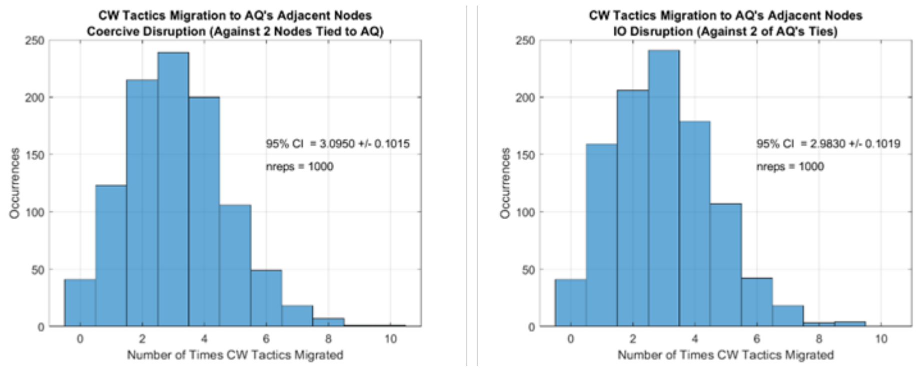


Figure 16. Coercive Disruption against Two Nodes (left) and IO Disruption against Two Ties (right)

Considering these results in the context of current events illustrating the simultaneous rise of peer adversaries and terrorist groups using CW as real and persistent threats, along with major paradigm shifts of CWMD responsibilities in the DoD and interagency organization yielding further resource constraints, there exists an urgent need to intelligently approach how we counter CW use. Ideally, coercion—kinetic and non-kinetic—and IO remain proficient irregular warfare options against CW-capable VNSA and regain the capability to counter China, Russia, Iran, and North Korea. However, with limited personnel, access, equipment, and funds, there are better ways to counter the often-elusive VNSA CW program.

By understanding the TAM and how organizations seek and implement new technologies and tactics (demand side), we can better predict which organizations may pursue CW and which strategic environments could serve as catalysts for CW programs. Next, we must have fundamental knowledge of tactics migration theory and acquire reliable intelligence on how VNSA are tied together in inter-organizational networks. Then, we use contagion theory to identify which organization-level nodes may serve as better diffusers of technologies and tactics.

Only once we understand the applicability of these relevant theories within the context of dark networks and nonconventional weapons development can we implement social network analysis methods. By assessing how central a VNSA is within its alliance network, or how much it acts as a broker, we can estimate how particular actions may affect a targeted network. Finally, by applying the custom actor-based model, we simulated those actions with negligible cost and consequence to evaluate different strategies and implementations of coercion (SOF/conventional) and IO actions to target nodes and ties, respectively. While each operation type has advantages and disadvantages, it appears that from these preliminary results, IO better serves to isolate organizations from tactics migration with the reduced risk inherent in loss of life. Policymakers and commanders should heed these results in campaign planning, as the tactical and operational decisions made by analysts and operators alike will have globally strategic effect whenever chemical weapons are involved.

In the next chapter, we see how a team of operators and intelligence analysts can work together in a notional (fictional, but realistic and based on some open source data) case study in which there is initially little presence in theater, increasing violence in a developing nation, a multitude of inter-organizational ties, and CW tactics among some VNSA.

V. CASE STUDY: MYANMAR VNSA ALLIANCE NETWORK

The continuous DoD/IC presence in areas such as Afghanistan and Iraq since 2001 has resulted in a developed analytic foundation that is atypical for most low intensity conflicts conducted by SOCOM units around the globe. Furthermore, as discussed previously, violent extremism disregards political boundaries as does the proliferation of WMD technologies and tactics, especially CW. Since CP operators and analysts cannot be expected to maintain a presence in every region experiencing a crisis that could possibly contain CW, there exists a need to quickly set up predictive intelligence models that can provide rough estimates of TTP migration to policymakers. While select analyses already exist on information transfer within an organization, this chapter continues with the methods of assessing how TTP (CW capability in particular) migrate through an inter-organizational network by using a notional case study based on the actual VNSA alliance network centered in Myanmar.

Myanmar presents a useful case study scenario for multiple reasons. First, there is little U.S. or Coalition presence in the country, so the effort inherent in building a predictive model based on limited data resembles the level of effort (in terms of resources needed to deploy to theater) necessary to successfully conduct CP at the cusp of tactical and operational levels of warfare with strategic implications.[151] Second, violence levels and political unrest have increased dramatically over the past few years due to Myanmar's security forces' and VNSA continued use of violence and human rights violations, particularly against the Muslim Rohingya population in the Rakhine State.[152] Third, there exists a major disconnect with the country's military junta and the democratically elected

151 Martin de Bourmont, "U.S. Pulls Military Assistance to Myanmar Over Rohingya Abuses." *Foreign Policy*. (Washington, DC, 2017). https://foreignpolicy.com/2017/10/24/u-s-pulls-military-assistance-to-myanmar-over-rohingya-abuses/.

152 "Rights Trends in Myanmar." *World Report 2019: Human Rights Watch*. (New York, 2019). https://www.hrw.org/world-report/2019/country-chapters/burma.

government that results in a quasi-shadow government.[153] Indeed, Myanmar's praetorian state—a political system in which "civilians serve in [a] government at the pleasure (and by permission) of the army"—is still alive and well despite the surge in publicity and governing power received by Daw Aung San Suu Kyi's National League for Democracy (NLD) party.[154] The systemic, nationwide poverty also contributes to instability as one of the three poorest countries in Asia with an average monthly income of $300 and 37% of its 53.4 million population at or below the poverty line.[155] In addition, the military junta has likely continued ties with rogue, adversarial nations like North Korea, and potentially is still coordinating arms sales to include WMD-related technologies despite the government denying such relationships.[156] Finally, the demographics create a fertile ground for ethno-religious conflict, as Myanmar is considered one of the world's most heterogeneous societies with 135 officially recognized ethnicities, each with their own culture, history, and language.[157]

The accusations of CW development in Myanmar includes suspected storage facilities from investigative journalists, reported CW-related symptoms among military, civilians, and agriculture by watchdog non-governmental organizations (NGOs), and other

[153] Kgalalelo Gaebee, and Thinzar Shunlei Yi. "Myanmar: Under the Name of Democracy, the Military Rules." *CIVICUS Global Alliance*, (Johannesburg, New York, Geneva, n.d.). https://www.civicus.org/index.php/re-imagining-democracy/stories-from-the-frontlines/3422-myanmar-under-the-name-of-democracy-the-military-rules.

[154] Yasser El-Shimy. "A Model of Praetorian States," (Cambridge: Harvard, 2014). https://www.belfercenter.org/sites/default/files/files/publication/2016-01-MEI_RFWP_ElShimy_0.pdf.

[155] Maneesha Khalae. "Poverty in Myanmar." *The Borgen Project.* (Seattle, 2019). https://borgenproject.org/top-10-facts-about-poverty-in-myanmar/.

[156] "Myanmar Maintains Military Ties with North Korea, U.S. Officials Claim." *South China Morning Post*, (Hong Kong, 2018). https://www.scmp.com/news/asia/southeast-asia/article/2103698/myanmar-has-maintained-military-ties-north-korea-us.

[157] Aurel Croissant and Philip Lorenz. "Myanmar: The Challenging Transition from Military to Democratic Government." *Comparative Politics of Southeast Asia*, 2017, 177–211. https://doi.org/10.1007/978-3-319-68182-5_7.

open source reports, as shown in Figure 17.[158] Given Myanmar's current social environment coupled with reliable accusations of CW sales, tests, and technology transfers, this case study will assess how CW proliferation could occur among VNSA within the country and among VNSA allegedly aligned with groups in Myanmar such as the case depicted in Figure 17.[159]

Figure 17. Suspected CW Production Facility in Magwe Region, Myanmar

A. SCENARIO

1. Notional, Realistic Scenario

While SOCPAC continues enduring SOF missions in the Philippines, Thailand, Indonesia, and elsewhere, civil unrest from violent extremism in Myanmar has increased significantly to the point of genocide and spiraled into a regional crisis due to the vast

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[158] Catherine Dill and Jeffrey Lewis. "Suspect Defense Facility in Myanmar." *James Martin Center for Nonproliferation Studies*. (Monterey: Middlebury Institute of International Studies, 2016). https://www.nonproliferation.org/suspect-defense-facility-in-myanmar/.

[159]Catherine Dill and Jeffrey Lewis. "Suspect Defense Facility in Myanmar." *James Martin Center for Nonproliferation Studies*. (Monterey: Middlebury Institute of International Studies, 2016). https://www.nonproliferation.org/suspect-defense-facility-in-myanmar/; Joshua Kurlantzick. "Chemical Weapons in Myanmar?" *Asia Unbound.* Council on Foreign Relations, (New York, 2014). https://www.cfr.org/blog/chemical-weapons-myanmar.

emigration and resulting human and economic strains. USINDOPACOM tasked SOCPAC as Commander, Joint Special Operations Task Force—Myanmar (which will subsequently be referred to as JSOTF-M) to combat ISIS, AQ, and affiliated groups operating within the country. In order to stabilize the country, provide humanitarian assistance, and increase U.S. influence, JSOTF-M is tasked as the supported commander to conduct limited IO and CT operations against certain VNSA that pose a threat to the civilian population and U.S. strategic interests. Furthermore, JSTOF-M is tasked to be prepared to conduct CP operations due to (notional) intelligence that North Korea, China, Russia, Iran, and VNSA like ISIS and AQ have supplied certain organizations within Myanmar with manufactured and crude chemical weapons and chemical agent precursors. Secondary strategic concerns include Myanmar's oil and mineral reserves and its role as a trade route for China to the Indian Ocean without needing to transit through the Straits of Malacca or Singapore.

2. Objective

To conduct an adequate intelligence preparation of the operational environment (IPOE), a small SOJ2/SOJ3 Ops-Intel CWMD Fusion Cell under JSOTF-M must leverage the scarce HUMINT, SIGINT, and MASINT capabilities (as well as CP operational assets) that are available to combat the proliferation of manufactured and crude CW. To that end, the SOJ2 initiates an effort to conduct SNA involving the inter-organizational VNSA network, dubbed the Myanmar-Affiliated VNSA (MAV) Network, consisting of organizations and state sponsors that are either already known to possess CW capabilities or have direct ties to organizations or states that do. Then, using simulations presented below, we assess whether it is more effective to cut ties between significant VNSA through information operations (IO) or conduct coercive direct action (kinetic or non-kinetic) CP operations that remove CW capabilities from a single organization in the MAV network. This type of coercive direct action could target a VNSA (the "node") by destroying CW storage and manufacturing facilities, offensive cyber operations (OCO) against CW facilities' infrastructure to disable certain processes, economic/diplomatic efforts, or covert actions that would render successful CW attacks highly unlikely or ineffective (or deter the VNSA's intent of such an attack). Direct action could also incorporate SOF or conventional assets to meet tactical objectives. On the other hand, IO activities target ties between VNSA and include cyber, PSYOPS, or other MISO actions between organizations to spread disinformation or distrust, or even kinetic actions that target communications infrastructure, all with the intent of disrupting or distorting the flow of communication (and therefore the transfer of CW TTP).

3. Dataset

The Terrorism Research and Analysis Consortium (TRAC) combines research efforts from 2,800 regional and topical experts reporting from hotspots around the globe, and its database offers open source information on VNSA, their affiliates, and the tactics used.[160] For this case study, we focus on all VNSA either predominantly operating in—or headquartered in—Myanmar, as well as VNSA and state sponsors that have direct ties with at least one Myanmar-based VNSA. Therefore, the unit of analysis is the organization, which includes VNSA and states as nodes. Positive ties (+1) include relationships that, using TRAC's terminology, are allies, affiliates, armed/military wing, political wing, inspired by, descendant, and other similar phrases. Rivals and enemies describe negative ties (-1), which we dichotomize in the SNA process to equal zero. All ties are unweighted such that a strong ally has the same value of connection as a loosely affiliated group. For the analysis, VNSA without a tie are removed.

B. MAV SOCIAL NETWORK ANALYSIS

The overall MAV network (excluding isolates) sociogram presents several clusters as shown in Figure 18. One cluster contains Iran, PRC, Russia, DPRK, and the former Myanmar Military Junta, all of which have a CW capability (either allegedly or self-proclaimed). The densest cluster, located on the right side of the graphic, consists of the different brigades and other extremist groups tied closely to the Junta. The primary cluster is centered around AQ near the middle, as the following centrality measures show. Finally, the bottom cluster is centered around ULFA and UNLF (see Appendix C for MAV organization names).

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[160] Veryan Khan and Arabinda Acharya, eds. "Tracking Terrorist Groups." TRAC. Walton Beacham, https://www.trackingterrorism.org/groups.

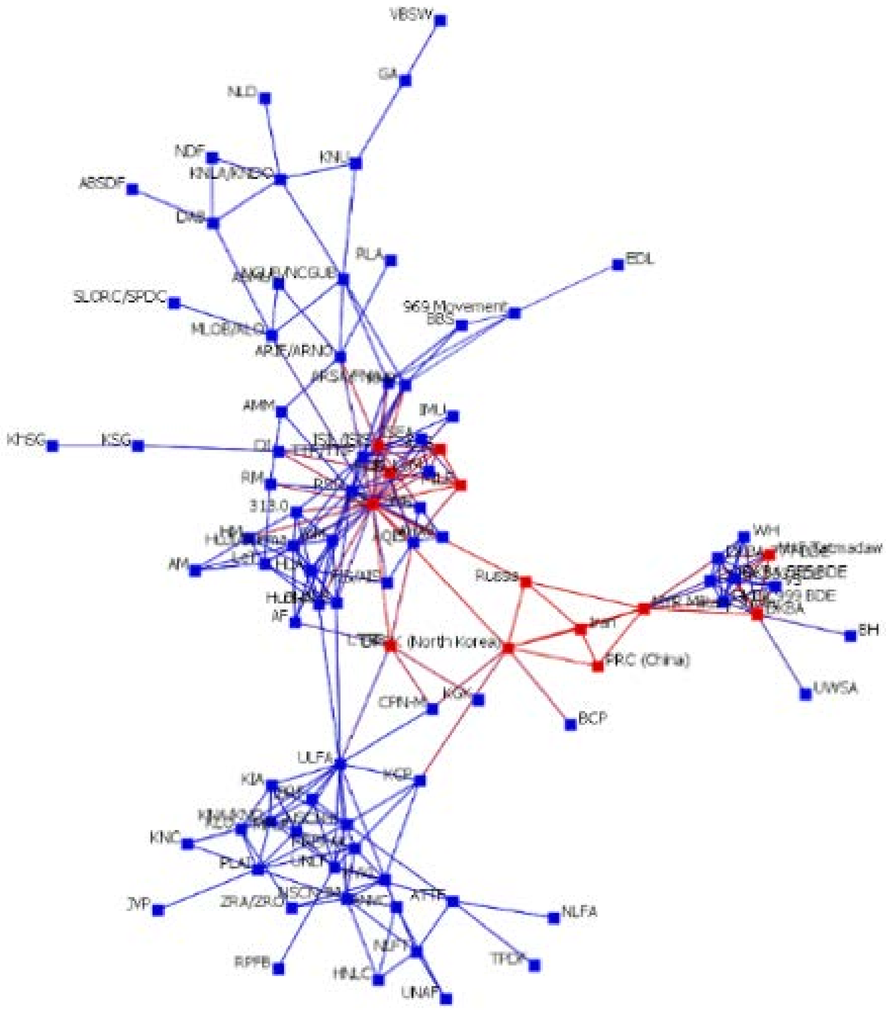

Figure 18. MAV Alliance Network (VNSA that have used CW are Red)

1. MAV Topology

Tables 8 and 9 show the same topology statistics for MAV as previously calculated for the AQ and ETA alliance networks. In the list of top 10 organizations in terms of centrality metrics, red groups are those that allegedly have CW capabilities. The MAV network's centrality measures suggest it closely resembles the AQ alliance network but shares a similar normalized variance as the ETA alliance network. The density measures show the network is denser than the previously analyzed AQ alliance network. This suggests the MAV network is fairly more hierarchical and denser than the AQ alliance network. One could interpret that information and material would transfer more efficiently from one group to another among MAV alliances but may be slightly more vulnerable to the removal of a handful of critical actors.

Table 8. Topographic Measurements

Centralization Measures

MAV Network	Network Size	Average Distance	Diameter	Normalized Variance	Degree Centralization	Standard Deviation
	99	3.889	10	17.109	0.260	4.136

Density Measures

AQ Alliance Network	Average Degree	Compactness	Normalized Clustering Coefficient
	5.051	0.279	0.518

Table 9. Top 10 Organizations' Centrality Measurements

Degree	Closeness	Betweenness	Eigenvector
AQ 0.310	969 Movement 0.085	AQ 0.435	AQ 0.680
ULFA 0.147	AQ 0.082	ULFA 0.242	HuJI/Burma 0.359
HuJI/Burma 0.127	DPRK (North Korea) 0.080	DPRK (North Korea) 0.199	RSO 0.330
RSO 0.127	HuJI-A 0.080	MYR Military Junta 0.165	TTP/TTIP 0.309
ISIL/ISIS 0.117	HuJI-B 0.080	MLOB/ALO 0.095	JeM 0.309
DKBA 0.107	LTTE 0.079	KCP 0.085	ISIL/ISIS 0.301
TTP/TTIP 0.107	RSO 0.079	NCUB/NCGUB 0.085	HuA 0.279
HuA 0.096	Russia 0.079	LTTE 0.079	HuJI-A 0.277
JeM 0.096	ULFA 0.079	HUJI-A 0.072	HuJI-B 0.277
KNA/KNO 0.096	HuJI/Burma 0.078	HuJI-B 0.072	JI 0.255

Unsurprisingly, AQ and DPRK consistently present near the top of the centrality measurements. ULFA and HUJI/Burma (and other HUJI groups, which are all in the same clique) also display consistently high centrality. In Figure 19, we see nodes sized according to degree centrality, since the other measures show similar results as was the case with the AQ alliance network.

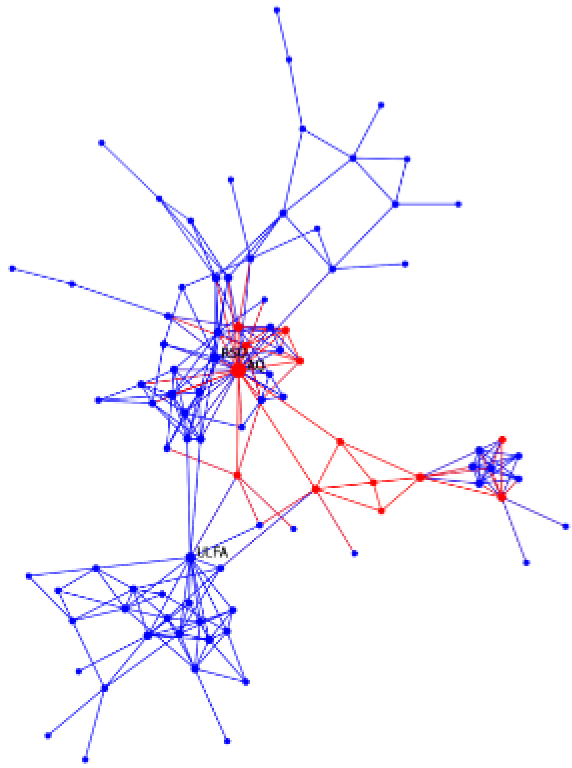

Figure 19. MAV Alliance Network, Nodes Sized by Degree Centrality

2. MAV Brokerage

Next, as with the AQ and ETA networks, we assess brokerage using the Burt constraint. This measure will again directly support IO planning in preventing the migration of CW TTP during the simulations. In the Burt constraint sociogram shown in Figure 20, the smallest nodes are least constrained and therefore better brokers of information and material by filling openings within the network that would otherwise remain disconnected. Larger nodes are most constrained and therefore poor candidates for brokers due to a lack of well-connected nodes tied to them. Red nodes are those with CW capabilities. Running the Burt constraint function in ORA, and confirmed in UCINet, AQ and ULFA present as the best potential brokers in the MAV alliance network.

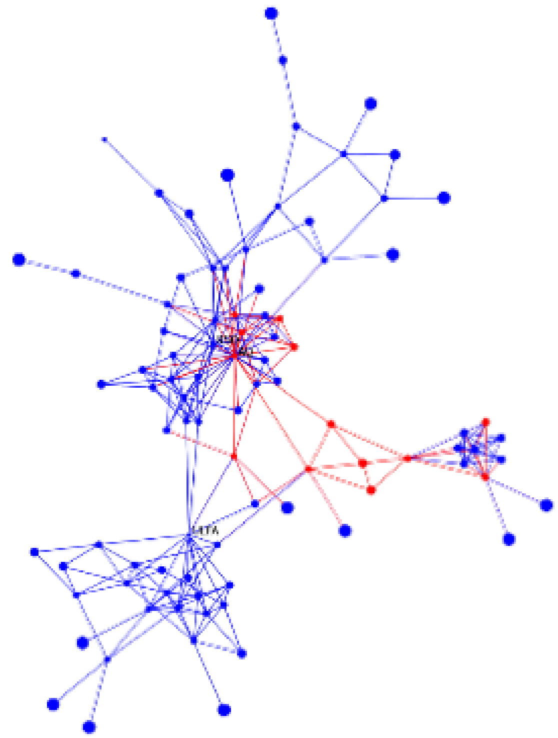

Figure 20. MAV Alliance Network, Nodes Sized by Brokerage

C. ACTOR-BASED MODEL

1. Model Assumptions and Characteristics

For this case study, and to simplify the ABM by omitting the "INTEL" actor, we assume intelligence assets have the full operational picture to detect whether or not every group being assessed has a CW capability in contrast to Chapter IV in which the CW status was unknown for some groups until intelligence reported the status. However, we capture the rate of intelligence collection as variable where more capabilities are determined early on in the simulation (upon initial IPOE) and less is determined per year as the conflict progresses. This concept is further explained in the following section. Next, we assume once a VNSA gains a CW capability, they retain it for the full duration of the simulation. We also assume CW TTP migration only occurs each year by one degree, meaning that a certain percentage of tied organizations to a CW-capable organization will gain the CW attribute, but it will not migrate past that point. This serves as a realistic assumption since it takes time for an organization to receive a technology and eventually adopt it successfully, especially if VNSA are constrained from US/Coalition CP efforts. Finally, we assume ties do not change throughout the simulation. With IO disruption, we will change the initial ties from the original MAV network, but the total number of ties will remain constant throughout each subsequent time-step.

2. Chemical Weapons TTP Migration

The constant CW TTP diffusion rate for each simulation will again manifest through non-exclusive pseudo-random selection of VNSA tied to CW-capable VNSA. This produces a natural logarithmic accumulation of CW-capable VNSA since some selections made from the pseudo-random number generator (PRNG) will sometimes already be CW-capable due to a previous PRNG iteration of CW spreading or initial conditions. In Chapter IV, we obtained a diffusion rate from observations for organizations that are not necessarily in the same networks and could in fact be of rival or enemy networks. The resulting linear trend from the region-specific GTD/POICN dataset does not account for imperfect intelligence of the environment and actors within the theater. Therefore, it is reasonable to assume that initially, as intelligence assets work to develop the environment, their account of CW-capable organizations increases rapidly and levels out after several years in theater while CW TTP continue migrating at a near-linear rate (based on historical data). This assumes that there is no significant increase in conflict levels and other factors that would change the strategic environment during the simulation (i.e. “Black Swan” events). These assumptions of relatively consistent conflict levels and the near-asymptotic nature of intelligence gathering upon initiating a campaign is captured in the algorithm used to simulate the ABM through nonexclusive pseudorandom selections when determining which nodes adjacent to a CW-capable node gain the CW attribute. Some selections will be of adjacent nodes that already hold the attribute, just as intelligence collected on an organization showing CW development will sometimes be latent information if the capability was captured in an earlier intelligence report.

Therefore, instead of importing raw numbers for an entire region, we must now import the year-over-year increase of CW-capable VNSA within an interorganizational network, such as the AQ alliance network. In this case, we include the GTD and POICN data, updated with well-known organizations from TRAC not already included in BAAD 1, but filtered to only include those VNSA that are AQ affiliates. In doing so, we show inf Figure 21 that a natural logarithmic function can describe the time-series cumulative plot below with an R-squared value of 0.9947. Next, we run the algorithm with different diffusion rates in increments of 5% up to 30% and plot the results in Figure 22 to assess which may be suitable candidates for the simulation.

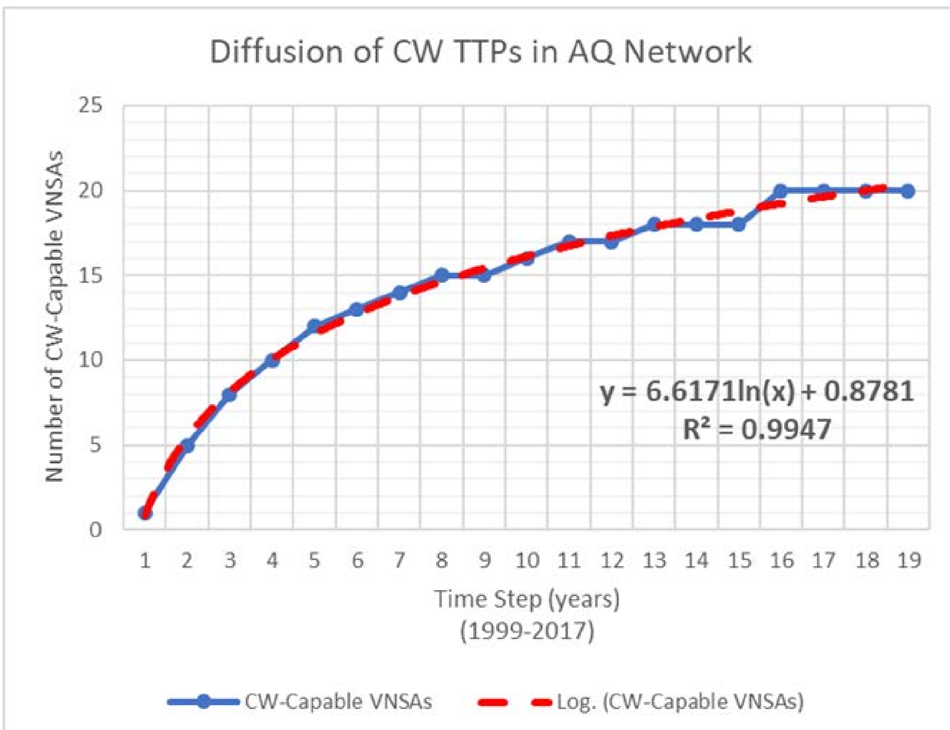

Figure 21. CW Diffusion in AQ Network

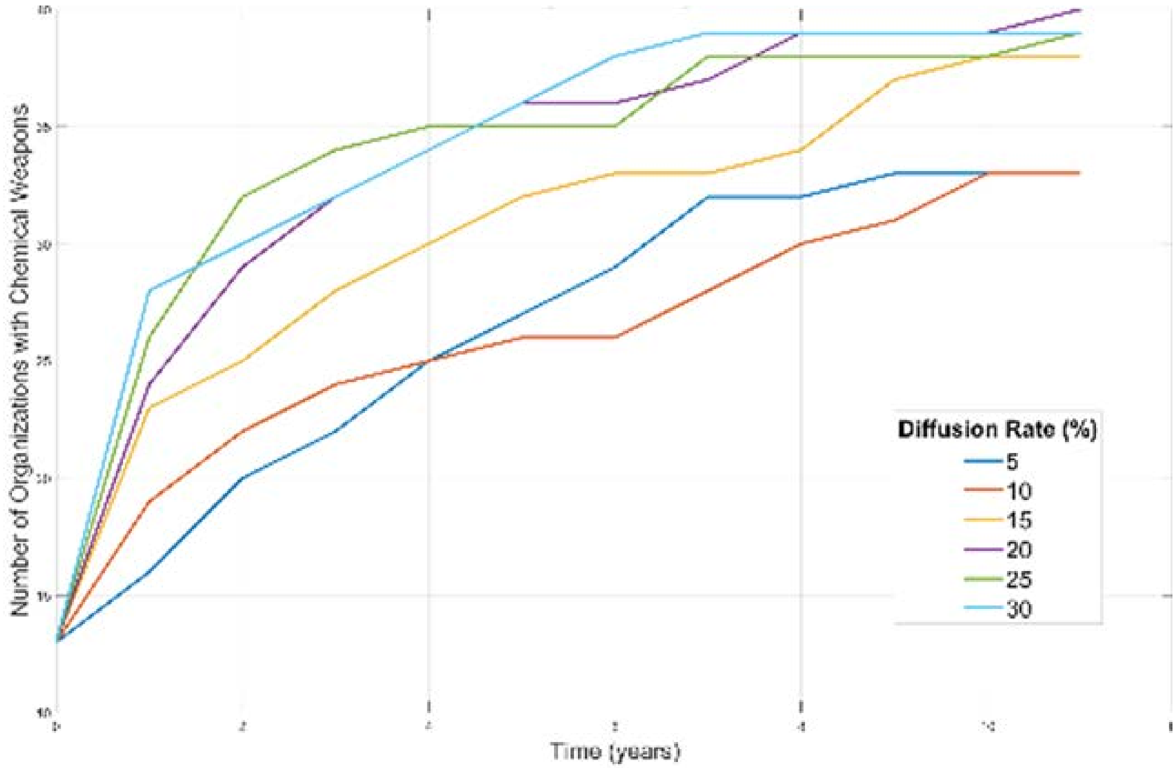

Figure 22. MAV Network Cumulative Plot of CW Groups Using Varying Diffusion Rates

Due to the algorithm's randomness, the complexity of how VNSA interact, psychological factors of leaders deciding to adopt CW, and the logistics and security issues with transferring technologies and tactics in constrained, non-permissive environments, there is a stochastic nature to this simulation. Thus, we assess each diffusion rate over 1000 iterations in Monte-Carlo simulations to obtain mean values of CW nodes and plot the results in Figure 23.

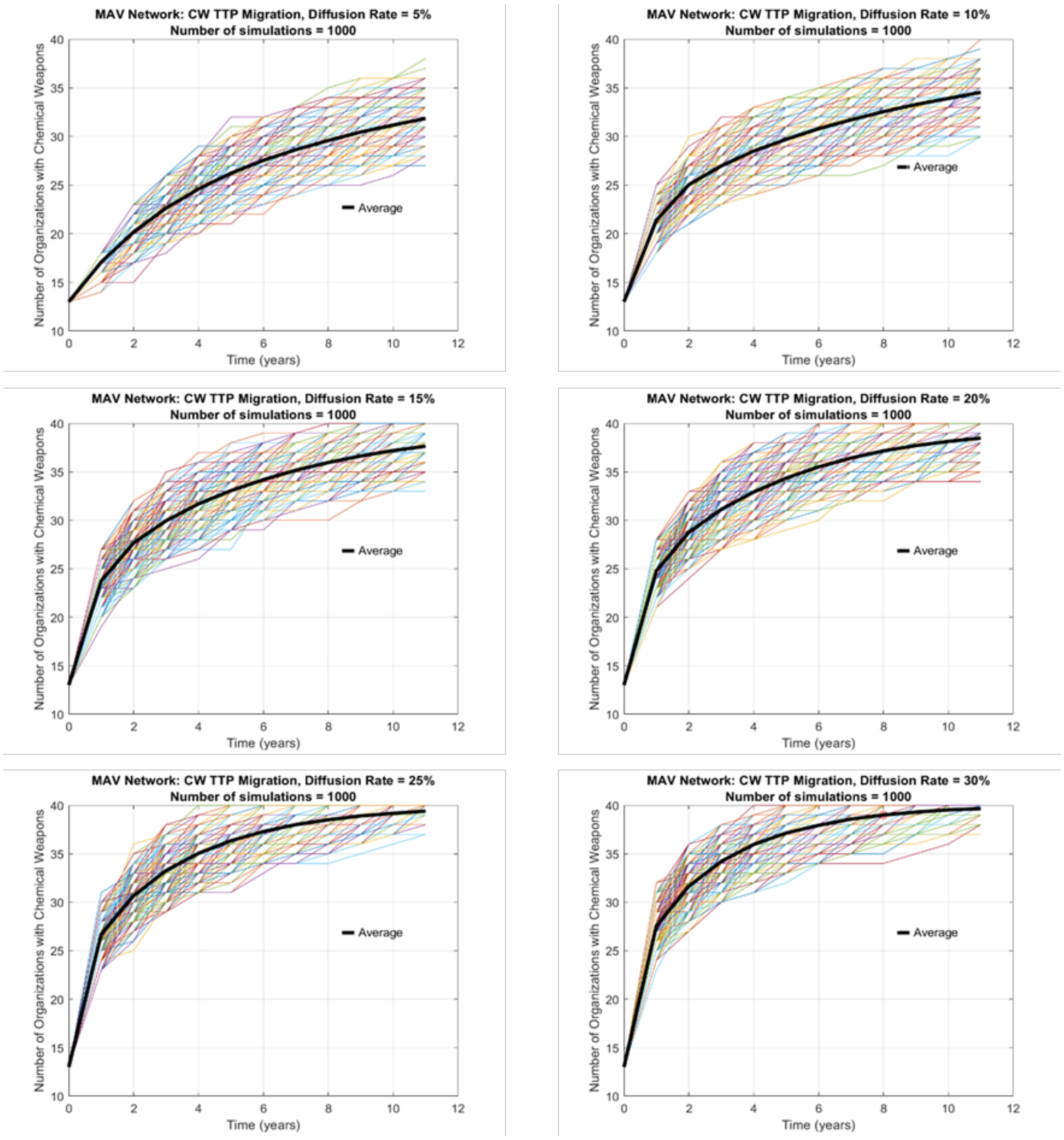

Figure 23. MAV Alliance Network Cumulative Plot: N = 1000 Simulations for Varied Diffusion Rates

After iterative analysis, initially running the simulation in increments of 5% followed by increments of 1% and 0.1%, we find 4.9% to be the most acceptable diffusion rate modeled by the natural logarithmic function for the algorithm, as seen in Figure 24 showing the MAV network plot with no disruption, overlaid with the AQ network cumulative plot's natural logarithmic trendline. For each series of sociograms in this section, the left image displays the network at year 3, the middle at year 6, and the right at year 10, where red nodes are CW-capable VNSA and blue nodes are not CW-capable. For cumulative plots, the thick, black lines indicate the mean values of CW-capable VNSA for each year labeled with the 3, 6, and 10-year values rounded to the nearest tenth.

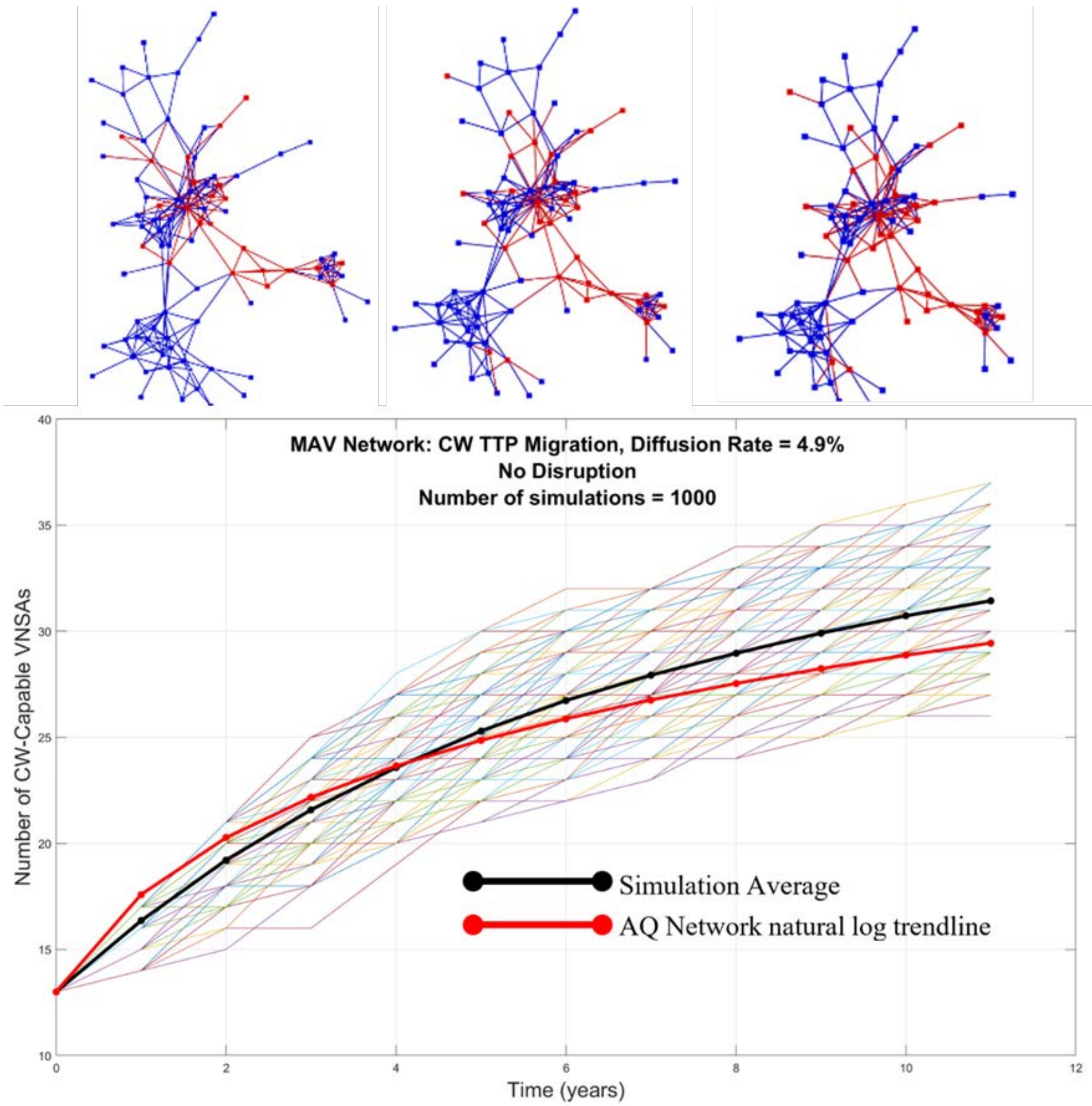

Figure 24. MAV Sociograms at Time = 3, 6, 10 (top), AQ Network Trendline vs. MAV Network CW TTP Migration (bottom)

D. COERCIVE DISRUPTION OF MAV NETWORK

For coercive disruption, we target the most central organizations' ability to continue their CW programs (i.e., node with highest degree centrality score). Therefore, in the coercive disruption model we remove AQ's CW attribute and ensure that throughout the simulation, ULFA does not adopt CW. For AQ, coercive disruption implies a comprehensive strategy applying pressure closer to their primary operating areas in Iraq and Afghanistan, leaving them risk adverse from spreading CW TTP. For ULFA, coercive CP involves intelligence collection on critical facilities and personnel and executing the targeting cycle on suspected CW development processes, scientists, and logistics using conventional and SOF assets. Figure 25 shows the cumulative plot and sociograms for this disruption simulation.

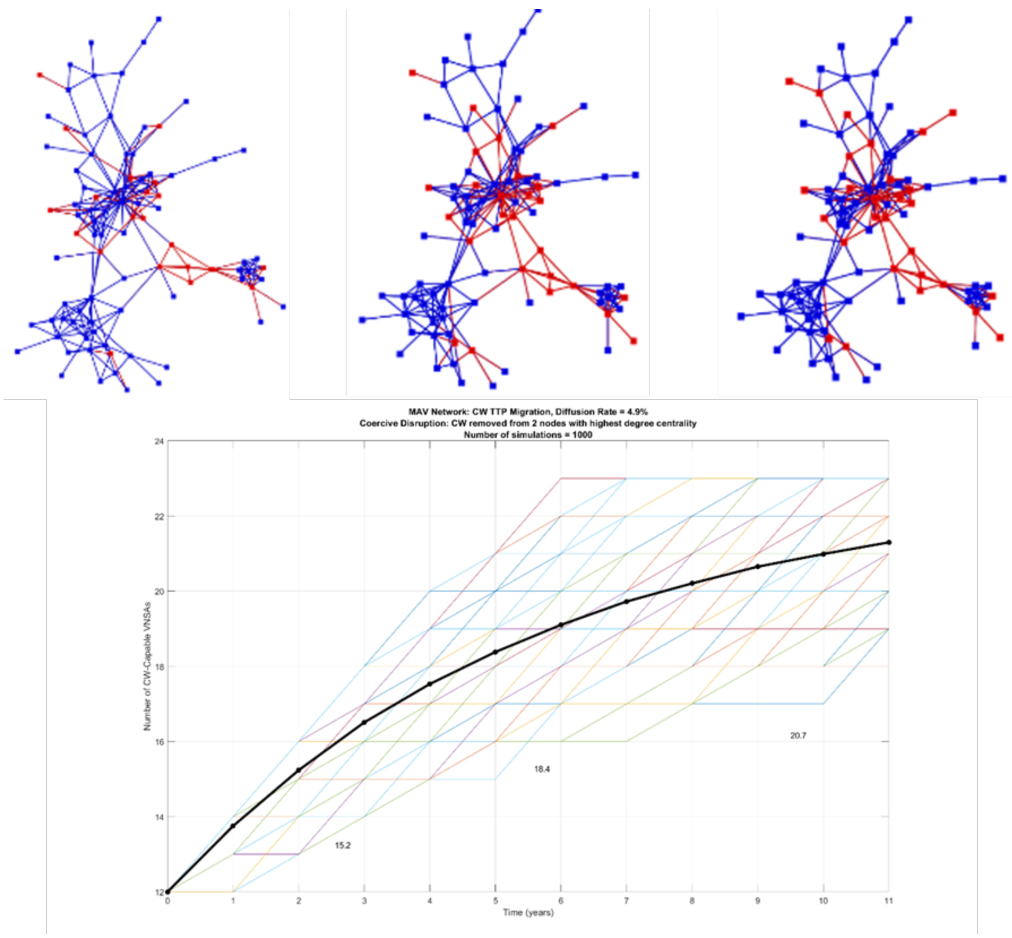

Figure 25. Coercion-Disruption CW Attribute at Time = 3, 6, 10 (top), CW Migration with Coercive Disruption, 4.9% Diffusion Rate (bottom)

E. IO DISRUPTION OF MAV NETWORK

In leveraging IO options to disrupt the MAV network, the alliances, or ties, are targeted rather than the organizations. Those ties could include trust and influence, direct communications, and logistics routes. Therefore, instead of targeting a central node, IO techniques target the ties emanating from the nodes with the highest brokerage (low Burt constraint) score. It just so happens that in the MAV network, the two nodes with highest degree centrality (AQ and ULFA) also have the highest brokerage scores, which further enables our coercion/IO comparative analysis by controlling for the topological measures and focusing on which disruption strategy is optimal.

To "conduct IO" against ties coming from AQ and ULFA, we sever one-third of their ties, consistent with the ABM from Chapter IV. These two IO actions could consist of a combination of cyber operation, psychological warfare technique, disinformation campaign, intelligence collection, and/or HUMINT source operation. The SOJ2/3 cell must work with kinetic and non-kinetic targeters to decide specific tactic within each category (coercive/IO) has the highest chance of success with greatest efficacy, which is usually largely driven by the timeline, target, and unit capabilities. Given these factors, we must also consider how the JSOTF-M monitors disruption effects. For example, in the case of ULFA which has a high brokerage score, it only has about a dozen ties initially, while AQ has over twice that amount. Admittedly, it could become difficult to know while conducting IO that one-third of AQ's ties remain disrupted. Nevertheless, for purposes of comparison against coercion operations, this method of analysis suffices because it would also be difficult to know with absolute certainty that AQ is no longer CW-capable after conventional or SOF operations remove the CW attribute. Figure 26 shows the cumulative plot and sociograms for this disruption simulation.

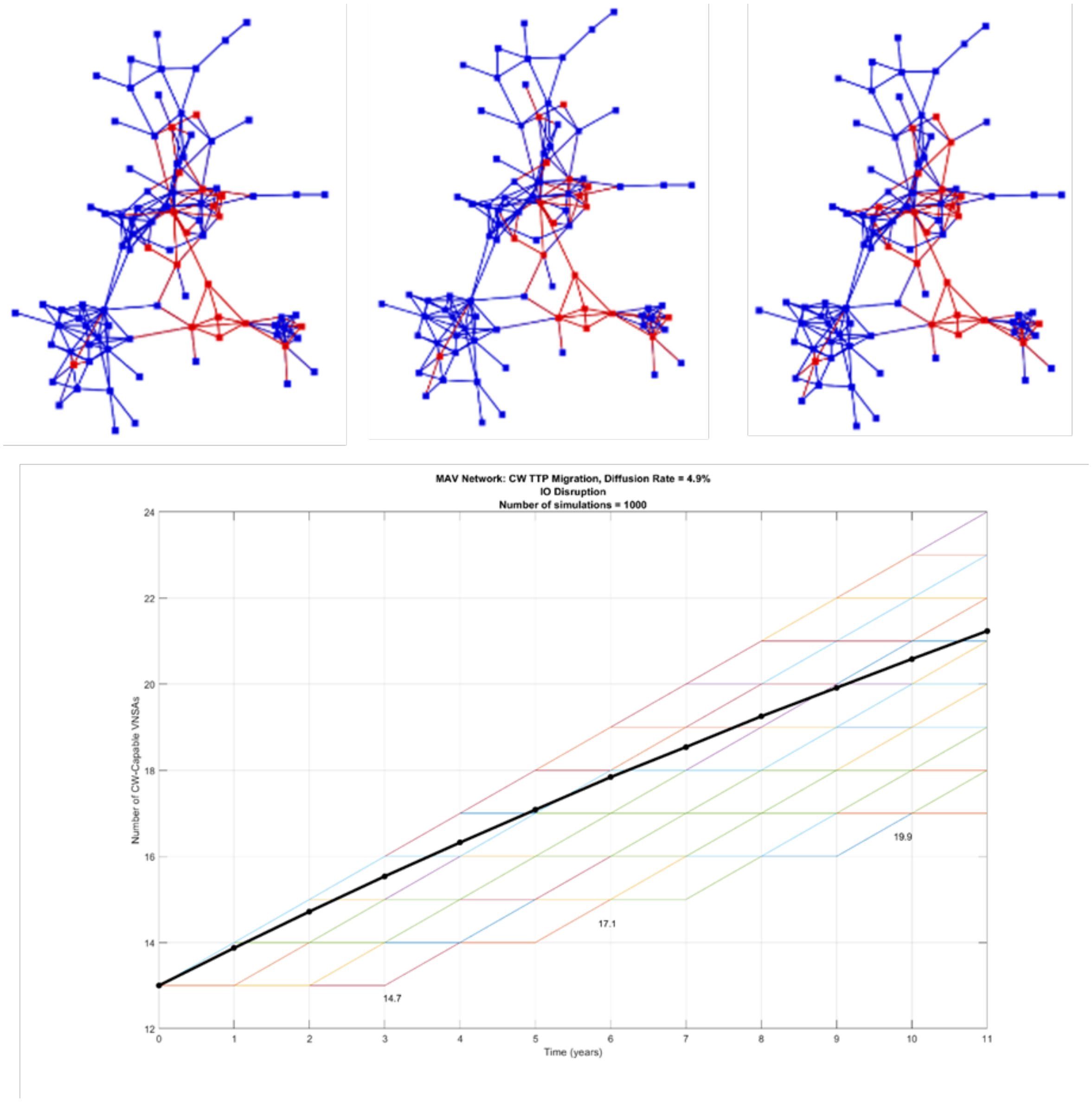

Figure 26. Top: IO-Disruption CW Migration (time = 3, 6, 10); Bottom: CW Migration with IO Disruption, 4.9% Diffusion Rate

From here, we see that on average, given the specified diffusion rate and defined coercion/IO actions, IO reduces the number of CW-capable nodes by approximately one more node in comparison to each corresponding time step from the coercion simulation. Interestingly, IO disruption yields a linear trend in year-over-year increase of CW nodes, while coercion retains the logarithmic trendline from the original diffusion plot without disruption. It is critical to note, however, that these simulations only present a framework for a notional, realistic case study to evaluate potential disruption strategies. With even a slightly different network or different environmental factors (and therefore different diffusion rates), the preferred disruption method could change for each scenario.

To evaluate robustness of this model and determine how important the environmental factors are, we rerun the simulation in Figure 27 with different diffusion rates representing more extreme (positive and negative) conditions. First, when assessing CW TTP migration with a diffusion rate less than approximately 4.4%, no migration occurs; instead, the initial number of CW nodes (13) persists for the full duration. On the other end of the spectrum, we present simulation results using a diffusion rate of 50% and see that the number of CW-capable nodes approaches 40 nodes by step 6. In comparing coercive and IO disruption at 50% diffusion, we see similar steady-state (final) values, although the maximum value (23 nodes) is reached by step 3 in coercive disruption and by step 6 in IO disruption.

We therefore conclude that in general, IO has the potential of mitigating CW TTP migration somewhat more effectively than coercive (kinetic/non-kinetic, using SOF/conventional) disruption, with the understanding that each tactic may perform differently with different network topologies. Nevertheless, these results show that varying degrees of diffusion (from different external, environmental, and strategic factors acting on the network) will not significantly change which disruption method performs better. Instead, the network topology likely plays a larger role (along with the specific objective as defined by the Commander's Intent, as shown in Chapter IV) in determining which disruption strategy CP assets should pursue.

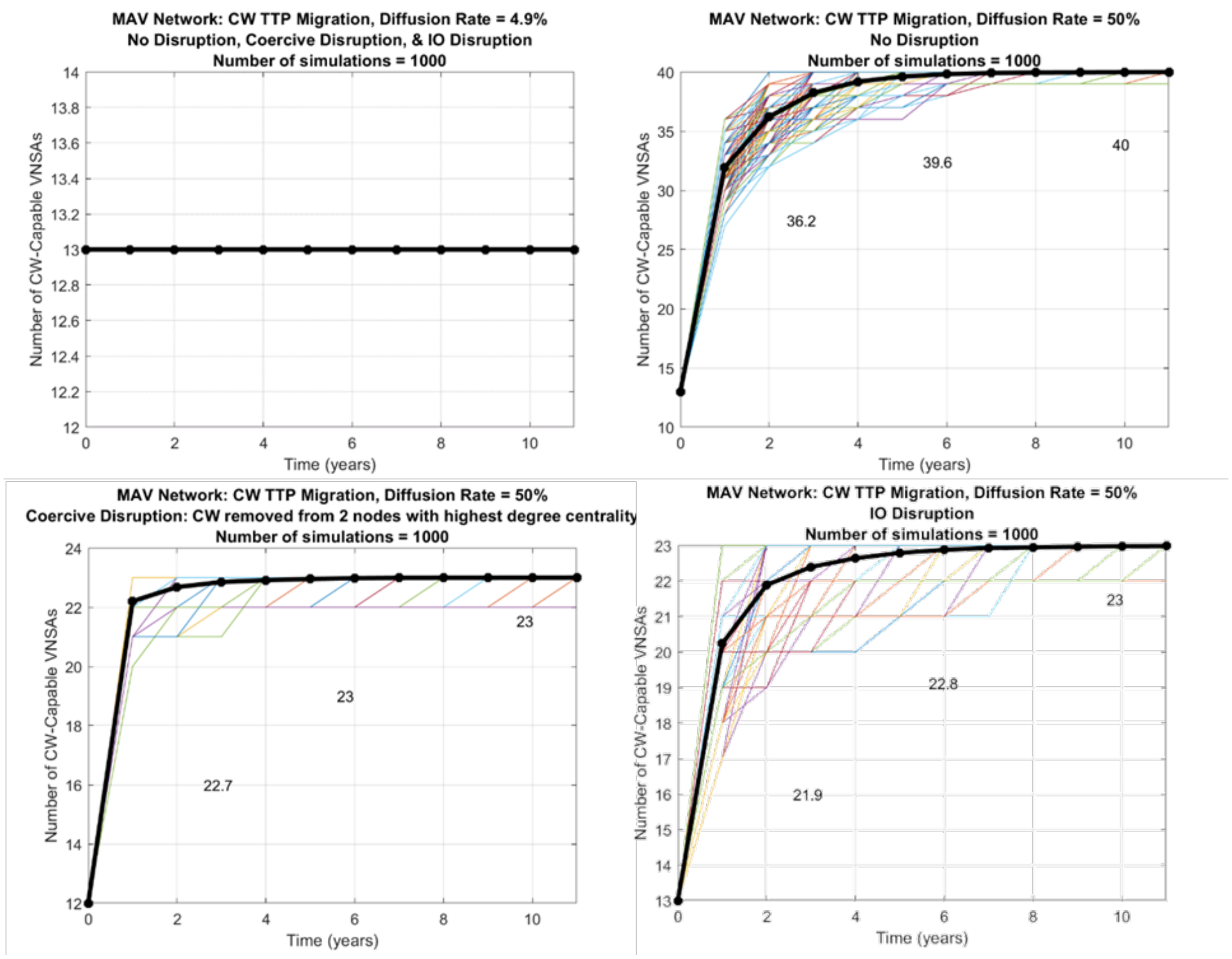

Figure 27. 4.4% Diffusion with Coercive & IO Disruption (top left), 50% Diffusion without Disruption (top right), 50% Diffusion with Coercive Disruption (bottom left), 50% Diffusion with IO Disruption (bottom right)

F. DISRUPTION MODEL RESULTS

In this case study, we see a modest advantage to using IO disruption over coercive disruption in preventing further CW TTP migration throughout the MAV alliance network. The point in time at which that choice becomes beneficial changes based on the CW TTP diffusion rates (which is dependent on the environmental, strategic factors acting on the network). However, this is specific to this situation, and even slightly different parameters could yield a completely different result. Therefore, it is critical to carefully consider the network's characteristics, timescales, unit of analysis, implementation of disruption methods, diffusion rates used, and what assumptions the user makes.

In a series of simulations using no disruption as the baseline, with a CW TTP diffusion rate of 4.9%, the model shows IO disruption reduces CW TTP migration by 8.91%, 16.79%, and 23.93% at years 3, 6, and 10, respectively. Coercive disruption reduces CW TTP migration by 14.36%, 12.60%, and 9.5% at years 3, 6, and 10, respectively. It is interesting that at this lower diffusion rate, coercive disruption is almost twice as effective as IO in the short term with lower diffusion rates, but less than half as effective in the long term. This is likely because less nodes gain the attribute initially when a highly central VNSA lost its CW capability during coercive disruption. On the other hand, IO disruption allowed the central node (AQ) to retain the attribute, but it was not able to spread the knowledge or material effectively due to the severed ties. Contrarily, in scenarios with a diffusion rate as high as 50%, IO is only slightly more effective in the short term than coercion, but each method has similar outcomes past year 6. This disparity is likely due to the fact that with higher TTP diffusion rates within an environment, communication becomes more important than the attribute itself, and so kinetic or non-kinetic coercion has a relatively limited effect in the near term compared to IO until a "critical mass" of CW-capable nodes exist.

VI. RECOMMENDATIONS AND CONCLUSION

A. POLICY RECOMMENDATIONS

Based on the analytic approaches conducted in this research, we obtain several policy recommendations for counter-proliferation (CP) forces in opposing VNSA seeking chemical weapons (CW).

- Strategic intelligence of countries and regions in crisis, or developing crisis, is essential to anticipating CW proliferation among VNSA networks. To that end, HUMINT operations must be incorporated early on to provide plans and intentions needed within an organization to understand the leadership's psychological factors with respect to CW adoption decisions.
- Operational intelligence of VNSA assists in later phases of the technology adoption model, in which the organization's leadership has decided to acquire CW materials and begin mobilization of assets for staging potential attacks. This demands intelligence collection and all-source analysts leverage dual use and logistics networks of relevant materials, with an emphasis on the demand side of transactions. Furthermore, the HUMINT-derived strategic intelligence must enable tipping/cueing of SIGINT, IMINT, and MASINT capabilities to monitor, and ultimately anticipate, the VNSA's tactical actions.
- Cyber operations must be integrated early on in crisis development to facilitate intelligence collection, information operations, and coercion operations throughout the CP campaign, particularly with decentralized VNSA alliance networks.
- The Commander must consider both Information Operations (IO) and coercive disruption techniques based on the characteristics of both the interorganizational network and the VNSA of interest. When a central VNSA adopts CW, short-term objectives support coercion operations but long-term (typically longer than 2–3 years) CP efforts demand IO methods to contain TTP migration. A two-pronged effort combining IO and coercive CP would likely provide enhanced results on a

larger array of network topologies and diffusion rates, although further analysis is needed to confirm this strategy.

- Other Units of Action within DoD and Interagency organizations could readily contribute to CP efforts. Expeditionary units that contribute significant capabilities (CP, EOD, expeditionary intelligence, expeditionary exploitation, etc.) would greatly benefit from more extensive integration in non-kinetic coercion and other IO functions. While these assets are often already involved in kinetic coercive disruption via direct support or TACON within a task force or other organizational structure, leveraging these expeditionary assets (although non-SOF) can serve as force multipliers due to their unique access, expertise, and perspectives.
- It would benefit relevant operations/intelligence fusion centers combatting CW (or WMD in general) proliferation to use concepts and recommendations presented herein with a feedback loop approach (see below).

In the feedback system model, developed in MATLAB's Simulink software, Figure 28 shows inputs (predetermined elements by the Fusion Cell conducting the analysis and CONOP development) and outputs (results of the model that can be used to measure performance and effectiveness). The inputs are Independent Variable (IV) 1–4 on the left-hand side, and they correlate to environmental factors to consider as used in Chapter III such as GDP, population, or conflict levels.

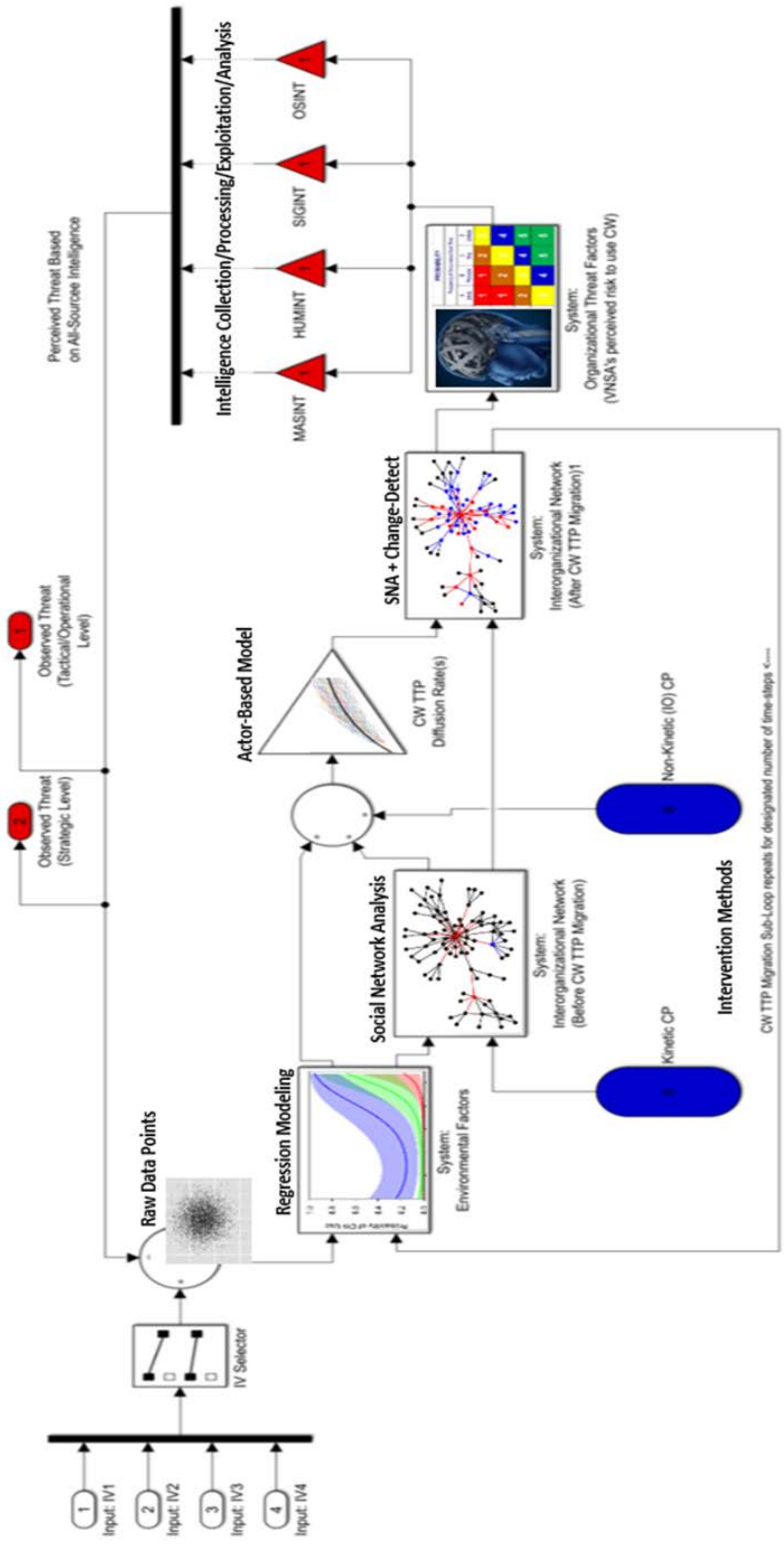

Figure 28. Ops/Intel Counterproliferation Feedback System

The more IVs used, the more accurate the model, but it may be challenging to isolate the effects of a particular IV. We use the IV selector to choose which environmental factors to consider in the model. The environmental factors system represents the model built from regression analysis, and the interorganizational network (before CW TTP migration) represents the initial condition of the alliance network and requires SNA for model development. The CW TTP diffusion rate (or rates if using a more robust model with variable rates based on the network or environmental factors) considers the network characteristics, environmental factors, and intervention methods. Intervention methods, as shown by the blue inputs, represent coercive CP operations (which directly affects a node within the network) or IO-centric CP (which directly affects the network structure by altering internodal ties). After CW TTP migration, and the predetermined number of time-steps desired for modeling, the organizational threat factors is represented by the respective system block on the right-hand side. This threat, which is ultimately affected by the organization's perceived risks and benefits to adopting CW TTP based on psychological, strategic, operational, and tactical factors already discussed. Finally, the observed strategic and operational/tactical threat levels of a region or operational area are measured through all-source intelligence collection and analysis on red forces, each with their own weighted values of effectiveness based on the situation.

B. FUTURE WORK

To improve the regression model's accuracy in predicting whether CW events will occur, additional independent variables are necessary. When possible, independent variables should be quantitative to reduce bias inherent with qualitative, categorical data. Future work must also confine datasets to specific strategic environments in terms of conflict level, region, types of actors on all sides of the conflict, demographics, recent events involving CW and the public reaction, and other factors that could promote or prevent CW use. Conducting regressions in certain parts of CENTCOM will look different than in other parts, and even more so in the vast, heterogeneous INDOPACOM region. Other factors to consider for independent variables include:

- State sponsorship of the VNSA, and the sponsor's characteristics such as stockpile data, historical CW use, and conflict levels within the nation state.
- Leadership of the VNSA, and the associated psychological factors as documented by UMD's START research and others.
- Whether or not recent events included CW incidents, whether the region of interest was aware of such incidents, and what the local and global reactions were in the media and public over such incidents.
- Success rate of other forms of terrorist attacks such as IEDs, firearms, and vehicles.
- Availability of CW precursors and dual use materials.
- Availability of expertise, either through industry, academia, military, or other means.

The actor-based model could also use several improvements to better predict how CW TTP migrate throughout the alliance network from a given CW-capable VNSA with high centrality scores. First, TTP migration has been shown to occur downstream beyond the initial transfer of a technology. Therefore, the ABM could be improved by determining what the diffusion rate is for second and third order transfers of the technology. Does a low-level member of a VNSA collaborate with a friend in another VNSA to provide CW technologies or materiel? Does a large VNSA that received CW from a state sponsor then quickly transfer that to some of its smaller proxy VNSA allies? Filling these gaps can better inform the ABM in providing variable diffusion rates throughout a network.

The ABM could also consider the strategic and operational environmental factors, as done in Chapter III with multiple regressions, for each organization and the country or region in which it operates. The ABM used in Chapters IV and V assumed constant environmental factors, and thus a constant diffusion rate. However, with the MAV network, organizations operating in India would likely have a different diffusion rate (either in exporting or importing CW TTP) than organizations operating in the Philippines due to a myriad of factors. Having diffusion rates associated to each node would create a much more robust ABM.

C. CONCLUSION

While some policymakers and academics are still attempting to identify what a weapon of mass destruction is and is not, SOCOM CP practitioners and operators are struggling to balance great power competition with the continuing Global War on Terror and a rise in VNSA pursuit of chemical weapons. Therefore, the CP community must prioritize its efforts to optimize results given the dynamic nature of the problem set. When faced with Priority Intelligence Requirements involving whether a VNSA will pursue CW, this study reveals that increased conflict levels usually lead to an increased probability of CW adoption. There are nuanced factors, such as the symmetry, duration, and nature of the conflicts, but in general the non-permissive environment increases a VNSA's demand to adopt CW. Therefore, when a region begins to show signs of increased violence and unrest, intelligence efforts should initiate a process to develop a HUMINT collection network and potentially begin allocating technical means of collection, to include a prominence on the demand side of dual use logistics networks.

Along with understanding a VNSA of interest that may pursue CW, intelligence efforts should also emphasize the inter-organizational networks in the physical and cyber domains. The methods and extent to which multiple VNSA interact have been shown to have a direct effect on whether CW TTP migrate across organizations and regions. Therefore, HUMINT, SIGINT, and other cyber/IO efforts should focus not only on a target organization but each of its closest allies. Using these collection methods, the Commander tasked with CP lines of effort will have more tools at their disposal to attempt disruption of the network, such as cutting ties via IO and eliminating or severely degrading CW capability from each node. Furthermore, extensive social network analysis (facilitated by all-source analysis that yields an adequately comprehensive view of the interorganizational network) enables the identification of optimal targets for CP and intelligence operations; the most central nodes should be the focus, and while we used degree centrality here for its straightforward calculation, alternative centrality measures could offer improved results if the network's topology warrants it. For example, some networks may be disrupted easier if CP assets coercively targeted nodes with high eigenvector centrality. Further analysis comparing different centrality measures and their corresponding disruption results could offer better insight into when an analyst should choose each centrality measure. Thus, a comprehensive actor-based model can run simulations using strategic and operational intelligence, in conjunction with operational and tactical disruption options, to identify the preferred course of action for counterproliferation campaigns.

Moving forward, this framework shows how regression analysis to create environmental factor models, social network analysis to map interorganizational networks, and a robust actor-based model via Monte Carlo simulations, can be combined to inform the SOF Commander in developing proactive efforts to prevent CW proliferation and enhance security in non-permissive environments. Further efforts to develop these capabilities will certainly be worth the resources expended when lives are saved through improved analysis of the complex dynamics of technology proliferation between violent non-state actors. With the models methods shown in this report, CWMD Task Forces can inject real-world data on environmental factors to inform predictive intelligence on the probability of CW adoption among non-state actors. Furthermore, if intelligence on alliances between organizations are available, analysts and operators can now simulate CP strategies and decide to what extent should kinetic/non-kinetic coercive actions and IO actions be taken to achieve the Commander’s intent and desired end state.

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APPENDIX A. R CODE

```
%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%
% Aaron Green & Chris Price: R Script for Chapter III                      %
%                                                                          %
%                                                                          %
%                                                                          %
%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%
################################################################################
##########
library(tidyverse)
library(naniar)
library(dplyr)
library(igraph)
library(readxl)
library(MagicMerge)
library(dplyr)
library(ggplot2)
library(stargazer)
################################################################################
##########
#input the GTD and POICN dataset (combined)
gtd <- read_csv('GTD_With POICN Chem Added.csv')
################################################################################
######
#filtering out the gtd for the particular years and needed columns
fgtd <- gtd %>%
 select(`iyear`, `country_txt`,`weaptype1_txt`) %>%
 filter(`iyear` >=1995) %>%
 filter(`iyear` <=2017)

#renaming the columns - probably unnecessary
fgtd <- rename(fgtd, `year` = `iyear`)
fgtd <- rename(fgtd, country = country_txt)

#adding a new column to count events using chemicals and assigning a 1 and 0 to
say whether there was a chem event or not.
fgtd$chemical <- NA
fgtd$chemical [fgtd$weaptype1_txt == 'Chemical'] <- 1
fgtd$chemical [fgtd$weaptype1_txt != 'Chemical'] <- 0

#same for explosives
fgtd$explosive <- NA
fgtd$explosive [fgtd$weaptype1_txt == 'Explosives'] <- 1
fgtd$explosive [fgtd$weaptype1_txt != 'Explosives'] <- 0

#same for incendiary
fgtd$incendiary <- NA
fgtd$incendiary [fgtd$weaptype1_txt == 'Incendiary'] <- 1
fgtd$incendiary [fgtd$weaptype1_txt != 'Incendiary'] <- 0

#removing column to remove unwanted duplicates
fgtd$weaptype1_txt = NULL


#set up df for country / year
df <- d_mutate(fgtd,
              cnt_chem = sum(chemical),
              cnt_inc = sum(incendiary),
```

```
              cnt_exp = sum(explosive),
              .by=c(country, year),
              .cross=TRUE,
              .reduce=TRUE)

#selecting the wanted columns
df <- select(df, year, country, cnt_chem, cnt_inc, cnt_exp)

#removing duplicates
df <-distinct(df, .keep_all = FALSE)

#adding column for binomial regression
df$chemical <- 0
df$chemical [df$cnt_chem >0] <- 1

#changing NAs to 0
df [is.na(df)] <- 0

#this formatted the dataset so that it can be merged with the following
datasets
################################################################################
#######
################################################################################
#######
#loading UCDP dataset
ucdp <- read_xlsx('UCDP Georeferenced Event Dataset.xlsx')

#filtering ucdp for year, type of violence, country, and best estimate of
resulting deaths
dp <- ucdp %>%
 select(year, type_of_violence, country, best) %>%
 filter(year >=1995) %>%
 filter(year <=2017)

#type of violence is 1 - state based; 2 - non-state; 3 - one-sided violence
######################################################################
#adding columns to tally the amount and type of violent events
dp$state <- 0
dp$state [dp$type_of_violence == 1] <- 1
dp$non_state <- 0
dp$non_state [dp$type_of_violence == 2] <- 1
dp$oneside <- 0
dp$oneside [dp$type_of_violence == 3] <- 1
dp$totalconflict <- 0
dp$totalconflict [dp$type_of_violence %in% c(1,2,3)] <- 1

#tallying the deaths so when one type of conflict = 1, it takes the number of
deaths (1 x # of deaths = # of deaths)
dp$state_deaths <- dp$state * dp$best
dp$non_state_deaths <- dp$non_state * dp$best
dp$oneside_deaths <- dp$oneside * dp$best

#creating country,year
dp_cy <- d_mutate(dp,
                 non_state_deaths = sum(non_state_deaths),
                 state_deaths = sum(state_deaths),
                 oneside_deaths = sum(oneside_deaths),
                 cnt_statebased = sum(state),
                 cnt_non_state_based = sum(non_state),
                 cnt_onesidebased = sum(oneside),
                 cnt_totalconflict = sum(totalconflict),
                 cnt_death = sum(best),
```

```
                .by=c(country, year),
                .cross=TRUE,
                .reduce=TRUE)

#removing unnessary columns
dp_cy$state=NULL
dp_cy$non_state=NULL
dp_cy$oneside=NULL
dp_cy$type_of_violence=NULL
dp_cy$totalconflict=NULL
#removing duplicates
dp_cy <-distinct(dp_cy, .keep_all = FALSE)

#changing NA to 0
dp_cy [is.na(dp_cy)] <- 0

#merging with df
df1 <- magic_merge(dp_cy, df)

df1 <- select(df1, gw_year, gw_name, cnt_death, cnt_statebased,
cnt_non_state_based, cnt_onesidebased, cnt_totalconflict, non_state_deaths,
             state_deaths, oneside_deaths,cnt_chem, cnt_inc, cnt_exp, chemical)

#changing NA to 0
df1[is.na(df1)] <- 0

################################################################################
##################
################################################################################
##################
#inport polity data
pol <-read_xls('p4v2017.xls')

#filtering pol
pol <- pol %>%
 select(`country`, `year`, `polity2`) %>%
 filter(`year` >=1995) %>%
 filter(`year` <=2017)

#merging pol with df
df2 <- magic_merge(pol, df1)

################################################################################
##################
################################################################################
##################
#reading in pop / gdppc
dev <-read_csv('WDIData.csv')

#creating vector for desired indicators
tgt_indicators <- c('GDP per capita (current US$)',
                   'Population, total',
                   'Population density (people per sq. km of land area)')

#adding a prefix to year so the years can be modified for long data vs wide
data
dev <- dev %>%
 rename_if(is.double, ~ paste0("year_," .)) %>%
 gather(year, indicatorvalue, starts_with("year_")) %>%
 mutate(year = str_remove(year, 'year_')) %>%
 mutate(year = as.integer(year))
```

```
#selecting the useful columns and filtering the required years and countries
dev1 <- dev %>%
 select(year, `Country Name`, `Indicator Name`, indicatorvalue) %>%
 filter(`year` >=1995) %>%
 filter(`year` <=2017) %>%
 filter(`Indicator Name` %in% tgt_indicators)

#adjusting the column names
dev1 <- rename(dev1, indicator = `Indicator Name`)
dev1 <- rename(dev1, `gw_name` = `Country Name`)

#spreading indicators
dev1 <- spread(dev1, indicator, indicatorvalue)

# Fix column names
names(dev1) <- fix_names(names(dev1))

#logging numbers to mitigate outliers
dev1$poplog <- log(dev1$population__total +1)
dev1$popdenlog <- log(dev1$population_density__people_per_sq__km_of_land_area_
+1)
dev1$gdppclog <- log(dev1$gdp_per_capita__current_us__ +1)


dev1_cy <- d_mutate(dev1,
                 popdenlog = sum(popdenlog),
                 poplog = sum(poplog),
                 gdppclog = sum(gdppclog),
                 .by=c(gw_name, year),
                 .cross=TRUE,
                 .reduce=TRUE)

df3 <- magic_merge(dev1_cy, df2)

################################################################################
####
#setting log for counts of conflict to mitigate outliers
df3$cnt_statebasedlog <- log(df3$cnt_statebased+1)
df3$cnt_non_state_basedlog <- log(df3$cnt_non_state_based+1)
df3$cnt_onesidebasedlog <- log(df3$cnt_onesidebased+1)
df3$cnt_totalconflictlog <- log(df3$cnt_totalconflict+1)
df3$cnt_deathlog <- log(df3$cnt_death+1)
df3$cnt_non_state_deathslog <- log(df3$non_state_deaths + 1)
df3$cnt_state_deathslog <- log(df3$state_deaths + 1)
df3$cnt_oneside_deathslog <- log(df3$oneside_deaths + 1)

## Lagging the dataset by 1 year, except for the chemical weapon events to show
whether a chemical weapon was a result of previous experiences
df3 <- d_mutate(df3,
               totalconflictlag  = lag(cnt_totalconflict, n=1),
               statebasedlag = lag(cnt_statebased, n=1),
               nonstatebasedlag = lag(cnt_non_state_based, n=1),
               onesidebasedlag = lag(cnt_onesidebased, n=1),
               totalconflictlaglog = lag(cnt_totalconflictlog, n=1),
               statebasedlaglog = lag(cnt_statebasedlog, n=1),
               nonstatebasedlaglog = lag(cnt_non_state_basedlog, n=1),
               onesidebasedlaglog = lag(cnt_onesidebasedlog, n=1),
               deathlaglog = lag(cnt_deathlog, n=1),
               nonstatedeathlaglog = lag(cnt_non_state_deathslog, n=1),
               statedeathlaglog = lag(cnt_state_deathslog, n=1),
               onesidedeathlaglog = lag(cnt_oneside_deathslog, n=1),
               state_deathslag = lag(state_deaths, n=1),
```

```
                peace_years   = spell(cnt_totalconflict, 0),
                .by = gw_name)

#selecting the columns of interest - just making it a little more streamlined
df3 <- select(df3, gw_name, gw_year, poplog, popdenlog, gdppclog, polity2,
chemical, nonstatebasedlaglog, statebasedlaglog, onesidebasedlaglog,
             deathlaglog, nonstatedeathlaglog, statedeathlaglog,
state_deathslag, onesidedeathlaglog, peace_years)

#getting rid of NAs that added up during the previous tidy
df3$chemical [is.na(df3$chemical)] <- 0
df3$nonstatebasedlaglog [is.na(df3$nonstatebasedlaglog)] <- 0
df3$statebasedlaglog [is.na(df3$statebasedlaglog)] <- 0
df3$onesidebasedlaglog [is.na(df3$onesidebasedlaglog)] <- 0
df3$deathlaglog [is.na(df3$deathlaglog)] <- 0
df3$nonstatedeathlaglog [is.na(df3$nonstatedeathlaglog)] <- 0
df3$statedeathlaglog [is.na(df3$statedeathlaglog)] <- 0
df3$onesidedeathlaglog [is.na(df3$onesidedeathlaglog)] <- 0
df3$state_deathslag [is.na(df3$state_deathslag)] <- 0

##############################################################################
####
#regressions

x <- glm(chemical ~ nonstatebasedlaglog + nonstatedeathlaglog +
statebasedlaglog + statedeathlaglog + onesidebasedlaglog + onesidedeathlaglog +
polity2 + I(polity2^2) + gdppclog + poplog + peace_years + I(peace_years^2) +
I(peace_years^3), data = df3, family = binomial)

a <- glm(chemical ~ nonstatebasedlaglog + statebasedlaglog + onesidebasedlaglog
+ gdppclog + polity2 + I(polity2^2) + poplog + peace_years + I(peace_years^2) +
I(peace_years^3), data = df3, family = binomial)

b <- glm(chemical ~ nonstatedeathlaglog + statedeathlaglog + onesidedeathlaglog
+ gdppclog + polity2 + I(polity2^2) + poplog + peace_years + I(peace_years^2) +
I(peace_years^3), data = df3, family = binomial)

c <- glm(chemical ~ statedeathlaglog + onesidedeathlaglog + gdppclog + polity2
+ I(polity2^2) + poplog + peace_years + I(peace_years^2) + I(peace_years^3),
data = df3, family = binomial)

d <- glm(chemical ~ statedeathlaglog + I(statedeathlaglog^2) +
onesidedeathlaglog + I(onesidedeathlaglog^2) + gdppclog + polity2 +
I(polity2^2) + poplog + peace_years + I(peace_years^2) + I(peace_years^3), data
= df3, family = binomial)

e <- glm(chemical ~ statebasedlaglog + I(statebasedlaglog^2) +
onesidebasedlaglog + I(onesidebasedlaglog^2) + gdppclog + polity2 +
I(polity2^2) + poplog + peace_years + I(peace_years^2) + I(peace_years^3), data
= df3, family = binomial)

#printing out model stats and organizing the variables appropriately
stargazer(x, a, b, c, d, e,  type='text',
         order = c(15,16,17,11,12,3,5,4,7,6,10,8,9,1,2,13,14),
         out='modelregression.html')

#confidence intervals for the regressions
confint.default(x)
confint.default(a)
confint.default(b)
confint.default(c)
confint.default(d)
```

```
confint.default(e)

#coefficient plot for the models. First plot are the control variables.
Choosing the model with
#all of the variables and the best model
p <- magic_plot(d, plot.type='coef',
               colors='dark green',
               coef.offset = 0.1,
               line.lwd = 30,
               yaxis.size = 6,
               xlim = c(-1, 1),
               xvar=c('peace_years',
                      'I(peace_years^2)',
                      'I(peace_years^3)',
                      'polity2',
                      'I(polity2^2)',
                      'poplog',
                      'gdppclog'),
               yaxis.labels=c('Peace Years',
                              'Peace Years (squared)',
                              'Peace Years (cubed)',
                              'Democracy',
                              'Democracy (squared)',
                              'Population',
                              'GDP per capita'),
               ylab.space = .05,
               legend=c('Model 5**', 'Model 1'),
               legend.loc = ('bottomleft'),
               legend.col=c('dark green', 'red'),
               background = 'white',
               finish=FALSE)
magic_plot(x, coef.offset=-0.1, colors='red', args=p, finish=TRUE)

#this plot is for the test variables
p2 <- magic_plot(d, plot.type='coef',
               colors='dark green',
               coef.offset = 0.1,
               line.lwd = 30,
               yaxis.size = 6,
               xlim = c(-1, 1),
               xvar=c('statebasedlaglog',
                      'statedeathlaglog',
                      'I(statedeathlaglog^2)',
                      'onesidebasedlaglog',
                      'onesidedeathlaglog',
                      'I(onesidedeathlaglog^2)'),
               yaxis.labels=c('State-Based Conflict',
                              'State-Based Deaths',
                              'State-Based Deaths \n(squared)',
                              'One-Side Violence',
                              'One-Side Deaths',
                              'One-Side Deaths \n(squared)'),
               legend=c('Model 5**', 'Model 1'),
               legend.col=c('dark green', 'red'),
               legend.loc = ('bottomleft'),
               background = 'white',
               finish=FALSE)
magic_plot(x, coef.offset=-0.03, colors='red', args=p2, finish=TRUE)

#plotting the graph for state death
g <- magic_plot(d,
               xvar = 'statedeathlaglog',
```

```
               ylab = ‘Probability of CW Use’,
               xlab=‘Deaths from State-Based Conflict’,
               alpha = 0.05,
               colors = c(‘dark green’),
               background = ‘white’,
               foreground = ‘black’,
               margin = c(60,60,35,15),
               title.space = c(5),
               ylim=c(0, 1),
               xlim = c(0,11),
               xlab.space = 45,
               ylab.space = 35,
               finish = TRUE)


view(g$predict)

#using zvar population
g1 <- magic_plot(d,
                xvar = ‘statedeathlaglog’,
                zvar = “poplog”,
                ylab = ‘Probability of CW Use’,
                xlab=‘Deaths from State-Based Conflict’,
                zlab = “Population”,
                alpha = 0.05,
                colors = c(‘Spectral’),
                background = ‘white’,
                foreground = ‘black’,
                margin = c(60,60,35,15),
                title.space = c(5),
                ylim=c(0, 1),
                xlim = c(0,11),
                xlab.space = 45,
                ylab.space = 35,
                finish = TRUE)

#using zvar for gdp
g2 <- magic_plot(d,
                xvar = ‘statedeathlaglog’,
                zvar = “gdppclog”,
                ylab = ‘Probability of CW Use’,
                xlab=‘Deaths from State-Based Conflict’,
                zlab = “GDP per Capita”,
                alpha = 0.05,
                colors = c(‘Spectral’),
                background = ‘white’,
                foreground = ‘black’,
                margin = c(60,60,35,15),
                title.space = c(5),
                ylim=c(0, 1),
                xlim = c(0,11),
                xlab.space = 45,
                ylab.space = 35,
                finish = TRUE)

view(g2$predict)

#using zvar for democracy
g3 <- magic_plot(d,
                xvar = ‘statedeathlaglog’,
                zvar = “polity2”,
                ylab = ‘Probability of CW Use’,
```

```
                xlab='Deaths from State-Based Conflict',
                zlab = "Democracy",
                alpha = 0.05,
                colors = c('Spectral'),
                background = 'white',
                foreground = 'black',
                margin = c(60,60,35,15),
                title.space = c(5),
                ylim=c(0, 1),
                xlim = c(0,11),
                xlab.space = 45,
                ylab.space = 35,
                finish = TRUE)

#initialize libraries
library(stargazer)
library(tidyverse)
library(naniar)
library(dplyr)
library(igraph)
library(readxl)
library(MagicMerge)
library(dplyr)
library(ggplot2)
library(stargazer)
library(leaflet)
library(lubridate)
library(boot)

################################################################################
##########
#input the GTD and POICN dataset (combined)
gtd <- read_csv('GTD_With POICN Chem Added.csv')
################################################################################
######
#filtering out the gtd for the particular years and needed columns
fgtd <- gtd %>%
 select(`iyear`, `country_txt`,`weaptype1_txt`) %>%
 filter(`iyear` >=1995) %>%
 filter(`iyear` <=2017)

#renaming the columns - probably unnecessary
fgtd <- rename(fgtd, `year` = `iyear`)
fgtd <- rename(fgtd, country = country_txt)

#adding a new column to count events using chemicals and assigning a 1 and 0 to
say whether there was a chem event or not.
fgtd$chemical <- NA
fgtd$chemical [fgtd$weaptype1_txt == 'Chemical'] <- 1
fgtd$chemical [fgtd$weaptype1_txt != 'Chemical'] <- 0

#same for explosives
fgtd$explosive <- NA
fgtd$explosive [fgtd$weaptype1_txt == 'Explosives'] <- 1
fgtd$explosive [fgtd$weaptype1_txt != 'Explosives'] <- 0

#same for incendiary
fgtd$incendiary <- NA
fgtd$incendiary [fgtd$weaptype1_txt == 'Incendiary'] <- 1
fgtd$incendiary [fgtd$weaptype1_txt != 'Incendiary'] <- 0

#removing column to remove unwanted duplicates
```

```
fgtd$weaptype1_txt = NULL


#set up df for country / year
df <- d_mutate(fgtd,
              cnt_chem = sum(chemical),
              cnt_inc = sum(incendiary),
              cnt_exp = sum(explosive),
              .by=c(country, year),
              .cross=TRUE,
              .reduce=TRUE)

#selecting the wanted columns
df <- select(df, year, country, cnt_chem, cnt_inc, cnt_exp)

#removing duplicates
df <-distinct(df, .keep_all = FALSE)

#adding column for binomial regression
df$chemical <- 0
df$chemical [df$cnt_chem >0] <- 1

#changing NAs to 0
df [is.na(df)] <- 0

#this formatted the dataset so that it can be merged with the following
datasets
################################################################################
#######
################################################################################
#######
#loading UCDP dataset
ucdp <- read_xlsx('UCDP Georeferenced Event Dataset.xlsx')

#filtering ucdp for year, type of violence, country, and best estimate of
resulting deaths
dp <- ucdp %>%
 select(year, type_of_violence, country, best) %>%
 filter(year >=1995) %>%
 filter(year <=2017)

#type of violence is 1 - state based; 2 - non-state; 3 - one-sided violence
######################################################################
#adding columns to tally the amount and type of violent events
dp$state <- 0
dp$state [dp$type_of_violence == 1] <- 1
dp$non_state <- 0
dp$non_state [dp$type_of_violence == 2] <- 1
dp$oneside <- 0
dp$oneside [dp$type_of_violence == 3] <- 1
dp$totalconflict <- 0
dp$totalconflict [dp$type_of_violence %in% c(1,2,3)] <- 1

#tallying the deaths so when one type of conflict = 1, it takes the number of
deaths (1 x # of deaths = # of deaths)
dp$state_deaths <- dp$state * dp$best
dp$non_state_deaths <- dp$non_state * dp$best
dp$oneside_deaths <- dp$oneside * dp$best

#creating country,year
dp_cy <- d_mutate(dp,
                 non_state_deaths = sum(non_state_deaths),
```

```
                 state_deaths = sum(state_deaths),
                 oneside_deaths = sum(oneside_deaths),
                 cnt_statebased = sum(state),
                 cnt_non_state_based = sum(non_state),
                 cnt_onesidebased = sum(oneside),
                 cnt_totalconflict = sum(totalconflict),
                 cnt_death = sum(best),
                 .by=c(country, year),
                 .cross=TRUE,
                 .reduce=TRUE)

#removing unnessary columns
dp_cy$state=NULL
dp_cy$non_state=NULL
dp_cy$oneside=NULL
dp_cy$type_of_violence=NULL
dp_cy$totalconflict=NULL
#removing duplicates
dp_cy <-distinct(dp_cy, .keep_all = FALSE)

#changing NA to 0
dp_cy [is.na(dp_cy)] <- 0

#merging with df
df1 <- magic_merge(dp_cy, df)

df1 <- select(df1, gw_year, gw_name, cnt_death, cnt_statebased,
cnt_non_state_based, cnt_onesidebased, cnt_totalconflict, non_state_deaths,
             state_deaths, oneside_deaths,cnt_chem, cnt_inc, cnt_exp, chemical)

#changing NA to 0
df1[is.na(df1)] <- 0

################################################################################
##################
################################################################################
##################
#inport polity data
pol <-read_xls('p4v2017.xls')

#filtering pol
pol <- pol %>%
 select(`country`, `year`, `polity2`) %>%
 filter(`year` >=1995) %>%
 filter(`year` <=2017)

#merging pol with df
df2 <- magic_merge(pol, df1)

################################################################################
##################
################################################################################
##################
#reading in pop / gdppc
dev <-read_csv('WDIData.csv')

#creating vector for desired indicators
tgt_indicators <- c('GDP per capita (current US$)',
                   'Population, total',
                   'Population density (people per sq. km of land area)')
```

```
#adding a prefix to year so the years can be modified for long data vs wide
data
dev <- dev %>%
 rename_if(is.double, ~ paste0(“year_,” .)) %>%
 gather(year, indicatorvalue, starts_with(“year_”)) %>%
 mutate(year = str_remove(year, ‘year_’)) %>%
 mutate(year = as.integer(year))

#selecting the useful columns and filtering the required years and countries
dev1 <- dev %>%
 select(year, `Country Name`, `Indicator Name`, indicatorvalue) %>%
 filter(`year` >=1995) %>%
 filter(`year` <=2017) %>%
 filter(`Indicator Name` %in% tgt_indicators)

#adjusting the column names
dev1 <- rename(dev1, indicator = `Indicator Name`)
dev1 <- rename(dev1, `gw_name` = `Country Name`)

#spreading indicators
dev1 <- spread(dev1, indicator, indicatorvalue)

# Fix column names
names(dev1) <- fix_names(names(dev1))

#logging numbers to mitigate outliers
dev1$poplog <- log(dev1$population__total +1)
dev1$popdenlog <- log(dev1$population_density__people_per_sq__km_of_land_area_
+1)
dev1$gdppclog <- log(dev1$gdp_per_capita__current_us__ +1)


dev1_cy <- d_mutate(dev1,
                   popdenlog = sum(popdenlog),
                   poplog = sum(poplog),
                   gdppclog = sum(gdppclog),
                   .by=c(gw_name, year),
                   .cross=TRUE,
                   .reduce=TRUE)

df3 <- magic_merge(dev1_cy, df2)

################################################################################
####
#setting log for counts of conflict to mitigate outliers
df3$cnt_statebasedlog <- log(df3$cnt_statebased+1)
df3$cnt_non_state_basedlog <- log(df3$cnt_non_state_based+1)
df3$cnt_onesidebasedlog <- log(df3$cnt_onesidebased+1)
df3$cnt_totalconflictlog <- log(df3$cnt_totalconflict+1)
df3$cnt_deathlog <- log(df3$cnt_death+1)
df3$cnt_non_state_deathslog <- log(df3$non_state_deaths + 1)
df3$cnt_state_deathslog <- log(df3$state_deaths + 1)
df3$cnt_oneside_deathslog <- log(df3$oneside_deaths + 1)

## Lagging the dataset by 1 year, except for the chemical weapon events to show
whether a chemical weapon was a result of previous experiences
df3 <- d_mutate(df3,
               totalconflictlag  = lag(cnt_totalconflict, n=1),
               statebasedlag = lag(cnt_statebased, n=1),
               nonstatebasedlag = lag(cnt_non_state_based, n=1),
               onesidebasedlag = lag(cnt_onesidebased, n=1),
               totalconflictlaglog = lag(cnt_totalconflictlog, n=1),
```

```
               statebasedlaglog = lag(cnt_statebasedlog, n=1),
               nonstatebasedlaglog = lag(cnt_non_state_basedlog, n=1),
               onesidebasedlaglog = lag(cnt_onesidebasedlog, n=1),
               deathlaglog = lag(cnt_deathlog, n=1),
               nonstatedeathlaglog = lag(cnt_non_state_deathslog, n=1),
               statedeathlaglog = lag(cnt_state_deathslog, n=1),
               onesidedeathlaglog = lag(cnt_oneside_deathslog, n=1),
               state_deathslag = lag(state_deaths, n=1),
               peace_years   = spell(cnt_totalconflict, 0),
               .by = gw_name)

#selecting the columns of interest - just making it a little more streamlined
df3 <- df3 %>%
 select(gw_name, gw_year, poplog, popdenlog, gdppclog, polity2, chemical,
nonstatebasedlaglog,
        statebasedlaglog, onesidebasedlaglog,deathlaglog, nonstatedeathlaglog,
        statedeathlaglog, state_deathslag, onesidedeathlaglog, peace_years)

#getting rid of NAs that added up during the previous tidy
df3$chemical [is.na(df3$chemical)] <- 0
df3$nonstatebasedlaglog [is.na(df3$nonstatebasedlaglog)] <- 0
df3$statebasedlaglog [is.na(df3$statebasedlaglog)] <- 0
df3$onesidebasedlaglog [is.na(df3$onesidebasedlaglog)] <- 0
df3$deathlaglog [is.na(df3$deathlaglog)] <- 0
df3$nonstatedeathlaglog [is.na(df3$nonstatedeathlaglog)] <- 0
df3$statedeathlaglog [is.na(df3$statedeathlaglog)] <- 0
df3$onesidedeathlaglog [is.na(df3$onesidedeathlaglog)] <- 0
df3$state_deathslag [is.na(df3$state_deathslag)] <- 0

#creating buckets to divide up into 4-year periods
df3 <- df3 %>%
 mutate(bins = case_when(
   gw_year >= 1995 & gw_year <= 1998 ~ “1995 - 1998”,
   gw_year >= 1999 & gw_year <= 2002 ~ “1999 - 2002”,
   gw_year >= 2003 & gw_year <= 2006 ~ “2003 - 2006”,
   gw_year >= 2007 & gw_year <= 2010 ~ “2007 - 2010”,
   gw_year >= 2011 & gw_year <= 2014 ~ “2011 - 2014”,
   gw_year >= 2015 & gw_year <= 2017 ~ “2015 - 2017”
 ))

df95 <- df3 %>%
 filter(bins == “1995 - 1998”)

df99 <- df3 %>%
 filter(bins == “1999 - 2002”)

df03 <- df3 %>%
 filter(bins == “2003 - 2006”)

df07 <- df3 %>%
 filter(bins == “2007 - 2010”)

df11 <- df3 %>%
 filter(bins == “2011 - 2014”)

df15 <- df3 %>%
 filter(bins == “2015 - 2017”)

a <- glm(chemical ~ statedeathlaglog + I(statedeathlaglog^2) + gdppclog +
polity2 +
          I(polity2^2) + poplog + peace_years + I(peace_years^2) +
          I(peace_years^3), data = df95, family = binomial)
```

```
b <- glm(chemical ~ statedeathlaglog + I(statedeathlaglog^2) + gdppclog +
polity2 +
          I(polity2^2) + poplog + peace_years + I(peace_years^2) +
          I(peace_years^3), data = df99, family = binomial)

c <- glm(chemical ~ statedeathlaglog + I(statedeathlaglog^2) + gdppclog +
polity2 +
          I(polity2^2) + poplog + peace_years + I(peace_years^2) +
          I(peace_years^3), data = df03, family = binomial)

d <- glm(chemical ~ statedeathlaglog + I(statedeathlaglog^2) + gdppclog +
polity2 +
          I(polity2^2) + poplog + peace_years + I(peace_years^2) +
          I(peace_years^3), data = df07, family = binomial)

e <- glm(chemical ~ statedeathlaglog + I(statedeathlaglog^2) + gdppclog +
polity2 +
          I(polity2^2) + poplog + peace_years + I(peace_years^2) +
          I(peace_years^3), data = df11, family = binomial)

f <- glm(chemical ~ statedeathlaglog + I(statedeathlaglog^2) + gdppclog +
polity2 +
          I(polity2^2) + poplog + peace_years + I(peace_years^2) +
          I(peace_years^3), data = df15, family = binomial)

stargazer(a, b, c, d, e, f, type='text',
         order = c(7, 8, 9, 4, 5, 1, 2, 3, 6),
         out='4 year model regression stargazer.html')

#95-98
g <- magic_plot(a,
               xvar = 'statedeathlaglog',
               title = "95-98")
#99-02
g2 <- magic_plot(b,
               xvar = 'statedeathlaglog',
               title = "99-02")
#03-06
g3 <- magic_plot(c,
               xvar = 'statedeathlaglog',
               title = "03-06")
#07-10
g4 <- magic_plot(d,
               xvar = 'statedeathlaglog',
               title = "07-10")

#11-14
g5 <- magic_plot(e,
               xvar = 'statedeathlaglog',
               title = "11-14")
#15-17
g6 <- magic_plot(f,
               xvar = 'statedeathlaglog',
               title = "15-17")

view(g$predict)

#setting up a bar chart to show the change in probability of a CW attack over
time based on a death rate between
#50 - 5000 in a country-year
form <- function(df) {
```

```
 df <- df$predict %>%
   select(pred, statedeathlaglog) %>%
   filter(statedeathlaglog >= 3.9 & statedeathlaglog <= 8.52) %>%
   filter(pred == min(pred) | pred == max(pred)) %>%
   mutate(differ = max(pred) - min(pred)) %>%
   select(differ) %>%
   distinct(.keep_all = FALSE)
}

#running form function
g95 <- form(g) %>%
 mutate(differ95 = differ) %>%
 select(differ95)

g99 <- form(g2) %>%
 mutate(differ99 = differ) %>%
 select(differ99)

g03 <- form(g3) %>%
 mutate(differ03 = differ) %>%
 select(differ03)

g07 <- form(g4) %>%
 mutate(differ07 = differ) %>%
 select(differ07)

g11 <- form(g5) %>%
 mutate(differ11 = differ) %>%
 select(differ11)

g15 <- form(g6) %>%
 mutate(differ15 = differ) %>%
 select(differ15)

#combining all the g(year) into one df
allpred <- g95 %>%
 mutate(“95-98” = g95$differ95,
        “99-02” = g99$differ99,
        “03-06” = g03$differ03,
        “07-10” = g07$differ07,
        “11-14” = g11$differ11,
        “15-17” = g15$differ15,) %>%
 select(“95-98,” “99-02,” “03-06,” “07-10,” “11-14,” “15-17”) %>%
 as_tibble() %>%
 distinct(.keep_all = FALSE)

allpred <- allpred %>%
 gather()

#plotting
predplot <- magic_plot(allpred,
                      xvar =‘key’,
                      yvar = ‘value’,
                      plot.type = ‘bar’,
                      ylim = c(0,1),
                      ylab = ‘VNSA CW Attack Probability’,
                      xlab = “Time Period”,
                      xaxis.labels = c(“95-98,” “99-02,” “03-06,” “07-10,” “11-
14,” “15-17”),
                      xaxis.angle = 15,
                      colors = c(“dark green”),
                      background = ‘white’,
```

```
foreground = ‘black’,
finish= TRUE)
```

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APPENDIX B. MATLAB CODE

```
clear; close all; clc;
% A (1 x n) vector enumerating each adjacent node to AQ.
% adjacent node (1) is directly up from AQ in ORA’s visualized network.
for ii = 1:33
   AQ_adj_nodes(ii) = ii;
end
AQ_adj_nodes = AQ_adj_nodes’;                  % transpose the array

%probability of CW tactics diffusing to adjacent nodes:
pCWdif = 0.1;                                  % 10 percent
%probability of CW tactics diffusing to 2 nodes out:
pCWdif2 = 0.05;                                % 5 percent
N = 1000;                                      % number of monte-carlo simulations
adj_nodes_CW = zeros(length(AQ_adj_nodes),1);    % initializes array

for kk = 1:N                                   % for each simulation:
   randnum = rand(length(AQ_adj_nodes),1); % pseduorandom num generator
   for jj = 1:length(randnum)                 % threshold to pCWdif values
       if randnum(jj) <= pCWdif               % conditional
           adj_nodes_CW(jj) = 1;              % CW diffused successfully
       else
           adj_nodes_CW(jj) = 0;              % CW did not diffuse
       end
   end
   numCWdiff(kk) = sum(adj_nodes_CW);         % Total CW diffusions this time
end
x = (1:N);                                     % variable used to plot
figure(1)
plot(x,numCWdiff,’.’)                          % plots as points
figure(2)
histogram(numCWdiff,’BinMethod’,’integers’);% histogram of CW diffusions
xlim([-1 11]); grid on;                        % format plot
xlabel(‘Number of Times CW Tactics Migrated’);   % horizontal axis label
ylabel(‘Occurrences’);                         % vertical axis label
title(‘CW Tactics Migration to AQ’’s Adjacent Nodes’);

% statistical analysis:
cint = .95;                                    % confidence interval (95%)
z = norminv(cint+(1-cint)/2);                  % z(conf int)
ave = mean(numCWdiff)                          % mean value
sdev = std(numCWdiff)                          % standard deviation
int = z*sdev/sqrt(N);                          % find CI range

% prints string with statistical data on plot:
text(6,N*.8/5,sprintf(‘95%% CI  = %.4f +/- %.4f’,ave,int));%text, CI
text(6,N*.7/5,sprintf(‘nreps = %d’,N))




%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%
%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%
%% Chris Price & Aaron Green                                              %
% This file simulates the spread of chemical weapons TTP throughout a     %
% one-mode, inter-organizational network of Violent Non-State Actors      %
% either operating in Myanmar or tied to a group operating in Myanmar.    %
%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%
```

```
clear; clc; clf;                                         % clears previous variables
%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%

%% USER INPUTS:
% User inputs rate of diffusion of chemical weapon TTP:
dif = 0.049;                                          % 4.9 percent
% User inputs number of timesteps to run:
num_steps = 10;                                       % 10 years (plus starting from
                                                     % year zero)
N = 1000;                                             % number of simulations
MAVchemSims = zeros(N,num_steps+2);                   % Initialize variable
AveChem = zeros(1,num_steps+2);                       % Initialize average num CW nodes
vector
%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%
% Read Data:
   MAVtable0 = readtable('MAV_dichotomized.xlsx','TreatAsEmpty',{''});  % input
MAV network
   MAVtable0{:,2:end}(isnan(MAVtable0{:,2:end})) = 0;% converts NaN to zero
   MAV0 = table2array(MAVtable0(:,2:end));           % converts table to array
   MAVchem_table0 = readtable('MYR_chem.xlsx');      % input chem attribute in
table
   MAVchem0 = table2array(MAVchem_table0(:,2:end)); % converts table to array
   t = 0:num_steps;                                  % timesteps vector


%%
for jj=1:N                                            % for N simulations...




% Simulation Stars...
   % Make a 3-d matrix of MAV over time (3rd dim is time):
   MAV = zeros(99,99,num_steps+1);          % 99 x 99 x 11 matrix
   for m=1:num_steps+1
       MAV(:,:,m) = MAV0;                   % initialize MAV at each timestep
   end                                      % as MAV0 (this assumes chem
attribute
                                            % doesn't go away once obtained).

   % initalize matrix that indexes chem-capable VNSA at each timestep:
   for m=1:num_steps+1
       MAVchem(:,:,m) = MAVchem0;
   end

   %%
   for m = 1:num_steps+1                   % for each time step...

       % If a VNSA is chem-capable, then 5% of its 1st degree affiliates will
       % become chem-capable.

       ichem = find(MAVchem(:,:,m)== 1); % indexes chem-capable VNSA

       if m>1
           clear chem_add;                  % reset for each column
           chem_add(:,1,m-1) = zeros(length(sum(MAV(:,(ichem),m))),1);
       end

       % determine how many VNSA need to become chem-capable for each
       % timestep:
       chem_add(:,1,m) = (round(sum(MAV(:,(ichem),m)).*dif))';
```

```
        for a = 1:length(chem_add(:,1,m))       % for each VNSA that has chem...
            if chem_add(a,1,m)>0                % if chem_add for this VNSA is
positive...
                b = chem_add(a,1,m);

                % define the a-th column of the m-th MAV network:
                V = MAV(:,ichem(a,1),m);

                v = sum(V);             % number of VNSA #a's ties
                vec = find(V==1);       % row numbers of a-th column of m-th MAV
matrix
                                        % indicating each tie of VNSA #a

                %column vector listing b random VNSA
                r = randperm(numel(vec),b)';
                for k = 1:length(r)     % for the k-th element of vector r...
                    kk = r(k);          % get the value of k-th element of r.
                    MAVchem(kk,1,m)=1;
                end
            end
        end
       n(1,m+1) = sum(MAVchem(:,1,m));
       x = (0:num_steps+1);

       if m<=num_steps+1
           MAVchem(:,:,m+1)=MAVchem(:,1,m);
       end

   end
   n(1,1) = sum(MAVchem0);
   plot(x,n); hold on;

% Put the Chemical Attribute into a matrix that captures multiple simulations:
MAVchemSims(jj,:) = n(1,:);

% Clears certain variables to re-run next simulation:
clearvars -EXCEPT N x dif num_steps jj MAVchemSims AveChem MAV MAV0 MAVchem
MAVchem0;

end
%% Write Excel Files to Export to SNA Software
MAVspread = MAV(:,:,4);
xlswrite('MAV3spread.xlsx',MAVspread)
MAVchem3spread = MAVchem(:,:,4);
xlswrite('MAVchem3spread.xlsx',MAVchem3spread)

MAV6spread = MAV(:,:,7);
xlswrite('MAV6spread.xlsx',MAV6spread)
MAVchem6spread = MAVchem(:,:,7);
xlswrite('MAVchem6spread.xlsx',MAVchem6spread)

MAV10spread = MAV(:,:,11);
xlswrite('MAV10spread.xlsx',MAV10spread)
MAVchem10spread = MAVchem(:,:,11);
xlswrite('MAVchem10spread.xlsx',MAVchem10spread)


%% Creates Cumulative Plots
AveChem(1,:) = mean(MAVchemSims);
plot(x,AveChem,'*-k','LineWidth',3)
% Format Plot:
grid on;
```

```
title({'MAV Network: CW TTP Migration, Diffusion Rate = 4.9%';'No
Disruption';'Number of simulations = 1000'})
xlabel('Time (years)');
ylabel('Number of Organizations with Chemical Weapons');

% Calculate mean values at years 3, 6, and 10:
values = round([mean(MAVchemSims(:,3)) mean(MAVchemSims(:,6))
mean(MAVchemSims(:,10))],1);

%Print mean values on plot as string:
txt3 = text(2.6,16,num2str(values(1)))      % Mean value at 3 years
txt6 = text(5.6,19,num2str(values(2)))      % Mean value at 6 years
txt10 = text(9.6,24,num2str(values(3)))     % Mean value at 10 yrs
xlim([0 11])                                % Defines x-axis limits

%% Plot Natural Log Trendline from AQ Alliance Network
hold on;
AQx = (0:11);
AQyln = 6.6171.*log(AQx+1) + 13;
plot(AQx,AQyln,'*-r','LineWidth',2.8);



%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%
%% Chris Price & Aaron Green                                              %
% This file simulates the spread of chemical weapons TTP throughout a     %
% one-mode, inter-organizational network of Violent Non-State Actors      %
% either operating in Myanmar or tied to a group operating in Myanmar.    %
% The network is disrupted by removing the 2 most central nodes' CW       %
% attribute.                                                              %
%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%
clear; clc; clf;                               % clears previous variables
%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%

%% USER INPUTS:
% User inputs rate of diffusion of chemical weapon TTP:
dif = 0.049;                                % 4.9 percent

% User inputs number of VNSA (nodes) CP assets will "Coerce" to remove the
% CW attribute:
coerce = 2;                                 % 2 nodes

% User inputs number of timesteps to run:
num_steps = 10;                             % 10 years (plus starting from
                                           % year zero)

N = 1000;                                   % number of simulations
MAVchemSims = zeros(N,num_steps+2);         % Initialize variable
AveChem = zeros(1,num_steps+2);             % Initialize average num CW nodes
vector
%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%
%% Read Data:
   MAVtable0 = readtable('MAV_dichotomized.xlsx','TreatAsEmpty',{''});  % input
MAV network
   MAVtable0{:,2:end}(isnan(MAVtable0{:,2:end})) = 0;% converts NaN to zero
   MAV0 = table2array(MAVtable0(:,2:end));          % converts table to array
   MAVchem_table0 = readtable('MYR_chem.xlsx');     % input chem attribute in
table
   MAVchem0 = table2array(MAVchem_table0(:,2:end)); % converts table to array

%% Determine the 2 nodes with highest degree centrality:
```

```
   num_ties = sum(MAV0)-1;                          % sums num of ties for each
node
   coerced = maxk(num_ties,coerce);                 % finds k (coerce) largest
elements of array
   ixcoerced = zeros(coerce,1);
   for c = 1:length(coerced)
       ixcoerced(c) = find(num_ties == coerced(c));% indexes node(s) with
highest
                                                    % degree centrality
   end

   fprintf('The %.0f nodes with highest degree centrality: \n',coerce)
   MAVtable0(ixcoerced,1)

% Modify the one-mode network's attribute vector to simulate Coerceive
Disruption:
   MAVchem0(ixcoerced) = 0;

%%
for jj=1:N                                   % for N simulations...
   t = 0:num_steps;                                 % timesteps vector

% Simulation Starts...
   % Make a 3-d matrix of MAV over time (3rd dim is time):
   MAV = zeros(99,99,num_steps+1);         % 99 x 99 x 11 matrix
   for m=1:num_steps+1
       MAV(:,:,m) = MAV0;                  % initialize MAV at each timestep
   end                                     % as MAV0 (this assumes chem
attribute
                                           % doesn't go away once obtained).

   % initalize matrix that indexes chem-capable VNSA at each timestep:
   for m=1:num_steps+1
       MAVchem(:,:,m) = MAVchem0;
   end

   %%
   for m = 1:num_steps+1                  % for each time step...

       % If a VNSA is chem-capable, then dif % of its 1st degree affiliates
will
       % become chem-capable.
       ichem = find(MAVchem(:,:,m)== 1); % indexes chem-capable VNSA
       if m>1
           clear chem_add;                 % reset for each column
           chem_add(:,1,m-1) = zeros(length(sum(MAV(:,(ichem),m))),1);
       end
       % determine how many VNSA need to become chem-capable for each
       % timestep:
       chem_add(:,1,m) = (round(sum(MAV(:,(ichem),m)).*dif))';

       for a = 1:length(chem_add(:,1,m))       % for each VNSA that has chem...
           if chem_add(a,1,m)>0                % if chem_add for this VNSA is
positive...
               b = chem_add(a,1,m);

               % define the a-th column of the m-th MAV network:
               V = MAV(:,ichem(a,1),m);
               v = sum(V);             % number of VNSA #a's ties
               vec = find(V==1);       % row numbers of a-th column of m-th MAV
matrix
                                       % indicating each tie of VNSA #a
```

```
                %column vector listing b random VNSA
                r = randperm(numel(vec),b)';
                for k = 1:length(r)     % for the k-th element of vector r...
                    kk = r(k);          % get the value of k-th element of r.
                    MAVchem(kk,1,m)=1;  % the VNSA becomes CW-capable
                    MAVchem(ixcoerced,m) = 0;    % (unless it was Coercively
                                                % Disrupted by CP forces)
                end
            end
        end
      n(1,m+1) = sum(MAVchem(:,1,m));
      x = (0:num_steps+1);
      if m<=num_steps+1
          MAVchem(:,:,m+1)=MAVchem(:,1,m);
      end
   end
   n(1,1) = sum(MAVchem0);
   plot(x,n); hold on;

% Put the Chemical Attribute into a matrix that captures multiple simulations:
MAVchemSims(jj,:) = n(1,:);

% Clears certain variables to re-run next simulation:
clearvars -EXCEPT N x dif num_steps jj MAVchemSims AveChem MAV MAV0 MAVchem
MAVchem0 coerce ixcoerced;

end
%% Write Excel Files to Export to SNA Software
MAVspreadco = MAV(:,:,4);
xlswrite('MAV3spreadco.xlsx',MAVspreadco)
MAVchem3spreadco = MAVchem(:,:,4);
xlswrite('MAVchem3spreadco.xlsx',MAVchem3spreadco)

MAV6spreadco = MAV(:,:,7);
xlswrite('MAV6spreadco.xlsx',MAV6spreadco)
MAVchem6spreadco = MAVchem(:,:,7);
xlswrite('MAVchem6spreadco.xlsx',MAVchem6spreadco)

MAV10spreadco = MAV(:,:,11);
xlswrite('MAV10spreadco.xlsx',MAV10spreadco)
MAVchem10spreadco = MAVchem(:,:,11);
xlswrite('MAVchem10spreadco.xlsx',MAVchem10spreadco)

%% Creates Cumulative Plots
AveChem(1,:) = mean(MAVchemSims);
plot(x,AveChem,'*-k','LineWidth',3)
% Format Plot:
grid on;
title({'MAV Network: CW TTP Migration, Diffusion Rate = 4.9%';'Coercive
Disruption: CW removed from 2 nodes with highest degree centrality';'Number of
simulations = 1000'})
xlabel('Time (years)');
ylabel('Number of CW-Capable VNSAs');

% Calculate mean values at years 3, 6, and 10:
values = round([mean(MAVchemSims(:,3)) mean(MAVchemSims(:,6))
mean(MAVchemSims(:,10))],1);

% Print mean values on plot as string:
txt3 = text(2.6,16,num2str(values(1)));      % Mean value at 3 years
txt6 = text(5.6,19,num2str(values(2)));      % Mean value at 6 years
```

```
txt10 = text(9.6,24,num2str(values(3)));     % Mean value at 10 yrs
xlim([0 11])                                 % Defines x-axis limits


%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%
%% Chris Price & Aaron Green                                                 %
% This file simulates the spread of chemical weapons TTP throughout a        %
% one-mode, inter-organizational network of Violent Non-State Actors         %
% either operating in Myanmar or tied to a group operating in Myanmar.       %
% The network is disrupted by removing ties from the 2 nodes with the        %
% highest brokerage scores.                                                  %
%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%
clear; clc; clf;                               % clears previous variables
%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%

%% USER INPUTS:
% User inputs rate of diffusion of chemical weapon TTP:
dif = 0.5;                                   % 4.9 percent
% User inputs # of IO disruptions (cut 50% of ties for this many nodes):
numIO = 2;
ties2cut = 0.5;         % 50% of ties between targeted node and its adjacent
nodes
% User inputs number of timesteps to run:
num_steps = 10;                               % 10 years (plus starting from
                                             % year zero)
N = 1000;                                     % number of simulations
MAVchemSims = zeros(N,num_steps+2);           % Initialize variable
AveChem = zeros(1,num_steps+2);               % Initialize average num CW nodes
vector
%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%
%% Import Data
   % Import MAV network after cutting appropriate amount of ties from
   % nodes with the highest brokerage scores (as determined by SNA
   % software):
   MAVtable0 = readtable('MAV_dichotomized_cutties.xlsx','TreatAsEmpty',{''});
   MAVtable0{:,2:end}(isnan(MAVtable0{:,2:end})) = 0;% converts NaN to zero
   MAV0 = table2array(MAVtable0(:,2:end));          % converts table to array
   MAVchem_table0 = readtable('MYR_chem.xlsx');     % input chem attribute in
table
   MAVchem0 = table2array(MAVchem_table0(:,2:end)); % converts table to array


%%
for jj=1:N                                    % for N simulations...



   t = 0:num_steps;                          % timesteps vector

% Simulation Stars...
   % Make a 3-d matrix of MAV over time (3rd dim is time):
   MAV = zeros(99,99,num_steps+1);           % 99 x 99 x 11 matrix
   for m=1:num_steps+1
       MAV(:,:,m) = MAV0;                    % initialize MAV at each timestep
   end                                       % as MAV0 (this assumes chem
attribute
                                             % doesn't go away once obtained).

   % initalize matrix that indexes chem-capable VNSA at each timestep:
   for m=1:num_steps+1
       MAVchem(:,:,m) = MAVchem0;
   end
```

```
%%
for m = 1:num_steps+1                  % for each time step...

    % If a VNSA is chem-capable, then 4.9% of its 1st degree affiliates will
    % become chem-capable.

    ichem = find(MAVchem(:,:,m)== 1); % indexes chem-capable VNSA

    if m>1
        clear chem_add;                  % reset for each column
        chem_add(:,1,m-1) = zeros(length(sum(MAV(:,(ichem),m))),1);
    end

    % determine how many VNSA need to become chem-capable for each
    % timestep:
    chem_add(:,1,m) = (round(sum(MAV(:,(ichem),m)).*dif.*1/3))';


    for a = 1:length(chem_add(:,1,m))   % for each VNSA that has chem...
        if chem_add(a,1,m)>0    % if chem_add for this VNSA is positive...
            b = chem_add(a,1,m);

            % define the a-th column of the m-th MAV network:
            V = MAV(:,ichem(a,1),m);

            v = sum(V);              % number of VNSA #a's ties
            vec = find(V==1);% row nums of a-th column of m-th MAV matrix
                                     % indicating each tie of VNSA #a

            %column vector listing b random VNSA
            r = randperm(numel(vec),b)';
            for k = 1:length(r)      % for the k-th element of vector r...
                kk = r(k);           % get the value of k-th element of r.
                MAVchem(kk,1,m)=1;
            end
        end
    end
   n(1,m+1) = sum(MAVchem(:,1,m));
   x = (0:num_steps+1);

   if m<=num_steps+1
       MAVchem(:,:,m+1)=MAVchem(:,1,m);
   end

end
n(1,1) = sum(MAVchem0);
plot(x,n); hold on;

% Put the Chemical Attribute into a matrix that captures multiple simulations:
MAVchemSims(jj,:) = n(1,:);

% Clears certain variables to re-run next simulation:
clearvars -EXCEPT N x dif num_steps jj MAVchemSims AveChem MAV MAV0 MAVchem
MAVchem0;

end
%% Write Excel Files to Export to SNA Software
MAVspreadio = MAV(:,:,4);
xlswrite('MAV3spreadio.xlsx',MAVspreadio)
MAVchem3spreadio = MAVchem(:,:,4);
xlswrite('MAVchem3spreadio.xlsx',MAVchem3spreadio)
```

```
MAV6spreadio = MAV(:,:,7);
xlswrite('MAV6spreadio.xlsx',MAV6spreadio)
MAVchem6spreadio = MAVchem(:,:,7);
xlswrite('MAVchem6spreadio.xlsx',MAVchem6spreadio)

MAV10spreadio = MAV(:,:,11);
xlswrite('MAV10spreadio.xlsx',MAV10spreadio)
MAVchem10spreadio = MAVchem(:,:,11);
xlswrite('MAVchem10spreadio.xlsx',MAVchem10spreadio)

%% Creates Cumulative Plots
AveChem(1,:) = mean(MAVchemSims);
plot(x,AveChem,'*-k','LineWidth',3)
% Format Plot:
grid on;
title({'MAV Network: CW TTP Migration, Diffusion Rate = 4.9%';'IO
Disruption';'Number of simulations = 1000'})
xlabel('Time (years)');
ylabel('Number of CW-Capable VNSA');

% Calculate mean values at years 3, 6, and 10:
values = round([mean(MAVchemSims(:,3)) mean(MAVchemSims(:,6))
mean(MAVchemSims(:,10))],1);

% Print mean values on plot as string:
txt3 = text(2.6,16,num2str(values(1)))      % Mean value at 3 years
txt6 = text(5.6,19,num2str(values(2)))      % Mean value at 6 years
txt10 = text(9.6,24,num2str(values(3)))     % Mean value at 10 yrs
xlim([0 11])                                % Defines x-axis limits
```

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APPENDIX C. MAV NETWORK ORGANIZATIONS

Organization Name	Primary Countries of Operation
313 Brigade Pakistan (313)	Pakistan
969 Movement- Wirathu (969)	Myanmar
Abu Sayyaf Group (ASG)	Philippines
Achik National Volunteer Council (ANVC), aka National Democratic Front of Bodoland (NDFB)	Myanmar, India, Bangladesh, Bhutan
Ahle-hadith Andolan Bangladesh (AHAB)	Bangladesh
al Madina (AM)	Pakistan, Kashmir, India
al-Fatah (AF)	Palestine
All Burma Muslim Union (ABMU)	Myanmar
All Burma Students' Democratic Front (ABSDF)	Myanmar, Thailand
All Tripura Tiger Force (ATTF)	Bangladesh
al-Qaeda (AQ)	Global
al-Qaeda in the Indian Subcontinent (AQIS)	Myanmar, India, Bangladesh, Kashmir, Pakistan
Aqa Mul Mujahidin (AMM)	Myanmar
Arakan Rohingya Islamic Front (ARIF), aka Arakan Rohingya National Organization (ARNO)	Myanmar, Bangladesh
Arakan Rohingya Salvation Army (ARSA)/Faith Movement of Arakan (FMA)/Harrakah al Yaqeen	Myanmar
Black Headbands (BH)	Myanmar
Bodu Bala Sena (BBS) aka Buddhist Power Force	Sri Lanka
Burma Communist Party (BCP)	Myanmar
Chin National Army (CNA), aka Cin National Force (CNF)	Myanmar
Communist Party of Nepal Maoist (CPN-M)	Nepal
Darul Islam (DI)	Indonesia
DBKA- 333 BDE	Myanmar
DBKA- 555 BDE	Myanmar
DBKA- 777 BDE	Myanmar
DBKA- 999 BDE	Myanmar
Democratic Alliance of Burma (DAB)	Myanmar
Democratic Karen Buddhist Army (DKBA)	Myanmar, Thailand
Democratic People's Republic of Korea, North Korea (DPRK)	North Korea
English Defense League (EDL)	England
God's Army	Myanmar, Thailand
Harakat al-Yaqin (HAY)	Myanmar, Bangladesh
Harakat ul-Ansar (HuA)	Myanmar, India, Pakistan, Kashmir, Bosnia, Tajikistan
Harakut ul-Jihad-i-Islami (HuJI)/Burma	Myanmar, India, Pakistan, Kashmir, Afghanistan

Organization Name	Primary Countries of Operation
Harakut ul-Jihad-i-Islami Arakan (HuJI-A)	Myanmar, Pakistan
Harakut ul-Jihad-i-Islami Bangladesh (HuJI-B)	Bangladesh
Hizbul Mujahideen (HM)	India, Pakistan
Hynniewtrep National Liberation Council (HNLC)	India, Bangladesh
Indo-Burma Revolutionary Front (IBRF)	Myanmar, India
Islamic Movement of Uzbekistan (IMU)	Uzbekistan
Islamic Salvation Front (FIS) and Army (AIS)	Algeria, Sudan, Iran, Germany, France, Libya, Pakistan, Afghanistan, Egypt
Islamic State Philippines (ISEA)	Philippines
Jaish-e-Mohammad (JeM)	Pakistan
Jama'at ul Mujahideen Bangladesh (JMB)	Bangladesh
Jemaah Islamiyah (JI)	Philippines
Kachin Independence Army (KIA)	Myanmar
Kanglei Yawol Kanna Lap (KYKL)	India
Kangleipak Communist Party (KCP)	India
Karen/Kayin National Liberation Army (KNLA), aka Karen National Defense Organization (KNDO)	Myanmar, Thailand
Karen/Kayin National Union (KNU)	Myanmar, Thailand
Karenni National Progressive Party (KNPP)	Myanmar, Thailand
Kebangkitan Mujahid Rohingya (KMR)	Myanmar, Bangladesh
Khmer Serei Guerrillas (KhSG)	Cambodia
Khun Sa Guerrillas (KSG)	Myanmar
Kongra-Gel Kurdistan People's Congress (KGK)	Turkey, Iraq
Kuki Liberation Organization (KLO)	Myanmar, India
Kuki National Army (KNA), Organization (KNO)	Myanmar, India
Kuki National Council (KNC)	Myanmar, India
Lashkar-e-Taiba (LeT)	Myanmar, India, Pakistan, Afghanistan, Russia, Syria, Australia, Bangladesh, Bosnia, France, Philippines
Liberation Tigers of Tamil Eelam (LTTE)	India, Germany, Canada, Afghanistan, Australia, Bangladesh, France, Indonesia, Malaysia, Myanmar (Burma), Netherlands, New Zealand, North Korea, Norway, Pakistan, Philippines, Singapore, Sri Lanka, Sweden, Switzerland, Thailand, Turkey, United Kingdom, United States.
Manipur People's Liberation Front (MPLF)	India, Myanmar
Mong Thai Army (MTA), aka Shan Land Army	Myanmar
Moro Islamic Liberation Front (MILF)	Philippines
Muslim Liberation Organization of Burma (MLOB), aka Arakan Liberation Organization	Myanmar
Myanmar Armed Forces (MAF)- Tatmadaw	Myanmar
Myanmar's Military Junta (Junta)	Myanmar

Organization Name	Primary Countries of Operation
National Coalition Government of the Union of Burma (NCGUB)	United States
National Council of the Union of Burma (NCUB)	United States
National Democratic Front- Burma (NDF)	Myanmar
National League for Democracy (NLD)	Myanmar
National Liberation Front of Arunachai Pradesh (NLFA)	China/Tibet, Myanmar, India
National Liberation Front of Tripura (NLFT)	Myanmar, India, Bangladesh, Bhutan, Pakistan
National Socialist Council of Nagaland-Isak-Muivah (NSCN-IM)	India, Myanmar
National Socialist Council of Nagaland-Khapang (NSCN-K)	Myanmar, India
People's Army- Myanmar (PAM)	Myanmar
People's Liberation Army- India/Manipur (PLAI)	Myanmar, India, Bangladesh
People's Liberation Army- Sri Lanka (JVP)	Sri Lanka
People's Republic of China (PRC)	China
People's Revolutionary Party of Kangleipak (PREPAK)	Myanmar, India, Bangladesh
Rabitat ul Mujahidin (RuM), aka Legion of Mujahidin	Myanmar, Pakistan, Thailand
Revolutionary People's Front- Bangladesh (RPFB)	Bangladesh, India
Rohingya Liberation Army (RLA)	Myanmar
Rohingya Mujahideen (RM)	Myanmar, India, Sri Lanka
Rohingya Solidarity Organization (RSO)	Myanmar, Bangladesh
Russia	Russia
Shan State Army (SSA)	Myanmar
Shan State Progressive Party (SSPP)	Myanmar
Shan United Revolutionary Army (SURA)	Myanmar
State Law & Order Restoration Council (SLORC), aka State Peace & Development Council	Myanmar
Tehreek-e-Taliban Islami Pakistan (TTP)	Pakistan
Tripura People's Democratic Front (TPDF)	India
United Achik National Front (UNAF)	India, Bangladesh
United Liberation Front of Assam (ULFA)	Myanmar, China, Bhutan
United National Liberation Front (UNLF)	Myanmar, India, Bangladesh
United Wa State Army (UWSA)	Myanmar
United Wa State Party (UWSP)	Myanmar
Vegetarian Soldiers (VS)	Myanmar, Thailand
Vigorous Burmese Student Warriors	Myanmar, Thailand
White Headbands (WH)	Myanmar, Thailand
Zomi Revolutionary Army (ZRA)	Myanmar, India
Zomi Revolutionary Organization (ZRO)	Myanmar, India

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