WHEN OPPORTUNITY DOESN'T KNOCK: EXAMINING MILITARY NON-INVESTMENT IN EMERGING TECHNOLOGIES

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LIST OF ABBREVIATIONS

ADS	Active Denial System
AEC	Atomic Energy Commission
AFOSR	Air Force Office of Scientific Research
ANP	Aircraft Nuclear Propulsion
APA	American Psychiatric Association
ARCAD	Advanced Riot Control Agent Device
ARO	Army Research Office
ASD	Acute Stress Disorder
BMA	British Medical Association
BOLD	Blood-Oxygen Level Dependent
BRAIN	Brain Research through Advanced Innovative Neurotechnologies
BWC	Biological and Toxin Weapons Convention
BZ	3-Quinuclidinyl Benzilate
CAPS	Clinician-Administered PTSD Scale
CDD	Capability Development Document
CFR	Council on Foreign Relations
CN	Chloroacetophenone
CNS	Central Nervous System
CS	2-Chlorobenzalmalononitrile
CSR	Combat Stress Reactions
CWC	Chemical Weapons Convention
CWS	Chemical Warfare Service (US)

DARPA	Defense Advanced Research Projects Agency
DCR	DOTmLPF-P Change Recommendations
DoD	Department of Defense
DoDI	Department of Defense Instruction
DOE	Department of Energy
DOJ	Department of Justice
DOTmLPF-P	Doctrine, Organization, Training, Material, Leadership and Education, Personnel, Facilities, and Policy
DSM	Diagnostic and Statistical Manual of Mental Disorders
DTRA	Defense Threat Reduction Agency
ECBC	Edgewood Chemical and Biological Center
EEG	Electroencephalography
ERDEC	Edgewood Research, Development, and Engineering Center
FAS	Federation of American Scientists
FDA	Food and Drug Administration
FM	Field Manual
FSB	Federal Security Service (Russia)
fMRI	Functional Magnetic Resonance Imaging
HEAP	Human Effects Advisory Panel
HERB	Human Effects Review Board
HHS	Department of Health and Human Services
HPA	Hypothalamic-Pituitary-Adrenal
ICA	Incapacitating Chemical Agent
ICBM	Intercontinental Ballistic Missile
ICD	Initial Capability Document

IDAR	Introduce, Digest, Assimilate, and Re-innovate
IED	Improvised Explosive Device
IOM	Institute of Medicine
IR&D	Independent Research and Development
IUPAC	International Union of Pure and Applied Chemistry
JCIDS	Joint Capabilities Integration and Development System
JNLWD	Joint Non-Lethal Weapons Directorate
KPP	Key Performance Parameter
KSA	Key System Attribute
LEAA	Law Enforcement Assistance Administration
LLNL	Lawrence Livermore National Laboratory
LSD	Lysergic Acid Diethylamide
LTL	Less-Than-Lethal (Weapons)
MAST	Micro Autonomous Systems and Technology
MEG	Magnetoencephalography
MOU	Memorandum of Understanding
MURI	Multi-Disciplinary University Research Initiative
NAM	Non-Aligned Movement
NASA	National Aeronautics and Space Administration
NIH	National Institutes of Health
NIJ	National Institute of Justice
NILECJ	National Institute of Law Enforcement and Criminal Justice
NIMH	National Institute of Mental Health
NLW	Non-Lethal Weapon
NRC	National Research Council

NSDD	National Security Decision Directive
NSF	National Science Foundation
NSSM	National Security Study Memorandum
OEF	Operation Enduring Freedom
OIF	Operation Iraqi Freedom
ONR	Office of Naval Research
OOTW	Operations Other Than War
OPCW	Organization for the Prohibition of Chemical Weapons
OSD	Office of the Secretary of Defense
PCL	PTSD Checklist
PET	Positron Emission Tomography
PIE	Proximity, Immediacy, and Expectancy
PTSD	Post-Traumatic Stress Disorder
R&D	Research and Development
RCA	Riot Control Agent
RDA	Research, Development, and Acquisition
RDT&E	Research, Development, Testing, and Evaluation
RFP	Request for Proposals
RSI	Risk of Significant Injury
S&T	Science and Technology
SAB	Scientific Advisory Board (CWC-OPCW)
SBIR	Small Business Innovation Research
SCOT	Social Construction of Technology
SIPRI	Stockholm International Peace Research Institute
SNRI	Serotonin and Norepinephrine Reuptake Inhibitor

SSRI	Selective Serotonin Reuptake Inhibitor
TBI	Traumatic Brain Injury
TI	Therapeutic Index
TM	Technical Manual
WHO	World Health Organization
UNOSOM	United Nations Operation in Somalia
USAMRDC	United States Army Medical Research and Development Command
USMRMC	United States Army Medical Research and Materiel Command
VA	(Department of) Veterans Affairs
WRAIR	Walter Reed Army Institute for Research

SUMMARY

Why do militaries invest in some emerging technologies but not others? Conventional wisdom suggests that capable states have reasons to hedge their bets and invest in emerging military technologies as widely as they can. Yet, even the most capable states do not invest in all technologies of military utility. Moreover, in some cases, early investments in research and development (R&D) are not sufficiently sustained to lead to any realized capability. This dissertation answers the question of why some emerging technologies are able to attract and sustain military investment while others cannot. I argue that decisions over such investments are influenced by relevant actors' assessment of feasibility during the R&D process, the military requirement the technology fulfills, and the availability of alternatives. In particular, a dominant belief in low feasibility, highly stringent requirements, and available alternatives can create an unfavorable condition that makes an emerging technology unappealing as an investment opportunity. Such a condition can prevent a technology from attracting or sustaining investment even if it were to have legitimate military use. Three case studies are conducted to illustrate this argument: biochemical non-lethal weapons, neuropharmacological treatment for combat stress, and aircraft nuclear propulsion. This dissertation yields important policy implications for understanding state investment behavior and managing defense R&D in emerging military technologies.

CHAPTER 1. INTRODUCTION

Acquisition of novel military capabilities has become integral to American military readiness. For instance, robotics, particularly autonomous ones, has attracted significant military interest in recent years. In February 2016, researchers from the University of California, Berkeley, reported that they had designed a robot capable of crawling through tight, confined crevices, much like the organism that inspired its design—a cockroach.[1] This "robot cockroach," which the research team has named CRAM (Compressible Robot with Articulated Mechanisms), was developed with the Collaborative Technology Alliance grant funding from the Micro Autonomous Systems and Technology (MAST) program from the United States Army Research Laboratory. The researchers claim that the "robot cockroach," for its ability to withstand forces significantly greater than its body weight and to traverse vertically confined spaces, can be useful in emergency response and rescue operations to disasters where victims may be trapped under tens of feet of rubble that are hard for first responders and rescuers (or even large robots) to access. Of course, the military's interest in such small-scaled robots is different. According to MAST's program website, the objective of this research and development (R&D) effort is to "enhance warfighter's tactical situational awareness in urban and complex terrain by enabling the autonomous operation of a collaborative ensemble of multifunctional, mobile microsystems," or in other words, information and intelligence gathering.[2]

The "robot cockroach" is but one example of the US military's recent interest in combining insights from biological systems with electro-mechanical ones. For instance, the Defense Advanced Research Projects Agency (DARPA), the "high-risk-high-payoff"

[1] Kaushik Jayaram and Robert J. Full, "Cockroaches Traverse Crevices, Crawl Rapidly in Confined Spaces, and Inspire a Soft, Legged Robot," *Proceedings of the National Academy of Sciences of the United States of America* 113(8) (February 2016): E950-957.

[2] United States Army Research Laboratory, "Micro Autonomous Systems and Technology (MAST) – Objective," http://www.arl.army.mil/www/default.cfm?page=332 (accessed February 11, 2016).

research agency of the US Department of Defense (DoD), has funded multiple projects on biomimetic robotics within the last decade. These robots range from the Legged Squad Support System (LS3) developed by Boston Dynamics, which resembles and is roughly the size of a horse and can be used for transporting equipment for dismounted soldiers in rough terrain, to the hummingbird-lookalike Nano Air Vehicle (NAV) that can be used for surveillance and reconnaissance. Whether these robots truly serve any significant military purpose is of course up to debate. Nevertheless, as futuristic and science fiction-like as these robots sound, they are not the first time the US has taken advantage of its science and technology base to exploit cutting-edge technologies for military purposes. The US military has a long tradition of turning scientific and technical ideas into potentially useful military capabilities. As unimaginable and unrealistic as some of these ideas may sound during their time, many have been and continue to be turned into reality. Since World War II, science and technology (S&T) have become a prominent component of the American military might, and R&D have enjoyed a privileged status in defense planning.

This "privileged" status of defense R&D is perhaps most noticeable in the amounts of money the federal government allots toward R&D. Since WWII and especially the end of the Cold War, significant amounts of federal money for R&D have been channeled through the military. Even technologies, such as the laser, that were developed without a clear defense utility were able to receive substantial military investment. Charles Townes himself has echoed the sentiment that the laser was "a solution looking for a problem"[3] and has recounted of his work preceding the invention on the millimeter waves, that, "At that time, the Navy had no clear goal for millimeter waves," and that its support for the research was to simply to ensure that "no fruitful avenues for practical technologies were missed."[4]

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[3] Charles H. Townes, *How the Laser Happened: Adventures of a Scientist* (New York, NY: Oxford University Press, 1999), 4.

[4] Townes (1999), 53. See also page 68.

Yet, even without the heightened investment climate that resulted from the intense rivalry of the Cold War, the military has continued to have a great amount of influence in directing national funding toward R&D. Defense R&D, most of which is channeled through the Department of Defense, accounts for approximately half of the total federal R&D budget each year (see Figure 1).

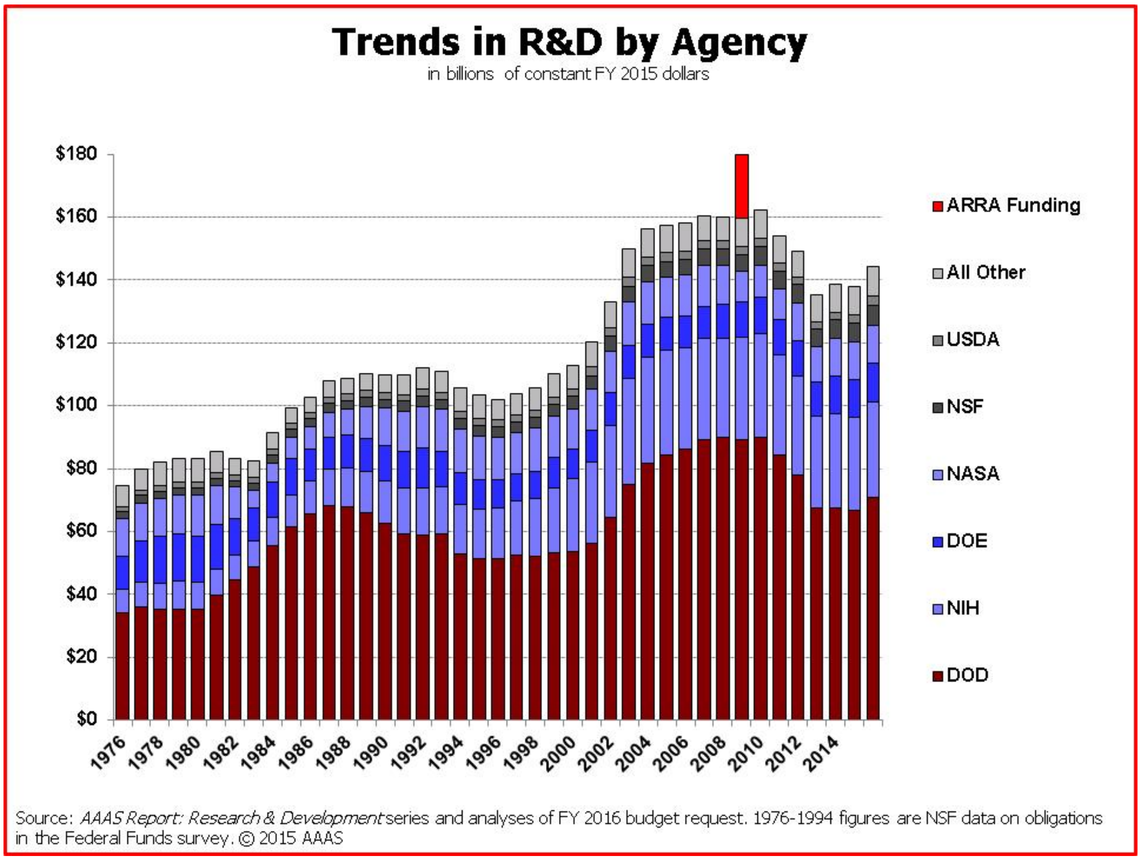

Figure 1 - Federal R&D Spending by Agency (1976-2016)[5]

[5] American Association for the Advancement of Science, "Total R&D by Agency, 1976-2016," R&D Budget and Policy Program – Historical Trends in Federal R&D," http://www.aaas.org/sites/default/files/Agencies_4.jpg (accessed February 11, 2016).

While in recent decades there has been a steady increase in federal funding for health and medical research (most through the National Institutes of Health), the DoD has continued to remain the most important funding source for all federal R&D activities. Based on the sheer volume of funding devoted to the development of military technologies it would certainly seem that, under the moniker of national security and strategic interest, any technology that can bear military utility is justifiable for investment.

This tendency toward investing in R&D for military technology is particularly true for countries seeking to maintain a technological edge over others in terms of their military capabilities. In the US, for instance, where technological superiority has become paramount in defense preparations, investing in "innovative" military technology seems to be the surest way to supply the military with the capabilities needed for its ever widening scope of missions and to prevent any future surprises by adversaries. Yet, despite all these reasons to favor investment in emerging and novel technologies for military purposes, not all technologies that bear military utility are invested in and, in certain cases, although some early investments were present, the R&D efforts could not be sustained to lead to any realized capability.

For instance, during the immediate aftermath of WWII, the Aircraft Nuclear Propulsion (ANP) project, which sought to leverage nuclear fission as a durable source of energy to power an aircraft at supersonic speeds, was vigorously pursued by the Air Force and the Navy. However, despite more than a decade's worth of initial efforts, the ANP project ultimately fizzled out without even getting close to producing any reasonable prototype.[6] Why did nuclear propulsion have difficulty attracting high-level policy endorsement and sustained interest, even though the bulk of the efforts toward its R&D occurred during a time when the competition with the Soviet Union stimulated high levels

[6] See, for instance, Carolyn C. James, "The Politics of Extravagance: The Aircraft Nuclear Propulsion Project," *Naval War College Review*, 53(2) (Spring 2000): 158-190.

of funding toward defense S&T, and significant research efforts were devoted to emerging nuclear technologies, particularly small-scale nuclear power plants/reactors?

As will be examined in more detail below, several decades later and in an entirely different domain of defense technology, the development of incapacitating biochemical agents that can be used as a form of non-lethal weapons languished since the early 2000s in the United States. This happened despite an increase in government and military interest toward brain research and an increasing call for such non-lethal capabilities as a result of the widening range of missions that the American military is called upon to carry out. Why has the US shied away from developing such non-lethal weapons, when the emerging research on neuroscience has continued to unravel the human brain and seems to promise potentials for the development of such a capability?

While national security has indeed driven and provided justification for many technological advances in the military, the empirical record of defense investment shows that some new or emerging technologies inevitably do not get invested in or cannot sustain investment. Although these emerging, prospective technologies may have military utilities that could be useful given the strategic environment under which they are considered for development, they nevertheless cannot gather enough sustained interest or support to be turned into deployable military capabilities. Why is this so? Why are some emerging technologies able to attract and sustain military investment while others cannot? Although conventional wisdom provides many reasons as to why militaries have incentives to invest in novel capabilities and emerging technologies, it says little about the cases in which they do not.

This dissertation takes an initial step at understanding why some areas of emerging S&T do not attract military interest, despite their alleged utility for the military. I argue that an emerging military technology's attractiveness as an investment opportunity depends on how it is understood by relevant actors in the R&D process with regard to its technical feasibility, the stringency of the requirement demands it fulfills, and the availability of alternatives. I posit that feasibility, requirements, and alternatives together determine whether the technical condition of a technology is favorable for investment. A specific configuration of these three factors—namely, a dominant belief in low feasibility, highly stringent requirements, and the existence of alternatives—creates a technical condition that is unfavorable for investing in an emerging technology. This unfavorable condition can prevent an emerging technology from attracting or sustaining investment even if it were to have legitimate military use.

This dissertation proceeds as follows: in Chapter 2, I map out potential state responses to an emerging military technology and analyze the challenge of military R&D investment, particularly for a country like the US that is interested in navigating at the technological frontier and being a forerunner. I show why there is this commonly held belief that any technology that has military utility gets invested in, particularly from a first-mover state dealing with emerging technologies. I then posit that in order to understand why some emerging technologies do not attract military investment, analyzing military R&D from the perspective of opportunity management rather than risk mitigation is necessary.

In Chapter 3, I define the dependent variable (defense S&T investment) and examine literature that bears insight on military research, development, and acquisition; predictions regarding defense S&T investment behavior; and shortfalls. In Chapter 4, I conceptualize the idea of opportunity, which refers to not only the expected utility but also the circumstances that make such utility realized. Applying the supply and demand framework to defense acquisition and summarizing the "Social Construction of Technology" literature, I explain how feasibility, requirements, and alternatives create conditions that may be unfavorable to technology investment in some cases. The chapter also includes a discussion of the design and methods underlying the empirical studies and provides a brief overview of cognitive neuroscience as a discipline, and the reasons behind its status as an emerging area of S&T.

Chapter 5 examines the R&D of biochemical incapacitants as non-lethal weapons. It shows that since the Dubrovka theater incident in 2002, the US investment in this area of research has stopped. The case study examines the changes in perceived feasibility, the stringent requirements in non-lethality from the DoD, and the institutional partnership between law enforcement and military communities, and shows why these factors contributed to the abandonment of this technology in the early 2000s. The chapter also traces the evolution of discussions on biochemical incapacitants within the Chemical Weapons Convention and changes in the US' stance on their research, development, and potential use.

Chapter 6 studies the changing perception of the effectiveness of neuropharmaceuticals in treating combat stress-related disorders such as PTSD from the Vietnam War era to the present. The case study highlights how the dominant psychosocial model of psychiatric practice during the Vietnam War era impacted the perceived feasibility of using psychoactive drugs in treating combat stress. The chapter examines how the shift from a psychosocial to a neurobiological model of psychiatric disorder contributes to the military R&D in neuropsychopharmacology.

Chapter 7 presents a summary of the main arguments and provides an analysis of the findings from the case studies. A mini-case study on aircraft nuclear propulsion is presented as an additional generalizability test of the theoretical model. The chapter concludes with a discussion of theoretical and policy implications.

CHAPTER 2. UNCERTAINTY, RISK, AND OPPORTUNITY – FIRST-MOVER DILEMMA AND INVESTMENT STRATEGIES

2.1 Mapping State Responses to an Emerging Technology

A technology, no matter how nascent, futuristic, or seemingly impractical, will get invested in if it purports to have military utility. Military technologies seem to enjoy a privileged status in a country like the US, where a large sum of money is channeled toward the research and development of new technologies every year, and it is sometimes hard to think about an emerging area of S&T that receives no military support. Why is there this perception of defense R&D, and is it true that the military always has the incentive to invest in an emerging technology with potential military utility? This chapter analyzes this question and provides some insight as to why such a perception exists. By exploring the concept of emerging technology in more detail and mapping out potential state responses to it, this chapter shows why countries like the United States have a tendency to invest very generously in military-relevant emerging technologies. It also presents a case of emerging S&T where this conventional wisdom does not apply and provides an alternative perspective to conceptualize why, in fact, there are some areas of emerging technology that may not see any investment despite military utility.

2.1.1 Defining Emerging Technology

This dissertation examines a state's defense[7] investments in emerging technologies. As such, it is important to understand what constitutes an emerging technology. In the

[7] Recognizing there is a difference between the terms defense and military, whereby the term "defense" encompasses both civilian (such as the civilian leadership and can also in some cases include other defense-related, but non-military communities, such as the intelligence communities) and military components relevant to a nation's security, this dissertation uses them interchangeably in the context of the United States because a very large portion of defense-related R&D is channeled through the military.

simplest sense, an emerging technology is a set of technological advancements that are at an early stage in their development in a given era. The concept of emerging technology thus includes at least two temporal components. The first is internal, referring to the developmental stages of a technology. An emerging technology refers to a technology that is at a nascent stage of development. The second temporal component is the larger historical context. An emerging technology needs to be understood in the context of the time period during which it is developed: a technology that was considered emerging in the 1960s (such as the laser) may be considered relatively mature today.

In addition to their temporal contexts, emerging technologies are most often characterized by their considerable uncertainty. Due to their nascent nature, emerging technologies carry with them a high degree of technical uncertainty in terms of the future trajectories of their development, the speed of their maturation toward practical applications, and the degree of their disruptive potential to existing market structure, societal norm, or organizational competence. The uncertain nature of emerging technologies makes investments in them highly risky, in the sense that the investors have little information to assess probability or likelihood that their investments will ultimately pay off.

Equally unpredictable as the futures of emerging technologies are the sources from which emerging technologies arise. New discoveries in basic research generate new areas of scientific inquiry with the potential for technology development. The invention of a piece of technological equipment can excite new research programs and breed new industries. The convergence of existing streams of research can create new synergy between previously separate scientific disciplines and engender unexpected innovations. As George Day and Paul Schoemaker describe,

> Emerging technologies are science-based innovations that have the potential to create a new industry or transform an existing one. They include discontinuous technologies derived from radical innovations…as well as more evolutionary technologies formed by the convergence of previously separate research streams…Each of these technologies offers a rich source of market opportunities that provide the incentive for risky investments.[8]

These many and varied sources further complicate the prospect of anticipating where emerging technologies may develop and projecting where they may go.

Nascence and uncertainty, nevertheless, merely provide the baseline for describing many of today's emerging technologies. Throughout the literature, contemporary emerging technologies have taken many additional characteristics that make their definition even more complex. Some, for instance, have emphasized the dual-use and converging nature of today's emerging technologies,[9] while others focused on their revolutionary or transformative potential.[10] In a 2014 report by the National Research Council, contemporary emerging technologies are further connoted as often readily available, possessing traits such as low barriers to entry, rapid change, and the blurring of basic and applied research.[11] Today's emerging technologies have the potential to revolutionize or transform human lives, both inside and outside the national defense and military circles.

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[8] George S. Day and Paul J.H. Schoemaker, "A Different Game," in *Wharton on Managing Emerging Technologies*, ed. George S. Day, Paul J.H. Schoemaker, and Robert E. Gunther (Hoboken, NJ: John Wiley & Sons, Inc., 2000), 2.

[9] Wilson W.S. Wong, *Emerging Military Technologies: A Guide to the Issues* (Santa Barbara, CA: Praeger, 2013), 1-13. See also Mihail C. Roco and William S. Bainbridge, eds., *Converging Technologies for Improving Human Performance: Nanotechnology, Biotechnology, Information Technology and Cognitive Science* (Dordrecht, The Netherlands: Kluwer Academic Publishers, 2003).

[10] Edna F. Einsiedel, "Introduction: Making Sense of Emerging Technologies," in *Emerging Technologies: From Hindsight to Foresight*, ed. Edna Einsiedel (Vancouver, Canada: University of British Columbia Press, 2009), 3-4.

[11] National Research Council, *Emerging and Readily Available Technologies and National Security: A Framework for Addressing Ethical, Legal, and Societal Issues* (Washington, D.C.: The National Academies Press, 2014).

This rich set of descriptors on the nature of emerging technologies provides a nuanced foundation upon which defense investments in science and technology programs are examined. In this dissertation, emerging technology refers broadly to an area of new scientific discoveries with the potential for practical applications or a set of nascent technological advancements in a given era. Understood in the context of defense investments, such a technology may be generated from within the military or other national security sectors, or it can be adapted from the civilian or commercial world. Emerging military technologies carry the potential to generate novel or significantly enhanced capabilities that impact the ways militaries operate and wars are fought. Therefore, understanding a state's interest in investing in them is an important component of deciphering how states determine their security needs and respond to threats in today's highly complex international security landscape.

2.1.2 Military S&T Investment in Strategic Context

States desiring security in the international system must provide security for themselves. This central tenant in structural realist thinking of international relations is rooted in the anarchic nature of the international system. The absence of a higher sovereign in the international system dictates that states engage in self-help. Since states cannot be sure of the intentions of other states, they must expend some efforts in providing means to protect themselves.[12] These efforts can be external or internal: External efforts most often refer to alliance behaviors between states. Internal efforts refer to a state's actions to strengthen its economic and military competitiveness.[13] Since not all states possess the capacity to fully ensure security on their own, some states inevitably engage in external

[12] Kenneth N. Waltz, *Theory of International Politics* (New York, NY: McGraw-Hill, 1979), 105-7.

[13] Waltz (1979), 118. See also James D. Morrow, "Arms versus Allies: Trade-Offs in the Search for Security," *International Organization* 47(2) (Spring 1993): 207-233, and Barry Posen, *Sources of Military Doctrine: France, Britain, and Germany Between the World Wars* (Ithaca, NY: Cornell University Press, 1984), 61-63.

balancing efforts by forming alliances.[14] Alliance formation and internal arms buildup thus constitute the traditional balancing behavior for states seeking security.

Investment in science and technology[15] for military purposes, in this sense, is an act of internal balancing. According to Keir Lieber and Gerard Alexander, internal balancing is characterized by increased defense spending, enlargement of the armed services, or investment in military research and technology.[16] Military strategists, policymakers, and international relations theorists alike have long considered technology a major component of state power.[17] States invest in the research and development of military technology because the history of warfare has shown that technology matters. The effects of nuclear weapons and radar during World War II are well known. Advancements in information and communications technology and precision guidance during the Gulf War have led some to herald the arrival of a new revolution in military affairs (RMA).[18] While few researchers today espouse such a deterministic view that technology alone defines power,[19] almost no one has found it wise to categorically dismiss the influence that technology has in the international system and national security affairs.

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[14] States may ally against or bandwagon with the source of threat. See Stephen M. Walt, *The Origins of Alliances* (Ithaca, NY: Cornell University Press, 1987).

[15] In this dissertation, S&T is understood as the early stages of the research, development, testing, and evaluation (RDT&E) of the acquisition process. Within the United States, such investments are characterized by budget activities 6.1, Basic Research, 6.2, Applied Research, and 6.3, Advanced Technology Development.

[16] Keir A. Lieber and Gerard Alexander, "Waiting for Balancing: Why the World Is Not Pushing Back," *International Security* 30(1) (Summer 2005): 119

[17] Martin van Crevald, *Technology and War: From 2000 B.C. to the Present* (New York, NY: The Free Press, 1991); Robert Jervis, "Cooperation Under Security Dilemma," in *Offense, Defense and War*, ed. Michael E. Brown, Owen R. Coté, Jr., Sean M. Lynn-Jones, and Steven E. Miller (Cambridge, MA: The MIT Press, 2004): 3-50; George H. Quester, *Offense and Defense in the International System* (New York, NY: Wiley, 1977).

[18] John Arquilla and David Ronfeldt, "Cyberwar is Coming!" in *In Athena's Camp: Preparing for Conflict in the Information Age*, ed. John Arquilla and David Ronfeldt (Santa Monica, CA: RAND Corporation, 1997), 23-60; Eliot Cohen, "A Revolution in Warfare," *Foreign Affairs* 72(2) (March/April 1996): 37-54; Andrew Krepinevich, "Cavalry to Computer: The Pattern of Military Revolutions," *The National Interest* 37 (Fall 1994): 30-42.

[19] For a discussion of technology as a component of military power, see, for instance, Stephen Biddle, *Military Power: Explaining Victory and Defeat in Modern Battle* (Princeton, NJ: Princeton University Press, 2004).

For states possessing the capacity, internal balancing is considered a more reliable measure to ensure a state's security, for it does not depend on the strength and reliability of a state's allies.[20] However, internal balancing efforts have important strategic ramifications. A state taking measures to increase its own security can inadvertently undermine the security of others. This phenomenon, known as the security dilemma, contributes to the escalation of tension in the international system and the potential of an arms race. In the realm of military R&D, investments in S&T that create the potential for a state to increase its military capability can at the same time undermine that of others, and a demonstration of technological prowess can elicit significant great power responses. The Soviet launch of Sputnik in 1957, for instance, sped up the process for the US to launch its own first satellite, Explorer 1, in 1958. Sputnik is also thought to have provided the impetus for the creation of institutions such as National Aeronautics and Space Administration (NASA) and what is now known DARPA. Military investments in S&T, therefore, contribute to the determination of national power and the dynamics of interstate relations.

2.1.3 Potential State Responses to an Emerging Technology

Given the importance of military technology, how does a state respond to advancements in military technology, particularly when a new technology has just arrived on the scene? Should an investment be made? In what manner should a state pursue these nascent technologies? Do states have a choice in terms of how they can respond? When a state faces a nascent field of scientific research or an emerging area of technological development that carries the potential for military applications, it has several choices of acquisition strategy. The fact that this new area of S&T has potential military applications does not mean that states will always decide to put money toward R&D. In some cases, the potential military applications of the emerging S&T may not be relevant to the state's

[20] Waltz (1979), 168.

security needs, or the state may simply not have the human, financial, or organizational capacity to develop the technologies on their own. Under these conditions, a state may choose not to invest militarily in the emerging S&T and entirely let go of the potential applications. This is especially true for states that have little to no established military (such as Monaco, Panama, and Costa Rica). For these smaller states whose security requirements are low and whose domestic scientific or technological capacities are limited, measures to ensure security are likely to be entirely external: they seek protection from major powers rather than build up armed services of their own. These states thus will forego the opportunity to invest in an emerging military technology.

Even if the military capabilities developed from this nascent area of S&T are desirable, states may still not invest in R&D. Instead, they may choose to simply procure the technology or the technological systems once they are developed by others, provided that the means to such procurement exist and that the developer country is willing to become a supplier of this new technology. This phenomenon, generally known as "arms transfer," has become prevalent since the second half of the twentieth century, when the norm of self-sufficiency in a state's military research, development, and production was replaced by a new emphasis on strong alliances and mutual support between states as a result of the Cold War.[21] Furthermore, despite the fact that globalization has broadened the S&T base worldwide, very few states can actually produce or develop military systems that incorporate cutting-edge S&T. According to estimates by the Stockholm International Peace Research Institute (SIPRI), in 2011, for instance, the top ten military spenders constituted 75% of the world's military spending.[22] This high concentration of defense spending in only a few states suggests that most states do not have the financial capacity

[21] Martin Edmonds, "International Military Equipment Procurement Partnerships: The Basic Issues," in *International Arms Procurement: New Directions*, ed. Martin Edmonds (New York, NY: Pergamon Press, 1981), 1-2.

[22] Stockholm International Peace Research Institute, *SIPRI Yearbook 2012: Armaments, Disarmament and International Security* (Oxford, UK: Oxford University Press, 2012).

to conduct independent research and development for military technologies as well as procure the necessary weapons and systems. Outside the select few military technology producers, most states acquire military technologies from foreign procurement.[23]

When a state has the scientific and technological capacity as well as the incentive to acquire some level of indigenous capability on an emerging technology, it may choose to invest in R&D. Here, a state faces two options as an investor: it can mimic what other states are developing as a second-mover,[24] or it may pioneer the R&D efforts in this new technology as a first-mover. While the records of great power struggles and arms race suggest that the anarchic international system provides strong incentives for states to be first-movers, there is increasing recognition that states sometimes deliberately choose to invest in military technologies as a second-mover. For instance, China is known to be a skilled imitator and creative adapter of technologies (including military ones) through its strategy of "introduce, digest, assimilate, and re-innovate (IDAR)."[25] Despite the common critique that countries like China imitate and adapt because they lack the capacity to truly innovate, states have the option of pursuing a new technology as a second-mover. Figure 2 below illustrates the different paths a state may take in response to a new military technology.

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[23] For the purpose of this dissertation, the term investment refers to the money put towards military R&D. Procurement activities, in this sense, are not considered investments.

[24] The second-mover, in this case, encompasses all states that are *not* the first-mover in a given field of military technology. For the purpose of this dissertation, whether the second-mover is an early or late entrant to the technology after it has been introduced is not of concern.

[25] Tai Ming Cheung, "The Chinese Defense Economy's Long March from Imitation to Innovation," in *China's Emergence as a Defense Technological Power*, edited by Tai Ming Cheung (New York, NY: Routledge, 2013), 32-3. See also William C. Hannas, James Mulvenon, and Anna B. Puglisi, *Chinese Industrial Espionage: Technology Acquisition and Military Modernization* (New York, NY: Routledge, 2013), 62.

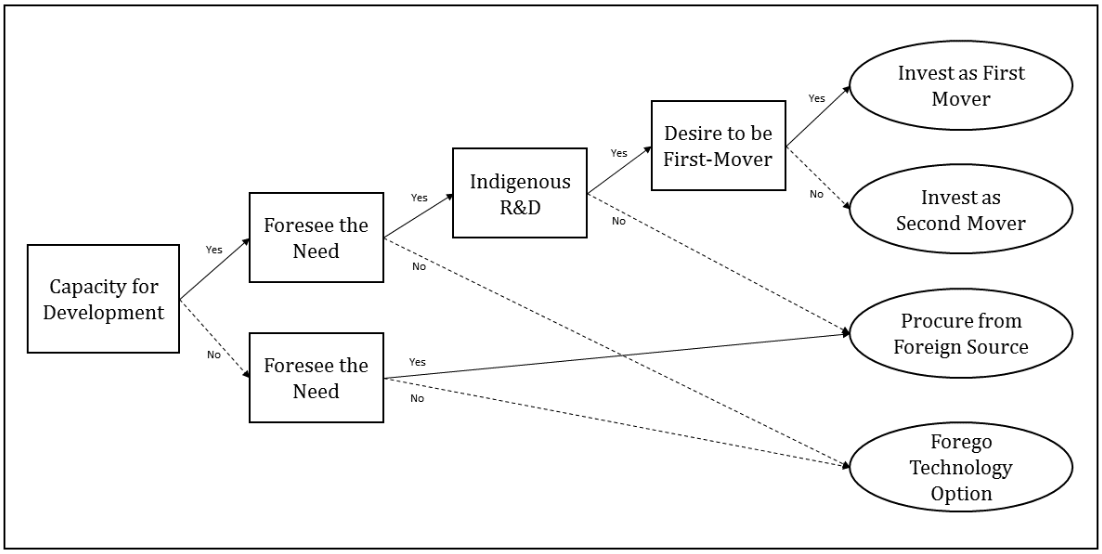

Figure 2 - Potential State Responses to an Emerging Technology

2.1.4 The Concept of a Technology First-Mover

A technology first-mover is an intuitive concept that is elusive to define. It is intuitive because all technological innovations must begin somewhere, and, inevitably, someone must be the first to develop a technology. Yet, defining the timing of when an actor becomes a technology first-mover can be challenging: is a state considered a first-mover when it begins to invest in a new technology before others do, or is a state a first-mover only when it has successfully developed a technology? Or, does a first-mover only exist when someone has been able to introduce the new technology to the market? These various potential entry points in the R&D process complicate the concept of a first-mover.

The literature pertaining to business management and military innovation in the realm of S&T have by and large characterized first-mover as an actor that first brought a technology to the market, despite the fact that this definition is better suited for understanding the advantageous effects of being a first-mover rather than clarifying the decision process of one. The idea of a first-mover and the advantage such a position can achieve can be traced back to Schumpeterian entrepreneurial profit, which posits that innovation can help the first-mover generate market advantage by creating essentially a temporary quasi-monopoly position where profits are gained.[26] A first-mover in this context is understood as an actor who introduces a new technology to the market.

In the context of military technological innovation, a technology first-mover refers to a state that is the first one to introduce a military technology to the international system. Whether or not the technology first-mover is conferred an advantage depends on the extent to which it can effectively incorporate the technology into military strategy, organization, and doctrine.[27] In both cases, a first-mover is identified only after the technology has been introduced. Such a definition, while useful in understanding first-mover advantage, provides little room to contextualize the decisions made about a technology by an actor prior to the unveiling of the technology.

This dissertation, in the context of defense R&D investment decisions, understands a technology first-mover in general, conceptual terms. In some cases, the first-mover will be among the first to have visible investments in a new military technology, whether through the allocation of financial resources or the establishment of organizational infrastructure for its R&D. In others, the first-mover will refer to those that are among the first to indicate an interest in an emerging technology. But the concept is also used without specifying a particular technological domain to indicate a state that has the tendency to engage in cutting-edge military research. Not restricting the definition of first-mover to a

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[26] Joseph A. Schumpeter, *The Theory of Economic Development: An Inquiry into Profits, Capital, Credit, Interest and the Business Cycle*, with a New Introduction by John E. Elliott (New Brunswick, NJ: Transaction Publishers, 1983), 128-156.

[27] Michael C. Horowitz, *The Diffusion of Military Power: Causes and Consequences for International Politics* (Princeton, NJ: Princeton University Press, 2010).

specific benchmark allows one to use the concept more broadly and apply it to cases where some of these markers may be difficult to identify.

The concept of a first-mover fascinates business and military strategists alike due to the potential advantage such a position confers. Being a technology first-mover has its challenges, however, and being a late-comer is not without benefits. In particular, first-movers face the challenge of a tremendous amount of risk and uncertainty associated with investing in new and uncharted areas, while second-movers reap the benefits of avoiding much of such uncertainties. A second-mover often can base its investment decisions on the information derived from the actions of the first-mover. What remains rather unclear, however, is how a first-mover makes its decision amidst uncertainty. Scholarship on diffusion (of military power more generally and of military technology more specifically) has, in recent years, begun to unravel the dynamics of how states respond to military innovations as a second-mover.[28] However, how the first-mover makes its decisions is a rather under-conceptualized area in the study of defense innovation.[29] This paucity of scholarship on how first-movers make investment decisions is curious, since an answer is far from apparent. The following section provides further insight into the unique challenges that a technology first-mover faces and reveals why a first-mover's ability to make a decision is in fact a puzzling phenomenon.

2.2 Dilemma for Technology First-Movers

[28] How military technology spread throughout the international system, or in other words, how it is adopted by second-movers once it is introduced, has been the subject of attention for an growing set of literature on diffusion. See, for instance, Emily O. Goldman and Leslie C. Eliason, eds., *The Diffusion of Military Technology and Ideas* (Stanford, CA: Stanford University Press, 2003); Andrea Gilli and Mauro Gilli, "The Diffusion of Drone Warfare? Industrial, Organizational, and Infrastructural Constraints," *Security Studies* 25(1) (February 2016): 50-84; and Horowitz (2010).

[29] Studies on weapons innovation have examined the process and success (or the lack thereof) in the development of major weapons systems, particularly in the context of the Cold War arms race. Yet, little has been said about how states make investments as a first-mover, and almost nothing on how they make decisions in areas of nascent science rather than on a weapon system. For a select set of this literature, see note 72.

2.2.1 Investing as a Technology First-Mover

For a state interested in maintaining the "technological edge" and harnessing the advantage of being a technology first-mover, such as the United States, investing in new military technologies is not just desirable, but imperative. The anarchic international environment provides strong incentives for states to do what they can to stay ahead of others – while being the first-mover does not always guarantee an advantage, not being proactive at the technological frontier carries the greater risks of being blindsided by others in conflict.[30] In the United States, this belief of maintaining leadership at the technological frontier is deeply ingrained in the military and strategic mindset, much of it arguably a result of the success the US enjoyed in its qualitative arms race against the Soviet Union.[31] Others have traced the root of this determination to Vannevar Bush's advocacy that science is essential for national security. Regardless the origin, defense and military communities in the US are "committed to a U.S. position of overall technical superiority in military technology; technical leadership is regarded as being essential in itself as well as being necessary to preclude technological surprise."[32]

The need to maintain technological superiority in the US military has been continuously highlighted in various strategic and national security documents,[33]

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[30] Efforts to understand and mitigate this kind of technological surprises are reflected in several studies, including National Research Council, *Avoiding Surprise in an Era of Global Technology Advances* (Washington, D.C.: The National Academies Press, 2005) and National Research Council, *Avoiding Technology Surprise for Tomorrow's Warfighter: A Symposium Report* (Washington, D.C.: The National Academies Press, 2009).

[31] Ashton B. Carter, Marcel Lettre, and Shane Smith, "Keeping the Technological Edge," in *Keeping the Edge: Managing Defense for the Future*, ed. Ashton B. Carter and John P. White (Cambridge, MA: Preventive Defense Project, Belfer Center for Science and International Affairs, Harvard Kennedy School, 2000), 127-162.

[32] Franklin A. Long and Judith Reppy, "Decision Making in Military R&D: An Introductory Overview," in *The Genesis of New Weapons: Decision Making for Military R&D*, ed. Franklin A. Long and Judith Reppy (New York, NY: Pergamon Press, 1980), 4.

[33] See, for instance, Department of Defense, *Quadrennial Defense Review Report, September 2001* (Washington, D.C.: Department of Defense, 2001), 40; Department of Defense, *Quadrennial Defense Review Report, February 2006* (Washington, D.C.: Department of Defense, 2006), 3; and Department of Defense, *Quadrennial Defense Review Report, February 2010* (Washington, D.C.: Department of Defense, 2010), 81.

reconfirmed in 2012 by then Secretary of Defense Leon Panetta, that the US is "shaping a Joint Force for the future that will be smaller and leaner, but will be agile, flexible, ready, and technologically advanced," and this force "will have cutting edge capabilities, exploiting our technological, joint, and networked advantage."[34] This need is also shown through the interest that the DoD has in engaging in direct, collaborative partnerships with innovation centers within the US in recent years. The opening of two DoD innovation hubs called Defense Innovation Unit Experimental (DISx) in Silicon Valley and Boston, in 2015 and 2016 respectively, under the current Secretary of Defense Ash Carter confirms this trend. To defense planners in a state desiring to be a technology first-mover, efforts in military R&D and investments in emerging S&T are essential to maintaining this technological advantage.

2.2.2 The Dilemma

Despite the importance of military technology, managing military technological innovation is rather difficult. This is, in part, due to the unpredictable nature of the direction of any technological progress and the uncertainty embedded in any R&D process. This technical uncertainty refers to the inability for one to estimate the potential outcome or the probability of such an outcome from the R&D process. Furthermore, unlike their commercial counterparts, technological advancements in the defense sector do not enjoy the market mechanisms that oftentimes provide the feedback for the innovation (such as the profitability of a new product). As a result, the advantages they confer on the users cannot be proven until the technologies are deployed on the battlefield in armed conflicts, which are rare events.[35] In this sense, a manager of military technology investment

[34] Department of Defense, *Sustaining U.S. Global Leadership: Priorities for 21st Century Defense* (Washington, D.C.: Department of Defense, 2012).

[35] For a more detailed discussion on how to assess the return of investment for military technology and how it may differ from commercial ones, see Albert Sciarretta et al., *A Methodology for Assessing the Military Benefits of Science and Technology Investments* (Washington, D.C.: National Defense University Center for Technology and National Security Policy, 2008). For a detailed discussion on assessing military

decisions also face the problem of strategic uncertainty, which, under certain circumstances one may have difficulty estimating the need for a technology and the probability that such a technology may meet the security demands.

The sentiments about these uncertainties, which were observed in the US development of intermediate-range ballistic missiles (IRBM) in the 1950s, still are true today:

> An irreducible element of conjecture is intrinsic in most weapons decisions. Knowledge of enemy capabilities and intention is at best incomplete and ambiguous. Attempts to anticipate the main lines of scientific advance [are] always a hazardous enterprise. While the element of unpredictability in advanced engineering is less dramatic, precise calculations of cost and lead time, as well as the operational utility of new weapons, have again and again defied systemic attempts at prediction.[36]

In this sense, managing military technological progress seems to be an effort of muddling through uncertainties. The way in which a defense planner determines the necessary course for military R&D investment thus relies on the extent to which he can mitigate the effects of uncertainty.

What further complicates the military R&D investment decisions is that any S&T choice made has long-term ramifications. Decisions about military R&D are important in that once they are made, they shape the rest of the decisions throughout the acquisition process. A closer examination of the full life-cycle cost of any military technology at a

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technology performance, see John A. Alic, "Managing US Defense Acquisition," *Enterprise & Society* 14(1) (March 2013): 1-36.

[36] Michael H. Armacost, *The Politics of Weapons Innovation: The Thor-Jupiter Controversy* (New York, NY: Columbia University Press, 1969), 6. Similar views can be found in Stephen Peter Rosen, *Winning the Next War: Innovation and the Modern Military* (Ithaca, NY: Cornell University Press, 1991), 221.

given time demonstrates that while the spending on the production, procurement, operation, and maintenance is most often disproportionally bigger than funds initially allocated for the R&D, these back-end activities inevitably flow from acquisition decisions made years ago during the R&D stage. “From a management point of view,” claims Edwin Deagle, “careful design and control of the military R&D process is one of the critical keys to successful financial and programmatic management of the much more expensive systems and military force structures which flow from that process.”[37] Since many of the basic technical details and characteristics for a military technology are settled in the early conceptual stages of acquisition (namely R&D), the decisions made during these stages affect everything that follows.

This path-dependent nature of defense acquisition has led Judith Reppy and Franklin Long to conclude that the “peculiar significance of military R&D is that the R&D projects are the principal determinants of future weapons,” and that while “the relations between military hardware, military strength, and national security are not rigid…they are sufficiently strong that the decisions on the RDT&E budget can have significant impact on force structure for years to come.”[38] From the non-technical dimension, the interest built around a new military technology inevitably grows over time. R&D programs which have been started and are underway, thus, greatly influence the character of military R&D programs: “Not only is there substantial commitment to continue these programs in the expectation of getting deployable systems, there are also substantial bureaucratic pressures from contractors and Congressmen to continue these systems.”[39] Military R&D

[37] Edwin A. Deagle, Jr., “Organization and Process in Military R&D,” in *The Genesis of New Weapons: Decision Making for Military R&D*, ed. Franklin A. Long and Judith Reppy (New York, NY: Pergamon Press, 1980), 162.

[38] Judith Reppy and Franklin A. Long, “The Decision-Making Role of Congress,” in *The Genesis of New Weapons: Decision Making for Military R&D*, ed. Franklin A. Long and Judith Reppy (New York, NY: Pergamon Press, 1980), 182.

[39] Judith Reppy and F. A. Long, “U.S. Military R&D: A Set of Questions,” *Bulletin of the Atomic Scientists* 34(5) (May 1978): 36.

investments, thus, face a serious “lock-in” effect: once a decision is made, it impacts the future course of the technology’s development, and whatever is spent early on will determine the trajectory of what will likely be spent in the future.

For defense planners, as a result, managing military R&D investments is a perpetual dilemma. On the one hand, they are compelled to act, for it is only through investing in military R&D that they can hope to maintain the technological edge and avoid future surprises. Yet, there is widespread recognition that the R&D process is filled with uncertainties and risks, and that any investment decision made will inevitably involve a level of conjecture. On the other hand, the difficulty in making a choice amidst uncertainty is further exacerbated by the lock-in effect that yesterday’s choice shapes the course of action today, and the investments made today oftentimes lead to commitments of resources tomorrow. Leveraging and paraphrasing what others have said about the uncertainties embedded in the process of military transformation, defense planners in a state desiring to be a technology first-mover have to make investment decisions that can potentially define the trajectory of technological progress in the military *ex ante*, while the effects of such investments and potential change on the military can only be appreciated and understood *ex post*.[40] How can a defense planner hope to cope with this element of choosing and committing amidst uncertainty that others have referred to as “flying blind”?[41]

2.3 Emerging Technologies and Cross-Cutting Pressure

The dilemma a first-mover faces is further complicated today by the rise of a new wave of emerging technologies, the shifting security requirements, and the mounting budget pressure. As mentioned previously, a whole set of emerging technologies today

[40] Adam N. Stulberg, Michael D. Salomone, and Austin G. Long, *Managing Defense Transformation: Agency, Culture, and Service Change* (Burlington, VT: Ashgate Publishing Company, 2007), 14.

[41] Stulberg, Salomone, and Long (2007), 14.

promises exciting transformational opportunities for the military. Yet, the complex dual-use and interdisciplinary nature of these technologies and attendant uncertainties in the rate and direction of how these technologies progress suggest that making decisions and choices about them presents difficult challenges. The pursuit of emerging technologies for military use, in turn, seems to be a quintessential case of choosing amidst uncertainties where the dilemmas facing a technology first-mover are the most pronounced.

Furthermore, since the end of the Cold War, many of the structural elements in the international and national security landscape that may have helped a technology first-mover like the US alleviate the effects of uncertainties are long gone. During the Cold War, the mantra of nuclear dominance and arms race defined the structure of international competition. The clear threat environment helped reduce some uncertainties regarding how and where to invest for military R&D. The primacy of nuclear weapons as the currency of power during this period spelled out rather clearly what technological options were important and desirable – weapons systems designed around the delivery, monitoring, and response to the nuclear force largely characterized the military R&D agenda. This threat environment has changed, and the US defense communities realize this. Since the end of the Cold War, efforts in defense transformation and force modernization have been ongoing and are being pursued even more rigorously during the past decade. This high fluidity in the international security environment however makes it even more difficult to determine which investments may ultimately pay off.

In addition, it is widely recognized that the United States has been in a continued process of drawing down its defense spending since the end of the Cold War. Although the total defense budget rose to a new height in the immediate aftermath of the terrorist attacks on September 11, 2001, and was sustained for several years due to the operations in Afghanistan and Iraq, the global economic downturn since 2008, the drawdown of the American engagements in Afghanistan, and the 2011 Budget Control Act that has led to the sequestration all have reignited the push towards the reduction of government spending. To date, the effects of the sequestration have received mixed assessments: some have noted that the industries are doing better than expected and that many of the doomsday predictions have not come to pass.[42] Even the Department of Defense, which has previously warned against the potentially crippling cuts,[43] has shown that it was able to weather sequestration better than expected.[44] Others have emphasized that the current minimal impact is merely the "calm before the storm", and that the true impacts of the sequestration will be seen during coming years. Regardless of which story turns out to be more accurate, budget-watchers agree on at least one thing – that no matter how the pie is sliced, defense investments will take a hit. As Lawrence P. Farrell, Jr., former President of the National Defense Industrial Association, suggests,

> Assuming [the] sequester continues for some time, the choices are shaping up to be between force structure and investment. There is talk of a reduction of flying squadrons in the Air Force, lower numbers of Army brigade combat teams, fewer battalions in the Marine Corps and a smaller fleet of Navy aircraft carriers. The problem is that force structure takes some time to come down. That leaves investment – research, development and procurement – and operations as the bill payers in the shorter term.[45]

As acquisition and other components of DoD expenditure, such as military pay and healthcare, become more expensive,[46] this reduction in the investment budget (even with

[42] David A. Fahrenthold and Lisa Rein, "They Said the Sequester would be Scary. Mostly, They were Wrong," *Washington Post* (June 30, 2013).

[43] "Squeezing the Pentagon: The Wrong Way to Cut America's Military Budget," *The Economist* (July 6, 2013).

[44] Stephen Dinan, "DoD Reversal: Sequester Pain Less Than Anticipated," *Washington Post* (August 6, 2013).

[45] Lawrence P. Farrell Jr., "Sequester Impact: More Than Meets the Eye," *National Defense* (September 2013): 6.

[46] Cindy Williams, *Making Defense Affordable* (Washington, D.C.: Brookings Institution, 2013), 6.

the protection of the S&T component of the R&D budget)[47] will likely add pressure on how the DoD makes investment decisions and selects S&T programs.

The decision to invest in this complex and nascent set of emerging technologies, exacerbated by the shifting international security environment coupled with increasing fiscal austerity pressure, suggests a set of challenging questions: Of the many and varied military applications made possible by emerging S&T, which ones deserve to be pursued? How can defense planners begin to draw conclusions about the expected utility or appropriateness of these various applications and define a path for their pursuit before these emerging technologies arrive on the scene? Do states invest in military research in certain areas of emerging S&T but not others? Is it possible to understand where other countries are likely to hedge their bets amidst the uncertainties associated with emerging technologies? Is it possible to understand what drives a state's S&T investments amidst uncertainty and why states choose to invest in certain technologies the way they do?

2.4 Uncertainty, Flexibility, and the Strategies for Risk Mitigation

Both scholars and policymakers dealing with defense planning writ large and the R&D process in particular understand the problem of uncertainty inherent in the management of technological innovation. Burton Klein, for instance, noted that both supply and demand uncertainties exist in military R&D decisions.[48] Supply uncertainties refer to the risks embedded in the R&D process, such as the technical uncertainty described above. Especially at the early stages of investing and pursuing emerging technologies, the potential costs, development direction, and timeline are all unknown and subject to large

[47] Department of Defense, *Defense Budget Priorities and Choices* (Washington, D.C.: Department of Defense, 2012), 10.

[48] Burton H. Klein, "Policy Issues Involved in the Conduct of Military Development Programs," in *Economics of Research and Development*, ed. Richard A. Tybout (Columbus, OH: Ohio State University Press, 1965), 319.

amounts of error in estimates. These uncertainties create the risk that the technology invested in may ultimately not achieve the desired payoff.

Demand uncertainties refer to the uncertain nature of the security requirements imposed by a state's actual or potential enemies, similar to what is referred to above as strategic uncertainty. This kind of uncertainty exists in the international system and is external to the R&D process, but it nevertheless shapes the R&D decisions, for defense investments are sensitive to the threat environment. A strategic environment in which the source of threat is ill-defined would, thus, heighten the level of demand uncertainties, and states can run the risk of investing in programs that ultimately do not meet the security demands.

In both cases, risks can be understood as the probability of a negative outcome. In the DoD acquisition process, for instance, risks are defined as "future events or conditions that may have an negative effect on achieve program objectives for cost, schedule, and performance."[49] The measure of risk, thus, includes both the probability of an undesired outcome as well as the consequence of such an outcome. However, unlike in economic theories, in which the concept of risk refers to situations where the decision-maker has the knowledge of all possible outcomes and probabilities of their potential occurrence and is thus distinct from uncertainty, in this dissertation the concept or risk subsumes uncertainty, in which the consequences of an outcome and the probability for such an outcome are both unknowns or are difficult to estimate.[50] The uncertainties associated with investing in an emerging technology are not separate from the risk calculus. Furthermore, in this

[49] Department of Defense, *Risk, Issue, and Opportunity Management Guide for Defense Acquisition Programs* (Washington, D.C.: Office of the Deputy Assistant Secretary of Defense for Systems Engineering, 2015), 3.

[50] This echoes how risk has been defined in the realm of foreign policy making, in which the lack of complete information is the norm, which makes risk calculus in the classical economic sense untenable. See Jeffrey W. Taliaferro, "Power Politics and the Balance of Risk: Hypotheses on Great Power Intervention in the Periphery," *Political Psychology* 25(2) (2004): 182.

dissertation, the negative outcome is defined as a technology investment not meeting the security demands through problems associated with technical or strategic uncertainties.

Klein suggests that being flexible pays when the future is uncertain: it mitigates the risks that arise from supply (technological) and demand (strategic) uncertainties. Adopting Klein's approach, Stephen Peter Rosen extends the logic of flexibility to military technological innovation.[51] According to Rosen, uncertainty can be managed by Klein's Type I flexibility, which in the context of technological innovation refers to investments on technologies that are multiuse – such as weapons that can be used for every contingency.[52] Since the cost of pursuing Type I flexibility is high, Rosen argues that uncertainty can also be managed by Type II flexibility, which is a hedging strategy that seeks to buy more information during early stages of development and defer costly decisions to a later date.[53] While the costs of these strategies are different, they both help defense planners manage the risks associated with high levels of uncertainty. In both instances, the probability of a negative outcome – that of an investment not meeting the security demand, is expected to be lowered even the value of such a probability is not known.

2.5 US Defense Investments in Cognitive Sciences Research – A Probe

Conventional wisdom thus suggests that when navigating through uncertainties, states are best off when they diversify or hedge, for such strategies help mitigate the risks

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[51] Rosen (1991), 243-249. Thomas McNaugher advocates very similar strategies. See Thomas L. McNaugher, *New Weapons, Old Politics: America's Military Procurement Muddle* (Washington, D.C.: The Brookings Institution, 1989).

[52] The capabilities-based uncertainty-sensitive planning, which aims to produce capabilities that can be used in a wide range of contingencies, is a form of Type I flexibility. See for instance Paul K. Davis, "Uncertainty Sensitive Planning," in *New Challenges, New Tools for Defense Decisionmaking*, ed. Stuart E. Johnson, Martin C. Libicki, and Gregory F. Treverton (Santa Monica, CA: RAND Corporation, 2003), 141-144. A shift from threat-based planning to capabilities-based planning was also discussed in the Department of Defense, *Quadrennial Defense Review Report* (2006).

[53] Articulations of acquisition policies that follow this Type II flexibility can be found in Paul H. Richanbach et al., *The Future of Military R&D: Towards a Flexible Acquisition Strategy* (Alexandria, VA: Institute for Defense Analyses, 1990).

embedded in R&D investments. Yet, do states actually follow this wisdom? An examination of some current defense S&T programs suggests that the story is more complicated. For instance, in the past decade, the United States in particular has been active in leveraging emerging cognitive science and neuroscience (hereafter collectively called cognitive sciences) research for military purposes. Like many other emerging technologies today,[54] cognitive sciences research is dual-use,[55] interdisciplinary, and controversial. Unlike most other critical emerging technologies in previous military technological epochs, cognitive sciences enable a wide range of possible military capabilities. Some of these applications can be developed into field-deployable weapons systems, while others are non-deployable but mission, capability, or capacity-enabling. Cognitive sciences have also been heralded as transformative because they tackle the matters of human mind – they study and make transparent the underlying cognitive and neurological processes of human thoughts and behaviors. In this sense, cognitive sciences' greatest promise to the defense communities is their potential to alter, redefine, or potentially revolutionize the use of the very foundational unit in military operations – the warfighters.

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[54] For scholarship discussing the military potential of other emerging technologies one may consult: for nanotechnology, Jürgen Altmann, *Military Nanotechnology: Potential Applications and Preventive Arms Control* (New York, NY: Routledge, 2006); Daniel Ratner and Mark A. Ratner, *Nanotechnology and Homeland Security: New Weapons for New Wars* (Upper Saddle River, NJ: Prentice Hall, 2004); Margaret E. Kosal, *Nanotechnology for Chemical and Biological Defense* (New York, NY: Springer, 2009); Margaret E. Kosal, "The Security Implications of Nanotechnology," *Bulletin of the Atomic Scientists* 66(4) (July 2010): 58-69; Frank Simonis and Steven Schilthuizen, *Nanotechnology: Innovation Opportunities for Tomorrow's Defense* (Netherlands: TNO Science and Industry Future Technology Center, 2006). For genomics, see for instance The MITRE Corporation, JASON Program Office, "The $100 Genome: Implications for the DoD" (December 2010). For a more historical case on artificial intelligence, one may consult reports such as Stephen J. Andriole and Gerald W. Hopple, *Defense Applications of Artificial Intelligence* (Lexington, MA: Lexington Books, 1988); Paul E. Lehner, *Artificial Intelligence and National Defense: Opportunity and Challenge* (Blue Ridge Summit, PA: Tab Professional and Reference Books, 1989); Allan M. Din, *Arms and Artificial Intelligence: Weapons and Arms Control Applications of Advanced Computing* (New York, NY: Oxford University Press, 1987).

[55] Both in the traditional sense that it can be used for both civilian and military purposes, as well as the modern definition that it can be used for both beneficial and harmful applications. See, for instance, National Research Council, Committee on Assessing Fundamental Attitudes of Life Scientists as a Basis for Biosecurity Education, *A Survey of Attitudes and Actions on Dual Use Research in the Life Sciences: A Collaborative Effort of the National Research Council and the American Association for the Advancement of Science* (Washington, D.C.: The National Academies Press, 2009).

How do cognitive sciences impact warfighters? The answer lies in the myriad of their potential military applications. These applications range from building computational models of cognition, which can be used to impact the recruitment and training of soldiers,[56] to developing better brain-computer interfaces that produce greater integration of human-machine systems and allow a soldier rehabilitation through intelligent prosthetics.[57] Other uses often discussed include the development and use of neuropharmaceuticals for a warfighter's performance enhancement or degradation[58] and neuroimaging technologies-enabled field-deployable biomarkers that monitor a warfighter's health and performance. These novel capabilities, while promising, are for the most part still at an early stage of technological development, even outside the realm of military research.[59] Given the complex and nascent nature of cognitive sciences research, the transformative potential they carry, the widely divergent possible applications and potentially risky payoffs, investments in the cognitive sciences R&D are highly uncertain and should present significant technology first-mover challenges to defense planners. Furthermore, due to their potential of drastically changing a warfighter's capabilities and nefarious uses, the uncertainties embedded in and the potential risk of military investments in cognitive sciences seem to be best managed by a Type II flexibility strategy of low-cost hedges that buys information and delays commitment.

Yet, the manner in which the United States, as a technology first-mover in military cognitive sciences research, has pursued its R&D programs in this emerging S&T in the

[56] National Research Council, *Opportunities in Neuroscience for Future Army Applications* (Washington, D.C.: The National Academies Press, 2009), 23-33.

[57] National Research Council, *Opportunities in Neuroscience* (2009), 85-87. For a more general discussion on neuroscience's impact on prosthetics, see also The National Academies *Keck Futures Initiative* Smart Prosthetics Steering Committee, *Smart Prosthetics: Exploring Assistive Devices for the Body and Mind* (Washington, D.C.: The National Academies Press, 2007).

[58] National Research Council, *Opportunities in Neuroscience* (2009) 45-66; National Research Council, *Emerging Cognitive Neuroscience and Related Technologies* (Washington, D.C.: The National Academies Press, 2008), 134-139.

[59] To date, at least within the United States, very few, if any, of these cognitive sciences applications have been developed past the stage of Advanced Technology Development (6.3), thus in terms of the larger acquisition process, most of these technologies are before the stage of the proof of concept.

past decade presents a rather different picture. The US military investments in cognitive sciences and related technologies, which have risen in the past decade, are broadly distributed across defense agencies like DARPA and the R&D arm of individual services. Yet, instead of pursuing a strategy of low-cost hedges, the US has chosen to invest in some areas of military-relevant cognitive sciences research but not in others. For instance, the types of cognitive sciences-related programs funded through DARPA include Human Assisted Neural Devices, Reliable Neural Interface Technology, Maintaining Combat Performance, and Revolutionizing Prosthetics. Among the services, the Army has allocated most of its funding to programs such as treatments for traumatic brain injury (TBI), neurosensory injury prevention and reduction, psychological resilience to Post-Traumatic Stress Disorder (PTSD), and neuroergonomics. The Navy invests in programs on human systems, human performance, training, and education, and in-house laboratory research on human performance sciences. Finally, the Air Force's investments include programs in human performance enhancement through cognitive modeling, mitigation of stressors on cognitive functions, performance evaluation in extreme environments.[60] If one were to use the general "framework" of health/medical applications, performance enhancement applications, and performance degradation applications[61] to categorize this diverse set of US military investments in cognitive sciences, a great majority of the investments go to health/medical and performance enhancement, but very little, if any, to performance degradation applications. Figure 3, using DARPA investments in cognitive sciences from 2000 to 2013 as an example, shows the investment across these three domains of military cognitive sciences. The red trend line marks the absence of investment in performance degradation applications.

[60] These investment areas are drawn from the President's Budget between 2008 and 2013.

[61] These categories are used in studies such as National Research Council, *Emerging Cognitive Neuroscience* (2008) and The Royal Society, *Brain Waves Module 3: Neuroscience, Conflict, and Security* (London, UK: The Royal Society Science Policy Centre, 2012).

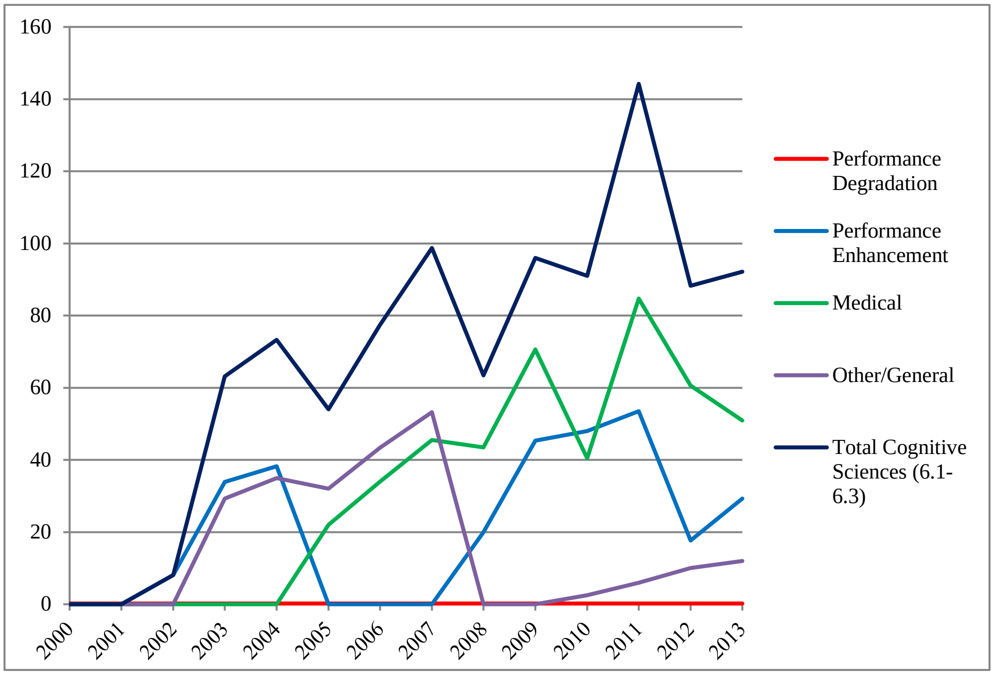

Figure 3 - Budget Requests for Cognitive Sciences Programs (in $ millions) - DARPA (2000-2013)

The performance degradation applications, in this sense, most often refer to the use of biochemicals or other means as non-lethal weapons (NLW). These NLW applications include irritants, which "can produce rapidly in humans sensory irritation or disabling physical effects which disappear within a short time following the termination of exposure," or incapacitants, which "cause more prolonged but still transient disability and include centrally acting agents producing loss of consciousness, sedation, hallucination, incoherence, paralysis, disorientation or other such effects."[62] It is important to note that while the use of chemical-based incapacitants in war is prohibited under the Chemical Weapons Convention (CWC), their use is permitted in law enforcement, including for the

[62] The Royal Society, *Brain Waves Module 3* (2012), 8-9.

purpose of domestic riot control.[63] Furthermore, the military application potential of cognitive sciences in the form of refinement of calmatives and incapacitants is well-recognized, for other countries have engaged in R&D (such as the Czech Republic and China) [64] and actual use of non-lethal incapacitants (such as in Russia in the 2002 Dubrovka Theater Incident against Chechen rebels).[65]

In this sense, the absence of military investments in non-lethal applications of cognitive sciences is curious, particularly when there is the increasing realization of the need for non-lethal weapons in today's counterinsurgency and asymmetric warfare often fought in highly urban terrain. Furthermore, US defense planners are cognizant of the potential of non-lethal applications from the emerging cognitive sciences research. The Joint Non-Lethal Weapons Directorate (JNLWD), established in 1997, as well as the 711th Human Performance Wing in the Air Force, have called for proposals to explore the "Chemical Immobilizing Agents for Non-Lethal Applications," and "'Chemical pathway area…to degrade enemy performance and artificially overwhelm enemy cognitive capabilities'" in 2000 and 2009, respectively.[66] Yet, very little, if any, visible military investments have gone to this area of performance degradation application of cognitive sciences research in the past decade.

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[63] And it is also important to note that this ambiguity in the CWC was discussed during the 2nd Review Conference in 2008 and 3rd Review Conference in 2013 without resolution.

[64] Alan Pearson, "Late and Post-Cold War Research and Development of Incapacitating Biochemical Weapons," in *Incapacitating Biochemical Weapons: Promise or Peril?* ed. Alan M. Pearson, Marie Isabelle Chevrier, and Mark Wheelis (Lanham, MD: Lexington Books, 2007), 89.

[65] Mark Wheelis, "Nonconsensual Manipulation of Human Physiology Using Biochemicals," in *Incapacitating Biochemical Weapons: Promise or Peril?* ed. Alan M. Pearson, Marie Isabelle Chevrier, and Mark Wheelis (Lanham, MD: Lexington Books, 2007), 5-6.

[66] See Department of Defense, *Chemical and Biological Defense Program*, "Topic CBD00-108: Chemical Immobilizing Agents for Non-lethal Applications," Small Business Innovation Research Solicitation, FY 2000, http://www.acq.osd.mil/osbp/sbir/solicitations/sbir20001/cbd001.doc (accessed September 10, 2016), CBD-13-14.

This pattern of US military investments in the emerging cognitive sciences begs the question "Why do states invest militarily in some areas of emerging S&T but not others?" Additionally, it raises several other interesting and related questions:

1) Since investments in emerging S&T are shrouded with uncertainty, how do states invest as a technology first-mover?

2) What happens when they do not hedge? What guides their investment decisions?

The lack of hedging in US military investments in the emerging cognitive sciences research is not entirely unique. States do not always hedge even when faced with great uncertainty in emerging S&T investments. For instance, when considering nanotechnology investments, others have observed how Russia and the US make divergent investment paths in spite of uncertainty.[67] This dissertation, therefore, seeks to examine how a state invests militarily in an area of nascent science and technology research as a technology first-mover. It explores the possibility that when facing uncertainty, states make investments by pursuing a strategy of managing opportunities rather than mitigating risk.

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[67] Adam N. Stulberg, "Flying Blind into a New Military Epoch: The Nanotechnology Revolution, Emerging Security Dilemmas, and Russia's Double-Bind" (paper presented at annual convention of the International Studies Association, New York, NY, February 2009).

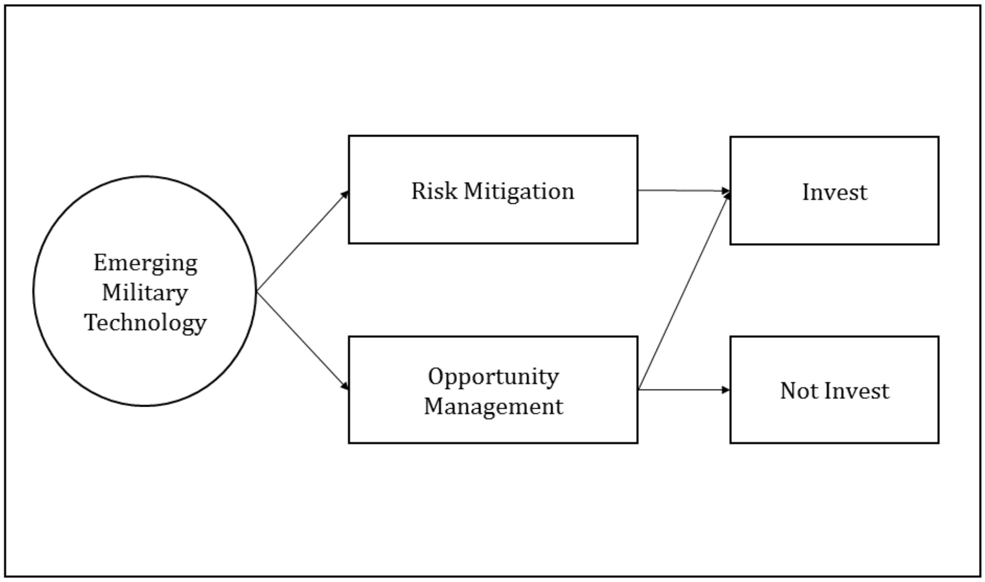

Figure 4 – Two Perspectives on First-Mover Behavior

2.6 The Concept of Opportunity

As shown in Figure 4, when making investment decisions amidst great uncertainty, a technology first-mover's strategy can be understood from two different perspectives. As suggested before, the first-mover may hedge its investments by being flexible. The hedging strategy, which broadens the investment portfolio by investing widely and delaying commitment to any particular technology, helps an investor manage uncertainty by mitigating against potential risks in the R&D process. In the case of investments in an emerging S&T like the cognitive sciences, the hedging strategy would suggest that the United States invests across as many cognitive sciences-based military capabilities as possible, including medical and health applications, performance enhancement applications, and performance degradation applications. In this sense, for a state pursing a hedging strategy, one should not observe an area of emerging military technology that does not receive investment, and certainly not one that has the most direct military utility.

However, as shown in the manner that the US has actually invested in cognitive sciences, the first-mover may sometimes invest in only a subset of potentially military-relevant areas of emerging S&T. In those instances, the investor's decisions are likely influenced by how the opportunities of the investment are understood. Opportunity, in this case, includes both the projected utility that can be derived from a technology as well as the set of conditions that will lead to the realization of such projected utility. The management of opportunity, therefore, means structuring investments in a manner that will maximize the likelihood that certain utilities will be realized. It also provides a means to understand why certain technologies are invested in while others are not – in the most simple sense, the technologies that do not get invested in may be unappealing opportunities.

Avoiding risk amidst uncertainty is conventional wisdom, but in practice, when states invest in emerging military technologies, some get money and others do not. Hence, it is important to understand how defense investment decisions may be framed according to opportunities rather than risk. Framing and differentiating technological investments according to the opportunities they present provides a way to understand why some areas of an emerging technology are pursued by a first-mover while others are not. Whereas a strategy of risk mitigation, such as hedging, avoids prioritizing investment in a given technology, a strategy of managing opportunities explains how such a prioritization would occur precisely because the technological options are different in terms of their projected utility as well as the circumstances that will lead to their projected utility's realization.

In other words, framing S&T investments according to opportunities provides a way to show how various emerging technologies are in fact different from one another. Not only are utilities of different emerging military technologies different, but the circumstances (or conditions) under which these technologies can be realized are also different. The following two chapters examine this concept more closely. Chapter 3 defines the dependent variable – the defense or military investment in S&T – and provides a review of three theoretical perspectives of defense S&T investment, with attention to how opportunity is understood under each perspective. Chapter 4 expands on this concept of opportunity and provides an argument for why, under certain technical conditions, an emerging military technology may be an unappealing investment opportunity despite its military utility.

CHAPTER 3. DEFENSE S&T INVESTMENT – CONSEQUENCE OF STRUCTURAL IMPERATIVES, IDEATIONAL FRAMING, OR BUREAUCRATIC INTERESTS?

3.1 The Dependent Variable: Defense S&T Investment

This dissertation seeks to explain investment in emerging defense S&T. It asks whether or not, to what extent, and why an area of S&T is funded by the defense establishments in a given country for the purpose of obtaining certain military capabilities. Defense establishments, in this case, refer to government agencies that are responsible for the supervision, coordination, and provision of national defense and national armed forces operations. In the United States, such establishments would entail an agency such as the Department of Defense. Although defense contractors are also often considered part of a country's defense establishments, their investments toward basic and applied research, such as independent research and development (IR&D) projects, do not count as defense S&T investment. The IR&D projects are initiated by contractors but not performed under contract, and most are conducted to improve existing products, meet dual-use demands, or address a known or potential requirement.[68] While such projects contribute to and help shape a country's defense S&T programs, they do not directly represent the defense establishments' priorities and interests. Therefore, they are not considered part of the defense establishments for the purpose of evaluating S&T program funding in this dissertation.

[68] "Dual-use" here refers to the traditional definition, which indicates a technology's ability to be used in both civilian as well as military sectors. For the US Department of Defense's definition of IR&D, see Federal Acquisition Regulation (FAR) 31.205-18, "Independent Research and Development and Bid and Proposal Costs," http://www.defenseinnovationmarketplace.mil/resources/FAR_31.pdf (accessed October 6, 2016).

The term S&T, in the context of defense investments, refers to the earliest stages of a defense establishment's Research, Development, Testing, and Evaluation (RDT&E) process. In the case of the United States, it entails basic research, applied research, and advanced technology development. In terms of funding, these activities fall under budget categories 6.1, 6.2, and 6.3 in the annual budget requests for the Department of Defense. The definitions of these activities are summarized in Table 1 below.

Table 1 - Budget Categories and Definitions for Defense S&T Programs in the US

Budget Category	R&D Activity	Definition
6.1	Basic Research	Systematic study directed toward greater knowledge or understanding of fundamental aspects of phenomena and of observable facts without specific applications towards processes or products in mind
6.2	Applied Research	Systematic expansion and application of knowledge to develop useful materials, devices, and systems or methods…directed toward general non-system specific military needs
6.3	Advanced Technology Development	Development of subsystems and components and efforts to integrate subsystems and components into system prototypes for field experiments and/or tests in simulated environments

Investment here refers to government funding. Defense investment, in this dissertation, refers to government funding channeled through and managed by the defense establishments. For the Department of Defense, such funding may occur through multiple channels: in addition to contract programs with laboratories and industries, DoD also funds S&T research through other collaborate avenues, including partnerships with universities through the Multi-Disciplinary University Research Initiative (MURI) or with small businesses through the Small Business Innovation Research (SBIR) Program. During the appropriation process, Congress may also earmark and fund specific programs or areas of

R&D through the DoD. These earmarked programs will also become part of defense S&T investment. Collectively, these streams of money from the DoD constitute the defense S&T investments in the United States.

Multiple research institutions perform R&D with funding from the DoD, ranging from national laboratories to small businesses. These institutions have been collectively referred to as the defense research (& engineering) enterprise,[69] and they can be either intramural or extramural to the defense establishments. Although variation exists, across the services in the US, basic research is most often conducted in university and service-specific laboratories, whereas applied research and technology development, for the most part, take place in service and industry laboratories. Figure 5 below shows the general distribution of the recipients of DoD S&T funds (using the 2008 President's Budget as an example). Defense-wide R&D institutions such as the Defense Advanced Research Projects Agency (DARPA) and the Defense Threat Reduction Agency (DTRA) also manage programs for both intramural and extramural defense R&D, although neither is associated with specific in-house laboratories.

[69] See, for instance, National Research Council, *Strategic Engagement in Global S&T: Opportunities for Defense Research* (Washington, D.C.: The National Academies Press, 2014) and Office of Assistant Secretary of Defense for Research & Engineering, *DoD Research and Engineering Enterprise* (Washington, D.C.: Department of Defense, 2014).

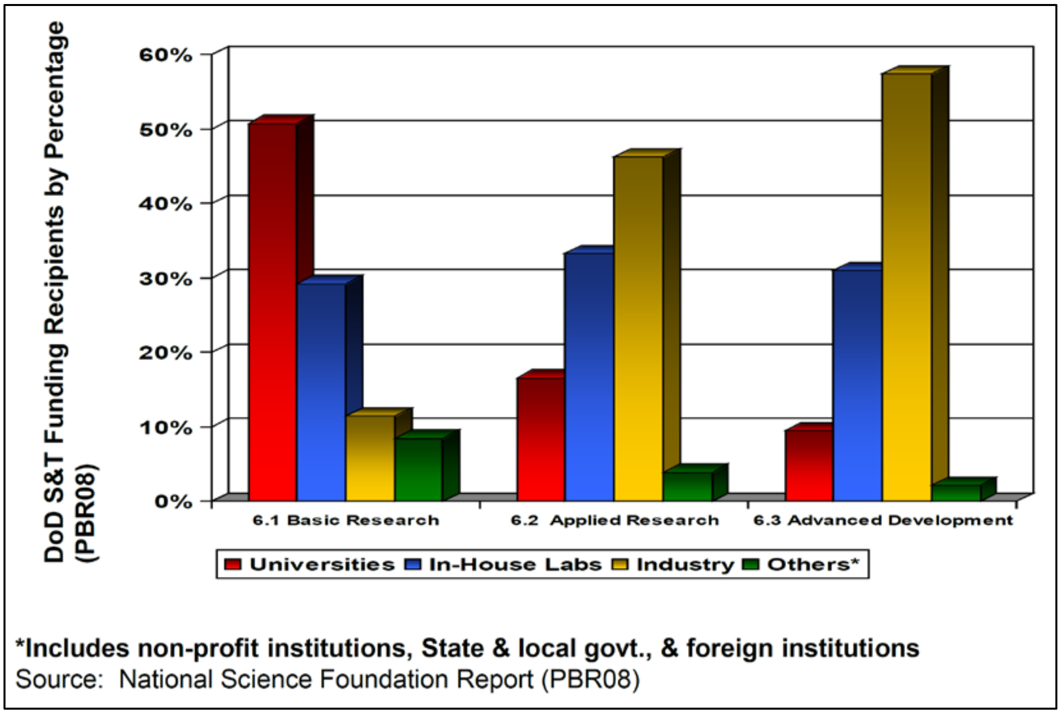

Figure 5 - Recipients of DoD S&T Funding[70]

For the purpose of this dissertation, defense S&T investment in the US is operationalized dichotomously as either present or absent. The presence of defense S&T investment indicates that a given area of S&T has been funded by the DoD. This can be measured directly as funding for programs shown in the President's Budget, regardless of the type of funding (whether a MURI, SBIR, or other types of funding contract) or the recipient of such funding. The absence of investment indicates that a given area of S&T does not appear in the budget request, even if it has otherwise been discussed in public or policy discourses as an area that warrants S&T investment from the defense establishments or has appeared in the DoD's request for proposals (RFPs). The presence and absence of funding, thus, also reflect a defense establishment's decision to invest or not to invest in an

[70] Bob Baker, "Fiscal Year 2011 President's Budget Request for the DoD Science and Technology Program" (Briefing at the 12th Annual Science & Engineering Technology Conference, National Defense Industrial Association, North Charleston, SC, June 21, 2011).

area of S&T. An indirect measure can also be used by examining the extent to which a program exists in official government records, which may include descriptions of research activities that have been undertaken as shown in research or other government reports. Both measures are used in this dissertation to determine the presence or absence of defense or military investment in an emerging technology.

As is the case in many other countries, federal R&D funding for defense-related technologies in the US can be subjected to control and regulation. Most often, such measures occur through the classification of information. It is therefore possible that a technology program does not appear explicitly in public documents such the President's Budget because it has become classified (gone "black"). It is important to note, however, that most programs that are still at the S&T stages of R&D are required by law to remain unclassified, and this is particularly true since 1985 when National Security Decision Directives (NSDD) 189 mandated that "the products of fundamental research remain unrestricted."[71] This policy has since been upheld by subsequent administrations, most recently in 2010 by Ash Carter, then Under Secretary of Defense for Acquisition, Technology, and Logistics. Emerging military technologies considered in this dissertation, most of which entails primarily basic and applied research, should therefore be unclassified and traceable in the annual budget or other publicly available records should they receive investment from the DoD.

3.2 The Context of Current Literature

If one accepts that military technology plays an important, if not pivotal, role in both national and international security, then the question of how military investments are

[71] Fundamental research here refers to basic and applied research in science and engineering. See The White House, National Security Decision Directive 189, "National Policy on the Transfer of Scientific, Technical, and Engineering Information" (September 21, 1985), http://fas.org/irp/offdocs/nsdd/nsdd-189.htm (accessed October 6, 2016).

made in emerging S&T deserves further scrutiny. Yet, the extant literature has yet to provide a satisfactory answer to this question. This lack of insight on defense S&T investment is perhaps understandable for a couple of reasons. First, much of the literature that concerns the politics of defense acquisition has focused on major weapons systems or military platforms.[72] There are good reasons why so much attention has been given to weapons systems and platforms like the strategic bombers, ICBMs, or missile defense. Since they constitute the bulk of the defense acquisition budget, both in terms of RDT&E as well as procurement, and they make up a large portion of the strategic and operational capability for the US military, an understanding of how these systems develop and whether they are successful is critical. Yet, this almost exclusive focus on major weapons systems and platforms also has limitations. Because the security and financial ramifications of their success or failure are significant, these studies have typically focused on later stages of the acquisition process (technology development, testing, evaluation, and procurement) rather than initial S&T investment decisions. As a result, they provide rather limited direct insight into the questions that concern this dissertation. Furthermore, since the R&D activities for major military systems and platforms are conducted by defense contractors, the explanations for R&D focus on the military-industry-Congress relationship with little attention paid to the functions of basic research and the roles of scientists outside the military-industrial complex (i.e., university scientists).

The second reason why the existing literature provides little insight into states' military S&T investments results from the inherent difficulty in studying this type of

[72] For a select set of examples, see Harvey M. Sapolsky, *The Polaris System Development: Bureaucratic and Programmatic Success in Government* (Cambridge, MA: Harvard University Press, 1972); Ted Greenwood, *Making the MIRV: A Study on Defense Decision Making* (Cambridge, MA: Ballinger Publishing Company, 1975); Edmund Beard, *Developing the ICBM: A Study in Bureaucratic Politics* (New York, NY: Columbia University Press, 1976); Lauren H. Holland and Robert A. Hoover, *The MX Decision: A New Direction in U.S. Weapons Procurement Policy?* (Boulder, CO: Westview Press, Inc., 1985); Michael E. Brown, *Flying Blind: The Politics of the U.S. Strategic Bomber Program* (Ithaca, NY: Cornell University Press, 1992); and Graham Spinardi, *From Polaris to Trident: The Development of US Fleet Ballistic Missile Technology* (New York, NY: Cambridge University Press, 1994).

inquiry. Studying why technologies are generated in the form and pursued in the direction they are is no easy task. Most researchers are more inclined to treat the direction of technological innovation as a given or as exogenous to the explanations at hand. In fact, "[s]ocial scientists have generally been reluctant to examine the causes of technical change, preferring instead to analy[z]e its consequences."[73] It arguably is easier to assess the impact that technology may have on the international system and military affairs than to explore why certain technologies or technological options are favored.[74] In this sense, technological innovation is often considered a possible, if not important, contributor to explanations of issues concerning military and security, but the nature of the actual technological pursuits is rarely examined itself.

The following sections provide a critical overview of three theoretical perspectives that have been used to examine the question of defense S&T investment: structural realism, social constructivism, and bureaucratic politics. The analysis focuses on why these theoretical perspectives are relevant to the question of defense S&T investment. An analysis of the limitations of each theoretical approach will conclude each section.

3.3 Realism and Structural Imperative

3.3.1 The Logic of Structural Realism

One of the explanations for the presence or absence of defense investments in emerging technologies can be derived from structural security imperatives. Structural

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[73] Ajey Lele, *Strategic Technologies for the Military: Breaking New Frontiers* (Thousand Oaks, CA: SAGE Publications Inc., 2009), 4.

[74] This is not to say that the work examining the implications of technology on the international system or military affairs is not important but merely that it is abundant. At a minimum, the body of literature that has come to be known as the offense-defense theory addresses the first and the policy and scholarly literature on revolution in military affairs (RMA) the second. One may consult Michael E. Brown et al., eds., *Offense, Defense, and War* (2004) for discussion on offense-defense theory, and Cohen (1996): 37-54; Jeffrey McKitrick et al., "The Revolution in Military Affairs," in *Battlefield of the Future: 21st Century Warfare Issues*, ed. Barry R. Schneider and Lawrence E. Grinter (Maxwell AFB, AL: Air University Press, 1995), 65-97; and Krepinevich (1994) among others for discussions on RMA.

realism holds that the roots of state behavior lie in the structure of the international system. This structure, according to Waltz, entails an ordering principle of anarchy, sovereign states that are functionally undifferentiated, and the distribution of capabilities among them.[75] In this anarchic international environment, which indicates the lack of a higher sovereign capable of managing the actions of the states, each state is forced to assure its own survival. As Waltz reasons, "in any self-help system, units worry about their survival, and the worry conditions their behavior."[76] Anarchy thus produces a structural constraint in the international system that encourages states to do what they can to ensure their security and penalizes those who fail to respond to this encouragement. A state engaged in self-help thus has the goal, first and foremost, to maximize its security.

Since in an anarchic international environment "some states may at any time use force, all states must be prepared to do so—or live at the mercy of their militarily more rigorous neighbors."[77] Yet, a state's actions to maximize its own security may inadvertently provoke others. This phenomenon, known as the "security dilemma," is a consequence of the zero-sum assumption of states' relative capabilities as well as states' inability to be sure of the intentions and actions of others.[78] The security dilemma is a constant feature in the international system and cannot be resolved, but its effects can be exacerbated or mitigated. It is with respect to managing the security dilemma that the different strands of structural realism diverge in their predictions of state behaviors.

3.3.1.1 Offensive Realism

[75] Waltz (1979), 88-99.
[76] Waltz (1979), 105.
[77] Waltz (1979), 102.
[78] See Jervis (2004), 3-50. For elaborations on the mechanisms of the dilemma, see Charles Glaser, "The Security Dilemma Revisited," *World Politics* 50(1) (October 1997): 171-201; and Ken Booth and Nicholas Wheeler, *The Security Dilemma: Fear, Cooperation and Trust in World Politics* (New York, NY: Palgrave Macmillan, 2007).

Simply stated, offensive realists argue that in the anarchic international environment states are best off maximizing their own relative capability for the sake of achieving security regardless of cost. From the perspective of offensive realism, a state can never be completely sure of the intention of others in the international system. Some states will inevitably have some type of offensive military capability, and a state will always be uncertain how much military power it needs in order to ensure its survival. These conditions suggest that states have reason to fear each other. States, realizing that they can best ensure their survival by being the most powerful entity in the international system, do whatever they can to stay ahead of others.

According to John Mearsheimer, great powers in an anarchic system are always primed for offense. Even if a great power does not possess the capacity to achieve hegemony, "it will still act offensively to amass as much power as it can, because states are almost always better off with more rather than less power."[79] States therefore are always exploiting opportunities to take advantage of one another and are willing to use any measure that helps them gain advantage over others. States thus constantly engage in security competition, and the security dilemma, as a result, cannot be effectively ameliorated as long as states operate under anarchy.

3.3.1.2 Defensive Realism

Whereas offensive realists maintain that states in an anarchic system will continue to engage in power competition, since they cannot ensure their security otherwise, defensive realists argue that states can in fact achieve security without provoking others. Defensive realists claim that states can ensure their security by maintaining the balance of power and that the effect of the security dilemma can be alleviated by the existing offense-

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[79] John Mearsheimer, *The Tragedy of Great Power Politics* (New York, NY: W. W. Norton & Company, Inc., 2001), 35.

defense balance. Offense-dominance and the inability to distinguish offense from defense worsen the security dilemma and encourage conflict. Defense-dominance and the ability to distinguish defense from offense lessen the severity of the security dilemma, providing potential for peace and cooperation.

Unlike offensive realists who argue that great powers will remain unsatisfied with the status quo unless they can achieve hegemony, defensive realists suggest that under certain conditions, it is possible for status quo powers to adopt compatible or cooperative security policies rather than competitive ones.[80] For them, a state's efforts at self-preservation do not have to result in power competition such as an arms race. This is especially true if the risks and costs of such a competition are high, if defense is dominant and the capabilities necessary to achieve defense are distinguishable from offensive ones, and when states are able to communicate their benign intentions through visible military policies. In short, even in an anarchic environment, rational actors, defensive realists argue, can reduce the competitive effect of security dilemma.

3.3.2 Predictions of Structural Realist Explanations

Offensive and defensive realists offer divergent predictions on a state's defense S&T investments through different mechanisms. For offensive realists, the anarchic international environment and its inherent uncertainty provide strong incentives for states to invest in and exploit any S&T option available. In other words, if a state has the capacity to pursue a new military technology, it should do so.

[80] Charles L. Glaser, "Realists as Optimists: Cooperation as Self-Help," *International Security* 19(3) (Winter 1994): 50-90.

The logic behind offensive realism-based understanding of a first-mover imperative is perhaps best shown in John Mearsheimer's articulation of reasons behind the competition for nuclear superiority:

> Great powers always prefer to be the first to develop new technologies; they have to make sure that their opponents do not beat them to the punch and gain the advantage for themselves. Thus, it made sense for each superpower to make a serious effort to develop counterforce technology and ballistic missile defense. At a maximum, successful breakthroughs might have brought clear superiority; at a minimum, these efforts prevented the other side from gaining a unilateral advantage.[81]

In this sense, offensive realism predicts that states will always have an incentive to be a technology first-mover, and it also predicts that states will invest, at a maximum, in everything they can, and at a minimum, according to the threats that exist in the international environment. In other words, for offensive realists, defense S&T investment is an imperative, but their argument is limited in lending theoretical insight as to why some technologies are pursued but not others. It also fails to account for the variance in technological investments across states. Particularly in an environment where sources of threat are fluid and resources are limited, offensive realism faces difficulty generating useful predictions regarding military technology investments.

For defensive realists, technology contributes to the determination of offense-defense balance. Technology that confers advantage to attackers contributes to offense-dominance, whereas technology that confers advantage to defenders increases defense-dominance. In this sense, offense-defense balance is a systemic variable, and the technology that defines it is assumed to have systemic effects on a given era of warfare.

[81] Mearsheimer (2001), 232.

When offense-defense balance is treated as a systemic variable, and the nature of the technology is treated as a given, the theory itself provides no direct prediction as to why a state would invest in military technologies a certain way.

It is possible, however, to define the logic of offense-defense balance in a dyadic manner (between two states, for instance) rather than a feature of the international system.[82] In the dyadic formulation of offense-defense balance, it is possible that a state may be inclined to invest in new military technologies according to the impact it will have on the offense-defense balance. For instance, a state may be inclined to invest in offensive technologies in order to tip the balance towards offense, or vice versa. This, of course, not only requires a clear understanding of how to measure the offensive vs. defensive nature of a technology, but it also requires a definable source of threat in the international system to which a state is responding.

In his critical assessment of defensive realists' claims, Keir Lieber finds that determining offense-defense balance and distinguishability is difficult and predictions are often empirically unsound, but he agrees that states can, and often, exploit a technology to advance policy objectives. Labeling this "technological opportunism," Lieber suggests that "states will rarely view technological developments as means to maintain status quo or preserve their power position," and "even defensive technological advances will tend to be seized upon by states as potential opportunities to pursue offensive political objectives."[83] For Lieber, states invest in an area of technology in order to advance their policy objectives, and since states are primed for offense, such investments are more likely to be leveraged for offensive policies than to preserve the status quo.

[82] Charles L. Glaser and Chaim Kaufmann, "What is Offense-Defense Balance and Can We Measure It?" in *Offense, Defense, and War*, ed. Michael E. Brown, Owen R. Coté Jr., Sean M. Lynn-Jones, and Steven E. Miller (Cambridge, MA: The MIT Press, 2004), 266-304.

[83] Keir Lieber, *War and Engineers: The Primacy of Politics over Technology* (Ithaca, NY: Cornell University Press, 2005), 5.

3.3.3 Critique

Structural realism has been the dominant theory in providing explanations and predictions in the security realm. Its parsimony and intuitive appeal have permitted derivation of its logic for a variety of explanations on state behavior. When leveraged to explain a state's investment decision in an emerging military technology as a first-mover, however, realism provides mixed results. Offensive realism provides the structural logic behind a state's pursuit of being a technology first-mover, and confirms the intuition (or conventional wisdom) that capable states tend to hedge their military technology investments when facing uncertainties. Yet, its understanding of S&T investments as an imperative does not help explain why in some instances states opt not to invest in a military-relevant technology.

Defensive realism provides a more nuanced understanding of investment choices. Defensive realist logic allows for the possibility that states may invest according to the impact that the technology has on the offense-defense balance. In other words, the opportunity presented by an emerging technology can be framed as either offensive or defensive. For a technology first-mover in a strategic environment shrouded with uncertainty, however, applying the offense-defense framework may be difficult, for its predictions rely on a dyadic evaluation of offense-defense balance, which requires an identifiable opponent as well as ways to measure the offensive or defensive nature of new technology. As a result, applying offense-defense theory may be difficult for a technology first-mover due to strategic and technological uncertainty.

3.4 Constructivism and Organizational Frame

3.4.1 The Logic of Organizational Frame

In recent years, the social constructivist approach has been increasingly leveraged to understand security issues.[84] Constructivist approaches emphasize the role of concepts such as norms, identities, and ideas in explaining social outcomes. Under the constructivist perspective, neither structure nor agency has ontological priority in the classic agent-structure debate typical for the study of social phenomena, but both are treated as mutually constitutive. Under constructivism, structures represent shared meanings between agents that arise out of their interactions, and in turn, constrain and shape the agent's actions.

One of the variables that has increasingly been used to explain organizational behavior is "organizational frame." In her study on the fire damage of nuclear weapons, Lynn Eden identifies organizational frames as "frameworks for action that structure how actors in organizations identify problems and find solutions."[85] Organizational frame emerges from the social construction of knowledge-laden routines. As organizations solve problems, they allocate and build organizational capacity on certain problems but not others. The accumulation of organizational capacity in solving certain problems creates organizational knowledge that is codified (formally or informally) into routines. These routines, in turn, enable the organization to be able to perform certain function and solve certain problems while at the same time constraining the scope of the organization's problem-solving.

In this sense, organizational frame resembles the idea of path dependence in historical institutionalism. Path dependence suggests that at any given decision point (or

[84] For a selection of work that typify this approach, see Peter J. Katzenstein, ed., *The Culture of National Security: Norms and Identity in World Politics* (New York, NY: Columbia University Press, 1997); Elizabeth Kier, *Imagining War: French and British Military Doctrine Between the Wars* (Princeton, NJ: Princeton University Press, 1997); Richard M. Price, *The Chemical Weapons Taboo* (Ithaca, NY: Cornell University Press, 1997); and Nina Tannenwald, *The Nuclear Taboo: The United States and the Nonuse of Nuclear Weapons since 1945* (New York, NY: Cambridge University Press, 2007).

[85] Lynn Eden, *Whole World on Fire: Organizations, Knowledge, & Nuclear Weapons Devastations* (Ithaca, NY: Cornell University Press, 2004), 50. See also Kathleen M. Vogel, *Phantom Menace or Looming Danger: A New Framework for Assessing Bioweapons Threats* (Baltimore, MD: The Johns Hopkins University Press, 2013) for use of technology frames in explaining the intelligence analysis of bioweapon threats.

critical juncture), the actions taken become the basis for future actions. Similar to path dependence, the construction of an organizational frame is self-reinforcing—with each new problem that an organization faces and solves that fits within the organizational frame, greater organizational capacity to problem-solving is generated and the routines of problem-solving are reinforced. As explained by Eden, "past choices and actions structure future possibilities, both by shaping the understandings that actors bring to the new situations and by shaping the social environment in which decisions are made and carried out."[86] Like path dependence, the self-reinforcing nature of the organizational frame makes change and outside learning difficult.

Yet, organizational frame differs from historical institutionalism in one important regard: whereas path dependence focuses on why an outcome occurs the way it does by showing its historical lineage, the concept of framing provides a way to visualize why some outcomes, actions, or missions are *not* present, considered, or pursued. In other words, the concept of framing provides logic to the cases of "dogs that don't bark." Just like the way framing is used in photography – materials that fall outside the frame are outside precisely because they are not the focus.

3.4.2 Predictions of Organizational Explanations

This effect of framing has been leveraged to explain the notion of "neglect" of biodefense from military research, development, and acquisition (RDA) in the United States. According to Frank Smith, organizational frames are "shared assumptions and heuristics that organizations use to solve problems," and "[s]hared assumptions and heuristics are ideas that provide a framework for interpreting reality."[87] Since the assumptions and heuristics only bring attention to a selected subset of reality, the

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[86] Eden (2004), 51.

[87] Frank L. Smith III, "A Casualty of Kinetic Warfare: Military Research, Development, and Acquisition for Biodefense," *Security Studies* 20(4) (November, 2011): 671-2.

"problems and solutions that are salient inside an organization's frame benefit from ample if not excessive attention," whereas "problems and solutions that fall outside of an organization's dominant frame are systemically deprived of resources."[88] As a result, issues that fall outside an organization's frame of reference are neglected precisely because they do not receive the attention needed for their comprehension.

Smith argues that the reason why biodefense is neglected by the US military is because it falls outside the military's organizational frame of kinetic warfare. The kinetic warfare frame of reference involves projectile weapons and explosives, and disease-based bioweapons and biodefense that are non-kinetic consequently fall outside the military's organizational frame. Since the organizational frame defines the types of problems an organization will solve through research, development, and acquisition, biodefense is neglected in the military's RDA efforts.

Smith's explanation of the neglect of biodefense lends important insight to the question of why states may invest heavily in some areas of emerging military technology but not others. According to his hypothesis on RDA, the opportunity to invest in an emerging military technology is defined by the kinetic warfare frame of reference. Therefore, military applications that provide opportunities for kinetic warfare will be invested in, while others that do not will be neglected and receive comparatively less attention and funding.

3.4.3 Critique

Organizational frame provides a parsimonious explanation as to why some technologies are pursued in earnest while others are not: technologies that fall within the organizational frame will get the attention and receive resources for research, development,

[88] Smith (2011), 672.

and acquisition, and technologies that fall outside the frame will be neglected. There are, however, several problems with explaining military investment decisions through organizational frame. First, the kinetic frame that the military supposedly espouses has difficulty explaining certain empirical facts. Smith argues that the military's frame of reference for RDA decisions is kinetic warfare and that technologies that are considered kinetic will receive attention. However, the medical application investments in cognitive sciences as well as information security-related investments by the DoD in recent years are both non-kinetic. The military's organizational frame, thus, does not seem to explain these instances of investment and organizational attention.

Second, the organizational frame argument Smith employs assumes that the military and its frame of reference is the only one that matters. His explanation on RDA decisions using organizational frame focuses on only one organization, which in this case is the military. Yet, investment as well as acquisition decisions are complex processes that involve more than just the military services. In this case, how other actors' frame of references are accounted for and to what extent they matter is unclear. This oversight is especially important when the empirical evidence shows that the military makes decisions to invest in areas outside its frame of reference.

Finally, it is not clear why "kinetics" is the organizational frame that would define a military's investment in a given area of S&T rather than a different frame of reference. Although the goal for the military's RDA process is to produce military capabilities to engage and hopefully succeed in armed conflicts, RDA as a decision process itself involves more than just considerations for the production of kinetic capabilities. For instance, some defense agencies, such as DARPA, invest in high-risk, high-payoff technologies that carry the potential to influence how warfare is conducted, whereas the services' investments, even in basic and applied research, are often targeted at evolutionary improvements to existing capabilities. Whether and to what extent such "shared heuristics" as to how these organizations understand their primary missions in S&T investments influence their decisions is unlikely to be accounted for in an explanation that defines military technologies merely along the lines of kinetics versus non-kinetics. In other words, frames of reference, as an ideational and social construct, can be highly fluid. Since they can be defined in a myriad of ways, why certain frames dominate over others in the RDA process begs further scrutiny.

3.5 Bureaucratic Politics and Interest Competition

3.5.1 The Logic of Bureaucratic Politics

Unlike the structural arguments proposed by the realists which derive the incentive and explanation of military technology investment decisions externally, and organizational frame arguments that derive explanations from the frame of reference of a single organization, the bureaucratic politics model argues that decision processes in reality are often much more complicated. Bureaucratic politics proponents, such as Graham Allison and Morton Halperin in their studies of foreign policy decision-making, eschew the idea that political decisions can be understood structurally. Instead, they suggest the need to "open the black box" of domestic politics in order to gain insight into the policymaking process. In the simplest sense, the bureaucratic politics model suggest that the concepts of "state" and "government" are in fact a collection of agencies, bureaucracies, organizations, and individuals, each with its own set of parochial interests and objectives.[89] Thus, so-called policy decisions result from competing interests of a constellation of subnational political actors.

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[89] One may consult Graham Allison and Philip Zelikow, *Essence of Decision: Explaining the Cuban Missile Crisis* (New York, NY: Addison-Wesley Educational Publishers Inc., 1999); James Q. Wilson, *Bureaucracy: What Government Agencies Do and Why They Do It* (New York, NY: Basic Books, 1989); and Morton H. Halperin and Priscilla A. Clapp, *Bureaucratic Politics and Foreign Policy* (Washington, D.C.: Brookings Institution Press, 2006).

Applying the model of bureaucratic process and organizational interests, John Alic has observed that institutionally, the process of defense acquisition in the United States involves three sets of relationships that help determine the decision outcome: the inter- and intra-service rivalries, the competition between military and civilian authorities, and the interaction between the policymakers and the industry.[90] These overlapping relationships suggest that the choice of investment or, in this case, acquisition at large, is rarely defined by national interests. Similarly, emphasizing the interests of armed services, Thomas Mahnken suggests that it is the culture of the individual US armed services that influences and helps determine the technologies they choose to pursue.[91] Investment decisions, in this sense, are a result of individual services picking and choosing technologies to suit their organizational culture.

According to the bureaucratic politics model, the presence or absence of investment in a military technology is likely to result from different agencies or political actors competing for influence in the decision process. Such an argument has intuitive appeal, since it better captures the complexity and multiplicity of actors involved in the policymaking process than the unitary actor assumption embedded in structural arguments. Indeed, the majority of Cold War-era studies of military innovation, which focuses less on S&T investments but more on military systems acquisitions, employs various forms of bureaucratic politics arguments. For instance, in his study of the Air Force's development of its intercontinental ballistic missile (ICBM) program, Edmund Beard notes the civil-military struggle and highlights the importance of civilian intervention in reshaping the Air Force's traditional preference towards manned bombers.[92] Harvey Sapolsky and Michael Armacost similarly evoke inter-service rivalry in their studies of the Polaris missile systems

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[90] John A. Alic, *Trillions for Military Technology: How the Pentagon Innovates and Why It Costs so Much* (New York, NY: Palgrave MacMillan, 2007), 7-10.

[91] Thomas G. Mahnken, *Technology and the American Way of War* (New York, NY: Columbia University Press, 2008), 11.

[92] Beard (1976).

and the Thor-Jupiter controversy, respectively.[93] Bureaucratic interest competition is thus a common alternative to structural arguments when the latter fail to generate useful explanations or predictions.

3.5.2 Predictions of Bureaucratic Explanations

Despite its popularity, the bureaucratic politics and interest competition model provides surprisingly little direct and predictive insight into the presence or absence of investment in a military S&T program. In a general sense, the bureaucratic politics model argues that the players involved in policy decisions have different preferences that reflect their parochial interests. The various military applications derived from emerging S&T, thus, represent different opportunities and have different meanings for different bureaucracies, and each has its own interpretation of what these new applications and capabilities mean and has varying degrees of interest in them. Some opportunities will appeal to the interest of certain agencies and organizations but not others. As a result, the interest competition between different agencies helps influence which opportunities are pursued and, in turn, which areas of S&T are invested in.

This type of explanation is of course difficult to operationalize without specifying what the interests for the various bureaucratic actors are and what these technologies mean to them. It is also difficult to generate any prediction as to whose interest will ultimately win out in the competitive process without specifying the rules of the game and what determines success. For some, the common interests that define all bureaucratic actors are greater resources and more autonomy in performing their bureaucratic missions. In other words, all bureaucracies, whatever their other parochial interests may be, will chase after more money and independence. This insight, then, helps to generate some predictions, less so about defense S&T investment decisions, but about bureaucratic behavior in light of

[93] Sapolsky (1972) and Armacost (1969).

such an investment. First, an agency or organization that is funding a certain S&T program is unlikely to surrender it to other agencies or organizations. Second, when facing a new area of investment, an agency or organization is likely to try to legitimize its claim over this new "pot of money" in order to expand its proverbial "turf" vis-à-vis others.

3.5.3 Critique

The bureaucratic politics and interest competition model provides a compelling vision of how the political reality of policymaking might work. Without carefully defining the interests of each actor, the rules of the interest competition, and the criteria for success, the bureaucratic politics model, however, cannot generate predictions about defense S&T investment *a priori*. In fact, it is a common critique that when underspecified, bureaucratic politics arguments are tautological: a bureaucratic actor's interest in a specific defense S&T investment wins out because that S&T program is invested in. In this sense, the bureaucratic politics model is good at providing detailed explanations of the policy process, but poor at predicting policy outcomes.

If one were to accept the assumption that all bureaucratic actors desire more resources and greater autonomy, then such defined interests may yield some predictions about bureaucratic behavior concerning an S&T investment. Yet, such predictions that a bureaucratic actor is unlikely to give up its "turf," if not actively try to expand it, merely reinforce why an emerging military technology is likely to be invested in, yet do not explain a lack of investment. In short, the bureaucratic politics model provides limited utility in explaining the presence or absence of a defense S&T investment.

3.6 Conclusion

When an emerging military technology arrives on the scene, great powers with the capability to pursue R&D as a technology first-mover have an interest in doing so. Yet, as shown by the way that the US has invested in the military research of cognitive sciences, not all military applications based on this research received attention and investment. Why are some emerging military technologies invested in while others are not? What accounts for the presence or absence of defense investment in an emerging technology?

The above analysis outlines three major perspectives that can be employed to explain decisions concerning defense S&T, but each has fallen short to account for why certain programs are funded by a technology first-mover while others are not. In the following chapter, I seek to provide an explanation by leveraging insights from the Social Construction of Technology (SCOT) literature. I argue that explanations based on structural realism, ideational framing, and bureaucratic politics are insufficient because they fail to properly conceptualize how certain properties of a technology, such as the feasibility of technical resolutions, become understood in the R&D process. I suggest that properties that help determine the favorability of technology as an investment opportunity become an important part of understanding why some military technologies do not get investment.

CHAPTER 4. FEASIBILITY, STRINGENCY, AND ALTERNATIVES – SUPPLY AND DEMAND FACTORS THAT CONDITION DEFENSE S&T INVESTMENT

Why do some nascent areas of S&T attract militaries' interest and investment while others do not? In this dissertation, I propose that investments of emerging military S&T are conditioned by how the opportunity of the technology is conceived and defined by relevant actors in the R&D and political processes. In other words, a technology and its military implications are not exogenous to the process from which it evolves – during the acquisition process certain understandings and meanings of a technology are confirmed and reinforced while others are rejected and undermined. In particular, I argue that how the expert communities define and come to a consensus or a dominant opinion on the feasibility of the technology, how the military define its requirements for the technology, and whether technology or institutional alternatives to fulfilling the capability gap are available determine the appeal of a given technology as an investment. I further posit that these variables together generate certain conditions for investment, and under unfavorable conditions, investments in certain emerging S&T are less likely to be initiated and sustained, despite the technology's military utility.

As examined in Chapter 3, existing structural, organizational, and bureaucratic explanations of defense acquisition all fail in some critical aspect in their ability to explain military technology investments, particularly in cases where the technology, by their predictions, should receive investments but does not. I posit that such a failure arises in part because these explanations 1) obscure the technical details of a technology, 2) ignore how different actors within the acquisition process, particularly the ones outside the military institutions, understand and define these details, and 3) fail to account for the possibility that understandings of the technical content of a technology may change over time. The argument presented and hypotheses generated in this chapter seek to provide a preliminary way at addressing these failings.

This chapter is divided into three parts. In part one, I examine three analytical frameworks that contextualize S&T as a variable in the defense acquisition process. The supply and demand framework identifies the relevant actors and institutions in defense acquisition. The Social Construction of Technology literature provides a means to understand how S&T is itself a variable in the acquisition process rather than a static, objective fact or product as it is often conceptualized in existing explanations. The quadrant model of scientific research provides a way to situate military basic research as potentially both knowledge and use-inspired. Part two explains feasibility, requirements stringency, and alternatives as meaningful variables in defense investment and acquisition, as well as their interactions, and advances a model of their potential impact to investment decisions. Finally, part three articulates the case-study research design for this dissertation, describes the methods used to understand the variables, and provides a succinct explanation for the emerging nature of cognitive neuroscience as an area of scientific research and technology development.

4.1 Contextualizing S&T as a Variable

4.1.1 Defense S&T Investment from the Perspective of Supply and Demand

The use of supply and demand as a framework to explain defense technology is not new. One of the most prominent examples where this economics-driven perspective is applied to weapons technology is in the field of nuclear proliferation. Scholars unpacking the dynamics of how nuclear weapons spread in the international system often rest their explanations on one side of this debate or the other.[94] From the supply perspective, nuclear weapons proliferate because suppliers of nuclear technology provide critical information (such as weapons design) or material (such as weapons-grade fissile material or construction of enrichment or reprocessing facilities) assistance to potential proliferators.[95] Scholars from the demand perspective, on the other hand, have attributed nuclear proliferation to security concerns, domestic interests, and normative or cultural considerations of the proliferators.[96] While this debate on proliferation is far from settled, the supply and demand framework has provided analytical unity to the many factors that impact state decisions and interstate dynamics for the acquisition of nuclear capabilities.

Others have similarly applied the supply and demand framework to arms production in a regional context. In analyzing the efforts of weapons acquisition and production of regional powers such as India, Israel, and Brazil, Amit Gupta finds that the interaction between demand and supply factors leads to a constraint on these countries' ability to develop their force structure.[97] According to Gupta, the need to counter a threat or a desire to fulfill competing bureaucratic interests among the armed forces, national leadership, and defense industries create a need for the weapons, but such a demand is complicated by factors such as the availability of external supplies and the state's ability

[94] For a review, see Scott D. Sagan, "The Causes of Nuclear Weapons Proliferation," *Annual Review of Political Science* 14 (June 2011): 225-244.

[95] See, for instance, Matthew Kroenig, *Exporting the Bomb: Technology Transfer and the Spread of Nuclear Weapons* (Ithaca, NY: Cornell University Press, 2010) and, in the context of non-sensitive nuclear assistance, Matthew Fuhrmann, "Spreading Temptation: Proliferation and Peaceful Nuclear Cooperation Agreements," *International Security* 34(1) (Summer 2009): 7-41.

[96] See for instance, Zachary S. Davis and David Frankel, eds., *The Proliferation Puzzle: Why Nuclear Weapons Spread and What Results* (New York, NY: Routledge, 1993); Peter R. Lavoy, "Nuclear Myths and the Causes of Nuclear Proliferation," *Security Studies* 2(3&4) (Spring/Summer 1993): 192-212; Stephen M. Meyer, *The Dynamics of Nuclear Proliferation* (Chicago, IL: University of Chicago Press, 1984); Etel Solingen, "The Political Economy of Nuclear Restraint," *International Security* 19(2) (Fall 1993): 126-169; Scott D. Sagan, "Why Do States Build Nuclear Weapons? Three Models in Search of a Bomb," *International Security* 21(3) (Winter 1996/1997): 54-86; T.V. Paul, *Power versus Prudence: Why Nations Forgo Nuclear Weapons* (Montreal: McGill-Queen's University Press, 2000); Nina Tannenwald, *The Nuclear Taboo: The United States and the Non-Use of Nuclear Weapons* (Cambridge, UK: Cambridge University Press, 2007), among others.

[97] Amit Gupta, *Building an Arsenal: The Evolution of Regional Power Force Structures* (Westport, CT: Praeger Publishers, 1997).

to raise resources for weapons procurement. The constraints created by both of these factors often lead these regional powers to have incomplete force structures, spotty modernization efforts, shifting military doctrines, and greater success at developing strategic as opposed to conventional weapons. Supply and demand, thus, can be a useful framework to understand the dynamics of acquisition of defense technology.

The supply-demand framework does not only apply to proliferation and acquisition dynamics in the international system, however. As a system of production, each state's own national defense system can also be conceptualized in terms of supply and demand institutions and forces. In her discussion of the weapons succession process (the process through which one weapons system succeeds another), Mary Kaldor articulates what such forces entail as they pertain to military technology. "Classical economics was concerned with the mechanism for reconciling demand and supply, the process by which resources are organized to satisfy a particular need,"[98] but such a process needs not be limited to the production of commercial goods and tradable commodities. Supply and demand factors exist in all systems that entail acts of production and consumption and can be applied to the fulfillment of a variety of socio-economic tasks.

In the realm of defense technology, the demand factors can be defined as the *need to have and use* a technology. Kaldor makes a clear distinction between acquisition and use:

> Demand theories are primarily concerned with the *use* of armaments, as though there were no distinction between use and acquisition, as though requirements defined by some external situation could be immediately translated into resources through the agency of some "rational" decision maker. If, however, the act of purchase is separated in time from the use of

[98] Mary Kaldor, "The Weapons Succession Process," *World Politics* 38(4) (July 1986): 577.

> the weapons, then the peacetime demand for weapons has to be assessed in terms of the situation of purchase as well as the potential or imagined situation of use (emphasis in original).[99]

The separation in time between acquisition and use is not just a matter of distinction as a consequence of peace or wartime. Technologies in early developmental stages also rely on potential or imagined uses as the demand-side factor.

Kaldor further explicates the different components of the demand-side institutions in defense technology. According to Kaldor, "The potential requirement for weapons as defined by the international situation can be said to be the *systematic aspect* of demand," but how this situation "is mediated by the perceptions of the armed services, various bureaucratic departments, and politicians represents the *institutional aspect* of demand (emphasis in original)."[100] In this sense, existing structural, organizational, and bureaucratic theories focus primarily, if not exclusively, on the demand side of defense acquisition.

Kaldor also distinguishes the supply-side institutions in the production of a defense technology. She posits:

> There are two types of supply institutions: those associated with the invention stage of the weapons succession process and those associated with the innovation stage. The former are primarily government, university, or private nonprofit laboratories. From these emerge new military technologies, some of which may be "revolutionary" in the sense that they challenge existing doctrine and organization…At the innovation

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[99] Kaldor (1986), 580.
[100] Kaldor (1986), 580.

> stage…prime contractors generally undertake responsibility for development and production of complete weapons systems.[101]

For Kaldor, the conservatism inherent within military organization and the resistance of bureaucracies to change suggest that in the absence of direct external security incentives (such as a war), military technological change (be it invention or radical innovation) is unlikely a result of demand-side factors or influence. Supply-side factors and pressure, thus, are more effective in causing such change.

The supply-demand framework has also been used to explain the dynamics of technology innovation. After all, one of the main goals for investment in R&D is innovation, and this applies to both the civilian as well as the military sectors. Technology innovations have long been understood to come from two separate but not mutually exclusive sources: technology-push or demand-pull.[102] Since the military is the main consumer of military technology, the dynamics of demand-pull are also understood as requirements-pull or capability-pull. Capability-pull occurs when the S&T investment is leveraged to fulfill or redress a capability gap. Technology-push occurs when the S&T investment creates new knowledge of potential military applications. When interpreting the opportunities arising from R&D investments, the military, whose interest is a technical solution and requirements-driven, tends to approach the decisions from the capability-pull perspective. On the other hand, scientists, particularly the ones who work in traditional open science institutions such as universities, are more likely to embrace the knowledge-generation opportunities in S&T investments.

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[101] Kaldor (1986), 584.

[102] Especially in the management of the larger defense S&T portfolio, these two sources are often considered complementary. See, for instance, Defense Science Board, *Defense Science Board 2006 Summer Study on 21st Century Strategic Technology Vectors, Volume III: Strategic Planning* (Washington, D.C.: Office of the Under Secretary of Defense for Acquisition, Technology, and Logistics, 2006), 13.

Depending on the nature of the technology and institutional context under which it is invested, the push and the pull dynamics may carry different weight in the R&D process. For instance, an emerging area of S&T that engenders multiple but divergent military applications or has significant non-military applications (such as dual-use technology)[103] may create conditions in which the research scientists hold greater sway over the investment decisions. This is due to the possibility that the varied applications create multiple stakeholders whose interest in an emerging field of S&T may diverge. This is particularly true for dual-use technologies which have stakeholders both in and outside the military. This diffusion of stakeholder interests creates conditions where 1) the scientists can have alternative sources from which their research are supported (i.e. the scientists have a wider scope of "audience" to whom they can pitch their ideas), and 2) the uncertainty in potential developmental trajectories allows scientists to leverage their expertise to identify where the R&D opportunities may lie. Both features increase the latitude of the scientists to sway the decision-making process.

Certain institutional conditions, such as the level of openness in the military R&D system, are also likely to impact the level of access a scientist has toward the R&D decision process. In discussing the different styles of military technological innovation between the US and the USSR, Matthew Evangelista highlights several characteristics important for innovation and suggests that these organizational features are important determinants for whether a new idea can be promoted within the R&D process.[104] In a relatively open military R&D system where there are fewer organizational and bureaucratic barriers to

[103] "Dual-use" is understood here as technologies that can be used in the civilian-commercial as well as the defense-military sectors.

[104] These characteristics include the degree of centralization of control, the degree of formalization of rules and procedures, and the level of interconnectedness among R&D participants. See Matthew Evangelista, *Innovation and the Arms Race: How the United States and the Soviet Union Develop New Military Technologies* (Ithaca, NY: Cornell University Press, 1988), 28-49.

R&D decisions, the scientists have a greater likelihood to promote their interests and ideas, facilitating the dynamics of technology-push.

The above discussion on the supply and demand factors and institutions in the production of a defense technology highlights several key considerations for understanding defense S&T investments:

1) Defense S&T investment, as part of the production of new military technology, is not just a political decision but also an economic one, where the potential or imagined needs (demand) are reconciled with potential or imagined possibilities of technological solutions (supply).

2) Defense S&T investment concerns both demand-side systemic and institutional factors, such as the variables employed in existing structural, organizational, and bureaucratic explanations, as well as the underexplored supply-side institutions such as the scientific or technical community and industry who produce the knowledge or the technology.

3) Supply and demand institutions are distinct – they have different functions and interests in the defense research, development, and acquisition process, thus they are likely to understand and conceptualize a technology differently.

4.1.2 The Social Construction of Technology

Existing theoretical insights regarding defense S&T investment often fail to consider whether or not S&T itself plays a role in investment decisions. They often consider the actual S&T, be it just the general scientific field or a specific set of technologies or technological systems, to be exogenous. This means that most structural, organizational, or bureaucratic explanations treat a technology as something that exerts influence or is simply "used" as is in the political process. As a result, in the existing literature, S&T is static – it does not involve any "process" but is instead treated as a product; it does not change, and even if it does, the changes are often not a critical component to the discussions at hand. However, understanding how a technology is viewed by the relevant actors is critical to appreciating the different meanings and opportunities they attach to such a technology, which, in turn, impacts the acquisition and investment decisions.

The very areas of science or technology programs that the defense community at large or the militaries in particular are interested in funding are not exogenous to the systems that create them. This alternative, constructive conceptualization of S&T in the political processes raises three important assumptions about science and technology that often evade realist and positivist inquiries into political processes: "First, science and technology are importantly *social*. Second, they are *active*—the construction metaphor suggests activity. And third, they do not provide a direct route from nature to ideas about nature; the products of science and technology are *not themselves natural* (emphasis in original)."[105] Science and technology are social because, for one, the generation of scientific knowledge and the production of a technology involve more than just one individual. Even if new knowledge is created by a lone scientist, such a scientist still works within the milieu of a socially defined profession. Science and technology are active because scientific research and technology development are social activities and involve processes. Even if they are used to denote specific scientific knowledge or technological artifacts, such knowledge and artifacts still embody the process through which they are produced. In other words, an end S&T product embodies the research, communications, debates, compromises, and many other human activities that shape its production. Finally, science and technology are not natural but are instead very human endeavors. While

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[105] Sergio Sismondo, "Science and Technology Studies and an Engaged Program," in *The Handbook of Science and Technology Studies*, Third Edition, edited by Edward J. Hackett, Olga Amsterdamska, Michael Lynch, and Judy Wajcman (Cambridge, MA: The MIT Press, 2008), 14.

science as a discipline seeks to explain nature, the act and the need to explain are not by themselves natural. The premise of social-constructivist arguments about science and technology is thus that they cannot be understood without references to the human actions that shape it.

In their now seminal study of the origin of modern-day bicycle design, Trevor J. Pinch and Wiebe E. Bijker articulate what this "social construction" entails.[106] The Social Construction of Technology (SCOT) model they develop, which posits that a technological artifact develops from a process of alternation and selection, entails three important components that clarify *what* is involved in the social construction of S&T. First, social construction of both science and technology involves a demonstration of "interpretive flexibility." This interpretive flexibility refers to the possibility that "different interpretations of nature are available to scientists and hence that nature alone does not provide a determinant outcome to scientific debate."[107] In scientific terms, such interpretive flexibility most often refers to the existence of a scientific controversy where the "truth" and meaning of an observation or scientific finding are contested. In the study of technology, such interpretive flexibility refers to "how people think of or interpret artifacts but also that there is flexibility in how artifacts are *designed* (emphasis in original)."[108] This flexibility, whether on scientific opinion or on artifact design, moves the process of S&T from the material and the natural to the human and the social.

[106] Trevor J. Pinch and Wiebe E. Bijker, "The Social Construction of Facts and Artifacts: Or How the Sociology of Science and the Sociology of Technology Might Benefit Each Other," in *The Social Construction of Technological Systems: New Directions in the Sociology and History of Technology*, Anniversary Edition, eds. Wiebe E. Bijker, Thomas Hughes, and Trevor Pinch (Cambridge, MA: The MIT Press, 2012), 22. Note that the word "artifact" is used here deliberately: the SCOT model argues essentially that any technology product is a consequence of a historical process in selecting among alternative designs, and the final design which stabilizes as a result is indeed an "artifact" from this historical process.

[107] Pinch and Bijker (2012), 33-34.

[108] Pinch and Bijker (2012), 34.

Second, interpretive flexibility results in the formation of “relevant social groups,” which refers to the “institutions and organizations (such as the military or some specific industrial company), as well as organized or unorganized groups of individuals,” who “share the same set of meanings” attached to a specific artifact.[109] The relevant social groups need not only be consumers or users, although their interest and connection to an artifact are rather apparent. Scientists, engineers, and marketers also constitute relevant social groups as a result of their participation in the development process of the artifact. Different relevant social groups associate different meanings to an artifact and as a result permit the exercise of interpretive flexibility. A single artifact, thus, can mean very different things to different relevant social groups.

Finally, the social construction of S&T involves the closure of the controversy or problem that has led different relevant social groups to have different opinions on an observation or finding or to associate different meanings to an artifact. This closure can be achieved by an actual resolution to the debate or problem, a “rhetorical” closure that permits the relevant social groups to “perceive” the debate or problem as resolved, or a redefinition of the problem, whereby the solution is achieved through reframing the key problem within a debate or an artifact. Since the process of technology development is inevitably social, the closure of a debate or the solution to a problem need not be actual – a closure is obtained so long as the “disappearance” of the problem is achieved.[110]

If the debates and controversies are such crucial elements in scientific research and technological development, where do they normally occur? Thomas Hughes, in his study of the electric light system, evokes the military concept of a “reverse salient,” whereby an area of technology (most often within a technological system) is lagging as a result of

[109] Pinch and Bijker (2012), 23.
[110] Pinch and Bijker (2012), 37.

uneven technological development.[111] Just like an advancing military frontline with sections of backward bow that are caused by enemy strongholds, the reverse salient in technological system development refers to barriers that prevent or perturb the process of development. As a result, just as generals are likely to focus their forces on the reverse salient in order to be able to advance the frontline, scientists and technologists are motivated to focus their efforts on the elimination of the reverse salient and might define it as a set of critical technical problems that, when solved, will allow the technology or the technological system to advance.

Yet, as Hughes points out, the social constructive nature of the development of a technological system suggests that the reverse salient does not necessarily need to be a technical one. In a complex system where multiple societal influences may be at play, the reverse salient may be a social, political, or economic one (or a combination thereof). Hughes, for instance, attributes the reverse salient in the development of the electric system to the significant losses that result from the need of transmitting high voltage currents over a long distance. This, of course, is not just a technical bottleneck but also a socio-economic issue. To make the system marketable, it has to be able to compete with the then existing gas system and be able to operate the electric system at a cost that is at least as competitive. This socio-economic consideration, thus, led to the pursuit of light-bulb filament that has high electrical resistance, which would then result in relatively high voltage as compared to the current.

The nature of this reverse salient may itself be contested. In his study of the development of guidance systems that have over time drastically improved the accuracy of missiles, Donald MacKenzie suggests that it would not be right to view the reverse salient

[111] Thomas P. Hughes, *Networks of Power: Electrification in Western Society, 1880-1930* (Baltimore, MD: Johns Hopkins University Press, 1983).

as given and independent of the actors involved.[112] "To agree on what constitutes a barrier to progress requires agreement on what one is trying to achieve," he elaborates, and "[m]ore interesting, even those who believe that they are in agreement with respect to goals may not agree on what precisely it is that hinders achievement of those goals."[113] The reverse salient, or the controversy and problem it embodies, is in this case similarly subject to social influences. People with different skills are therefore likely to view the nature of the reverse salient differently – different types of engineers, for instance, may disagree on whether it is the hardware or software that constitutes the reverse salient.

The highly social nature of the reverse salient and the potential for its fluid definition by relevant social groups have led MacKenzie to conclude that most often it is only with "the wisdom of hindsight (and sometimes not even then) will the nature of the barriers to advance be beyond at least potential dispute."[114] Prospectively, the issue of the reverse salient becomes a debate over what is *possible*, a question over which there is of course plenty of room for disagreement. Is the reverse salient something that can be solved by devoting research efforts, or is it simply an "intractable natural limitation"?[115] MacKenzie finds in his study that the existing, dominant form of missile guidance system was also once believed by some to be physically impossible. As a result, he concludes that "beliefs about the true nature of the world differ widely and often in socially patterned ways," and these "beliefs can bear directly on the forms of technical change that are taken to be feasible."[116]

[112] Donald MacKenzie, "Missile Accuracy: A Case Study in the Social Processes of Technological Change," in *The Social Construction of Technological Systems: New Directions in the Sociology and History of Technology*, Anniversary Edition, eds. Wiebe E. Bijker, Thomas Hughes, and Trevor Pinch (Cambridge, MA: The MIT Press, 2012), 191.

[113] MacKenzie, "Missile Accuracy" (2012), 191.

[114] MacKenzie, "Missile Accuracy" (2012), 191.

[115] MacKenzie, "Missile Accuracy" (2012), 192.

[116] MacKenzie, "Missile Accuracy" (2012), 192.

Unlike existing structural, organizational, and bureaucratic explanations which often treat science and technology as exogenously given, history and sociology scholars examining science and technology have shown that science and technology are in fact not as static as they are often portrayed as. Science and technology, in this sense, are not merely products of research and development efforts, but they also embody the very R&D process that created them. This process is social, active, and human. In other words, scientific knowledge and technological artifacts are social constructs and cannot be understood without the social, political, economic, and other human factors involved in the processes that create them.

The SCOT literature also highlights the importance of debates, controversies, and problems as critical components of this constructive process. These controversies and problems create opportunities for interpretative flexibility, whereby different actors involved in the R&D process are able to attach their own understanding and definition to findings and artifacts, permitting them to mold the process as well as the final product. Of course, as stated, these so-called “reverse salients” are often contested themselves. Scientists, along with other parties of interest, may not agree on where the bottleneck may lie, and any agreement that can be achieved might not necessarily be a result of natural observation but one of a social construction.

This deliberate focus on science and technology as a variable may appear to some as another form of technological determinism, yet such an understanding is incorrect. By examining science and technology as a social process and its products as a construction, scholars of SCOT are deliberate in arguing that science and technology are not a sole or dominant determinant of social processes but are in fact products of such processes. The SCOT literature problematizes S&T as a variable rather than treating it as static, and by doing so, it creates room for social processes to interact with technological ones and generates more nuanced understandings of their mutual impact.

The Social Construction of Technology literature thus provides a means to understand how S&T and their main parameters, as variables, are able to change. It emphasizes the social forces that are part of the creation of an area of scientific research or technology development. These characteristics are not static – they are constructed by those involved in defining what each characteristic means for a technology. For the defense community, the military constructs its needs and expresses them in terms of requirements, whereas the scientific community constructs the utility of a technology through their interpretation and definition of its feasibility and possible applications.

Technology itself in this case is problematized. It is conceived as a construction of social forces surrounding it rather than as an objective fact. By association, the understanding of what a technological opportunity entails, is in and of itself a social construction – the utility of an emerging technology as well as the conditions that matter for its realization are determined by the experts who study and create it as well as the users.

4.1.3 The Nature of Defense S&T Investment: Pasteur's Quadrant

One of the complexities that face defense S&T investment concerns the issue of application, which is an especially acute problem when applied to basic research. Basic research is most often defined as not application driven. As a result, understanding military S&T investments in basic research from the demand perspective – namely, investment with the goal of fulfilling a customer's needs, seems problematic. If basic research is by definition not application driven, then where does the demand-side interest – namely that of the military in defense S&T investments – come in, aside from the general belief that the investment would contribute to some abstract notion of future military capabilities?

As many have noted, the basic research investment in the military is, in fact, not so "basic." Very few defense R&D programs are conducted for the sole purpose of advancing scientific knowledge. The R&D activities in the service laboratories address a specific service's needs, and even a service specific research organization, such as the Air Force Office of Scientific Research (AFOSR) or the Army Research Office (ARO), contracts research with a specific service's mission, needs, and requirements in mind. As opposed to traditional "blue sky" or "exploratory" notions of basic research, service-specific basic research programs are mission, application, and requirement oriented. In this sense, the directionality of their investment is influenced, implicitly or explicitly, by the demands of the services.

This particular tendency of the DoD to invest in "basic research" with an eye towards applications has raised concerns across multiple communities. In 2005, the Congress mandated that National Research Council (NRC) to conduct a study on the character of defense basic research programs. This study was motivated by concerns of university research departments and defense laboratories that "[s]ome research conducted using funds designated specifically for basic research is not, under the DoD's definition, considered basic research."[117] The concern was that a diversion of funding from basic to applied research or technology development defies the purpose of the DoD's basic research funding, which is to help ensure a robust and competitive technological base.

The NRC committee found, however, that the nature of the issue has less to do with the appropriateness in the allocation of funding. According to the report, DoD "research managers apply consistent and reasonable judgment on the level of specificity that is appropriate to the purposes of basic research."[118] Instead, what the committee uncovered was that the very definition used for basic research is not at all helpful. As referred to in Chapter 3, basic research in the DoD is defined as "[s]ystematic study directed toward greater knowledge or understanding of fundamental aspects of phenomena and of

[117] National Research Council, *Assessment of Department of Defense Basic Research* (Washington, D.C.: The National Academies Press, 2005), ix.

[118] National Research Council, *Assessment* (2005), 9.

observable facts without specific applications towards processes or products in mind." For the committee, the criterion "without specific applications towards processes or products in mind" is not helpful to distinguish basic research from other kinds of R&D activities. The committee instead defines basic research along a set of attributes and characteristics that are not constrained by the "end-use" phrasing in the original definition.

The committee further finds that the 6.1 money, which is categorized as basic research, in fact funds several types of R&D activities, all of which can qualify under the broad notion of basic research. These activities include, but are not limited to:

1) Exploratory, unrestricted research that is not tied to short-term goals or specific applications at the frontier of knowledge which may carry long-term benefits to military capabilities,

2) Research that aims to develop standard reference data,

3) Research that develops exploratory systems or devices intended to enhance specific functions or performance without consideration for the design's final robustness or cost-effectiveness.

The committee found that the various missions these research programs serve and the motivation behind them are essential for fulfilling the wide range of basic research needs, but the distinction of these activities also revealed that in recent years, there is an increasing emphasis on the second and third types of activity listed above. The report highlights that the mounting budgetary pressure and increasing scope of demand for defense S&T resources have made program managers more inclined to invest in shorter-term, more sharply focused programs that are easier to "justify." The report warns that a focus away from "unfettered" exploratory aspects of basic research will likely undermine national security interests in the long-term.

The rather optimistic assessment of the DoD basic research program from the NRC was not without debate, however. In a 2009 JASON[119] study sponsored by the Director of Defense Research and Engineering (DDR&E),[120] an independent panel of scientists found that the issue of "6.1 drift," or "the extent to which 6.1-funded activities conform to the definition of 6.1 research or rather are of a more applied character" was more pronounced than the NRC report suggested.[121] The panel of JASON scientists, in examining grants funded by the AFOSR and ARO, observed that many programs do not conform to the 6.1 definition of basic research. In their judgment, among the proposals that received 6.1 funding, 25% to 81% were not basic research.[122] While this observation, as the panel suggested, does not serve as a judgment on the value or worthiness of the funded programs, it highlights the possibility that a large subset of the DoD's basic research programs are funded with goals of deliberate, albeit general, applications in mind.

This observation of the possibility of a "6.1 drift" is further reinforced by the ways through which the program managers at the DoD describe their job and daily routines, according to the 2009 JASON report. From their conversations with DoD personnel, the JASON panelists find that the program managers for basic research programs think of their jobs as matching the capabilities of the universities or other research communities to the needs of the services. In particular, the program managers highlighted that one of the critical criteria for funding a research program is "'where there is a "service" customer for the resulting data,'" and that it is only when such a customer exists that a program manager would consider funding the research.[123] In this sense, the basic research programs in the services are funded with particular customer needs in mind. Although this does not mean

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[119] JASON is a scientific advisory group to the US Department of Defense.

[120] The title to this position has changed several times throughout the past decades. Since 2011, this position is officially known as the Assistant Secretary of Defense (Research and Engineering).

[121] JASON, *S&T for National Security* (McLean, VA: The MITRE Corporation, May 2009), 22.

[122] JASON (2009), 23.

[123] Interview quoted in JASON (2009), 25.

that only research that addresses specific, short-term goals of the services will attract funding, it shows that the research needs to at least be able to engender some kind of future application that can solve service-specific requirements or capability gaps in order to be funded.

The lack of agreement regarding the nature of the DoD's investments in basic research programs prompted a third comprehensive study by the Defense Science Board (DSB) task force in 2010. The task force, in addition to being charged with advising on long-term planning and strategies for defense basic research, was also asked to evaluate the quality of DoD basic research programs and, among other things, to determine whether current 6.1 programs are basic or applied in character. As a response to this mandate, in a study conducted by the Director for Basic Research in ASD(R&E) with a sampling of basic research projects conducted by and for all services, it was found that on average, over 85% of the extramural research and over 70% of the intramural research in 6.1 are deemed basic in nature.[124] A subset of the task force members performed similar tasks for DARPA programs and reached similar results. The task force concluded that DoD 6.1 funding is in general appropriate for the purpose of basic research and highlights that it is impossible to draw a sharp distinction between basic and applied research.

This "6.1 drift" is not just a concern for the defense community or the government, however. Some in the scientific and other research communities at large share this belief that the character of defense basic research is changing. The shifting security requirements from engaging in large-scale, technology-driven interstate competition to countering a "loosely organized, deliberately low-tech enemy" heightens the need for "'soft' skills such as trust-building, intelligence-gathering and cultural insight" while diminishing the

[124] Defense Science Board, *Report of the Defense Science Board Task Force on Basic Research* (Washington, D.C.: Office of the Under Secretary of Defense for Acquisition, Technology, and Logistics, January 2012), 28.

importance and influence of science.[125] Consequently, echoing the JASON report, some in the scientific communities see recent developments in defense S&T as "a lack of sustained Pentagon support for blue-sky basic science and a preference for applied research with a short-term pay-off."[126] Ironically, in recent defense budget drawdowns, some of the greatest reductions are coming out of the later stages of technology development, whereas attempts have been made to preserve most of the basic research budget.

This controversy over the basic versus applied nature of defense 6.1 funding has not fazed all parties, however. In both the NRC and the DSB reports, it is recognized that drawing a distinction between basic and applied research is not only impractical but is often impossible. In fact, some agencies have thrived on working along the blurry boundaries between these two categories of research. For instance, the Defense Advanced Research Projects Agency (DARPA), an R&D organization within the DoD known to be the radical innovator in military technologies, has long had a sizeable investment in basic research programs, but much of its investments in cutting-edge, innovative basic research have a distinctively applied character. According to former DARPA director Regina Dugan and deputy director Kaigham Gabriel, "The presence of an urgent need for an application creates focus and inspires genius," and a "central reason DARPA has been so successful over time is its unwavering commitment to work in…pushing the frontiers of basic science to solve a well-defined, use-inspired need."[127] It is in this so-called "Pasteur's Quadrant," named after Louis Pasteur by political scientist Donald Stokes, that DARPA has found its ingenuity.

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[125] Sharon Weinberger, "The Changing Face of Military Science: Basic Research Funded by the Pentagon is Facing an Uncertain Future," *Nature* 477 (22 September 2011): 386

[126] Weinberger (2011), 386.

[127] Regina E. Dugan and Kaigham J. Gabriel, "'Special Forces' Innovation: How DARPA Attacks Problems," *Harvard Business Review* 91(10) (October 2013): 77. DARPA's interest in the application-oriented basic research finds its roots in the 1970s, when Mansfield Amendment to the Defense Authorization Act of 1970 forced all defense research to have direct and apparent relationship to military functions and needs. See Erica R.H. Fuchs, "Rethinking the Role of the State in Technology Development: DARPA and the Case for Embedded Network Governance," *Research Policy* 39 (2010): 1137.

Donald Stokes challenges the belief that the goals of understanding and application in scientific research are empirically distinct.[128] Contrary to the linear model of technology development which envisions the trajectory of technology from basic research, through applied research and technology development, to production, testing, and evaluation,[129] Stokes argues, research can occur at the intersection of the basic research's pursuit of understanding and the applied research's goal for use (see Figure 6).

Research is inspired by?

		Consideration of use?	
		No	Yes
Quest for fundamental understanding?	Yes	Pure basic research (Bohr)	Use-inspired basic research (Pasteur)
	No		Pure applied research (Edison)

Figure 6 - Quadrant Model of Scientific Research[130]

Whereas the linear model of research envisions scientific research to fall strictly within the domain of pure basic research (Bohr's quadrant), which is "guided solely by the quest for understanding without thought of practical use,"[131] or the domain of pure applied

[128] Donald E. Stokes, *Pasteur's Quadrant: Basic Science and Technological Innovation* (Washington, D.C.: Brookings Institution Press, 1997).

[129] This linear model of technology development also serves as the basis to the R&D funding categories in the DoD.

[130] Stokes (1997), 73.

[131] Stokes (1997), 73.

research (Edison's quadrant), which is "guided solely by applied goals without seeking a more general understanding of the phenomena of a scientific field,"[132] the more dynamic quadrant model creates space (Pasteur's quadrant) for basic research that fulfills both the goals of fundamental understanding as well as consideration of use.

In this sense, most, if not all, of the DoD basic research programs can be understood as occurring within the Pasteur's quadrant. The limited amount of basic research at the service laboratories is likely to reflect an individual service's organizational mission and needs, whereas the extramural basic research, most of which occurs in universities, is funded by the DoD because it represents opportunities to technologies and applications that can be beneficial to the military, no matter how abstract and long-term such an application may be. As Stokes points out, this differentiation of goals needs not be a result of the institutional setting under which the research is taking place. Not all research that carries the applied characteristics is the consequence of institutional or sponsor influence, and "the annals of research are replete with examples of work by investigators who were directly influenced both by the quest of general understanding and by considerations of use."[133] Therefore, even the research initiated by investigators at a university, who have a genuine interest in expanding understanding and knowledge of a particular field, can have equally legitimate interest from the investigators in terms of its real-life applications, including potentially military ones.

his dissertation posits that all basic research conducted with sponsorship by the DoD *can* have knowledge- as well as use-inspired goals. The possibility that some research *may* fall under the domain of pure basic research does not diminish the possibility or importance of those basic research programs that are also use-inspired. In particular, this dissertation is interested in how the opportunity for such use is conceived by both the scientific

[132] Stokes (1997), 74.
[133] Stokes (1997), 79.

community and the military, regardless of whether such research also carries inherent pursuits of understanding of a phenomenon in a scientific field.

4.2 The Argument

Leveraging the supply-demand and SCOT frameworks outlined above, with recognition of the “quadrant” model of scientific research, I argue that military investments in an emerging area of S&T are conditioned by the interaction between supply and demand variables. These variables are built upon how the supply and demand side institutions conceive of the opportunity that an area of S&T may bring. In other words, how the scientists and the military conceive and define the scientific possibility and the military need. These variables, combined, can produce favorable and unfavorable conditions for investment. These conditions can make an emerging area of S&T easier or more difficult to sponsor and justify as well as initiate and sustain, which in turn, impacts the levels of investment. In other words, opinions regarding feasibility, stringency of the technical requirements, and the availability of alternative access to capability impact the expected cost-utility calculus regarding an investment.

More specifically, I argue that defense investments in a new or emerging technology are impacted by how the technology is conceived by the supply-side institutional actors, such as the scientific or technical expert community, as well as the demand-side institutional actors, like the military. I posit that certain characteristics of how an emerging technology may be defined and understood by the technical community and the military can make it unappealing for investment, and this lack of appeal is conditional upon how the possibility and the need are constructed. While I detail below the logic behind each individual supply- and demand-side variable, my main argument is that a set combination of these variables creates a condition under which a new area of technology becomes unappealing for military investment despite its utility.

4.2.1 Supply Side Variable – Consensus on Technical Feasibility

As Kaldor suggests, a military innovation system (such as the weapons succession she describes) contains a set of both supply and demand institutions. From the supply side, she distinguishes between the invention and the innovation stages of the military innovation system: invention-stage supply institutions entail government, university, and defense laboratories, whereas innovation-stage supply institutions entail prime contractors in the defense industry. The supply in this case refers to the supply of knowledge, expertise, and research and development activities. Despite the services' knowledge of military affairs and control over the requirements process, the actual task of performing scientific research and advancing technological progress is nevertheless delegated to the scientists and engineers in the laboratories and industries.[134] The military personnel who set the goals for military R&D and who ultimately benefit from new weapons systems or other scientific progress often do not themselves have expertise in science, nor do they perform the R&D. Therefore, how an area of S&T is understood by the scientific or technical expert community is an important component of the R&D process as well as investment decisions.

The meaning that the expert community attaches to an area of S&T is of particular importance when there is a high degree of uncertainty, such as is the case when the S&T is emerging. "The relation between science and government policy is one of functional authority," and with regard to R&D, policymakers often defer to scientific opinions because the complexity of the process often renders a decision impossible without some

[134] As described in Chapter 3, in the United States, S&T funding for military R&D encompasses Basic Research (6.1), Applied Research (6.2), and Advanced Technology Development (6.3). The 6.1 funding most often goes to the scientists and researchers in universities through Department of Defense contracts, and 6.2 and 6.3 generally funds R&D that has transitioned to the defense laboratories. This roughly corresponds with Kaldor's distinction between invention and innovation stages of supply institutions.

kind of simplified form.[135] The relationship between the military and the scientific, expert community is a case of functional delegation. It typifies the situation where one who lacks ability defers to authority. This trust in the functional authority of the scientific community is not necessarily based on the veracity of the scientific claims, but rather, on the competence of the scientific system. Policymakers therefore rely on the expert community to produce the necessary heuristics, and in some cases, specific guidance, that aid the decision-making process.

With their functional authority scientists or technical experts can play several different roles in the policy process. In certain socio-economic contexts, scientists exercise the role as an instrument of persuasion on policy decisions, whereas in other contexts the scientific community's main function may be the holder and interpreter of scientific as well as technical information.[136] Still, scientists may play an even more active role in policymaking through their advising capacities in regulatory agencies, performing functions such as setting standards and assessing safety, and internationally, through their roles as representatives of knowledge communities, coordinating international policy.[137] Of course, scientists' functional authority and expert knowledge are not devoid of the socio-economic and political influences under which their roles in the policy process take place.[138] Yet, the possession of expert knowledge, which serves as the basis to the

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[135] René von Schomberg, "Controversies and Political Decision Making," in *Science Politics and Morality: Scientific Uncertainty and Decision Making*, ed. René von Schomberg (Dordrecht, The Netherlands: Kluwer Academic Publishers, 1993), 7.

[136] For the range of scientists' role in policymaking, see for example Etel Solingen, "Domestic Structure and the International Context: Toward Models of State-Scientists Interaction," in *Scientists and the States: Domestic Structures and the international Context*, ed. Etel Solingen (Ann Arbor, MI: The University of Michigan Press, 1994), 1-31; and Roger A. Pielke, Jr., *The Honest Broker: Making Sense of Science in Policy and Politics* (New York, NY: Cambridge University Press, 2007).

[137] See, for instance, Sheila S. Jasanoff, *The Fifth Branch: Science Advisers as Policymakers* (Cambridge, MA: Harvard University Press, 1990); and Peter M. Haas, "Introduction: Epistemic Communities and International Policy Coordination," *International Organization* 46(1) (Winter 1992): 1-35.

[138] In fact, scholars studying the relationship between science and policy often argue quite the opposite. See, for instance, Jasanoff (1990).

functional authority that the scientific and technical communities exercise, can play a non-trivial role in the policy process and political decision.

Studies of the US military innovation system confirm this view that scientists and the technical community can play a vital role in the military's investment decisions in technology. According to Evangelista, "[t]he first of the five stages in which U.S. weapons innovations area carried out generally begins when scientists in weapons laboratories and military officials in close contact with them recognize technical possibilities for new weapons."[139] Evangelista argues that US military technological innovation begins with what he terms as "technocratic initiative," where the innovation decisions are not made at the higher levels of policymaking, but by the technical and organizational procedures for R&D. This was evident in the early developments of tactical nuclear weapons, which occurred during a time "when strategic bombing dominated U.S. military thinking and discussion of alternatives was rare."[140] Yet, the scientists who saw the potential for tactical nuclear weapons still were able to get funding because "they held a monopoly on information about nuclear weapons and they enjoyed tremendous prestige within the U.S. government and among the public at large."[141] These scientists were thus able to influence policy directions, sway funding priorities, and guide investment decisions.

In terms of the investment decisions with respect to an emerging area of S&T, one of the most important authorities the scientific community exercises is defining the technical possibilities. The uncertain nature of emerging technologies suggests not only that the policymakers are reliant on the scientific community to set the boundaries of what is possible, but also that such possibility can be highly contested even among the scientists and technologists themselves. In this case, the scientific and technical communities'

[139] Evangelista (1988), 53.
[140] Evangelista (1988), 95.
[141] Evangelista (9988), 95.

function is more than "selling" a "technical potential." It is "a vital resource of technologists (as distinct from political leaders, generals, or corporate executives)," articulates Donald MacKenzie, "that in questions of weapons design they are arbiters of what is *feasible* as distinct from the 'softer' issues of what is acceptable, needed, or affordable (emphasis added)."[142] When confronting the uncertain nature of emerging technologies, it is as important to define what is infeasible as it is to define what is possible, and the interpretation of such information relies on scientific or technical authorities.

To determine whether or not a technology is feasible, it is necessary to understand where the "reverse salient" lies and what constitutes the barriers to the realization of a capability. Of course, as a concept, the reverse salient is constructed and can be highly contested even among the experts. As aforementioned, it would not be right to view a reverse salient as given, for an agreement on what constitutes a barrier requires an agreement on the goals one is trying to achieve, and such a claim is often subject to controversies and debates. Yet, even if one were able to define what the end goal may be (in terms of technology development), or if such a goal is understood as a given, those who are in agreement with the goals may not agree on what are the obstacles to achieving these goals. Not only are people with different kinds of skillsets likely to understand what constitutes the reverse salient and how to address it differently, but there may also be disagreements over the nature of the barrier. Some barriers could be overcome with concerted R&D efforts and investment, while others may be intractable problems that are difficult if not impossible to resolve.

For these reasons, one of the key variables analyzed in this dissertation is how the scientific or technical expert community, as a relevant social group in the decision process, leverages its expertise and expresses a consensus (or lack thereof) regarding the feasibility

[142] Donald MacKenzie, *Inventing Accuracy: A Historical Sociology of Nuclear Missile Guidance* (Cambridge, MA: The MIT Press, 1993), 10

of an area of science (to be used for a particular purpose) or the development of a technology or technological system. The scientific and technical expert community, in this case, can include scientists participating in the military R&D process in a variety of capacities as discussed above. These scientists may serve in an advisory role to the military, such as on boards or study groups, or they may take an advocacy role and attempt to influence the R&D process and outcome. The community may also include experts who are directly involved in the military R&D process, whether as program managers or research scientists. What "binds" them as a community is their shared interpretation of a specific controversy in an area of S&T. Similar to the "epistemic communities" that Peter Haas describes, which is "a network of professionals with recognized expertise and competence in a particular domain and an authoritative claim to policy relevant knowledge within that domain or issue-area,"[143] the scientific community refers to the network of scientists, technologists, engineers, or other technical experts who hold expertise in a scientific or technical domain.[144]

The term consensus here refers to a general agreement between the participants in a social group on a position about a certain issue at hand. In terms of considering the S&T as a process, as the SCOT literature suggests, it indicates a closure.[145] Scientific consensus refers, thus, to the collective opinion, judgment, and position of the community of scientists on a given topic. In this dissertation, consensus does not imply unanimity but rather the strength of collective opinions, neither does it necessarily exist in dichotomous terms (whether a consensus exists or it does not). A spectrum of potential states of the collective opinions is possible—in other words, scientific opinion can converge toward consensus or diverge towards the lack of consensus. The concept of consensus is important because it

[143] Haas (1992), 1.

[144] Although this dissertation does not assume that they have to hold certain shared normative beliefs as articulated in Haas's definition of epistemic communities.

[145] Wiebe E. Bijker, Thomas P. Hughes, and Trevor Pinch, eds. *The Social Construction of Technological Systems: New Direction in the Sociology and History of Technology*, 6-7.

conveys the level of policy-informing power that a scientific or technical opinion may have. Since the “functional authority of science is threatened whenever there are signs of a controversy,”[146] the policy-influencing power of the scientific claims declines as controversy increases. Therefore, the greater the degree to which there is an agreement on a scientific or technical opinion, the more weight such an opinion will carry in the policy process.

The term feasibility refers to the possibility of something being done. In terms of S&T investment, it refers to whether the proposed use of a particular scientific advancement or the production of a certain technology or technological system is possible. From the perspective of SCOT it refers to the possibility for a “reverse salient” to be overcome. The barriers to feasibility of course can be manifold and are perceived constructions – the lack of feasibility may be a consequence of human factors such as social, economic, or political barriers, or it can be technological such as technical impossibility or natural limitations given an existing state of knowledge.[147]

These two components of the supply side variable constitute three conceptually distinct potential states of scientific or technical opinion on feasibility: consensus on feasibility, lack of consensus (lack of apparent agreement on feasibility), or consensus on infeasibility. These three states, however, produce two different conditions regarding the R&D investment (see Figure 7).

[146] von Schomberg (1993), 9.

[147] In some cases, the actual barrier to feasibility could also arise out of the necessary knowledge production or transfer in a given scientific or technological area. For instance, see Sonia Ben Ouagrham-Gormley, *Barriers to Bioweapons: The Challenges of Expertise and Organization for Weapons Development* (Ithaca, NY: Cornell University Press, 2014).

<table>
<tr><th></th><th></th><th colspan="2">Scientific Consensus</th></tr>
<tr><th></th><th></th><th>Yes</th><th>No</th></tr>
<tr><td rowspan="2">Feasibility</td><td>Yes</td><td>Favorable</td><td rowspan="2">Favorable</td></tr>
<tr><td>No</td><td>Not Favorable</td></tr>
</table>

Figure 7 - The Impact of Consensus of Feasibility on R&D Investment Conditions

General agreement on a technology or technical system's feasibility incentivizes and provides justification for investments in research and development. A lack of consensus on feasibility indicates the potential for controversy and debate among experts, which can provide incentive for further research investment (in order to resolve the controversies). At a minimum, a lack of consensus regarding feasibility is unlikely by itself to preclude further R&D efforts. Scientific opinions tending toward a consensus on the infeasibility of a technology, however, can disincentivize R&D investment: a technology that is regarded by experts as "impossible" is less likely to attract sustained, mainstream investment.

Since this dissertation is interested in how scientific or technical expert opinions can shape investment incentives for an emerging technology, it is not as concerned about the nature of the scientific consensus or the veracity of the feasibility claims. Extensive literature exists to show that scientific opinions can be shaped by extra-scientific factors including culture, power and funding, politics, and personal credibility and can be achieved through various sociopolitical processes and mechanisms, including result negotiation, boundary construction, micro-politics of translation, and bandwagoning practices.[148] Similarly, scientific consensus does not necessarily indicate veracity – scientific agreements are products of time and are reflective of the state of knowledge of a given era. States of knowledge can change, and "truths" once established can be overturned by future studies, insight, and evidence.[149] For the purpose of this dissertation, scientific consensus thus neither assumes a socio-politically neutral position of science, nor does it indicate transcendental truths. It indicates only the strength of the collective opinions of the expert community on an issue and the way it impacts investment decisions: as the scientific opinion converges toward a consensus on the infeasibility of a technology, or as the opinions on a technology's infeasibility become dominant, the incentive to invest in such a technology declines.

Hypothesis 1: As scientific agreement on the feasibility of an emerging military technology declines, the investment condition for such technology also becomes less favorable.

4.2.2 Demand Side Variable – Defining Technical Requirements

The demand side variable in the military R&D processes is the articulation of the performance parameters of a given defense technology within the military requirements process. From the military perspective, defense technology is designed and developed to meet capability needs of a service, and these capability needs, in turn, are derived from the types of missions that a particular service needs to conduct. A requirement, thus, is a stated

[148] See, for instance, the concise summary provided in Uri Shwed and Peter S. Bearman, "The Temporal Structure of Scientific Consensus Formation," *American Sociological Review* 75(6) (December 2010): 819.

[149] See, for instance, Thomas S. Kuhn, *The Structure of Scientific Revolutions*, Third Edition (Chicago, IL: The University of Chicago Press, 1996) and Harry Collins, *Gravity's Shadow: The Search for Gravitational Waves* (Chicago, IL: The University of Chicago Press, 2004). See, also, Naomi Oreskes, "Science and Public Policy: What's Proof Got to Do with It?" *Environmental Science & Policy* 7 (2004): 379-381.

operational need for the military. Such a need may have developed in the field as a result of some observed operational problem, or it could have resulted from an analysis of projected future missions. In some other cases, a requirement may be developed as a response to a new technology opportunity. In any case, it refers to the demand of a capability and the operational parameters under which this capability is expected to work.

The structure of the defense industry is unique in the sense that it constitutes a relatively rare, monopsonistic or oligopsonistic "market" structure where only a single buyer or very few buyers exists. In such a market, the buyer exercises a great degree of influence over the terms via which a product is developed, produced, or sold. In the defense industry, where the government is often the sole buyer of defense technology products, the military exercises significant control of the R&D process through its unique power in articulating the requirements. In their studies of the defense industries' role in implementing military modernization, particularly with regard to network-centric warfare, Peter Dombrowski and Eugene Gholz describe this unique role of the military: "One major component of military transformation is producing a new set of equipment requirements…our theory suggests that developing the technology to implement the envisioned military innovation will require firms to respond to the new requirements, and to add their engineering capabilities and their political strength to the military's authoritative interpretation of the international environment."[150] In Dombrowski and Gholz's view, the defense market is customer-driven, where the military's visions of the security environment, perceptions of the desirable capabilities, and articulations of what is needed are dominant features of defense innovation.

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[150] Peter Dombrowski and Eugene Gholz, *Buying Military Transformation: Technological Innovation and the Defense Industry* (New York, NY: Columbia University Press, 2006), Kindle Edition, Location 801-802 of 4981.

In the United States, civilian control over the military has long been a tradition, but such control "has not often been effectively exercised in the somewhat specialized area of military R&D."[151] As Deagle describes:

> The central political feature of the…acquisition process is that its control inevitably resides mainly in the hands of the services. No one else in the system has the information and the financial and staff resources to wield the day-to-day influence over programs that "micromanagement" permits. Moreover, no one can match the unique claim to control of the military-requirements process that the wearing of a uniform conveys.[152]

This situation is exacerbated by the fact that since there are multiple civilian authorities and political constituencies to the DoD, their interests are inevitably pluralistic and fragmented, which diffuse and limit their abilities to influence the defense acquisition process.

Yet, the process of articulating a military requirement is by no means autonomous and free from other sociopolitical influences. Despite the primacy that the military has over the requirements process, a myriad of actors is involved in defense acquisition and holds a stake in the investment and development decisions of a military technology. As Deagle further attests with regard to the organization and process of defense acquisition, "the stakes involved – programmatic, institutional, financial, and frequently the highest national interests – guarantee that management of military R&D will be buffeted by intense political forces."[153] The current staffing and validation process in the Joint Capability Integration and Development System (JCIDS) in the United States reflects this situation:

[151] Franklin A. Long and Judith Reppy (1980), 15.
[152] Deagle (1980), 176.
[153] Deagle (1980), 163.

> The staffing process ensures stakeholders are afforded visibility into proposed new capability requirements, or changes to previously validated capability requirements. This visibility enables Sponsors to benefit from stakeholder inputs as they refine their capability requirement documents, ensuring that new or altered capability requirements are compatible with, and collectively provide the best value to, the Joint Force. It also enables validation authorities to shape and validate capability requirements to best serve the needs of the Joint Force.[154]

In other words, at least in the US, the process in turning a military demand of a capability into a material solution is designed to ensure that various stakeholders within and outside the Joint Force are able to influence the articulation of the requirements.

This problem of multiple stakeholders is especially acute when the capability being developed has high technological uncertainty, is complex, and impacts multiple end-users both inside and outside the services. As Thomas McNaugher accounts in his study on defense procurement, the problems of failed projects often begin with the initial articulation of requirements, where cost schedules, performance goals, and technical specifications are established amidst pressures to compromise and consensus-building. Such pressures lead to elaborate requirements, some may be competing with one another, because each stakeholder wants to protect capabilities, technologies, or performance specs that matter to the political actor it represents.[155] As a result, cost and schedule overrun become constant features in defense acquisition.

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[154] Chairman of the Joint Chiefs of Staff Instruction, CJCSI 3170.01I, "Joint Capabilities Integration and Development System (JCIDS)," (January 20, 2015), A-5. The JCIDS process became formalized in the United States in 2003, under the direction of then Secretary of Defense Donald Rumsfeld, in order to address problems with joint force capability development. Prior to the JCIDS process, the requirements in the United States were service specific.

[155] McNaugher 124-135.

Even if such a consensus-building process has not led to a maze of competing and contradictory performance goals, the military itself may not always possess accurate and complete information to determine requirements that would permit a smooth development process. Such is the problem of "flying blind," where both strategic as well as technical uncertainties preclude rational decision-making. In Michael Brown's study of US strategic bombers, for instance, he notes that "in every case examined…the air force decision makers compounded the unknowns their programs faced by setting performance requirements beyond, frequently far beyond, the state of the art."[156] Because of this lack of information and in some cases, the lack of ability to obtain such information, "doctrinal and organizational preconceptions [play] an important role in shaping key decisions" regarding performance parameters and the technical criteria used in developing a capability or technology can be far from technical realities.[157]

Donald MacKenzie and Judy Wajcman have perhaps summarized best this socially constructed and political contested nature of defense technology requirements. As they suggest:

> In the military, as elsewhere, organizations develop technological style and preferences which are embodied in the criteria they use to evaluate technical changes. In effect, organizations can come to hold socially specific definitions of what it is for a technology to 'work'.[158]

They elaborate on this by using the development of a rifle as an example:

> In the case of the ordnance corps, the definition of what it was for a rifle to work was influenced strongly by the 'gravel-bellies', the sharpshooters

[156] Brown (1992), 14.
[157] Brown (1992), 14.
[158] Donald MacKenzie and Judy Wajcman, eds. *The Social Shaping of Technology,* Second Edition (Maidenhead, UK: Open University Press, 1999), 347.

whose key criterion was the accuracy of a weapon in controlled, deliberate, long-range firing on the best range.[159]

Since "it is impossible to test any technology for all possible conditions, or to shape it to satisfy all possible demands on it," they conclude, "an organization must select criteria," and "[t]he criteria it prioritizes will depend in part on its history and its relations to other competing organizations."[160] The militaries, thus, generate, articulate, and define the parameters under which a technology works according to its organizational style and mission.

In his seminal work on the development of inertial guidance systems, MacKenzie shows this highly sociopolitical nature of the military requirements. The navigational requirements for the early strategic ballistic missiles were set at 5,000 feet, which, after a flight time potentially as great as ten hours, was an extremely demanding specification for accuracy. This requirement was later adjusted to 1,500 feet of circular error probable in the contracts for the MX-1593 (Atlas) missile.[161] A theoretical analysis by Charles Draper and his colleagues at the Instrumentation Laboratory in 1947 reveals that in order to achieve even just a nautical mile of accuracy (a little more than 6,000 feet) after an hour of flight time, the inertial guidance system required gyroscopes that were at least a hundred times more accurate than what was available as the state of the art.[162] MacKenzie argues that "[t]here was of course nothing ultimately sacrosanct about this requirement," for the "later British inertial navigator project had an Air Staff accuracy requirement of five miles after 20 minutes."[163] Such a demanding requirement in the US likely stemmed from the Air

[159] MacKenzie and Wajcman (1999), 347.

[160] MacKenzie and Wajcman (1999), 347.

[161] MacKenzie, *Inventing Accuracy* (1993), 114. According to MacKenzie, circular error probable refers to "the radius of the circle around the target within which half of the warheads should land." At that time, none of the cruise missile programs have achieved the accuracy goal of 5,000 feet.

[162] MacKenzie, *Inventing Accuracy* (1993), 75.

[163] MacKenzie, *Inventing Accuracy* (1993), 75.

Force's unwillingness to adopt the missiles into its operations, which were regarded at the time as a competitor to the strategic bombers. Since, during the same time period, the circular error for "blind" bombing by a strategic bomber was believed to be 1,500 feet, it was expected the ballistic missiles would need to "perform" at least equally well in order to be an acceptable system for the Air Force.[164] The requirements, in this case, are defined not according to a reasonable expectation of the existing technical or scientific possibility but a performance measure that is designed to preclude the missiles from being an acceptable investment and development option.

Because of the competing political pressure both within and outside the military organization as well as the inherent uncertainties embedded within the acquisition process, the military sometimes defines the requirements for a military technology with operational parameters quite independently of the scientific and technical realities. Beard, recognizing this, concludes about the Air Force's reluctance to the earliest developments of ICBM this way, "Whatever the reasoning, there was in the highest levels of the Air Force R&D hierarchy opposition to the accelerated development of long-range ballistic missiles and an apparent failure to appreciate technological unpredictability or even to recognize technological advances."[165] This is not to say that the military makes requirements decisions in a void and free from scientific or technical input, but that such decisions may be made with very limited scientific and technical information. In some cases, such information may even take a back seat to existing understandings of a military organization's mission, operational doctrine, and dominant technology.

Regardless of their potentially political and contested nature, requirements and their associated operational parameters are a critical component to defense acquisition and the military's investment decisions. They materialize "consumer demands" in the defense

[164] MacKenzie, *Inventing Accuracy* (1993), 114.
[165] Beard (1976), 222.

technology market and reflect how the military perceives and understands a technological opportunity. The levels at which the military sets its desired operational parameters for a technology, thus, impact the attractiveness of the technology as an investment option. As seen from the case of the early developments of the ICBM, a highly demanding requirement can undermine potential and in some cases, actual investments to a technology. The more demanding a requirement is, the less likely that it is going to be achieved, which in turn leads a technology to be regarded as an insufficient solution to a capability gap or mission need.

In this dissertation, the degree to which a requirement is "demanding" is conceptualized as the stringency of the requirement. The word stringency is used here to connote a sense of tightness, strictness, and specificity. A stringent requirement is one that articulates the operational parameters within a narrow range, precludes deviations from such parameters, and allows little room for interpretation. With regard to technology development, stringency also suggests difficulty to achieve a requirement. A stringent requirement in this sense is one that is defined far from the existing technological frontier and will require tremendous research efforts in order to be reached. Since it is impractical and often impossible to define a threshold of stringency, the stringency of a military requirement is understood in this dissertation in comparative terms to other similar military demands or the state-of-the-art science and technology of the time.

Hypothesis 2: The more stringent a military requirement, the more difficult it is to be achieved, and the less favorable are the investment conditions for a technology intended to address such a requirement.

4.2.3 Institutional and Technology Alternatives

Investment decisions are impacted by the availability of alternatives. Alternatives refer to both the potential for as well as the existence of more than one option to the way that a capability gap is addressed through the acquisition process. In other words, an alternative is an additional technological option or an additional way that a technology may be accessed and acquired beyond indigenous development from the military R&D system.

Not all military mission requirements and capability gaps require material solutions developed from R&D. Some capability gaps maybe addressed by additional training and changes in existing force organization and management, while other mission requirements maybe met by shifts in policy and adjustments to operational doctrines. In the US, this is reflected in the Joint Capabilities Integration and Development System (JCIDS), where deliberate (non-urgent or emergent) requirements identified and validated in the initial capability documents (ICD) can translate to material solutions (through Capability Development Documents), non-material solutions (through the Joint DCR[166]), or a combination of both.[167] The recent focus on stability operations as part of core US military missions since 2005 is one such example where changing missions have required non-material solutions based on doctrinal changes and updates.[168]

When a technical or material solution is required, however, alternatives can exist from both an institutional as well as a technology perspective. Institutional alternative refers to alternative avenues through which a technology can be developed and the capability need fulfilled. This may refer to efforts conducted by industry IR&D,[169] by other agencies, or by existing R&D for commercial/civilian purposes. In this sense, a technology may be acquired from outside the military R&D process. In *Beyond Spinoff*, John Alic and

[166] DCR stands for DOTmLPF-P (Doctrine, Organization, Training, material, Leadership Policy and Education, Personnel, Facilities, and Policy) Change Recommendation.

[167] CJCSI 3170.01I, A-5.

[168] Jennifer Morrison Taw, *Mission Revolution: The U.S. Military and Stability Operations* (New York, NY: Columbia University Press, 2012).

[169] As explained in Chapter 3, Independent Research and Development (IR&D) refers to "R&D initiated and conducted by defense contractors independent of DoD control and without direct DoD funding. IR&D includes: (1) basic research, (2) applied research, (3) development, and (4) systems and other concept formulation studies." See also Defense Innovation Market Place, "About Independent Research & Development," http://www.defenseinnovationmarketplace.mil/about.html (accessed October 7, 2016).

others discuss several modalities where military and civil technologies influence one another.[170] These include deliberate investment and development choices as well as, more often, indirect and unintended pathways toward technology development. According to Alic et al., there are several ways for the military to acquire a technology without being the sole funder for its development. For instance, technology can be developed concurrently for use in both military as well as civilian sectors, and this can occur in the form of a technology component, as in the case of a major contractor's development of jet engines and aircrafts,[171] or technological infrastructure, such as the development of small-scale nuclear reactors for electric power production. This is especially likely when an area of science or a technology is dual-use.

Since the military is but only one government agency that invests in scientific research and technology development, other government agencies may also invest in technologies that can be leveraged by the military. In certain technical areas, the military's needs may overlap with the missions and functions of other agencies. In the US, for instance, certain DoD technological needs may overlap with those of the Departments of Energy, Health and Human Services, Homeland Security, Justice, or the intelligence communities. This is especially true for today's military whose mission scope continues to broaden and for technologies that are dual-use or infrastructural in nature. These different government agencies can serve as cost-sharing partners for R&D or alternative technology developers/funders. Technologies developed in this manner can thus be a multi-agency effort, such as the early developments of artificial intelligence which attracted investments from DARPA, NIH, and NSF.[172] In his study on American biodefense, Smith has similarly noted that although biological weapons have traditionally been within the military domain,

[170] Alic et al. (1992), 64-75.

[171] For instance, the development of Boeing aircrafts KC-135, which is used by the military for aerial refueling, and its civilian counterpart Boeing 707 commercial airliner, are both developed from Dash 80 prototype.

[172] Alic et al. (1992), 73.

civilian authorities such as the Department of Health and Human Services (HHS) have in recent years become the major sponsor and funder for defense against such weapons, including the research, development, and acquisition of biodefense technologies.[173] Smith attributes such a neglect of the military investment in and the rise of civilian sponsorship of biodefense to the military's faulty stereotypes of biological weapons and its kinetic organizational frame of reference. Such stereotypes and frames caused the defense against biological weapons to fall outside the military's problem-solving domain, and as result, even when opportunities arose during the 1990s and early 2000s, the military's interest in funding biodefense languished. In other words, the stereotypes and organizational frames prevented the military from seeing biodefense as *its* problem, and since "military and civilian biodefense involve similar science and technology,"[174] it was not difficult for the military to pass the responsibility of biodefense on to someone else.[175]

The military can also acquire a technology as a result of a "reverse spin-off" (or "spin-on") where a technology developed entirely in the civilian sector is adapted for use by the defense communities. Alic et al. suggest that, for instance, CMOS (Complementary Metal-Oxide Semiconductor) circuits, a technology integral to today's integrated circuits, were perfected in Japan for wristwatches but are now used in military applications due to their status as the dominant chip technology. Although the Department of Defense has since made further investments in chip technologies, it provided very little funding for the early R&D efforts. Commercial products developed and acquired in this manner can be used off the shelf by the military, or they can be subject to further R&D and other sorts of modification (such as hardening, for instance) in order to better suit the needs and the

[173] Frank L. Smith, III. *American Biodefense: How Dangerous Ideas about Biological Weapons Shape National Security* (Ithaca, NY: Cornell University Press, 2014).

[174] Smith, *American Biodefense* (2014), 102.

[175] Smith, *American Biodefense* (2014), 119.

specific operational environment of the military. In either case, the military may have invested very little, if at all, in the technologies it uses.

Alternatives can also exist in terms of suitable technology options to fulfill a mission or capability need for the military. In this case, a technology alternative refers to the possibility or the existence of one or more alternative technologies that can be developed to fulfill a capability gap. For a given mission, from which technological requirements are derived, the capability gaps may be addressed by an array of possible technological options. The presence or absence of technology alternatives can be highly influenced by the way a given mission is understood and defined by the relevant services. Many studies focusing on the development of specific weapons systems and the inter- or intra-service rivalry attest to this. For instance, in the early stages of the development of intercontinental ballistic missiles in the United States during the late 1940s and early 1950s, the lack of technological maturity, the declining defense budget, and the long time horizon have led the Air Staff to favor the development of subsonic bombers over long-range missiles, despite having won the right to its R&D from other services.[176] From this perspective, the Air Force considered strategic bombers viable alternative technology to ballistic missiles in fulfilling the mission of long-range air bombardment, which in term impacted the order of priority in terms of missile research and development.[177] Whether or not this perception was accurate during the early stages of development, the Air Staff estimated the need for ICBMs to be low due to the ability to conduct strategic bombing missions using the then heavily focused on bombers.

[176] Beard (1976), 51-62. One of the consequences of this shift in priority was evidenced in the cancellation of the Convair's MX-774 project (later converted to Atlas), which, at the time of its cancellation in 1947, was the first US effort at ballistic missiles in the intercontinental range and the only 5,000-mile range ballistic missile under development in the Air Force's arsenal.

[177] Beard (1976), 61.

In other words, alternatives refer to the availability of options—options both in terms of access to a technology as well as the technology itself. Both institutional and technology alternatives are supply-driven, but alternatives can also exist from a resource and demand perspective. In this sense, there may be alternative sources of demand that impact the incentives to invest. The military may not be the only institution that is interested in a given area of science and technology, and other political entities or institutions' interest can impact the military's calculus regarding technology investment. In some cases, alternative demands may create incentives for the military to invest in a certain area of science and technology. This can occur as a result of higher order policy (such as a President's directive) that permits additional resources to be allocated through the defense sector for certain S&T fields. Other times, this may mean that there is a mandate for investment in specific S&T areas and that specific funds may be provided through the military. In the United States, this most often occurs in the form of congressional earmarks, where the Congress directs certain funds from the discretionary portion of the federal budget toward certain locales or for certain purposes.

This is not to say that the funds allocated through the military this way necessarily compromise the military's interest, constrains its investment choices, or misguides its priorities. It is possible and often that such an "alternative demand" is consistent with the military's needs or is at least not in direct contradiction to military functions. Such demand alternatives provide ways for the military to invest in R&D for technology options that may be outside its existing portfolio or to supplement existing efforts through expanded funding. As Smith notes in terms of the civilian adoption of biodefense, where the Clinton administration has issued Presidential Decision Directives to delegate such authorities to the HHS, and its subsequent failures, “decisions made by Congress and the president have an independent effect on policy.”[178]

The presence or absence of alternatives, whether institutional or technological, can have an impact on investment decisions. Availability of institutional alternatives can undermine the military’s interest in pursuing or maintaining research and development efforts in a technology that may entail tremendous developmental uncertainties. It also presents the possibility that funding as well as research efforts can become highly diluted and interests highly dispersed, undermining the chance for the military to want to sustain its efforts. A technological alternative, on the other hand, dilutes the demand requirements. The more alternatives to a technology exist, the fewer claims the military has to any particular technological option. As a result, as the availability of institutional and/or technological alternatives increases, the interest to invest in any given, specific technology decreases, making an investment unappealing.

In this dissertation, an institutional alternative refers to the possibility of a technology to be developed by an institutional actor (i.e. a firm, a government agency, an organization, etc.) that is not the sponsor under consideration whose need is being fulfilled. This institutional alternative can be either inside or outside the defense establishments depending on how broadly the sponsorship is defined. For instance, for the Air Force’s development efforts on ICBMs, the Army and the Navy may serve as internal institutional alternatives, whereas for the DoD’s effort in developing treatments for PTSD, the NIH or the pharmaceutical industry may be an external institutional alternative.

A technology alternative is said to exist when, for a given mission need, more than one technological solution is possible. Such a definition relies on how the mission is defined as well as how the need is articulated. Using the familiar examples from above,

[178] Smith, *American Biodefense* (2014), 125.

ICBMs and strategic bombers may be considered alternative technologies to the strategic nuclear missions of the Air Force, for both can implement the necessary long-ranged bombing. On the other hand, to solve the need for missile guidance, inertial and radio guidance systems can also be considered alternative technologies. Each technology alternative carries with it different stakeholder interests and developmental challenges, to be sure, but each is considered an alternative because it is a *viable* pathway through which a *defined* need or problem is redressed. The importance of technology alternatives in shaping investment conditions increases when a given technological option's ability to fulfill the military requirements declines, and for a given technology, the greater the availability of alternatives, the less favorable is the condition for its investment.

Hypothesis 3 – Increased availability of institutional or technology alternatives to address a capability gap reduces the interest of the military to invest in any particular technology option, resulting in less favorable investment conditions.

4.2.4 Cost, Time, and Performance

Military acquisition decisions are influenced by estimates of product life-cycle cost, time required to bring a technology to operation, and projected performance. These interlinked variables are often evoked as both reasons to acquisition decisions and metrics for acquisition failures: one of the most common complaints of the acquisition process, both in the policy circle as well as in the academic community studying it, is that the existing system is broken because of escalating life-cycle costs, schedule overruns, and compromised performance of the products. These variables are therefore perpetual features of defense acquisition, have become the focal points for the numerous reports and studies that try to "fix" the system, and are, rightfully, critical components of the acquisition process.

Cost, time, and performance are important considerations for acquisition decisions and integral mechanisms to the acquisition system, and in this dissertation they are also accepted as important variables that matter for defense investment decisions. As can be expected, investment in a military technology can be sidetracked, paused, or terminated because of high costs, schedule overruns, and under-delivered performances. These measures are therefore components of a rational, expected-utility based calculation regarding investment decisions.

Yet, as aforementioned, the inherent uncertainties embedded in emerging S&T complicate matters by making predictions about cost, time, and performance difficult. The lack of clarity regarding the development trajectory of an emerging technology makes it difficult to predict with confidence the amount of money and time needed for a technology to become mature enough for deployment, and such a lack of clarity also makes it difficult to have reliable expectations about a technology's ultimate performance. As a result, amidst uncertainties, these variables integral to acquisition decisions are at best heuristics and not always reliable measures for determining investment decisions.

The supply and demand-side variables articulated above regarding technical feasibility and requirements stringency nevertheless impact cost, time, and performance. A low level of agreement on the expected feasibility means that a technology may be far beyond the existing technical horizon, for it often indicates, at a minimum, that significant controversies still exist and significant research efforts are needed to resolve certain bottlenecks. This also generally means that such a technology would require more time and money to develop than those that the experts deem feasible. Disagreements on feasibility may also lead to a lack of clarity in reasonable performance expectations of the technology.

The issues of feasibility are further complicated by the way that the consumer, in this case the military, sets the requirements demanded from the technology. Given a state of scientific or technical feasibility, the more stringent the requirement, the more difficult it is to achieve, and the more time and money it is likely to take in order to fulfill it. The requirements also directly impact the expected performance of a technology. Stringent requirements can undermine the expected performance, thereby making a technology less appealing, especially when compared to more viable and more easily obtainable alternatives. MacKenzie's study of missile accuracy demonstrates this: the 1,500-foot circular error probable requirement during the early stages of ICBM development, which the US did not achieve until two decades later, made it impossible for the ICBM to "perform" on par with the strategic bombers.[179] Stringent requirements can thus preclude a technology from being competitive in the acquisition decisions.

Cost of R&D, time to maturation, and quality of expected performance impact investment decisions. In this dissertation, by contextualizing S&T as a variable, I show that the technical contents as conceived by the relevant actors in the investment decisions process can produce conditions that make an emerging technology more or less attractive. Under unfavorable conditions, the cost of R&D is likely to rise, the time to technology maturation and deployment lengthen, and the expected performance decline. Technical feasibility and requirements stringency are therefore tied to the expected cost, time, and performance for a military technology investment.

4.2.5 The Model

The discussions of feasibility, requirements stringency, and alternatives above delineate the different mechanisms via which S&T can influence technology investment. Yet, because the extent to which a technology is appealing as investment cannot be solely determined by supply or demand side factors, I argue that each of these variables is insufficient to impact investment decisions. In other words, these variables are individually

[179] MacKenzie, *Inventing Accuracy* (1993), 114.

necessary but not individually sufficient to alter investment conditions. Furthermore, I argue that these variables interact – the relative importance of each as a contributor to the favorability of investment condition relies on the value of the other variables.

It is recognized in this dissertation that variables such as degree of consensus on technical feasibility and requirements stringency operate on a continuum. However, for the purpose of clarity and simplicity, both variables are evaluated in a dichotomous manner and are examined in relative terms. A consensus opinion on a technology's feasibility and a lack of consensus, in this case, are treated as functionally the same, for they both incentivize R&D efforts. Availability of alternatives refers to the presence and absence of either or both institutional and technology alternatives. It is understood as the availability of an alternative pathway to fulfilling a capability gap. The investment conditions generated by these three variables are summarized in Table 2.

Table 2 - Feasibility, Stringency, and Alternatives on Investment Conditions

Technology Feasibility	Requirement Stringency	Presence of Alternatives	Conditions for Investment
High or Mixed	High	Yes	Favorable
		No	Favorable
	Low	Yes	Favorable
		No	Favorable
Low	High	Yes	Not Favorable
		No	Favorable
	Low	Yes	Favorable
		No	Favorable

Together, technical feasibility and requirement stringency constitute the technical content of an emerging military technology and, along with availability of alternatives, condition its investment at a given time. As offensive realists argue, the special status of a military technology and its role in national defense suggest that, given available resources, decision makers have an incentive to invest. In other words, given the resources, investing in a military technology is the normal practice. The favorability of investment conditions, for this reason, is defined "negatively": a favorable condition means that there is an absence of sufficiently compelling reasons that make a technology an unappealing opportunity. Nevertheless, the "favorable" conditions that result from the different configurations of these three variables are not all equal – in some cases, investing in a technology may be an easy choice, while in others more considerations may be necessary regarding the potential cost, time schedule, and expected performance.

For instance, when a technology is generally regarded feasible and the performance goals it is trying to meet are not very difficult, the R&D efforts are more likely to yield returns (such as allowing the technology to be produced). However, given the same level of feasibility but a highly stringent performance goal, the technology may still be produced but will likely incur greater cost and take longer to mature. While in neither case the acquisition of the technology has become so prohibitive that it would prevent a defense planner or decision maker from making the investment (in neither case would the investment conditions be unfavorable), they carry different implications regarding the potential cost, time, and performance expected from the R&D process.

As stated above, feasibility, requirement stringency, and availability of alternatives are interacting variables, and the relative importance of contributing to the favorability of investment of each is dependent on the value of the other. For instance, the stringency of the requirements becomes especially important when the feasibility of a technology is considered low. Low feasibility suggests that the technology may have bottlenecks that, even with significant investments in R&D, are difficult if not impossible to eliminate. Under this setting, a highly stringent performance requirement will make the technology even less appealing for investment, for the investors will unlikely be able to achieve the expected performance.

On the other hand, the idea of feasibility carries with it an implicit assumption about an outcome. Generally speaking, a feasible technology is one that is possible to *exist*. In this case, the expected outcome is implied as some kind of truth about nature. However, feasibility can also be understood with respect to an expected level of performance. In this case, feasibility may be used to denote the possibility of achieving a *certain* outcome that is functionally defined or threshold driven. Therefore, the meaning of feasibility of a military technology may shift during the acquisition process. At the beginning of the acquisition, feasibility may merely mean a proof of concept, but as the acquisition process progresses, feasibility may refer to the possibility of achieving a specified, expected level of performance. Furthermore, as noted above, the experts' beliefs in feasibility are themselves a product of time – their assessment of as well as their ability to assess the feasibility of a technology are built upon an existing state of knowledge. As science progresses, however, previously established beliefs may be overturned, due to new techniques, approaches, and evidence. For these reasons, a consensus verging toward low feasibility alone does not preclude a technology from being invested in, not only because that consensus can be overturned, but also because the issue of feasibility is mitigated by what is expected of the technology.

Finally, the existence of technology or institutional alternatives becomes increasingly important as the difficulty of acquiring a capability increases. It plays the greatest role in shaping investment conditions when low levels of feasibility and highly stringent requirements suggest that a technology may not be able to be developed to meet the performance goals. When a technology is unlikely to be developed according to the expected performance levels, the military may still choose to invest if there is sufficient demand for such a capability and if there are no alternative ways to fill the gap. This may require increases in expected cost and time, a recalibration of research focus (by concentrating on overcoming one specific bottleneck, for instance), or an adjustment of expected performance if possible, but the military will continue to have an incentive to invest despite the fact that the condition would not be ideal. However, given the same context with available technological or institutional alternatives, the military is more likely to abandon the troubled technology and opt for the alternatives. Therefore, the role that technology and institutional alternatives play in shaping investment conditions for a technology is dependent on the degree of difficulty (which is impacted by feasibility and requirement stringency) in acquiring such a technology to resolve a capability gap.

As shown in Table 2, consensus regarding the lack of feasibility, highly stringent performance requirements, and available technology or institutional alternatives together creates an unfavorable condition for the military to invest in a technology. As stated before, these factors are likely to increase the expected cost and time of the R&D and can also impact the expected performance, and as a result, the technology would become unappealing as an opportunity. Yet, *how* specifically does an unfavorable condition impact the levels of investment in a military technology? What does a lack of appeal for investment do to a technology during the acquisition process? To answer these questions requires an examination of how a new technology is introduced and its investment sustained in the acquisition process. The early stages of such a process are characterized by advocacy, consensus building, and sponsorship promotion, and after R&D has been initiated, the sustainment of investment requires the technology to continue to be justifiable despite potential challenges.

According to Evangelista, in a relatively open military R&D system like the one in the United States, the introduction of a new military technology is more likely to come from the bottom.[180] For him, the impetus for technological innovation comes from scientists who work in close contact with military officials. The proposal for a new technology and early investment decisions rest with lower levels of decision-making, such as program managers, and are only pushed up the decision hierarchy as the technology progresses into advanced development, integration, and production. This characterization of the early stages of defense R&D within the US, although written at the end of the Cold War, contains elements that continue to ring true today. As suggested in the Defense Science Board 2012 study of DoD basic research, for instance, all major decisions of DoD funding on basic research are highly subjective.[181] In this context, investment decisions at the early stages of R&D are highly influenced by the access that individual scientists have to relevant program managers and their ability to advocate for their novel ideas.

Of course, in order for the idea for a technological opportunity to germinate within the acquisition process and attract long-term investment, simple advocacy is often insufficient. If an idea for a new technology is to attract support and funding, it needs promoters who are willing to work with relevant people, both in the military and expert communities, to generate interest.[182] In this case, the promoters not only need to be able to relate the new technology to the military's needs, but they also need to be able to demonstrate feasibility of the new technology. The greater support the promoters are able to gather from the expert community and military officials, and the greater ability the promoters have in demonstrating (or finding endorsements for) the viability of the new technology, the more likely the technology will be sponsored.

Under favorable investment conditions, thus, technology opportunities will attract and accumulate interests as described above and be invested in. Yet, not all technology

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[180] Evangelista, x.
[181] Defense Science Board, *Report…on Basic Research* (2012), 25.
[182] Evangelista, 56.

opportunities enter the acquisition process under such favorable conditions, and even if they did, conditions can change over time. Under unfavorable conditions, as articulated by the theoretical model, these mechanisms for advocacy, consensus building, and promotion may fail, causing a technology opportunity to not be able to gather sufficient support to be initiated. Thus, one way that the technical contents can impact the investment is by making it difficult for the technology to go through the necessary mechanisms to build and consolidate interest.

Hypothesis 4: When the condition is unfavorable, a technology has difficulty generating sufficient support to attract sponsorship and be initiated.

The ability to get a new technology to enter initial R&D does not guarantee the sustained investment required for a technology to be developed into a capability. Even during the early stages of R&D, a new technology may run into difficulties, which may arise from a multitude of organizational, political, or in some cases social challenges. One possible organizational challenge, for instance, may arise if the technology poses a challenge to a military organization's traditional missions. The early development effort of the ICBM is one such example, where the missile's challenge to the Air Force's strategic bombing mission caused it to have limited support within the Air Force. Political challenges may also arise from multiple sources: interagency rivalry, political pork barreling, and in some cases, arms control concerns, for instance. These challenges can threaten the continued viability of a technology investment.

In some cases, those promoting a technology or having an interest in its sustained investment may leverage external threats or certain critical events as justifications for the technology's continued development. Yet, threats and critical events work both ways. A change in actual or perceived external threat may lower interest in some technological capabilities and, depending on what event one is dealing with, may also lead to reevaluations of the investments. As much as the promoters of a technology may advance their interest by leveraging threats and events, those who oppose its development may also encounter opportunities that embolden their challenge. In this sense, the favorability of the investment becomes important, for under unfavorable conditions, the technology may become vulnerable to these challenges. This effect can be articulated as follows:

Hypothesis 5: When the condition is unfavorable, a new technology is less resistant to potential organizational, political, or social challenges, making it more difficult to sustain should such challenges arise.

The political mechanisms articulated above regarding the initiation and sustainment of a technology investment are not intended to be comprehensive with regard to how the technical dimensions of a technology may impact investment decisions. Nevertheless, they provide some initial ways to envision *how* the political process of military technology acquisition may work differently under different investment conditions. It is recognized that other mechanisms may exist, and it is hoped that by pursuing a case study design, any additional pathways through which the technical content of a technology impacts its investment will be revealed. The following section describes the design and methodology used for this study.

4.3 Design and Methodology

4.3.1 Research Design and Case Selection

This dissertation employs a qualitative, case study design to assess the way different actors envision an emerging military technological opportunity. The case study approach helps reveal how a technology becomes defined and understood during the acquisition process and how such understandings can condition investment decisions. A study on why the military invests in some emerging technologies but not others requires scrutiny of programs that are invested in as well as those that purportedly have the potential for military applications but are nevertheless not invested in. While some data on invested programs are available, a potential military technology that is not invested in often leaves few records and scarce information. Therefore, a case study approach to this dissertation is used because a comprehensive dataset on investment and non-investment in emerging military technologies is not available, making systematic, quantitative study untenable.

The case study approach is also useful for examining more closely the highly linked variables studied and hypothesized in this dissertation. As aforementioned, technology feasibility, requirements stringency, and alternatives availability do not individually constitute sufficient conditions for non-investment in an emerging technology. The interactive and constructed nature of these variables makes it difficult to conduct systematic comparisons across the cases. A case study approach, which allows for situating these variables in different contexts, can better illuminate the impact they have on investment decisions.

Finally, the case study approach allows the opaque mechanisms through which the scientific and technical "content" of an emerging technology influence investment to be better explored. As has been shown by the extensive literature on military innovation and defense technology, explanations of military investment decisions are by nature multi-causal, and there are multiple ways in which the technical contents may interact with other social, political, organizational, or structural factors and impact the decision to invest in a technology. A case study approach therefore offers opportunities to examine such mechanisms more closely and has the potential to allow the uncovering of any missing or alternative mechanisms not already postulated.

The main question addressed in this dissertation is motivated by the curious absence of noticeable investment in the R&D of non-lethal weapons applications based on military neuroscience in the last decade despite increasing military attention and funding for cognitive neuroscience as an area of emerging S&T. In order to address this, I use cognitive neuroscience-enabled military applications as the basis for the cases chosen in the dissertation. As aforementioned, this dissertation adopts the categorizations of the 2008 NRC report assuming that the applied cognitive neuroscience technology has three "markets" – health, enhancement, and degradation. The two cases chosen for this study fall under two different categories of investment. The first case, examining the non-lethal weapons, focuses on the performance degradation application of cognitive sciences. The second case, the treatment and prevention of combat stress disorders, investigates one of the many medical/mental health applications of cognitive neuroscience research. This dissertation does not choose a case from the third area of application in performance enhancement because the technologies that fall under this category and their investment patterns do not have sufficient variance to yield useful analytical insight.

Since investments in biochemical incapacitants as non-lethal weapons and neuropsychopharmacological treatment for combat stress disorders have changed over time, these two cases provide an opportunity for within-case comparisons. Media and policy attention toward human brain research in recent years, particularly through cognitive neuroscience, have presented this area of S&T as emerging, and the United States is at the frontier of pushing the boundaries of the understanding of the human brain. Indeed, significant military research efforts to date in this area of S&T remain in basic and early-applied research. Yet as explained in greater detail below (section 4.3.3), military interest in research of the human brain has a long history. In both of the cases studied in this dissertation, despite this long-standing interest, levels of military investments have varied over time, and this variation allows for multiple observations in each case and helps reveal how the technical contents of these technologies, as conceptualized and defined by the expert communities and the military, have mattered for investment.

By using these two case studies I do not suggest, nor do I argue, that these cases are structured as direct comparisons. In fact, R&D efforts in non-lethal weapons and mental health treatments occur in and are funded through different components of the DoD, and the scientific community that is involved and expertise required for developing each application are not exactly the same (despite recent interests in them and the belief in their military potential are driven by advancements in cognitive and neuroscientific research). Nevertheless, these two cases provide a way to showcase how, despite their roots in a common area of emerging science, different conceptualizations of their feasibility and utility influence the military's investment interests.

Most importantly, the two cases examined in this dissertation raise significant doubts on existing structural, organizational, and bureaucratic explanations of defense technology investment. Structural theories suggest that states respond to strategic needs from the international system and are primed to invest in new military technologies as long as they can. Yet, this logic fails to explain why the US has not more rigorously pursued the non-lethal weapons applications from recent advancements in cognitive neuroscience. Structural theories also have difficulties explaining why the US has had more visible investments in medical applications of neuroscience. Clearly, US engagements in Afghanistan and Iraq since 2001 have generated significant concerns over issues of PTSD and TBI of returning service members, but investments toward treatments of these disorders and injuries are less reflective of a strategic necessity in the current era than a domestic concern. This demand for treatment R&D as a result of recent US overseas operations, whether structural or domestic, also fails to account for the relative lack of attention the military gave to similar problems during and in the immediate aftermaths of the Vietnam War.

Theoretical predictions based on the military's organizational frame also have difficulties in explaining military investments in neuroscience applications, particularly if such a frame is understood as a kinetic one. A strict understanding of the military's kinetic frame, namely that the military focuses its attention only on the RDA of kinetic weaponry such as projectiles and explosives, suggests that the military would neglect investments in all cognitive sciences research, since none is, strictly speaking, kinetic. To a certain extent this is true, since the amount of military investments in cutting-edge cognitive neuroscience research is much smaller than that for conventional kinetic weaponry. Yet, this logic fails to explain why there are varied levels of investment in the different types of neuroscience applications. Furthermore, the kinetic frame hypothesis has little reason to predict that, presently, the military would invest in medical treatments of cognitive and neurological deficits and trauma over non-lethal weapons. The lack of military investment in non-lethal weapons applications and the relatively greater attention to treatment technologies since the early 2000s suggest that the organizational frame hypothesis has difficulty providing predictions for the cases considered in this dissertation.

Bureaucratic explanations of investments that define bureaucratic interests as quests for resource and autonomy would suggest that the military has an interest in investing in cognitive neuroscience applications as policy attention and resources given to this area of research increases. Once a research program is established, the military is unlikely to give up its functional authority over the program to other competing organizations or agencies. Furthermore, bureaucratic explanations would also suggest that the military is likely to "fight harder" for getting or keeping the functional authority of R&D in an area of emerging S&T, should that area of S&T and the capabilities produced fall traditionally within the domain of the military. These predictions, however, are better at explaining presence of investments than the lack thereof, particularly in an area of S&T that is traditionally military-relevant, such as non-lethal weapons. As the case studies reveal, while some bureaucratic interests are at play in a political decision such as a military technology investment, these interests alone do not explain the investment patterns.

4.3.2 Methods and Data

To evaluate the cases, this dissertation employs the congruence method and, to the extent possible, process-tracing. These two analytical methods are chosen because: 1) the cases of investment or non-investment do not constitute the ideal controlled comparison, but each case can be examined independently for the variables' validity, and 2) the mechanisms and processes of how technical contents as understood by the relevant actors impacting investment decisions are sometimes opaque, and the process-tracing method may reveal additional insights regarding these processes. The congruence method "begins with a theory and then attempts to assess its ability to explain or predict the outcome in a particular case."[183] For this research, congruence method has a special appeal, because the three main variables need to be configured in a very specific way in order to predict non-investment. Testing for congruence in this manner adds more validity to the model proposed. Process-tracing "attempts to identify the intervening causal process—the causal chain and causal mechanism—between an independent variable (or variables) and the outcome of the dependent variable."[184] For this dissertation, process-tracing is used to explore how the investment conditions generated by feasibility consensus, requirement stringency, and alternatives availability impact investment decisions.

Each case study examines the historical context surrounding the development of the respective technologies and investigates the nature of their status as emerging military technologies. As is discussed in greater detail below, the military applications of cognitive neuroscience have received more media and policy attention in the last decade primarily due to breakthroughs in the techniques to understanding the human brain, but each of these applications has seen different iterations and levels of research efforts for many decades

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[183] Alexander L. George and Andrew Bennett, *Case Studies and Theory Development in Social Sciences* (Cambridge, MA: The MIT Press, 2005), 181.

[184] George and Bennett (2005), 206.

before. Each case study then examines the levels of feasibility, stringency of requirements, and availability of alternatives. In each instance answers to the following questions are sought:

1) Is the technology feasible? What are the recognized technological barriers or other “reverse salients” in its development? To what extent do the expert communities agree on its feasibility and was there a dominant opinion regarding feasibility?

2) What are the requirements for the technology set by the military? How stringent are the requirements? How were these requirements determined?

3) Do institutional or technology alternatives to the technology capability exist, and if so, which ones?

Each case will then examine how these different understandings of the technology matter for the decision process and explore the ways in which the different conditions produced by the variables led to investment decisions.

As data availability across the cases is different, not all cases will use exactly the same types or sources of data, and each case will entail different levels of use of primary and secondary source materials. In terms of measuring the supply-side variable, the degree to which there is an agreement or a dominant opinion on the feasibility of a military technology by those in the expert communities, the main unit of analysis is scientific or technical opinion, which in this case refers to a scientific or technical expert’s evaluation regarding the viability of the technology. In cases where the viability of an emerging technology is in doubt, the reasons (expected bottlenecks and the nature of such bottlenecks) will also be noted. The degree to which there is consensus in the scientific or technical community regarding a technology’s feasibility is evaluated by assessing the opinions on the subject and by drawing on the existing literature.[185] In this dissertation, such opinions are drawn from a variety of sources, including academic and policy journals, scientist assessment reports from government agencies as well as advocacy groups, forecasting studies, briefings, survey results, and news reports.

Studies on scientific consensus formation within a discipline have employed a wide variety of techniques, but outside discipline-specific studies, consensus has been determined primarily via immersion in a scientific domain or subject, evaluation of existing literature, and thus obtainment of conclusions about the status of the field. Efforts to move beyond this approach have employed surveys[186] and network analysis of citation records[187] to assess the nature and the formation of consensus. Due to the limited availability (small *n*) of reported expert opinions on feasibility in some of the cases studied, and the fact that much of such opinions are expressed through non-academic publications and venues, this dissertation analyzes consensus through qualitative evaluation of the expressed opinions by relevant experts on feasibility and the extent to which any particular opinion has become the dominant interpretation of the feasibility of a technology among these experts.

The demand side variable examines the military requirements for a technology, which is most formally expressed in the US as Key Performance Parameter (KPP) and Key System Attribute (KSA) in the acquisition process. Key Performance Parameter refers to attributes of a system "considered critical or essential to the development of an effective military capability," whereas Key System Attribute refers to attributes of a system "considered important to achieving a balanced solution/approach to a system, but not

[185] Adapting the approach in Naomi Oreskes, "Beyond the Ivory Tower: The Scientific Consensus on Climate Change," *Science* 306(5702) (December 3, 2004): 1686 and its extension in John Cook et al., "Quantifying the Consensus on Anthropogenic Global Warming in the Scientific Literature," *Environmental Research Letters* 8 (2013): 1-7.

[186] Dennis Bray, "The Scientific Consensus of Climate Change Revisited," *Environmental Science & Policy* 13 (2010): 340-350.

[187] Shwed and Bearman (2010), 817-840.

critical enough to be designated as a KPP."[188] Both KPPs and KSAs are expressed with a threshold and an objective value, whereby the threshold indicates a value under which the performance is considered not operationally effective or suitable, and the objective value indicates a value of higher level performance that "represents significant increase in operational utility."[189] For the purpose of this dissertation, the threshold value of KPPs and KSAs of a technology is used when available as the most definitive measure of the stringency of the requirement, for technologies that perform under the threshold are deemed not suitable for operation and run the risk of being cancelled.

In contemporary US military acquisition systems, KPPs and KSAs for technology development are articulated in requirements documents. Yet, these operational attributes and objective values are not necessarily available across all cases, since both cases contain a historical component where these contemporary benchmarks for performance may not exist. For these reasons, in this dissertation, less formal statements of the requirements and the expected threshold values for performance will also be considered. Depending on the case and where possible, military requirements for a given technology will be drawn from primary source documents, including announcements, proposal requests, program reviews, reports, and reference books. Where formal declarations of requirements are not accessible or non-existent for a technology (as in the case of technologies that are early in R&D and technologies that are not being invested in), other primary and secondary sources will be leveraged to show the kinds of requirements that would be demanded from functionally comparable technologies.

The presence and absence of alternatives, both institutional and technological, are analyzed through interpreting primary and secondary source accounts of a technology's

[188] "Manual for the Operation of the Joint Capabilities Integration and Development System (JCIDS)," JCIDS Manual, (12 February 2015), D-A-1.
[189] JCIDS Manual, D-A-2.

development goals and the types of missions or capabilities it is trying to satisfy. Such information may be articulated in agency announcements and requests, or conveyed through other types of policy documents such as reports and recommendations. Institutional alternatives can be said to exist when a technology program is or can be funded and developed by institutional actors (both agency and industry) other than the expected sponsor for the development of a capability. In general, the more broadly defined a mission requirement is, the more likely that it can be fulfilled by multiple technological solutions. Similarly, technology programs that have greater dual-use potentials or have their technology base outside traditional military domains are more likely to have alternative sponsors and developers outside the military.

For most military technologies, a complete lack of institutional and/or technological alternatives is rare. Furthermore, the presence of alternatives has its greatest impact on investment decisions when low feasibility and highly stringent requirements make a technology a difficult investment option. Therefore, the importance of the presence of alternatives as a contributing factor to investment conditions is contingent upon the technical content of an emerging military technology as understood by the expert community and the military.

4.3.3 What is Emerging about Cognitive Science and Neuroscience?

The two cases used in this study, namely biochemical incapacitants as non-lethal weapons and medical treatments to combat stress related disorders, have received in recent years popular as well as policy attentions as areas of cognitive neuroscience research that can impact the military and future war. The rapid growth of academic literature in cognitive neuroscience research in the last decades brought with it new insights on human cognitive functions as well as new “possibilities” to unpack and manipulate the human brain. Along with nanotechnology, biotechnology, and information technology, cognitive sciences have long been considered part of converging technological trends at improving human performance and altering human existence.[190]

Yet, what exactly is emerging about cognitive science and neuroscience? Recent discussions on cognitive neuroscience research seem to imply that there is something new about human brain research, but the history of science suggests otherwise. The following section seeks to set the recent "emergence" of cognitive neuroscience in its historical context. A brief history of cognitive neuroscience shows that human brain research has in fact been ongoing for centuries, albeit it has in many instances appeared under very different guises. The following account also reveals that the quest to unraveling the human brain has been highly techniques and tools driven. Much of what is emerging about cognitive neuroscience today has to do with refinements of measurement tools and advancements in analytical techniques, most notably in computational modeling and noninvasive imaging. This has resulted in better understanding of the neuroanatomy of the brain. This increasing knowledge of the roles that various parts of the brain play on human cognitive behavior has permitted the various functions of the brain to be explored, studied, and where possible, influenced or altered.

4.3.3.1 Brief History of Cognitive Neuroscience

While cognitive neuroscience, as a term and as a discipline, has only come into existence in the late 1970s, the quest for understanding human cognition has a much longer history.[191] The word cognitive refers to the "psychological and physiological processes underlying human information processing, emotion, motivation, social influence, and development," and the term neuroscience denotes "the study of the central nervous system

[190] Roco and Bainbridge (2003).

[191] Michael S. Gazzaniga, Richard B. Ivry, and George R. Mangun, *Cognitive Neuroscience: The Biology of the Mind*, Third Edition (New York, NY: W.W. Norton & Company, 2009), 3. See pages 1-16 for a history of cognitive neuroscience.

(e.g., brain) and somatic, automatic, and neuroendocrine processes."[192] In this sense, cognitive neuroscience is an approach to the study of the human mind, and more specifically, it refers to the study of cognitive processes by examining the neural substrate to such processes. This is done through fine-grained studies of neuronal activities as well as examinations of regions of the brain and collective neuronal activation patterns.

The belief that human cognitive tasks and functions are tied to the brain structures and neural processes can be traced back to early 19th century phrenology, a study of the human skull, based on the assumption that certain human cognitive functions are tied to specific regions of the brain. Leading phrenologists of the time, Franz Gall and J. G. Spurzheim, posit that if one uses certain brain functions more than others, the parts of the brain that are associated with those functions will grow, causing bumps in the skull. They therefore believe that careful studies of the skull can lead to an understanding of the personality of a person. This localizationist view of the human brain and cognitive function was challenged by the aggregate field theory championed by Jean-Pierre Flourens, a French physiologist. In his studies on brain lesions in birds, Flourens discovered that the birds were able to recover with no apparent impairments from the lesions regardless where they occurred in the brain, leading him to believe that the entire brain participates in the generation of behavior. Of course, these early studies have since been discredited. Yet, they helped establish the assumption that the mind is a function of the brain, providing a basis to many of the later neurological studies of the human mind.

By the mid- to late 19th century, early phrenology and aggregate field theory had given way to clinical studies based on behavioral observations of patients who have suffered from neurological deficits or injuries. In England, John Hughlings Jackson's study on patients with epilepsy led him to propose a topographic organization of the cerebral

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[192] National Research Council, *Emerging Cognitive Neuroscience* (2008), 2.

cortex where the different regions of the brain are proposed to be linked to human body parts. In France, Paul Broca found that stroke-induced damage to a patient's left interior frontal lobe led to speech impairment and, in Germany, Carl Wernicke discovered in his patient that stroke damage to posterior regions of the left hemisphere (where temporal and parietal lobes meet) caused a different language acquisition problem, where the patient was able to speak but lacked comprehension. These clinical discoveries further helped establish not only that the human brain is linked to cognitive functions, but also that damage to specific brain regions can cause specific behavioral deficits.

The work by Jackson, Broca, and Wernicke emphasized the importance of localized regions of the brain in contributing to cognition and behavior and inspired later studies on categorizing human brain regions, such as the work by Korbinian Brodmann, who, in his analysis of the cellular structures of the cortex, characterized 52 distinct regions. These advances in understanding the structure of the human brain were accompanied by further explorations of how neurons function. In particular, Camillo Golgi's development of a silver stain that allows individual neurons to be visualized, and Santiago Ramón y Cajal's extension to confirm the unitary nature of neurons and the directional electrical transmission within a neuron, provided the foundation to much of 20th century studies in neurology and neuroscience. Thus, even before the development of cognitive neuroscience as a discipline, the quest toward understanding human cognition and the brain has seen contributions from a variety of disciplines through clinical as well as scientific discoveries.

As have been amply demonstrated by Mitchell Glickstein in his recount of the history of neuroscience, each new discovery of the way human brains are structured and how they function entails a long road of past discoveries, improvement of techniques, and accumulation of insights. Like in many other scientific disciplines, what the scholarly community knows about various forms of sensation and perception, types of disease, and categories of human behavioral functions relies on a history of past work.[193] In particular, as an interdisciplinary field of research, cognitive neuroscience relies heavily on a variety of techniques, methods, and other contributions from its consisting disciplines.[194] Advancements in this diverse set of methods and tools have propelled cognitive neuroscience research in the last several decades.

In addition to conceptual contributions from cognitive psychology, modern cognitive neuroscience research includes a wide range of methods and techniques, and as discussed above, some of the major discoveries regarding the human brain have relied on neurological studies or clinical observations of patients suffering from brain lesions and other neurological disorders. Yet, such studies are by nature limited to animal studies where deliberate surgical manipulations are possible, or in the case of human studies, due to chance. This lack of systematic ways to examine a normal human brain has led to developments of a set of modern neuroscience techniques, including, but not limited to, computational modeling, functional neuroimaging, and neuropharmacology. The continued refinement and convergence of these techniques and tools are what defines cognitive neuroscience as an emergent area of research and development. The following section explores functional neuroimaging as an area of emerging techniques for cognitive neuroscience research. While it is important to note that imaging is not the only area in which neuroscience techniques have seen significant advances, it has most certainly become one of the most dominant. A result, a better understanding of it helps clarify what is emerging about cognitive neuroscience.

4.3.3.2 Modern Imaging Techniques

[193] Mitchell Glickstein, *Neuroscience: A Historical Introduction* (Cambridge, MA: The MIT Press, 2014).

[194] For an overview, see Gazzaniga, Ivry, and Mangun (2009), 110-161.

Most modern-day research in cognitive neuroscience relies heavily on functional neuroimaging techniques in order to capture the fluctuations in the brain state responding to external stimuli. Functional neuroimaging, in short, is a "class of research techniques that create images of functional organization of the brain."[195] This is particularly important because it allows greater insight into the way that activation patterns impact normal human cognitive processes in a timely manner rather than understanding various cognitive functions and their neural substrates through the structural studies generated through neurological disorders or injuries. Through functional neuroimaging, researchers are finding more and more that human cognitive functions engage multiple parts of the brain and that a single brain region may contribute to multiple cognitive functions.

Many imaging techniques and technologies are used in the study of human cognition, and their utility can be differentiated by levels of spatial and temporal resolutions (see Figure 8 for a comparison between common cognitive neuroscience techniques and technologies). Spatial resolution refers to the ability to detect and distinguish changes in and across spatial locations.[196] Higher spatial resolution indicates greater granularity in the image acquired from the imaging technology, which in neuroscience most often means that changes can be detected in smaller brain structures and at greater depth from the cortical surface. Increase in spatial resolution helps the identification of the locales of brain activation. Temporal resolution refers to the ability to distinguish and detect changes over time. Higher temporal resolution indicates a more frequent sampling rate at which a measurement is made. Higher sampling rates allow greater amounts of images to be captured during a time period and better detection of quick changes in activation. Together, spatial and temporal resolutions contribute to the level of

[195] Scott A. Huettel, Allen W. Song, and Gregory McCarthy, *Functional Magnetic Resonance Imaging*, 2nd Edition (Sunderland, MA: Sinauer Associates, Inc., 2008), 4.
[196] Huettel, Song, and McCarthy (2008), 11.

granularity at which brain activation can be detected and analyzed in terms of both location and speed.

The different neuroimaging techniques can also be distinguished by their invasiveness and the types of signal they detect. Invasive techniques often provide both greater spatial and temporal resolutions, but at the cost of greater potential for damage or risk. For instance, electroencephalography (EEG), which measures the electrical currents generated through neuronal activation by placing the electrodes on the skin surface (in this case, the scalp), is non-invasive and can be used widely on human patients. In a similar technique called electrocorticography (ECoG), the electrodes are applied to the cortical surface, which allows greater spatial resolution as well as better signal-to-noise ratio but is also more invasive, for its operation requires craniotomy. The planting and removal of electrodes in ECoG therefore carries clinical risks—even if the surgery is successful, the intruded portions of the scalp are still subject to infections and other complications.

The types of signals that modern imaging techniques detect can be roughly divided into two categories: electromagnetic and metabolic. Techniques such as EEG and magnetoencephalography (MEG) detect changes in electrical potentials and magnetic flux that result from neuronal activation. Depending on the level of invasiveness, the electrical signals can be detected form the scalp, the surface of the cortex, and within the brain, whereas techniques using the magnetic properties of neuron firing are for the most part non-invasive. Electrical and magnetic signals in general enjoy a greater response time between activation and detection but are often subject to noise from surroundings. Other techniques, such as near-infrared spectroscopy (NIRS) and positron emission tomography (PET), rely on metabolic activities. NIRS uses an optic window in which skin, muscle, or bone tissues are transparent but hemoglobin is visible to measure the blood flow. PET, on the other hand, relies on tracking radioactive isotopes to reveal changes in blood glucose levels. Unlike electrical and magnetic signals, metabolic signals are indirect measures of neuronal activity, for they detect metabolic changes that result from neuronal firing, such as the consumption of blood oxygen and glucose. As a result, although such measures often have greater spatial resolution (for they can track neuronal activity that occurs further way from the surface of the cortex), the signals are often “sluggish” and have less temporal resolution than techniques like the EEG.

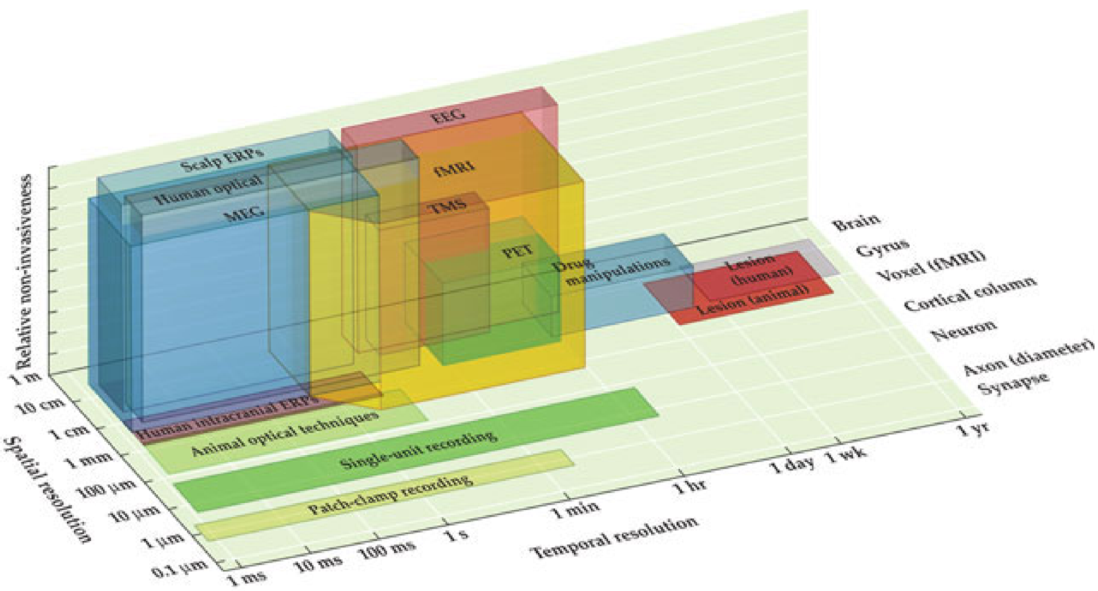

Figure 8 - Temporal Resolution, Spatial Resolution, and Invasiveness of Neuroscience Techniques[197]

Amidst all neuroscience techniques that have been used to study human cognition, functional magnetic resonance imaging (fMRI) has in recent decades become dominant.[198] The increasingly wide-spread use of fMRI is largely due to both hardware and software improvements that have occurred with magnetic resonance imaging in the last two decades.

[197] Huettel, Song, and McCarthy (2008), 14 (Figure 1.8).
[198] Huettel, Song, and McCarthy (2008), 3.

On the one hand, there has been tremendous growth in the power of MRI machines, while on the other, computational power and tools capable of handling large volumes of imaging data have also grown. Improvements in both hardware and software have allowed MRI machines to produce images with greater clarity and granularity that can be analyzed at greater speed.[199] These advancements have enabled this imaging technique to be used for understanding human brain functions in not just clinical but also cognitive research settings.

Functional MRI uses blood-oxygenation-level-dependent (BOLD) signals to detect neuronal activity. The firing of neurons consumes energy (in the form of glucose), and following neuronal activations, oxygenated blood flows to the activated regions to restore the neuron into pre-activation, polarized state. Since blood oxygenation levels change quickly following the neuronal firing, and because such changes are localized to the activation sites, changes in blood oxygenation levels produce localized signals of brain activation. Using the hemodynamic properties of neuronal activity, fMRI has been used to identify neural activations in the brain that contribute to certain cognitive functions and has allowed scientists an opportunity to examine *in vivo* the dynamic nature of cognition.

Functional MRI has gained its importance in the research of cognitive neuroscience because of its ability to achieve relatively high spatial resolution when compared to other non-invasive imaging techniques (see Figure 8 for comparison between fMRI and other neuroscience techniques).[200] Although the temporal resolution of fMRI is relatively low (when compared to other techniques that detect electrical signals) due to the sluggish nature of hemodynamic processes (which can last up to 10 seconds after the neuronal activation), fMRI, to date, remains one of the non-invasive imaging methods with the greatest spatial

[199] For a brief history of the MRI, its advancements in recent years, and its application to neuroimaging, see Huettel, Song, and McCarthy (2008), 15-24 and 201-207.

[200] For a more nuanced discussion of fMRI's spatial and temporal resolutions, see Huettel, Song, and McCarthy (2008), 214-229.

resolution. Of course, each neuroscientific and imaging technique has its unique strengths and weakness, and no single method can be suited to all neuroscience research tasks and designs. Nevertheless, as shown by the increasing literature on cognitive neuroscience studies using fMRI,[201] fMRI has established itself as a powerful tool in the study of cognitive neuroscience and has brought with it significant breakthroughs in the understanding of the human brain.

As the above discussion has shown, cognitive neuroscience research relies on a variety of measurement techniques, research methods, analytical tools, and forms of inquiry, and to understand it as an emerging field of scientific research and technological development, one needs to have a better appreciation for what and how the different techniques, methods, and tools are generating insights regarding the human brain. As Gazzaniga, Ivry, and Mangun suggest, neuroscientists "are continually refining techniques for measuring and manipulating neural processes at a finer and finer level," and each year there is "development of more sensitive equipment to measure the electrophysiological signals of the brain or the metabolic correlates of neural activity, and the mathematical tools for analyzing these data are constantly becoming more sophisticated."[202] Questions about the brain and the mind that can be answered are necessarily tied to the available measurement tools and analytical techniques, and new tools and techniques also help frame the types of questions that can be asked. The current emergence of cognitive neuroscience is thus, for the most part, driven by the increasing ability of scientists to analyze the brain in greater detail and to an extent, to manipulate brain functions more precisely.

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[201] This increasing amount of literature spans across the academic and scientific circles as well as the journalistic and sociopolitical ones. For some more recent "popular" portrayals of the use and meaning of fMRI that are geared towards to non-academic audience, one may consult Judith Horstman, *The* Scientific American *Brave New Brain* (San Francisco, CA: Jossey-Bass, 2010) and Miriam Boleyn-Fitzgerald, *Pictures of the Mind: What the New Neuroscience Tells Us About Who We Are* (Upper Saddle River, NJ: FT Press, 2010).

[202] Gazzaniga, Ivry, and Mangun (2009), 160.

A quick review of the historical developments in cognitive neuroscience has also revealed that research of human cognition has long been ongoing, and this applies to R&D that occurs both inside and outside the military domain. At least in the United States, notable national security-related research regarding aspects of human cognition and neuroscience can be traced back to as early as the 1960s. Investment in brain research has waxed and waned, but with the arrival of improved neuroimaging technologies and the maturing of their analytical techniques in the last couple of decades, there has been a reinvigoration of interest. Most certainly, at least in the US, research of the brain has now gained policy attention, and more deliberate and greater amounts of federal funding are devoted to it. While one often refers to this recent attention as the emergence of cognitive science research, it is important to note that research of the brain and human mind is not something that has only started to exist recently, and that any account for its current investment needs to be understood in historical context.

The following two chapters consist of case studies of military applications of cognitive neuroscience research in which the arguments and model posited in this chapter are applied. Chapter 5 examines the non-lethal weapons application of cognitive neuroscience, namely, the potential for weaponizing neurochemical incapacitants. Chapter 6 looks at medical aspects of cognitive neuroscience research regarding treatment and prevention measures of combat related stress disorders.

CHAPTER 5. BIOCHEMICAL INCAPACITANTS AS NON-LETHAL WEAPONS

One of the major potential application areas for the military regarding contemporary cognitive neuroscience research is the possibility of designing neurochemicals as incapacitating and otherwise non- or less-than lethal weapons. Especially for a country like the US, whose military continues to face an ever-widening scope of possible missions, having the ability to do something that is not just a choice between "shout or shoot" is becoming increasingly important. Non-lethal capabilities,[203] in this case, provide the military the option to address complex operational scenarios in which casualties of non-combatant civilians may be an operational concern.

In this sense, the military has a vested interest in cognitive science and neuroscience research. For the military planners and those concerned with military cognitive sciences research in the policy realm, "it is the expectation that knowledge and techniques gained from advances in neuroscience could enhance [soldiers'] combat effectiveness while degrading that of their opposition that makes neuroscience such an alluring subject to military planners."[204] As discussed, one of the major considerations of military use of neuroscience research is that such research can lead to better, more efficient non-lethal biochemical incapacitants, the use of which can be particularly relevant when the mission requires dealing with a mixture of armed combatants and civilians. Since "most discussions

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[203] Defined by the US DoD as "Weapons, devices, and munitions that are explicitly designed and primarily employed to incapacitate target personnel or material immediately, while minimizing fatalities, permanent injury to personnel, and undesired damage to property in a target area or environment. Non-lethal weapons are intended to have reversible effects on personnel and material." See Department of Defense, "DoD Executive Agent for Non-Lethal Weapons (NLW), and NLW Policy," DoDD 3000.03E (April 25, 2013), http://www.dtic.mil/whs/directives/corres/pdf/300003p.pdf (accessed December 10, 2015).

[204] Irene Tracey and Rod Flower, "The Warrior in the Machine: Neuroscience Goes to War," *Nature Reviews Neuroscience* 15(12) (December 2014), 825.

of drugs and their effects are organized along the lines of current models of the brain and nervous system functioning," changes "in models of brain function may create new and surprising ideas about how, when, where, and why drugs produce their effects" and about the kinds of neurochemicals that can alter human functioning.[205] Advances in the knowledge of the brain, particularly in neuropharmacology and drug delivery across blood-brain barrier, can present opportunities and unique challenges to the military's pursuit of an increasingly diversified portfolio of weaponry and can in particular engender new forms of biochemical incapacitants.

Despite its purported military utility and the increasingly voiced concerns by its skeptics, this particular area of research on biochemical incapacitants has seen fluctuated levels of investments from the US DoD. In particular, as shown in Chapter 2, since the early to mid-2000s, there has been little to no visible US military investments in this area of research, despite that military investment in cognitive sciences has been on the rise. Why did this happen? This chapter answers this question in the following manner: it first provides a recount of US investments in non-lethal programs, with particular attention to the programs that leverage research in biochemistry, pharmacology, and neuroscience that engender the weaponization of biochemical incapacitants. This chapter analyzes the evolving expert opinions on the feasibility of non-lethal weapon systems based on bio/neurochemicals as well as the military demand specifications for such weaponry, with particular attention given to injury risk and lethality. It is argued that the low levels of feasibility, highly stringent performance requirements, and the availability of alternative acquisition pathways have made the military investment in this area of research unappealing. The chapter then analyzes the international legal issues that concern biochemical incapacitants and shows how a shift in the international opinion on the

[205] National Research Council, *Emerging Cognitive Neuroscience* (2008), 41-42.

viability and acceptability of developing such weapons likely reinforces the US's lack of interest to continue its investment in this area of cognitive sciences research.

5.1 "Non-Lethal" Chemical Weapons – A Historical Overview

5.1.1 Early Investments: Law Enforcement or Military Technology?

The idea of weaponries that are designed not to kill, but to disable or incapacitate, is not necessarily novel. Some of the earliest reported usage of such non-lethal chemical agents can be traced back to World War I, where the prevalent use of chemical agents has earned the war the moniker as the "Chemist's War." Although some of the most well-known cases of the deployment of chemical agents, such as chlorine gas, were lethal in nature, non-lethal chemical irritants or harassing agents were also deployed by both sides. For instance, at the outset of the war, the French used ethyl bromoacetate, a lachrymatory agent, following the practice of police-issue tear gases earlier in the decade.[206] The Germans soon followed with the use of upper respiratory mucous membrane irritant *Niespulver* (o-dianisidine chlorosulphonate) at Neuve-Chapelle in October 1914, albeit with little success.[207] While the development and use of chemical agents soon escalate to the lethal varieties following the first-use of chlorine, a broad range of non-lethal chemical agents also became a mainstay of the war and were developed, produced, weaponized, and deployed.[208]

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[206] Stockholm International Peace Research Institute, *The Problem of Chemical and Biological Warfare: A Study of the Historical, Technical, Military, Legal, and Political Aspects of CBW, and Possible Disarmament Measures*, Volume 1 (New York, NY: Humanities Press, 1971), 28. See also Jonathan B. Tucker, *War of Nerves: Chemical Warfare from World War I to Al-Qaeda* (New York, NY: Pantheon Books, 2006), 11.

[207] Stockholm International Peace Research Institute, *Problem of Chemical and Biological Warfare* (1971), 27.

[208] For a list of non-lethal chemical irritants developed and used during World War I, see, for instance, Stockholm International Peace Research Institute, *Problem of Chemical and Biological Warfare* (1971), 42-46. One may also find a list of historical accounts where chemical or biological agents are used in Ladislaus Szinicz, "History of Chemical and Biological Warfare Agents," *Toxicology* 214 (2005): 169-172. For more accounts on early use and chronology, see also Martin Furmanski, "Historical Military Interest in Low-Lethality Biochemical Agents," in *Incapacitating Biochemical Weapons: Promise or*

The early efforts in producing non-lethal chemical agents, particularly around the time of WWI, focused on bromoacetate-based tear gases that are usable for both military and law enforcement purposes. Tear gases are lachrymatory chemical irritants that stimulate nerves in mucous membranes in the eyes, nose, and lungs, which can cause crying, sneezing, coughing, and other irritations. These irritants are quick in their onset of action and their effects often wear off in tens of minutes to a few hours. As opposed to chemical agents designed to produce casualties, non-lethal irritants force the enemy to put on protective gear such as respirators, disrupts his operational plan and activities, and reduces his combat effectiveness. An enemy exposed to a lachrymatory agent may temporarily lose his ability to carry out his mission but can recover relatively easily after the exposure ceases.

As the war wore on, however, the interest and search for more potent irritants also increased. By the end of the war, all belligerents had developed more potent forms of non-lethal chemical irritants. In the US, for instance, the development of a more potent lachrymator, chloroacetophenone (CN), has received significant renewed interest in the immediate aftermath of the war. Although developed too late in the war to be useful in the military operations, this military-originated lachrymator soon became used for riot control and law enforcement purposes. According to Stockholm International Peace Research Institute (SIPRI), "In the 1920s the US Army Chemical Warfare Service (CWS) conducted more research on CN than on any other agent: in 1921 the CWS offered a CN device for experimental trial to the Philadelphia police, and built a manufacturing plant for the agent at Edgewood Arsenal in the following year."[209] Other countries soon followed and

Peril? eds. Alan M. Pearson, Marie Isabelle Chevrier, and Mark Wheelis (Lanham, MD: Lexington Books, 2007), 35-66. In the SIPRI 1971 study, the non-lethal chemical agents are characterized as "harassing agents," which in its field deployment concentration has temporary disabling effects that last for a limited duration, and lethal chemical agents are characterized as "casualty agents," which causes severe injury or death in its field deployment concentration. See SIPRI, *Problem* (1971), 39.

[209] Stockholm International Peace Research Institute, *Problem of Chemical and Biological Warfare* (1971), 59-60.

developed CN, and "during World War II it was the principal lachrymatory harassing agent in the chemical-weapons stockpiles" for many countries, albeit it was not used.[210]

As can be observed with the development of CN, prior to WWII, the main source of innovation in non-lethal capabilities came from military investments in chemical weapons. This is so because during this time law enforcement agencies often lacked any significant research and development budget (if they had any at all).[211] As a result, although there was longstanding recognition that the law enforcement communities need capabilities that are beyond just "point and shoot," most of the development of police-use non-lethal capabilities came as civilian by-products of military R&D. In the US, this situation persisted into the 1950s and 1960s, when rampant crime in cities as well as major protests and riots resulting from prevalent racial inequalities and anti-war movements focused policymakers' attention on the need of the law enforcement communities.[212]

In particular, the report from the President's Crime Commission on Law Enforcement and the Administration of Justice in 1967 and the 1969 *Report of the National Advisory Commission on Civil Disorders* both recommend restriction on as well as provisions of alternatives to the use of lethal force by the police. These commission reports further recommend that "The Federal Government should sponsor a science and technology RDT&E program with three primary components: systems analysis, field experimentation, and equipment-system development"[213] and highlight the need for federal support to local officials in "Develop[ing] guidelines governing the use of control

[210] Stockholm International Peace Research Institute, *Problem of Chemical and Biological Warfare* (1971), 60.

[211] Neil Davison, '*Non-Lethal' Weapons* (New York, NY: Palgrave Macmillan, 2009), 12-13.

[212] Davison (2009), 12-16.

[213] President's Commission on Law Enforcement and Administration of Justice, *The Challenge of Crime in a Free Society* (Washington, D.C.: United States Government Printing Office, 1967), 270.

equipment and provid[ing] alternatives to the use of lethal weapons" when maintaining control of incidents that could lead to disorder.[214]

With the passing of the Omnibus Crime Control and Safe Street Act in 1968, which established the Law Enforcement Assistance Administration (LEAA) within the US Department of Justice, grants became available to state and local police for the purpose of enhancing their capabilities, including the acquisition of non-lethal weapons. In addition, the Act also established the National Institute of Law Enforcement and Criminal Justice (NILECJ)[215] within the LEAA, which provided the law enforcement communities grants for research and development. The law enforcement communities therefore in the 1960s and 1970s started to become contributors to the development of NLWs.

This is of course not to say that the military interest in non-lethal chemical irritants has dwindled. According Neil Davison, by the 1950s, countries have begun to find tear gas agent CN lacking in its consistency and potency.[216] The British military, in particular, which at the time had troops in various colonial holdings on internal security duties and faced the increasing need of controlling civil disturbances, had a high demand for a better and more effective substitute to CN.[217] 2-chlorobenzalmalononitrile (CS), first investigated during the interwar period, which proved in British operations in Cyprus to be a more effective tear gas agent than CN, was developed and stockpiled. By 1959, CS was also adopted by the US military for combat training and riot control purposes.

The law enforcement communities also soon adopted CS as the main tear gas agent, but primarily after this nominally "riot control agent" was used the most extensively during

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[214] National Advisory Commission on Civil Disorders, *Report of the National Advisory Commission on Civil Disorders* (Washington, D.C.: Department of Justice, 1969), 8-9.

[215] Which has been renamed in 1978 and is now known as National Institute of Justice

[216] Davison (2009), 17.

[217] Stockholm International Peace Research Institute, *Problem of Chemical and Biological Warfare* (1971), 212.

the Vietnam War, starting in 1965. According to the SIPRI 1971 study, "Almost every type of weapons delivery system in Viet-Nam has a CS capability, so that CS could swiftly be spread over almost any size of target area, at any range and, if necessary, in close coordination with other forms of firepower."[218] This prevalence and unrestricted use of CS, however, was not done for the purpose of exploiting the non-lethal capability of the agent on the enemy, but was done in order to make more effective other forms of firepower.[219] In the end, the rate of casualty incurred was not reduced despite the use of a non-lethal agent – the enemy inflicted with irritants that incapacitated his ability to fight only made shooting him that much easier.

5.1.2 BZ Weaponization and Destruction

As a result of the burgeoning of biochemistry and the pharmaceutical industry and the increasing interest in non-lethal capabilities in the 1960s and 1970s, the military began exploring new options for biochemical weapons that are more effective at disabling an enemy beyond just eye or respiratory irritation. Many of today's non-lethal capabilities by the military or the police can trace their origins to this period.[220] Besides irritants, the chemical/biochemical agents explored by the US during this time included obscurants (smoking agents to obscure sight), sticky foams, malodorants, lubricant (to make surfaces slippery and thus impassable), and incapacitating neurochemicals (see definition and analysis of desired characteristics of an "incapacitant" in section 5.2 below). As noted by James Ketchum and Frederick Sidell in 1997, "Virtually every imaginable chemical technique for producing military incapacitation has been tried at some time" between 1953

[218] Stockholm International Peace Research Institute, *Problem of Chemical and Biological Warfare* (1971), 190.

[219] Davison (2009), 18.

[220] Davison (2009), 23.

and 1973, and "Chemicals whose predominant effects were in the central nervous system were of primary interest and received the most intensive study."[221]

One of the chemicals that received significant military attention was a chemical deliriant called 3-quinuclidinyl benzilate (BZ). As an anticholinergic agent, BZ blocks the effects of acetylcholine, a principal neurotransmitter that operates in both the peripheral as well as central nervous system on voluntary neuromuscular functions. Inhibiting the effects of acetylcholine leads to physical weakness, delirium, and possible hallucination.[222] Although BZ was not the first psychochemical agent that attracted the military's attention as a chemical incapacitant (other psychedelics such as lysergic acid diethylamide (LSD) has been studied extensively in the 1950s), its ability to achieve effect at very low dosage increased its appeal to the military, and by 1962 it was standardized and produced into M43 cluster bomb and M44 generator cluster as part of the US chemical weapons stockpile.[223] Nevertheless, the stockpiled BZ munitions were considered to have significant operational problems and were, therefore, never deployed.[224]

In addition to the exploration of BZ, the military has also extended its search to other drugs, including anesthetics, analgesics, tranquilizing agents, and vomiting agents, in the 1960s. Other anticholinergics, such as glycolates, received attention from the military as a possible replacement to BZ due to its quicker onset of effects. Yet, this active search for psychoactive chemicals occurred during the peak of US involvement in Vietnam. The extensive use of herbicides (defoliants) such as Agent Orange and tear gas such as CS, along with the deaths caused by these chemical agents, attracted public criticism,

[221] James S. Ketchum and Frederick R. Sidell, "Incapacitating Agents," in *Medical Aspects of Chemical and Biological Warfare*, eds. by Frederick R. Sidell, Earnest T. Takafuji, and David R. Franz (Falls Church, VA: Office of the Surgeon General, United States Army, 1997), 291.

[222] Davison (2009), 108.

[223] Davison (2009), 108.

[224] Malcolm Dando and Martin Furmanski, "Midspectrum Incapacitant Programs," in *Deadly Cultures: Biological Weapons since 1945*, eds. Mark Wheelis, Lajos Rózsa, and Malcolm Dando (Cambridge, MA: Harvard University Press, 2006), 247-249.

particularly from the international community.[225] Furthermore, the failed open-air test of VX agent at the Dugway Proving Ground in 1968 and the congressional discovery of Operation CHASE (Cut Holes and Sink 'Em)[226] in 1969 both led to further domestic demands for a review of the military's chemical and biological weapons programs.[227] As a movement to divert the public's attention, President Nixon in 1969 unilaterally renounced the US biological program and at the same time, reaffirmed the US stance on non-first-use of chemical weapons.

President Nixon's speech on November 25, 1969, reflected a six-month long review process and interagency bargaining.[228] Despite the military interest in maintaining the programs and existing stockpile, the general consensus across agencies, including some among the civilian leadership at the Pentagon, was that the biological weapons were ineffective as a battlefield weapon and carries more risk than the benefits they may provide. President Nixon endorsed this perspective in his statement, emphasizing that "Biological weapons have massive, unpredictable and potentially uncontrollable consequences."[229] He further stated that the United States "reaffirms its oft-repeated renunciation of the first use of lethal chemical weapons" and "extends this renunciation to the first use of incapacitating chemicals."[230] As a confirmation to these points, the President further called for the Senate ratification of the Geneva Protocol of 1925, which the United States had signed, but had, at that point in time, yet to ratify.

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[225] Agent Orange has also been reported to cause long-term injuries and illnesses, most frequently noted in the form of cancer years later from exposure.

[226] A series of DoD operations to dispose unwanted munitions at sea, including chemical weapons, that started earlier in the decade.

[227] Jonathan B. Tucker and Erin R. Mahan, *President Nixon's Decision to Renounce the U.S. Offensive Biological Weapons Program* (Washington, D.C.: National Defense University Press, 2009), 1-2.

[228] For a concise summary of the process, see Tucker and Mahan (2009). The study can also be found in the now declassified National Security Study Memorandum (NSSM) 59.

[229] Richard M. Nixon, "Statement on Chemical and Biological Defense Policies and Programs," in *Richard Nixon: 1969: Containing the Public Messages, Speeches, and Statements of the President* (Washington D.C.: Office of the Federal Registrar, 1971): 968.

[230] Nixon (1971), 968.

As a result of President Nixon's unilateral disavowal of biological weapons programs and reaffirmation on the no-first-use policies regarding chemical weapons, both lethal and non-lethal, the US stockpile of BZ munitions were declared obsolete a few years after.[231] Although a number of incapacitating biochemical continued to be explored past 1969, the military interest and R&D activity in incapacitating biochemical agents started to wane toward the end of the Vietnam War in 1975.[232] The BZ stockpile was eventually destroyed at the Pine Bluff Arsenal in the late 1980s, before the US entered into a bilateral agreement with the Soviet Union on the destruction of chemical weapons in 1990 and signing the Chemical Weapons Convention in 1993.

5.1.3 Interim Years – Turn to Other Agents

As a result of a decrease in immediate demand and an increase in public scrutiny, in the aftermath of the Vietnam War, interest in the research and development of non-lethal weapons declined to an extent. Some other chemical agents studied in the 1970s, such as EA 3834,[233] were never weaponized. According to Davison, however, some research and development continued, including explorations on new chemical compounds and methods of delivery.[234] For instance, by the mid-1980s, the previous focus on psychomimetic compounds, such as the anticholinergics, has shifted to analgesics, including opioid drugs such as fentanyl and its analogues, and much of the effort on the discovery, research, and development of new compounds were linked to developments in the academic and commercial research on better anesthetics.

In addition to the search of a more potent biochemical compound, from the mid-1970s through the 1980s, some research efforts were also devoted to the weaponization of

[231] Dando and Furmanski (2006), 250.

[232] Davison (2009), 111.

[233] EA 3834 is an anticholinergic glycolate and is a more potent variant of BZ. It was explored and experimented at the Edgewood Arsenal as a potential substitute for BZ.

[234] Davison (2009), 110-111.

biochemical compounds. In a chronology generated by Malcolm Dando of incapacitating chemical weapon program research during this timeframe compiled from DoD reports to the US Congress, thermal dissemination of agents through explosives and pyrotechniques was studied and experiments were conducted during this period.[235] Some efforts were also devoted toward exploring the possibility of delivering the agent through routes other than inhalation (such as percutaneously through the skin). Although the full extent to which these efforts were successful were difficult to determine (for none seemed to have yielded actually deployable systems), the historical records show that at least some R&D activities continued at places like the Edgewood Arsenal on all fronts of the incapacitating chemical weapons program.

During this time, interest from the law enforcement communities also prompted continued research on incapacitating chemicals. The National Institute of Justice (NIJ, formerly NILECJ), for instance, initiated programs on less-than-lethal technologies in the late 1980s, and some of its earliest efforts focused on the development of incapacitating chemicals were in collaboration with the Army.[236] The military has also adopted the language of less-than-lethal weapons to describe these capabilities. These joint developments helped facilitate the process through which the military redefined the R&D conducted in this area as "Advanced Riot Control Agent Device" (ARCAD) rather than chemical incapacitants. In a NBC (Nuclear, Biological, and Chemical) Modernization Plan released in 1992, the ARCAD is described as a "'hand held grenade, or device,'" that "'will deliver a potent riot control compound, which will provide a rapid onset of effects where the safety of the individual(s) is the primary concern)."[237] Although the description does

[235] Malcolm Dando, *A New Form of Warfare: The Rise of Non-Lethal Weapons* (London, UK: Brassey's, 1996), 149-151.

[236] Davison (2009), 112.

[237] J. Perry Robinson, *Disabling Chemical Weapons: A Documented Chronology of Events, 1945-200*, Harvard Sussex Program, University of Sussex, unpublished manuscript version dated October 8, 2003, 68, quoted in Davison (2009), 113.

not specify the actual chemical agent that would be deployed in the ARCAD, it does indicate that the "'candidate compound will be effective primarily through the respiratory tract,'" suggesting that the candidate agent will achieve its effect through inhalation and would likely be designed as an area effect weapon rather than individual effect capabilities in which the law enforcement communities have more interest.[238]

When the Chemical Weapons Convention opened for signature in 1993, the prospect of using any kind of Riot Control Agent by the military became severely limited, which curtailed further developments on the ARCAD (see section 5.4 below for an analysis of CWC and NLWs). Nevertheless, the R&D efforts toward incapacitating chemical agents continued. Several agency requests and submitted proposals to the Edgewood Research, Development, and Engineering Center (ERDEC) reveal the ongoing military interest. For instance, in a SBIR solicitation issued by the US Army in late 1992 and early 1993, it was noted that "most recent less-than-lethal (LTL) programs at U.S. Army ERDEC focused on the fentanyls as candidate compounds" which are "well-characterized, rapid acting, very potent, and reliable in their activity," but "for many LTL applications they have safety ratios that are too low and durations of actions that are too long."[239] As a result, "candidate immobilizers with improved safety ratios and shorter duration of action are needed."[240]

Some of the agents under consideration during that the late 1980s and early 1990s included the ones that act upon the alpha$_2$ adrenergic receptors.[241] Agonists of alpha$_2$ adrenergic receptors, such as medetomidine, a sedative used in veterinary practices, activates the inhibitory functions of the receptors which with catecholamines and can lead

[238] J. Perry Robinson, *Disabling Chemical Weapons* (2003), 68, quoted in Davison (2009), 113.

[239] J. Perry Robinson, *Disabling Chemical Weapons* (2003), 92, quoted in Davison (2009), 113. See also Alan Pearson, "Late and Post-Cold War Research and Development of Incapacitating Biochemical Weapons," in *Incapacitating Biochemical Weapons: Promise or Peril?* eds. Alan M. Pearson, Marie Isabelle Chevrier, and Mark Wheelis (Lanham, MD: Lexington Books, 2007), 73.

[240] J. Perry Robinson, *Disabling Chemical Weapons* (2003), 92, quoted in Davison (2009), 113.

[241] The alpha$_2$ adrenergic receptor inhibits the release of catecholamines such as norepinephrine and epinephrine.

to heavy sedation. Although agonists of $alpha_2$ adrenergic receptors can lead to side effects such as hypotension (low blood pressure), it was deemed to be "safer" because, "'Unlike opioids, these compounds are devoid of the usual liabilities associated with respiratory depression, physical dependence and environmental concerns after dissemination.'"[242] Other proposals in the early 1990s nevertheless showed that the interests in the opioids continued despite the known dangerous side effects of respiratory depression. These proposals, which suggested research toward synthetic opioids, such as fentanyl analogues, as well as strategies to mitigate the side-effect by mixing agonist and antagonists, revealed that the prospects of using opioid analgesics as incapacitants or less-than-lethal weapons were still within the purview of the military's interest at the time.[243] Other research proposals suggested the possibility of using serotonin antagonist[244] to achieve "calming" effects. Although information was limited and there was no conclusive evidence, it appeared that these proposals were not funded. Nevertheless, these activities suggested that at least in the early 1990s chemical non-lethal or less-than-lethal incapacitants continued to be within the scope of military interest in the US.

At the same time, the law enforcement community has also continued to explore biochemical incapacitant as NLWs. For instance, in late 1992, the NIJ initiated projects with the Lawrence Livermore National Laboratory (LLNL) to review potent pharmaceutical agents that are able to be used as non-lethal weapons, particularly fentanyl and its derivatives. The study conducted at LLNL was but one of the many collaborative projects on LTL weapons that the NIJ had with various Department of Energy (DOE)

[242] Edgewood Research, Development and Engineering Center (1989-94), *Scientific Conference on Chemical and Biological Defense Research: Abstract Digest*, US Army Chemical and biological Defense Command, Aberdeen Proving Ground, MD, quoted in Dando (1996), 162.

[243] Davison (2009), 114-115.

[244] 5-HT receptors, or 5-hydroxytryptaime receptors, are activated by serotonin and have inhibitory as well excitatory effects on the neuronal activities through its release of multiple kinds of neurotransmitters as well as hormones.

national laboratories at the time.[245] Similar to previous military explorations, one of the major themes of the work at LLNL was to analyze the feasibility of using a combination of fentanyl and its derivatives along with an antidote to mitigate the side effects of respiratory depression and enhance the safety margins. In addition to the research on biochemical incapacitating agents, researchers at LLNL also investigated the potential ways of weaponizing them. Inspired by skin patches used to deliver drugs, the researchers examined the possibility of transdermal application of fentanyl through felt pads soaked in the fentanyl solution. While it is unclear as to what extent further research was conducted by the LLNL, it was clear that the law enforcement communities shared much of the military's interest in this area of biochemical incapacitants.

Incidents in Somalia in the early to mid-1990s further justified the military and law enforcement communities' continued search for better NLWs. During the early 1990s, the United Nations had a series of operations in Somalia (UNOSOM I and II) to address issues of widespread famine and disease, as well as armed engagements between the various clans, but the operations reached very little success. In particular, the nation-building and disarmament objectives of UNOSOM II led to significant turmoil and oppositions from the warlord-controlled local militia. In late 1994 the UN operations were declared failures and peacekeeping forces began to withdraw. During the US-led withdrawal operation, Operation United Shield, the marines were equipped with many of the then-available NLWs (such as various forms of blunt impact projectiles, OC sprays, stinger and flash bang grenades, sticky foams, and dazzling lasers) and some of which were deployed during the operation. Although the full extent to which these NLWs were effective was unclear, their use received positive endorsements from those in charge of the operation and gained wide media attention.

[245] Lois Pilant, *Science and Technology: Less-than-Lethal Weapons: New Solutions for Law Enforcement* (Alexandria, VA: International Association of Chiefs of Police, 1993), 2.

5.1.4 Establishment of the JNLWD

The operations in Somalia and the various strands of non-lethal weapons research led to increasing discussion of combining the dispersed efforts into a single entity that focuses on a cohesive plan to develop military non-lethal weapons. Until the mid-1990s, non-lethal weapons have been developed in a variety of national laboratories under contracts with different services as well as some industry ones. In its 1995 report on non-lethal weapons technology at the time, the Council on Foreign Relations (CFR) noted that in the absence of a national policy, "development of non-lethal technologies has been largely driven by various scientific laboratories offering proposals as their nuclear warfare budgets were reduced."[246] This lack of coordination has made it difficult for the US to include non-lethal options as part of military and foreign policy planning.

With the founding of the Joint Non-Lethal Weapons Directorate in 1996, however, R&D on NLW received a new home base in the military with the Marine Corps and gained some new momentum. Of note, in 1999, the Army, in consultation with JNLWD, issued a solicitation through its SBIR initiatives on "Chemical Immobilizing Agents for Non-Lethal Weapons," which sought to "identify new agent and agent combinations including an analysis of 'recent breakthroughs in the pharmacological classes such as Anesthetics/analgesics, tranquilizers, hypnotics, and neuromuscular blockers.'"[247] By 2000, a contract under this initiative was given to OptiMetrics, Inc., with the principal researcher a past ERDEC scientist who had worked on calmative agents.

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[246] Council on Foreign Relations, *Non-Lethal Technologies: Military Options and Implications* (New York, NY: Council of Foreign Relations Press, 1995), 5.

[247] Department of Defense, *Chemical and Biological Defense Program*, "Topic CBD00-108: Chemical Immobilizing Agents for Non-lethal Applications," Small Business Innovation Research Solicitation, FY 2000, http://www.acq.osd.mil/osbp/sbir/solicitations/sbir20001/cbd001.doc (accessed September 10, 2016), CBD-13-14.

In addition, a literature review was conducted by the Applied Research Laboratory and the College of Medicine at Pennsylvania State University, which resulted in a report in 2000 titled *The Advantages and Limitations of Calmatives for Use as a Non-Lethal Technique*. This report provided a review of medical literature on drugs or other biochemical agents that could be used as NLW. Although the JNLWD and the NIJ denied funding this report, researchers like Davison note the strong connection between the two institutions and Penn State. [248] Furthermore, at the same time that the Penn State report came out, the JNLWD awarded funding to Army's Edgewood Chemical and Biological Center (ECBC, previously ERDEC), which proposed to conduct workshops and analyses on "'identifying "non-lethal" chemical materials for further testing which have minimal side effects for immobilizing adversaries in military and law enforcement scenarios.'"[249] These activities revealed that in the early 2000s, even after the signing of and the ratification of the CWC (which entered into force in 1997), the military continued to have interests toward investing in biochemical incapacitants.

Experiences from Somalia notwithstanding, the interest in developing greater non-lethal weapons capacity at this time seemed to be particularly justifiable and warranted given the types of peacekeeping missions with which the American military was engaged at the time. For instance, in 1997, an incident in Brčko, Bosnia, where the US stabilization forces were attacked by civilians with rocks and two-by-fours prompted the US to have an emergency procurement of off-the-shelf NLWs and to equip its soldiers with tear gas,

[248] Davison (2009), 123.

[249] Joint Non-Lethal Weapons Directorate, *JNLWD Newsletter*, 2nd Quarter 2001, Quantico, VA: JNLWD, quoted in Davison (2009), 123.

sponge grenades, and dye-marking kits.[250] While the NLWs were not used in Bosnia, the US operations there showed the need for greater military non-lethal capabilities.[251]

The military's interest in developing its non-lethal capabilities was reinforced two years later when, during US peacekeeping missions in Kosovo, NLWs were both supplied to and used by the troops. For instance, in April 2000, the US troops seized contraband weapons from Sevce, a small village in Kosovo, and were attacked by the local people using rocks and sticks upon their exit.[252] The troops, reinforced with non-lethal weaponry, responded with sponge grenades, stinger rounds, and other non-lethal munitions and were able to disperse the crowd.[253] Less than a year later, the US ground forces in Kosovo faced a similar situation in removing an illegal roadblock and was able to scatter the crowd using NLWs. "'The ability to use non-lethal weapons,'" claimed the on-site commander, "'saved hundreds (possibly more) of lives'"[254] and prevented the troops from having to take lethal measures in order to ensure their own safety.

In addition to Bosnia and Kosovo, non-lethal weapons were also used during US operations in Iraq and Afghanistan in the 2000s. For instance, in Iraq, the US troops consistently used NLWs for crowd control at locations for food and fuel distribution.[255] In Afghanistan, dazzling lasers were used to deter locals from throwing rocks at the troops and their vehicles.[256] NLWs had over time demonstrated their utility in US military missions that have become more complex and requiring more delicate measures to deal

[250] Linda Kozaryn, "U.S. Troops in Bosnia Get Nonlethal Weapons," American Forces Press Service (September 5, 1997), http://archive.defense.gov/news/newsarticle.aspx?id=41128 (accessed March 21, 2016).
[251] National Research Council, *An Assessment of Non-Lethal Weapons Science and Technology* (Washington, D.C.: The National Academies Press, 2003), 61.
[252] National Research Council, *An Assessment of NLW* (2003), 61.
[253] Susasn D. LeVine and Joseph A. Rutigliano, Jr., "U.S. Military Use of Non-Lethal Weapons: Reality vs Perception," *Case Western Reserve Journal of International Law* 47(1) (Spring 2015): 244.
[254] Personal communication with LTC James Brown, USA, April 11, 2001, quoted in National Research Council, *An Assessment of NLW* (2003), 61-62.
[255] Levine and Rutigliano (2015), 244-245.
[256] Levine and Rutigliano (2015), 245.

with violence from civilians. Despite this increasing attention, the continued pursuit of biochemical incapacitants as a non-lethal weapon has not led to deployable systems that can be used and tested in operational settings, at least not until the 2002 Dubrovka theater incident in Moscow that brought speculations of the utility of such weapons into reality.

5.1.5 The Moscow Theatre Incident

On October 23, 2002, a group of radical militant Chechen separatists from the Special Purposes Islamic Regiment, led by Movsar Barayev, took over the Dubrovka Theater in Moscow. The theater was at that time putting on a popular musical, *Nord-Ost*. Over 900 hostages were taken captive by a group of 40 Chechen separatists armed with automatic weapons, pistols, and various forms of explosives.[257] In addition to the female separatists who had explosives attached to their belts, the separatists also planted in the theater a large bomb that could lead to its collapse (a bomb which, after the crisis ended, was found to be incapable of being detonated).[258] Through the former minister of propaganda of the Chechen Republic, Movladi Udugov, and the few interviews granted to Russian and other western media, the separatists exhibited a "militant radical Muslim stance" and ultimately demanded the end of military operations and the withdrawal of Russian troops from Chechnya.[259]

Several performers were able to escape the building from back stage during the initial siege. Upon taking over the theater, the Chechen separatists released some of the hostages, including children, some women, foreigners, and those requiring medical attention, and a couple of hostages managed to escape. Over the next two days, the hostage-takers conducted negotiations with several intermediaries, some of whom including Duma

[257] John B. Dunlop, *The 2002 Dubrovka and 2004 Beslan Hostage Crises: A Critique of Russian Counter-Terrorism* (Stuttgart, Germany: Ibidem-Verlag, 2006), 131-2.
[258] Dunlop (2006), 125.
[259] Dunlop (2006), 133-5.

deputies and journalists, and allowed at least one doctor to enter the theater and treat hostages. Several more hostages were released on each day of the negotiation, but aside from agreeing to some necessary sustenance, nothing else was reached by the negotiations.

As the negotiations were taking place with the voluntary mediators (or ones demanded by the hostage-takers), the Putin administration was also making plans for a Special Forces raid of the building. During this time, the Russian government made only a few direct announcements to the Chechen separatists, and in one of the message sent the head of Federal Security Service (FSB), Nikolai Patrushev, guaranteed the lives of the hostage-takers should the hostages be released. The negotiations that helped buying time continued well into the evening of October 25, when the separatists were told that a special representative would begin engaging in serious negotiations the next day. By 5PM on October 25, nevertheless, Russian President Vladimir Putin came to an "irrevocable" decision to storm the theater, according to Duma faction leader Grigory Yavlinsky.[260]

Early in the morning of October 26, the Spetsnaz from the FSB began pumping a "gas" into the theater through its ventilation system. According eye witness accounts, some of the hostage takers as well as the hostages originally thought that the "smoke" came from a fire.[261] It was soon realized that some unknown gas was pumped into the building, which immediately created panic in the main auditorium where the hostages were held. Some of the Chechen separatists who had gas masks equipped left the main auditorium in anticipation of the impending attack by the Russian forces. Half an hour after the initial pumping of the gas, hostages and most separatists fell unconscious, and the siege of the theater took place. The remaining rebels who were still conscious at the time of the siege were killed during the exchange of fire, and the ones who had been incapacitated by the

[260] Dunlop (2006), 143.

[261] Sabrina Tavernise and Sophia Kishkovsky, "Hostage Drama in Moscow: The Scene; The Survivors Dribble Out, All With a Story to Tell," *The New York Times* (October 28, 2002).

gas were shot dead by the Spetsnaz team. At 7AM, approximately two and half hours after the initial attack, the building was secured and the evacuation began.

Among the hostages who were still held captive by the time the Russian troops stormed the theater, at least 125 (~15%) died during the raid or in the immediate aftermath of the crisis. According to Andrei Seltsovsky, the chair of the Moscow Committee on Health, only a couple of the hostages died of gunshot wounds while the rest died from effects of the gas.[262] However, a final account of the number of victims continued to be debated, and in some accounts, the number of hostages who died due to the effects of the chemical agent has been estimated to be over 200, with many more who have suffered long-term impairments.[263] Despite this, the Russian government initially withheld the specifics of the death toll as well as the identity of the gas used prior to the raid, claiming that the casualties were victims of terrorism and their deaths caused by heart attacks and other health issues exacerbated by the hostage situation. It was not until a few days later, when several countries pressed for more information about the agent used in order to better administer treatment, that the Russian authorities responded. According to Yuri Shevchenko, the Russian Health Minister, the "gas" used during the raid was an aerosol mixture that contained derivatives of fentanyl.[264] Nevertheless, to date, both the final death count of the hostages as well as the specific agent that was used during the raid continued to be points of controversy regarding this crisis.

The use of chemical agents by the Russian authorities during this crisis, furthermore, has attracted attention from policymakers and the scientific communities alike

[262] Susan B. Glasser and Peter Baker, "Gas in Raid Killed 115 Hostages; Only 2 Slain by Rebels; More Than 600 Remain Hospitalized in Moscow," *The Washington Post* (October 28, 2002): A.01.

[263] Dunlop (2006), 146.

[264] Susan B. Glasser and Peter Baker, "Russia Confirms Suspicions About Gas Used in Raid; Potent Anesthetic Pumped Into Theater; 2 More Hostages Die From Drug's Effects," *The Washington Post* (October 31, 2002): A.15. As fentanyl and its derivatives are not actually "gas," what is reported as "gas" in the reports are likely referring to the agent in the form of aerosolized droplets.

from abroad. Prior to the official statement from Shevchenko, a wide range of chemical compounds were speculated to have been used, including some report by the Russian media identifying the agent as *Kolokol*-1, which is suspected to be an inhalational anesthetic using fentanyl derivatives mixed with halothane. Since the Russian authorities declined to provide any more information about the agent beyond Shevchenko's declaration, and due to the fact that all hostage casualties were a result of poisoning from the agent used, experts on toxicology, anesthesiology, and chemical and biological weapons, some of whom challenged the Russian claims, began their own diagnostics.[265] Some have suspected that compounds more potent than any fentanyl or its derivatives, such as etorphine (a derivative of morphine used in veterinarian practices), were likely the agent used in order to have such a rapid onset effect, while others speculated that some derivative forms of BZ were used. Nevertheless, barring further information from official Russian authority, these diagnostics have continued to remain speculations.

5.1.6 Current Postulations on NLW and Neuroscience

The many specifics of the Dubrovka incident, including the exact agent used and the death count, and its ramifications, such as its legality under the context of the CWC, continue to be debated. Nevertheless, the incident has brought the biochemical incapacitants to the forefront of public discussions of non-lethal weapons. In the US, however, this incident seemed to have resulted in the abatement of the research activities on such incapacitants. Despite the increasing attention and funding toward cognitive sciences research, since the early 2000s, very little, if any, visible investment has been made by the US military towards the R&D of new biochemical agents capable of being used as non-lethal incapacitants. In his 2007 recounting on the R&D of chemical

[265] Martin Enserink and Richard Stone, "Questions Swirl over Knockout Gas Used in Hostage Crisis," *Science* 298(5596) (November 8, 2002): 1150-1151. See also Josef Rieder et al., "Moscow Theatre Siege and Anaesthetic Drugs," *The Lancet* 361 (March 29, 2003): 1131, and Schiermeier (2002), 7.

incapacitants over the previous decade, Alan Pearson observed that “little information is publicly available about the U.S. activities since early 2003,” and “No U.S. government documents concerning delivery systems have made references to immobilizers, calmatives, or incapacitants other than malodorants, tear gas and pepper spray since 2002.”[266] Davison came to similar observations in 2009, suggesting that “since the 2003 NRC report recommending expanded research on incapacitating agents there has been no further openly available information on the military programme.”[267] Although overall investment in cognitive sciences research has grown during this time, almost none of the funding has been allocated to activities that can be characterized in anyway as developing biochemical incapacitants.

Observing this absence in investment, Pearson reached three possible explanations: “This may reflect a decision to discontinue or put a hold on such work, or it may simply mean that the work is continuing under conditions of increased secrecy,” and a “third possibility also exists—that the U.S. military has already identified a short list of biochemical incapacitants it considers adequate and has placed payload development on hold pending further improvement of delivery and dissemination devices.”[268] While the following discussions in this chapter endorse the first view and provide an explanation as to why an unfavorable technical condition has likely caused the effort to be discontinued by the US military, the other two explanations warrant further discussion.

First, existing records indicate that as of the early 2000s the requests for biochemical incapacitants were still aiming at identifying novel agents, making the third explanation unlikely. Second, while federal R&D funding for defense-related technologies in the US can be subject to classification of information, most programs at the S&T stages

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[266] Pearson (2007), 90.
[267] Davison (2009), 125.
[268] Pearson (2007), 90.

of R&D are required by law to remain unclassified since 1985, according to the National Security Decision Directive 189, which prescribes that "the products of fundamental research remain unrestricted."[269] Since any radical advancement in identifying or creating a biochemical incapacitant through cognitive neuroscience research is likely attributable to new understandings of neuropathways in the human brain, it is more likely that such research work will occur in basic or early applied research where significant exploration is still possible. Investment for such work should thus be observable in the annual budgets, particularly from an agency like DARPA. Finally, in both 2013 and 2014, senior officials representing the US at international arms control forums have made public statements confirming that the US is not engaging in any development, production, stockpiling, or use of biochemical incapacitants.[270] These reconfirmations lend support to the explanations provided below.

5.2 What is an Incapacitant?

Prior to examining the issues of feasibility, requirement stringency, and availability of alternatives, it is essential to understand what an incapacitant[271] is and what its ideal attributes are. Some of the earliest articulation in the international arena regarding the difference between an "incapacitant" and the more commonly referred to "riot control agent" (RCA) appeared in a World Health Organization (WHO) report on the *Health Aspects of Chemical and Biological Weapons*, where a distinction was made between

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[269] Fundamental research here refers to basic and applied research in science and engineering. See White House, National Security Decision Directive 189, "National Policy on the Transfer of Scientific, Technical, and Engineering Information" (September 21, 1985).

[270] In 2013, in a statement made by US Ambassador Robert Mikulak at the 72nd session of the Executive Council Meeting of the OPCW in May, it was emphasized and reconfirmed that "the United States is not developing, producing, stockpiling, or using incapacitating chemical agents." Similarly, in her address to the nineteenth session of the Conference of State Parties of the OPCW, Rose Gottemoeller, the Under Secretary of State for Arms Control and International Security, reiterated that "the United States is not developing, producing, stockpiling, or using incapacitating chemical agents." See Michael Crawley, *Chemical Control: Regulation of Incapacitating Chemical Agent Weapons, Riot Control Agents and Their Means of Delivery* (New York,, NY: Palgrave Macmillan, 2016), 35 and Malcolm Dando, *Neuroscience and the Future of Chemical-Biological Weapons* (New York, NY: Palgrave Macmillan, 2015), 119.

[271] In this dissertation, incapacitant and incapacitating agent are considered interchangeable terms.

traditional lethal chemical agents (such as vesicants and nerve agents), incapacitating agents (including psychochemicals such as LSD and BZ), and harassing agents (agents such as CS and CN).[272] According to the report, a lethal agent is one that is designed to kill or injure an enemy severely that will require the target to seek medical treatment, an incapacitating agent puts a target completely out of action for several hours or days but the target is able to recover from the disablement without medical aid, and a harassing agent disables an enemy while he remains exposed, but as soon as the person leaves the area of exposure, he can recover very quickly on his own.

These distinctions, of course, are tactical in the sense that they rely on the types of effects an agent can produce on a target and are not reliant on the toxicological properties of the agent. Yet, as the report suggests, "If too much of an agent intended for harassment is used, it may kill or severely injure"; likewise, "if a low concentration of lethal agent is disseminated, its effects may be only incapacitating or harassing."[273] Therefore, to define chemical agents according to the effect they have on a target is problematic, for the boundaries between the categories of these weapons are often blurry and can become quite fluid depending on the concentration levels a target receives.

It is perhaps for this reason that the US military has come to understand chemical incapacitants according to both their intended effects as well as their toxicological properties. According to US military doctrines and similar to the WHO definition,

> An incapacitating agent is a chemical agent which produces temporary disabling conditions. The disabling conditions persist for hours to days after

[272] World Health Organization, *Health Aspects of Chemical and Biological Weapons* (Geneva, Switzerland: World Health Organization, 1970), 23.
[273] World Health Organization (1970), 23-25.

exposure to the agent (unlike that produced by riot control agents, which usually are momentary or fleeting in action).[274]

In terms of site of action, an incapacitant is a highly potent chemical that produces the incapacitating effects "by altering the higher regulatory activity of the CNS" that are temporary in duration and unlikely in producing permanent injury.[275] In this sense, an incapacitant is different from a RCA in that it produces effects by acting on the central nervous system (CNS), such as the human brain, rather than the peripheral nervous system.

This distinction has in recent years become one of the more accepted understandings of what distinguishes an incapacitant from other non-lethal chemicals. For instance, in the Spiez Laboratory's report from its 2011 workshop on incapacitating chemical weapons, it is noted that while there has been little consensus on what an incapacitating chemical agent (ICA) is despite the many proposals for its clearer definition, the ICAs are indeed distinguishable from the common RCAs because of their site of action on the human body.[276] Similarly, in the 2012 Royal Society report, ICAs are considered "substances intended to cause prolonged but transient disability and include *centrally* acting agents producing loss of consciousness, sedation, hallucination, incoherence, paralysis, disorientation or other such effects (emphasis added)."[277] While there is still a lack of accepted ways to fully differentiate an incapacitant from a lethal agent, the site of action of the agent provides ways to set riot control agents and incapacitants apart.

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274 Departments of the Army, Navy, and Air Force, and Commandant, Marine Corps, *Treatment of Chemical Agent Casualties and Conventional Military Chemical Injuries* (Washington, D.C.: Headquarters of Department of Army, Navy, and Air Force, and Commandant of the Marine Corps, 1995), 3-1. Hereafter shorten in subsequent references as Field Manual 8-285.

275 FM 8-285 (1995), 3-1.

276 Stefan Mogl, ed., *Technical Workshop on Incapacitating Chemical Agents: Spiez, Switzerland, 8-9 September 2011* (Spiez, Switzerland: Spiez Laboratory, 2012), 10.

277 The Royal Society, *Brain Waves Module 3: Neuroscience, Conflict, and Security* (London, UK: The Royal Society Science Policy Centre, 2012), 44-45.

A wide range of biochemicals that act on the central nervous system can achieve the kinds of incapacitating effects described in the Royal Society definition. Ketchum and Sidell, for instance, suggest that such agents can be grouped into four general categories: stimulants, depressants, psychedelics, and deliriants.[278] Using different categorizations, others have suggested the list of potential candidates can include anesthetic agents, skeletal muscle relaxants, opioid analgesics, anxiolytics, antipsychotics, antidepressants, and sedative-hypnotic agents.[279] In essence, any biochemical that acts on the human central nervous system that can alter an individual's psychological or other behavior functions have the potential to be used as an incapacitant.

Despite this wide range of potential candidates, to design an ideal incapacitant is not an easy task. Any such agent used as a NLW needs to, at a minimum, be able to accomplish the task effectively while maintaining safety (wide safety margins with a relative lack of toxicity), be quick to the onset of the effect and have defined, short, and predictable durations, and be logistically feasible to produce and deliver. Table 3 below identifies the basic criteria as well as the ideal characteristics of an incapacitating biochemical agent.

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[278] Ketchum and Sidell (1997), 292-294.

[279] Michael Crawley, *Application of the OPCW Mechanisms for Reviewing and Addressing Science and Technology Developments: The Case of Incapacitating Chemical Agents (ICAs)* (Bath, UK: University of Bath, 2013), 5; see also Joan M. Lakoski, W. Bosseau Murray, and John M. Kenny, *The Advantages and Limitations of Calmatives for Use as Non-Lethal Technique* (The Pennsylvania State University College of Medicine Applied Research Laboratory, 2000), 46-50.

Table 3 - Basic Criteria and Ideal Characteristics of Incapacitants

Basic Criteria	Explanation	Ideal Characteristics	Explanation
Effectiveness	The agent is able to severely impair or disrupt an enemy's ability to fight	Potency/Dosage	The agent is able to achieve its intended effect with minimum dosage (μ/kg body weight)
		Toxicity/Safety	The agent is low in toxicity that when used as intended it produces few deaths or permanent injuries, or in other words, has a high safety margin to the danger of overdosing (high therapeutic index)
		Treatability/Reversibility	The effects brought about by the agent is fully reversible, be it a result of the effect naturally wearing off or due to the administering of an antidote
		Predictability	The effects brought about by the agent is predictable, in that the consequent behavior is consistent across populations
Temporality	The effects of the agent must be relatively short in terms of duration	Time to Onset	The agent is able to generate its effect within a relatively short timeframe (within minutes)
		Persistence	The effect brought about by the agents lasts sufficiently long for the mission to be accomplished but is otherwise temporary, preferably minutes to hours
		Predictability	The onset and the duration of the effect is predictable across populations
Feasibility	The agent is able to be produced, stockpiled, and delivered	Stability	The agent is chemically stable during the production, storage, and delivery
		Weaponizability	The agent can be incorporated into practical munitions or can be otherwise weaponized effectively (e.g. easy to aerosolize and difficult to detect)
		Cost-Effectiveness	The agent and its resulting weapons system are affordable within the context of the overall military budget and the type of mission it serves)

Source Material: Lakoski et al., 3 and Ketchum and Sidell, 288.

The development and use of an effective biochemical incapacitant, therefore, face complex and interconnected challenges, both technical and sociopolitical in nature. Some of the ideal characteristics of the agent and its resulting weapons system are constrained by science and nature, such as the potency of the agent, the quickness to the onset of action, the predictability of the effects, and the stability of the agent. Some other characteristics are predominantly determined by the sociopolitical context under which the incapacitant would be used, such as the cost-effectiveness of the weapons and the predictability of its effects.

Furthermore, some of these criteria or desired characteristics may entail significant trade-offs from one another. For instance, opioids such as morphine or its analogs can be highly potent, but its potency also leads to higher levels of toxicity that can more easily lead to overdosing.[280] On the other hand, psychedelic agents such as LSD may be highly potent while maintaining low toxicity (very high levels of therapeutic index), but the behaviors it engenders are highly unpredictable.[281] As a result, designing an agent that can fulfill all the desired characteristics is a significant technical challenge. The sections below explain some of these challenges in more detail.

5.3 Feasibility, Requirements, and Alternatives

This dissertation argues that the reason as to why the US has little to no military investment in biochemical incapacitants as a form of NLWs since the early 2000s was likely due to a growing recognition of the unfavorable investment conditions caused by the increasingly dominant expert opinion on the lack of feasibility, a stringent performance requirement the military has set for the NLWs, and the availability of institutional alternatives in developing such a technology. In particular, since the Dubrovka theater

[280] Ketchum and Sidell (1997), 293.
[281] Ketchum and Sidell (1997), 293.

incident in Moscow in 2002, many in the scientific and technical communities, particularly those in favor of a more restrictive arms control regime on chemical weapons, have become increasingly vocal in articulating the significant technical barriers, such as the dose-response problem, that prevent the development of biochemicals as usable NLWs. Over the decade a consensus converging toward the infeasibility of such a technology emerged, which led to significant doubts of the viability of such R&D programs.

Furthermore, at least in the United States, the performance requirement for developing a NLW became increasingly stringent as the concept of risk of significant injury was developed and codified into the NLW R&D process. A very low threshold of lethality and risk of injury made it even less likely that a biochemical incapacitant could be developed and used according to expectation. Finally, the long-standing partnership between the military and law enforcement agencies regarding NLWs and the tightening of international arms control on chemical weapons show that the military has the incentives to shy away from investing in biochemical incapacitants, for there is an alternative pathway to the research, development, and acquisition of such weapons outside the military R&D establishments. The following section illustrates these factors in more detail.

5.3.1 Technical Barriers and Expert Opinions

Most recently, in an article published in *Natures Reviews Neuroscience*, researchers Irene Tracey and Rod Flower discussed two issues in designing and using neuropharmaceuticals or CNS-activing biochemicals as non-lethal weapons: the weaponization and delivery problem and the "dose-response problem."[282] According to Tracey and Flower, these problems have plagued many drugs that otherwise, superficially, would have appeared to be suitable candidates for use as non-lethal weapons. As the decades-long history of military's interest in such drugs shown above illustrates, many

[282] Tracey and Flower (2014), 828.

types of biochemical substances, including anesthetics, opioid analgesics, anxiolytics, and sedative-hypnotic agents have all been considered at one time or another. Yet getting an agent that is easily administered; has rapid, short-lived, and reversible action with little side effects; and produces predictable responses from all individuals exposed to it has been an elusive goal, because even if an agent can possess all of these qualities, it may still not be easily weaponizable, and even if it can be weaponized, it does not guarantee that it can be delivered to all individuals in the right dosage.

5.3.1.1 Weaponization and Agent Delivery

Although delivering a drug to an individual in a clinical setting is commonplace, it is not as easy when such an activity is taking place in an uncontrolled setting with multiple intended targets, such as what would be the case for most military operations. First, in controlled settings, depending on the pharmacodynamics and the effects desired, drugs can be delivered through multiple methods, including oral ingestion or various forms of injections. These practices of drug delivery are predicated upon the fact that in a controlled setting, chemical substances can be administered in appropriate dosages.

However, in terms of designing a usable non-lethal weapon, traditional forms of drug delivery are neither ideal nor practical, especially if the drug is meant to achieve some kind of area effect that impacts multiple targets. This problem is especially acute for operations that require covertness and secrecy—it is hardly possible to subdue a group of terrorists, for instance, by injecting them with sedatives without them noticing. By design, therefore, in order to do achieve an area effect on multiple targets, such drugs or biochemicals need to be weaponized in the form of gaseous or vaporized compounds or aerosolized liquid droplets or solid particles, and they need to achieve their clinical effects via respiratory or transdermal routes – in other words, they need to be small enough particles that can be breathed in or absorbed through skin.[283] For instance, in order to release a chemical agent through a munition, the munition must be able to convert the payload into evenly distributed droplets or solid particles in appropriate sizes. For inhalation and lung penetration, the size should range from one to five microns in diameter, whereas for skin penetration, the size of the particles should be at least 70 microns in diameter or larger.[284]

Furthermore, "to exert a pharmacological effect, a drug has to reach its site of action in adequate concentrations," and this can be particularly problematic for neuroactive drugs, "as their target is within the CNS so they must also penetrate the blood-brain barrier,"[285] which is in itself a substantial problem. Although in recent years advancements in nanotechnology have facilitated the delivery of certain drugs across the blood-brain barrier, how to deliver the sufficient amount to the right locale within the brain continues to be a challenge for certain substances. Even those who hold favorable views toward the potential for such a weapon to be developed recognize this challenge: for instance, in their 2000 report from Penn State, Joan Lakoski and her colleagues note that the "controlled delivery of macromolecular drugs, such peptides, proteins, oligonucleotides and polysaccharides, remain a key issue in the development of [calmative] agents as non-lethal techniques."[286] Weaponization and drug delivery are thus major obstacles in the development of biochemical agents as NLWs.

5.3.1.2 Dose-Response Problem

[283] See, for instance, Brian D. Andresen and Patrick M. Grant, "Dose Safety Margin Enhancement for Chemical Incapacitation and Less-Than-Lethal Targeting: NIJ Final Report and Recommendations," Lawrence Livermore National Laboratory Forensic Science Center R-Division, Nonproliferation, Arms Control, and International Security Directorate, January 1997. In this report the authors propose the use of felt pallets infused with fentanyl and naloxone as the delivery mechanism.

[284] Edward M. Spiers, *A History of Chemical and Biological Weapons* (London, UK: Reaktion Books Ltd., 2010), 18.

[285] Tracey and Flower (2014), 828.

[286] Lakoski, Murray, and Kenny (2000), 46.

Even if the weaponization and delivery problem were able to be addressed, there is still the related pharmacological and toxicological challenge of the so-called "dose-response" problem. Because biochemical incapacitants used as NLWs do not take place in a controlled manner, the way through which they are dispersed in the operational setting can highly impact the dosage that each intended target receives. These varied levels of dosage, in turn, can create significant problems, for if the targeted population contains a mixture of people who vary widely in age, gender, or physical constitution, the targets may respond to the drug and the dose received differently.

Of course, this insight is not new, for as early as mid-sixteenth century it was already known that the dosage is what differentiates a drug from being a poison.[287] Yet, to what extent does this adage apply to the military development of biochemical incapacitants, and to what extent can the dosage issue be mitigated and resolved by modern advancements in neuroscience and pharmacology, seem to be subject to debate. For one, the history of the military interest in the development of biochemical incapacitant, both in the US as well as elsewhere, seems to suggest that there is at least some degree of support for the belief that with advancements in S&T some ideal agent can be found that could overcome this dose-response problem.

Indeed, historical records from early US interest in this area of R&D notwithstanding, some recent accounts on the development of NLW technologies support this interpretation. For instance, in the aforementioned 2000 report from Penn State, it is noted that "drugs can be tailored to be highly selective and specific for known receptor (protein) targets in the nervous system with unique profiles of biological effects on consciousness, motor activity and psychiatric impact."[288] The authors of the report further

[287] This is most often attributed to Paracelsus, a Swiss German philosopher and physician who famously claimed that "all things are poison and nothing is without poison; only the dose makes a thing not a poison," in *Septem defensiones* (1538).

[288] Lakoski, Murray, and Kenny (2000), 3.

conclude that “The use of pharmacological agent to produce a calm behavioral state…is a topic with relevance to achieving the mission of law enforcement and military communities.”[289] By identifying a list of potential agents, the authors of the report “recommended that further research be continued regarding calmatives as non-lethal techniques” and that “consideration of partnerships with the pharmaceutical industry be explored”[290] because of the industry’s current focus on the development of new and innovative drugs with increased potency and specificity.

Similarly, in the aftermath of the Moscow theater incident, Theodore Stanley, an anesthesiologist at the University of Utah, comments that, despite the controversies over the death counts, in the siege and hostage rescue operation at Dubrovka, over 650 hostages survived the incident. He further suggests that “remarkable progress has been made in the techniques to deliver immobilizing agents and the development of safer, faster-acting potent compounds of extremely short duration”; therefore, the “time may now have come to expand this research so that these and superior techniques and drugs may be used by special forces to deal with terrorists.”[291] These comments from the Penn State researchers and Stanley show that some in the scientific community hold the view that the development of usable biochemical incapacitants as NLWs is feasible and, perhaps, quite desirable.

Yet, not everyone in the scientific community working on issues of anesthesiology, toxicology, or chemical weapons agree with such an assessment, and many researchers interpret the more-than-125 hostage deaths from Dubrovka as evidence to why issues of dosage make it infeasible to develop a biochemical incapacitant that could be used in any meaningful way as a “non-lethal” weapon. In a 1994 proposal to develop sedative compounds such as $alpha_2$ adrenergic agonists as potential NLWs, for instance, it was

[289] Lakoski, Murray, and Kenny (2000), 48.
[290] Lakoski, Murray, and Kenny (2000), 49.
[291] Theodore Stanley, “Human Immobilization: Is the Experience in Moscow Just the Beginning?” *European Journal of Anaesthesiology* (20) (2003): 428.

already noted that for any incapacitant, "'Operational limitation include the potential use in mixed populations of the very young, the elderly, those in poor health and those who may react adversely to a specific chemical,'"[292] all of whom may react to the varied levels of dosage received very differently.

Of course, the concern is not just with the potential operational problems that such a weapon may encounter when it needs to be used on a population with wide-ranging physical constitutions. Writing about the rise of non-lethal weapons during the 1990s, Dando suggests that it has been challenging to find a suitable agent: "Many chemicals have been screened as potential incapacitants and a prime consideration in the US programme has been to find agents with a large gap between the effective and the lethal dose so that the agent could be used with little risk of permanent harm to those affected."[293] The long history that the US has in searching for an incapacitant suggests that there are "probably many agents with excellent incapacitant properties which have been rejected because they lacked a satisfactory safety ratio."[294]

Ketchum and Sidell similarly noted this challenge of finding a biochemical agent with the right kinds of safety ratio and pharmacokinetic profile. According to them, very few chemical agents that act on the CNS are actually suitable for use as an incapacitating NLW. Most of such psycho/neurochemicals are either not potent enough or produce unpredictable behaviors that cannot be reliably expected to produce desired effects if they were to be used as weaponry. For instance, depressants such as barbiturates, a drug traditionally used for sedation and anesthesia, oftentimes require several hundred milligrams in dosage in order to achieve some effect on the target's performance.[295]

[292] C. Ferguson, *Antipersonnel Chemical Immobilizers: Sedatives*, research proposal, April 27, 1994, Aberdeen Proving Ground, MD: US Army ERDEC, quoted in Davison (2009), 115.
[293] Dando, *A New Form of Warfare* (1996), 156-157.
[294] Dando, *A New Form of Warfare* (1996), 156-157.
[295] Ketchum and Sidell (1997), 293

Similarly, part of the reason for BZ's lack of operational use was attributed to the unpredictability in the responses it generates. This lack of potency and predictability of effect may be a result of the agent's pharmacokinetic constraints as well as the difficulty in designing an effective delivery system to disperse such an agent.

The issues of safety, potency, and predictability of a biochemical agent are further complicated by the fact that some biochemicals can have dangerous side effects. In a US patent filed by the ERDEC in 1998, titled "Opiate Analgesic Formulation with Improved Safety," similarly notes this challenge of finding a suitable agent due to potential side effects. Despite the amount of attention opiate or opioid analgesics (like fentanyl) have received since at least the 1980s, "the development of opiate drugs to create a drug that causes analgesia with respiratory depression has been an elusive goal."[296] Furthermore, even more recent developments of opiate drugs with more selective pharmacological properties "have not resulted in any significant reduction of respiratory depression associated with the opiate agonists."[297] It is also for this reason that some of the research on the opioid analgesics in the 1990s focused specifically on mixing the agents with antagonists in order to alleviate the agents' harmful side effects, although the extent to which such an approach has reached success remains unclear.

As some in the expert communities argue, however, even if an agent with reasonable safety ratio, potency, and predictability can be found, in operational settings where dosage control is not possible the agent can still lead to significant, expected amounts of casualties, as was witnessed at the Dubrovka theater in 2002. Prior to the incident, in the spring of 2002, in a comment on biochemical non-lethal weapons, Mark Wheelis, a microbiologist at University of California, Davis, emphasized the dose-response

[296] United States Patent Office, "Opiate Analgesic Formulation with Improved Safety." United States Patent 5,834,477, 10 November 1998.
[297] US Patent 5,834,477.

problem and asserted that "In fact, a categorical distinction between lethal and non-lethal chemical agents is not strictly possible, since 'non-lethal' agents may be lethal at high concentration or for specific individuals."[298] This sentiment was very much so echoed in a report on the Dubrovka incident from *Nature*, where Alan Zelicoff, a former senior scientist at the Center for National Security and Arms Control at Sandia National Laboratory, comments that "'It was a grotesque assumption on the part of the Russian leadership that sloppy use of highly effective anaesthetics, pumped into a confined room full of weakened hostages, would not kill many people.'"[299] According to the *Nature* article, the very narrow "therapeutic window" of fentanyl means that potentially fatal side effects of the drug, such as respiratory depression, "occur at doses only slightly higher than those required for their therapeutic effect."[300] As a result, for some experts, the death toll that came out of Dubrovka was not all that surprising – whatever agent was used, the expectation that it could have achieved no or very minimal lethality was faulty.

To demonstrate this faulty assumption, a 2003 study published by the Federation of American Scientists (FAS) shows how seemingly non-lethal incapacitating agents can in fact be quite lethal in actual use. In the study, an agent with the therapeutic index (TI, which refers to lethal dosage in 50% of the population divided by the effective dosage in 50% of the population, i.e. $TI=LD_{50}/ED_{50}$) of 1,000, which would be considered exceptionally safe by pharmacological standards, would result in 9% deaths within the population if the goal is to ensure 100% incapacitation (see Figure 9). The authors of the FAS study further contend that even if the agent has an exceedingly high therapeutic index, in operational settings of a rescue mission like the one at Dubrovka, the dosage each target

[298] Mark Wheelis, "Biotechnology and Biochemical Weapons," *The Nonproliferation Review* 9(1) (Spring 2002): 52.

[299] Quirin Schiermeier, "Hostage Deaths Put Gas Weapons in Spotlight." *Nature* 420 (7 November 2002): 7. Similar sentiments can be found in Daniel G. Dupont, "Storm Before the Calm: Can Knockout Gases Really Be Nonlethal?" *Scientific American* (February 2003): 17-18.

[300] Schiermeier (2002), 7.

receives will depend heavily on factors such as its distance to the agent source and its length of time in exposure to the agent, etc., which could make an individual take in doses of the agent at a much higher level than anticipated. For these reasons, the authors conclude that "genuinely non-lethal chemical weapons are beyond the reach of current science."[301]

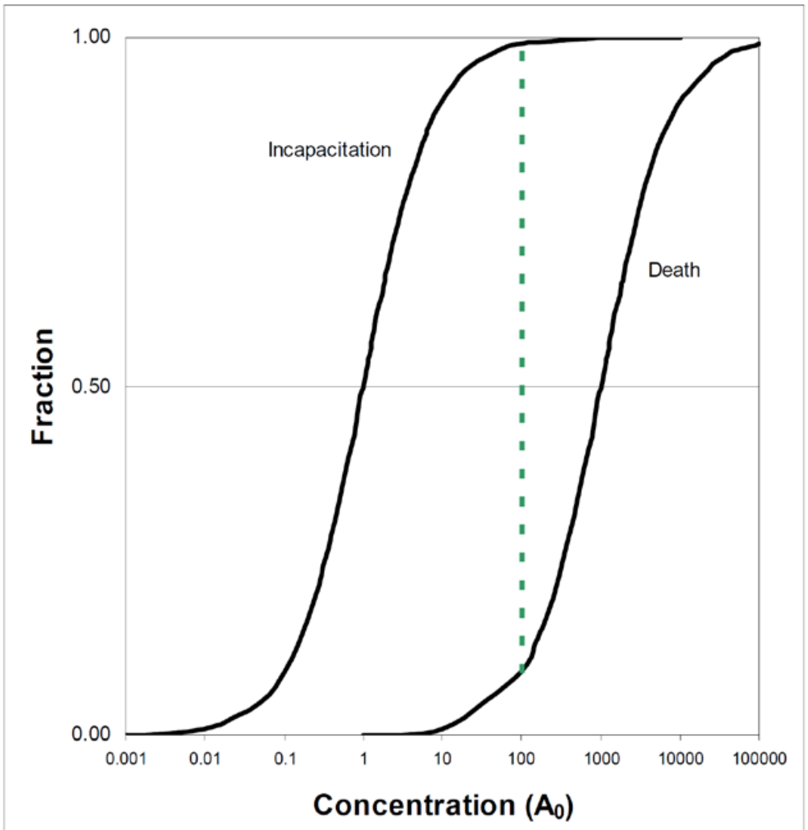

Figure 9 - Relationship among Dose, Incapacitation, and Lethality in a Two Receptor Model[302]

[301] Lynn Klotz, Martin Furmanski, and Mark Wheelis, "Beware the Siren's Song: Why 'Non-Lethal' Incapacitating Chemical Agents are Lethal," Federation of American Scientists, 1, https://fas.org/cw/documents/sirens_song.pdf (accessed February 12, 2016).

[302] Klotz, Furmanski, and Wheelis, 3.

The explanation offered by the FAS study and its conclusions have been endorsed by others. For instance, Robin Coupland reached similar conclusions in his study on the risks and uncertainties of biochemical incapacitants, that "there is no evidence that any currently existing pharmaceutical agent, when used as an incapacitating weapon, will consistently result in a lower lethality than when other weapons are used."[303] He further reiterates that "delivering a rapidly effective dose [of an agent] from a tactical perspective means some people will inevitably receive a dangerous if not lethal dose,"[304] and there is no evidence that the issues of dosage can be regulated to ensure consistency in non-lethality. Dando similarly remarks in his analysis on the Dubrovka incident that the operation demonstrated the dose-response problem: a substance like fentanyl will certainly put people to sleep, but "in higher concentrations it will stop people breathing…the concentration of fentanyl in any particular part of the building was difficult to control, the effects of any given concentration of it on any particular individual would not have been known in advance, and crucially, the separation of the lethal and incapacitating effects of the drug are not sufficiently large to eliminate the chance that some of the hostages were going to die."[305] Unlike the optimism shown in the Penn State Report in 2000, the commentaries by experts in the aftermath of Dubrovka clearly reveal that the incident has prompted scientists and other experts to vocally express their understanding of the technical barriers that face the biochemical incapacitants as NLWs and to cast their doubts on the feasibility of their development.

Perhaps most importantly, the converging consensus on this infeasibility has become increasingly and openly endorsed by several important scientific organizations

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[303] Robin M. Coupland, "Incapacitating Biochemical Weapons: Risks and Uncertainties," in *Incapacitating Biochemical Weapons: Promise or Peril?* eds. Alan M. Pearson, Marie Isabelle Chevrier, and Mark Wheelis (Lanham, MD: Lexington Books, 2007), 227.

[304] Coupland (2007), 227-228.

[305] Malcolm R. Dando, "Scientific Outlook for the Development of Incapacitants," in *Incapacitating Biochemical Weapons: Promise or Peril?* eds. Alan M. Pearson, Marie Isabelle Chevrier, and Mark Wheelis (Lanham, MD: Lexington Books, 2007), 127.

domestically and internationally. In 2007, the British Medical Association in its study on the use of drugs as weapons concludes that "the use of drugs as weapons is simply not feasible without generating a significant mortality among the target population" and that an agent capable of incapacitating without risk in tactical situations "does not exist and is unlikely to in the foreseeable future."[306] Within the US, the 2008 NRC report on *Emerging Neuroscience* also notes that delivering sufficient dosage to targets without overkill remains a challenge: "Pharmacological agents are not used as weapons of mass effect, because their large-scale deployment is impractical; it is currently impossible to get an effective dose to a combatant."[307] While the NRC committee notes that technologies could be available in the next 20 years that "would allow dispersal of agents in delivery vehicles that would be analogous to a pharmacological cluster bomb or a land mine,"[308] the extent to which the issues of drug effects and dosage and their complex interaction with individual humans can be mitigated is unclear.

The need to understand these issues of technical barriers to the development of biochemical incapacitants heightened around the time of the Third Review Conference of the CWC in 2013, and the expert opinions on these issues became more resolute. For instance, in a 2012 study done by The Royal Society on neuroscience, the participants in the working group assert that "It is *not technically feasible* to develop an absolutely safe incapacitating chemical agent and delivery system combination because of inherent variables (emphasis added)" that are beyond the control of user in operational settings.[309]

Furthermore, a 2012 international workshop convened at the Spiez Laboratory in Switzerland on the issue of incapacitating chemical agents and a technical report from the

[306] British Medical Association, *The Use of Drugs as Weapons: The Concerns and Responsibilities of Healthcare Professionals* (London, UK: British Medical Association, 2007), 1.
[307] National Research Council, *Emerging Cognitive Neuroscience* (2008), 137.
[308] National Research Council, *Emerging Cognitive Neuroscience* (2008), 137.
[309] The Royal Society (2012), iv.

International Union of Pure and Applied Chemistry (IUPAC) in 2013, both of which were intended to serve as technical advice to the Third Review Conference through the Scientific Advisory Board (SAB) of the Organisation for the Prohibition of Chemical Weapons (OPCW), reached the same conclusions about the infeasibility of achieving any kind of meaningful non-lethality through biochemical incapacitants. According to the Stefan Mogl, the editor to the Spiez Laboratory report,

> ICA (will) typically act on the CNS, but any effect is dose dependent, and any agent – including ICA – will have side effects. Furthermore, there is significant variability in the effects due to individual susceptibility… [and] over-dosing is a typical occurrence when an agent is used in the field, as is known to happen during field use of RCA. There are just too many variables to ascertain that a use would be 'safe' in all circumstances.[310]

This sentiment was endorsed by the IUPAC report, stating that "currently available S&T does not have the capabilities required to enable the delivery such 'incapacitating chemical agents' for law enforcement purposes in a 'safe' manner."[311] The scientific and expert opinions on the issue of feasibility of biochemical incapacitants as NLWs, thus, have over the past decade converged toward a consensus on infeasibility, which contributes an unfavorable condition for countries intending to invest in this area of military technology.

5.3.2 Military Requirements on Risk of Significant Injury

From the military's perspective, the potential interest in developing a NLW using biochemical incapacitant is subject to the ability to which such a weapon can meet the expected performance standards. In an ideal sense, as shown in Table 3, a biochemical

[310] Stefan Mogl, ed., *Technical Workshop on Incapacitating Chemical Agents: Spiez, Switzerland, 8-9 September 2011* (Spiez, Switzerland: Spiez Laboratory, 2012), 6-7.

[311] Katie Smallwood et al., "Impact of Scientific Developments on the Chemical Weapons Convention (IUPAC Technical Report)," *Pure Applied Chemistry* 85(4) (February 2013): 855.

agent that functions well as a non-lethal weapon should be easy to administer with sufficient potency so that it has a rapid onset of its effects, but at the same time these effects need to be reversible and last only a limited duration. Moreover, the ideal agent should elicit similar and predictable responses from its targets and have otherwise little side effects.[312] Although it may be difficult for one agent to satisfy all of these criteria, especially when some of them may be at odds with one another, these ideal qualities provide guidance as to what the military may desire from a non-lethal capability and specify as its requirements.

Since, currently, there is no visible US military investment in biochemical incapacitant as NLWs, there is no direct data on what the current military requirements for such a capability would be. However, historical examples of military R&D efforts in this kind of capability can provide some insight as to what the requirements may be. One of such example is agent BZ, which, as aforementioned, was weaponized and stockpiled as part of the US chemical arsenal during the 1960s and 70s. While the exact extent to which the military (army) conducted the R&D for BZ is not entirely clear, what is known is that it was selected as the incapacitating agent under the general requirements that such agent should: 1) have onset action less than one hour, 2) ideally, have no permanent effects (though this was desirable, it was not an essential characteristic), 3) be as potent as nerve agents, 4) have low toxicity in handling and stability in storage, and 5) be deployable from aircraft in all weather conditions.[313] Although multiple agents ranging from anesthetics to muscle relaxants were considered at the time, psychochemicals such as BZ were preferred due to their potency and wider margin of safety compared to other agents.

[312] Lakoski, Murray, and Kenny (2000), 3.

[313] Martin Furmanski, "Historical Military Interest in Low-Lethality Biochemical Agents: Avoiding and Augmenting Lethal Force," in *Incapacitating Biochemical Weapons: Promise or Peril?* eds. Alan M. Pearson, Marie Isabelle Chevrier, and Mark Wheelis (Lanham, MD: Lexington Books, 2007), 53.

Despite being stockpiled, BZ never went into operational use because it had major shortcomings. For one, BZ has a long onset time. In dosages that reach 50% incapacitation in its target population, the effect takes approximately an hour to appear. Although this fell within the requirements specified for the agent, such a slow onset time limited its use.[314] Furthermore, as a deliriant BZ leads to a high degree of unpredictability in response from its targets.[315] Some affected individuals remain able to function with assistance, while others need to be restrained in order to avoid self-injury. Still others demonstrate paranoia and mania both while under the effect as well as during recovery. All of these considerations led to BZ's lack of operational utility and its eventual elimination.

Surprisingly, in no literature that has examined the reasons for BZ's elimination is the potential for lethality discussed, given in estimation BZ has a therapeutic index of 40.[316] This is possibly due to the fact that non-lethality or the risk for significant injury, at the time, was not considered a very important requirement. It is also possible that the lethal effect of BZ was never fully realized, for it was never deployed and was tested under only very favorable and controlled conditions where dosages were kept low.[317] Nevertheless, since the 1990s, the degree to which a non-lethal weapon can ensure actual non-lethality has become an increasingly important consideration in the R&D of such weapons.

In particular, after its founding in 1996, the JNLWD has devoted significant efforts in understanding a NLW's human effects, which refers to the "physiological and behavioral responses produced by non-lethal weapons employment."[318] Such an effect is advised by both the Human Effects Advisory Panel (HEAP), an independent advisory panel,

[314] Furmanski (2007), 54.

[315] Furmanski (2007), 55 and Davison (2009), 108-109.

[316] James S. Ketchum and Harry Salem, "Incapacitating Agents," in *Medical Aspects of Chemical Warfare*, ed. Joan Redding (Falls Church, VA: Office of the Surgeon General, United States Army, 2008), 427.

[317] Furmanski (2007), 55.

[318] Joint Non-Lethal Weapons Program, "Non-Lethal Human Effects Fact Sheet," October 2011.

comprised of academic, medical, and law enforcement experts, that conducts assessments of human effects, and the Human Effects Review Board (HERB), which is comprised of representatives from the offices of services' surgeons general and legal, treaty, and policy experts, and the HERB also conducts its own independent assessments of the health risks of a NLW. HEAP and HERB provide guidance to program managers and developers to ensure that emerging NLW technologies minimize the risk of injury.

One of the key components of the human effects assessment is the Risk of Significant Injury (RSI). RSI refers to the probability that a NLW will cause a significant injury, which includes death, permanent injuries, or injuries that require certain levels of healthcare as defined by Health Care Capability Indices 1 and 2.[319] While the evaluation of RSI has long guided the human effects characterization of NLWs since the late 1990s, in 2012, under Department of Defense Instruction (DoDI) 3200.19, it became an official requirement, expressed in terms of KPP or KSA, in all developments of NLWs.

As a KPP or KSA, RSI of a NLW is expressed as a percentage threshold (i.e., X% of the targeted population will sustain significant injury) and serves as the key criteria in determining the non-lethality of a weapon. Currently, the generally accepted definition of RSI levels of a NLW is established at 1% of the population with which 0.5% will die from effects of the weapon.[320] While, depending on the mission or intended use, this value is not necessarily fixed for all NLWs, it is unlikely that a NLW whose performance in ensuring non-lethality drastically deviates from these thresholds will be deemed acceptable for the US military.

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[319] Shannon Foley, "Non-Lethal Weapons Human Effects," November 19, 2014. HCC 1 refers to injuries that requires first responder capabilities, such as stabilization and emergency care; whereas HCC 2 refers to injuries that require forward resuscitation and hospitalization, where advanced emergency, surgical, and ancillary services are needed.

[320] John M. Kenny, "Human Effects Advisory Panel Program," (Presented to NDIA Non-Lethal Defense IV, March 22, 2000).

As a comparison, one of the more recently developed non-lethal weapons under JNLWD, the Active Denial System (ADS), is reported to have RSI under 0.1%.[321] As a directed-energy system, the mechanisms through which the ADS generates its effects on the targets are of course different from a biochemical weapon, and the performance measures are thus likely to be somewhat different. Nevertheless, the ADS's very low RSI demonstrates that within the US military, for a non-lethal weapon system to be deployable, its ability to maintain very low levels of injury and lethality is likely to be expected.

Given what is known of existing incapacitating biochemical agents, 0.5% lethality is a highly stringent requirement. At a minimum, barring other operational challenges and barriers that have been outlined above, the biochemical agent needs to have at least a TI of 20,000 according to Klotz, Furmanski, and Wheelis's model in order to achieve such a threshold (fentanyl, as a matter of comparison, has a TI around 300). The significant technical challenges facing the development of a biochemical incapacitating agent as the experts have come to believe and vocalize, combined with a highly stringent performance requirement demand from the military, creates an unfavorable condition for those interested in investing in the performance degradation applications from emerging cognitive sciences research.

5.3.3 Alternative Development Pathway through Law Enforcement

The technical challenges facing the development of biochemical incapacitants, combined with a highly stringent military operational definition of non-lethality, create an unfavorable technical condition and suggest that the military's investment in this area is not only likely to incur significant cost and schedule problems but may even result in

[321] LeVine and Rutigliano (2015), 252. See also Department of Defense, Non-Lethal Weapons Program, "Active Denial System FAQs," http://jnlwp.defense.gov/About/FrequentlyAskedQuestions/ActiveDenialSystemFAQs.aspx (accessed March 25, 2015).

failure. What further complicates this effort, however, is that the existing international arms control treaty on chemical weapons restricts the latitude that the military has in exploring such capabilities (explained in more detail below in section 5.4.1). In particular, the CWC specifically prohibits states parties from developing, stockpiling, and using any chemical agents (including biochemical incapacitants discussed in this paper) other than for selected purposes such as law enforcement. Military developments in this area of research, thus, could be hamstrung by treaty obligations.

This situation is mitigated by the fact that there is an apparent willingness, at least in the US, to delegate R&D efforts in this area of research to the law enforcement communities. As discussed and shown above, throughout the history of US development programs in non-lethal weapons,[322] law enforcement communities and the military have long-standing, mutually recognized shared interests. Although the operational goals and parameters may be different (the military has, in general, focused on capabilities that can be used with an area effect, whereas the law enforcement communities have focused their work on individual targets),[323] the two institutions overlap in their interest in many of the technical areas that are meaningful for non-lethal weapons development, including biochemical agents. For instance, when the NIJ started its Less-Than-Lethal Technology programs in 1987, the first contract was given to the Army's Chemical Research, Development, and Engineering Center at the Aberdeen Proving Ground for feasibility assessment on dart-delivered incapacitants.[324]

This relationship on technology collaboration between the two institutions was codified in 1994 when a Memorandum of Understanding (MOU) was signed between the Departments of Defense and Justice on technology developments for Operations Other than

[322] For more details on the history of law enforcement and military's mutual interest in NLW, see Davison (2009).

[323] For instance, see Davison (2009), 116-117.

[324] Davison (2009), 112.

War (OOTW) and law enforcement. Under the MOU, a Joint Program Steering Group with participants from both institutions will co-direct efforts to share existing technology and co-direct future R&D programs relevant for both OOTW and law enforcement. [325] Although it is unclear as to how much work on biochemical incapacitants have been conducted under the premise of this MOU, the agreement establishes the two agencies as cost-sharing partners and each other's institutional alternatives to NLW technology acquisition.

The collaborative relationship between the law enforcement agencies and the military becomes especially useful when the latter desires to circumvent the international legal prohibitions on its technology acquisition, according to Davison. In a report from a joint UK-US meeting on non-lethal weapons and urban operations, it was noted that "If there are promising technologies that DOD is prohibited from pursuing, set up MOA with DOJ or DOE [Department of Energy]."[326] To what extent has this been done to research on biochemical incapacitants has not been examined comprehensively, but it is instructive to note that while the military has had no visible investments in non-lethal biochemical incapacitants since the early 2000s, the NIJ has continued to explore this area of research and has funded research to "explore the potential of operationalizing calmatives and to examine possible pharmaceuticals, technologies, and legal issues"[327] at Penn State in 2007.

Both historical records as well as more recent endeavors have shown that multiple government agencies have a substantial interest in the development of non-lethal weapons. As Dando finds, "The more detailed information available on the history of this work [on

[325] Department of Justice, "Department of Justice and Department of Defense Joint Technology Program: Second Anniversary Report" (February 1997), 1, https://www.ncjrs.gov/pdffiles/164268.pdf (accessed February 20, 2016).

[326] United States/United Kingdom, *US/UK Non-Lethal Weapons (NLW)/Urban Operations Executive Seminar*, *November 30, 2000*, London, Assessment Report, ONR-NLW-038, quoted in Davison (2009), 124.

[327] Danielle M. Weiss, "Calming Down: Could Sedative Drugs Be a Less-Lethal Option?" *NIJ Journal* (261) (2007): 42-46.

biochemical incapacitants] in the United States also shows how interest in such chemical agents can be switched from and between the police, intelligence and military."[328] At a minimum, both the Department of Defense and the Department of Justice have for a long time maintained active programs in this area of research. The military, therefore, has not just an institutional, cost-sharing partner in the development non-lethal capabilities from the law enforcement communities, but the latter also serves as a viable pathway through which technology programs that are of interest to both parties can be acquired.

5.3.4 Summary

The above analyses show that in the realm of the performance degradation application of military cognitive neuroscience research, namely the use of biochemical incapacitants as NLWs, the converging consensus on technical infeasibility due to significant technical barriers, the highly stringent performance requirements in the US non-lethal weapons program with regard to thresholds of injury and lethality, and the presence of an alternative developmental pathway through the law enforcement communities have made it unappealing for the military to continue its commitment to invest in this area of research despite decades of efforts in doing so. Even with the rising interest in the 2000s on cognitive neuroscience research, which has been widely speculated to potentially enable the development of better biochemical agents, the investment from the US military languished.

In particular, the Dubrovka theater incident that took place in Moscow in 2002, in which such a biochemical incapacitant was used, has prompted the expert community to become more vocal in expressing its reservations on the development of such weapons. Furthermore, the increasing discussion on the biochemical incapacitants has also

[328] Dando, *Neuroscience* (2015), 119.

highlighted the level of difficulty for such a weapon to meet the expected operational requirement the US military has set for its non-lethal weapons.

As Pearson notes, it is ultimately "the ability of a prospective weapon to meet military and political requirements, within existing political and operational constraints, which determines whether the weapon is developed, fielded and used."[329] In the case of biochemical non-lethal weapons, the technical constraints cannot be reconciled with the expected performance demands from the military, which, along with an increasing international recognition of the non-viability of such weapons, have made the investment unappealing as an opportunity. The following sections explain the international legal considerations regarding developing biochemical incapacitants in more detail.

5.4 Non-Lethal Chemical Agents and the CWC

As stated above, one of the peculiarities of discussing the development of biochemical incapacitants as non-lethal weapons has to do with international arms control treaties and, in particular, the Chemical Weapons Convention. Since biochemical incapacitants' effect on humans is generated by their toxicological properties, regulations on their development, stockpiling, and use fall under the CWC. However, due to the ambiguous status of incapacitants as potentially a form of riot control, and because of RCAs' permissive use in law enforcement activities, the legality of its development and use have been the subject of significant debate. As can be seen below, some states have sought to preserve their ability to use incapacitants and other non-lethal chemicals in certain conflict scenarios, while others have opposed to such a loophole and have sought to tighten the regulations of the CWC.

[329] Pearson (2007), 68.

This contention between states parties to the CWC came to a head in the mid-2000s when the Dubrovka theater hostage crisis in 2002 brought to the fore some unresolved ambiguities within the CWC regarding incapacitating biochemical agents. Prior to the Moscow incident, discussions on the legality of biochemical incapacitants have primarily been speculative. However, the incident in Moscow drew international attention toward the CWC and its provisions for permissible uses of chemical agents, including RCAs and ICAs. This renewed (from the original negotiations over the treaty language) debate over the legality of developing and using chemicals such as incapacitants has provided the impetus to a shift in the understanding of these agents in the context of the CWC, where some states parties have begun to actively pursue a tightening of existing treaty loopholes. This changing international political context, as is analyzed and argued below, likely has further prevented the US from seeing developing biochemical incapacitant as a viable opportunity for non-lethal weapons.

5.4.1 Ambiguities and Loopholes in the CWC

The issues concerning incapacitating chemicals and the chemical weapons arms control regime are age-old. Even before it was open for signing, the CWC had already been troubled by the issues of riot control agents or other chemical agents not intended to cause lethal effects. This was evident during the negotiating process of the treaty itself in 1992, where the states parties disagreed over the treaty terms with regard to the permissible uses of RCAs. In particular, the US delegation headed by Stephen Ledogar held the view that non-lethal chemical agents, unlike other conventionally lethal ones, can have legitimate uses in law enforcement and some defensive military operations to save lives, and the ability of states to employ such weapons should be preserved.[330] While this particular

[330] J.P. Perry Robinson, "Non Lethal Warfare and the Chemical Weapons Convention," Further HSP Submission to the OPCW Open-Ended Working Group on Preparations for Second CWC Review Conference, Harvard Sussex Program (October 24, 2007), 7, http://www.sussex.ac.uk/Units/spru/hsp/Papers/421rev3.pdf (accessed December 10, 2015).

perspective was not a popular one even among the Western Group (which entailed mostly western European states, and traditional US allies such as Australia and Canada) during the negotiation process, it did cause the treaty language on “law enforcement” (as a “purpose not prohibited”), “riot control agent,” and “method of warfare” to be contentious through the final days of the negotiation.[331] It was nevertheless clear that compromises were needed between states parties that preferred flexibility in treaty language and those that preferred a narrower and more defined interpretation on these terms and their relationship to one another.

The compromise that was reached in the end entailed several features as reflected in the final treaty language. First, it was recognized that deliberate uses of any toxic chemical as a form of warfare is unacceptable. This was not only clearly demonstrated in what has come to be interpreted as the General Purpose Criterion of the CWC,[332] which defines chemical weapons in a comprehensive manner according to the purpose and use of any toxic chemical and their precursors, but it was also specifically stated, in Article I.5., that “Each State Party undertakes not to use riot control agents as a method of warfare.”[333] However, what was left out of the convention was any specific definition of “method of warfare.” This omission provided room for states parties to interpret what a “method of warfare” may entail, which became very important for countries like the US that preferred to have the flexibility in using RCAs in certain military operations that may not be construed as “warfare.”

[331] Robinson (2007), 12.

[332] The General Purpose Criterion of the CWC is generally thought to refer to the general prohibition of the use of toxic chemicals and their precursors for any purposes other than the ones not prohibited under the CWC. It often refers to Article II.1(a), which identifies “Chemical Weapons,” as ‘Toxic chemicals and their precursors, except where intend for purposes not prohibited under this Convention, as long as the types and quantities are consistent with such purposes.”

[333] Chemical Weapons Convention, Article I.5.

Second, the texts on the "purposes not prohibited" under the convention as it appears in Article II.9.(d) shifted from "Domestic law enforcement and riot control purposes," which appeared in the rolling text of the convention under the then-outgoing chairman Sergey Batsanov, to "Law enforcement including domestic riot control purposes" in the final agreed upon version.[334] This change, which went from defining law enforcement and riot control as specifically domestic, to defining domestic riot control as a subset of law enforcement, also created room for interpretation on what constitutes law enforcement as purposes not prohibited under the convention.

Finally, while "riot control agent" itself is defined in the convention,[335] its relations to the types of law enforcement activities permitted as "purposes not prohibited" are not clearly specified. Within the CWC, the term "riot control agents" appears in only five different places, but its only specification is that its use as a method of warfare is prohibited, and in none of these places mentioned are RCAs defined with respect to law enforcement. This detachment of RCAs from law enforcement activities is not accidental but rather a reached compromise. This was made especially evident regarding the terms of compliance and monitoring of RCA in the CWC as specified in Article III.1(e), which, during the final rounds of the negotiations in Geneva, went from requiring declarations of chemicals used for "domestic riot control and domestic law enforcement" in the earlier drafted texts to requiring declarations of only "riot control agents" in the final, agreed upon text.[336] By placing the emphasis of transparency on RCAs rather than law enforcement activities, the CWC has left it open for states parties to have divergent interpretations on what is permissible to use for law enforcement activities.

[334] Robinson (2007), 10.

[335] CWC defines RCA as "Any chemical not listed in a Schedule, which can produce rapidly in humans sensory irritation or disabling physical effects which disappear within a short time following termination of exposure"; see Article II.7.

[336] Robinson (2007), 11-12.

These ambiguities in language have several ramifications on the later interpretations on RCAs, warfare, and law enforcement within the context of the CWC. First, by singling out and defining RCAs specifically, it has led some to argue that RCAs are somehow qualitatively different from the rest of the chemicals considered in the CWC.[337] By granting this special status to the RCAs and by defining RCAs by their effects (sensory irritation or *disabling physical effects*) rather than their toxicological properties, the treaty left a loophole for states parties wishing to develop non-lethal chemicals to do so under the guise of riot control agents. Indeed, this is what happened in the US in the early 1990s. Although the signing of the CWC seemed to have curtailed developments on the ARCAD program, some of the Army research at the time on incapacitating chemicals was reprogrammed as riot control research.[338]

Second, by leaving out any definition of "method of warfare" or "warfare" itself, the treaty also opened room for states parties to define whether certain military activities can be construed as warfare. Indeed, to preserve the ability to use RCAs during certain kinds of military operations, the US has specified in its ratification of the CWC a set of conditions that permit the US to use RCAs in conflicts, including against combatants who are parties to a conflict, if: 1) the US is not a party to the conflict; 2) the US is conducting peacekeeping operations with the consent by the receiving state; and 3) the US is conducting peacekeeping operations sanctioned by the Security Council under Chapter VII of the UN Charter.[339] Furthermore, the US also specified in the conditions to the RCAs' permitted use that Executive Order 11850[340] of April 8, 1975 be upheld.

[337] Robinson (2007), 11.

[338] Davison (2009), 112.

[339] U.S. Senate's Conditions to Ratification of the CWC, Senate Resolution 75, 105th Congress, 1st Session (April 24, 1997), Section 2.(26), http://www.cwc.gov/cwc_authority_ratification_sec2.html (accessed December 10, 2015).

[340] Executive Order 11850 on April 8, 1975 was a renunciation of US first use of RCAs in war except in certain military modes to save lives, such as to controlling rioting prisoners of war, in situations where civilians are mixed with combatants in order to save civilian lives, to rescue downed aircrew and passengers, and to protect convoys from attacks in the rear echelon areas.

Third, by treating domestic riot control as a subset of law enforcement activities, interpretations on what constitutes law enforcement are left to the states parties. This ambiguity in language has led to some concerns as to whether or not chemical agents are permitted to be used in law enforcement contexts outside of domestic riot control (such as to implement certain international law, for instance). Finally, by disassociating RCAs from permitted law enforcement activities, the treaty left open as to what kind of chemical agents could be used during such enforcement activities. This particular loophole gave justification for the use of incapacitants during permitted law enforcement activities, even if the qualification of an incapacitant as a non-lethal weapon or RCA may be subject to debate. As shown below, these ambiguities in treaty language led states to by and large recognize the legality of Russia's use of fentanyl at Dubrovka, even though an agent like fentanyl would not be in an ordinary sense understood as a RCA.

As the analysis above shows, many loopholes exist in the CWC. The US in particular has embraced these loopholes if not actively advocated for them during the negotiation process. Although some US R&D efforts were curtailed by the CWC, it is clear that the existing treaty terms do not fully prevent the development of biochemical incapacitants. This is likely recognized by the states parties, for research activities in the US have continued during the 1990s and into the early 2000s, even after the US has signed and ratified the CWC. Signing of the CWC alone thus did not sufficiently disincentivize the US from investigating further into incapacitants.

If this is so, then what caused such a change in US investment during the 2000s? As is shown below, this dissertation argues that in addition to the technical conditions that have made biochemical incapacitants an unappealing investment, the Dubrovka theater incident in 2002 also propelled renewed interest and willingness at the international level to reexamine and potentially address the R&D (and use) of such biochemicals as weapons. In this sense, as the international opinion toward the non-viability and unacceptability of these biochemical weapons grow, the political costs for deviating from such a position increases, which likely has contributed to the unwillingness on the part of the US to sustain its investment.

5.4.2 The Legacy of the Dubrovka Theater Incident

According to David Fidler, "in the Moscow incident the use of a toxic chemical that is not an RCA for law enforcement purposes provides some evidence of State practice that the CWC does not limit the range of chemicals that can be used under Article II.9(d) to RCAs."[341] Because Russian special forces' use of a fentanyl derivative has in large part been considered by analysts as "legal," and certainly few states, if any, have voiced strong concern of such use of chemical incapacitants, the Dubrovka incident has essentially set an international precedent toward the legality of using such agents in a scenario which almost all would have identified as "for law enforcement purposes."

Yet, the issue of legality in the context of biochemical incapacitants is more complex than whether or not an agent can be used. As is specified in the CWC, even if certain agents are permissible for states parties to use for specific purposes (such as law enforcement), the "types and quantities" of the agents developed, produced, acquired, or used must be consistent with such permitted purposes. For this reason, if a chemical agent cannot be produced or used in a manner that is consistent with the permitted purposes, it can still generate concerns about its legality with respect to the CWC.[342] As Fidler argues, the use of incapacitating chemicals "in the contexts in which neither individual dosage nor the exposure conditions can be controlled is…legitimate only in extreme situations," where there is a "need to resort to potentially lethal force to resolve urgent, life-threatening

[341] David Fidler, "The Meaning of Moscow: 'Non-Lethal' Weapons and International Law in the Early 21st Century," *International Review of the Red Cross* 87(859) (September 2005): 537.

[342] Fidler (2005), 537.

situation because less violent and dangerous means…have failed."[343] He further posits that while the Moscow theatre incident was one such extreme scenario that warranted the use of fentanyl derivatives, the Russian government's lack of timely response to treat rescued hostages, particularly those who have suffered from opioid-induced respiratory depression, still raised questions from the perspective of international human rights law.

Legal controversies also surround the term "law enforcement" as stated in the CWC's Article II.9.(d). Although the term is not defined within the CWC, it is generally understood and accepted that such a term applies to domestic law enforcements. Such an interpretation is not only reflective of the conventional understanding of the term, but it is also supported by the texts of CWC, where "domestic riot control purposes" is presented as an example of law enforcement. Yet, to what extent can the concept of law enforcement be extended beyond the domestic domain of a sovereign government within its jurisdiction falls into a grey area. In particular, whether or not this permissive use of chemical agents can be applied to the various forms of international law enforcement and non-traditional military operations (such as counterinsurgency) have ignited debates.

According to Fidler, the permissive use of chemical agents to "law enforcement" purposes in Article II.9.(d) is clearly not intended for extrajurisdictional enforcement of a state's domestic law, unless such enforcement has the consent of the state under whose jurisdiction it is taking place.[344] Fidler further posits that, since international law by nature has a deficiency in the implementation of its rules, and that peaceful settlements are generally the accepted practice in resolving disputes arising from violations of international laws, states are not supported from an international legal perspective to attempt to compel

[343] Fidler (2005), 538.
[344] Fidler (2005), 541.

others to comply with international law through “enforcement” actions using armed forces, regardless whether such actions involve chemical incapacitants.[345]

Of course, in certain contexts, armed forces may be employed in traditional or non-traditional operations that are sanctioned by international law, and some of these operations may entail “law enforcement” like activities. For instance, a legitimate occupying power has the responsibility to maintain order within its jurisdiction and the security of its people, and it may employ armed forces for the purpose of maintaining social order, securing its facilities and peoples, and addressing threats from non-combatants in the occupied territory. Armed forces may also conduct non-traditional operations, including peacekeeping, that are in accordance with international law or mandate. In those situations, the use of chemical agents for the purpose of law enforcement is understood to be permitted against non-combatants, although, to date, nothing beyond the traditionally defined RCAs have been used.[346]

In this sense, in addition to bringing the complex legal issues to the fore, the Moscow theater incident has also provided a reality check for both advocates and skeptics of chemical incapacitants as non-lethal weapons alike. For the proponents, who see the promise of biochemicals as a viable means to achieving certain operational goals in today’s military missions that may require sensitivity to casualties, particularly in environments where civilians and combatants may be mixed, the restriction in the CWC regarding CW uses for only the limited setting of law enforcement warrants change. In the 1999 CFR report, which holds not just a favorable view toward but makes an urgent call for the development of non-lethal weapons, it was suggested that “U.S. security might be improved by a modification to a treaty such as the Chemical Weapons Convention or the

[345] Fidler (2005), 542.
[346] Fidler (2005), 545.

Biological Weapons Convention."[347] While the CFR task force did not focus on the issues of chemical incapacitants in particular aside from the RCAs, from its inclination to change restrictions within existing arms control treaties, it was concerned about how such restrictions can hinder non-lethal capabilities from being developed and used.

The skeptics, on the other hand, often emphasize the need to uphold existing terms of the arms control agreements. Where they have issues with the existing terms, they often refer to the ambiguities in treaty language and promote changes that would lead to more precision and greater clarity. Like the proponents, skeptics of chemical incapacitants have also taken issue with the provision in the CWC that allows states parties to use chemical agents for law enforcement purposes, but their concerns lie with the lack of clear definition on whether or not CNS-acting bio/neurochemicals should be considered by the convention in the same category as riot control agents and on what constitutes law enforcement. In this sense, the skeptics are not only in favor of upholding the existing treaty terms and interpreting them in a manner that is the most restrictive to the R&D and use of biochemical incapacitants, but some of them have in fact advocated for defining and codifying such restrictions into the CWC in order to alleviate ambiguities and close up existing loopholes on this issue. The Dubrovka theater incident, in this sense, opened the window for states to reengage in this debate about the legality and acceptability of biochemical incapacitants.

5.5 Evolving Understanding of Chemical Incapacitants and Policy Impact

One impact that the Dubrovka incident has engendered was a slow-to-evolve but growing demand in the international system to clarify existing ambiguities within the CWC and to more restrictively define the permissive use of toxic chemicals in specified circumstances such as law enforcement. This particular trend can be observed from two

[347] Council on Foreign Relations, *Non-Lethal Technologies: Progress and Prospects* (New York, NY: Council on Foreign Relations Press, 1999), 16

perspectives: first, there is an increasing discussion in the international fora regarding the loopholes and ambiguities within the CWC and the problems biochemical incapacitants present; in addition, there is also an increasing willingness on the part of at least some states parties to address these loopholes and ambiguities and to strengthen the CWC. This is observable particularly in the three Review Conferences to the CWC, in which the issue of biochemical, incapacitating weapons are drawing increased attention. Second, certain states have, in their pursuit to closing existing loopholes and defining biochemical incapacitants into the CWC, adopted the belief in the lack of legality as well as feasibility in developing such weapons. This is observable from the stance that the states parties have taken during their discussions on the issues of biochemical incapacitants in the context of the CWC. The following sections analyze these trends in more detail.

5.5.1 A Shift in International Understanding?

In his discussion on the legal ramifications of the Dubrovka incident in Moscow, Fidler notes that the incident seemed to have caused a "sea change" within the US regarding the biochemical incapacitants. In particular, he references the two CFR reports on non-lethal weapons before and after the incident to show such a shift in the mindset. The CFR report published in 1999, prior to the incident in Moscow, clearly endorses the need for the US to develop non-lethal capabilities even if such pursuits would challenge existing arms control agreements. As stated above, in that report the CFR task force members contemplated that it might be in the interest of the US to change the treaty terms so that US security and technology development efforts would not be hamstrung by them.

However, this attitude took a drastic change in the 2004 report on NLWs in which the task force members argue for the opposite from what was recommended in 1999. More specifically, the task force "believes that to press for an amendment to the CWC or even to assert a right to use RCAs as a method of warfare risks impairing the legitimacy of all

NLWS," and to press for such an amendment would "free others to openly and legitimately conduct focused governmental R&D that could more readily yield advanced lethal agents than improved non-lethal capabilities."[348] As a result, the CFR task force recommends that it is best for the US to reaffirm its commitment to existing arms control treaties including the CWC and the Biological and Toxin Weapons Convention (BWC) and to provide leadership in national compliance to the terms of these treaties.

In light of this drastic change from the CFR reports, and along with other evidence within the US in which the legality of biochemical incapacitants were increasingly questioned, Fidler suggests that there is a growing awareness in the US that loosening the CWC and BWC for non-lethal weapons purposes would be harmful to US interests, threaten the integrity of the treaties, and damage the legitimacy of all NLWs.[349] While this "sea change" according to Fidler was beginning to take place in the US post-Moscow incident, a shift in the understanding of biochemical incapacitants was taking place internationally as well during the 2000s. This was most noticeable, perhaps, from the way that issues of incapacitants were addressed during the three Review Conferences to the CWC in 2003, 2008, and 2013.

Despite that the first review conference took place only half a year after the Dubrovka incident, the topic of advancements in incapacitating, non-lethal chemicals was not addressed in anyway aside from a brief mention in the national statements from New Zealand, Norway, and Switzerland.[350] According to Richard Guthrie, who reported on the

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[348] Council on Foreign Relations, *Non-Lethal Weapons and Capabilities* (New York, NY: Council on Foreign Relations, 2004), 32.

[349] Fidler (2005), 548.

[350] "'Non-Lethal' Weapons, the CWC and the BWC," *The CBW Conventions Bulletin* 61 (September 2003): 1. See also House of Commons Foreign Affairs Committee, *Global Security: Non-Proliferation: Fourth Report of Session 2008-09, Report, Together with Formal Minutes, Oral and Written Evidence* (London: The Stationery Office Limited, 2009), 229. In the Swiss statement it was noted that "A lack of transparency exists particularly in the grey areas of the Convention where the red line between activities not prohibited and those prohibited is difficult to discern. To shed more light on these areas, the Conference could ask the States Parties to declare not only chemical products they hold for riot control

second and third Review Conferences, efforts toward addressing the growing biochemical incapacitants concerns at the First Review Conference were blocked by the United States and others.[351] According to some commentators who observed the First Review Conference, the time was not quite ripe for any serious discussion on incapacitating chemical agent or for the inclusion of its clearer definition into the CWC.[352]

For the 2008 Second Review Conference, the topic of addressing existing ambiguities regarding incapacitating chemical agents was once again brought up, this time with more inputs from the technical community. For instance, in the report from an IUPAC meeting in 2007 in preparation of technical advice to the Second Review Conference, it was noted that "Many of the chemicals that are being synthesized and screened…will have incapacitating properties that could make them suitable as so-called 'nonlethal agents,'" and if "these developments were to continue unchecked…there is a serious danger that…the CWC would be undermined."[353] The report, therefore, advocated that states parties at the CWC review conference address the potential risks of these technological advancements and to assess the compatibility between CWC and the development and use of "non-lethal" chemicals for law enforcement purposes.

The IUPAC advices, conveyed through the Scientific Advisory Board and the Technical Secretariat, were relayed to the Second Review Conference by the Director General, who, in his speech, suggests that "State Parties may also wish to look into the developments related to incapacitating agents and address questions such as the effect on

purposes but for law enforcement purposes in general." See "News Chronology: February through April 2003," *The CBW Conventions Bulletin* 60 (June 2003): 49.

[351] Richard Guthrie, "CWC Review Conference Report: The Run-up to the Conference: Preparations and Expectations" (April 7, 2008), 2, http://www.cbw-events.org.uk/cwcrc01.pdf (accessed December 10, 2015). Also see the journal version of its consolidated report in Richard Guthrie, "The Second Chemical Weapons Convention Review Conference," *The CBW Conventions Bulletin* 79 (June 2008): 2.

[352] Alexander Kelle, "The CWC after Its First Review Conference: Is the Glass Half Full or Half Empty?" *Disarmament Diplomacy* 71 (July 20003): 31-40.

[353] Mahdi Ballali-Mood et al., "Impact of the Science Developments on the Chemical Weapons Convention (IUPAC Technical Report)," *Pure and Applied Chemistry* 80(1) (January 2008): 185.

the Convention of their possible introduction for the purposes of law enforcement and of new means of their use."[354] This time, a number of states, including Switzerland and Pakistan, voiced their concerns and called for the Conference to address the issues of incapacitants. Switzerland, in particular, presented a National Working Paper on riot control and incapacitating agents, with the aim to get states parties to "consider adopting during the Second Review Conference a mandate for a discussion of, inter alia, an agreed definition of incapacitating agents, the status of incapacitating agents under the Convention, and possible transparency measures for incapacitating agents."[355]

In addition, as noted by Crowley, in a proposal by the Non-Aligned Movement (NAM) states and China on the draft report of the Second Review Conference, the issue of incapacitant was also brought up. The proposal recommends that the Conference should "'categorically condemn the use of chemical weapons including incapacitating agents or riot control agents as a method of warfare by any state, group or individual under any circumstances.'"[356] Furthermore, the Cuban Ambassador, speaking on behalf of NAM states and China during the open-ended working group meeting prior to the Review Conference, noted that, "'The advancements in Science and Technology have increased the risk of development new riot control and incapacitating agents…The [Second] Review Conference therefore needs to carefully consider their impact.'"[357]According to Crowley, despite that an agreed text indicating the states parties' willingness to consider the issue of incapacitants for law enforcement purposes was not included in the final report from the

[354] OPCW, Opening Statement by the Director General to the Second Special Session of the Conference of the States Parties to Review the Operations of the Chemical Weapons Convention, RC-2/DG.2 (April 7, 2008).

[355] Switzerland, Riot Control and Incapacitating Agents Under the Chemical Weapons Convention, Second Review Conference, RC-2/NAT.12, (April 9, 2008), 5.

[356] Statement of the Cuban Ambassador on Behalf of the NAM and China, 15th Meeting of the Open Ended Working Group preparing for the Second CWC Review Conference, OPCW Headquarters, The Hague, quoted in Michael Crowley, *Application of the OPCW Mechanisms for Reviewing and Addressing Science and Technology Developments: The Case of Incapacitating Chemical Agents (ICAs),* Policy Paper 1, Biochemical Security 2030 Project (Bath, UK: University of Bath, 2013), 19.

[357] Crowley, *Application* (2013), 19.

Review Conference due to last minute objections by Iran, "the issue was rising up the OPCW's agenda."[358]

The momentum to address the ambiguities within the CWC regarding law enforcement and biochemical incapacitants continued for the Third Review Conference in 2013. As stated above, before the official Conference took place, a special meeting was convened at the Spiez Laboratory at the request of the OPCW Technical Secretariat to address the issues of incapacitants, and the issue was also highlighted by the IUPAC report to the SAB, in which it was recognized that "The decision on the appropriateness of the development and use of ICAs for law enforcement purposes, including whether such use would be permitted under the provisions of the CWC, is an issue which requires political, legal, and other inputs."[359]

This sentiment was clearly endorsed by the SAB in its preparation for the Third Review Conference, for it has since its 15th meeting in 2010 considered the technical issues relating to incapacitants at five of its subsequent meetings throughout 2011 and 2012. In a SAB report to the Third Review Conference, the issue of dose-response was highlighted:

> The Board considers the term "non-lethal" as inappropriate when referring to chemicals intended for use as incapacitants, *because for all chemicals toxicity is a matter of dosage*. The Board noted that chemicals considered having high safety margins in the context of controlled pharmaceutical use can have very low safety margins in the context of incapacitants when factors such as uneven dissemination, variability in human response, and the possible need for a rapid onset are required. It was also emphasized that the issue is not just what incapacitating chemical is used for law

[358] Crowley, *Application* (2013), 19.
[359] Smallwood et al., 855.

enforcement purposes, but how it is used, and the consequences such a use may have (emphasis added).[360]

This technical advice was noted by the Director General, who, in his response to the SAB report at a Conference of the States Parties earlier in 2013, suggests that the states parties might consider using the Third Review Conference to examine and further discuss the issues regarding incapacitants.

At the Third Review Conference, a number of states voiced their concerns on the issue of incapacitants and their potential for law enforcement. A selection of their statements pertaining to this topic is presented below in Table 4. What emerges from these national statements, reflect, to an extent, the growing awareness of the international community on the issue of non-lethal incapacitating chemical agents and their potential ramifications within the context of the CWC. Although, as some reports on the Third Review Conference noted, there was not much substantive discussion on the topic of incapacitants in subsequent plenary meetings, and that much of the discussion conducted on incapacitants was at the margins with the goal of finding some commonly acceptable text to include in the final report in order to move the issue forward. Nevertheless, the degree to which states parties are willing to recognize incapacitants and ambiguities in the CWC as relevant issues grew from the first two Review Conferences.

[360] OPCW, Conference of the States Parties, Report of the Scientific Advisory Board on the Developments in Science and Technology for the Third Special Session of the Conference of the States Parties to Review the Operation of the Chemical Weapons Convention, RC-3/DG.1, (October 29, 2012), 4.

Table 4 - Selected National Statements at the Third Review Conference of CWC on Incapacitants

State Party	O	C	Statement	Representative
Germany	x		In Germany's view State Parties at this Conference also need to consider ways to prevent that new chemical weapons may be developed or produced under the guise of permitted purposes, such as law enforcement...In the past years the issue of "toxic chemicals for law enforcement" has been extensively discussed in various fora outside the OPCW. These chemicals are commonly called "incapacitating chemical agents". There is now a substantial body of scientific analysis on developments that have taken place since the entry-info-force of the Convention...in Germany's view, the Review Conference should through its final declaration initiate discussions on the issue of "toxic chemicals for law enforcement".	Rolf Wilhelm Nikel
Ireland	x		Ireland also notes its conclusions in relation to incapacitating agents. We share the concerns which have been expressed in relation to the potential use of incapacitating agents from both a humanitarian and legal perspective. We support the proposals made at this Conference to initiate a discussion on this topic.	Mary Whelan
Norway	x		State Parties should also pay special attention to the well founded advice from the Scientific Advisory Board, and make sure that this is reflected in the outcome document. A particular issue is that of toxic chemicals in law enforcement. Norway agrees with the Board that the technical discussions on the potential use of toxic chemicals for law enforcement have been exhaustive. This Review Conference is an excellent opportunity to further discussing the broader implications of the use of toxic chemicals for law-enforcement purposes.	Anniken R. Krutnes
Romania	x		My delegation supports the idea of considering the issue of incapacitants, in the context of relevant scientific and technological developments, if it will be agreed by the States Parties.	Nineta Barbulescu
Slovakia	x		We have to be fully aware of the necessity to deal not only with originally declared stockpiles of weapons, which might not be absolutely exact as one recent case showed us, but also ready to deal with those chemical agents which have not been properly covered by the Convention, especially incapacitating agents.	Jaroslav Chlebo
Switzerland	x		My country is particularly concerned about the issue of so-called incapacitating chemical agents. By 'incapacitating chemical agents' we mean toxic chemicals for law enforcement purposes that are not riot control agents and act on the central nervous system...Switzerland fears that the silence and uncertainty surrounding the use of toxic chemicals for law enforcement purposes other than riot control agents risks eroding the Convention...We hope that all State Parties share our concerns and agree with our conclusion that the risks of inaction are far greater than the benefits of keeping the current uncertainty. With the proposal, Switzerland hopes to convince State Parties to agree on report language, which will allow for a discussion on incapacitating chemical agents to take place within the OPCW.	Markus Borlin

United Kingdom	x		The United Kingdom is taking part in the ongoing discussions on the place of incapacitating chemical agents in the Convention, particularly given scientific change and the absence of any definition or common understanding of law enforcement. Outside the Convention experts have exchanged views and expressed opinions. The Royal Society in the UK highlighted the significance of this issue in its February 2012 report on developments in neuroscience. The Director-General's Scientific Advisory Board drew attention to the issue in its report to this conference. Both have set out the scientific position as well as advancing our understanding of the complex issues surrounding this topic. The OPCW should also be willing to address such relevant issues and show leadership...the UK believes we should work together to establish a norm to discourage the use of chemicals more toxic than Riot Control Agents for law enforcement and consider transparency measures or limitations.	Alistair Burt
United States	x		There is much to be done to prepare for the post-destruction era and the challenges both known and unknown that it will present. Switzerland and the International Committee of the Red Cross have sought to sensitise the international community to one of those challenges--the implications of so-called incapacitating chemical agents--for the Chemical Weapons Convention. Concern has increased that illicit programmes could possibly be concealed under the guise of a legitimate treaty purpose, such as law enforcement. The Convention is clear: the development, production, acquisition, stockpiling, or use of incapacitating chemical agents--or any other toxic chemicals--in types and quantities inconsistent with purposes not prohibited by the Chemical Weapons Convention, is clearly prohibited by Article I of the Convention. Nevertheless, we must all be vigilant to ensure that incapacitating chemical agents and other technologies do not jeopardise the twin goals of the Convention--the destruction of all chemical weapons and the prevention of the re-emergence of chemical weapons.	Rose E. Gottemoeller
The Netherlands		x	Finally, we are deeply disappointed that this Review Conference could not agree to include the possibility of discussing incapacitating chemical agents in our final document. We hope we can continue this discussion during the next session of the Executive Council.	Jan Lucas Van Hoorn
Switzerland		x	Nevertheless Mr. Chairperson, on the bright side, discussions on incapacitants have been launched, despite the lack of reference in the final document. Due to the increasing support we could experience during the last months the momentum has been built. Consequently we will continue our efforts in order to further develop it.	Philippe Brandt

O=Opening Statement, C=Closing Statement. Sources: Chemical Weapons Convention Third Review Conference Opening National Statements by Germany, Ireland, Norway, Romania, Slovakia, US, and UK, and Closing National Statements by The Netherlands and Switzerland. <https://www.opcw.org/rc3/documents-from-the-third-review-conference/national-papers/>

The Swiss-led effort to include some texts with reference to further work on incapacitants in the final report encountered some opposition, at first by Russia and later by the US. Due to the inclusion of a discussion on the RCAs in the original final proposed text, a set of chemicals that the US has specific mandates in certain operational uses such as the ones specified in Executive Order 11850, the US delegation voiced its concern that there were legal issues and needed guidance from Washington. Since the final compromised text was not reached until the last day of the Review Conference, and since the US delegation did not receive response on the issue before the end of the work day, the Swiss delegation withdrew the text from the draft final report.[361] Nevertheless, the ability for states parties to at least reach some agreement on the need to address the incapacitants showed that the issues have gained some momentum and attention from the international community.

It is of particular interest to note here, perhaps, that the US position on the incapacitant issue has changed quite significantly upon reaching the Third Review Conference, especially when considering the US had played a major role in preventing such agents from being addressed in the First Review Conference and had kept silent during the Second. As can be seen in the address by Gottemoeller at the Third Review Conference, the US was rather explicit in its interest to uphold the terms of the CWC regarding toxic chemicals (regardless whether or not they are lethal) and pointing to the potential for states to develop “illicit” programs under the guises for law enforcement. Furthermore, in the first Executive Council session following the Third Review Conference, Robert Mikulak, US Ambassador to the OPCW, made explicit that the US is not developing, producing, stockpiling, or using incapacitating chemical agents.[362] It was

[361] See Crowley, *Application* (2013), 28.

[362] OPCW, Statement by Ambassador Robert P. Mikulak, United States Delegation to the OPCW at the Seventy-Second Session of the Executive Council, EC-72/NAT.8, (May 6, 2013), 2.

thus clear that as of 2013, at least, the US has adopted position to abide by a strict interpretation of the CWC terms on the development and use of incapacitants.

In the years following the Third Review Conference, the US position on the issue of incapacitants became more pronounced as it took a more active role in the efforts to resolve existing legal ambiguities within the CWC. For instance, in the March 2015 Executive Council session at the OPCW, Mikulak remarks,

> We welcome the renewed leadership of the Australian and Swiss delegations to informally engage delegations on this issue [of incapacitating chemicals as weapons, purported for law enforcement purposes]. In this regard, let me re-state once again that the US is not developing, producing, stockpiling or using incapacitating chemical agents nor are we using riot control agents as a method of warfare. We equally encourage all OPCW Member States to follow the example of a number of delegations…to confirm in an official statement to the Council that they are not using, developing or stockpiling incapacitating chemical weapons for any purpose.[363]

As of 2015, the United States not only reconfirmed in an international public forum that it is not developing incapacitants, but it also for the first time actively encourages other states to make clear their position on this issue.

The US statement in the next Executive Council session in July 2015 was also instructive. In his statement, Mikulak emphasizes that, "we encourage all delegations to consider and subscribe to the notion that the development of so-called incapacitation agents

[363] OPCW, Statement by H.E. Ambassador Robert P. Mikulak, Permanent Representative of the United States of America to the OPCW at the Seventy-Eighth Session of the Executive Council, EC-78/NAT.10, (March 17, 2015), 3.

for law enforcement purposes is incompatible with the Chemical Weapons Convention and to put their views on record in the Executive Council."[364] The statement, also for the first time alluding to the official US position on the legality of incapacitants within the context of the CWC, reflects an embrace of the incapacitant skeptics' perspective that the development of such weapons is against the intention of the treaty.

Finally, most recently, in the Twentieth Session of the Conference of States Parties in December 2015, Mallory Stewart, Deputy Assistant Secretary for Emerging Security Challenges and Defense Policy, remarked in her statement to the Conference that the United States had co-sponsored a paper, led by Australia and along with 18 other states, that highlights the risks posed to the Convention by "the use of central nervous system (CNS)-acting chemicals, so-called incapacitating chemical agents, in law enforcement scenarios."[365] The US leadership on this issue at the OPCW thus reflects not only a "sea change" as suggested by Fidler, but an actual change in the US position on the consideration for the developing, producing, and using biochemical incapacitants, which it has over the past decade come to deem as incompatible not only with US interests, but also with international law.

5.5.2 State Endorsements

In addition to this shift in the attitudes of both the US and the larger international community toward incapacitants and this increasing willingness to define its restriction within the CWC, it is also instructive to examine how, and to what extent, have the technical and legal understandings of these incapacitants been adopted by individual states,

[364] OPCW, Statement by H.E. Ambassador Robert P. Mikulak, Permanent Representative of the United States of America to the OPCW at the Seventy-Ninth Session of the Executive Council, EC-79/NAT.36, (July 7, 2015), 3.

[365] OPCW, Statement by Deputy Assistant Secretary Mallory Stewart, Delegation of the United States of America at the Twentieth Session of the Conference of the States Parties, C-20/NAT.19, (December 1, 2015), 3.

which likely have contributed to their positions on the issue. In addition to the potential threat to CWC's integrity and the potential for such weapons to be developed in an illicit manner under the guise of law enforcement, it is clear, at least from the most recent SAB report at the Third Review Conference, that the converging consensus from the scientific and technical communities on dosage issue is that a "non-lethal" weapon cannot realistically be designed.

One of the first country-specific endorsements on the non-viability of using biochemical incapacitants as NLWs came from Switzerland, which has been particularly active in leading the effort toward creating room for discussion on the ICA issue within the OPCW. In the National Working Paper that was circulated by the Swiss delegation at the Second Review Conference in 2008 on "Riot Control and Incapacitating Agents Under the Chemical Weapons Convention," it was noted that first, incapacitants are different from RCAs in that their action on life processes are different: whereas RCAs produces local sensory irritant effects, an incapacitant acts on the CNS; impairs cognition, perception, and consciousness; and may require antidote for its treatment.[366] Second, "Switzerland is of the view that the development of substances that will incapacitate a wide range of people with varying degree of susceptibility, but not endanger their health, is *technically close to impossible* (emphasis added)."[367] Therefore, "Because of their toxicity and their severe effects on life processes, Switzerland does not believe that the use of incapacitating agents for 'law enforcement' purposes in an international context can be brought in line with the object and purpose of the Convention."[368]

From this 2008 National Working Paper it is clear that part of the reasons for the Swiss delegation to have an interest in defining restrictions on the use incapacitants for law

[366] Switzerland, Riot Control and Incapacitating Agents Under the Chemical Weapons Convention, Second Review Conference, RC-2/NAT.12, (April 9, 2008), 2.
[367] OPCW, RC-2/NAT.12, 4
[368] OPCW, RC-2/NAT.12, 4.

enforcement in the CWC is due to its belief that such weapons cannot technically achieve the kinds of non-lethality they "promise" but also that their operational use can actually endanger the targets. In a simpler sense, biochemical incapacitants are not viable for development and use as a non-lethal weapon. Since 2008, several other states have also adopted this view of the non-feasibility of biochemical incapacitants as a weapon that could be use in a manner consistent with the goals of the CWC.

For instance, several states parties have expressed in their national statements at the Third Review Conference an agreement with the assessment on the biochemical incapacitants as reported by the SAB, which held the view that to call such weapons non-lethal is unsupported due to the issues of toxicity and dosage. In Germany's national statement, it was made clear that the "extensive" discussions on the issue of biochemical incapacitants and the "substantial" body of scientific analysis on their developments warrant the attention of states parties at the Review Conference. Norway similarly pushed the states parties to pay special attention to the advice from the SAB and to make sure that some language for discussion is reflected in the outcome document, for "Norway agrees with the Board that the technical discussions on the potential use of toxic chemicals for law enforcement have been exhaustive."[369] The United Kingdom made reference to both the SAB report as well as the Royal Society 2012 study on neuroscience, which also held the belief in the non-viability in developing such weapons, and remarked that "both have set out the *scientific position* (emphasis added)" on the incapacitants and that the international community should "work together to establish a norm to discourage the use of chemicals more toxic than Riot Control Agents for law enforcement."[370] These statements show that

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[369] OPCW, Norway: Statement by H.E. Ambassador Anniken R. Krutnes, Permanent Representative of Norway tot the OPCW at the Third Review Conference, RC-3/NAT.25, (April 8, 2013), 2.

[370] OPCW, United Kingdom of Great Britain and Northern Ireland, Statement by Mr. Alistair Burt, Parliamentary Under Secretary of State for Foreign and Commonwealth Affairs, at the Third Review Conference, RC-3/NAT.22, (April 9, 2013), 2.

despite a lack of resolution within the official treaty framework at the Third Review Conference, there was increasing endorsement by states of the technical position that the technical barriers in the development and use of biochemical incapacitants make them not acceptable NLWs.

In addition to Switzerland, recent OPCW efforts at addressing the issue of incapacitants have also been led by Australia. In its statement at the Nineteenth Session of the Conference of States Parties in 2014, Australia expressed a clear understanding of the dose-response problem and endorsed the view that such a problem makes developing or using biochemical incapacitating weapons undesirable:

> Australia's position is that it is not possible for a State Party to disseminate anaesthetics, sedatives or analgesics by aerial dispersion in an effective and safe manner for law enforcement purposes. The effects of these chemicals are dose dependent and determined by a number of factors including the individual's age, weight, gender, general well-being and possible adverse reactions with other medications being taken.[371]

In the next Conference of States Parties in 2015, Australia reconfirms its position and endorsement on the technical infeasibility of such weapons, stating that,

> Many States Parties believe that an unchecked threat to the architecture of the Chemical Weapons Convention, capable of undermining its integrity, are Central Nervous System-Acting Chemicals…many of these chemicals are highly dangerous – as toxic as sarin and other nerve agents we ban under

[371] OPCW, Australia, Weaponisation of Central Nervous System Acting Chemicals For Law Enforcement Purposes, C-19/NAT.1, (November 14, 2014), 1-2.

the Convention. It is not possible to disperse these chemicals through the air – *en masse* – without significant risk of death or serious injury.[372]

It is with this understanding that Australia, along with Switzerland and 18 other states (including the US), submitted a joint paper to the Conference in order to reinvigorate the discussion about incapacitants within the OPCW and to urge other States Parties to articulate their positions on these agents.

This 2015 joint paper, which is co-signed by Australia, Austria, Belgium, Brazil, Bulgaria, Canada, Chile, Cyprus, Estonia, Germany, Finland, Ireland, Japan, New Zealand, Norway, Poland, Portugal, South Korea, Spain, Switzerland, Turkey, the UK, and the US, reflects these states' collective scientific and technical understanding of the biochemical incapacitants in the context of the CWC and their position regarding its feasibility.[373] The paper makes the following major points:

1) CNS-acting chemicals pose a challenge for the CWC;
2) CNS-acting chemicals, which include anesthetics, sedatives, and analgesics, are designed to be delivered under strict medical supervision, for some of them have lethal doses comparable to traditional nerve agents;
3) CNS-acting chemicals are not RCAs due to their different sites of action;
4) Individuals exposed to aerosolized CNS-acting chemicals face safety risks and potential long-term health effects;

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[372] OPCW, Australia, Statement by H.E. Ambassador Dr. Brett Mason, Permanent Representative of Australia to the OPCW at the Twentieth Session of the Conference of the States Parties, C-20/NAT.31, (December 1, 2015), 2.

[373] OPCW, Joint Paper by Australia, Austria, Belgium, Brazil, Bulgaria, Canada, Chile, Cyprus, Estonia, Germany, Finland, Ireland, Japan, New Zealand, Norway, Poland, Portugal, Republic of Korea, Spain, Switzerland, Turkey, United States of America, United Kingdom of Great Britain and Northern Ireland, Aerosolisation of Central Nervous System-Acting Chemicals for Law Enforcement Purposes, C-20/NAT.2/Rev.2, (December 3, 2015).

5) It is extremely challenging, if not impossible, to uniformly disseminate CNS-acting chemicals and to control the dose received by an individual outside clinical setting;
6) Therefore, CNS-acting chemicals cannot be dispersed by aerosol in a completely safe manner in law enforcement settings and can thus also potentially used as a chemical weapon.

The technical details presented in this joint paper, which reflect the converging consensus over the last decade on the technical barriers challenging the development of biochemical incapacitants as non-lethal weapons, not only show that the states skeptical of biochemical incapacitants have grounds for their suspicion beyond the issue of their legality under the CWC, but also that they have concerns that such a weapon is, in fact, due to its technical barriers really indifferent in its effects from other chemical weapons. This lack of differentiation, of course, rests on the understanding that such chemicals are dangerous to use operationally and cannot be ensured to prevent significant casualties from occurring. In sum, several states in the international system have since the mid-2000s taken the view that the development as well as use of such weapons cannot be supported and justified.

The above analyses reveal that since the 2002 Dubrovka incident, the international community has shown increased attention and interest toward the legal ambiguities within the CWC and the challenges the biochemical incapacitants present to the convention. Over the last decade, an international understanding on the legal implications of ICAs has slowly been forming, with an increasing number of states seeking to clarify existing ambiguities in the CWC as well as well as define the biochemical incapacitants, and their development and use, into the convention. Furthermore, many states have over time adopted and endorsed the technical interpretation on the lack of feasibility in developing biochemical incapacitants for NLW purposes. This technical "norm formation," along with an interest in strengthening the integrity of the CWC, has likely added additional international political costs for those states that are considering to deviate from this effort and develop biochemical incapacitant weapons. This not only likely reflected a shift in the US interest on this issue but also reinforced the unfavorable condition for biochemical incapacitant R&D and further prevented continued military investment in this technology in the US.

5.6 Conclusion

The potential use of emerging cognitive neuroscience research to develop biochemical incapacitants as non-lethal weapons presents an interesting case for military technology investment. Although over the last fifteen years the development of non-lethal weapons has become increasingly demanded, military investment in cognitive science and neuroscience has been on the rise, and significant popular media and policy attention has been given to both brain research and its potential to be used for such an application by the military, the investment in this area of research by the US military has languished since the early 2000s. This, of course, has taken place under the context that the US military has long maintained an interest in incapacitating chemical agents and has engaged in its exploration and development since at least the 1960s. Why then, is this absence of investment happening?

In this study, it is argued that the US military has refrained from continuing its investment in this area of research because it is not an appealing investment opportunity despite the alleged potential. In particular, the lack of feasibility on developing such a weapon system using biochemical incapacitating agents according to the dominant expert opinions, the highly stringent performance requirements the US military has come to expect of its non-lethal weapons systems, and the possibility to develop and acquire such capabilities through law enforcement if needed, particularly when the military activities in this area of research are becoming increasingly scrutinized under international legal obligations, have together created a techno-political condition for this technology that is highly unfavorable to sustained support and investment from the military in incapacitant research. As a result, the military investment in this potentially emerging technology has languished despite an increase in funding and policy attention to cognitive neuroscience research.

It is further argued that this unfavorable technical condition is likely exacerbated by the increasing international political costs associated with developing such a weapon. Since the Dubrovka theater incident in 2002, the international community has slowly begun its effort at resolving the inherent ambiguities within the CWC regarding the issues of incapacitants and their potential use in law enforcement. Not only has there been a movement toward defining the biochemical incapacitant within the CWC, which would not only create significant legal barriers to its development and use by states parties, but many states have also embraced and endorsed the technical position that since such a weapon cannot be feasibly designed to ensure little to no lethality, its use will undoubtedly be contrary to the premise of the CWC and thus be unjustifiable. As a result, states like the US are becoming less likely to want to develop, stockpile, and use biochemical incapacitants as NLWs not only because it is not fruitful to do so, but also because doing so is becoming difficult to justify and support internationally.

CHAPTER 6. TREATMENT AND PREVENTION OF COMBAT STRESS REACTION AND POST-TRAUMATIC STRESS DISORDER

When President Obama in April 2013 announced the BRAIN (Brain Research through Advanced Innovative Neurotechnologies) Initiative, it was described as the new "Grand Challenge" similar to the Human Genome Project. According to statements released from the White House, the Initiative supports "the development and application of innovative technologies that can create a dynamic understanding of brain function," and it "aims to help researchers uncover the mysteries of brain disorders, such as Alzheimer's and Parkinson's diseases, depression, and traumatic brain injury."[374] This came perhaps as no surprise that this major national scientific initiative has a deliberately medical focus, for research on human brain has long been driven by, and has been in service to, advancements in the understanding of human psychological deficits and ways to redress psychiatric disorders.

This pursuit of medical innovations in dealing with brain-related cognitive or neurological disorders is further buttressed by the growing concern that a large number of veterans returning from US operations in Iraq and Afghanistan have suffered or are likely to experience Post-Traumatic Stress Disorder (PTSD).[375] Although the reporting on the prevalence has varied, many have noted that veterans returning from Operation Enduring

[374] White House, "Fact Sheet: Over $300 Million in Support of the President's BRAIN Initiative," https://www.whitehouse.gov/sites/default/files/microsites/ostp/brain_fact_sheet_9_30_2014_final.pdf (accessed September 30, 2014).

[375] Erin K. Dursa et al., "Prevalence of a Positive Screen for PTSD Among OEF/OIF and OEF/OIF-Era Veterans in a Large Population-Based Cohort," *Journal of Traumatic Stress* 27(5) (October 2014): 542-549; Brian C. Kok et al., "Posttraumatic Stress Disorder Associated with Combat Service in Iraq or Afghanistan: Reconciling Prevalence Differences Between Studies," *The Journal of Nervous and Mental Disease* 200(5) (April 2012): 444-450.

Freedom (OEF) in Afghanistan and Operational Iraqi Freedom (OIF), especially those exposed to combat, seem to have a greater propensity to develop PTSD when compared to their non-combat exposed contemporaries. In addition to PTSD, traumatic brain injury (TBI) has also become a prevalent issue among veterans returning from OEF and OIF, so much that some have termed TBI as the "signature wound" or the "silent epidemic" from these two overseas operation.[376] Brain-related disorders, particularly as they relate to combat trauma and war stress, have thus attracted national policy attention since at least the 2000s.

The problem of the increasing complexity in dealing with combat-related traumatic stress disorder and brain injury was also noted in the 2009 NRC Report on *Opportunities in Neuroscience for Future Army Applications*. The report task force not only notes that there is increasing evidence that stress disorders, including PTSD, are more common among soldiers than previously believed, but it also highlights that there is a "growing recognition that minimal to moderate brain traumas have chronic effects" and can have "long-term implications for future care requirements and associated costs." Nevertheless, the report is optimistic of the possibility of remedying these issues, stating that "Neuroscience research into immediate care in combat areas, rehabilitation, new pharmaceutical treatments, and diagnostic tools can provide solutions to these problems."[377]

Given these considerations, it is perhaps no surprise that R&D for preventing and countering the psychological as well as neurological effects of war have been pursued in earnest in the last decade. Not only was there a demand for such measures, but the

[376] Susan Okie, "Traumatic Brain Injury in the War Zone," *New England Journal of Medicine* 352(20) (May 2005): 2043-2047; Tracy Hampton, "Traumatic Brain Injury a Growing Problem among Troops Serving in Today's War," *Journal of the American Medical Association* 306(5) (August, 2011): 477-479.

[377] National Research Council, *Opportunities* (2009), 5.

advancements in science also seemed to promise some solutions to these problems. Yet, this apparent increase in military R&D of treatment and prevention measures to combat-related psychiatric illnesses also raises some interesting questions. For one, this is not the first time in which neuroscience-based research could have helped the US military in mitigating the negative psychiatric effects of combat. During the Vietnam War, the emergence of psychotropic drugs also provided the US military an opportunity to leverage the research momentum in psychopharmacology for dealing with combat-related traumatic stress. However, the military did not make any visible investments in this area of emerging R&D during that time.

This is particularly perplexing, not only because it was largely due to the experiences of Vietnam War veterans that PTSD as a psychiatric diagnosis, which had become the defining model of traumatic stress-related psychiatric disorder, was created in the late 1970s, but also because certain military medical R&D organizations, such as the US Army Medical Research and Development Command (USAMRDC - USMRMC since 1994) "saw its budget for medical research grow more than fivefold during the Vietnam era from the sum of $12 million in 1958 to more than $53 million in 1968."[378] Furthermore, psychiatric casualties due to combat stress were an operational concern for the military during the Vietnam War, and significant advances in treatments of psychiatric disorders had been made through the development of psychotropic drugs just the decade before the US involvement in Vietnam. Given these circumstances, there seemed to be no reason as to why the US military would not invest in the R&D of the then-emerging psychopharmacology for treating or managing combat stress.

Nevertheless, psychopharmacology did not attract military R&D investment during Vietnam. As a telling example, according to Vietnam War-era annual research reports from

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[378] US Army Medical Research & Materiel Command, *USAMRMC: 50 Years of Dedication to Warfighter, 1958-2008* (Fort Detrick, MD: US Army Medical Research & Materiel Command, 2008), 30

the Neuropsychiatry Division at Walter Reed Army Institute of Research (WRAIR), the premier military medical research organization on neuroscience and psychiatry during that time, there were no research projects that examined the efficacies of existing psychotropic medications that were used in theater in Vietnam, nor was there any effort toward research, development, or refinement in the then-emerging field of psychopharmacology. Why was this so?

This chapter examines this discrepancy in the R&D investment in neuropsychopharmacology between the Vietnam War era and the one after September 11, 2001. It first provides a history of the evolution in the understanding of combat stress, trauma reactions, and the development of psychiatric practices and treatment measures in the military. This chapter then analyzes the different scientific contexts under which combat stress-related psychiatric disorders have been understood between the Vietnam War era and the present. It is argued that when compared to the present, post-September 11 era, the predominant psychosocial model of combat stress reaction and psychiatric care during the Vietnam War created a conceptual barrier to recognizing psychopharmacology as a viable area of investment for treating combat stress. This chapter provides an analysis of how the shifting scientific understanding of psychiatry and the changing conceptualization of trauma and stress interact with political forces to create these two quite different pictures in the R&D for combat stress-related treatments and prevention.

6.1 Combat Stress, Psychiatry, and Neuroscience – A Historical Overview

The following section provides an overview on the evolving understanding of combat stress, psychiatry (particularly military psychiatry), and neuroscience. It serves two purposes: First, it provides the historical context under which combat stress can be studied, particularly with regard to how it is understood in American military psychiatry before, during, and after the Vietnam War. Second, it defines within the process of recounting the history several important concepts that are used in the analysis in this chapter, including how illnesses such as PTSD arose as a diagnostic category and how it has changed in terms of its diagnostic criteria over time. This section shows that the concept of trauma and stress has always been part of the debate on the dualism between mind and body, and that the neurobiologicalization of the psychiatric profession toward the end of the 20th century has contributed to the R&D of therapeutic measures in addressing combat stress.

6.1.1 "Shell Shock" – Combat Stress Prior to World War II

The impact of war on human psyche is a timeless issue. Researchers today studying psychiatric reactions to wartime stress claim that the mental impact of war can been found in the records of history throughout the ages. Some, for instance, noted a recorded incident from the Battle of Marathon (which took place 490 BC) where an otherwise fine and brave soldier became blind without any physical injury after witnessing a fellow soldier killed in action.[379] According to them, similar accounts can be gleaned throughout classic Greco-Roman (as well as other) tales of wars and battles, found in literary work, and studied from memoirs.[380] Yet, while the impact of war on human psyche has always been known and recorded, it also seems to be conveniently forgotten or fallen into obscurity once a society enters a period of relative peace. As the war ends and the memories of the battles fade, the

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[379] Marc-Antoine Crocq and Louis Crocq, "From Shell Shock and War Neurosis to Posttraumatic Stress Disorder: A History of Psychotraumatology," *Dialogues in Clinical Neuroscience* 2(1) (March 2000): 47-48.

[380] It is important to note, however, not that everyone embraces this view. See, for instance, Edgar Jones and Simon Wessely, *Shell Shock to PTSD: Military Psychiatry from 1900 to the Gulf War* (New York, NY: Psychology Press, 2006). They doubt the claim that PTSD as a disorder is necessarily "timeless" as the proponents citing historical precedents are often attempting to make the case. They argue instead that such responses to stress are culturally dependent, which can differ according to different locales or time periods. According to them, "clear-cut literary references were rare" (174). In their study on reactions to combat trauma using pension records, they found very few clear and direct cases of war experience flashback, a central feature of PTSD diagnosis, among a random sample of WWI and WWII pensioners. See Edgar Jones et al., "Flashbacks and Post-Traumatic Stress Disorder: The Genesis of a 20th-Century Diagnosis," *British Journal of Psychiatry* 182(2) (February 2003): 158-163.

interest to understand what happens to those returning from the war as a changed person with mental illnesses also wanes.

With the industrial revolution, however, the increasing use of machineries such as steamed locomotives brought with it man-made, large-scale disasters outside the battlefield. Railroad disasters, for instance, caused survivors to display symptoms that were reminiscent of those who survived the frontlines. Unusual and lasting reactions from these events brought back the need to understand the impact that disastrous events had on human body and psyche, especially when some symptoms, seemingly psychological or "mental," could not be attributed to observable damages (such as fractures or lesions, etc.) on the human body. This not only led to the creation of the terms such as "railway spine," and later, "traumatic neurosis," that were used to describe these survivors' abnormal reactions,[381] but it also caused a controversy in the longstanding debate on mind and body. Some argued that the symptoms were caused by microscopic lesions in the brain or spine, while others claimed that the reactions were mental in nature due to the trauma from the shock of the incident. Before the argument on the etiology of the "railway spine" was settled, however, this debate manifested itself back on the battlefields of the American Civil War.

During the American Civil War, physicians observed in soldiers symptoms such as anxiety, rapid pulse, and trouble breathing, and it was hypothesized that the stress and the traumatic experience of the battlefield led some to suffer from an overstimulation of the heart's nervous system, for which this syndrome received the name "Soldier's Heart" or "Irritable Heart." At the same time, however, other symptoms that also appeared which seemed less somatic in nature, such as depression, sleeping problems, emotional numbing, disassociation, and recurring nightmares, were viewed as based on mechanisms outside the

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[381] John Eric Erichsen, *Railway and Other Injuries of the Nervous System* (Philadelphia, PA: Henry C. Lea., 1867).

cardiac system and were identified through a resurrected term of "nostalgia." The protracted nature of the American Civil War resurfaced the issue of war experience-induced psychiatric trauma which, at that point, produced a specific kind of mental illness that were implicated with both somatic-organic as well as mental-emotional etiologies. This mind-body dualism in the cause of the symptoms notwithstanding, many soldiers who were afflicted with these symptoms during the war continued to suffer from them after returning home. In an account of the post-war experiences of Indiana's Civil War veterans, Eric Dean, Jr. made the following conclusion:

> one can find [in these veterans] a wide array of symptoms consistent with the diagnosis of PTSD (of both acute and delayed variants), although many of these veterans seemed eventually to develop more serious, chronic mental disorders that left them completely disabled and, often, totally out of touch with reality—living in a kind of personal hell in which they were constantly in fear of being killed or maimed, or in which they continued to relive the battles and horrific experiences of the Civil War.[382]

The war experience, thus, seemed to have created a generation of trouble veterans, not unlike what occurred a century later as a result of US engagements in Indochina.

The unresolved issue of whether the stress and trauma reactions stemmed from somatic or mental roots continued into World War I. It was during this time leading up to the Great War that the concept of "traumatic hysteria," discovered and coined by Sigmund Freud and with its correlates of dissociation, the pathogenic role in forgotten memories, and cathartic treatments, had taken hold alongside the more somatically-oriented term of neurosis.[383] As the shells began to fall along the trench lines on the Western Front and

[382] Eric T. Dean, Jr., *Shook Over Hell: Post-Traumatic Stress, Vietnam, and the Civil War* (Cambridge, MA: Harvard University Press, 1997), 114.

[383] Crocq and Crocq (2000), 49.

psychiatric casualties started flooding in from the frontlines, however, the question of etiology of war reactions urgently needed an answer. Reports started to appear of soldiers suffering from some kind of mental disturbance due to the shells. The massively increased firepower with large caliber artillery and explosives produced a kind of casualty in large numbers that the physicians were unprepared for: some of the soldiers were blinded; others became deaf, numb, or semi-paralyzed; still others seemed to have lost their memories or abilities to function and react and existed in state of stupor.[384] What many of them had in common, however, were that they had experienced being shelled on or being near an explosive but was able to luckily escape unscathed physically. This led to the creation of the term "shell shock" in 1915, which soon took hold in describing this new form of psychiatric casualty.

Yet, despite the term "shell shock" seemed to imply some form of physical trauma done to afflicted soldiers, the true origins of these cases of psychiatric casualty remained a heated debate. Many physicians were inclined to think that the cause was physical in some way, that by being near an exploding shell or mine some aspects of a soldier's central nervous system were damaged, potentially by the concussive forces, though no one knew for sure how it worked. Yet, there were also those who believed that the origin of the reactions were emotional or psychological, that it was the traumatic experience of seeing their comrades dying and the intensity of the war that led to the mental breakdown of these soldiers. The fact that some soldiers who reported a narrow escape from an exploding shell nearby were able to move on from the incident without developing shell shock seemed to support the psychological interpretation. Furthermore, as was found in a June 1916 report by Harold Wiltshire, a British physician serving at a base in France, none of those who were actually wounded by the exploding shells physically displayed symptoms of shell

[384] Ben Shephard, *A War of Nerves: Soldiers and Psychiatrists in the Twentieth Century* (Cambridge, MA: Harvard University Press, 2000), 1.

shock, and in many cases of reported shell shock, the soldier was not even near an exploding shell.[385] The Wiltshire report thus casted even greater doubts over the biological, somatic explanation of shell shock.

At the same time, the academic issue of etiology was further complicated by other pragmatic concerns. Aside from the considerations for the potential of malingering and the pension implications of shell-shocked soldiers, one such concern was that as the trench war wore on, the evacuated psychiatric casualties from shell shock flooded the hospitals, particularly in Britain. This caused not only a large loss of manpower but also significant problems back at home. Almost by necessity, the treatment for psychiatric casualties had to be conducted closer to the frontline. It was further noticed that those treated closer to the frontline, within the military milieu and with support from comrades and a clear expectation to return to duty, had a better chance of recovery than those evacuated to the rear. Forward treatment as a result became standard, partially out of necessity, but also because it was shown to be effective in handling cases of psychiatric casualty, including shell shocks. Its principles, summarized by American psychiatrist Thomas Salmon who was with the American Expeditionary Force in France, included proximity, immediacy, and expectancy (PIE).[386] This forward treatment doctrine, as will be explained in more detail below in section 6.3.2, became one of the most lasting legacies of military psychiatry from World War I and was implemented during World War II and subsequent major conflicts in the US military.

The discovery of the effectiveness of forward treatment doctrine, along with increasing evidence that shell shock arose out of psychic trauma instead of physical ones, helped marginalize the biological/somatic views of combat stress and trauma reaction, despite the term shell shock continued to be used widely during that time period. An

[385] Shephard (2000), 30-31.
[386] See also Shephard (2000), 123-142.

alternative term of French origin, “war neurosis,” which was less specific in implicating a cause, also emerged. As was reflected later on during the Vietnam War regarding the importance of World War I, Peter Bourne commented that,

> It is only since World War I that the Medical Corps has been called upon to prevent and treat psychiatric casualties in an effort to conserve the fighting strength. At that time because the primary cause of such casualties was apparently artillery fire the term “Shell Shock”, was coined. This term was unfortunate because it led many people, both patients and physicians to believe that it was an organic disorder. By the early part of World War II this concept had been discarded, and such terms as “psychoneurosis, anxiety state”, “psychoneurosis mixed”, and conversion hysteria” were being used.[387]

While the etiological debate on psychiatric reactions to war trauma and stress was not definitively “solved” as a result of World War I, a certain model of understanding war neurosis and its treatment was established for later operations, and that model tried its best to downplay the physical nature of reactions to combat stress and trauma. As will be seen below, however, almost a century later, the post September 11 American experience from operations in Afghanistan and Iraq would show that the neurophysiological roots to stress and trauma reaction, not unlike what was suspected from the organic explanation of shell shock during this time, could in fact be quite important in understanding war-induced psychiatric disorders.

6.1.2 Combat Fatigue – World War II to Vietnam

[387] Peter G. Bourne, “Combat Psychiatry,” *US Army Vietnam Medical Bulletin* (January 1966): 11

Despite the impact that psychiatric casualties such as shell shock victims had on WWI, most countries seemed rather ill-prepared for World War II. Part of the reason was perhaps that the twenty years of relative peace provided some space between the experience from the previous war and the needs of the current one. According to historian Ben Shephard, the time gap was enough for the relationship between psychiatrists and the military to lapse and require rebuild.[388] Furthermore, WWII ended up being a type of war that was quite different from WWI, where the diverse geographical locations and intermittent fighting produced a different kind of psychological stress. For most militaries in different theaters with different hierarchies, psychiatric care was ignored until it became urgently needed. In any case, the insights derived from the WWI experience, particularly how to provide battlefield psychiatric care in order to retain force strength, were only resurrected after some time into the war as the need to manage psychiatric casualties became apparent.

One particular area of psychiatric practice that countries did learn from WWI, however, was the belief in the need of a rigorous psychiatric screening. Given the nature of shell shock patients and the influx of psychiatric casualties once the war started, any preventive measures that could be taken to avoid the same kind of operational nightmare seemed warranted and desirable. Certainly, "If there was one lesson British doctors took away from their experiences in the Great War," it was the need for selection: "Vulnerable people like 'misfits' and 'congenital defectives' must be kept away from the battlefield by 'efficient examination of recruits.'"[389] This wisdom translated outside Great Britain as well. For instance, in the United States, Henry Stack Sullivan, a Neo-Freudian psychoanalyst known for his work on the interpersonal theory of psychiatry, served as a

[388] Shephard (2000), 205.

[389] Shephard (2000), 188. However, it should also be noted that despite this "belief" by the doctors, little was done in actual practice during the first two years of Britain's involvement in the war, and the British Army in fact made no systematic attempt at screening out recruits for psychiatric tendencies.

consultant to the Selective Service Commission during WWII. "Captive to his theory that anxiety is universally pathogenic," Sullivan promoted policies "that resulted in the rejection of young men…if they showed any taint of anxiety or neurotic tendencies," including neuropathic traits such as nail biting.[390] As a result of these policies, approximately one out of every seven men were deemed ineffective for service due to mental or emotional defects.

To what extent was this selection effective? According to William Menninger in his review of WWI and WWII statistics, during WWI, with a more liberal selection policy, approximately two percent of inductees were rejected for neuropsychiatric reasons and only two percent of the soldiers experienced a breakdown during the war. The more strict policy during WWII set by Sullivan, however, led to a rejection rate 11% of all inductees, while the rate of breakdown mounted to a staggering 12%.[391] The belief that psychiatric casualties can be minimized by screening out those with propensity to emotional or psychiatric breakdowns, thus, was shown to be unfounded, at least from the evidence derived from the World War II experience.

In addition to its inability to prevent psychiatric casualties, the practice of screening had another rather undesirable consequence—it precluded any advanced preparation for treating a large number of psychiatric casualties on the battlefield. This was certainly the case for the United States, which, for the first two years of its involvement in the war, had no psychiatric care personnel or service available at the division or field army level. It was not until psychiatric casualties started to turn out in droves in North Africa that more systematic forward psychiatric treatment was deployed in the US military. Fred Hanson, a psychiatrist who had served in England with the Canadian Army, helped resurrect the

[390] Franklin D. Jones, "Military Psychiatry Since World War II," in *American Psychiatry After World War II (1944-1994)*, eds. Roy W. Menninger and John C. Nemiah (Washington, D.C.: American Psychiatric Press, Inc., 2000), 6-7. See also Shephard (2000), 197-201.

[391] Jones, "Military Psychiatry" (2000), 7.

wisdom lost from WWI. In particular, he had a firm belief that most cases of war neuroses were due to sheer exhaustion, which lowered a soldier's ability to adapt to the emotional strain of war. He thus advocated a simple treatment regimen close to the frontline that involved physical recuperation, counseling, ventilation, and persuasive suggestion to return to duty.

While Hanson's method may have appeared rather crude and simplistic, it seemed to provide the solution the American military needed: "during the battles of Maknassy and El Guettar," he was able to return "'more than 70% of 494 neuropsychiatric casualties to combat after 48 hours of treatment.'"[392] It was due to Hanson's rediscovery of WWI principles of battlefield psychiatric care, along with an emphasis on the problems caused by exhaustion, that forward psychiatry was re-established in the American military during the later years of WWII. "Combat exhaustion" or "combat fatigue," for this reason, also became the first-line diagnosis for psychiatric or emotional reactions to battlefield stress.

As a result of the WWII experience, psychiatric screening was deemed to be ineffective at preventing psychiatric casualties, the PIE principles of battlefield psychiatric care were reestablished, and a new emphasis on fatigue and exhaustion, a biophysiological explanation for combat stress, was recognized. Although, at the outset of the Korean War, the US military was not prepared for battlefield psychiatric care in advance, the WWII experiences allowed a combat psychiatric program to be quickly established soon afterwards. For the most part, due to these measures, psychiatric casualties seemed to be relatively well-managed during the Korean War. Upon the completion of the war, much of the insight from the WWII and Korean War experiences became codified in the military doctrine (see section 6.3.1 below for more detailed analysis) regarding military psychiatry.

[392] Shephard (2000), 216-217.

Despite the protracted nature of WWII, however, there was very little additional analysis on the effects that war trauma has on an individual, unlike the extensive literature that was built around the cases of shell shock in WWI.[393] One exception was the work done by Roy Grinker, a psychiatrist at the University of Chicago and a contemporary of Fred Hanson, who served in the US Army Medical Corps during the war in North Africa. In his 1943 book *War Neuroses in North Africa* and 1945 book *Men Under Stress* with John Spiegel, which were based on his study of psychiatric casualties among the fliers as well as his experience in treating them in North Africa, he posited an explanation of war neurosis based on psychoanalytical theories and proposed treatment methods through some form of abreactive, cathartic psychotherapy aided by barbiturates, which he called "narcosynthesis." In particular, Grinker and Spiegel claim that for most soldiers and airmen, psychological breakdown comes from the weakening of an individual's ego's strength due to battlefield stress, and the individual is either able to master the circumstances in the harsh reality that causes the struggle or would resort to a "neurotic compromise and partial defeat."[394] In other words, the psychiatric reactions are a result of an individual's ego losing control of its ability to deal with the environment, and "The observable clinical symptoms, the anxieties, the phobic reactions, the host of physical and psychological responses to battle stress, should be considered as manifestations of this loss of control."[395] While the extensive and explorative nature of narcosynthesis as a therapy measure made it difficult to be used extensively and deployed widely on the battlefield, it was nevertheless incorporated into the military psychiatric doctrine in the aftermath of the Korean War, and Grinker's articulation of war neurosis also provided the "academic"

[393] Shephard (2000), 330.

[394] Roy R. Grinker and John P. Spiegel, *Men Under Stress* (New York, NY: McGraw-Hill Book Co., Inc., 1945), 82.

[395] Grinker and Spiegel (1945), 83.

backing to the psychoanalytical model of war stress that the US military adopted during the Vietnam War.

Another unexpected result of WWII was that it brought psychiatrists from all over the world to the United States, and it was becoming apparent at the time that psychiatry as a profession lacked standardization. Multiple approaches to understanding mental illnesses from different conceptual frameworks using different languages prevented researchers and practitioners alike from effectively communicating with each other. This led to the effort of developing the first Diagnostic and Statistical Manual of Mental Disorders (DSM-I) from the American Psychiatric Association (APA) in 1952. Recognizing the need to have a way to describe the observed phenomenon of stress reaction that have been seen in the two World Wars, DSM-I included a diagnosis, "gross stress reaction," under the category of Transient Situational Personality Disorders. In particular, the diagnosis states that it can occur "in situations in which the individual has been exposed to severe physical demands or extreme emotional stress, such as in combat or in civilian catastrophe (fire, earthquake, explosion, etc.)," but the reactions, which did not include any description of symptoms, should be transient and reversible.[396] While for clinical use such a vague diagnosis is not the most valuable, it does reveal an interest, at least among some in the psychiatric community, to codify the war experiences of stress reaction into psychiatric practices. As shown below, the way that psychiatry as a profession structures its clinical practices has a profound impact on the way military understands combat stress and war trauma.

6.1.3 Vietnam and Post-Vietnam Era: The Emergence of PTSD and ASD

The experience from WWII and the subsequent implementation of forward psychiatric treatment during the Korean War had a tremendous impact on the Vietnam

[396] American Psychiatric Association, *Diagnostic and Statistical Manual: Mental Disorders* (Washington, D.C.: American Psychiatric Association, 1952), 40. Hereafter shortened in subsequent references as DSM-I.

War. As explored in more detail below, the very model of battlefield psychiatric care and management of war stress reactions during the Vietnam War reflected a culmination of insights gleaned from these previous engagements. In fact, at the outset of major US involvement in Vietnam in 1965, a fully implemented psychiatric care program was in place, ready for an anticipated influx of a large number of psychiatric casualties. While such an influx never fully materialized during the early stages of the war, the implementation of frontline psychiatric care showed that there was increasing awareness of the need to manage psychiatric reactions as part of war planning.

The relationship between the Vietnam War and psychiatric care can be broadly understood in three phases. In the earliest days of the conflict, the issue of psychiatric casualty was not a major concern, and there were few reports of actual incidents. As the war intensified, the theater saw a build-up of the troops, and psychiatric casualties also grew but continued to be maintained at a relatively low rate. As troops began to withdraw toward the later stages of the war, however, a relatively large number of psychiatric casualties that did not follow the traditional patterns of combat stress reactions began to take place.[397] Psychiatric casualty management in the war zone in Vietnam, thus, seemed to have been relatively successful at least in the early stages of the war. However, as significant numbers of veterans returning from Vietnam in its aftermath during the 1970s began to show psychological and physiological symptoms related to their time in Southeast Asia, their difficulties attracted societal attention and prompted the creation of the diagnosis of PTSD, which became one of the most important medical legacies of the era.

Following the practice of treating psychiatric casualties from the two World Wars, the initial periods of deployment and buildup in Vietnam saw a range of psychiatric service that followed primarily the principles of PIE. Despite the widespread and intermittent

[397] Jones, “Military Psychiatry” (2000), 16.

nature of the combat, few cases of psychiatric casualties due to combat stress were reported. Part of this was likely due to the forward deployment of psychiatric services, but the low intensity of the conflict for the most part and the short deployment cycles (which has been established since Korean War as a means to prevent combat fatigue and exhaustion) also seemed to help lessen the incidences of psychiatric casualties than was originally anticipated. According to some early, optimistic reports from Vietnam on battlefield management of psychiatric reactions to combat stress, "Psychiatric casualties need never again become a major cause of attrition in the United States military in a combat zone."[398] This view changed, however, toward the end of the 1960s. For one, there was an increasing rate of substance abuse and behavioral disorders, which were suspected by some to be a result of a decline in troop morale. There was also an increased prevalence of the "short-timer syndrome" that was caused by the one-year rotational system. By the time of troop drawdown in the early 1970s, psychiatric casualties mounted, most of which due to substance abuse. Thus, unlike WWII and the Korean War, in which initial measures of battlefield psychiatric care were lacking but the management of psychiatric casualties over time improved during the war, the Vietnam War saw the opposite trend.

What was perhaps the most striking about the Vietnam War, however, was the amount of veterans who, having returned home, began to experience delayed onset symptoms that were related to their war experiences. Although the numbers were subject to some debate, many veterans reported recurring nightmares, difficulty of relating to people back at home, and problems adjusting back to civilian life. In addition, these veterans also experienced continued physiological arousal or heightened anxiety, which were reflected in symptoms such as difficulty to concentrate or sleep, irritability, and hypervigilance. These symptoms reminiscent of certain aspects of combat stress were

[398] Peter G. Bourne, "Military Psychiatry and the Viet Nam Experience," *American Journal of Psychiatry* 127(4) (October 1970): 487.

especially paradoxical, considering that during most of the war psychiatric reactions to wartime trauma and stress were considered to be relatively well-managed.

Some suspected that the veterans' experience was related to the broader societal trend at the time. For one, as the war dragged on in the late 1960s and early 1970s, it became increasingly unpopular among the civilian population in the United States, and those who served in the war did not enjoy a warm welcome as they returned home. As Edgar Jones and Simon Wessely described, the psychiatric woes that Vietnam veterans faced "lay not only in the jungles of southeast Asia, but also in the social climate of an America that was turning against the military in general."[399] This social climate not only impeded the veterans' ability to reconcile their war experiences with their civilian lives, but it also potentially limited the social support to veterans who may have, in fact, been suffering from war trauma.

In addition to larger social trends, the veterans returning home from the Vietnam War were also facing certain "technical" issues from the psychiatric profession. In the 1968 revision to the DSM, the diagnosis for "gross stress reaction" was eliminated. It was not entirely clear why that was the case, though some suggested that since the revision was written during a time of relative peace, it may have a skewed view of traumatic stress reactions, which seemed to be a highly war- or combat-relevant type of mental disorder.[400] Therefore, during peacetime, such a diagnosis became less relevant and needed. Whatever the reason, the elimination of such a diagnosis that at least could have provided a name to war-related trauma reactions became an impediment for veterans in dealing with hospitals, insurance companies, or courts, in which an official diagnosis that categorized their

[399] Jones and Wessely (2006), 212

[400] Nancy C. Andreasen, "Posttraumatic Stress Disorder: A History and a Critique," *Annals of the New York Academy of Sciences* 1208 (October 2010): 68. In DSM-II, the diagnosis that most closely resembles gross stress reaction in DSM-I and PTSD in DSM-III is "Transient Situational Disturbance," although its stated pathology and etiology are quite different from how PTSD has come to be understood today.

sickness was needed.[401] As result, in the then-ongoing process of revising the DSM-II from 1968 at the end of the Vietnam War, conscious efforts were made by activists and other psychiatrists who have worked with veterans to put in the next DSM a diagnosis for the psychiatric conditions from which many veterans were suffering.[402]

The diagnosis of PTSD was adopted in the DSM-III published in 1980, but its inclusion was not without debate despite the recognition that its creation rectified some of the problems that Vietnam War veterans were facing. While the proponents of the diagnosis of PTSD reify the concept as a "universal" reaction to distress and trauma, others holding a more critical view suggest that such reactions are a natural part of the human experience under distress, and that such reactions should not be considered a disorder. Still others, noting the social-political nature of its creation, have doubted its objective existence.[403] Nevertheless, as the concept of trauma and the related stress symptoms that follow became solidified in the medical literature, it soon gained wide acceptance by the society at large. It also spurred intense research effort into psychological as well as physiological understandings of the effects of trauma and stress, that "During the 1980s an enormous quantity of time and money was spent in investigating Post-Traumatic Stress Disorder, and the resulting literature was infinite."[404] If nothing else, its inclusion in the medical nosology and the specification of its diagnostic criteria in terms of measurable symptoms provided focal points for clinical as well as academic research of this complex disorder.

[401] Shephard (2000), 365.

[402] See, for example, Shephard (2000), 355-368 and Allan Young, *The Harmony of Illusions: Inventing Post-Traumatic Stress Disorder* (Princeton, NJ: Princeton University Press, 1995), 89-117

[403] See, for example, Derek Summerfield, "The Invention of Post-Traumatic Stress Disorder and the Social Usefulness of a Psychiatric Category," *British Medical Journal* 322(7278) (January 13, 2001): 95-98.

[404] Shephard (2000), 387.

In the 1980 DSM-III, PTSD was first introduced as an anxiety disorder that is precipitated by an etiological event that is outside the range of usual human experience.[405] This event, as the stressor, should according to the diagnostic criteria evoke significant symptoms in almost anyone, and the symptoms include reliving of the traumatic event, emotional numbing or dissociation, and hyperarousal (such as hyperalertness, sleep disturbances, or concentration difficulty).[406] The disorder may be: a) acute (defined as an onset of symptoms within six months of trauma and with a duration of symptoms less than six months), or b) delayed (onset of symptom after six months from the event) and/or chronic (with the duration of symptoms lasting more than six months). Although hardly a precise definition, the presence of a traumatic event or experience as the cause to later psychiatric reactions set PTSD apart from other illnesses.

Over the next few decades, however, the diagnostic criteria for PTSD continued to evolve. For one, the concept of a traumatic event as the etiological stressor and the ways through which it is "experienced" by the patient widened in the later revisions. For instance, in the 1987 revision to DSM-III (DSM-III-R), the patient no longer needed to be a direct participant in the traumatic event—indirect experience, such as witnessing or hearing about harm done to another individual, can be enough of a cause as a traumatic stressor. This change was solidified in the 1994 DSM-IV, in which the criterion to experience the traumatic event can be: a) direct personal experience "of an event that involves actual or threatened death or serious injury, or other threats to one's physical

[405] It should also be noted that by the time the discussion to create a diagnostic category of PTSD was underway in the 1970s, the issue of stress reactions to traumatic events were not limited to Vietnam veterans. The experiences of death camp survivors and prisoners of war, which were also increasingly discovered from decades prior in the aftermath of WWII, contributed to the need to create a diagnosis that captures the common elements in the illnesses that were frequently observed among those who had traumatic experiences.

[406] American Psychiatric Association, *Diagnostic and Statistical Manual of Mental Disorders (Third Edition)* (Washington, D.C.: American Psychiatric Association, 1980), 238. Hereafter shortened in subsequent references as DSM-III.

integrity,"[407] b) witnessing an event that involves those types of threats to others, or c) learning about unexpected deaths or serious harm experienced by family members or close associates. Furthermore, in DSM-IV, the types and examples of such stressful events were broadened to include being diagnosed with life-threatening illnesses or traumatic experiences during childhood. In the most recent revision of the DSM in 2013 (DSM-5), the diagnostic criteria for the stressor event was further broadened to include "repeated or extreme indirect exposure to aversive details of the event(s), usually in the course of professional duties."[408] The broadening of the stressor event diagnostic criteria over time has allowed a wider range of patients to be identified with PTSD, some potentially with a delayed onset of symptoms much later in life from trauma suffered in early stages of life.

Another component of the diagnostic criteria that has been the subject of revisions and debates concerns the symptoms of emotional numbing and dissociation. In the original definition of PTSD as articulated in the DSM-III, one of the diagnostic criteria was dissociation shown through emotional numbing or reduced involvement with the external world (termed in the diagnosis as "psychic numbing" or "emotional anesthesia"), and the symptoms for the criteria were refined in the DSM-III-R to include a broader range of behaviors, including specific acts of avoiding thoughts related to the trauma or activities that could remind the patient of the trauma. These dissociative types of symptoms have since DSM-III-R received increased diagnostic weight: for example, both DSM-III-R and DSM-IV required three or more of the symptoms to fall under the criteria of emotional numbing and dissociation in order for the diagnosis of PTSD to be made for a patient. This

[407] American Psychiatric Association, *Diagnostic and Statistical Manual of Mental Disorders*, Fourth Edition (Washington, D.C.: American Psychiatric Association, 1994), 424. Hereafter shorten in subsequent references as DSM-IV.

[408] American Psychiatric Association, *Diagnostic and Statistical Manual of Mental Disorders*, Fifth Edition (Washington, D.C.: American Psychiatric Association, 2013), 271. Hereafter shortened in subsequent references as DSM-5. It is also important to note here that in DSM-5, PTSD and several other similar disorders (such as ASD) which are presumed to have similar etiology (traumatic events leading to stress) are categorized separately from other disorders—it is no longer a form of anxiety disorders but rather, belongs to a separate category of trauma and stress-related disorder.

particular criterion, which according to some “introduced a psychodynamic coloring that was not intended,”[409] was reflective of an implicit assumption of the Freudian conceptualization of response to trauma, which included attempts to relive the event as well as attempts to avoid or defend against the recollections of the event.[410] In the most recent revision of the DSM, symptoms of avoidance and emotional numbing (termed negative alterations in cognitions and mood) are separated into two distinct diagnostic criteria for PTSD, and an additional dissociative subtype of the disorder is added to set apart certain dissociative traits of the disorder such as depersonalization and derealization. These changes in the diagnostic criteria reflect an increasing emphasis on the dissociative component of trauma and stress reaction.

Finally, there have been several changes to the criteria regarding time to onset of symptoms and symptom duration. Although in the original DSM-III definition, both acute and chronic forms of the disorder as well as the delayed onset of symptoms were specified as subtypes of the disorder, these distinction disappeared in the DSM-III-R. Although an additional diagnostic criteria of symptoms lasting more than one month was added, there was otherwise no mention of an acute form of the disorder in DSM-III-R, and it was noted only that the disorder should have a specification of delayed onset if the symptoms appeared six months after the traumatic event. In the 1994 DSM-IV, however, the distinction of acute and chronic forms was again made as specifications, with the temporal marker reduced from six months to three months, only to be removed again in the DSM-5. However, since DSM-IV, an additional category of Acute Stress Disorder (ASD) was created. In diagnostic terms, ASD resembles PTSD, with greater emphasis on the dissociative symptoms such as numbing, depersonalization, or dissociative amnesia and with symptoms that last for a minimum of two days, but no more than four weeks and occur

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[409] Andreasen (2010), 69-70.

[410] Elizabeth A. Brett, Robert L. Spitzer, and Janet B.W. Williams, “DSM-III-R Criteria for Posttraumatic Stress Disorder,” *The American Journal of Psychiatry* 145(10) (October 1988): 1232.

within four weeks of a traumatic event. Both ASD and PTSD in DSM-IV and 5 also require that the disturbances cause "clinically significant distress or impairment" in one's ability to function in order for the diagnosis to be made.

These revisions on the duration and onset of symptoms have a couple of important ramifications. First, the symptoms of stress and trauma related psychiatric reactions or mental disorders can occur at various time points with various durations after a traumatic event. These revisions showed an increasing recognition that traumatic stress induced reactions can occupy a wide time spectrum. This helps connect immediate stress reactions to the more delayed and long-term illnesses due to traumatic stress. Second, by differentiating between ASD and PTSD, there is also increased understanding that traumatic stress can lead to significant psychiatric conditions that impact an individual's ability to function in the immediate aftermath of trauma, and that its management may be important for preventing the disorder from spiraling into a more long-term form.

The understanding of PTSD and the revisions of its diagnostic criteria developed along with several other important trends during the 1980s and 1990s. For one, the growing weight in the dissociative symptoms in diagnosing PTSD and the lengthening of timeframes under which the reactions to a traumatic event may occur reflect an emphasis on the central role of "traumatic memory," which according to Freud and Pierre Janet leads to repression and dissociation.[411] There was growing interest from the mid-1980s to the early 1990s regarding dissociative aspects of trauma and its repressed memories, and the discussions on the traumatic memory as the basis PTSD echoed this trend.[412] In addition, extending from the psychological models of traumatic memory, some of the hypotheses

[411] Shephard (2000), 389.

[412] David Spiegel, "War, Peace, and Posttraumatic Stress Disorder," in *American Psychiatry After World War II, 1944-1994*, eds. Roy W. Menninger and John C. Nemiah (Washington, D.C.: American Psychiatric Press, 2000), 42-43. In fact, one of the key debate regarding revising the criteria for PTSD leading up to DSM-III-R in 1987 was whether it should be classified as an anxiety disorder or dissociative disorder. See Brett, Spitzer, and Williams (1988), 1234-1235.

implicating different brain regions involved in the memory consolidation process (such as the amygdala and hippocampus, the mechanisms for which are explained in more detail below) were also developed during this time to explain the symptoms of PTSD. As imaging and other neuroscientific techniques improved over time, some of these hypotheses have been able to move beyond animal models and be examined within PTSD patients.

The recognition that traumatic stress reactions can occur along a wide temporal spectrum has also allowed finer distinctions to be made regarding reactions to combat stress within the military setting.[413] During the last couple of decades in the 20th century, the term of combat stress reaction (CSR or currently at least within the US, combat and operational stress reaction (COSR)) has emerged and become more widely used in lieu of terms such as combat exhaustion or combat fatigue used during earlier wars.[414] Although CSR is primarily used to denote broadly the transient state of physical, emotional, cognitive, and behavioral reactions to combat or operational stress, it is generally recognized to be similar to the diagnosis of ASD in civilian nosology with the assumption of possibly an immediate onset.[415] By understanding traumatic stress reactions along a time spectrum, combat stress reaction is placed in the context of its potential long-term

[413] See, for instance, Franklin D. Jones, "Chronic Post-Traumatic Stress Disorder," in *War Psychiatry*, eds. Franklin D. Jones, Linette R. Sparacino, Victoria L. Wilcox, Joseph M. Rothberg, and James W. Stokes (Falls Church, VA: Office of the Surgeon General, United States Army, 1995), 416.

[414] This chapter/dissertation uses combat stress reactions (CSR) as the contemporary equivalent to concepts such as shell shock, war neurosis, combat fatigue, and combat exhaustion, with the understanding that there are likely some minor differences between the terms and certainly differences in what they try to connote as the nature of the stress reactions. In this sense, combat stress reaction, unless otherwise specified, refers broadly to the phenomenon of psychiatric, cognitive, and physiological reactions to the traumatic stress from combat or military operational experience. It thus can refer both to the immediate onset of symptoms as well as delayed or chronic forms such as what could be experienced in a PTSD patient, as long as the etiological traumatic event to that patient is combat-related stress.

[415] Franklin D. Jones, "Traditional Warfare Combat Stress Casualties," in *War Psychiatry*, eds. Franklin D. Jones, Linette R. Sparacino, Victoria L. Wilcox, Joseph M. Rothberg, and James W. Stokes (Falls Church, VA: Office of the Surgeon General, United States Army, 1995), 59. For further distinction between CSR, ASD, PTSD, and the diagnosis of Acute Stress Reaction (ASR) in the International Statistical Classification of Diseases and Related Health Problems (ICD), see Department of Veterans Affairs and Department of Defense, *VA/DoD Clinical Practice Guideline: Management of Post-Traumatic Stress Guideline Summary* (Washington, D.C.: Department of Veterans Affairs, 2010), 4-5 and Leanna Isserlin, Gadi Zerach, and Zahava Solomon, "Acute Stress Responses: A Review and Synthesis of ASD, ASR, and CSR," *American Journal of Orthopsychiatry* 78(4) (2008): 423-429.

ramifications, such as PTSD. This practice also influences the way reactions to combat stress and war are viewed and managed. In particular, instead of understanding reactions to combat stress as only a transient physiological and emotional response and its psychiatric ramification in the long-term as something quite separate, the creation of PTSD and ASD helps situate CSR as a prognosis to a spectrum of traumatic stress disorder.

Nevertheless, this evolution of PTSD as a mental disorder has raised as much awareness and attracted as much attention as it has caused concerns. For some, the doubt over the usefulness of PTSD as a psychiatric diagnosis comes from the increasing numbers of veterans seeking benefits for their war trauma who in fact just lack the interest to get themselves reintegrated into the society. Certain celebrated cases of PTSD from the Vietnam War, for instance, were later revealed to be fraudulent, and in some cases the patient had never even been to Vietnam or only served in rear-echelon units while there.[416]

From a research and clinical standpoint, some of the earlier psychological explanations of PTSD have become increasingly challenged and discredited throughout the 1990s. One of the central concern was that the prevailing explanation has not been able to account for all the instances in which PTSD did not develop even when one is subject to severe stress. PTSD proponents' reliance on pathological records (such as those reporting PTSD like symptoms to the VA) rather than some sort of overall record of post-trauma incident report was said to have significantly skewed the perception of the prominence of the issue. Nevertheless, despite these concerns and questions, by the time of American involvements in Iraq and Afghanistan in the 2000s, PTSD had taken a firm hold in the American public's understanding of stress, trauma, and war; with extensive research on its treatment and prevention, it has also become the dominant framework under which the management of traumatic stress reactions is considered.

[416] Shepherd (2000), 393.

6.1.4 Post 9/11 – Conflation of Traumatic Brain Injury and PTSD

Aside from the problems of non-occurrence and individual susceptibility, the research on traumatic stress and PTSD has also been consistently challenged by the issue of comorbidity with other psychiatric or behavior disorders.[417] By the early 2000s, it was known that patients suffering from PTSD frequently had comorbid substance abuse issues, antisocial personality disorder, and major depression.[418] In fact, many aspects of PTSD overlaps with symptoms of these other disorders. For example, symptoms of hyperarousal, such as sleep disturbance and trouble concentrating, are also commonly found in patients with major depression. Symptoms of diminished interest and avoidance are not only present in major depression, but they can also occur in antisocial personality disorder. These symptom overlaps have made understanding the nature of PTSD and the effect that traumatic stress has on an individual more difficult. As noted in the introduction to this chapter, this problem of comorbidity became even more complicated since the US engagements in Afghanistan and Iraq. The frequent co-occurrence of PTSD and TBI observed in OEF and OIF veterans has in particular added a neurobiological character to wartime trauma and stress reaction.

It has been suspected that the prevalence of TBI from OEF and OIF is largely a result of the pervasive use of improvised explosive devices (IEDs) and the increased survival rate from blast injuries due to better protective equipment and improved medicine.[419] According to a RAND report in 2008, approximately 19% of returning service members from OEF and OIF have had a possible TBI while deployed, and possibly as high as 7% are reporting both probable brain injury with concurrent PTSD or depression

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[417] It should be noted that like PTSD, many other psychiatric disorders also face challenges of comorbidity.

[418] Kathleen T. Brady et al., "Comorbidity of Psychiatric Disorders and Posttraumatic Stress Disorder," *The Journal of Clinical Psychiatry* 61(Supplement 7) (2000): 22-32.

[419] Deborah Warden, "Military TBI During the Iraq and Afghanistan Wars," *Journal of Head Trauma and Rehabilitation* 21(5) (September-October 2006): 398-399.

symptoms.[420] A different estimate from the Defense Veterans Brain Injury Center suggests that at least 30% of the troops in combat in Afghanistan and Iraq for four months or more likely have suffered some mild form of TBI as a result of the IEDs.[421] Although accounts do vary, several epidemiological studies have supported the general notion that there is a prevalence of TBI in OEF and OIF veterans, which have earned TBI the status as the "signature injury" to these overseas operations.

In the US military healthcare system, a TBI is defined as "traumatically induced structural injury and/or physiological disruption of brain function as a result of an external force."[422] TBI is indicated by new or worsening of at least one of the following signs immediately after the event that caused the trauma: any loss or decreased level of consciousness, any loss of memory for events immediately before or after the injury, any alteration in mental state, or any neurological or physiological deficits such as sensory loss or intracranial lesion. The external forces may take various forms, including causing the head to strike an object or being struck by one, causing acceleration or deceleration movements of the brain, or causing foreign objects penetrating the brain. Although not all people exposed to an explosive blast develop TBI, and many who have suffered some milder forms of TBI recover quickly, some do develop more persistent symptoms.

Although traditional neurological injury from brain trauma during war has been understood primarily from more invasive types of injuries (such as blunt trauma that causes penetrations to the skull), most cases of TBI from OEF and OIF occur in a less intrusive and visible form and are mild in severity similar to what is colloquially known as

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[420] Terri Tanielian and Lisa H. Jaycox, eds., *Invisible Wounds of War: Psychological and Cognitive Injuries, Their Consequences, and Services to Assist Recovery* (Santa Monica, CA: RAND Corporation, 2008), 97.

[421] Tanielian and Jaycox (2008), 4.

[422] Department of Veterans Affairs and Department of Defense, *VA/DoD Clinical Practice Guideline for the Management of Concussion-Mild Traumatic Brain Injury* (Washington, D.C.: Department of Veterans Affairs, 2016), 6.

concussion. Although the definition of diagnostic criteria on mild TBI (mTBI) varies, at least in clinical practice by the VA and the DoD, mTBI entails loss of consciousness that lasts less than 30 minutes, with alteration of consciousness (including memory loss or disorientation) that lasts less than 24 hours. Structural imaging of the brain would appear normal for mTBI patients, for any physical injury is likely to be microscopic and not easily visible. Table 5 below summarizes these criteria in contrast to moderate or severe TBI.

Table 5 - Severity Levels of TBI and Diagnostic Criteria

	Mild	**Moderate**	**Severe**
Diagnostic Criteria			
Loss of consciousness	< 30 minutes	> 30 minutes & < 24 hours	> 24 hours
Post-traumatic amnesia (memory loss)	< 24 hours	> 24 hours & < 7 days	> 7 days
Confused or disoriented state	< 24 hours	> 24 hours	> 24 hours
Structural Imaging (such as CT)	Normal	Normal or abnormal	Normal or abnormal
Glasgow Coma Score (GCS)	13 - 15	9 - 12	< 9

Sources: Traumatic Brain Injury and PTSD <http://www.ptsd.va.gov/professional/co-occurring/traumatic-brain-injury-ptsd.asp>, DoD TBI World Wide Numbers since 2000 <http://dvbic.dcoe.mil/files/tbi-numbers/DoD-TBI-Worldwide-Totals_2000-2016_Q1_May-16-2016_v1.0_2016-06-24.pdf>, Department of Veterans Affairs and Department of Defense, *VA/DoD Clinical Practice Guideline for the Management of Concussion-Mild Traumatic Brain Injury* (Washington, D.C.: Department of Veterans Affairs, 2016), 7.

While the extent to which veterans of OEF and OIF are having the comorbidity of mTBI and PTSD varies depending on the account and there has been few full-scale studies, there is growing recognition of this trend in the medical as well as defense circles. According to Charles Hoge, former director of the Division of Psychiatry and Neurosciences at WRAIR from 2002 to 2009, and his colleagues, who surveyed over 2,500 infantry soldiers three to four months after their return from Iraq, 44% of the soldiers who reported loss of consciousness and 27% of those reporting altered mental status (such as being dazed or confused) from any kind of head injury sustained during deployment met the criteria for PTSD.[423] This is compared to the 16% of those with other injuries and 9% without injuries. These results show that mild TBI is strongly associated with PTSD, although Hoge and his colleagues recognize that the specific neurological or biological mechanisms for such a strong association is still to be explained. This comorbidity of mTBI and PTSD presents a more complex medical picture for OEF and OIF veterans, but it also further strengthens the claim that further research towards understanding the neurological substrate of PTSD is warranted.

Many mTBI-related symptoms (also referred to as post-concussive symptoms) are somatic in nature, but some do suffer cognitive and affective deficits. The somatic symptoms most often include fatigue, dizziness, or headache, whereas the cognitive and affective deficits can include symptoms that are also found in cases of PTSD, such as anxiety, depression, as well as various forms of hyperarousal or avoidance.[424] While many patients are likely to experience these symptoms immediately following the event that leads to the injury (particularly the somatic symptoms) and are likely able to recover relatively quickly in several weeks or a few months, some do report symptoms that can last several years. The persistent symptoms are often emotional in nature in a manner highly reminiscent of PTSD: "'free-floating anxiety, fearfulness, intense worry, generalized uneasiness, social withdrawal, interpersonal sensitivity and anxiety dreams.'"[425] Figure 10

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[423] Charles W. Hoge et al., "Mild Traumatic Brain Injury in U.S. Soldiers Returning from Iraq," *The New England Journal of Medicine* 358(5) (January 2008): 453-463; also Louis M. French, "Military Traumatic Brain Injury: An Examination of Important Differences," *Annals of the New York Academy of Sciences* 1208 (October 2010): 38-45.

[424] Jan E. Kennedy et al., "Posttraumatic Stress Disorder and Posttraumatic Stress Disorder-Like Symptoms and Mild Traumatic Brain Injury," *Journal of Rehabilitation Research and Development* 44(7) (2007): 897.

[425] Vani Rao and Constantine G. Lyketsos, "Psychiatric Aspects of Traumatic Brain Injury," *Psychiatric Clinics of North America* 25(1) (2002): 43-69, quoted in Kennedy et al. (2007), 897.

below shows the overlap of symptoms between PTSD and persistent symptoms from mTBI (termed in the figure as persistent post-concussive symptoms, or PPCS).

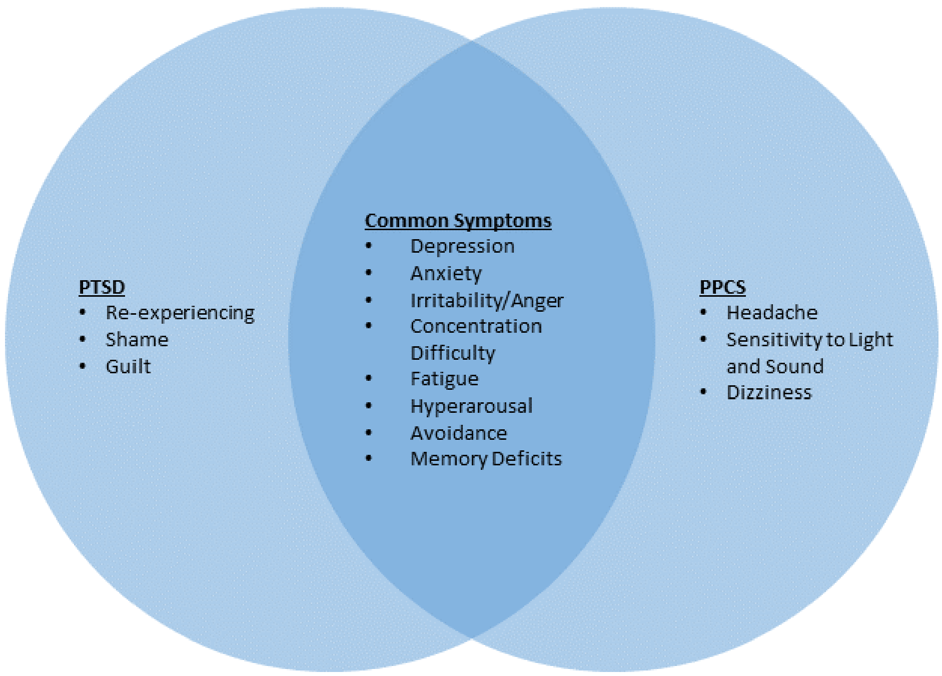

Figure 10 - Symptom Overlap between PTSD and PPCS[426]

As can be seen in Figure 10, patients of mTBI suffer from many of the symptoms that are also present in PTSD. Since in patients with comorbid mTBI and PTSD the etiological trauma that causes these symptoms can overlap, on the one hand, it becomes more difficult delineate between the psychological type of causes from the trauma (as in

[426] Adapted from Murray B. Stein and Thomas McAllister, "Exploring the Convergence of Posttraumatic Stress Disorder and Mild Traumatic Brain Injury," *American Journal of Psychiatry* 166(7) (July 2009): 770. Of note here is that the author moved memory deficits from the original categorization as a PPCS to the common symptoms, for extensive literature has suggested that memory deficits in the form of post-traumatic amnesia occur as a symptom for PTSD as well.

traumatic memory) from the biochemical or physiological ones (such as microscopic lesions or wounds in the brain). Particularly for the veterans of OEF and OIF, since many cases of the mTBI were likely not documented at the time the traumatic event took place, the reporting of persistent symptoms would often take place only sometime after the event, which could lead to attribution errors.[427] On the other hand, as explored in more detail below, the comorbidity provides further justification to studying the neurobiological nature of PTSD and reactions to combat stress. As discussed above, in the recent decades, more traditional psychological explanations of PTSD (such as the ones based on psychological impact of the traumatic memory) have become increasingly challenged. Aligning TBI with PTSD thus allows greater emphasis being placed on the potential neurological roots to the various psychiatric symptoms in patients suffering from traumatic stress.

6.2 Neurological Models of Stress, Traumatic Memory, and Psychiatric Disorders

The above section summarizes the historical contexts under which combat-related trauma and stress and their associated psychiatric impact have evolved. As noted, during the latter part of the 20th century, particularly after the creation of DSM-III, there has been an increase in research on the cognitive and neurological basis of traumatic stress reactions. In the following sections, the neurophysiological model of stress, the fear conditioning and memory consolidation cognitive neuroscience models of PTSD, and the neurological basis to TBI and PTSD are briefly summarized. This section does not intend to serve as a comprehensive review of the existing state of scientific literature on these subjects, nor does it try to suggest, in any way, that there is necessarily a consensus on the neurobiology to trauma and stress. Rather, it is intended to provide an overview of how neurobiological mechanisms have been leveraged to explain critical cognitive components that contribute

[427] E. Lanier Summerall and Thomas W. McAllister, “Comorbid Posttraumatic Stress Disorder and Traumatic Brain Injury in the Military Population,” *Psychiatric Annals* 40(11) (November 2010): 564.

a complex psychiatric phenomenon such as stress-related disorders.[428] By doing so, the following section also provides the scientific context as to why neurologically-based treatment and prevention to stress-related disorders have been able to gain the momentum in R&D efforts in the last few decades.

6.2.1 Neurophysiology of Combat Stress

For a warfighter, the experience in almost any kind of armed engagement is stressful. The battlefield's uncertainties and its constant threat to one's life create a highly stressful environment in which a warfighter operates. How does this stress impact the warfighters? Over the years, scientific research has established a neurophysiological basis of trauma and stress from which treatment and intervention measures can be built. This neurophysiological model of trauma and stress has also provided the foundation upon which a neurocognitive model of PTSD evolved.

Several neurophysiological systems have been implicated in responses to stress, including the serotonin system, the opiate system, and the sex steroidal systems.[429] However, the most prominent explanations come from the activation of sympathetic nervous system through the hypothalamic-pituitary-adrenal (HPA) axis. When under stress, particularly in a "fight-or-flight" situation, a person's adrenal gland becomes active through the HPA axis that allows for greater release of cortisol from the adrenal cortices and epinephrine (adrenaline) from the adrenal medulla.[430] The increasing level of epinephrine is part of the activation of the sympathetic nervous system that leads to the opening of the air pathways, the increased heartbeat, as well as the diversion of blood flow

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[428] For an example of comprehensive review of the current state of knowledge on the neurobiological basis of PTSD, see J. Douglas Bremner, ed., *Posttraumatic Stress Disorder: From Neurobiology to Treatment* (Hoboken, NJ: John Wiley & Sons, Inc., 2016).

[429] Institute of Medicine, *Treatment for Posttraumatic Stress Disorder in Military and Veteran Populations: Initial Assessment* (Washington, D.C.: The National Academies Press, 2012), 60.

[430] This was first articulated in Hans Selye, "Stress and Psychiatry," *The American Journal of Psychiatry* 113(5) (November 1956): 423-427.

to skeletal muscles (which allows for action). The high level of cortisol will also be released to suppress the immune system as well as to speed up the process of gluconeogenesis, which provides the “fuel” necessary for mental and physical operations. Although, in a limited quantity, the cortisol released by the adrenal glands during stressful situation allows a person to be more alert and attentive, a constant high level of stress can lead to permanent physiological changes.

This potentially damaging effect of elevated levels of cortisol have been shown to impact the highly malleable hippocampus, particularly in the anterior portion of the structure where there is a significant concentration of glucocorticoid receptors that are activated by cortisol. A high level of cortisol has been shown to contribute to hippocampal atrophy, although the specific mechanisms is not fully known. It is hypothesized that impact of corticoid on the hippocampus could involve a regression in dendritic processes, an inhibition of neurogenesis, an impairment of neuron’s ability to survive coincident insults, or neurotoxicity.[431] Some patients with PTSD have been found to have elevated levels of cortisol and, in some cases, enhanced sensitivity of glucocorticoid receptors.

6.2.2 Fear Conditioning, Memory Consolidation, and PTSD

The stress reaction that leads to the elevation of cortisol provides the neurophysiological context for a warfighter experiencing the traumatic stress of combat. However, the development of cognitively-related symptoms in stress reactions suggests that the functions of cognitive organs are likely also impacted in the development of disorders such as PTSD. The fear conditioning and memory consolidation models of neurocognitive processes are some of the areas that have been implicated in patients with stress-related disorder.

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[431] Robert M Sapolsky, “The Possibility of Neurotoxicity in the Hippocampus in Major Depression: A Primer on Neuron Death,” *Biological Psychiatry* 48(4) (October 2000): 755-765.

As a brain structure, the hippocampus is critical to the process of encoding short-term memories into long-term ones along with certain spatial learning functions. Surgical removal of the anterior portion of a patient's hippocampus has been shown to contribute to anterograde amnesia.[432] Further experiments have confirmed that a concentrated level of cortisol can impair the formation of episodic memories via its impact on the hippocampus.[433] It has also been revealed that some PTSD patients suffer from a reduction in volume of their hippocampus (possibly due to mechanisms stated above regarding the impact cortisol has on the hippocampus), and the degree of atrophy is correlated to the level of cognitive impairment experienced.[434] These results point to the possibility that the high-level of stress experienced by those who developed PTSD can change a person's physiology (in this particular case, the hippocampus) that contributes to later cognitive impairments.

In addition to the impact that stress can place on the hippocampus, stressful situations also excite responses from the amygdala, a structure in the brain considered to be associated with the learning of emotional memories, particularly fear. More specifically, the amygdala has been found to be critical in the implicit learning of fear, which is most often demonstrated by the classic "fear conditioning." For instance, in patients with dysfunctional amygdala, it was shown that they cannot be conditioned to respond to conditioned stimulus, even though these patients still show normal reactions to unconditioned stimulus.[435] In other words, patients with dysfunctional amygdala can still respond to the unpleasant unconditioned stimulus and understand the concept of fear, but

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[432] Gazzaniga, Ivry, and Mangun (2009), 325-6.

[433] Clemens Kirschbaum et al., "Stress- and Treatment-Induced Elevations of Cortisol Levels Associated with Impaired Declarative Memory in Healthy Adults," *Life Sciences* 58(17) (22 March 1996): 1475-83.

[434] J. Douglas Bremner, "Stress and Brain Atrophy," *CNS & Neurological Disorders – Drug Targets* 5(5) (2006): 503-12.

[435] Ralph A. Adolphs et al., "Impaired Recognition of Emotion in Facial Expressions Following Bilateral Amygdala Damage to the Human Amygdala," *Nature* 372 (6507) (15 December 1994): 669-672; Ralph Adolphs et al., "Fear and the Human Amygdala," *Journal of Neuroscience* 75 (9) (September 1995): 5879-91.

they cannot be made to associate certain things (conditioned stimulus) with fear. Their emotional memory of fear, in short, is impaired.

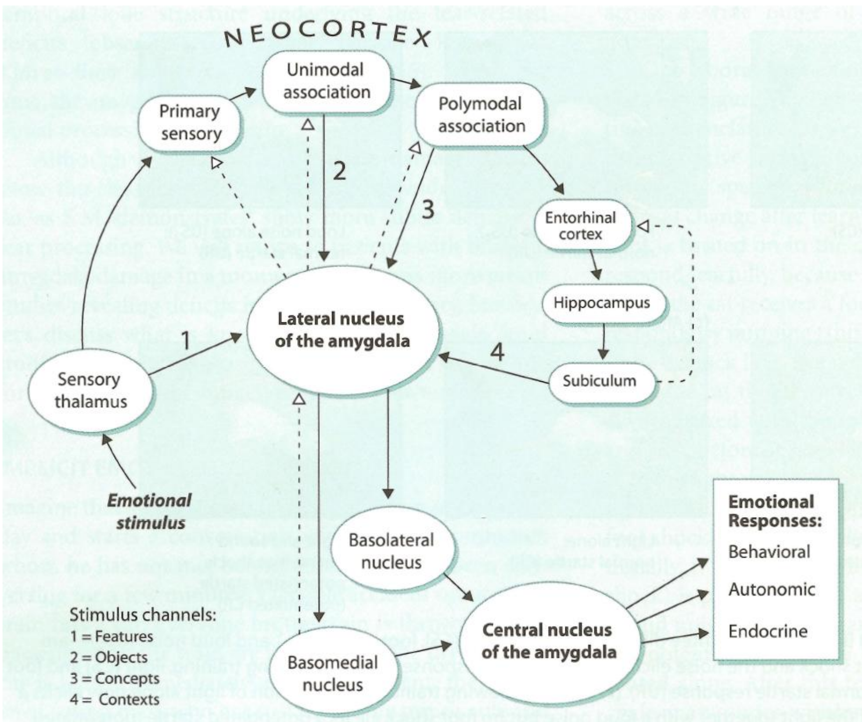

Figure 11 - Amygdala Pathways and Fear Conditioning[436]

In recent years, scientists have developed a vision of how amygdala functions in the neuropathways of fear conditioning (see Figure 11). It is hypothesized that the human response to fear actually operates along two pathways simultaneously. The quick route, or the "low road," sends the sensory emotional information directly to the lateral nucleus of the amygdala through the thalamus. The analysis that the thalamus can provide is limited, and the signal sent to the amygdala, as a result, is crude. However, by taking the direct

[436] Gazzaniga, Ivry, and Mangun (2009), 372.

route, the body can respond quickly to the stimulus so it is prepared to act in a timely manner. The other route, the “high road,” follows memory consolidation through signals that are sent from the amygdala to the sensory cortex, the medial prefrontal cortex (particularly anterior cingulate cortex and orbitofrontal cortex, both of which have been implicated for decision-making, impulse control, and emotional processing), as well as several other brain regions that deal with fear reactions and avoidance behavior.[437] These brain regions gate the processing of information generated from the fear signal, which is eventually processed at the hippocampus where memory consolidation occurs. As shown in Figure 11, the lateral nucleus of the amygdala serves an important gating mechanism through which fear response is activated. Its processing of fear stimulus is a critical step in the regulated release of catecholamine, including both the adrenocorticotropic ones as well as cortisol.

This neuropathway analysis shows that the recurrence of nightmares and war-time trauma in PTSD patients is possibly due to the blunting of the hippocampal memory process. This can be a result of the stress combined with the increased activity in the amygdala that lead to an impairment in properly coding and analyzing the traumatic experiences. In other words, the mitigating “high-road” that involves the mediating effect that the medial prefrontal cortex has on the amygdala is impaired in PTSD patients, and all stimuli that resemble the conditioned fear stimuli (such as loud sound, light flashes, etc.) will cause signals to be sent directly through the amygdala, which leads to increased adrenergic and noradrenergic activities. In this sense, using blockers for α and/or β-adrenergic receptors (such as the increasing interest on the use of propranolol) could decrease the impact of the catecholamine and reduce the possibility of conditioning one to a fear stimulus. Furthermore, this neurological model of fear conditioning and memory

[437] M. Davis and P.J. Whalen, “The Amygdala: Vigilance and Emotion,” *Molecular Psychiatry* 6(1) (2001): 13-34.

consolidation supports the evidence-based treatment methods such as cognitive-behavioral and exposure therapies.

6.2.3 Neurology of TBI and Comorbidity with PTSD

As discussed above, recent increase in the comorbidity of TBI and PTSD in OEF and OIF veterans have prompted greater examination on the neurophysiological mechanisms underlying PTSD. Certainly, the debates over its prevalence and its conflicting understanding regarding memory mechanisms (TBI being associated with a degree of amnesia whereas PTSD cognitive mechanisms rely on the recurrence of traumatic memory) notwithstanding,[438] the comorbidity between the two illnesses provides interesting and fruitful ways to examine the neurology of PTSD. For instance, in patients with the comorbidity, one would expect that the brain injury has impacted in regions of the brain that are often implicated in the cognitive neurological model of PTSD.

Hypotheses along this line of inquiry have been generated in order to examine the comorbidity that could be caused by the physiological impact of external forces on the brain. There are broadly two types of forces that cause brain injury: a contact or impact injury that comes from the brain tissues impacting the skull or other objects as a result of the force, and an inertial acceleration or deceleration generated by the force. In the former, the surface shape of the brain and structural shape of the skull become factors that cause certain brain regions to be more susceptible to such an injury, and these include the anterior temporal lobe, the lateral and inferior temporal cortices, the frontal lobe, and the orbital frontal cortices. In the latter, the acceleration or deceleration forces can result in shear, tensile, or compression forces on the brain, which can create axonal injury, tissue tear, or intracerebral hematoma. Finally, the mechanical forces acting on the neurons can cause the

[438] See, for instance, Thomas W. McAllister and Murray B. Stein, "Effects of Psychological and Biomechanical Trauma on Brain and Behavior," *Annals of the New York Academy of Sciences* 1208 (October 2010): 49-50.

release of neurotransmitters that can lead to a complex excitotoxic cascade. These types of cascade, along with hypoxia and ischemia, can have disproportionate damage on certain brain regions such as the hippocampus.[439]

Several different types of forces generated by an explosive device like the IED can cause these injuries could be generated by a change in atmospheric pressure a result of blast wave (primary blast injury), from objects put in motion by the blast wave come in contact with an individual (secondary blast injury), and by individuals being put in motion by the blast and hitting something (tertiary blast injury).[440] Certain brain regions could be more vulnerable to specific types of blast injury. For instance, the tertiary blast injury could result in acceleration or deceleration forces, and a secondary blast injury could generate contact or impact injuries.

Currently, few studies have produced conclusive results and there are etiological debates about this comorbidity: does the PTSD occur as a result of the neurological trauma that leads to alteration of the brain (neurological reasons), do both occur as a result of the trauma experienced (psychological reasons), or some combination of both etiologies? Nevertheless, the increasing incidence has inspired neurobiological studies on the brain both with a focus on specific brain structures implicated in the fear or memory circuitry as well as an attention to the general connectivity between brain regions. To highlight just one example in this area of research, white matter damage (axonal damage) has been observed following TBI, which has been implicated to cause changes in cognitive processing speed and executive abilities. White matter degradation has also been observed within two months of return of a deployed military personnel who has reported mTBI and displayed

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[439] McAllister and Stein (2010), 47. See also A.E. Tschiffely, S. T. Ahlers, and J.N. Norris, "Examining the Relationship Between Blast-Induced Mild Traumatic Brain Injury and Posttraumatic Stress-Related Traits," *Journal of Neuroscience Research* 93 (September 2015): 1770-1771 for a more granular look at the molecular-level changes as a result of a blast injury.

[440] Warden (2006), 399.

PTSD symptoms.[441] These findings can potentially contribute to understandings of how impacts on network connectivity between different brain regions contribute to PTSD.

6.3 Feasibility, Requirements, and Alternatives

As the historical summary and the scientific overview above show, since the Vietnam War, trauma and stress as they relate to war experiences have over time become a policy as well as a research interest. In particular, the emergence of neuroscience has impacted the way both general and military psychiatry are practiced, which likely have contributed to greater interest in as well as ability to conduct research on neurocognitive treatments for stress disorders, such as psychopharmacology. However, this interest in the R&D of psychopharmacological treatments did not arise during the Vietnam War, despite that just a decade before the war the creation of several psychotropic medications marked psychopharmacology as an emerging technology at the time as well.

The following section explores how psychopharmacology, as a treatment option for stress disorders, was viewed and understood by psychiatrists as well as the military during the Vietnam War. The feasibility of psychopharmaceuticals as a treatment for combat stress, the military requirement for controlling psychiatric casualties, and treatment alternatives are analyzed. As is shown below, the dominance of psychosocial explanations of combat stress impacts the way psychiatric care was practiced on the battlefield, which in turn influenced the perceived effectiveness of pharmacological treatments for such stress reactions.

6.3.1 From Psychotherapy to Pharmacological Treatments

[441] Tschiffely et al. (2015): 1771. See also Gershon Spitz et al., "White Matter Integrity Following Traumatic Brain Injury: The Association with Severity of Injury and Cognitive Functioning," *Brain Topography* 26(4) (October 2013): 648-660; and Michelle E. Costanzo et al., "Connecting Combat-Related Mild Traumatic Brain Injury with Posttraumatic Stress Disorders Through Brain Imaging," *Neuroscience Letters* 577 (2014): 11-15.

In the early 2000s, the Food and Drug Administration (FDA) approved two Selective Serotonin Reuptake Inhibitors (SSRIs), sertraline (Zoloft) and paroxetine (Paxil), for treatment of PTSD. While these SSRIs were not originally developed to address PTSD, their approval came with evidence from clinical trials demonstrating the independent effectiveness (independent of other treatment measures) they have in treating all three major symptom clusters of PTSD (re-experiencing, avoidance, and arousal).[442] While these SSRIs have an overall response rate of only approximately 60% and a full remission rate that is less than 30%,[443] their approval by the FDA and endorsement by organizations like the American Psychiatric Association (APA) suggest that there is an increasing recognition in the clinical practice of psychiatry on the feasibility of using pharmacological treatments for stress disorders such as PTSD.

Outside the psychiatric clinical circle, the broader research community is also increasingly viewing neuroscience-based treatments as potentially quite effective in addressing complex mental disorder such as PTSD. For instance, it was noted in a 2009 NRC report that, "Over the past two decades, neuroscience has made remarkable advances in understanding the neural circuitry of memory, drive, mood, and executive function," and "This knowledge has provided the pharmaceutical industry with targets for developing drugs that perturb specific neurotransmitters, with the potential for treating disorders in which these neural systems have been implicated."[444] The report further suggests that, "Over the next 5 to 10 years, it is highly likely that many new classes of drugs will be developed that mitigate symptoms and deviant behaviors associated with neuropsychiatric

[442] American Psychiatric Association, *Practice Guidelines for the Treatment of Patients with Acute Stress Syndrome and Posttraumatic Stress Disorder* (November 2004), 13.

[443] William Berger et al., "Pharmacologic Alternatives to Antidepressants in Posttraumatic Stress Disorder: A Systematic Review," *Progress in Neuro-Psychopharmacology and Biological Psychiatry* 33(2) (March 2009): 169-180; see also Murray B. Stein, Neal A Kline, and Jeffrey L. Matloff, "Adjunctive Olanzapine for SSRI-Resistant Combat-Related PTSD: A Double-Blind, Placebo-Controlled Study," *The American Journal of Psychiatry* 159(10) (October 2002): 1777-1779; and Joseph Zohar et al., "Double-Blind Placebo-Controlled Pilot Study of Sertraline in Military Veterans with Posttraumatic Stress Disorder," *Journal of Clinical Psychopharmacology* 22(2) (March 2002): 190-195.

[444] National Research Council, *Opportunities* (2009), 54.

disorders…some of them are likely to alleviate the adverse neuropsychological consequences of combat and other extreme stressors, including major depression and stressed related disorders such as post-traumatic stress disorder."[445] Furthermore, not only is neuropharmacology expected to provide treatment for chronic illness such PTSD, but it is also suggested that it can provide useful measures as first-line intervention to acute stress disorders.[446]

This potential for neuroscience and psychophysiology-based treatment for stress disorder has been recognized by the military community as well. According to the clinical guidelines that the DoD and the VA have established for treating PTSD, "There is growing evidence that PTSD is characterized by specific psychobiologic dysfunctions, which have contributed to a growing interest in the use of medications to treat trauma-related biologic effects."[447] In fact, in the guidelines, the FDA-approved sertraline and paroxetine have received a Strength of Recommendation of "A" (along with a couple of other ones such as SSRI Fluoxetine and Serotonin and Norepinephrine Reuptake Inhibitor (SNRI) Venlafaxine), which denotes "A Strong recommendation that clinicians provide the intervention to eligible patients," for "Good evidence was found that the intervention improves important health outcomes and concludes that benefits substantially outweigh harm."[448] As Jones and Wessely observe, "One area in which consensus has started to emerge, lies in the field of drug treatments for PTSD."[449] Among the military, civilian-clinical, and research communities combatting stress-related disorders, there appears to be

[445] National Research Council, Opportunities (2009), 54.
[446] American Psychiatric Association, *Practice Guidelines* (2004), 12 and 28.
[447] See Department of Veterans Affairs and Department of Defense, *VA/DoD Clinical Practice Guideline for Management of Post-Traumatic Stress* (Washington, D.C.: Department of Veterans Affairs, 2010), 149. See also Walter Alexander, "Pharmacotherapy for Post-traumatic Stress Disorder in Combat Veterans: Focus on Antidepressants and Atypical Antipsychotic Agents," *Pharmacy and Therapeutics* 37(1) (January 2012): 33.
[448] Department of Veterans Affairs and Department of Defense, *Management of Post-Traumatic Stress* (2010), 7.
[449] Jones and Wessely (2006), 186.

an increasing agreement over the value of neuropsychologically-based treatment options, particularly psychopharmaceuticals.

This growing consensus over the last two decades on the feasibility and increasing effectiveness of neurologically-based treatments, however, was not the case during the Vietnam War, despite just the decade before the war significant advancements in pharmacology had allowed several new classes of psychotropic medications to become widely available for use in psychiatry. Part of the reason for the doubt over the effectiveness of such drugs during that time was a result of a lack of coherent neurophysiological model of trauma and stress reactions from which researchers and practitioners (clinical psychiatrists) can communicate, but it was also because where there was an agreement in clinical practices, the pathology of trauma and stress was believed to be psychosocial in nature rather than neurobiological. In other words, how treatment measures for stress disorders were understood during the Vietnam War era, particularly in the military, were rather different from the kinds of treatment R&D for PTSD today, where the cognitive-neurobiological models of stress reaction, trauma response and fear conditioning, and memory consolidation provide the basis for a large majority of the contemporary research. One of the major reasons that the use of psychopharmacology as treatment for combat stress was doubted during Vietnam War was thus a conceptual barrier that led to a belief that pharmaceuticals had limited utility in treating a psychosocial disorder.

Peter Marin, a journalist specializing in psychology, argues that psychologists working with Vietnam veterans tended to skirt around the issue of judgment on the nature of their disorder, which was fundamentally due to the "'limits of the discipline itself, the inadequacy of psychological categories and language in describing the nature and pain of human conscience.'"[450] Prior to the standardization of PTSD as a diagnostic category for

[450] Peter Marin, "Living in Moral Pain," in *The Vietnam Reader*, ed. Walter Capps (New York, NY: Routledge, 1991), 40-53, quoted in Shephard (2000), 374.

trauma-related disorder, the very phenomenon of trauma and stress reactions and their related symptoms were subject to significant debate—there lacked a robust conceptual framework to understand the phenomenon of stress reaction, whether acute or delayed.

As a complex phenomenon, stress reactions necessitate understandings from multiple perspectives. For example, from a biological or neurological perspective, PTSD may result from structural changes in the central nervous system, such as the neurological mechanisms described above. However, a cognitive model of PTSD may examine the nature of the problem from the perspective of information and memory processing. Under the behavioral approach, the disorder arises as a result of conditioned responses to fear stimulus, whereas according to psychoanalytic interpretations, the psychogenesis of the disorder lies within the conflict between the conscious and subconscious parts of oneself and the larger society. As a result of these competing theoretical and conceptual paradigms, beliefs in what may be appropriate treatments for psychiatric disorders due to combat stress also varied widely.[451] Of course, since PTSD has only been recognized as a psychiatric diagnosis in 1980, a direct comparison between today's treatment and prevention research for PTSD and that in the Vietnam War era is impossible. Combat stress, nevertheless, was a concern for the military during the Vietnam War, and an analysis on the psychiatric practices during that time can yield insight on how such stress was managed and what kinds of treatments were viewed as efficacious.

As compared to the largely cognitive-behavioral and neuro-biological models of trauma and stress today, there was a predominance of psychodynamic and psychosocial model in American psychiatry during the immediate aftermath of WWII through the Vietnam War era.[452] This particular psychoanalytic orientation to understanding

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[451] Dean (1997), 41-42.

[452] Mitchell Wilson, "DSM-III and the Transformation of American Psychiatry: A History," *The American Journal of Psychiatry* 150(3) (March 1993): 400.

psychiatric disorder, however, was not friendly toward systematic R&D in treatment methods outside of clinical practices. For one, the fundamental assumption of the psychosocial model is that the genesis of mental disorder lies with the struggle between oneself and the environment, in which war experiences represent the epitome of that struggle.[453] In this sense, the neurosis that arises from the war experience has to do with the suffering individual soldier's inability to adjust and adapt to the war environment.

From this perspective, rather than treating stress reactions as a manipulation of the symptoms, the treatment method of psychosocial model is to "understand the meaning of the symptom and undo its psychogenic cause," and such cause, under psychodynamic terms, is maladjustment and adaptive failure. The main form of treatment for psychiatric disorder based on this model is, thus, psychotherapy, in which the patient is made aware of the underlying psychic tension and struggle that engender the symptoms, and at least in military terms, be reassured of his ability to cope with such maladaptation problem.

To what extent was the psychosocial understanding of war-related stress and trauma reactions used as the basis to psychiatric treatments for combat stress reactions during the Vietnam War? In the most authoritative and comprehensive analysis of Vietnam War era psychiatry to date, Norman Camp distill the principles of combat psychiatry from senior Army psychiatrists and the Army Technical Manual (TM) 8-244, *Military Psychiatry*: "the soldier who becomes incapacitated by combat has undergone a transient psychological *regression*—a failure of *adaptation* (emphasis added),"[454] and this follows a "disruption of his physical and psychological *defense*" that "his dysfunction represents the final common pathway produced by the stress of his ordeal in interaction with his physical and *personal*

[453] For concise explanation of the psychosocial model of psychiatric disorder, and its impact on American psychiatry in the immediate aftermath of World War II, see Wilson (1993), 400-401 and Young (1995), 89-94.

[454] Norman M. Camp, *US Army Psychiatry in the Vietnam War: New Challenges in Extended Counterinsurgency Warfare* (Fort Sam Houston, TX: Office of the Surgeon General, Borden Institute, US Army Medical Department Center and School, 2015), 212.

limitations (emphasis added)."[455] From this perspective, the treatment for such psychiatric casualty[456] is the timely provision of mostly recuperative measures such as safety, wound care, and rest; "peer support; and psychologically supportive assistance, *including recounting their disturbing combat experiences* (emphasis added)."[457] By treating a soldier's reaction to combat stress as an issue of adaption to the combat environment, and that his inability to deal with such adaptation as a result of a disruption of his psychological defense, the principle of combat psychiatry during the Vietnam War follows the psychosocial model that emphasizes the psychic struggle as the underlying cause. Furthermore, the treatment method of recounting combat experiences is also typical of abreactive therapy.

More specifically, TM 8-244, published in 1957 with knowledge gained from the Korean War, instructs that psychiatric care is to be provided at three levels: primary care at the battalion aid station, specialized care at the brigade/division clearing station, and more extensive specialized care in hospitals with psychiatric specialty attachment. Yet, at each level, the principle of treatment follows the same psychosocial rationale: at the divisional level, non-specialized medical personnel will provide supportive psychotherapy, which may be assisted by pharmacologically assisted sleep or rest. At the brigade/battalion level, the physician/psychiatrist follows psychotherapeutic techniques that include allowing the patient to vent, supporting the patient's superego, uncovering traumatic experiences through abreaction and, if necessary, narcosynthesis. Similar treatments are suggested for those hospitalized with specialized psychiatric care, with the additional benefit of being further removed from the frontline.[458] These treatment guidelines follow

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[455] Camp (2015), 213.

[456] Defined at the time by the Army as a soldier "missing 24 hours or more of duty for psychiatric reasons." See Camp (2015), 213.

[457] Camp (2015), 213.

[458] Camp (2015), 216-219.

the clinical practice of psychotherapy, and pharmaceuticals are used only as assistive measures.

To what extent did military psychiatrists in Vietnam actually follow this psychosocial model for therapies and treatment in their encounters with psychiatric casualties? Some anecdotal evidence can be drawn from articles published in the *US Army Vietnam Medical Bulletin*, which was published in order to provide information to Army Medical Department personnel in Vietnam from 1966 to 1971. For instance, in a 1967 report from William Baker, a division psychiatrist, it was indicated that following a period of heightened combat intensity (combat actions nearly every day), a few cases of combat fatigue occurred and most were able to be treated with some rest and sedation.[459] However, in some of the cases in which he described as the "Ten Month Veteran" syndrome, the soldier suffered from all the short-timer symptoms (which is typically understood as a very severe case of burnout that includes mental and physical fatigue but in the case of combat also increased fear of being killed, irritability, and withdrawn behavior) but also additional symptoms. According to Baker, "often there is a fear of artillery noise[;]…some of them develop 'dry heaves' in response to such noise," and "The patient is often more distressed by his recurrent dreams…[that] are 'reruns' of something that did happen," such as "being splashed with a friends [sic] brains, etc."[460]

This syndrome, in today's diagnostic terms resembling ASD or PTSD, was treated "With ventilation, night time sedation, a few days of rest and recreation."[461] The reliving of trauma in dreams was "'cured'" with "h-s [hypnotics-sedatives] sedation" in order to interrupt the dream patterns and "talk[ing] about their dreams."[462] In short, concluded the

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[459] William Baker, "Division Psychiatry, 9th Infantry Division, January – October 1967," *US Army Vietnam Medical Bulletin* (November-December 1967): 5.

[460] Baker (1967), 7.

[461] Baker (1967), 7.

[462] Baker (1967), 8.

psychiatrist, "most can be returned to duty in 48-72 hours with sedation, rest, recreation, supportive psychotherapy."[463] Thus, even for soldiers afflicted with rather severe symptoms that would today be qualified as PTSD, the primary model of treatment was one based on psychosocial measures, such as support, ventilation, and catharsis, whereby pharmaceuticals were used primarily to sedate the patients and alleviate certain symptoms.

If one is only able to glean from Baker's report the elements of the psychosocial model of military psychiatry at the time in terms of what is shown through treatment measures, some others have made this belief in the psychosocial cause for stress reaction much clearer through the way they describe the pathogenesis of such reactions. In another report on the management of combat reactions, division psychiatrist John Bostrom indicated the following: "The Normal Combat Syndrome consists of a state of anxiety secondary to the emotional and physical stress of combat…When individuals experiencing this syndrome seek help, it must be suspected that what ideally (from a military point of view) is egosyntonic is becoming egodystonic (underline in original)," and the "essential therapeutic message is aimed at acceptance of the symptoms."[464] In other words, according to Bostrom, those who suffered from combat stress had difficulty embracing that the anxiety caused by the combat environment was in fact a natural reaction. They, therefore, rejected it, and such a rejection caused a psychic disagreement that led to persistent symptoms. In order to overcome this, Bostrom suggested treatment measures that would on the one hand be supportive in a manner that reinforces a soldier's belief in his ability to adapt, and on the other, rationalizes the symptoms as well as the mission for the soldier.

In addition to those psychiatrists serving at the frontline, this type of psychosocial model-based treatment seemed to be followed by those hospitalized in the rear echelon as

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[463] Baker (1967), 9.

[464] John A. Bostrom, "Manage of Combat Reactions," *US Army Vietnam Medical Bulletin* (July-August 1967): 6.

well. In a report by the 935th Medical Detachment Team, which was attached to an Evacuation Hospital, "Therapeutic approach for psychiatric patients includes brief psycho-therapy, both ventilative and supportive," and "Also the usual tranquilizing drugs are available."[465] The report further indicated that "The inpatient service is oriented to the milieu principle," where a soldier continues to perform certain functions, such as policing the ward area, that would remind him that "he is part of the United States Army in a combat situation."[466] By setting the afflicted soldiers in a military social milieu, the belief was that the environmental factors would help the soldier-patients readapt to their role as a soldier and better adapt to the war environment.

It is clear from the above anecdotal evidence that for the most part, treatment for psychiatric casualties during the Vietnam War consisted of physical recuperation with some level of counseling and psychotherapy based on psychodynamic principles. It is also clear that the psychiatrists took advantage of the then newly available psychotropic (psychoactive) pharmaceuticals, even though from these accounts, the psychoactive drugs seemed to be primarily used as tranquilizers or sedatives in order to: 1) assist other treatment measures using counseling and psychotherapy, and 2) to manage or alleviate certain symptoms such as anxiety or recurring nightmares. The conceptualization of trauma and stress reaction during the Vietnam War was, thus, psychosocial in nature, which created a conceptual barrier to recognizing the independent therapeutic utility of pharmacological treatments.

Yet, psychotropic drugs used during the Vietnam War, including anxiolytics such as Valium or Librium, and neuroleptics, such as Mellaril and Thorazine, had just been developed the decade before and were adopted in psychiatric practices only a few years before the US deployed full-scale ground force in Vietnam in 1965. Since none of these

465 "Functions of the 935th KO Team," *US Army Vietnam Medical Bulletin* (April-May 1966): 21.
466 "Functions of the 935th KO Team" (1996), 21.

drugs were developed specifically for treating combat stress, there was little information on these drugs' believed feasibility in treating combat stress-related disorders by the research community. One way to understand the technical feasibility of these drugs, then, is to assess the clinical community's opinion in their efficacy in treating combat stress disorders during the Vietnam War. To what extent did the psychiatrists in Vietnam endorse their feasibility as useful treatment to combat stress, especially when compared to other treatment measures?

Aside from the anecdotal accounts detailed above, two broader and more systematic reports shed light on how treatment measures such as psychotherapy and psychopharmacology were perceived by those providing psychiatric care during the Vietnam War. The first was a survey conducted two years into the Vietnam War, in 1967, on the use of psychotropic prescription medication in Vietnam by Army physicians not stationed in a hospital. Part of the motivation for doing this survey, according to report authors William Datel and Arnold Johnson, was because "The Vietnam conflict represents the first period of armed hostility in which this country engaged after the advent in the mid-1950's of modern psychopharmacology."[467] Since combat is a highly stressful human activity, and since the new drugs at that time had been "hailed as distress reducers," a look into their efficacy as a treatment option was warranted.

What Datel and Johnson found was that the use of the newly developed drugs was quite pervasive: out of the 110 Army non-psychiatrist respondents (general physician or physicians of other specialty who were assigned to troop clinics or mental health clinics as primary care) who returned the survey (233 were sent the survey), 92 indicated that one or more of the psychoactive drugs that were available to them had been prescribed during the preceding 30-day period. Of the eight psychiatrists who responded (23 were sent the

[467] William E. Datel and Arnold W. Johnson, *Psychotropic Prescription Medication in Vietnam* (Washington, D.C.: Office of the Surgeon General, Department of the Army, 1978), 1.

survey), including two from the Navy who were serving in the Marine divisions, all reported the use of one or more drugs during the preceding 30 days. Despite the low response rate, this pervasiveness was surprising, for, the official Army model of treating psychiatric casualties at the time considered medications only assistive measures primarily meant for sedation. Furthermore, Datel and Johnson reported that "In general the psychotropic drugs prescribed were perceived by the prescribing physicians as being quite efficacious,"[468] and this seemed to have been the case for almost all the major psychiatric conditions the physicians were seeing, except for anorexia and headaches.

While Datel and Johnson's report portrayed a rather favorable picture for the efficacy of the then newly available psychotropic medication as a treatment option for psychiatric casualty, there are some caveats, some of which the authors themselves noted. First, since the survey was based on assessing the psychotropic medication prescribed rather than the psychiatric disorder diagnosed, not all of the psychotropic drugs prescribed were intended for, strictly speaking, psychiatric problems. For instance, among all the cases for which primary care physicians prescribed psychotropic medications, 45% were for gastroenteritis (stomach flu) and another 2% were for hypertension, and Compazine and Serpasil, both of which qualified as major tranquilizers, were prescribed for these conditions, respectively. This is notable, not only because it skewed the statistics on the prevalence on the use of psychotropic medication as well as their perceived effectiveness, but it also showed that the physicians were using some of these drugs not for their properties to address psychiatric illnesses but rather, to alleviate certain somatic symptoms that may not be related to psychiatric conditions.

Second, although both non-psychiatrist physicians and psychiatrists used psychotropic drugs, the non-psychiatrist physicians tended to view the effectiveness of

[468] Datel and Johnson (1978), 9.

medications much more favorably than the psychiatrists. Of course, part of this could be attributed to the fact the psychiatrists, as specialists, were referred the more difficult cases that would be harder to treat, but it could also suggest that psychiatrists, who were likely more skilled in using other forms of psychotherapies, had less confidence in the effectiveness of psychotropic drugs in treating illness than other treatment methods. Certainly, based solely on this report, which did not compare psychopharmacological treatments to other therapies, whether or not this was true would be hard to determine.

Finally, not all of the cases reported in which psychotropic medications were prescribed were defined as combat fatigue. In the Datel and Johnson report, cases of combat fatigue were a subset of anxiety cases (which was 56 out of 464), but the specific criteria for its identification were not reported. Thus, for the purpose of understanding the effectiveness of psychotropic medication in treating combat fatigue or stress reactions as a specific psychiatric condition, two critical elements were missing: First, it was not clear how many cases of combat fatigue were treated without prescribing psychotropic medication, and to what extent were the treatments effective. Second, it was not clear as to how many of the combat fatigue cases were able to return to combat duty, and if they did, how well they were able to perform during the remainder of their tour. Thus, while the Datel and Johnson report did provide a useful and rather favorable first-hand evaluation of the use of psychotropic medications in Vietnam, some questions remained.

In a postwar survey conducted in 1982 by the Walter Reed Army Institute of Research on Army psychiatrists who served in Vietnam, some of these problems that plagued the Datel and Johnson report were better addressed. In this survey, the psychiatrists were asked to recall what was done in theater for incidences for combat stress reactions and were inquired about the treatment for CSR cases in general as well as treatment for specific symptoms. The report analyzed the responses according to the duration of the CSR symptoms: acute CSR was defined as symptoms to last less than two days, extended between two to five days, and persistent greater than five days. This classification of CSR symptoms corresponded with the types of cases that would have been treated at the three different echelons of psychiatric care in Vietnam. Most of the psychiatrists who responded to the survey treated CSR cases in more than category of duration, the most common being extended CSR.

The psychiatrists were asked about their perception of the effectiveness of different major therapeutic measures to treat CSR, including physical recuperative, social milieu, psychotropic medication, interpersonal therapy, and environmental protective disposition on a scale of 1-to-5 (1 being seldom useful and 5 being most useful).[469] Overall, the rating of effectiveness for social milieu-based treatment, interpersonal therapy, and psychotropic medication were rated similarly for their effectiveness for acute, extended, as well as persistent CSR: social milieu-based treatments ranked the highest across all durations of CSR, whereas psychotropic medication was deemed more effective in acute CSR cases than interpersonal therapy, but the latter was deemed more effective when the CSR symptoms became extended or persistent. Physical recuperative measures were the most useful for acute CSR when compared to all other treatment measures, but its effectiveness drastically dropped as the symptom duration lengthened. Environmental-protective disposition measures saw the reverse trend and their effectiveness increased as the symptom duration lengthened, but was otherwise not perceived to be very effective. The respondents were also asked to rate the effectiveness of different interpersonal therapy measures, for which abreaction and counseling were rated as the most effective in general when compared to other interpersonal treatment, although as CSR symptoms became more

[469] Camp (2015), 245. Interpersonal treatment includes counseling, catharsis(abreaction), individual or group therapy, and narcosynthesis; social milieu treatment includes ward milieu, military environment, staff expectancy of return to duty, and contact with unit or home; physical recuperative measures include safety, sleep, nourishment, hydration, rest and recreation, and treatment for wounds or disease; environmental-protective disposition includes return to duty in noncombat position or to less stressful unit, and evacuation out of the area of risk or out of Vietnam; psychotropic medications includes the use of anxiolytics, neuroleptics, antidepressants, and sedatives.

persistent group therapy and individual psychotherapy also became more effective, whereas narcosynthesis saw the opposite trend.[470]

Finally, the psychiatrists directly rated their endorsement on four kinds of psychotropic medications that were used during the Vietnam War, including anxiolytics (Librium and Valium), neuroleptics (Thorazine, Mellaril, and Stelazine), sedatives (Chloral Hydrate) and antidepressant (Tofranil), cross-analyzed with the severity of the symptoms.[471] Although the author of the survey report concludes that psychiatrists who treated CSR "highly valued psychotropic medications, especially the neuroleptics and anxiolytics, in the treatment of soldiers with normal fear/apprehension and with combat stress reactions of all stages";[472] the actual data collected and presented seem to suggest a different picture. For one, across the four categories of psychotropic medications prescribed, Valium was the only one that consistently had endorsement of use by over 50% of the psychiatrists across multiple levels of symptom severity (other than complete disorganization) and was the only drug that received an over 50% endorsement rating (at 54%) for the normal fear/apprehension severity level. All of the other drugs that were surveyed received less favorable endorsement ratings, ranging from as low as 4% (Stelazine) to a high of 43% (the other anxiolytic drug, Librium). Second, neuroleptics, such as Thorazine and Mellaril, received endorsement ratings from a majority of the psychiatrists only for severe cases of CSR (partial or complete disorganization). Since they were considered major tranquilizers, their favored use for more severe cases of psychiatric

[470] Camp (2015), 246. In abreaction treatment, therapist mostly listens and allows patient to have an emotional catharsis, while offering sympathy and support; counseling is defined as abreaction as well as measures to provide reassurance, encouragement, inspiration, or exhortation; individual psychotherapy includes both abreactive and counseling measures, but it also includes an interpretation of psychological conflict (and group psychotherapy is the same except therapist conducts such treatment with a group of patients); narcosynthesis uses short-acting barbiturate to facilitate recall, abreaction, and reintegration.

[471] The severity levels range from normal fear/apprehension, incipient disorganization, partial disorganization, to complete disorganization. It is unclear whether the benchmarks for differentiating between these levels of severity were indicated in the survey, but their associated traits were available in the report in Camp (2015), 147.

[472] Camp (2015), 250.

reactions were expected. Nevertheless, contrary to the report author's conclusion, most of the psychotropic drugs were not seen as useful for treating less severe CSR cases. For these reasons, instead of viewing the psychotropic medications as something that were "highly valued" by Vietnam War psychiatrists, their endorsement of the psychotropic medications as an effective treatment for CSR was lukewarm at best, other than for the cases in which the reactions were severe.

The report from the WRAIR survey did present an additional interesting finding regarding the effects that psychotropic drugs may have on combat performance, where certain kinds of drugs seemed to be favored over others for soldiers who needed maintenance medication upon returning to duty. Psychiatrists were surveyed about the medications they "routinely prescribed" for soldiers returning to duty followed CSR treatment. The result showed that none of the drugs was particularly "endorsed" by a large number of psychiatrists: the highest endorsement rating (in terms of percentage of psychiatrists endorsing the use/prescription for treating continued CSR symptoms) was 30% for Librium and Mellaril in cases of persistent CSR. It was speculated that Mellaril was preferred over other neuroleptics because it has less impact on combat performance: it was "less sedating than Thorazine and less activating than Stelazine."[473] Although there was no conclusive evidence that psychiatrists during the Vietnam War were fully aware of the all the potential effects the psychotropic drugs prescribed had on combat performance, the limited levels of prescription of drugs that were mild in effect suggested that some may have at least been cognizant of the potential side-effects.

To an extent, the concerns for potential side-effects of psychotropic drugs to impact performance were also shown in anecdotal evidences from psychiatrists' reports, although the results were quite mixed. In one 1970 account by Edward Colbach, a theater hospital

[473] Camp (2015), 251.

psychiatrist, and Matthew Parrish, a Neuropsychiatry Consultant during the war, it was suggested that the psychotropic drugs (particularly phenothiazines, such as Thorazine and Mellaril) "'have been safely used to control excessive anxieties in combat infantry men without any apparent interference in duty performance.'"[474] Yet, in another recollection 15 years later, Colbach offered a more mixed account: "Our main psychotropic weapons [in Vietnam] were the major tranquilizers, primarily the phenothiazines…Many soldiers went into the field with Thorazine or Mellaril in their pockets," but "Among ourselves we debated whether this was really a good idea," for "Obviously the medication made people less alert."[475] As a result, prescribing psychotropic medication was "a balancing act, trying to weigh the benefits of medication against its drawbacks."[476] In this sense, although the impact that psychotropic drugs used during Vietnam had on soldier performance would likely never be fully known due to a lack of systematic data, it could be safely suggested that at least some, if not most, of the psychiatrists had at least some reservation about the use of those drugs due to the potential effects on the soldiers' ability to perform.[477]

What to make of all these evidences presented by anecdotal accounts and more systematic studies regarding the treatment model during the Vietnam War, the effectiveness of psychotropic drugs used, and the expert opinions on them? While it is difficult to conclude definitively what the "consensus" may have been, several important trends arise: 1) compared to the current model of stress and trauma disorders, which is

[474] Edward M. Colbach and Matthew D. Parrish, "Army Mental Health Activities in Vietnam: 1965-1970," *Bulletin of the Menninger Clinic* 34(6) (1970): 340, quoted in Camp (2015), 237.

[475] Edward M. Colbach, "Ethical Issues in Combat Psychiatry," *Military Medicine* 150(5) (1985): 261.

[476] Colbach (1985), 261.

[477] As a contemporary example on the potential concern of side effects from some of the psychotropic drugs used during Vietnam, one could consult, Nancy M. Clayton and William P. Nash, "Medication Management of Combat and Operational Stress Injuries in Active Duty Service Members," in *Combat Stress Injury: Theory, Research, and Management*, eds. Charles R. Figley and William P. Nash (New York, NY: Routledge, 2007), 234, which states that antipsychotics such as chlorpromazine (Thorazine) has "not been studied extensively in PTSD, and due to their adverse side effect profile, it is doubtful that this group of medication will receive any further attention from researchers in the treatment of combat and operational stress injuries."

based more on the understanding of their cognitive-neurological mechanisms, the psychiatric as well as treatment model for combat stress during the Vietnam War era was distinctly psychosocial, in which the roots to a soldier's psychiatric problems from combat stress was understood to be a maladaptation to the environment; 2) Compared to the present era, in which neurobiological treatment methods such as psychopharmaceuticals have been endorsed as an independently feasible treatment option to address stress disorders such as PTSD, neurobiology-based treatments during the Vietnam War era were not deemed sufficiently feasible to treat psychiatric disorders caused by combat stress.

As can be gleaned from the anecdotal reports as well as the systematic surveys, psychotropic medication was used during that time by deployed psychiatrists in their encounters with psychiatric casualties. However, because the roots to combat stress were believed to be psychosocial in their pathogenesis, pharmaceuticals were often used as an assistive measure to the main psychosocial-based therapies, and they were not regarded as an independently feasible treatment to combat stress. Certainly, when compared to other treatment methods, psychotropic medication was not the preferred therapy. Furthermore, very few drugs actually received favorable endorsement from their prescribing psychiatrists. Therefore, when compared to the favorable view on neurobiological treatments today, there was a lack of confidence in psychopharmacology as a feasible treatment method during the Vietnam War.

6.3.2 The Military Requirement of Return to Duty

Understanding the "requirements" in the military sense for a treatment for psychiatric conditions is a rather difficult, if not impossible task. This is in part due to the fact that there is inevitably an abstract and subjective part of dealing with mental illnesses and psychiatric disorders: as an example from PTSD, how does a psychiatrist "objectively" evaluate a patient's remission in terms of "reliving traumatic events," other than to inquire the patient about his or her experience? Even for conditions in which there could be visible signs (such as sweating or trembling in the case of anxiety) or measurable biomarkers (speed of heart rate), an improvement in those measures does not automatically constitute the full picture as to how a patient "feels," which is ultimately what accounts for the effectiveness for a treatment.

In addition, as much as a psychiatrist is able to diagnose and treat a patient with psychiatric disorder, it is difficult to objectively ascertain the levels of severity or the degree of symptom improvement, other than in rather general, comparative terms. In that context, the evaluations are likely to be subject to interpretation—whether through a patient's self-reporting or through the psychiatrists' evaluation. Of course, in illnesses that lead to cognitive function impairments, certain measurements of performance deficits or improvements can be useful in the diagnostic and rehabilitative processes. However, not all psychiatric disorders are tied to cognitive deficits that may be observable or measurable. Certain disorders can cause issues in social and relational functions that, while impacting a patient's performance, can be equally challenging to determine.

This is not to say that there is no way to measure or examine the effect of treatment on a psychiatric disorder. As a disorder is established, efforts are made not only to specify its criteria but also tools to determine its diagnosis (at least in the post-DSM-III American psychiatry). For instance, in the past several decades, diagnostic tools have been developed for PSTD: started with DSM-IV, a PTSD Checklist (PCL) has been developed as a self-screening questionnaire, and a more specific Clinician-Administered PTSD Scale (CAPS) has also been in use as the "gold standard" for PTSD assessment and diagnosis. Clinical trials of PTSD treatments often rely on CAPS score for measuring the treatment's efficacy. Yet, are such diagnostic tools something that the military can use as a way to establish its "requirement" on the expected performance of a treatment measure? Certainly, for treatment development that will enter clinical trials, such diagnostic tools are likely used to determine a treatment's suitability and effectiveness. Yet, for military operations, such measurements are less helpful in articulating the military's need.

While the specifics of the types of requirements from military psychiatry in dealing with soldiers afflicted with symptoms of combat stress are difficult to find, historical narratives have suggested from the military's perspective, the ultimate goal for treatment and prevention of psychiatric casualty is the preservation of force strength and the prevention of psychiatric attrition. As a result, treatment measures, whatever their scientific or clinical orientation, are useful to the military insofar that they can return a soldier-patient back into the field as quickly as possible in order to preserve the troop's fighting strength. This was the general goal for military psychiatry during the Vietnam War.[478] The principles of proximity, immediacy, and expectancy, which guided the treatment practice for psychiatric casualties, reflect this goal of force preservation and returning a soldier to duty.

The principle of proximity suggests that soldiers affected with combat stress is more likely to recover if they are treated closer to their unit at the frontline, which helps the soldiers in maintaining contact with their comrades, which in turn helps preserves their unit identity that would be beneficial in rehabilitating them to return to the battlefield. The maintenance of this unit identity also provides the rationale for the need for immediacy in treatment of combat stress reaction: "acute combat reaction tend to be…potentially reversible psychiatric states stemming from the soldier's having been psychologically overwhelmed or worn down by his combat experiences," and his suggestibility is a "consequence of the soldier's still ongoing internal struggle between his emotional

[478] Shephard (2000), 346. See also Franklin D. Jones, "Psychiatric Lessons of War," in *War Psychiatry*, eds. Franklin D. Jones, Linette R. Sparacino, Victoria L. Wilcox, Joseph M. Rothberg, and James W. Stokes (Falls Church, VA: Office of the Surgeon General, United States Army, 1995), 18. This idea of return to duty as the objective of combat psychiatry and combat stress management and treatment still applies today, and it is a goal irrespective of the service branch. See, for instance, Nicholas L. Rock et al., "U.S. Army Combat Psychiatry," in *War Psychiatry*, 171; for Air Force, see David R. Jones, "U.S. Air Force Combat Psychiatry," in *War Psychiatry*, 202.

investment in his primary combat group and his heightened self-protective impulses."[479] Therefore, an immediate intervention is more likely to circumvent the spiraling of worsening conditions and better enable the soldier's ability to resume his duty.

The principle of expectancy specifically outlines the goal of treating cases of battlefield psychiatric casualty, which is to return a soldier to active duty. The attitude of expectancy among psychiatric care providers can shape the way that a soldier's treatment unfolds—with all measures taken to restore his self-confidence and to prevent him from believing that he would be exempt from future combat. In order to better reach this goal, a fourth principle of simplicity has been incorporated into the doctrine, which suggests that the treatment regimen for the soldier should be simple and consistent, whereby straightforward somatic measures, such as physical recuperation, and psychotherapeutic measures, such as ventilation, should be favored over other forms of treatment (including the prescribing of medication, which could contradict the effort of convincing a soldier that he is in fact not ill but rather suffering from normal reactions to stress).[480]

This orientation toward returning a soldier suffering psychiatric casualty to duty as the primary goal for treatment was also clearly embodied in the procedures of dealing with combat stress reaction as described in TM 8-244, which, as described above, has taken the rather specific psychosocial view of war-time stress reactions as an issue of maladaptation. Certainly, the view that the root cause of combat stress reaction lies with a soldier's ability to adapt to the stressful war environment is easier to reconcile with the need to preserve the force strength than it is to qualify such reactions as a form of illness or disorder. As an example to this notion of "return to duty" as the ultimate goal for psychiatric care during

[479] Camp (2015), 213-214.

[480] In this sense, some have argued that perhaps even more in-depth psychotherapeutic measures, such as techniques for abreaction, should be reserved for severe cases, for such treatment can reveal a "logical" reason for a soldier to have suffered from combat stress and may become counterproductive to convince him of his ability to return to duty.

the War, at the division-level psychiatric care "'Every possible step is taken to foster the patient's expectation of return to full duty after a brief rest."'[481] What this included was that psychiatric care was operated in a tent where a uniformed specialist was providing the care, and "the soldier-patient would sleep on folding cots with neither mattress nor sheets, remain ambulatory and wear their regular uniform, serve themselves meals and go the latrine unassisted, and perform work details when asked."[482] In other words, soldiers afflicted with combat stress during the Vietnam War were expected to behave in every possible way as though they were still on active duty in order to maintain this expectation that they will return to their assignments as early as possible.

According to Camp, from the standpoint of military missions, the inherent metric that serves to validate these principles for the treatment of combat stress "is the percent of psychiatrically disabled soldiers who can be restored and returned to duty, especially combat duty. Of course this objective includes the proviso that, upon release from medical control, they perform their duties capably."[483] Yet, what should be the target that the military psychiatric care should be trying to achieve with their treatment effectiveness in returning a soldier to duty? As Camp extrapolates from TM 8-244, "the overall goal with respect to all forms of psychiatric attrition—measured in evacuation rate from the theater—has been to approximate the apparent irreducible minimum, one to two per 1,000 deployed troops, which equals the Army's worldwide rate for psychosis through periods of war and peace."[484] Using psychiatric evacuations from the operational theater as the metric seems a rather logical way in determining the military requirement of managing and treating psychiatric casualties. After all, a soldier who is evacuated would have been unable to be

[481] US Department of the Army, *Military Psychiatry* (Washington, D.C.: Headquarters of the Department of the Army, 1957), Technical Manual 8-244, 75, quoted in Camp (2015), 217.

[482] Camp (2015), 217.

[483] Camp (2015), 219.

[484] Camp (2015), 219.

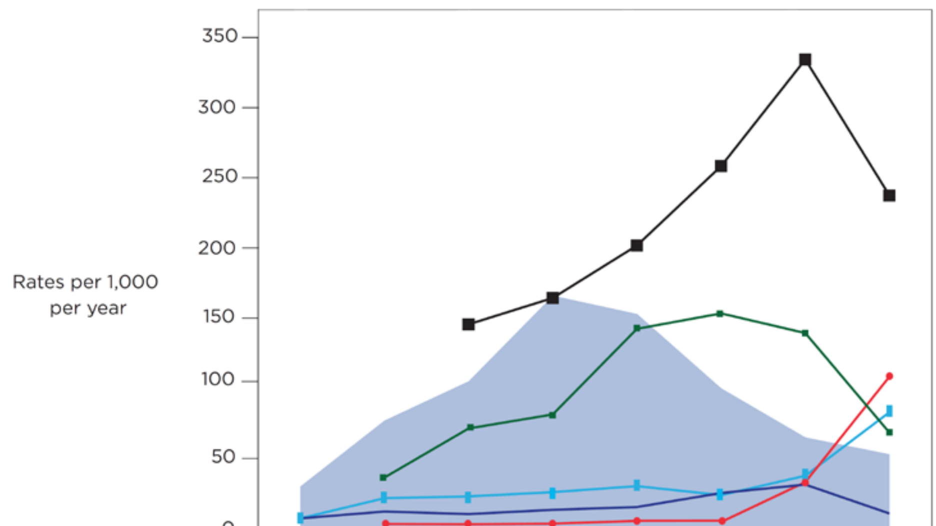
treated by the psychiatric care available (through whatever means) in the theater in a way that would allow him or her to return to duty in any capacity during the operation.

What remains unclear, however, is how difficult is this requirement? Is keeping psychiatric evacuation to one to two military personnel per 1,000 deployed a "stringent" requirement, in the sense that it would be rather difficult to achieve? And was this requirement in particular difficult for psychiatrists deployed during the Vietnam War? The best way to have an understanding on the stringency of this requirement is perhaps to examine the rates of psychiatric attrition due to evacuation across major wars in which the US has engaged. Table 6 below shows the rates of psychiatric evacuations from a select set of major US wars from WWII to the recent OEF/OIF in a comparative perspective.

Table 6 - Psychiatric Evacuation Rate from WWII to OEF/OIF

Major War	Psychiatric Evacuations (Per 1,000 Deployed Soldier)
World War II	13.8 (European Theater)
Korean War	2.6
Vietnam War	1.97 (Through mid-1968) ~4-5 (Through 1970) 42.3 (July 1971) 129.8 (July 1972)
OEF/OIF	.7 (2004) (rounded estimates) 1 (2005) 1.2 (2006) 1.9 (2007) 1.6 (2008) 1.8 (2009) 2 (2010)
Sources: Norman M. Camp, *US Army Psychiatry in the Vietnam War* (2015), 44 and 56; and Margaret Wilmoth, Andrea Linton, Richard Gromadzki, Mary J. Larson, Thomas V. Williams, and Jonathan Woodson, "Factors Associated with Psychiatric Evacuation Among Service Members Deployed to Operation Enduring Freedom and Operation Iraqi Freedom, January 2004 to September 2010," *Military Medicine* 180(1) (January 2015): 54.	

According to the historical record, in most of the earlier wars, psychiatric evacuation rates per 1,000 deployed personnel wars were higher than the upper benchmark of two per thousand deployed. The evacuation rate during WWII was in particular quite high at almost fourteen soldiers per thousand. Since the TM8-244 was published in 1957, its articulated benchmark for psychiatric evacuation was most heavily influenced by the experiences in the Korean War, but even then, the rate of evacuation was higher than 2/1,000. During the Vietnam War era, when the psychiatric evacuation rate seems to have been managed quite well during the early years of war, the situation quickly deteriorated after 1970. Figure 12 below shows a more granular picture of psychiatric casualty rates during the Vietnam War.



	1965	1966	1967	1968	1969	1970	1971	1972
WIA rate	30.1	77.7	105.1	166.3	152.9	100.7	65.0	52.6
Psychiatric outpatient visit rate	—	36.3	71.3	81.3	142.5	153.8	138.8	68.3
Psychiatric hospitalization rate	6.98	11.8	9.8	12.7	15.4	25.2	31.3	10.4
Psychiatric out-of-country evac rate	—	1.9	1.85	2.3	4.3	4.33	32.7	108.0
Court martial rate	6.97	21.25	22.58	25.6	30.0	23.5	37.3	77.8
Nonjudicial punishment rate	—	—	145.2	164.5	201.5	258.6	334.5	237.9

Figure 12 - US Army Vietnam Rates for Wounded in Action and Psychiatric Casualty[485]

[485] Camp (2015), 264.

As Figure 12 shows, psychiatric evacuation, somewhat meeting at least the 2/1,000 mark prior to 1968, became much higher in the second half of the war, surpassing even rates of psychiatric hospitalization in theater in 1971 and 1972. Part of this rise was due to the increasingly prevalent issue of drug abuse toward the end of the war, but the rate spike was quite striking. Furthermore, drug abuse, as would be judged later, was another manifestation of the psychiatric difficulties many soldiers had in dealing with their deployment.

Judging by the historical records, one-to-two-per-thousand rate for psychiatric evacuation is, in fact, quite difficult to meet. Only during the OEF/OIF, in which the most recent and advanced technologies and techniques for dealing with combat stress would have been available, was the rate for psychiatric evacuation managed within the goal consistently. This is compounded by the fact that not all psychiatric casualties or evacuations are due to combat stress (which means in absolute terms of psychiatric evacuation rate due to combat stress would be even lower than the 1 to 2 per 1,000 goal) and that often in operational psychiatric care more than one therapeutic measure would be used to treat cases of combat stress or psychiatric casualty. Therefore, at least during the Vietnam War, this requirement of "return to duty," was difficult to meet. It can also be argued that in general, for any single treatment option that is available for handling combat stress, the expected success rate for returning an afflicted combatant to duty is set very high.

6.3.3 Institutional Partners and Treatment Alternatives

Stress-related disorder, as a complex phenomenon, afflicts the military and civilian communities alike. Of course, the stressors for military personnel operating in combat situations are different from that of what is normally experienced within the civilian population. Nevertheless, ever since the publication of the first DSM in 1952, stress reactions, whether acute (such as Acute Stress Disorder in DSM-IV onward and arguably, as seen in most cases of combat stress reactions) or delayed (such as the case of PTSD), have taken a character that is neither civilian nor military specific. Research and development on its treatment, therefore, concerns military and civilian actors alike.

It is clear from the present discussions and efforts toward addressing PTSD that agencies such as the DoD, VA, and National Institutes of Health (NIH) all have a stake. According to an Institute of Medicine (IOM) report on the treatment for PTSD in military and veteran populations, it is noted that "DoD, VA, and NIH all conduct or support PTSD research and they have distinct but complementary research missions."[486] Whereas research in the VA tends to focus on the long-term health issues and the DoD focuses on the operational needs, they have in recent years engaged in active collaborations, including projects that are intended to improve access to mental health for military and veteran populations and their families. According to the IOM report, "DoD relies to some extent on the expertise and infrastructure of VA and NIH for research in PTSD prevention and treatment."[487] This is because the VA is able to support and leverage clinical trials and epidemiological studies and can also translate research into care practice, and because the NIH has the expertise in funding basic and clinical research, mostly through the National Institute of Mental Health (NIMH). Although much of this implicit collaboration has only been made explicit and transparent in the recent years from a push toward greater clarity in terms of what is being done for veterans afflicted with psychiatric illnesses, the relationship between these agencies has been rather longstanding.

[486] Institute of Medicine, *Treatment for Posttraumatic Stress Disorder in Military and Veteran Populations: Final Assessment* (Washington, D.C.: The National Academies Press, 2014), 176.
[487] Institute of Medicine, *Final Assessment* (2014), 176.

This relationship between the VA, the DoD, and the NIH can also be traced back to post-World War II years preceding Vietnam, where the Cold War environment had in general provided very strong support for multiple areas of scientific research by the federal government. In fact, from the early 1950s all the way through the early years of the Vietnam War, there were significant investments by the federal government in the NIH. Especially during the Vietnam era, one researcher recalled, the NIH "was in an enormous boom period," partly because "the best of the output of American medical schools had decided…that a couple of years' research at the NIH was probably preferable to going to the jungles of Vietnam," so instead, "they fought each other to get into the NIH to do their military service in that way and the NIH had the pick of the most talented young doctors."[488] This increase in investment from the federal government also impacted the NIMH, which saw a manifold increase in funding from 1950 all the way to 1966, at which point it started to see a gradual decline into the 1980s.[489]

Nevertheless, the benefits of the drugs that were discovered in the 1950s to treat various psychiatric conditions, many of which had an European origin, only in the early 1960s started to become better appreciated in North America. As described above, by the time the Vietnam War started, the military had already incorporated these new drugs that it did not develop off-the-shelf into its arsenal in combatting stress disorders. So in addition to the other agencies like the VA and NIMH who have had substantial interests in pharmacology, the military also had at least in its purview an alternative partner in the pharmaceutical industry.

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[488] Leslie Iversen, "Neuroscience and Drug Development," in *The Pharmacologists II, Interviews by David Healy* (London, UK: Arnold), 326-327.

[489] Ross Baldessarini, "American Biological Psychiatry and Psychopharmacology, 1944-1994," in *American Psychiatry after World War II, 1944-1994*, eds. Roy W. Menninger and John C. Nemiah (Washington, D.C.: American Psychiatric Press, Inc., 2000), 385.

Yet, what was perhaps more important to the military during Vietnam was that the psychopharmaceuticals had a viable "technology" alternative in psychotherapy. In fact, given the dominant status of psychotherapy at the time as the main treatment method according the military's model of psychiatric care, psychotropic medications were the alternative to the mainstream psychotherapeutic methods. Unlike their status today which endorses their potential as a monotherapy, psychotropic drugs were almost always used in conjunction with some other psychosocial-based treatment during the Vietnam War.

There also seemed to have been a belief that psychosocial therapies are more effective in returning a soldier to the battlefield than pharmacological agents. For instance, Bourne notes that while psychotropic drugs "have been effectively used in Viet Nam with certain groups, their overall impact has been relatively slight. Rest, emotional support, the opportunity to ventilate, and time to reintegrate adaptive capacities that are temporarily overwhelmed have proven infinitely more effective than any specific pharmacological agent in enabling average patient to return to duty."[490] The survey findings by Camp also show that during the Vietnam era, there were several treatment measures employed, some of which receive more favorable ratings in terms of their effectiveness than psychopharmacology. As it does today, the military during the Vietnam War not only had a set of institutional alternatives through which advancements in treatment methods for psychiatric casualties can be accessed, but it was also equipped with a set of therapeutic measures beyond the neuroleptics and the anxiolytics in combatting battle stress disorders.

6.3.4 Summary

The above analyses indicate that when compared to the present era, during the Vietnam War, there were challenges to recognizing psychopharmacology as an independently effective treatment option for cases of combat stress reaction despite its

[490] Bourne, "Military Psychiatry" (1970), 487.

rather prevalent use. Part of this challenge arose from the dominance of a psychosocial definition of stress reaction in the military's model of psychiatric care, which led to a conceptual barrier that prevented psychotropic medications, such as neuroleptics and anxiolytics, from being viewed as viable means to treat the illness. Furthermore, given the dominance of psychotherapy as the preferred treatment method, it was difficult to evaluate the effectiveness of psychotropic medications as a monotherapy. Thus, whereas the feasibility of neurobiologically-based treatments for stress disorder has been confirmed and widely embraced by the scientific as well as clinical communities today, such feasibility was very much in doubt during the Vietnam era.

In addition, the military requirements at the time were also not conducive to the development of this nascent treatment option. The military expectation from the psychiatric care provided at that time was essentially an "irreducible minimum" of loss of force strength due to psychiatric reasons. As shown through comparative historical examples, such an expectation would be difficult to meet even under the best circumstances today, not to mention that, in retrospect, it was very difficult for psychiatrists deployed in Vietnam, especially toward the later years of the war. Vietnam was certainly a difficult environment under which the new psychotropic medication had to prove its effectiveness.

Finally, because the medications used during the Vietnam War were able to be incorporated into the operational psychiatric care off-the-shelf, and that there were available institutional and technology alternatives to R&D in psychopharmacology, the military had little incentive to believe that its independent investment in their further research, development, or refinement were necessary. This was likely compounded by the fact that earlier in the war, psychiatric casualties seemed to have been managed relatively well by existing psychosocial treatment methods (with the assistance of psychotropic medication), that there would be little incentive to actively seek out other alternative treatment measures.

These factors, combined, presented a rather unfavorable condition for neurobiologically-based treatment options, such as the psychopharmaceuticals, to be looked upon by the military as a fruitful area of emerging technology for investment during the Vietnam War, especially when other problems, such as infectious disease and substance abuse, seemed to have preoccupied the military's medical attention, as further discussed below. This situation has changed for the present era, not only due to advancements in science and technology, but also because there has been a broader transformation from understanding psychiatric problems as psychosocial to potentially neurobiological. As will also be shown below, the medicalization of psychiatry, and what can be called the "neurobiologicalization" of trauma and stress, have contributed to the burgeoning of research today on psychiatric disorders such as the PTSD as well as greater interest in psychopharmacology.

6.4 Competing Priorities and Different Models of Psychiatry

As shown above, the way psychiatric care was practiced during the Vietnam War made neuropsychopharmacology unappealing as a R&D investment option for the military. What complicated the matter at the time was that there were other medical and mental health problems that also demanded the military's attention aside from the issues of combat stress. The tropical climate of Vietnam led to several operational challenges for the US military, and one of these challenges was the prevalence of infectious disease. Furthermore, as the war wore on, the problem of substance abuse, particularly with narcotics such as heroin, became an important problem that occupied the attention of military mental health communities, both clinical and research. These other medical priorities of the time likely detracted from the military the attention given to the issues of combat stress.

In addition to these competing priorities, the dominant psychosocial conceptualization of combat stress likely prohibited greater investment into the R&D of psychopharmaceutical treatments. The impact of this conceptual barrier becomes more apparent as psychiatry as a profession became medicalized in the post-DSM-III era and the conceptualization of trauma and stress became more neurobiologicalized in recent decades, both of which facilitated the growing investment in pharmacological means to remedy psychiatric disorders. The following sections explore these issues in more detail.

6.4.1 Infectious Diseases and Drug Abuse – Competing Priorities in Vietnam

6.4.1.1 <u>Infectious Diseases and Therapeutic/Prophylactic Development</u>

Multiple types of medical problems and challenges confronted the US military in Vietnam, and throughout the war some of these problems preoccupied the military and demanded its researchers' attention. In particular, some infectious diseases were running rampant among American forces during the Vietnam War, including dengue fever, Japanese encephalitis, hepatitis, scrub typhus, amebic dysentery, among others.[491] Other diseases of concern during the time included respiratory infections, diarrheal diseases, and skin diseases. According to a 1973 study done by the Army regarding medical support in Vietnam from 1965 to 1970, disease admissions accounted for 69% of all hospital admissions in Vietnam.[492]

Yet, among all the infectious diseases that confronted the US troops in Vietnam, the most significant was malaria. The military, of course, has long had a history in combating malaria. While significant efforts were made during World War II to address it during engagements in southern Europe, North Africa, and South Pacific (due to the fact over a half-million cases of malaria had caused significant impact on troop strength), much of that effort in treatment research and development came to a halt immediately after the

[491] Coreen M. Beaumier et al., "United States Military Tropical Medicine: Extraordinary Legacy, Uncertain Future," *PLOS Neglected Tropical Diseases* 7(12) (December 2013): e2448, 2.

[492] Spurgeon Neel, *Vietnam Studies: Medical Support of the U.S. Army in Vietnam 1965-1970* (Washington, D.C.: Department of the Army, 1973), 32-33.

war ended. While the US encountered some issues with malaria during the Korean War, its impact on the military became much more pronounced during the Vietnam War, where malaria was the leading cause of medical disability in deployed troops.

What was particularly difficult in dealing with the issue of malaria during Vietnam was that a deadly strain of malaria, *Plasmodium falciparum*, which ran rampant in the tropic jungles of Vietnam, had by the time of full-scale US engagement in 1965 became resistant to chloroquine, the main treatment then available to combat malaria. Chloroquine was developed during the WWII era and has been used both as a therapeutic as well as prophylactic for other milder strains of malaria, such as *P. vivax*, which characterized most of the malaria cases in US troops during the Korean War. Since malaria primarily impacted those in developing countries, major pharmaceutical companies in the developed world had little incentive to conduct the R&D necessary for new drugs that could overcome the drug resistance.[493] The military, recognizing this need to manage as well as generate antimalarial R&D in-house, established in 1963 a sustainable program on malaria drug research coordinated through the Division of Experimental Therapeutics at WRAIR. As the war wore on and cases of malaria began to impact the force strength, the need for effective antimalarial drug that can overcome chloroquine-resistance in *P. falciparum* became more urgently needed.

The antimalarial search, supported by the federal government, received vast resources and commanded the WRAIR's attention during the Vietnam War. At the field, a central rehabilitation hospital was established to collect the data and evaluate new therapeutics.[494] Over 250,000 potential antimalarial compounds were screened during the

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[493] Christian Ockenhouse et al., "History of U.S. Military Contributions to the Study of Malaria," *Military Medicine* 170(4S) (April 2005): 14.

[494] Neel (1973), 130.

course of the war,[495] and mefloquine (later marketed as Lariam) and halofantrine (later marketed as Halfan) were developed. Both mefloquine and halofantrine, however, only received FDA approval years after the Vietnam War ended, in 1989 and 1992, respectively.[496] In addition to the developmental efforts of antimalarial therapeutics and prophylactics, substantial portions of the funding were also devoted to related areas of basic research, including immunology.

What is important to note of this institutional attention to malaria is that it inevitably took attention away from other issues that may not have been apparent at the time to be as critical. Infectious disease like malaria and the toll it created were of sufficient concern to "focus military public health authorities on the immediate need to control malaria in areas of high troop concentration in order to preserve operational capabilities."[497] At a minimum, such an attention on infectious diseases likely caused more institutional resources to be devoted to this area of research, which could cause other areas of research to not receive the institutional support needed to move its work beyond sustainment.

6.4.1.2 Substance Abuse

Whereas the issues of infectious diseases and research on their treatment and prevention may have been the most prominent medical concerns facing the military medical communities during the Vietnam War and became the foremost priority for research centers like WRAIR, even for the mental health providers, a psychiatric problem different from combat stress preoccupied the attention of the researchers. The generally

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[495] Ashley M. Croft, "A Lesson Learnt: The Rise and Fall of Lariam and Halfan," *Journal of the Royal Society of Medicine* 100 (April 2007): 170.

[496] Lynn W. Kitchen, David Vaughn, and Donald R. Skillman, "Role of US Military Research Programs in the Development of US Food and Drug Administration-Approved Antimalarial Drugs," *Clinical Infectious Diseases* 43(1) (July 2006): 69-70.

[497] Mark Fukuda and Tom Cullison, *U.S. Department of Defense Contributions to Malaria Elimination in the Era of Artemisinin Resistance* (Washington, D.C.: Center for Strategic & International Studies, 2014), 3.

low-intensity nature of combat in Vietnam and the one-year rotational system, which has often been attributed as a cause of low levels of troop cohesion, contributed to the prevalence of substance abuse, which as the war wore on became an increasingly noticed problem. Although substance abuse was a recognized problem, during the earlier stages (prior to 1967) it was in some cases silently condoned or intentionally overlooked. However, as the war prolonged, its impact on the troops and on the war became more apparent. Especially in the second half of active US engagements in Vietnam, substance abuse became such a rampant problem that it required research scientists at WRAIR to examine its prevalence and work on potential solutions.

This trend of substance abuse was facilitated by several contributing factors of the time. First, although during that time, the value the broader society placed on psychological resilience and emotional reticence had become less prominent and there was increasing acceptance of the idea of mental disorders, such a changing perception was not quite the case within the military where psychological weakness was still stigmatized. As a result, troops deployed in Vietnam were less likely to seek help than to attempt to "self-medicate" through drugs and alcohol in order to alleviate their reactions to combat stress. Second, the use of drugs was also on the rise within the United States at the time, and there was less of a social taboo against it, especially among younger generations. Given the less than ideal conditions in Southeast Asia and the stress from deployment in an unpopular war, it became even easier for many who were deployed in Vietnam to try to "temporarily escape" their realities through drugs. Finally, although many of the drugs of abuse, including marijuana, amphetamine, and later on in the war, heroin, were clearly illegal under US law, the legal status of these drugs was much more ambiguous in Vietnam, and such drugs were thus much more widely available. It did not help that some local Vietnamese people had an active interest in profiteering from the widening drug epidemic amongst US troops and made narcotics such as heroin excessively easy to access for American soldiers.[498] These factors combined contributed to the drug problem among the Vietnam War troops.

The issue of drug abuse nevertheless became not just an operational problem of the commanders but also an issue for both psychiatrists deployed in the field as well as psychiatric researchers back at home. In the field, the growing awareness of the drug epidemic "led to a search for a flexible, nonpunitive response that would encourage drug users to seek professional help in solving their problems,"[499] and what resulted was that hospitals were "flooded with drug cases," and psychiatrists "fought a losing battle to keep beds for psychiatric patients."[500] Although throughout the war and as early as 1967 there were periodic attempts at surveying the deployed troops in order to ascertain the prevalence of substance abuse,[501] it was not until when the main drug of abuse switched from marijuana and barbiturates to heroin around 1970 that the military commands took the steps to implement any major initiatives. For instance, the Army in December of 1970 published Army Regulation 600-32, *Drug Prevention and Control*, to provide limited rehabilitation for restorable drug abusers, and the regulation was followed in the same month by a directive for a "Drug Rehabilitation/Amnesty Program" issued by the US Army in Vietnam Headquarter.[502] Soldiers under this directive were able to voluntarily ask for amnesty and rehabilitation with no retribution on their drug use and addiction. Without any specific guidelines on how the support programs would be provided, however, implementation became an issue and a collection of unstandardized treatment and rehabilitation programs ensued amongst the Army commands.

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[498] For further elaboration of these contributing factors, see, for instance, M. Duncan Stanton, "Drugs, Vietnam, and the Vietnam Veteran: An Overview," *American Journal of Drug and Alcohol Abuse* 3(4) (February 1976): 557-570. See also Camp (2015), 358-363 and Shephard (2010), 350-353.

[499] US Army Medical Research & Materiel Command (2008), 40-41.

[500] Shephard (2010), 352.

[501] See for instance Camp (2015), 334-343.

[502] Camp (2015), 343-344.

Back in the United States, the issue of drug abuse not only attracted the public as well as the federal government's attention, but it also became an area of acute research interest from places like WRAIR. The first half of 1971 saw a series of inspections and visits due to the increased public scrutiny of the drug addiction issues in Vietnam. In March, 1971, Stewart Baker, the Neuropsychiatry Consultant to the Army Surgeon General, conducted an inspection, and the reports from the inspection highlighted the non-standardized nature of the various medical approaches to treating soldiers with addiction. In April, a congressional visit to Vietnam reported that an estimated 10-15% of deployed soldiers were addicted to drugs, particularly heroin.[503] In May, Harry Holloway, a research psychiatrist from the Army Medical Research and Development Command (now known as Army Medical Research and Materiel Command), who later headed the Division of Neuropsychiatry at WRAIR, did a more comprehensive epidemiological survey on drug additions in deployed soldiers.[504] These studies and inspection yielded some of the first meaningful data on drug abuse for the DoD, which in June of 1971, coinciding with President Nixon's announcement of the "War on Drugs," led to the deployment of urine screening for drugs among all soldiers who were scheduled to return to the United States. Those screened positive for drugs were then detained in Vietnam for rehabilitation.

Upon the implementation of the urine screening program, the incidence of drug abuse decreased drastically, and this decrease became even more drastic after a random urine screening practice was put in place in November of 1971. However, because those detained for rehabilitation and detoxification were returned to the US through medical (psychiatric) evacuation after they were medically cleared in the theater and were distributed among the Army hospitals for further evaluation and treatment upon their return, this practice of urine screening also led to highly skewed and biased data on the

[503] Camp (2015), 345.

[504] Harry C. Holloway, "Epidemiology of Heroin Dependency among Soldiers in Vietnam," *Military Medicine* 139(2) (February 1974): 108-113.

prevalence of psychiatric evacuations toward the end of the Vietnam War (as seen in Figure 12). Furthermore, as drug abuse became an increasingly prevalent issue both within the US as well as among troops in Vietnam, efforts toward understanding its pathology, prevention, as well as potential treatment and rehabilitation also became more pressed. The agency that was tasked with initial, more systematic studies, was the USAMRDC.[505]

As but one example of R&D efforts on drug abuse undertaken within the military, for instance, in 1972, WRAIR conducted research on heroin dependence and withdrawal in the US army in Vietnam, and by 1973 an array of research projects were conducted on drug abuse at WRAIR, including studies on drugs' impact on military performance; addiction prevention; drug test systems; addiction epidemiology; as well as others attempting to understand the nature of drug addiction pathology from a variety of approaches including neurophysiology, neuroendocrinology, neurochemistry, cellular metabolism, and pharmacokinetics. While these projects were administratively organized outside the programs on military psychiatry, they were nevertheless headed by WRAIR psychiatric researchers and greatly leveraged the expertise in neuropsychiatry that WRAIR had accumulated over the previous decades.

The full extent to which medical priorities such as infectious diseases and substance abuse impacted the military research interest on combat trauma and stress reactions is difficult to evaluate, but the above discussions reveal that during the Vietnam War, the military, particularly the Army, faced other major medical problems beyond combat stress. Of course, malaria and heroin were among the many issues that the military had to confront in Vietnam, but their prevalence during the War and the impact they had on operational efficiency demanded the services' attention. Certainly, the war efforts also shifted the focus and objectives for military medical R&D institutions like WRAIR, both in terms of broad

[505] US Army Medical Research & Materiel Command (2008), 41.

organizational objectives as well as the focus of researchers in neuropsychiatry: “Rather than broad-based studies of the entire nervous system, the group took on a more mission-focused research program,” according to a centennial report on the Institute’s history.[506]

Barring the availability of more direct and granular data, perhaps one crude measure to assess the extent to which infectious diseases and drug abuse defined WRAIR’s research priorities is the sheer volume of research output in these areas of medical R&D compared to issues pertaining to combat stress and military psychiatry. In WRAIR’s Annual Progress Reports on research programs from 1963 to 1973, research on malaria alone received three times as much coverage (calculated in terms of sheer page count) in the reports compared to research on psychiatry. When combined with research on other infectious diseases, such a difference in coverage increased to roughly tenfold. Similarly, as the public, the government, and the military began to increase their scrutiny of drug abuse in the early 1970s, research on it was quickly established at WRAIR as a program outside of military psychiatry, and within the first few years the drug research program produced research outputs that were similar in terms of report coverage to that of malaria-specific research. While coverage in the research report is not the most concrete measure of levels and intensity of research activities, it does show that WRAIR, and its neuropsychiatry research arm in particular, had substantive research activities and interests in other medical issues beyond combat stress.

6.4.2 From Psychosocial to Neurobiological – Impact on Pharmacology

Malaria and heroin challenged the US military during the Vietnam War, and the need to redress these issues preoccupied the attention of military medical and psychiatric researchers. Research on the treatment and prevention of combat stress, thus, paled in

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[506] Craig Collins, “The Center for Military Psychiatry and Neuroscience: To Protect and Promote Soldier Resilience, CMPN Researchers Focus on Both Body and Mind,” in *120 Years of Advances for Military and Public Health* (Tampa, FL: Faircount Media Group, 2013), 55 (55-65).

comparison to these other priorities. This was particularly troublesome because, as explained above, treatment measures of combat stress beyond existing psychosocial therapeutic measures (such as the use of psychopharmaceuticals) were not perceived as particularly appealing areas of investment largely due to the way that combat stress was conceptualized.

The dominance of the psychosocial model in understanding combat stress during the Vietnam War nevertheless caused a broader and more deeply rooted issue for research on non-psychosocial based treatments such as pharmaceuticals. As described in detail in previous sections, combat stress during the Vietnam War was understood specifically as a psychosocial issue of maladaptation, and this belief was embodied by the way that psychiatric care was practiced. This led to a marginalization of pharmacological therapy as an effective means of treating psychiatric reactions to combat stress, which in turn, likely undermined the military's interest in investing in further exploring psychopharmacology.

This trend of a dominant psychosocial view of psychiatric practice was not something that only happened in the military, however. Beyond the practical reasons behind which the military deliberately adopted during that time a psychosocial view to combat stress (such as minimizing the perception that psychiatric reactions to war stress and trauma was a real illness), this dominance also reflected the broader professional norm in psychiatry at the time.

In accounting for the development of psychopharmacology in the second half of the twentieth century in the US, Ross Baldessarini made several observations. First, World War II caused an emigration of many prominent psychoanalysts from Europe to the United States, and from the immediate WWII years to the 1970s, "psychoanalytically based psychosocial theories and practices clearly dominated American psychiatry."[507] Second,

[507] Baldessarini (2000), 377.

most of the major breakthroughs in psychopharmacology in the 1950s were of foreign origin (for instance, Thorazine prescribed during Vietnam War is produced by GlaxoSmithKline, a British company, and Mellaril and Valium are both produced by Swiss pharmaceutical companies), and its dispersion in the American market encountered skepticism in a profession in which some of the "complex human psychiatric problems" were "only trivially and incidentally biologically based and biologically treatable."[508] Third, this dominance of psychosocial theories and practices in psychiatry led to a relatively slow initial introduction of psychopharmaceuticals into clinical practice, because "The new pharmacotherapies initially were widely viewed as competing with the psychotherapies, which sometimes led to harsh clashes based on dissimilar value systems and expectations."[509] Medicinal treatments for psychiatric disorders in the 1950s and 1960s were thus often treated as merely palliative, which, it was posited, could lead the suppression of symptoms that prevented the patient from pursuing actual resolution to the underlying psychic conflicts.

In other words, the dominant psychosocial view of combat stress and trauma became a conceptual barrier to the R&D of psychopharmaceuticals, and this view contributed to the lack of visible military investment in this area of treatment and therapy for combat stress during the Vietnam War. Although several kinds of psychoactive drugs developed in the 1950s had by the time of the Vietnam War been used to treat illnesses such as psychosis, depression, anxiety, and manic-depressive disorder[510] (and as shown above, many were also used by physicians and psychiatrists during the War itself), it was recognized that these drugs were not specific enough for the supposedly discrete symptoms. Furthermore, as shown above in the analysis of the results obtained from the

[508] Baldessarini (2000), 389.
[509] Baldessarini (2000), 389.
[510] Young (1995), 97.

1982 WRAIR survey as well as other anecdotal evidences, psychiatrists at the time viewed pharmaceuticals as at most symptomatic treatments and used them as such.

The extent to which this psychosocial view of combat stress impacted the directions and choices of military R&D in treatments can be observed in the research activities from the Division of Neuropsychiatry at WRAIR, which, at the time, was a pioneer in interdisciplinary research on neuroscience under David McKenzie Rioch. Since establishing the Division in 1951, Rioch had deliberately built an interdisciplinary program of research on the human mind and body that welcomed and embraced disciplinary differences. In fact, the broad ranging work conducted at WRAIR at the time[511] has garnered the reputation for Rioch as well as WRAIR as a progenitor in modern neuroscience research.[512] Despite its broad-based work, Rioch's Neuropsychiatry Division had a deliberate goal to address psychiatric casualties and combat stress within the military. According to Robert Galambos, a member of the Division at its founding, Rioch at the time of his interview for the job was told by the commandant of WRAIR that "'psychiatric casualties had reached the top of the Army's list of medical problems,'" and Rioch's mission was "'to supervise the basic research effort that would drop it to the bottom.'"[513] Research on combat stress and trauma was thus a central concern to Rioch's interdisciplinary research team.

Given that combat stress was a major concern for the military in general and the army in particular (at least as part of their planning for the full-scale deployment), that the Division of Neuropsychiatry's mission was to reduce psychiatric casualty, and that under

[511] For example, see Joseph V. Brady and Walle J.H. Nauta, eds., *Principles, Practices, and Positions in Neuropsychiatric Research: A Volume in Honor of Dr. David McKenzie Rioch* (New York, NY: Pergamom Press, 1972).

[512] For example, see W. Maxwell Cowan, Donald H. Harter, and Eric R. Kandel, "The Emergence of Modern Neuroscience: Some Implications for Neurology and Psychiatry," *Annual Review of Neuroscience* 23 (2000): 345-346.

[513] Quoted in Collins (2013), 55.

Rioch's leadership the research work was deliberately interdisciplinary, it is reasonable to assume if any R&D were to be done on the innovation or improvement of treatments for combat stress within the DoD during the Vietnam War era, and particularly in a highly neuroscience or neurology-influenced field such as psychopharmacology, WRAIR's Division of Neuropsychiatry would be part of, if not leading, this effort. Yet, that was not the case. WRAIR, in fact, had little research activity on treatment measures for combat stress throughout the Vietnam War. This is not to say that combat stress was not studied during this time—certainly, combat stress remained a focus, but the research efforts concentrated mostly on its management through psychosocial means, and where the somatic components of stress are concerned, the work analyzed primarily the autonomic and endocrinal aspects of stress reaction pathology and its impact on performance. Based upon available records and research reports, there was little to no R&D activity on non-psychosocial treatment measures such as the use of psychotropic medications, whether it was to examine its effectiveness,[514] to understand its underlying pharmacodynamics, or to refine its mechanisms.

There are few records that can directly attest to exactly why, during the Vietnam War era, despite its emergent status and increasingly prevalent use both in civilian psychiatry and in the military, treatment measures such as psychotropic drugs received such little attention from the military R&D community. Some later recollections about Rioch lends some insights. From a reflection by Harry Holloway, Rioch "was aware of advances in psychopharmacology but clearly did not equate these advances with an operational understanding of psychiatric disease."[515] This was not due to some kind of

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[514] The Datel and Johnson survey, though conducted during the Vietnam War, was not a result of R&D efforts at WRAIR. The first known systematic research on drug effectiveness done at WRAIR was the 1982 survey done by Camp, which was by then a decade after the troops had left Vietnam and after PTSD was recognized as a diagnostic category in DSM-III.

[515] Harry C. Holloway, "Interpersonal Psychotherapy and Neuroscience," *Psychiatry* 66(2) (Summer 2003): 103.

conceptual oversight, however, but rather an understanding of psychopharmacology as potentially prohibitive to the study of the underlying mechanisms to psychiatric illnesses. According to Holloway,

> [Rioch] was well aware that the contributions of Galen to neuroanatomy and physiology in the second century AD were most impressive. He also knew that these contributions were followed by medical Dark Ages in which pharmacopoeias substituted for scientific studies and Galen's contribution became the end of scientific study, not a beginning. The perception that a treatment worked substituted for understanding the operational basis for natural phenomenon…He also appreciated that the profits associated with medications might lead to the deemphasis of studies required to move beyond the superficial.[516]

Rioch's understanding of psychopharmacology during the Vietnam War echoed the psychosocial understanding of combat stress in which the somatic and cognitive symptoms were epiphenomenal to the underlying causes of maladaption, and the symptomatic treatment that psychopharmaceuticals could provide was superficial and ran the risk of undermining further research that would be required to resolve the underlying psychosocial or intrapsychic tension. The psychosocial conceptualization of combat stress, thus, prevented psychopharmacology from being viewed as a favorable investment option but rather, as something that could be counterproductive to the research on understanding combat stress.

To what extent was the lack of R&D in psychopharmacology during the Vietnam War an intentional avoidance or a situational oversight is not entirely clear, but given the available evidence, it is possible to infer that the conceptual barrier did not help. This is

[516] Holloway, "Interpersonal Psychotherapy" (2003), 103.

especially apparent when comparing investments on psychopharmacology during that era to the one post-DSM-III or even more so to the one after the September 11 attacks. As described above, DSM-III not only created a common nosology among psychiatric researchers and practitioners, but it was also deliberately symptomology-focused and intentionally atheoretical. According to Robert Spitzer, who headed the task force that developed DSM-III, "the new edition was to be based on two principles: theories of pathogenesis would be confirmed by 'principles of testability and verification,' and each disorder would be identified by criteria accessible to empirical observation and measurement."[517] In other words, through DSM-III, psychiatric disorders became more "medical" in the sense that they were defined according to explicit diagnostic criteria and observable symptoms rather than based on assumed psychopathology.

The virtues of defining illnesses this way notwithstanding, the medicalization of psychiatry made the study of psychiatric disorders experiment-friendly and facilitated the growth of more specifically targeting psychoactive drugs. Conceptualizing psychiatric disorders, including reactions to traumatic stress, as a medical problem instead of a psychological one paved the way for the R&D of biological and neurological based therapies, such as the psychopharmaceuticals. According to Shadia Kawa and James Giordano, in examining the effect of DSM-III on psychopharmacology, it was noted that "while the DSM-III classification system did not explicitly link diagnostic categories to any particular treatment options, the symptom-based, somatically-oriented nature of the classification scheme was particularly compatible with biological therapies customized to discretely constructed disease entities."[518] This medicalization of psychiatry as a profession and its impact on opening more avenues for deliberate research on biology or neurology-

[517] Young (1995), 99.

[518] Shadia Kawa and James Giordano, "A Brief Historicity of the Diagnostic and Statistical Manual of Mental Disorders: Issues and Implications for the Future of Psychiatric Cannon and Practice," *Philosophy, Ethics, and Humanities in Medicine* 7(2) (January 2012): 6

based therapies, including the development of drugs, are significant. Started in the 1980s, following the DSM-III, "billions of dollars were allocated by the government and pharmaceutical companies for psychopharmacological research," and during that decade, "federal research budget allocated to the NIMH increased by 84 percent, to about $484 million annually."[519] Furthermore, as the psychiatric profession became more medicalized, there was an increase in psychopharmacological interventions on disorders that would have previously been treated with psychotherapeutic or behavioral approaches. This further enabled research in neurochemistry and pharmacology of allegedly psychopathological conditions.

To a large extent, Rioch's fear that the rise of psychopharmacology may detract research from "understanding the operational basis" of psychiatric disorder never materialized. If anything, psychiatric research in the post-DSM-III era took a turn for the better and became focused on both the neurobiological substrates of disorders as well as the psychocognitive mechanisms. Nevertheless, this turn of psychiatry from the psychological to the medical and then to the neurobiological is not without detractors. Norman Camp, writing in 2013, notes of this change in the post-DSM-III era of psychiatry:

> The revolutionary change in the American taxonomy of psychiatric disorder in 1980, the 3rd edition of the Diagnostic and Statistical Manual of Mental Disorder (DSM-III), served by extension to cast doubt on earlier, empirically derived theories of causation for combat stress casualties—theories that encompassed predisposition, psychosocial disturbances, and psychic conflict. The resultant vacuum led some to favor neurophysiologic theories as alternatives.[520]

[519] Kawa and Giordano (2012), 6.
[520] Camp (2015), 446.

Of course, what Camp refers to as "empirically" derived theories of causation for combat stress casualties have evolved, for the most part, out of clinical practices on the battlefield, which to a large extent also reflects the military's need to preserve troop strength. This is made clear as Camp further contends that the current medicalization and "neurobiologicalization" of combat stress appear "to have reverted to the abandoned World War I model of shell shock with its disastrous potential for unsustainable psychiatric attrition, unnecessary and high soldier morbidity, and the risk of military defeat."[521] According to Camp, understanding the neurological substrates to combat traumatic stress seems to be outdated thinking akin to the way shell shock was once understood. To what extent does combat stress impact a soldier neurologically, and whether existing neurological research on combat stress reactions and PTSD provide avenues for potentially improved treatment measures, thus, do not seem to concern him.

Others, however, have suggested that compared to what is known now, the way that combat stress was conceptualized during wars like Vietnam was in fact too "demedicalized" and "normalized," which not only perpetuated the persistent stigma against psychiatric casualty and mental illness within the military, but also could circumscribe efforts toward prevention and treatment. In a nutshell, "if all combat stress is normal" and non-medical, then "what is there to prevent or treat?"[522] From this perspective, the increasing neurobiologicalization of combat stress and the medicalization of its reactive symptoms are helpful in destigmatizing combat stress reactions and can perhaps facilitate more effective and targeted interventions: if combat stress can in fact create neurological harm, then psychiatric reactions to it are not based on an individual's capability, character, or predisposed susceptibility. Rather, the trauma and stress of combat experience can

[521] Camp (2015), 446.

[522] William P. Nash, Caroline Silva, and Brett Litz, "The Historic Origins of Military and Veterans Mental Health Stigma and the Stress Injury Model as Means to Reduce It," *Psychiatric Annals* 39(8) (August 2009): 791.

wound an individual and lead to functional impairments just like any other physical wound, and the impairments would, in this sense, not be due to one's own failure or weakness. Recent policy advances toward destigmatizing disorders like PTSD echoes this view. In a town hall meeting at Fort Lee on September 28, 2016, for instance, President Obama, in addressing concerns over the stigma of mental disorders within the military, likened disorders developed from combat stress to breaking a leg and advocated that there is no difference between seeking medical help for PTSD and that for physical injuries. This kind of policy endorsement of the medicalization of psychiatric disorders and physicalization of trauma suggests an increasing recognition of the neurobiological model of mental illnesses in the recent decade.

Interestingly, the trend of neurobiologicalization of psychiatry, particularly with regard to understanding trauma and stress, may inadvertently be undermining a disorder like PTSD. Alison Howell, for instance, suggests that "In Western military contexts, and especially in the US Army, PTSD is being parsed…through the biomedicalization of traumatic events in war, in particular through the diagnosis of mild traumatic brain injury…and what might be called the 're-physicalization' of trauma in military contexts."[523] By physicalizing trauma, the authority over defining a traumatic experience such as combat shift from the mind to the brain, and the diagnosis to the stress reactions such traumatic experience causes also changes from an issue of psychology to an issue of neurology. This, in turn, could undermine a primarily psychological construct of trauma such as PTSD as the defining model of the impact of combat stress.

Whether neurobiologicalization of combat stress will derail the research on underlying causes of war-time psychiatric casualties, lead to a rise in psychiatric attrition and soldier morbidity, destigmatize mental health issues among military and veteran

[523] Alison Howell, "The Demise of PTSD: From Governing through Trauma to Governing Resilience," *Alternatives: Global, Local, Political* 37(3) (August 2012): 220.

populations, or delegitimize the authority of PTSD remains to be seen. One thing that is certain, however, is that the way combat stress can be, and is, conceptualized in the post-September 11 US is the same as what it was during the Vietnam War. The medicalization of psychiatry and the neurobiologicalization of traumatic stress helped shift how combat stress is conceptualized and diminished the conceptual barrier that casts doubt on the feasibility of treatment methods such as psychopharmacotherapy in resolving combat stress reactions. This, in turn, has facilitated the growing attention toward cognitive as well as neuroscience-based research on the treatment of combat stress in recent decades.

6.5 Conclusion

In recent decades, with the emergence of neuroscience research as well as increasing demand from overseas military operations, the research and development of neuroscience-based therapeutic measures to treat and prevent combat stress-related psychiatric disorders such as PTSD have been pursued in earnest in the United States. In particular, neuropsychopharmacology has been heralded as one area of emerging S&T that could provide the greatest contribution. Interestingly, however, this is not the first time that psychopharmacology could be leveraged to address the military's need to manage psychiatric casualties and fight combat stress reactions and other psychiatric disorders that arise from war experiences. With great strides made in the discovery of several psychoactive drugs during the 1950s, psychopharmacology was an emerging area of S&T during the US engagement in the Vietnam War. However, the US military had little interest during that time in the R&D of better psychoactive drugs to treat combat stress. Why was this so?

This chapter argues that the reason why treatment measures like psychopharmaceuticals attracted such little military R&D investment during the Vietnam War was because, first and foremost, the way trauma and stress were conceptualized during the War made psychopharmacology not an appealing area of investment for the purpose of redressing combat stress. As has been demonstrated, the dominant psychosocial model of stress marginalized the role that psychoactive drugs can play in treating soldiers with CSR. Furthermore, a low threshold for the acceptable rate of psychiatric evacuation from theater suggested a difficult environment under which newer treatment measures such as psychopharmaceuticals would need to demonstrate its independent effectiveness in managing combat-related psychiatric casualties. Finally, the military had rather abundant alternative accesses to psychopharmacological advancements, which likely reduced its interest in investing in this area of emerging research. These factors combined made psychopharmacology an unappealing investment for the military during the Vietnam War.

This chapter further explores and shows that competing medical priorities, such as the need to fight against infectious diseases and manage substance abuse, occupied the military's attention during the Vietnam War, and medical research organizations like WRAIR devoted much of its effort into remedying these urgent operational concerns. As a consequence of these competing priorities, pharmacological developments to treat combat stress likely became further sidelined. The chapter concludes by highlighting that the recent increase in military R&D interest in psychopharmacology for treating stress disorder is likely facilitated by the medicalization of psychiatry as a profession and the neurobiologicalization of the concept of trauma and stress as they relate to combat experiences. Just like the psychosocial model of combat stress and psychiatric care during the Vietnam War created conceptual barriers to recognizing the value of R&D in psychopharmacology, the deterioration of such barriers in the recent decades through increasing neurobiologicalization of psychiatry has enabled pharmacological means to become viewed as effective in managing stress-related disorders.

CHAPTER 7. CONCLUSION

Given their prospective military utility, why do some emerging technologies attract and sustain military investment in R&D while others do not? While militaries, particularly ones that are striving to be a technology first-mover, always seem to be able to find reasons to invest in an emerging technology (with the "unassailable" logic of military necessity and avoiding technological surprises), some emerging technologies nevertheless do not attract or cannot sustain military investment interest despite their purported military utility. This dissertation answers this question and argues that the way a technology is understood by relevant actors in the R&D process matters for its investment. Under certain technical conditions, a technology becomes unappealing as an investment opportunity, which leads to its inability to attract or sustain funding. The following sections recount the central argument of this dissertation, provide some comparative analysis of the cases examined, assess the argument's generalizability through a mini-case study on Aircraft Nuclear Propulsion, and discuss the study's theoretical and potential policy contributions.

7.1 Summary of Arguments and Analysis of Evidence

States desiring to be a first-mover in a military technology invest in emerging areas of S&T at the technological frontier. To manage the uncertainties of emerging technologies and to mitigate the risk of being technologically blindsided by an adversary, these first-mover states propel their defense planners to hedge and invest in military technologies widely. This logic provides the underpinning of the conventional perception that R&D in the defense sector and military technology enjoy a "privileged status" in that any emerging technology that purports to have military utility gets invested in. Nevertheless, historical records show that some emerging technologies do not get or cannot sustain military investment despite their purported utility. Existing systemic-structural, bureaucratic, and organizational explanations of defense acquisition decisions in general fall short in some critical aspects in their ability to explain military technology investments, and perhaps more importantly, non-investments. This dissertation addresses this shortfall.

This dissertation ascertains that in order to understand why the military does not invest in some areas of emerging technologies, one needs to conceptualize military R&D investment not just in the manner of risk mitigation, but also as the pursuit of specific opportunities. Opportunity, in this sense, entails not just an expected utility, but also the "circumstances" that make achieving the utility possible. In some cases, depending on how a technology is understood by relevant actors in the R&D process, it may acquire specific characteristics that make it not an appealing investment opportunity. Put differently, the circumstance surrounding each technological opportunity is different, and some circumstances make a technology unappealing as an investment. This dissertation describes this circumstance as the technical condition and posits that in an emerging military technology, this condition consists of, at a minimum, how the scientific or technical expert community defines the feasibility of the technology, how the military as the end user sets the expected performance parameters, and the extent to which technology or institutional alternatives exist. The hypotheses derived from these arguments are reiterated below:

Hypothesis 1: As scientific agreement on the feasibility of an emerging military technology declines, the investment condition for such technology also becomes less favorable.

Hypothesis 2: The more stringent a military requirement, the more difficult it is to be achieved, and the less favorable are the investment condition for a technology intended to address such a requirement.

Hypothesis 3: Increased availability of institutional or technology alternatives to address a capability gap reduces the interest of the military to invest in any particular technology option, resulting in less favorable investment conditions.

Although the three independent variables that constitute the technical condition and their impact on the favorability of an investment are presented separately, the main argument of this dissertation is that a certain combination of these variables produces a technical condition that is unfavorable. In particular, when the dominant opinion from the expert community on the feasibility of the technology is low, when the expected performance parameters of the technology from military are high, and when there are institutional or technology alternatives to acquiring the capability, the technology becomes an unappealing investment. In this dissertation, this central claim is examined using congruence method through two cases: the first on the R&D of biochemical incapacitants as a non-lethal weapon, and the second on the R&D of psychoactive drugs (neuropsychopharmacology) as a treatment option for combat stress-related disorders. The results are summarized below in Table 7.

Table 7 - Summary of Evidence

Case Study	Time Frame	IV			DV
		Feasibility	*Requirements*	*Alternatives*	*Military Investment*
Biochemical Incapacitants	Before 2002	Mixed to High	Low	Yes	Present
	After 2002	Low	High	Yes	Absent
Neuropsycho-pharmacology	Before 1980	Low	High	Yes	Absent
	After 1980	High	High	Yes	Present

As highlighted in the table, both cases in general confirm the central claims of this dissertation that, 1) militaries sometimes do not invest in an emerging technology even if it has military utility, and 2) low feasibility, highly stringent requirements, and available alternatives can make a technology an unappealing investment opportunity. In both cases, the understanding of the technology's feasibility changed over time. In the biochemical incapacitant case, the prospect of finding biochemical agents capable of incapacitating individuals while avoiding the risk of lethality has driven decades of research as well as the stockpiling of agent BZ. However, it has also been known that one of the critical barriers to the development of a CNS-acting biochemical that is capable of producing incapacitation is the dose-response problem, in that for any agent sufficiently strong to incapacitate a large group of people there is always the potential for some to die from overdosing, leading some technical experts and arms control proponents to conclude that it is not feasible to produce a biochemical non-lethal weapon.

As this technical position gains prominence in the early 2000s and attracts endorsement from many in the expert communities after the Dubrovka incident in Moscow in 2002, the belief in the technical feasibility of a non-lethal biochemical weapon declined. This, coupled with the increasingly stringent requirement for non-lethality that the US military has come to expect from its non-lethal weapon systems (at least since the creation of JNLWD in 1996), created an unfavorable technical condition for the R&D of biochemical incapacitants as a military technology since the early 2000s, which contributed to the languished investment by the US military in this area of S&T.

In the neuropsychopharmacology case, the feasibility of using psychoactive drugs to "treat" combat stress-related psychiatric disorders was very much in doubt during the Vietnam War era. The main barrier, in this case, was as much a conceptual one as it was technical. The broader American psychiatric practice at the time focused on the psychoanalytical aspects of mental disorder, which conceived the underlying mechanisms for mental illnesses as a psychic conflict. The dominance of psychoanalysis meant that neurobiological theories of psychiatry were marginalized, and certain therapeutics, such as psychoactive drugs, were perceived as symptomatic treatments. The US military, from operational experience in previous wars and for pragmatic reasons, adopted this psychosocial perspective in its psychiatric practice in dealing with combat stress.

Therefore, despite the emergence of significant advances in psychopharmacology in the 1950s and the use of psychoactive drugs during the Vietnam War, those who practiced military psychiatry and directed psychiatric research programs had little faith that a neurobiological solution, such as drugs, could effectively solve a problem such as combat stress that was perceived as psychosocial in its pathology. This lack of belief in the feasibility of psychoactive drugs as effective treatments for combat stress, combined with the need to keep psychiatric casualties at a very low rate, meant an unfavorable condition under which psychopharmacology, as a treatment option, was to be invested by the military during the Vietnam War era. As psychiatry after DSM-III in 1980 became increasingly medical and neurobiological, combat stress also became understood as potentially neurobiological in its pathology. The perceived feasibility of psychoactive drugs in treating the stress reactions that combat experience causes thus also increased, which facilitated the growth of investment in neuropsychopharmacology and enabled military R&D efforts in it to combat stress disorders in recent decades.

This dissertation also examines how the favorability of technical conditions impacts investment decisions. For a technological opportunity to germinate within the military R&D system and attract investment, it requires advocacy, promotion, and endorsement. Under unfavorable technical conditions, such activities may become difficult. Furthermore, even if an emerging technology can attract initial investments, its sustained funding can become challenged for a variety of organizational, political, or social reasons. Under unfavorable technical conditions, the technology may become less able to withstand such challenges. Thus, two additional hypotheses are proposed with regard to how the favorability of technical conditions impacts investment decisions.

Hypothesis 4: When the condition is unfavorable, a new technology has difficulty generating sufficient support to attract sponsorship and be initiated.

Hypothesis 5: When the condition is unfavorable, a new technology is less resistant to potential organizational, political, or social challenges, making it more difficult to sustain should such challenges arise.

The two cases analyzed in this dissertation tell contrasting stories regarding hypotheses 4 and 5. The neuropharmacology case, in general, supports hypothesis 4. The lack of belief in the feasibility of using psychoactive drugs to treat combat stress disorders is reflected in the way that David Rioch, the director of the Division of Neuropsychiatry at WRAIR, thought of psychopharmacology – that it could be counterproductive to generating an operational understanding of psychiatric diseases. Because the roots to psychiatric disorders were believed to be psychological, and because advancements in psychopharmacology were viewed as enabling primarily symptomatic treatments that do not address the underlying pathological cause for the disorder, an investment in research, development, or refinement of psychoactive drugs would potentially distract the needed attention away from the study of psychiatric disorders. Therefore, although combat stress was studied by the military and the research on it did take place at WRAIR, research on psychoactive drugs, such as the exploration of their pharmacokinetic mechanisms, never attracted sufficient attention from the researchers and their leadership.

The biochemical incapacitant case supports hypothesis 5. The unfavorable technical condition that emerged after the Dubrovka Theater incident in 2002 made it difficult for the military to justify its continued R&D effort in this area of NLW research. Because the dominant view from the technical expert community suggests that a CNS-acting biochemical cannot be developed, designed, and used in a manner that would meaningfully limit lethality, and since this technical position has slowly gained international recognition by states in arms control forums such as the CWC, the rationale for military R&D in this area has become increasingly challenged by those in favor of tighter arms control. The shift in the US position on the incapacitants as shown in the Third Review Conference of the CWC and onward is perhaps reflective of this recognition of the rising international political cost for support military R&D in biochemical incapacitants. Whereas the US was deliberate in preventing the issue of incapacitants from being discussed in the First Review Conference and was silent on the issue during the second one, its recent turn to support greater clarity within the CWC on the restriction of biochemical incapacitant shows that those in the US who may have favored and supported the military investment in this area of NLW development are likely fighting a losing battle to keep this research continually funded.

The two main case studies analyzed above, thus, support the main argument of this dissertation, that the technical condition for an emerging military technology becomes unfavorable when the feasibility is low, the military requirements are high, and the alternatives are present. Furthermore, under this unfavorable technical condition, a technology has difficulty attracting sufficient support for its investment by the military, Even if it receives some initial investment, such support becomes unsustainable when challenges confronting the validity of the investment arise. Nevertheless, the findings derived from these two case studies could be subject to some limitations. First, both biochemical non-lethal weapons and neuropsychopharmaceuticals for addressing combat stress disorders are relatively small-scale R&D projects (despite the latter's increasing investment by the federal government in the recent decade) that do not fall under a more traditional, kinetic-weapons-focused conceptualization of military R&D. The distinctively biomedical and cognitive neurological character to these two areas of S&T could suggest that the reason why their investment has been marginalized at times is because ultimately, they do not fit the bill as mainstream investment programs that interest the military. Second, although NLW R&D has since 1996 been unified under the JNLWD, which is administered by the Marine Corps under the Navy, most of the research prior to that on biochemical incapacitants (such as the BZ development) were conducted at the ERDEC (now Edgewood Chemical Biological Center) under the Army. Similarly, although combat stress reaction is not unique to the Army, most of the discussion on the psychiatric practices during the Vietnam War and the research at WRAIR focused on the Army. As a result, the Army-centered focus of these two cases could raise doubts that the variance in their investment is related to how Army as a service branch handles R&D in emerging technologies. Finally, even though these two cases contain useful within case comparisons, the variance in some of the variables that constitute the technical conditions is low (as shown in Table 7, for instance, institutional or technological alternatives are present in both cases across the time periods studied), which could suggest that these cases do not provide sufficient control or support of the impact that each individual variable has on the favorability of the technical conditions. These concerns could inhibit the perceived value of the insights these two case studies generate.

In order to overcome these limitations and further assess the generalizability of the theoretical model proposed, a mini-case study on Aircraft Nuclear Propulsion, which took place in the US from 1945 to 1961, is presented below. The features of this case are helpful in extending the generalizability of the model. First, the ANP was a large-scale project that fell within the traditional conceptualization of military R&D on weapons systems (although, as is shown below, such a conceptualization proved to be problematic). Second, the ANP was primarily an Air Force project with the Navy as a minor partner, with little to no Army involvement. Third, the ANP case provides additional variance in the variables that constitute the technical condition. The ANP case thus provides a contextual contrast to the two main case studies analyzed in this dissertation.

7.2 Theoretical Extension – Mini-Case Study on Aircraft Nuclear Propulsion

In the immediate aftermath of World War II, the US actively engaged in the research and development of nuclear power. This R&D included not only nuclear power plants but also the emerging nuclear-powered military systems and platforms, including strategic bombers, submarines, and aircraft carriers. The Aircraft Nuclear Propulsion (ANP) project, a joint technology development program between the Atomic Energy Commission (AEC) and the Air Force which aimed to produce nuclear-propelled, manned aircraft capable of conducting missions such as strategic bombing, sought to leverage nuclear power for extremely long-term continuous flight without the need to refuel. The original proposal put forth by the Engineering Division of the Air Technical Service Command in 1945, just after WWII ended, argued that it was as important to further develop nuclear weapons as it was "'to develop nuclear energy as propulsive means,'" and 'Special consideration should be given to a system whereby nuclear energy would first be used for propulsion to the target and then the nuclear matter detonated as an atom bomb.'"[524] Although originally conceived as a measure to ensure the US's air superiority and ability to conduct long-distance nuclear strikes, as the Cold War wore on and the mutual assured destruction logic took hold, the ability to launch a nuclear weapon as a "massive retaliation" from a strategic bomber that has tremendous speed, endurance, and range seemed appealing and necessary.

Nevertheless, despite fifteen years of R&D efforts and at least one billion dollars in 1950s currency, the project continued to have difficulty in sustaining high-level policy

[524] Engineering Division, Air Service Technical Command, "Proposed Air Engineering Development Center," December 10, 1945, iii, vi, vii, TBL, Records of the President's APC, box 28, quoted in James (2000), 162.

interest and faced constant challenges that threatened its cancellation. By the time the project was officially cancelled under the Kennedy administration's Secretary of Defense Robert McNamara in 1961, it yielded no product and a prototype system was still many years away.[525] This was not necessarily a result of a lack of incentives from the international system. For one, the launch of Sputnik in 1957 raised concerns within the US that it had fallen behind the USSR in science and technology and prompted some in the government to advocate for a crash program that would lead to an early nuclear flight demonstration. In addition, throughout the 1950s, it was known that the Soviet Union also had an interest in building a nuclear-powered aircraft. An *Aviation Week* article in December 1958, which claimed (albeit later proven to be false) that the Soviets were able to "successfully" test a nuclear-powered aircraft, also caused further program reviews despite the slowly declining project support from the Office of the Secretary of Defense (OSD) at that point in time.[526] The project nevertheless from the very beginning suffered from many of the problems that can plague the development of a military system with high levels of funding, including the inter-service rivalry between the Air Force and the Navy that led to duplicated efforts and shifting requirements. Yet, inter-service rivalry alone only captures a part of why ANP ultimately became abandoned.[527] Most importantly, the ANP had several significant technical barriers that needed to be overcome, and as the R&D process unfolded, the scientific and technical expert opinion became increasingly negative toward the feasibility of this project, which created problems for its continued support from policymakers.

[525] It is important to note that the project nevertheless led to developments and later successes in some other related areas of technology such as materials and shielding. See James 184 and US Comptroller General, *Report to the Congress of the United States: Review of Manned Aircraft Nuclear Propulsion Program, Atomic Energy Commission and Department of Defense* (Washington, D.C.: General Accounting Office, 1963), 182-5.

[526] Robert D. Little, *Nuclear Propulsion for Manned Aircraft: The End of the Program, 1959-1961* (Washington, D.C.: Us Air Force Historical Division Liaison Office, 1963), 14.

[527] This is particularly important when one compares the US experience to that of what is known from the Soviet program, which, having decided on a direct cycle system much earlier and had much less inter-service rivalry induced requirements controversies, still cannot sustain the program.

Given the technical concerns, the ANP nevertheless enjoyed some early support from some in the scientific community, who believed that the project was feasible despite its likely high price tag and long developmental timeline. For instance, in 1948, a group of researchers at the Massachusetts Institute of Technology, at the request of the AEC, conducted a feasibility study of the idea of nuclear-propelled aircraft. The outcome, the "Lexington Report," indicated that manned nuclear-powered flight could be achieved in fifteen years if at least one billion dollars and a large quantity of the nation's vital scientific resources were devoted to it. This affirmation gave the needed backing to the initiation of the ANP. Basing its judgment on this report, the AEC also remarked at a project review at the end of 1950 that ANP was technically feasible and that the AEC could find the necessary people and facilities to work on this issue, so long as the need for it can be justified. This early enthusiasm was in part because the need for investment in high technology programs in order to keep the US competitive against the USSR seemed difficult to refute, but also because at the time (in the late 1940s) there were no alternatives to the nuclear strike capability besides strategic bombers, which made the need to develop a highly capable bomber seemed all that more necessary despite the difficulties.

Nevertheless, several interrelated technological problems constituted critical barriers to the ANP project. As the project continued, some of these problems became increasingly apparent. First, in order for a nuclear reactor to be useful in propelling an aircraft, it had to be significantly more compact and efficient than what was available due to weight considerations. At a minimum, it needed to create some 500 percent more energy than the nuclear reactor used in the first *Nautilus* submarines. What this meant was that more resistant materials needed to be developed for the reactor in order for it to operate at higher temperatures in a more compact space without a meltdown. Second, the nuclear reactor needs to be able to generate power that can be efficiently used in an aircraft engine, whether through a direct or indirect power cycle. This meant that in the process of reactor development the design also needed to take into consideration the engines that would be used in conjunction. Third, and perhaps the most critical, in order for the aircraft to be manned, shielding from the reactor in order for the crews and other aircraft components to be protected needs to be significantly more efficient than what was available. The many feet of concrete that constituted the shielding for a rector on the ground would certainly not work, and even the shielding that would have been sufficient for *Nautilus* would be too heavy for an aircraft. According to Carolyn James, all of these considerations "could be rolled up in terms of 'power loading,' pounds of vehicle weight per horsepower; on that practical scale, the *Nautilus* nuclear-powered submarine measured more than 150, while a supersonic bomber would have to be closer to four."[528] These interlinked technical barriers proved to be significant scientific and engineering challenges.

Despite the Lexington Report, the scientific community was in general skeptical of the feasibility of the project due to these technical barriers. Several important figures from the Manhattan Project, who then carried the most policy weight on nuclear matters, were unequivocal in their lack of confidence of the project's feasibility. Some were pragmatic about the project in terms of its likely significant and unjustifiable cost. For instance, as consultants to the AEC, Robert Oppenheimer and James Conant asserted in 1948 that, "although the aircraft could be developed, the technological barriers were too immense to make the endeavor cost-effective."[529] Others had reservations on a more fundamental level. Edward Teller, for instance, expressed in 1953 doubts that a nuclear aircraft could ever reach the test-flight stage given the technical barriers.[530] More than a decade later, in 1967, Teller seemed to still hold the same view. In a National Academy of Sciences report to the House of Representatives on applied science in the US, Teller remarked that for the ANP, "The weight of the radiation shielding was the decisive factor," that even the "Use of the

[528] James (2000), 163.
[529] James (2000), 165.
[530] James (2000), 169.

greatest ingenuity in designing the best shielding led no further than to the conclusion that the weight of the shielding could not be reduced below a very high minimum."[531] What resulted was that "no nuclear-propelled aircraft could be competitive with conventionally propelled ones unless the aircraft was exceeding large, weighing almost a million pounds (in contrast to present airliner weights of a few hundred thousand pounds," and "For lighter aircraft the irreducible weight of the nuclear equipment [including shielding] overbalanced the advantage of exceedingly light fuel [in nuclear materials]."[532] The weight of the scientific opinion was, thus, against the ANP despite the interest from the Air Force (and as a minor partner in this project, the Navy) and the Congress.

Some initial testing in 1956, in which a turbojet engine was coupled to a direct air cycle reactor, saw many of these problems come into light. According to Robert Little in his historical account on how the ANP ended, "An inherent hazard of the direct air cycle, leaks of radioactive material through cracks in the coating of the fuel elements, forced several shutdowns of this test system," and "It was…obvious that reactor operating temperatures would have to be raised much higher to secure a useful system," which "in turn would increase the danger of leakage unless new, more heat-resistant materials were developed."[533] These technical failures, particularly the leaking of radioactive materials, also confirmed many scientists' belief in the inherent danger of a flying nuclear reactor and the public outcry it may create – the exaggerated news reports on the leaks from the testing were sufficient to raise public alert that halted further testing and threatened the need to relocate the research programs to more isolated areas.

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[531] Edward Teller, "The Evolution and Prospects for Applied Physical Science in the United States," in *Applied Science and Technological Progress: A Report to the Committee on Science and Astronautics, U.S. House of Representatives*, edited by the National Academy of Sciences (Washington, D.C.: Government Printing Office, 1967), 367.

[532] Teller (1967), 367. It is important to note that Teller also noted the tremendous environmental risk that a large nuclear-propelled aircraft would incur should it crash in any populated area. He described the resultant casualties as simply "completely intolerable," which was in fact reflective of the opinion of at least some policymakers with regard to the need to end the ANP at the end of the 1950s.

[533] Little (1963), 8.

These problems in technical feasibility were coupled by the fact that the Air Force envisioned this nuclear-propelled aircraft as a supersonic strategic bomber and pursued its R&D in the form of a weapons system.[534] This was made apparent when the Air Force in 1955 generated the operational requirements for weapon system 125A as a move to accelerate the ANP into a weapons program. The minimum performance requirements specified for WS-125A was 1) a radius of 11,000 nautical miles with a dash radius of 1,000 nautical miles; 2) cruising altitude at 30,000 feet with a dash altitude at 60,000 feet; 3) cruising speed of Mach 0.9 and "maximum possible supersonic" dash speed; and 4) bomb load of 10,000 pounds.[535] The desired operational parameters, however, were much higher. These minimum requirements, in short, surpassed the operational capacity of a B-52, then the state of the art conventional (chemical-fueled) strategic bomber, in every aspect except the armament payload, which was likely reduced because the reactor itself was expected to weigh at least a couple hundred thousands of pounds.

Although these requirements remained in place for several more years, it was realized pretty soon that these performance expectations were extremely high for an aircraft in which none of the components, from its propulsion system to the airframe design, were close to be mature, and the entire development trajectory was shrouded with high levels of uncertainty. In 1957, three different ad hoc groups, reporting to the OSD (Littlewood Committee), the Air Force Deputy Chief of Staff for Development (Mills Board), and the Air Research and Development Command (Canterbury Committee) all concluded that the existing requirements were unrealistic with regard to its expected performance and R&D schedule. They also doubted the existing weapons system approach to ANP, suggested the project to return to basic research on reactor development, and recommended an adjustment

[534] Whereas the Navy in fact saw the ANP a little differently as primarily an anti-submarine, reconnaissance, and advanced warning seaplane.

[535] Little (1963), 7.

of the initial goal to the development of a subsonic, low-altitude experimental aircraft.[536] When the principal contractors testified in Congress in mid-June that year and none of them could promise a flyable experimental aircraft for at least another five years, the Air Force changed its requirements for the ANP project to focus mostly on reactor-propulsion system research with an expectation on the accelerated development of at least an experimental aircraft, even if it would be far below the then existing standards for a bomber.

Even with this reduction in expected requirements in the late 1950s on the ANP, given the state of R&D in reactor, propulsion, and shielding technologies, to produce an experimental aircraft at subsonic speed and low altitude that had little military utility remained a tall order that needed concerted effort and large sums of money. However, the Air Force's switch to this goal of an accelerated development of an experimental aircraft caused another problem – what would be the point to spend more money and time on the ANP, if the foreseeable result was an experimental aircraft that had no military utility? The proponents of the ANP argued that the demonstration of nuclear flight, even as an experiment, could have significant psychological value in reassuring the domestic as well as international audiences that the US had not fallen behind, but even that argument was difficult to support when other areas of strategic weapon R&D had seen significant breakthroughs during the same timeframe. Over the 1950s, conventional, chemical-fueled strategic bombers have improved their operational capacity with greater range, speed, and altitude, which has led to less of an urgent need for the theoretically superior albeit much more costly nuclear-fueled ones. Furthermore, although beaten by the Soviet launch of Sputnik, the intercontinental ballistic missile (ICBM) development, which started around the same time as nuclear flight, also had made significant headway and was within grasp at the end of the decade (the first successful flight of the *Atlas* missile took place before the end of 1958). These new and improved strategic weapons alternatives, which were not

[536] Little (1963), 10.

available when the ANP was first conceived, raised questions whether there was truly a military necessity to develop a nuclear aircraft, especially given the expected additional cost it would take.

This problem became an acute concern in 1959 when Donald Quarles, the Deputy Secretary of Defense under Eisenhower, who was in general supportive of the ANP, died unexpectedly. His successor, Thomas Gates, passed the duty of overseeing the ANP within the OSD to Herbert York, the Director of Defense Research and Engineering. York, who worked on the Manhattan Project and was the first director of Lawrence Livermore National Laboratory, commanded respect both within the DoD as well as the White House. Unlike Quarles, York was convinced that the primary problem of the ANP concerned the development of an efficient reactor-propulsion combination and was not inclined to support what he termed the "brute force" approach of an accelerated development for an experimental aircraft that carried no military utility.[537] York remarked in a report to the Secretary of Defense in 1959, for instance, that "no 'reasonably possible' program could lead to militarily useful flight before 1970."[538] Based on York's recommendations, buttressed by reports from the Air Force Science Advisory Board and the Assistant Secretary of the Air Force, which endorsed York's position, the program was reoriented to reactor research. When McNamara took office as the Secretary of Defense under Kennedy, he cancelled the program by reorienting efforts to reactor development strictly within the AEC largely following York's rationale: the significant amounts of accumulated and projected costs, the technical uncertainties and hazards, and the lack of a clearly defined military need.

The ANP case presented above also confirms the main argument of this dissertation, that low feasibility, stringent requirements, and available alternatives led to

[537] Little (1963), 19.
[538] Little (1963), 20 and James (2000), 179.

an unfavorable technical condition for investment in an emerging military technology. The increasingly negative opinion toward the technical feasibility of the project, the stringent performance requirements that were set too high and too early in the developmental process, and the arrival of technology alternatives that placed increasing doubt over the military necessity all made the ANP increasingly unappealing as an investment as the R&D process unfolded.[539] These factors contributed to the changing technical conditions from the initial conceptualization of the project to its demise that led to significant costs, lengthy development timelines, with very little observable results. For these reasons, despite some initial interest, the ANP continued to have difficulty sustaining investment during its developmental process and ultimately was cancelled. Table 8 below shows the preliminary evidence from the ANP case in juxtaposition to the two major studies.

Table 8 - Summary of Evidence (with ANP Case)

Case Study	Time Frame	IV			DV
		Feasibility	*Requirements*	*Alternatives*	*Military Investment*
Biochemical Incapacitants	Before 2002	Mixed to High	Low	Yes	Present
	After 2002	Low	High	Yes	Absent
Neuropsycho-pharmacology	Before 1980	Low	High	Yes	Absent
	After 1980	High	High	Yes	Present
Aircraft Nuclear Propulsion	Early Years (Before 1955)	Mixed to Low	Low (Unspecified)	No	Present
	Later Years (After 1955)	Low	High	Yes	Absent

[539] Henry Lambright's study on the ANP echoes this conclusion. See W. Henry Lambright, *Shooting Down the Nuclear Plane* (Indianapolis, IN: The Bobbs-Merrill Company, Inc., 1967): 32.

The ANP case, when contrasted with the two main case studies, yields some important insights. For one, in the ANP case, the role of technology alternative is highlighted. Whereas in the incapacitant case and the neuropsychopharmacology case, alternative accesses to fulfilling the capability gap, whether through R&D efforts from institutional partners or other "technological" solutions, were in general available during the time periods examined, in the earliest stages of the ANP project, alternatives to strategic bombers for long-distance delivery of a nuclear weapon were scant. This lack of alternative options made the investment in improvements on the strategic bombers, including the potential of nuclear-powered ones, that much more compelling in spite of the low feasibility of the project that many in the scientific community believed. In this sense, the lack of alternatives can play a critical role in the investment of otherwise unappealing technological options.

In addition, similar to how the stringent lethality threshold the military has come to expect from a NLW likely made the use of biochemical incapacitants too risky and their R&D unappealing, the ANP case also highlights that the way requirements are set can impact the perception on the need for an investment. When the Air Force set the requirements for WS-125A in 1955, it likely envisioned that the high expected performance would justify the need to invest more time and money into the project. However, by setting the requirements so high, the Air Force also raised the perceived value of the ANP's utility: investing in the ANP was worthwhile because it was expected to perform much better than conventional strategic bombers. This became problematic when, realizing that the high performance requirements were unlikely to be met anytime soon, the Air Force reduced the scope of the project. This change in the goals caused doubts over the value of a crash down investment program on an experimental aircraft that carried no military utility. In other words, the Air Force overpromised the ANP project and its expected operational ability and did so too early in the developmental process. When such an expectation was shown to be very difficult to meet, the perceived value and need for the technology declined.

The three cases presented in this dissertation confirm that the way a technology is understood by relevant actors in the R&D process matters for its investment. Under certain conditions, these understandings can jeopardize or degrade the technology's appeal as a good investment opportunity. The following sections discuss the theoretical contributions and policy implications of this research.

7.3 Theoretical Contributions

Existing literature in international relations and security studies, particularly as it pertains to defense acquisition or military R&D, has not adequately answered the question of why militaries invest in some areas of emerging technology but not others. For the most part, structural, organizational, or bureaucratic accounts treat technology investment from a demand perspective – these explanations are based on the need to have and use a technology. The arguments and research presented in this dissertation show that the demand perspective is only one side of the coin – the supply of R&D comes from the scientific and technical community, and their understanding of what a technology is and what it can do, in fact, can and does matter for investment decisions. This is especially true for emerging technologies, where uncertainties in developmental trajectories mean that the technical community possesses the authority in defining (or in some cases, interpreting) what is technically possible and *feasible*. As shown in the three case studies presented in this dissertation, the judgement on the feasibility of a technology from the technical and expert communities plays an important role in conditioning whether or not a technology is an appealing investment opportunity. Examining the R&D investment decision from both the supply and the demand perspectives can provide a more complete picture of who is involved in this process, how they are involved, and why their involvement matters.

As discussed, the demand-side explanations often obscure technology as meaningful variable in military R&D investment decisions. Because demand-side explanations focus on the need and the desirability for a technology and place the analytical weight on the structural incentives, organizational ideas, and bureaucratic interests surrounding these factors, they often treat technology itself as exogenous to the political (and sometimes, economic) decision of investment. This dissertation shows that treating technology as a static concept that is exogenous to the politics of defense acquisition is problematic, because technology itself is a sociopolitical product, and its defining characteristics as well as its meaning to those doing the R&D can change over time. As the case studies in this dissertation show, even as technical a concept as feasibility can change over time depending on how the critical barriers that determine it are understood and accepted by those in the expert community.

Furthermore, the recognition of a technology's feasibility or infeasibility is itself a sociopolitical product: The opinion that a biochemical, incapacitating NLW is not feasible due to the dose-response problem arose to prominence as the dominant opinion after the Dubrovka incident in 2002 by the deliberate advocacy of those in the technical community in favor of tighter arms control on chemical weapons. The recognition of neuropsychopharmacology as a meaningful treatment for combat stress came not only as a result of the improvement of neuroscientific techniques, but also as a result of the rise of cognitive neuroscience as a discipline, which facilitated a broader conceptual change within psychiatry from understanding stress-related disorders from being psychoanalytical to neurobiological. Without understanding how a technology and certain characteristics associated with it can change over time, why certain R&D investments occur or disappear may seem puzzling, especially when demand-side explanations cannot seem to account for such a change.

Because this dissertation argues that technology is a product of the time and that a feature such as feasibility is a constructed concept by those who hold power in defining and interpreting it, this dissertation also shows that an explanation that emphasizes the role of technology as a variable need not be understood as technological deterministic. In this sense, the reason for a technology's military investment or non-investment is neither strictly political nor technical. The meaning and the utility of a technology depend on how they are understood by relevant actors in the R&D process. Whether or not a technology is appealing as an investment is a result of the interactions between how the technical details are interpreted and the needs are defined by both those in the expert community, as well as those in the military. This research shows that feasibility, requirements, and alternatives as components that determine the favorability of a technology's investment interact with each other. Thus, it is important for analysts of military R&D to be cognizant that neither technology nor politics alone determines the outcome of investment decisions.

More broadly, this dissertation synthesizes a framework to understand how states may respond to an emerging military technology and shows that risk mitigation is but only one perspective to understand the expected behavior of a technology first-mover. To an extent, the explanatory model of this dissertation helps clarify why there is the perception that states tend to hedge its bets when it comes to emerging military technologies: under most circumstances, the technical conditions are not sufficiently unfavorable to prevent the military from investing in a technology. As shown in the biochemical incapacitant case and the ANP case, the military did spend money to explore the possibility of these technologies early on, and it is only when the feasibility, requirements, and alternatives change to a very specific configuration (low feasibility, high requirement stringency, and available alternatives) that investments in those technologies become sufficiently unappealing. In this sense, it is true that militaries tend to hedge and most military technology investments would seem to be justifiable. What is *not* true, however, is to assume that *all* military technology investments are justifiable and that the military *always* hedges. This dissertation shows that under certain technical conditions, a technology may not be sufficiently appealing for the military to invest in spite of its military utility. To understand this is important for analyzing military R&D and defense acquisition, particularly with regard to how states react to emerging technologies. This dissertation shows a way to divert the analytical thinking on defense acquisition from a dominant, risk-driven perspective to a more nuanced understanding where the conditionality of a technology matters.

Finally, this dissertation provides empirical examples in understudied areas of defense R&D that could be helpful in extending the knowledge on the early stages of defense acquisition. To date, most studies on defense acquisition focus on major programs, such as military weapon systems or platforms. Because the ramifications for these expensive programs' success or failure are significant, these studies focus more on the later stages of defense acquisition (including technology development, testing, evaluation, and procurement) and by nature emphasizes the dynamics of military-industry relations. Yet, the insights derived from these studies are not the most directly useful when examining emerging S&T, where activities often occur at a basic or early applied level of research. This dissertation provides conceptualization of important factors (such as feasibility) as well as actors (such as scientist or technical experts outside the defense industry) and their role in defense R&D, both of which matter for understanding emerging technologies. In addition, since both major case studies examined in this dissertation fall outside the domain of weapons systems or platforms and are unconventional areas of S&T for studies in acquisition, the dissertation provides an initial step at addressing this empirical gap in the analysis of defense acquisition and military R&D.

7.4 Policy Implications

Science and technology have advanced at a very rapid pace in recent eras, and states today face a myriad of emerging technologies, many of which carry implications for the military. Understanding how a state invests in these military-relevant emerging technologies is of critical importance to those desiring to be technologically superior to its adversaries or peer competitors in military terms. This dissertation shows, nevertheless, not all emerging military technologies will get invested by a first-mover state despite its tendency to hedge against uncertainty. As shown in this research, whether or not a technology gets invested depends on the favorability of its technical condition – if the condition is unfavorable, the technology can have difficulty attracting or sustaining investment despite its military utility.

Internationally, this knowledge is important for states that have an interest in understanding the investment behavior of a technology first-mover, which may include states investing as second movers or ones competing to be the first-mover. Among the emerging military technologies, what may have attracted a first-mover's investment does not necessarily represent the full scope of technological opportunities. Some technologies may in fact fail to attract a state's investment because they are not perceived as appealing for technical reasons. Yet because the factors that determine the technical condition for a technology are not necessarily universal and can be highly contextual to a specific state, what may be neglected or abandoned in one state does not mean that it carries no utility or R&D potential for another. In a similar vein, an emerging military technology that is invested by one state does not automatically mean that its potential could be realized in another.

In this sense, for those observing the international military S&T investment landscape, high level measures that assess a state's R&D capacity, security requirements, military organization, or bureaucratic structure may, in some cases, not provide sufficiently granular information on whether or not, and how, this state will invest in an emerging military technology. In some cases, information on how this technology is understood by the technical community within the state and whether there is a dominant position on the technology's feasibility, what are the performance expectations of this technology by the military and from what sources does it likely derive its expectations, and what technologies are regarded as alternatives and to what extent are they available, may be important in understanding a state's investment behavior. Efforts to evaluate and assess the directionality of a state's investment in emerging military technology can require not just technical or military expertise, but also more detailed knowledge of the state's technical communities.

For defense planners managing a state's military investment in an emerging technology, this research shows that the way requirements articulated by the military can adversely impact the prospect of developing the technology. As shown in the biochemical incapacitant and the ANP case, performance requirements that are derived from what may be perceived as comparable technologies could, in some cases, be unreasonably high for an emerging technology. Such a high expectation can threaten a R&D program when it faces potential challenges because the possibility for the goals to be reached within a reasonable cost and schedule can come in doubt. Furthermore, benchmarking the performance expectations of an emerging technology against a more mature alternative can inadvertently cause the value of the investment to be questioned if the emerging technology fails to meet the goals. In comparison to a mature and available alternative, an emerging technology that may work better but would take significantly more time and funding to achieve runs the risk of becoming unappealing in the eyes of budget and schedule-conscious policymakers. Military requirements for an emerging technology, in this sense, can be set too early and too high. When managing the R&D in an emerging technology that has the potential to face significant political challenges, an incremental approach to goal setting whereby the performance expectation are benchmarked by what can be realistically expected from the technological horizon rather than a mature alternative technology whose performance this emerging technology is expected surpass is more likely to ensure the research program's long-term viability.[540]

This research also shows that in order to better understand and manage emerging technology investments, supplementing the dominant risk-mitigation analytical policy thinking with a more nuanced understanding of the opportunities new emerging technologies represent is critical. Because risk mitigation behavior, by nature, avoids prioritizing a technology when decisions need to be made with great uncertainty, it carries the potential of overlooking important differences between technological options. More importantly, without some knowledge as to how the feasibility is understood, how the requirements are derived, and where alternatives may lie, risk-avoidance driven investments in emerging technologies may yield little to no result or at its worst jeopardize the long-term viability of developing a potentially promising technology. In this sense, as important as it is to hedge one's bet in order to avoid technological surprises, understanding the conditions that can make a technology an unappealing investment opportunity is equally important. Greater efforts at understanding and analyzing the scientific or technical opinions surrounding the technology, with particular attention to where technical barriers may lie and how they are understood, for instance, could be beneficial for defense planners managing investments in emerging technologies.

Finally, buying knowledge can be as important as buying flexibility in the investment management of emerging military technologies. Faced with broadened scope of military missions, rapidly developing technologies, and increased budget pressure, since 2010 the DoD has engaged in efforts at changing its acquisition system through the Better

[540] This of course does not apply to R&D efforts that are deliberately meant to be high-risk, high-payoff, limited (and temporary) in scope, and problem-driven (rather than requirements-driven), and most critically, insular from political challenges that may arise should they fail, like how DARPA programs are managed.

Buying Power, with the most recent iteration (Better Buying Power 3.0) launched in 2015. This initiative, which seeks to make the defense acquisition system more agile, efficient, and cost-effective, emphasizes in its most recent iteration the importance of rapid prototyping. This effort, which enables quicker access to new technologies for field testing and avoids early commitments to production, allows the DoD and the military to have greater flexibility in its ability to respond to changing technological needs. However, as demonstrated by the research conducted in this dissertation, particularly through the neuropsychopharmacology case, science and technology operate outside the military domain with their own set of political as well as social forces, and sometimes a potential technological solution to a problem can be marginalized because the existing state of knowledge limits how the problem and solution can be conceptualized. It was through increased knowledge of the human brain resulting from basic research on cognitive sciences, along with significant sociopolitical efforts in medicalizing psychiatry, that a shift from a psychosocial to a neurobiological model of psychiatry was able to occur.

Thus, while a quick route to a solution, such as rapid prototyping, may help the DoD's acquisition system reduce cost and increase its responsiveness, it can also inadvertently lead to what David Rioch was wary of in his belief about investing in psychopharmacology: obtaining a perceived "silver bullet" may prohibit the additional scientific research needed to better understand the underlying mechanisms of a problem. In this sense, it is important that policymakers and defense planners in their pursuit to have flexibility in dealing with emerging technologies not undermine the need for basic research. Use-inspired research that pushes scientific and knowledge-boundary, such as the kinds that would fall under the Pasteur's quadrant, could be very important in broadening the knowledge base, which may ultimately enable different and novel routes to defining and solving a problem.

Understanding and managing investment for emerging military technologies is difficult, and uncertainty can be a strong motivator that pushes states to behave in a risk-avoidance manner that undermines their ability to appreciate important differences that may exist between emerging technologies. Sensitivity to how an emerging technology is understood by relevant actors in the R&D process, particularly in regard to its feasibility as interpreted by the technical community, its requirements as defined by the military, and its potential alternatives can lead to not only greater insight about investment decisions, but also better policy understanding as to how to best manage the technology.

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