Agroterrorism: National Defense Assessment, Strategies, and Capabilities

Edited by:
Mr. Albert Mauroni
Dr. Robert A. Norton

United States Air Force
Center for Strategic Deterrence Studies
Maxwell Air Force Base, Alabama

Agroterrorism: National Defense Assessment, Strategies, and Capabilities

Edited by

Mr. Albert Mauroni
Dr. Robert A. Norton

August 2020

U.S. Air Force Center for Strategic Deterrence Studies
Air University
Maxwell Air Force Base, Alabama 36112

Table of Contents

Disclaimer

ISBN: 978-0-9914849-5-9

Preface

Lt. Gen. Ronald L. Burgess, Jr.
U.S. Army (Ret.)
Executive Vice President of Auburn University

Just as this book on agroterrorism reaches the final stages of development, our nation is in the midst of fighting a global war. Our foe is not an intractable nation-state bent on world domination, but rather an invisible, inanimate, mindless enemy that surrounds us.

The United States spends massive resources annually on responding to “thinking adversaries.” However, this “unthinking adversary,” the SARS-CoV2 virus and cause of the COVID-19 pandemic, has caused unprecedented global disruption, worthy of the most clever and powerful adversarial nation-state. Nature has once again proven to be the most dangerous bioterrorist and again reminded us that we have much to learn from it.

As of this writing, we certainly do not yet understand the full spectrum of implications from the coronavirus. Who would have anticipated that physicians and medical personnel in some parts of the country would experience pay cuts or job loss during a pandemic? And yet, it has happened. Before the start of the pandemic, the thought would have been inconceivable, yet what would happen to us if the trained health professionals just walked away, exhausted by the relentless hours and no longer willing to absorb the risks or personal costs?

We must recognize that a deliberate attack against our crops and livestock could be equally as devastating and exhausting as this current crisis. For many human and animal outbreaks that have occurred over the years, government, medicine, and business decisionmakers have demanded new technologies to help detect, contain, and mitigate the spread of disease. In most instances, the existing plans and capabilities had to be rapidly modified once the disease gained momentum. As is often the case, some assumptions borne of long planning and gaming were wrong, or perhaps only partly right, while others were spot on.

As the current pandemic has reminded us, logistics challenges always seem to occur during emergencies. A future agroterrorism incident will have similar features, such as a shortage of emergency supplies, deterioration of strategic stockpiles of certain items (e.g., surgical masks and gloves), or bureaucracies that emphasize form over function.

As we prepare to defend against agroterrorism, we must factor in the human element, the thinking adversary who chooses to advance the chaos borne of a pathogen to gain advantage. To be successful, the adversary must penetrate our nation’s defenses before his pathogenic weapon can be deployed. Once deployed, the pathogen remains first undiscovered or undiagnosed, enabling it to gain a foothold in the targeted animal or plant population.

From there, the disease takes on a life of its own within that population, magnifying the disease effects, as its spreads. With the pathogen now delivered, the adversary can fade into the darkness, awaiting the next opportunity to attack.

Due to the intentionality of the adversary, agroterrorism has the real potential of needing an even more complex response than an outbreak of a naturally produced virus. The very real possibility of intentional *chemical* contamination of food further complicates matters, because response time and medical management would almost certainly prove inadequate.

Agroterrorism differs greatly from natural disease outbreaks and disasters for many reasons, primarily because Americans have not known widespread hunger since the Great Depression. Government and agribusiness are supposed to be vigilantly on the lookout for adversaries. However, as has been proven many times since the Sept. 11, 2001, (9/11) terrorist attacks, those in charge of surveillance have to be right every time while the adversary gains advantage by only having to be right once. The primary goal of the adversary, beyond diminishing the availability of the actual food supply, is stoking fear about what remains. Is it safe to eat?

Amidst the problems encountered in emergencies, people emerge by discovering expedient solutions to problems unimagined in white papers or mathematical models. People and their intellectual prowess will always remain our greatest assets and yet we often do not treat them as such with the freedom to think, question and challenge.

Countless times in our nation’s history, these people have proven essential to our survival. The selections in this book demonstrate that we can listen to them and prepare for these crises, rather than have such crises come upon us unannounced.

About the Authors

Dr. W. Seth Carus is Emeritus Distinguished Professor of national security policy at the Center for the Study of Weapons of Mass Destruction at the National Defense University. He was on the NDU faculty from 1997 through 2017, serving from 2003 to 2013 as the deputy director of the Center. From 2001 to 2003, Dr. Carus was detailed to the Office of the Vice President at the White House, where he was the senior advisor to the vice president for biodefense. Before joining NDU, Dr. Carus worked at the Center for Naval Analyses (1994 to 1997), the Policy Planning staff in the Undersecretary of Defense for Policy, Office of the Secretary of Defense (1991 to 1994), and the Washington Institute for Near East Policy.

Dr. Carus' work has focused primarily on issues related to biological and chemical warfare. His current research focuses on the history of chemical and biological warfare. He is author of *A Short History of Biological Warfare: From Pre-History to the 21st Century* (2017), "The History of Biological Warfare: What We Know and What We Don't" in *Health Security* (2015), and *Defining 'Weapons of Mass Destruction,' Revised and Updated* (2012), as well as the working paper *Bioterrorism and Biocrimes: The Illicit Use of Biological Agents Since 1900* (2001). He is the co-author of *The Future of Weapons of Mass Destruction: Their Nature and Role in 2030* (2014).

Dr. Carus has a doctorate in international relations from Johns Hopkins University.

Dr. David Ellis is a research toxicologist at Wright-Patterson Air Force Base, Ohio, and an adjunct faculty member in the Department of Pharmacology & Toxicology, Boonshoft School of Medicine, Wright State University, Ohio. Dr. Ellis earned a bachelor of science degree in toxicology from Ashland University, a master of science degree in pharmacology and toxicology and doctorate in biomedical sciences from Wright State University. He has worked in industry (Kao, Procter & Gamble, HMR Pharmaceuticals, Wil Research), government (U.S. Environmental Protection Agency HERL, Aerospace Research Laboratories, Air Force Research Laboratory, Naval Medical Research Unit), and academia (Wright State University), giving him strong scientific expertise. He is also a member of Dayton Infragard, FBI Cincinnati Citizen's Academy Alumni Association, AAAS, the Ohio Academy of Science, the Aerospace Medical Association, and the International Society for Gravitational Physiology.

Mr. William Greer Jr. leads the 711th Human Performance Wing's Aircraft CBRN Survivability team within the Air Force Research Laboratory (AFRL). He is a graduate of the Syracuse University School of Engineering and holds an MBA from Chapman University, Calif. He was commissioned and served more than 23 years in the U.S. Air Force where he was involved with a number of acquisition and research programs including Peacekeeper ICBM development, Space Systems development, various chemical and biological (CB) studies and experimental research to advance aircraft CB decontamination capabilities.

Currently, he leads research and development covering several chemical, biological, radiological, nuclear (CBRN) survivability initiatives.

Mr. Paul Imbriano received his master's degree in biomedical sciences at Eastern Virginia Medical School and is currently a fourth-year medical student at the University of New England College of Osteopathic medicine. He has a particular research interest in medical response protocols in the setting of unconventional warfare. In addition, he is a current United States patent holder of smart weapons technology.

Mr. Reid Kirby is a military historian and consultant to government, scholars, publishers, and television documentarians. His focus is on the history of chemical and biological weapons technology development and doctrine. He is currently working on a historical study of American Cold War biological weapons relating to air power doctrine and nuclear weapons.

Dr. Douglas Lewis leads the 711th Human Performance Wing's Protection Systems team. He has degrees from the U.S. Air Force Academy in biology, Penn State in genetics and George Mason University in biodefense. He is a retired lieutenant colonel, having served more than 27 years in the U.S. Air Force and U.S. Army. He has several CBRN-related assignments to include the Defense Intelligence Agency, (DIA), U.S./U.K. scientific exchange, the Defense Threat Research Agency (DTRA), Headquarters, Air Force, and the Air Force Institute of Technology. He currently heads a research team advancing medical and C-WMD protection for deployed airmen in austere environments.

Ms. Janet Marroquin is currently a researcher at the Institute for Defense Analyses, a federally funded research and development center that provides technical expertise to the U.S. government on matters of national security and defense. Her projects have focused on assessing defense capabilities against chemical, biological, radiological, and nuclear threats and analyzing emerging technologies. She has a master of science degree in biodefense from George Mason University and bachelor of arts in speech and hearing sciences from the George Washington University, Washington, D.C. Additionally, she is completing her doctoral studies at George Mason University, specializing in technology and weapons of mass destruction.

Mr. Albert Mauroni is the Director of the U.S. Air Force Center for Strategic Deterrence Studies at Air University, Maxwell Air Force Base, Ala., and an adjunct scholar at the Modern War Institute. He has more than 30 years of experience in Department of Defense counter-weapons of mass destruction (WMD) policy and program development. In his current position, he oversees the development and execution of Air Force education, research, and outreach initiatives relating to counter-WMD and nuclear deterrence operations. Mr. Mauroni served as a U.S. Army chemical officer for seven years before leaving active duty in 1992.

He holds a master's degree in administration from Central Michigan University and a bachelor's degree in chemistry from Carnegie-Mellon University. He is the author of eight books and numerous journal articles, to include articles in *War on the Rocks*, *Modern War Institute*, *Texas Security Review*, and *Joint Forces Quarterly*. His latest book is *Countering WMD: Assessing the U.S. Government's Policy* (Rowman-Littlefield, 2016).

Dr. Todd M. Myers has been advancing our understanding of chemical threats and evaluating the safety and efficacy of medical countermeasures for 20 years. After receiving his doctorate from West Virginia University in 2000, he served as a National Research Council Post-Doctoral fellow at Walter Reed Army Institute of Research, and earned the Edward L. Buescher Young Scientist Award For Innovation. Working as a research toxicologist, program advisor, and subject matter expert at the United States Army Medical Research Institute of Chemical Defense, Dr. Myers has studied chemical and biological threats in several, diverse in vivo animal models, including mice, transgenic mice, rats, ferrets, swine, and several species of monkeys. In these roles, Dr. Myers has provided pivotal and actionable data on the physiological, pharmacological, biochemical, and behavioral characteristics of several advanced candidate medical countermeasures and serves on numerous domestic and international committees to deepen our understanding of chemical threats and advance medical defense.

Dr. Terry Oroszi is a faculty member and director at Boonshoft School of Medicine (BSOM), part of Wright State University in Dayton, Ohio. Her subject matter expertise is homeland security. As part of her role at BSOM, she serves as director of the graduate and the chemical biological, radiological, nuclear (CBRN) defense programs. She started her career in the U.S. Army, transitioned to the laboratory doing molecular genetics work, and merged her military and science experiences to develop the homeland security focus for the medical school and the Department of pharmacology and toxicology.

Dr. Oroszi has several collaborations with military, industry, academia, and the government in the areas of CBRN, terrorism and crisis decision-making. She is the founder and chair of The Dayton Think Tank, a gathering of the top 50 crisis leaders in the region. As a civilian, Oroszi has received training from the FBI through two programs in 2018 and 2019, and president of the Dayton InfraGard (FBI/public sector partnership) and has shared her expertise with NSA, at Quantico, and members of Congress in Washington, D.C. Her subject-matter expertise in terrorism and crisis leadership has been recognized in media, including print, web, and television and as an invited speaker at national conferences for military, government, and industry leaders. Along with several journal publications, she is a co-editor and contributing author of *Weapons of Mass Psychological Destruction and the People that Use Them*, Praeger ABC-Clio, *The American Terrorist: Everything You Need to Know to be a Subject Matter Expert*, Greylander Press (a book covering four years of dedicated research on American citizens charged with acts related to terrorism).

Dr. Henry S. Parker is an adjunct professor at the Georgetown University School of Medicine, where he taught a course on biological threats to food and agriculture from 2009-2019. He was formerly a research manager and Acting Director of Homeland Security for the Agricultural Research Service of USDA, and a university professor of marine sciences. He is a retired captain in the U.S. Naval Reserve. He is also a writer. His debut novel, *Containment* (a bioterror thriller), was published by Simon & Schuster (Touchstone imprint) in January 2017.

Dr. Nathaniel C. Rice received his doctorate from West Virginia University in 2014, where he studied learning and forgetting in timing tasks and developed a slot-machine analogue to evaluate gambling and risk-taking behavior in pigeons. This latter work formed his dissertation, which earned a basic dissertation award from APA Division 25 in 2016. Now a research scientist at the United States Army Medical Research Institute of Chemical Defense, he continues to develop animal models to characterize physiological, pharmacological, and behavioral effects of chemical agent exposure and to evaluate the safety and efficacy of traditional and newly developed medical countermeasures. Together, Dr. Myers and Dr. Rice developed voluntary ingestion models in rats and non-human primates to assess organoleptic properties of potential chemical threats. Their efforts have directly improved risk assessments and threat modeling used by collaborative government agencies to better predict outcomes in a civilian mass-casualty intentional adulteration event.

Mr. Steven Schmitt is a U.S. Army officer candidate with 10 years of service. He has four years of experience in WMD/CBRN response and specializes in technical decontamination in a WMD civil support team. He is a doctoral student of strategic intelligence at American Military University. He completed a bachelor of arts in English at Ashford University. He also holds a dual master of arts in homeland security and emergency and disaster management from American Military University.

Major Kelley Williams is a U.S. Army officer with more than 17 years of service. He has more than 11 years of experience in WMD/CBRN response and held numerous positions on WMD-Civil Support Teams and the 20th CBRNE Command's Nuclear Disablement Teams. He is a doctoral candidate in emergency management at Capella University. He also holds a master of science degree in combatting WMD from the Air Force Institute of Technology, microbiology and immunology from Wright State University, and management from Embry-Riddle Aeronautical University. He completed his bachelor of science in aerospace engineering from Virginia Tech and is an alumnus of the Virginia Tech Corps of Cadets.

Colonel (Dr.) Oliver Wisco is a U.S. Air Force officer with more than 22 years of military service. Currently, Colonel Wisco is an Individual Mobilization Augmentee Reserve Officer assigned to Air University, Maxwell AFB, Ala. In this position, he serves as the Academic Program Manager for the Center for Strategic

Deterrence Studies where he directly supports the Air Force Strategic Master Plan's strategic vector to "Provide Effective 21st-Century Deterrence." Previous to this position, he served for three years as the Commander of the 142nd Detachment 1 Squadron. In this position, he led the Oregon CBRN and Mass Casualty Medical response team. Colonel Wisco is also a USAF flight surgeon. In his civilian position, Wisco is the Director of Cutaneous Oncology at Brown University. In both his civilian and military careers, his work has been focused on risk analysis and policy development to mitigate risk, with a special focus on CBRN deterrence and response.

CHAPTER 1

Introduction

Albert Mauroni

The agriculture industry in the United States accounts for more than five percent of the U.S. gross domestic product (about a trillion dollars) and provides jobs for more than 10 percent of U.S. workforce. Agriculture impacts more than just the food provided for the family dinner. It's a part of forestry, fishing, food and beverages for restaurants, textile, and leather products, plus tobacco products.[1] In order to keep this industry vibrant and healthy, farmers require a significant investment in resources and technology to keep their businesses solvent. To ensure that the food is safe to eat and affordable, Congress plays a significant role in providing oversight on farm policy as well as the U.S. Department of Agriculture's role in regulatory management. Given these points, it becomes important to understand what might negatively impact this pillar of American society.

We know that climate change, natural disease outbreaks, and imports of foodstuffs all have dramatic impacts on farming and nutrition programs. In 2018, the Trump administration signed a bill authorizing $867 billion in farm subsidies to take place between 2018 and 2023. We have seen presidential guidance as well as congressional legislation developed to protect this industry. However, we also must understand the possibility of deliberate attacks on agriculture. Farmland and ranches, by the very nature of their vast size and presence on open lands, would be soft targets for any extremist group or adversarial nation that wished to introduce a biological disease into the U.S. agricultural system. Fortunately, there has not yet been an actual agroterrorism event within the United States, but are we just taking that absence of incidents for granted?

The Office of the Director of National Intelligence provides an unclassified assessment of threats to the United States every year in testimony to Congress. Routinely, there is a paragraph on the threat posed by nation-states and violent extremist organizations in their development of weapons of mass destruction (WMD). In the 2019 *Worldwide Threat Assessment*, the intelligence community notes that, "The threat from biological weapons has also become more diverse as BW agents can be employed in a variety of ways and their development is made easier by dual-use technologies."[2] Often we view these statements as cautions warning about anti-human biological warfare (BW) agents, but is the United States prepared for deliberately developed biological agents that target crops, plants, and animals?

Between 2000 and 2004, there were a number of academic papers and discussions on the threat of anti-plant and anti-animal BW agents. Without much surprise, this was building on the recent 2001 Amerithrax incident and concerns from the White House as to the needs for a more comprehensive national strategy on biodefense. Also in 2004, the Defense Threat Reduction Agency (DTRA) asked the U.S. Air Force Counterproliferation Center (now the Center for Strategic Deterrence Studies) to conduct a study to determine the potential involvement of defense forces in response to a domestic agroterrorist event. This report, titled *Agroterrorist Attack: DOD Roles and Responsibilities*, was released in 2006 to start a discussion on the threat and the military's role in combating agroterrorism.[3]

The report identified a number of challenges to the successful use of Department of Defense (DOD) assets in response to an agroterrorism incident. It should not be a surprise that DOD defers to the Department of Homeland Security (DHS) and U.S. Department of Agriculture (USDA) for options on how to handle such events, and that DOD's priorities are often pointed at contingency operations in overseas locations. That said, there are natural affinities to the DOD homeland security role, both in the form of forces provided through plans developed by U.S. Northern Command and in the extensive medical management and biosurveillance capabilities within the military services. It becomes a matter of employing the interagency to leverage DOD capabilities in a timely manner, ideally in a proactive manner, to prepare for agroterrorism events.

This edited book provides an update on several of the topics associated with concepts to address agroterrorism. In Chapter Two, Reid Kirby and Dr. Seth Carus provide a historical review of agroterrorism, and in particular, a focus on the anti-crop program of the United States. There are few agroterrorism cases of which to study, making it difficult to predict the possibility of future incidents. Natural disease outbreaks testify to the severity of possible agroterrorism incidents, but terrorists have not, for whatever reason, taken advantage of this form of warfare.

In Chapter Three, Dr. Terry Oroszi and Dr. David Ellis offer an examination of the terrorist profile by examining the demographics of individuals who have been charged with terrorism. Understanding what drives people to such a level of violence may offer a window into anticipating and mitigating acts of terrorism, to include agroterrorism. Of particular concern are those individuals who joined the military for training so as to become more adept at using firearms and explosives.

In Chapter Four, Maj. Kelley Williams and Steven Schmitt discuss some of the challenges in detecting an agroterrorism incident, in particular a foreign animal disease (FAD), and how the United States might investigate such incidents. A key aspect of this response will be professional training and an understanding of the interagency approach necessary to mitigate the damage.

Henry Parker and Janet Marroquin outline the numerous government agencies and their responsibilities to address agroterrorism in Chapter Five and discuss the challenges of organizing and directing these agencies given the complex arena within which they operate. Again, using the interagency in addressing an agroterrorist incident will be key to successfully mitigating the overall damage to the agricultural sector of the United States.

Dr. Nathaniel Rice and Dr. Todd Myers offer an assessment tool for food defense chemical threat prioritization in Chapter Six. Given the many possible permutations of the threat source and target, it becomes very important to provide technical approaches to determining which chemical threats might be undetected by the general population and to preempt such attacks, if possible. In an environment where such incidents are seen as low probability, high consequence, being able to prioritize resources toward the most damaging incidents will be key to future mitigation strategies.

In Chapter Seven, Bill Greer and Dr. Douglas Lewis discuss the processes by which the U.S. military practices pest control and works to prevent its forces from inadvertently introducing invasive species into the United States or other nations, as U.S. forces move around the globe. These processes can readily be adapted to support domestic and foreign responses to agroterrorism incidents or to support humanitarian relief and disaster assistance missions. While the Air Force does not have a unique capability or process to address agroterror threats, there are promising technologies that could be developed for this purpose.

Col. (Dr.) Oliver Wisco and Paul Imbriano take a look at the aspects of deterrence theory and how it might be applied against terrorists seeking to attack the U.S. agricultural sector in Chapter 8. By examining DOD policy and homeland security strategies, they offer recommendations on how the CBRN Response Enterprise could benefit DOD's agroterrorism response capabilities and thereby enhance deterrence against these groups.

Finally, in the final chapter, Dr. Robert Norton and Greg Weaver review the interconnections between the U.S. agricultural sector and other critical infrastructure sectors, noting the potential catastrophic impact on the U.S. agricultural sector may be achieved with means other than traditional biological pathogens. We conclude with a set of recommendations for consideration.

This book is not meant to be an all-encompassing review of U.S. agroterrorism policy with all the right answers. We understand that DOD is not the lead agency for agroterrorism prevention or response, but that the department does have certain unique capabilities and will certainly be expected to support the USDA in any future catastrophic incident. With that in mind, we need to refresh our understanding of the issues, DOD capabilities, and potential policy changes that could improve the resiliency of the U.S. agricultural sector.

Chapter 1 Notes

1. U.S. Department of Agriculture, September 2019, available at www.ers.usda.gov/data-products/ag-and-food-statistics-charting-the-essentials/ag-and-food-sectors-and-the-economy.

2. Office of the Director of National Intelligence, "Statement for the Record: Worldwide Threat Assessment of the U.S. Intelligence Community," Jan. 29, 2019, p. 8, available at www.dni.gov/index.php/newsroom/congressional-testimonies/item/1947-statement-for-the-record-worldwide-threat-assessment-of-the-us-intelligence-community.

3. Tasha Pravecek, Jim Davis, and Thomas Berg, *Agroterrorism Attack: DOD Roles and Responsibilities* (Maxwell AFB, Ala.: USAF Counterproliferation Center, 2006), available at www.airuniversity.af.edu/Portals/10/CSDS/Books/agro_terror2.pdf.

CHAPTER 2

Agroterrorism Perspectives

Reid Kirby and Dr. Seth Carus

Despite the many fears of agroterrorism, such attacks are uncommon and rarely cause significant damage when they do occur. The picture would not change greatly even if agroterrorism was broadly defined to include not just attacks on crops and farm animals, but also those aimed at forestry, food processing, and draft animals for use as transport. Nor does the picture change appreciably when the range of violent actors is extended to include state use in armed conflict, covert state terrorist-like attacks, and criminal acts for personal gain. As John Parachini noted in 2003, "There are surprisingly few historical examples of intentional attacks by subnational actors or states against agricultural production and food processing."[1] Almost all known terrorist attacks on agriculture employing chemical or biological agents have been small scale, consisting of a single attack inflicting limited damage, or multiple small-scale attacks, generally ineffective.

There was only a single significant example of a country attacking agriculture using chemical or biological agents warranting closer examination: the development and employment of herbicides by the United States military before and during the Vietnam War. While the main goal was destroying vegetation giving cover to North Vietnamese and Viet Cong forces, the herbicides also targeted crops used by the Viet Cong to support their operations. Accordingly, this survey of agroterrorism starts with a survey of state programs for attacking agriculture, followed by a short history of the U.S. program to provide insight into the complexities associated with mounting large-scale attacks on agriculture. Although other countries, such as the Soviet Union, certainly devoted effort to agricultural attack capabilities, extensive, publicly available archival records exist only for the U.S. program. Only following that is the incidence of agroterrorism reviewed.

State Covert Attacks on Agriculture

During the 20th century, several countries organized programs to use biological and chemical agents for attacking agricultural targets. Most of these programs sought to find means to covertly employ plant and animal pathogens, although not necessarily against food. France researched such capabilities during the First World War and subsequently during the interwar period. Discovery of this research after France's defeat in 1940 led to similar endeavors in Germany, although no formal program resulted. Both Britain and the United States organized anti-agriculture programs during the Second World War. The only product of that work was a large number of anthrax cakes that the British kept for retaliatory attacks if the Germans employed biological agents by releasing them over German farms, expecting that cattle would consume them and die from anthrax. Instead of relying primarily on pathogens, as will be discussed in more detail below, the United States focused increasing attention on chemical substances for killing plants. After the Second World War, the United States, the Soviet Union, and Iraq are known to have had components of their biological weapons programs targeted at agriculture.[2]

There are many claims that one country or another used biological agents to attack the agricultural resources of another. Most of these allegations are patently false, and many were deliberately crafted lies, components of disinformation campaigns. However, there have been a handful of incidents and campaigns for which there is credible evidence.

That people worried about the threat is evident from the beginning of the 20th century. During the Boer War, a 1901 London newspaper report, apparently based on rumors originating in New Orleans, claimed that Boer agents operating in the United States had deliberately infected horses and mules purchased for use by the British Army in South Africa with the organism responsible for glanders.[3] A similar story circulated the next year.[4] There is no evidence to support those claims.

In contrast, the Germans conducted a global campaign during the First World War to interfere with Allied purchases of replacement horses in the United States and elsewhere. Before armies mechanized, they relied on horses and mules for logistics and tactical mobility, so killing or incapacitating such animals had considerable strategic utility. These operations are well documented and have been well documented elsewhere, so will not be described here.[5] However, the campaign had little if any effect. British Army veterinarians kept a close eye on the health of their draft animals and detected only a few cases of anthrax during the entire war, although there were several hundred cases of glanders, which may or may not have resulted from the German operations. Indeed, of 269,000 horses and mules lost by British forces in France, only 772 became sick with glanders or anthrax, and it is possible that those glanders and anthrax cases were of natural origin.[6]

Even after the First World War, both Germany and the United Kingdom feared that the other country would target their agriculture. In particular, both countries came to worry about a release of Colorado potato beetles to infest crops. There was at least one claim by a British scientist that the Germans disseminated such insects in the British Isles, but there is no corroborating evidence, and the claim should be discounted.[7]

During the Cold War, Soviet bloc countries claimed that the United States and other Western powers attacked them with biological agents. While the most notorious of these allegations is the allegation that the United States created AIDS and deliberately spread it, there also were several claims of attacks on Eastern bloc agricultural resources. East Germans made the first such allegation, accusing the United States of deliberately spreading Colorado potato beetles in their country. The East German claims were followed by "Germ War" propaganda during the Korean War. The most careful review of such allegations, undertaken by Milton Leitenberg, shows that they were part of a deliberate disinformation campaign mounted by the Soviet Union and its allies.[8]

Although an American source sympathetic to the Cubans once blamed the United States for about two dozen agriculture-related attacks on their country, ostensibly targeting sea turtles, sugar cane, swine, poultry, dairy cattle, bananas, bees, tobacco, rabbits, citrus, and coffee, a review by Ray Zilinskas identified only a dozen allegations in Cuban sources. The most widely publicized, and the only one that the Cuban government gave official status, was a 1997 claim that the United States deliberately introduced a pest insect, *Thrips palmi* (Thrips) in 1996, leading to widespread infestations and thus damaging many crop plants. The Cuban complaint led to a consultative meeting of the State Parties to the Biological and Toxin Weapons Convention. The meeting ended inconclusively. Most of the participating countries found the Cuban evidence unconvincing. Zilinskas, in his assessment, found plausible explanations for all of the alleged outbreaks and also found the Cuban evidence supporting their claims either nonexistent or unconvincing.[9]

For reasons that are not completely evident, in 2010 the Russian government resumed is disinformation activities claiming that the United States and its regional allies had resumed biological warfare activities, including attacks on Russia and others. In 2013, a Russian government official asserted that a laboratory funded by the United States in the Republic of Georgia was responsible for the deliberate introduction of African swine fever into Russia, causing a massive outbreak that caused considerable economic damage.[10]

Much disputed is the 1978 anthrax outbreak in Rhodesia, now Zimbabwe. At the time, a small European elite had seized control of what had been a British colony and were fighting to prevent the black majority population from taking over the country. The Rhodesian government is known to have employed chemical agents against the insurgents. They probably employed biological agents as well, although this is less well documented. It has been argued that an anthrax outbreak, which caused 10,738 documented human cases, including about 200 human fatalities, resulted from the deliberate introduction of *Bacillus anthracis* into the cattle herds of the indigenous population. While the outbreak had many unusual features, the evidence is not sufficiently strong to confirm an intentional attack. As a result, the most recent assessments are either skeptical of the claim or call for additional research.[11]

The former Soviet biological weapons scientist, Ken Alibek, reported having been told that sometime between 1982 and 1984 the Soviet Union mounted an operation using Il-28 light bombers to disseminate the causative agent of glanders, *Burkholderia mallei,* apparently to eliminate horses used for transport by *mujahidin* forces.[12] The accuracy of the allegation and the effectiveness of the infections, assuming they occurred, is unknown.

United States Anti-Crop Program

The United States had an active biological warfare program from 1941 through 1969. The program was under the auspices of the Army Chemical Warfare Service (CWS), which became the Chemical Corps in 1946, centered at Camp Detrick, Md. (which became Fort Detrick in 1956). Throughout the life of the program, advocates repeatedly argued that biological warfare could selectively target either people, plants, or animals. Strategically, they claimed, biological warfare could neutralize an enemy's war-making industries, directly by killing or temporarily incapacitating a country's workforce or indirectly from famine through food denial.[13]

The number of known plant pathogens is around 8,000 mycotic agents, 200 bacterial agents, and 500 viral agents, not counting numerous additional subtypes pathovars. Pests are known to spread more than 100 plant diseases. Periodically, a plant disease will break out into a first-order epiphytotic, destroying 50 percent or more of annual yields. The result at a minimum is market scarcity, but at worst leads to famine and death. The United States Department of Agriculture (USDA) has been waging a virtual biological war against natural agricultural diseases and pests since the late 1800s. It played a crucial collaborative role in the American efforts to develop biological warfare capabilities against crops and livestock.

Out of the many plant pathogens, sparingly few have progressed to the point of weaponization. As a general rule, the U.S. military assigned a military symbol when research and development progressed to the point where war planners could consider availability within three to five years *(Table 1).* Though numerous biologicals were considered, only two progressed to the point of stockpiling by the end of the program – 40 tons of wheat stem rust (TX), and 0.9 tons of rice blast (LX).[14]

Table 1: Prominent United States Anti-crop Biologicals (1941 – 1969)

Military Symbol	Original Military Symbol	Plant Disease (Etiological Agent)
C	-	Southern Blight (*Sclerotium rolfsii*)
LO	-	Late Blight of Potato (*Phytophthora infestans*)
E	-	Brown Spot of Rice (*Cochliobolus miyabeanus*)
LX	IR	Rice Blast (*Magnaporthe grisea*)
TX	-	Wheat Stem Rust (*Puccinia graminis var. tritici*)
SX	RX	Rye Stem Rust (*Puccinia graminis f.sp. secalis*)
IE	-	Fusarium Head Blight (*Fusarium graminearum*)

During the early years of the U.S. programs, weaponeers believed carriers were necessary for delivering biologicals in an infective form. In the Second World War, the United States considered disseminating the southern blight (C) fungus in a mycelia-coated wheat seed carrier against German potatoes. At the time, this agent was developed because of its favorable range of susceptibility. Field trials found potatoes with a susceptibility roughly between carrots (16 pounds of agent needed per acre) and more resistant conventional garden vegetables (requiring 48 pounds of agent per acre).

Later, when the focus of the war shifted to Japan, work transitioned to late blight of potatoes (LO) because Japanese crops were remarkably resistant to C. A mycelia-pellet formulation of LO was considered, but proved unstable in storage (losing viability after three months), and requiring cold and wet field conditions to initiate plant infection. LO failed to infect in two out of three field trials, making it an unreliable choice in agent.

Brown spot of rice (E) was of primary interest for use against Japan, disseminated as a dry formulation of spores. American planners believed that a single bomber was capable of infecting eight square miles with E using M10A1 500-pound bombs to scatter 330 modified shot shell bomblets. As with C, tests showed that E would be difficult to employ effectively. Crop infection was limited by temperature and leaf wetness duration. For this reason, the U.S. Army came to believe chemical herbicides were the reliable option for food denial.[15]

This history retains its importance because it illustrates the complexity of using pathogens to attack crops. Formulating agents in a form that could survive the rigors of storage and dissemination proved problematic, but the real problem was reliability. Field tests simply did not indicate that it would be possible to disseminate any infectious agent and have confidence that it would infect the exposed plants and produce an epiphytotic that would destroy food crops.

During the Cold War, the United States devised Operation Steelyard, a plan to destroy 50 percent of the Soviet Union’s winter wheat using wheat stem rust (TX) mixed with feathers (known as the M1 carrier).[16] If the president approved Steelyard, Boeing B-29 Superfortress bombers were to drop M115 500-pound “feather” bombs filled with TX in a 60-day campaign starting in March. The Air Force forward-deployed empty M115 bombs to RAF Lakenheath and Wheelus Strategic Air Command (SAC) airbases for this purpose. The M2 two-pound containers would be airlifted to the Air Force from the TX stockpile at Edgewood Arsenal, Md. TX required an annual revolving stockpile as it had a half-life of eight months.[17] Rye stem rust (SX) was added to augment the inventory. Steelyard was the first operational biological war plan of the United States in 1952 with a stockpile of 0.8 tons TX and SX. Secretary of Defense Charles Wilson made Steelyard a standing capability in 1954 with an arsenal of eight tons of TX and SX.[18]

M115 500-pound Biological Bomb

Each M115 could cover 10 to 50 square miles with one pound of TX and 10 pounds of feathers, having an estimated 100 to 500 square miles of secondary epiphytotic spread. The M115 bombs required heated bomb bays to prevent TX from being deactivated by freezing. The Chemical Corps developed the insulated E86 750-pound bomb with internal heating and six E-14 3.5-pound containers of TX and feathers for the Boeing B-47 Stratojet. Field trials of the M115 also indicated that carriers like feathers were not required and so were replaced by aerosols of dry-type agent formulations.[19] The Chemical Corps had also invented self-dispersing bomblets using the Magnus lift principle for 20-degree lateral glide. Opening at 1,000 feet, E-95 10-ounce barometric spherical self-dispersing bomblets carried more agent and covered more area than weapons using feathers as carriers. A B-47 could deliver slightly more than 28 pounds of TX using 21 E86 bombs, or 720 pounds using the XMC1 900-pound bomb bay dispenser loaded with 4,608 E95 bomblets, effectively decreasing the number of bomber sorties by more than 95 percent.

Along with anti-crop warfare, in 1947 the Air Force requested weapons against livestock. Of the candidate biologicals against livestock *(Table 2)*, primary importance was for foot and mouth disease (FD), rinderpest (R), and what was known as fowl plague (OE). Using the British Second World War anthrax-tainted feed cakes as a model, the Chemical Corps in 1950 developed a 2,400-pound bucket-type bomb bay hopper to spread 5,200 pounds of rinderpest-tainted feed pellets over 1,000 square miles.[20] A 1951 field trial of what was then termed hog cholera (OH) demonstrated anti-crop weapons like the M115 bomb were interchangeable for disseminating agents against livestock.[20]

Table 2: Prominent United States Antianimal Biologicals (1941 – 1969)

Military Symbol	Original Military Symbol	Plant Disease (Etiological Agent)
FD	OO	Foot and Mouth Disease *(FMD Virus)*
R	-	Rinderpest *(RP Virus)*
OE	-	Highly Pathogenic Avian *Influenza (HPAI Virus)*
NI	-	Newcastle Disease *(ND Virus)*
OH	-	Classical Swine Fever *(CSF Virus)*
FW	-	African Swine Fever *(ASF Virus)*
EK	-	Vesicular Exanthema of Swine *(VES Virus)*
ET	-	Vesicular Stomatitis *(VS Virus)*

Public Law 48-496 forbade the importation of exotic animal diseases into the conterminous United States. The law forced the Chemical Corps to construct a research facility at Fort Terry on Plum Island off the coast of Long Island, N.Y. The Air Force canceled its requirement for biological warfare against livestock in 1953 and ordered the Chemical Corps to transfer activities and facilities to the USDA for defense-only work. The laboratory at Fort Terry reverted to the USDA in 1954 and became operational in 1956. Though there was a minor resurgence of interest in biological warfare against livestock in 1961, it did not advance to the same level of activities in the early 1950s.

Analysis by John Hopkins Operations Research Office (ORO) and the Defense Department Weapon Systems Evaluation Group (WSEG) in 1952 passed negative judgment in reviewing the anti-crop program. WSEG dismissed biological warfare against livestock as unimportant as meat constituted less than five percent of the typical Soviet diet.[22] The Soviet Union winter wheat belt extended over 550,000 square miles within a 700,000-square-mile spring wheat belt. At 50 percent crop destruction, Steelyard would take two years to inflict a famine. The necessary crop destruction for a famine within one year was 80 percent.[23] After the Soviet Union started its “New Lands” initiative to increase agriculture by an additional 115,000 square miles into Siberia, the required stockpile for Steelyard jumped to an unattainable 40 tons a year.[24] The Air Force canceled Steelyard in 1957 as part of a general deemphasis of chemical and biological warfare.

Air Force interest in chemical and biological weapons was rekindled in 1960 by Tactical Air Command (TAC), including the anti-crop warfare role. Wheat stem rust was produced from infected crops at four government-own sites and processed at Rocky Mountain Arsenal (RMA) in Colorado (primary), and Beale Air Force Base in California (secondary). The lyophilized dry-type formulation of TX could remain viable for up to three years at 41 degrees Fahrenheit, making a 40-ton stockpile at RMA attainable by 1964. The McDonnell Douglas F-4 Phantom II fighter could cover about 400 square miles with TX using the A/B45Y-2 65-gallon dry agent spray tank.[25] The 40-ton arsenal gave the United States the capability to infect 106,400 square miles of wheat, which represented 85 percent of Sino-Soviet Bloc wheat-producing lands.[26]

The field conditions required to infect crops with TX were temperatures above 60 F and leaf wetness duration from dew of six hours. In 1967, as an escalation option to coerce North Vietnam into abandoning support of the Viet Cong in South Vietnam, the United States procured 0.9 tons of rice blast (LX). It was a quantity suitable for covering 5,000 square miles, or for two attacks on the North Vietnamese rice fields.[27] The United States had worked on LX since the Second World War, where it was found not usable outside areas with climates sustaining double-crop rice cultivations, i.e., nightly temperatures greater than 70 F and 10 hours of leaf wetness duration. LX also required delivery at night. Due to the North Vietnamese air defenses, it was not operationally possible to use LX until the 1970s when the General Dynamics F-111 Aardvark with its terrain-following radar could fly nap-of-the-earth missions at night.[28]

On Nov. 25, 1969, President Richard Nixon unilaterally renounced offensive biological warfare by the United States.[29] All work on offensive biological warfare ceased, followed by a 1971 demilitarization effort. The stockpiles of TX and LX were inactivated by treatment with ethylene oxide and verified with 99.5 percent confidence that it was 99.964 percent sterilized before incinerating. The remaining ash was disced into the soil. By 1974 the demilitarization was complete with decontamination and transfer of facilities.[30]

Developing a viable biological weapon against crops was difficult, even if less so than against antipersonnel biological weapons. Choice of agent was limited by crop susceptibility and required unique field conditions to initiate an epiphytotic. Beyond the logistics of a revolving stockpile were the seasonal window and the one to two years before food denial was expected to result in famine. The operational aspects of biological warfare against crops were complicated with a high degree of uncertainty. Attacking livestock was seen as strategically irrelevant, given that the diet of Soviet and Chinese civilians contained little meat.

Targeting Cuba

In contrast to Sino-Soviet Bloc propaganda, which often ascribed natural outbreaks to American malevolence, the United States did make covert plans to use biological warfare against Cuban sugarcane crops, but those plans were never executed. During the Second World War, the CWS Special Assistance Division supported the Office of Strategic Services (OSS) and investigated the use of herbicides introduced by saboteurs into crop irrigation systems.[31] During the Cold War, the Special Operations Division (SOD) Fort Detrick supported the Central Intelligence Agency (CIA) in covert chemical biological warfare, including the development of three anti-crop capabilities primarily targeting Cuba.[32]

In February 1962 the United States included attacks on Cuba's sugarcane industry as part of Operation Mongoose. Such economic warfare was to discredit the newly established Castro regime and eliminate a source of convertible currency by destroying Cuba's principal export. One option was to spread a rumor that a normal annual military exercise in the region was a cover for an invasion, thereby provoking Cuba to divert labor from harvesting to mobilize its militia. More directly, Task 33b of Mongoose called for temporarily disabling sugarcane workers by covertly releasing an insect-borne disease. Task 33b was dropped in March 1962 as it was not technically feasible.[33]

In August, the S.S. *Streatham Hill* made port in Puerto Rico for repairs, offloading 80,000 sacks of Cuban sugar bound for the Soviet Union. The CIA took the opportunity to taint 14,135 sacks with a harmless chemical intended to render the sugar unpalatable to Soviet consumers. When President John F. Kennedy learned of the operation, he ordered the tainted sugar seized.[34]

Task 32 of Mongoose was to covertly use a biological or herbicide to destroy Cuba's sugarcane crops in September 1962. The main concern was that the Cubans would be able to attribute the attack to the United States, so the operation had to make the destruction appear as if it resulted from natural sources.[35] The Cuban Missile Crisis suspended Task 32. Sugar prices increased in 1963 and a Soviet-Cuba trade protocol in 1964 rekindled interest in anti-crop efforts. In September 1964 the Army proposed covert Operation Square Dance to introduce the parasitic plant bunga (*Aeginita indica Roxb.*) against sugarcane, and foot and mouth disease (FD) against livestock. To lower observable attribution, the attack was to be offshore by air for three to six years, resulting in an estimated 60 percent crop loss in 1966. When the White House learned of Square Dance in November, it was characterized as contemptible and more shocking and unacceptable than plans of assassination. Due to this opposition, Square Dance never took place.[36]

The Development and Use of Herbicides by the United States

The United States discovered herbicides as part of its biological warfare program during the Second World War. As already discussed, the U.S. Army discovered that a multitude of obstacles made it difficult to develop an effective biological agent for attacking crops. Thus, by the end of the Second World War, the War Department came to favor herbicides for anti-crop action. At the time, herbicides were considered harmless to people, and not regarded as chemical or biological weapons in a traditional sense. Herbicides were exempt from the retaliatory-only policy of antipersonnel chemical biological weapons. As a consequence, the U.S. Army devised war plans for the use of herbicides against Japan during the Second World War and later against North Korea in the Korean War. It was not until the Vietnam War, however, that the United States first used them in combat, spreading more than 20 million gallons of agent before ending herbicidal operations in 1971.[37]

The United States screened tens of thousands of candidates for herbicidal activity, but sparingly few proved interesting *(Table 3).* Although chemical substances not of biological origin, herbicides initially were categorized as biological weapons for administrative reasons, by originating from the biological warfare program. Herbicides were initially divided into defoliants (e.g., ammonium thiocyanate) and plant growth regulators (e.g., 2,4-D).[38] By the late-1950s, plant growth regulators had displaced defoliants, with optimal defoliation using 2,4-D against coniferous trees and 2,4,5-T against deciduous trees. In 1950, Fort Detrick discovered IPC was superior to 2,4-D against cereal crops, separating herbicides into those optimal against narrowleaf crops (e.g., IPC) or against broadleaf plants (e.g., 2,4-D). As narrowleaf herbicides were necessary for attacking wheat and rice crops, Fort Detrick developed multiple types until settling on CA because it had the least variability in effect associated with plant growth stages.[39] Picloram was introduced in 1966 as a replacement for 2,4,5-T. After the reorganization of Army technical services, into the Army Material Command (AMC), herbicides were reclassified as chemical warfare in the mid-1960s. From operational experience in the Vietnam War, herbicides matured into three distinct doctrinal classes – Orange for general defoliation, White for slow-acting long-lasting defoliation, and Blue for either quick-acting defoliation or anti-crop use.

Table 3: Prominent United States Anticrop Herbicides (1941 – 1969)

Military Symbol	LN Number	Drum Band	Chemical Agent
-	-	-	Ammonium Thiocyanate
LNA	LN8/LN143	-	2,4-Dichlo-rophenoxyacetic Acid (2,4-D)
LNB	LN14/LN94	Pink/ Green	2.4.5-Trichlor-ophenoxyacetic Acid (2,4,5-T)
-	LN32	-	2-Methyl-4-Chlorophenoxyacetic Acid (MCPA)
LNX	-	Purple/ Orange	1:1 mixtures of LNA and LNB
-	LN33	-	Isopropyl Phenyl Carbamate (IPC)
LNC	-	-	Isopropyl 3-chlorophenyl Carbamate (CIPC)
KF	-	-	4-Flouro-phenoxyacetic Acid
LNF	-	-	Butyl-2-chloro-4-flourophenoxyacetate
CA	-	Blue	Cacodylic Acid (Phytar)
-	-	White	4:1 mixture of LNA and 4-Amino-3,5,6-trichloro-2-pyridinecarboxylic Acid (Picloram)

During World War 2, the island-hopping campaign left many Japanese garrison holding isolated and bypassed islands. The Army Air Force (AAF) requested a substitute for diesel and crankcase oil being sprayed from aircraft to contaminate and destroy the garden plots sustaining these isolated Japanese garrisons. The CWS proposed the defoliant ammonium thiocyanate as a solution. Ammonium thiocyanate had proven to be an effective defoliant at 32 gallons per acre. In the autumn of 1944, the Army rejected the recommendation over doubts it was harmless to people and fears that Japan might interpret it as a type of chemical warfare.

By the end of 1944, plant growth regulators had surpassed defoliants in terms of potency with an application rate of five gallons per acre. George C. Merck, the civilian head of the biological warfare program, bypassed military channels and presented 2,4-D (LN8) as an option against isolated Japanese garrison garden plots to Secretary of War Special Assistant Harvey Bundy.[40] The proposal was accepted, contingent on its legal permissibility and proof LN8 was harmless to people. On Jan. 11, 1944, the Judge Advocate General determined herbicides were exempt from prohibitions concerning poisons and chemical warfare and that food denial was a legitimate tactic of war.[41] A three-week animal study concluded LN8 was "harmless." A person would have to consume an unimaginable 100 square yards of garden vegetables before suffering any ill effects it, was claimed.[42]

The CWS procured 60 tons of LN8 in anticipation of anti-crop action against 25,000 acres of isolated Japanese garrison garden plots. By March 1944, however, the United States began Operation Starvation, which eventually resulted in 1,529 B-29 bomber sorties dropping 12,000 sea mines to cut 80 percent of Japan's sea lanes.[43] While Operation Starvation created significant shortages of imported food, U.S. war planners believed Japan could hold-out from surrender for a couple of years from indigenous food sources. For that reason, the War Department Operations Division changed the anti-crop option from attacks on remote, isolated gardens to the destruction of 10 percent of Japan's rice in the Summer of 1945, followed by a 30 percent reduction in Japan's total agriculture during the 1946 growing season.[44]

Destruction of garrison garden plots would have involved tactical pursuit and attack aircraft applying a VKL solution (a five percent strength LN8 Vegetable Killer Liquid) from modified M10 30-gallon and M33 70-gallon spray tanks.[45] Flying low and slow made spray tanks an anathema to a "fly high and fast" strategic bomber force. Against Japan, applying herbicides required bombs to dispense VKA granules (100 percent strength LN8 Vegetable Killer Acid). The CWS developed the M16 500-pound bomb to deliver 150 pounds of VKA, improving delivery with the SPD Mark 2 500-pound bomb by using the M10A1 500-pound bomb to spread 192 pounds of VKA granules from a paperboard shipping container wrapped in a length of detonation cord.

Destroying crops on a national scale using herbicides was a significant undertaking, yet still seemed technically feasible. Planners estimated that destroying 10 percent of Japan's rice would have required 1,010 B-29 sorties dropping 24,200 M16 bombs, thus applying 18,000 tons of LN8 to 725,000 acres of crops.[46] Eliminating 30 percent of Japan's agriculture required attacking 7.9 million acres of crops using 20,000 tons of LN8 against rice, 10,000 tons of LN33 against corn, and 1,000 tons of LN8 or LN32 against root crops.[47] Destroying 10 percent of Japan's rice would have meant diverting five percent of the strategic bomber force from its primary incendiary bombing mission against industrial targets. Attacking 7.9 million acres of crops would have required more than a quarter of the bomber force to drop 310,000 SPD Mark 2 bombs. The herbicidal option would require significant prioritization of wartime resources. With only 60 tons LN8 and a rapidly closing growing season, the Joint Chiefs of Staff (JCS) tabled the plan to use herbicides on Japan until 1946.

In July 1945 the JCS offered theater commands enough LN8 for 50 percent destruction of 15,000 acres of crops. However, some officers in the Operations Division believed using herbicides on Japan would be counterproductive and complicate post-war reconstruction. Similarly, the China-Burma-India (CBI) theater command replied that food denial would put excessive hardship on the people they were liberating and instead recommended use on Japan's main islands.[48] The South West Pacific Area (SWPA) theater command stated the resulting famine would exterminate native island populations already in danger from food shortages under Japanese occupation.[49]

Herbicides were not used in the Second World War, but the discovery of 2,4-D heralded the "chemical era of agriculture" that has played an important role in enabling the increase in human population since 1950. During the Korean War, the United States would again consider using herbicides, this time to replace napalm that was in use on North Korean rice paddies. The Air Force initiated Hourglass, a crash program for an immediate herbicidal anti-crop capability using the MC1 1,000-gallon large capacity bomb bay spray tank assembly from B-29 bombers.[50]

Aircraft spray systems could not spread granular VKA. VKL could be sprayed, but was only at five percent strength. Esters of 2,4-D and 2,4,5-T were liquids suitable for spraying and at 100 percent strength. In 1953 the Chemical Corps standardized the n-butyl esters of 2,4-D (LNA) and 2,4,5-T (LNB) in a 1:1 mixture (LNX) for anti-crop use in the Korean War. The Chemical Corps purchased 36,525 tons of LNX[51] and the Air Force procured 100 MC1 spray systems.[52] The spray systems and herbicides were at Guam en route to Korea when the armistice ended the war. In 1955, the spray systems and herbicides were shipped back to the United States as a contingent capability against rice crops until the Vietnam War.[53]

The use of herbicides in the Vietnam War was on a massive scale, 93 percent for defoliation. Herbicides defoliated vegetation along perimeters, lines of communications, and suspected infiltration routes. The Air Force adapted Fairchild C-123 Provider aircraft into the UC-123B Ranch Hand for defoliating large areas with LNX using a modified MC1 spray system. To a lesser extent, Army helicopters also contributed to defoliation. The flow rate of the MC1 proved inadequate for achieving the three gallons per acre application needed for defoliation, requiring two passes over an area making the UC-123B vulnerable to ground fire. By the mid-1960s, the MC1 was replaced with the A/A45Y-1 1,000-gallon spray system on UC-123K aircraft, a combination able to defoliate in a single pass with more armor protection and a pair of auxiliary jet engines to provide more thrust to pullout of a spray run.

Called "Rainbow Herbicides" from the four-inch color band on the 55-gallon shipping barrels, the Korean War vintage LNX (Purple) ran out in 1965 and was replaced by Orange. The defoliation demand for herbicide spiked in 1966, forcing the United States to nationalize commercial manufacturing of 2,4,5-T under the Defense Production Act of 1950. Drift from defoliation impacted crops and rubber plantations to an extent requiring additional operational control and calibration trials of spray systems to determine buffer distances for protecting civilian cultivations.

When President John F. Kennedy approved of the use of herbicides in November 1961, he explicitly excluded use against crops unless alternative food sources or relocation could prevent impact to civilians. A year later, he approved anti-crop use upon receiving assurances from the president of South Vietnam that Viet Cong cultivations were distinctly different and removed from civilian crops.[54] Only seven percent of the total herbicide used in the Vietnam War targeted crops, covering 7.5 million acres with Blue and Orange.[55]

Anti-crop action was highly sensitive and controlled under centralized Ranch Hand procedures. Anecdotal evidence implied anti-crop warfare was successful. There were reports of enemy defections from areas impacted by crop destruction and indications a third of Viet Cong soldiers were diverted to procuring food. Leaflets were used to assure civilians that herbicides were harmless weed killers, was necessary due to Viet Cong presence, and that the government would compensate for crop losses. However, civilians did not believe herbicides were benign, and Vietnamese government corruption interfered with compensation claims. A 1967 RAND Corporation analysis concluded that anti-crop warfare was counterproductive to winning the "hearts and minds" of civilians. RAND also concluded that targeting crops was a losing strategy, due to the abundance of food in South Vietnam and that any food shortages were absorbed by local civilians before impacting the Viet Cong.[56]

The United States restricted the use of Orange in March 1969 after Fort Detrick received a draft copy of the *Bionetics Report* concluding a contaminant in 2,4,5-T called Dioxin produced birth defects in laboratory animals.[57] Harvard professor Mathew Meselson discussed the report with Presidential Science Advisor Lee DuBridge in April 1970, who in-turn called Deputy Secretary of Defense David Packard. An immediate decision was made to end the use of Orange.[58]

Over the summer of 1970, the American Association for the Advancement of Science (AAAS) sent Matthew Meselson and other scientists to study the consequences of tactical herbicide use in South Vietnam, where it was discovered, among other findings, that Hmong crops were mistakenly identified as Viet Cong. That precipitated a critical review of the herbicide program, especially anti-crop missions, which ultimately led President Richard Nixon to end anti-crop use of herbicides and phase out the defoliation program in December 1970. The last anti-crop mission was on Jan. 7, 1971.[59] Defoliation missions ended after stocks of White was depleted in May 1971.

The remaining 1.37 million gallons of Orange in South Vietnam was moved to Johnston Island in Operation Pacer Ivy during April 1970. The 860,000 gallons of Orange held at the Naval Construction Battalion Center in Gulfport, Miss., for supply to South Vietnam was loaded onto the MT *Vulcanus* incinerator ship in July 1977. From July through September 1977, the MT *Vulcanus* incinerated the entire stockpile of Orange 200 miles west of Johnston Island.[60] On April 8, 1975, President Gerald Ford formally renounced the first use of herbicides by Executive Order 11850.

The objective of anti-crop warfare by the United States was to eliminate an enemy's war-making potential through a famine. Herbicides prevailed in American anti-crop strategy as they were more controllable, less variable to field conditions, and faster-acting than the use of biologicals. From the start, however, the anti-crop strategy was flawed in that it assumed every grain of wheat or rice consumed was equivalent to a grain grown in the field. By 1952, WSEG cast doubt on food denial, noting the 50 percent crop losses from Operation Steelyard could be absorbed through a more extensive distribution network. When the U.S. Army Corps of Engineers Strategic Studies Group (ESSG) evaluated the military worth of herbicides in 1972, it concluded crop destruction was useful, but ultimately the enemy could compensate and overcome localized food shortages. At best, crop destruction was a form of harassment.[61] Where anti-crop action appeared to have the most benefit was against isolated military units in areas far removed from alternative food sources. From an analysis of the Bengal Famine of 1943, Amartya Sen posited a market economic theory of famine from disparities in food entitlements.[62] Agroterrorism, unlike anti-crop military action, uses fear, doubt, and uncertainty to disrupts markets and deny resources.

Non-state Agroterrorism

Although clearly uncommon, assessing the true incidence of agroterrorism is difficult. There is no dataset designed to permit an analysis limited only to such incidents. Existing terrorism datasets are not coded to permit easy identification of attacks on agricultural infrastructure or associated food supply chains. In contrast, several datasets focus on attacks on the food supply, including food contamination incidents, but their main emphasis is on food consumption, rather than on attacks near the sources of production.[63]

The Center for Nonproliferation Studies (CNS) created a list of agroterrorism, no longer maintained, that identifies 23 incidents caused by both state and non-state actors (both terrorists and criminals) employing chemical and biological agents. Unfortunately, its inclusion criteria were undefined, and it includes armed attacks on farms, as well as contaminations of food and water near the point of consumption. As evident from a comparison with other sources, the survey was neither deeply researched nor comprehensive and provided no basis for assessing the incidence of agroterrorism nor its impact. Its main virtue is the breadth of coverage, spanning the period from 1915 to 2006 in its final form. Excluding false allegations and claims for which there is limited supporting evidence, the CNS list included only about a dozen agroterrorism incidents (three biological and the rest chemical).[64]

A more carefully curated source is the Global Terrorism Database (GTD), the most widely used terrorism dataset.[65] As of early 2019, the GTD recorded more than 180,000 terrorism incidents covering the period 1970 to 2017.[66] Unfortunately, the GTD has no distinct category for “agroterrorism,” so that caution is needed when interpreting its data. Although it contains a field identifying the targets of terrorist attacks that codes for “Farmer,” “Farm/Ranch,” and “Food Supply,” a random review of the incidents coded for “Farmer” and “Farm/Ranch” suggested that they were unrelated to agroterrorism, but merely described the occupation of the victim or the location of the attack. Typical was an incident, coded as having a

"Farmer" target, dated March 26, 2008. "Palestinians in the Gaza Strip opened fire at an Israeli kibbutz across the border wounding a farmer."[67]

More pertinent for our purposes were the 72 incidents coded as attacks on "Food Supply." The majority (56 percent) involved food transport, mostly armed assaults on food convoys. Other targets were food storage facilities or ration distribution points (15 percent), food contamination (11 percent), assaults on agriculture-related facilities (11 percent), and only five on farms (seven percent). The most devastating assaults on farms resulting from burning of a wheat field in one case and the destruction of a banana plantation by chopping down the plants in another.[68]

Also useful for our purposes is a third study. In 2009, Gregory Dalziel, a researcher at the S. Rajaratnam School of International Studies (RSIS) in Singapore, published a comprehensive survey of intentional food contaminations, what he termed "food defence incidents." As such, he reviewed every incident in which people might have been exposed to a toxic chemical, biological, or radiological substance through deliberate contamination of food and water. Thus, while Dalziel focused on only a subset of agroterrorism incidents and included some clearly not related to agriculture (water contamination), his work is arguably the most comprehensive such review yet undertaken.

The results of Dalziel's analysis are striking. He identified only a single example of preharvest contamination that resulted in a health risk for people, the deliberate contamination of the water used by a crop spraying service with glyphosate, the active ingredient in the well-known herbicide Roundup. About 40 hectares were affected, but government officials allowed harvested food on the market after determining that the produce remained safe for human consumption.[69] Overall, 24 percent of contaminations that he identified occurred at retail or food services locations, 75 percent at homes, and only about one percent at "product assembly" site (which included food processing).[70]

These results, it is important to emphasize, is not an accurate reflection of the prevalence of agroterrorism. Dalziel was studying the risk to consumers from contamination of food supplies, reviewing the entire farm-to-fork chain, excluding any incidents that might have caused damage to agricultural produce that did not result in the spread of contaminated food. As a result, he ignored attacks that might have destroyed crops, such that they never entered the food supply, or that were intercepted before they reached consumers. Also, Dalziel's analysis focused only on proven incidents, thus ignoring some significant possible examples of agroterrorism, such as the alleged infection of Rhodesian cattle with *Bacillus anthracis*. Both types of incidents will be discussed more in detail below.

Although Dalziel's analysis excluded attacks on farms, ranches, dairies, and fisheries that did not result in food contamination, he reported on a handful of such incidents uncovered during his research.

These include:

- The alleged poisoning of cattle during the Mau Mau rebellion in Kenya
- The poisoning of the water supply to a farm in Alabama with cyanide in 1970, resulting in the deaths of 30 cattle
- The contamination of cattle feed by Brian “Skip” Lea in Wisconsin, 1999. No cattle died, but it forced a recall, costing the company millions of dollars
- The intentional contamination in 2001 of a Northern Ireland fishery, destroying 500,000 fish
- The killing of 3,100 chickens, 243 pigs, 300 fish and 10 oxen by Chinese serial murderers Du Runqiong and Tang Youhua, most likely using the banned rat poison Dushuqiang (which roughly translates to “strong rat poison”) containing tetramine[71]

Terrorists were responsible for only one of these incidents, the Mau cattle poisoning, while the others were criminal, even if the precise motivation was unclear in some instances.

Dalziel’s analysis confirms the impression gained from reviewing the GTD dataset. The food supply chain is far more resilient than most people realize, due to the efforts of companies and governments by agricultural inspectors and public health investigators. While deliberate contaminations do occur, they are remarkably rare given the vast size of the global trade in food.

Unfortunately, in the absence of a comprehensive dataset of agroterrorism incidents, created using consistent coding standards, our understanding of the agroterrorism threat is based mostly on anecdotes, which may be illustrative provide no sense of the rate of incidence. All we know for certain is that agroterrorism using chemical or biological agents is extraordinarily rare and rarely causes more than limited damage.

Known Agroterrorism Incidents

Little is known about most agroterrorism incidents. In late 1952, British authorities in Kenya discovered 33 head of cattle poisoned by a plant known as the African milk bush. The plant latex was inserted into cuts made into the animals. Reportedly, the Mau Mau also conducted other attacks on livestock, using arsenic to contaminate water supplies, as well as likely use of other unidentified toxins.[72] In January 1986, a Tamil separatist group informed foreign embassies in Sri Lanka that it had contaminated tea with a cyanide compound, according to press reports. There is no evidence such contamination ever occurred.[73]

The best-known agroterrorism incident was the 1978 mercury contamination of citrus exported to north European countries. According to most accounts, the mercury was injected into the citrus by a Palestinian organization calling itself the Arab Revolutionary Army. However, the most careful analysis of this incident, undertaken by Ehud Sprinzak and Ely Karmon, established that the contamination almost certainly occurred in Europe, that the leading Palestinian organizations denied involvement, that most of the citrus contaminated did not come from Israel, and that many of the items containing mercury resulted from copycat actions.[74]

Sprinzak and Karmon also identified two other incidents involving threats to citrus. They found that a 1988 claim that Israeli grapefruits exported to Italy had been poisoned was false. On the other hand, Israeli authorities reportedly did disrupt a January 1979 plot undertaken by the Popular Front for the Liberation of Palestine (PFLP) to inject Israeli oranges with mercury.[75]

In March 1989, the American Embassy in Chile received a series of anonymous telephone calls asserting that cyanide was going to be injected into grapes being exported to Japan and the United States. In response, the U.S. government placed a temporary halt on the import of Chilean produce.[76] During a subsequent phone call in June 1989, the caller admitted that the threat had been a hoax. The Chileans claimed that the incident cost them $333 million, while U.S. importers lost another $40 million, due to destruction of produce and other costs.[77]

There also have been some other unusual attacks on agriculture. During the 1980s, radical ecologists seeking to halt lumbering operations placed spikes into trees, which broke saws, potentially endangering lumberjacks. However, such groups did not employ chemical or biological agents in their attacks.[78]

The same was not true in two other strange incidents. An otherwise unknown group calling itself the "Breeders" claimed to have bred and spreading Mediterranean fruit flies (medflies) in protest to the widespread spraying of the insecticide malathion. California was experiencing a particularly large medfly infestation, which posed a serious threat to the state's fruit and vegetable crops. The perpetrators apparently wanted to convince government officials that such deliberate introductions would make the eradication effort fruitless, leading to a termination of the use of malathion. Although there was some evidence for the deliberate release of medflies, the claim was never proven, nor was there evidence that the group was breeding medflies.[79]

Last, and probably least, in 1985 U.S. Department of Agriculture officials began to suspect that personnel involved in an effort to eradicate the screwworm population in northern Mexico were deliberately spread the pest, apparently to protect their jobs.[80] No other details are available, so the validity of the concern cannot be assessed.

Conclusion

Agroterrorism incidents are sufficiently rare that it is impossible to predict whether past incidents illustrate possible future incidents, or whether they were idiosyncratic events that have little relationship to the future. However, concerns about agroterrorism, illustrated by the substantial literature that has appeared during the past two decades, says less about the experience of bioterrorism than about our anxiety about a radically more dangerous future. Unfortunately, past studies of agroterrorism, focused primarily on vulnerabilities and risks associated with the agricultural sector, provide little basis for assessing the likely motivations for attacks on agricultural targets. If the concern is that the future will reveal a significantly heightened threat to agriculture, additional research is needed into why terrorists might change their focus from other targets. Until such studies appear, history cannot teach us much about what to anticipate in a future involving significant agroterrorism attacks.

Chapter 2 Notes

1. John Parachini, "Preface: WMD Terrorism: As Terrorism Evolves, Is Agriculture a Likely Target?" in *Agro-Terrorism: What Is the Threat?*, ed. Jason Pate and Gavin Cameron (Livermore, Calif.: Lawrence Livermore National Laboratory, 2003), p. vi.

2. Piers Millett and Simon M. Whitby, "State Agro-BW Programs," in *Agro-Terrorism: What Is the Threat?*, ed. Jason Pate and Gavin Cameron (Livermore, Calif.: Lawrence Livermore National Laboratory, 2003), pps. 9-24.

3. "Alleged Boer Plot to Kill Horses," *The Daily Chronicle*, April 25, 1901, p. 5.

4. "Boers Inoculating Horses?," *New York Times*, April 25, 1901, p. 1; "Doubts That Boers Inoculated Horses," *New York Times*, April 29, 1901, p. 1.

5. Mark L. Wheelis, "Biological Sabotage in World War I," in *Biological and Toxin Weapons: Research, Development, and Use from the Middle Ages to 1945*, ed. Erhard Geissler and John Ellis van Courtland Moon, SIPRI Chemical & Biological Warfare Studies 18 (New York: Oxford University Press, 1999), pps. 35-62.

6. Martin Furmanski, "Defense against Biological Warfare in the Great War: The Victory of Veterinary 'Public Health,'" (PowerPoint Presentation, September 2004).

7. Benjamin C. Garrett, "The Colorado Potato Beetle Goes to War," *Chemical Weapons Convention Bulletin*, no. 33 (September 1996), pps. 2-3.

8. Milton Leitenberg, Raymond A. Zilinskas, and Jens H. Kuhn, *The Soviet Biological Weapons Program: A History* (Cambridge, Mass.: Harvard University Press, 2012), Chapter 14. For a more recent work expanding on this work, see Viktoriya V. Romanova and Yaroslav A. Shulatov, "The Echo of the Khabarovsk Trials: The USSR and the Allegation Campaign against the USA of Using Biological Warfare during the Korean War (1950-1953)," *History of Medicine* 5(4) (Dec. 31, 2018), pps. 262-72; Milton Leitenberg, *China's False Allegations of the Use of Biological Weapons by the United States during the Korean War*, Cold War International History Project Working Paper 78 (Washington, D.C.: Wilson Center, 2016), www.wilsoncenter.org/publication/chinas-false-allegations-the-use-biological-weapons-the-united-states-during-the-korean; Wu Zhili, "The Bacteriological War of 1952 Is a False Alarm," trans. Drew Casey, *Yanhuang Chunqiu*, November 2013, pps. 36-39.

9. Raymond A. Zilinskas, "Cuban Allegations of Biological Warfare by the United States: Assessing the Evidence," *Critical Reviews in Microbiology*, vol. 25, no. 3 (1999), pps. 173-227.

10. "African Swine Fever Comes to Russia from Georgia in Act of Economic Sabotage - Onishchenko," *Military News Agency*, April 9, 2012.

11. Glenn Cross, *Dirty War: Rhodesia and Chemical Biological Warfare 1975-1980* (Solihull, England: Helion and Company, 2017); James M. Wilson et al, "Reanalysis of the Anthrax Epidemic in Rhodesia, 1978-1984," *PeerJ*, vol. 4 (Nov. 10, 2016), p. e2686, https://doi.org/10.7717/peerj.2686.

12. Ken Alibek, "The Soviet Union's Anti-Agricultural Biological Weapons," *Annals of the New York Academy of Sciences*, vol. 894 (1999), p. 19; Ken Alibek and Stephen Handelman, *Biohazard: The Chilling True Story of the Largest Covert Biological Weapons Program in the World, Told from the inside by the Man Who Ran It* (New York, N.Y.: Random House, 2000), p. 268.

13. *Activities of the United States in the Field of Biological Warfare*. War Department, Washington, D.C.; Theodor Rosebury, *Peace of Pestilence: Biological Warfare and How to Avoid It* (New York, N.Y.: McGraw-Hill Book Company, 1949).

14. Morton H. Halperin memorandum for Dr. Henry Kissenger, Aug. 28, 1969, U.S. Policy, Programs and Issues on CBW, The White House.

15. Rexmond C. Cochrane, *Biological Warfare Research in the United States: History of the Chemical Warfare Service in World War II*, vol. II (Fort Detrick, Md.: Historical Section, Plans, Training and Intelligence Division, Office of Chief, Chemical Corps, November 1947).

16. Feathers replaced the need for using pigeons, *Feathers as Carriers of Biological Warfare Agents: I. Cereal Rust Spores.* Special Report No. 138 (Camp Detrick, Md.: U.S. Army Chemical Corps, Biological Department, 1950).

17. Wheat stem rust (TX) was produced by extracting from infected wheat harvested on government lands. The U.S. Department of Agriculture grew Soviet varieties wheat for producing TX on government lands. American varieties of wheat were resistant to TX.

18. Air Force Office Atomic Testing; Dorothy L. Miller, *History of Air Force Participation in Biological Warfare Program 1944 – 1951*, Historical Study No. 194; *History of Air Force Participation in Biological Warfare Program 1951 – 1954*, Historical Study No. 313 (Wright Patterson AFB, Ohio: Historical Office, Air Material Command, 1957).

19. Cf. Chemical Corps Biological Laboratories, *Seventh Annual Report of the Chemical Corps Biological Laboratories*. Report Series No. 7 (Camp Detrick, Md.: U.S. Army Chemical Corps, Biological Laboratories, 1953).

20. Ibid, p. 18.

21. A. M. Webb, and W. B. Strough, *Field Evaluation Study of Desiccated Agent on Carrier for an Antianimal Biological Warfare Munition (Operation Green)*, Special Report No. 159. (Camp Detrick, Md.: U.S. Army Chemical Corps, Biological Laboratories, 1952).

22. Cf. Evaluation Staff, *Evaluation of WSEG Report No. 8*. (Maxwell AFB, Ala.: Air War College, Air University, 1952).

23. G. E. Davis, *Memorandum For Record: Summary of ORO Reports on Anticrop Attacks* (Oct. 7, 1952). AFOAT.

24. The areas of winter and spring wheat belts, including New Lands, represented the total area from which wheat production was possible. Target folders were made to attack individual Sovkhozes and Kolkhozes (farm collectives) with primary coverage of M115 bombs over smaller areas, which would initiate an epiphytotic over a wider area throughout the region.

25. United States Air Force, *Half a Loaf: Evaluation of an Anti-Crop Weapon*. Film Report FR 949, 1969.

26. Ibid, 14. This represented area of primary coverage at application rates assured to initiate infection under less than ideal field conditions, and the secondary spread of a resulting epiphytotic would cover 85 percent of wheat-producing lands.

27. Ibid, p. 14.

28. James D. Watson, *Avoid Boring People: Lessons From A Life in Science* (New York, N.Y.: Alfred A. Knopf, 2007).

29. Jonathan B. Tucker and Erin R. Mahan, *President Nixon's Decision to Renounce the U.S. Offensive Biological Weapons Program*, Case Study 1 (Washington, D.C.: Center for the Study of Weapons of Mass Destruction Case Study Series, National Defense University Press).

30. N. Covert, *U.S. Army Activity in the U.S. Biological Warfare Programs,* vols. I and II. (Fort Detrick, Md.: U.S. Army, 1977).

31. It is doubtful this would have worked, noting one to three pounds per acre was required. D. B. Summers, *Final Report Summary Report of BW*. (Edgewood Arsenal, Md.: Special Assistance Division, 1945).

32. U.S. Senate, Hearings Before the Select Committee to Study Governmental Operations with Respect to Intelligence Activities of the United States Senate, Ninety-Fourth Congress (First Session, Volume 1), Unauthorized Storage of Toxic Agents (Sept. 16-18, 1975). Intelligence Activities Senate Resolution 21. (Washington, D.C.: Government Printing Office), p. 114.

33. P. Buchen, *Castro* (Report), (Washington, D.C.: White House, 1975).

34. T. Wicker, J. W. Finney, M. Frankel, E. W. Kenworthy, et al, "C.I.A. Operations: A Plot Scuttled. Plan to Doctor Cuban Sugar Depicts Control Problem," *New York Times,* April 28, 1966, p. 1.

35. Memorandum for Record, National Security Agency, "Minutes of Meeting of Special Group (Augmented) on Mongoose," Sept. 6, 1962.

36. LBJ Presidential Library Box 438-20, R522, *National Security Papers Touching on Assassination and Covert Action in Cuba: A Summary with Key Documents* (July 21, 1975).

37. After 1971, the United States continued to use herbicides for small-scale clearing of vegetation along perimeter defenses in remote areas, but no longer for large-area defoliation operations.

38. During the Second World War, candidate defoliants were D-numbered and plant growth regulators were LN-numbered. In the Cold War, candidate herbicides were M-numbered.

39. J. W. Brown, *The Importance of Rice and Possible Impact to Antirice Warfare,* Technical Study No. 5. (Fort Detrick, Md.: U.S. Army, Biological Warfare Laboratories, 1958).

40. Two of Bundy's sons, McGeorge Bundy and William Bundy, were influential in justifying the policy for using herbicides in the Vietnam War.

41. Records of the War Department's Operations Division.

42. Ibid, p. 15.

43. Gerald A. Mason, *Operation Starvation* (Maxwell AFB, Ala.: Air War College, Air University, 2002).

44. Ibid, p. 41.

45. The spray tanks were modified to halve the flow-rates, equivalent to the improvised insecticidal spray tanks in use for applying DDT.

46. Ibid, p. 41.

47. Paul Fildes, *Potentialities of Weapons of War During the Next Ten Years,* Memorandum TWC, Joint Technical Warfare Committee, United Kingdom, Nov. 12, 1945.

48. Ibid, p. 41.

49. Rear Admiral Charles H. McMorris, *Policy on the use of Chemical Agents for the Destruction of Japanese Food Crops*, Memorandum from Commander in Chief, Pacific Ocean Areas to Commander in Chief, United States Fleet, Aug. 14, 1945.

50. The MC1 spray tank was also called Hourglass after the project that created it.

51. Alvin. Lee Young, *The History of the US Department of Defense Programs for the Testing, Evaluation, and Storage of Tactical Herbicides* (Cheyenne, Wyo.: A. L. Young Consulting, Inc., 2006).

52. Ibid, pps. 18-19.

53. William. A. Buckingham, *Operation Ranch Hand: The Air Force and Herbicides in Southeast Asia 1961 – 1971 (*Washington, D.C.: Office of Air Force History, 1982).

54. Ibid, p. 53.

55. Against rice it required five gallons per acre of Orange or one gallon per acre of Blue.

56. A. J. Russo, *A Statistical Analysis of the U.S. Crop Spraying Program in South Vietnam* (Santa Monica, Calif.: RAND Corporation, 1967); Russell Betts and Frank Denton, *An Evaluation of Chemical Crop Destruction in Vietnam* (Santa Monica, Calif.: RAND Corporation, 1967);

57. After Rachel Carson's book *Silent Spring* (Boston, Mass.: Houghton Mifflin, Sept. 27, 1962), the Presidential Science Advisory Committee recommended the study of the long-term health effects of pesticides, which led to the Bionetics Report, *Evaluation of Carcinogenic, Teratogenic, and Mutagenic Activities of Selected Pesticides and Industrial Chemicals. Teratogenic Study in Mice and Rats*. Vol II (Yorktown, Va.: Bionetics Research Laboratories, 1968)

58. Matthew Meselson, "From Charles and Francis Darwin to Richard Nixon: The Origin and Termination of Anti-plant Chemical Warfare in Vietnam," a chapter in Bretislav Friedrich, Dieter Hoffman, et al, *One Hundred Years of Chemical Warfare Research, Deployment, Consequences*. (Cham, Switzerland: Springer Nature. 2007), pps. 335-348.

59. Ibid, p. 58.

60. Ibid, p. 51.

61. *Herbicides in Military Operations,* vol I, Main Paper. No. 219, (Fort Belvoir, Va.: Engineer Strategic Studies Group Office, 1972).

62. Amartya Sen, *Poverty and Famines: An Essay on Entitlement and Deprivation*. (New York, N.Y.: Oxford University Press, 1982).

63. Hamid Mohtadi and Antu Panini Murshid, “How Secure Is Our Food? A Risk Analysis of the Threat to the Food Sector,” National Center for Food Protection and Defense at the University of Minnesota, Oct. 20, 2006; Gregory A. Dalziel, *Food Defence Incidents 1950-2008: A Chronology and Analysis of Incidents Involving the Malicious Contamination of the Food Supply Chain* (Singapore: S. Rajaratnam School of International Studies, Nanyang Technological University, 2009); Julii Brainard and Paul R. Hunter, “Contextual Factors Among Indiscriminate or Large Attacks on Food or Water Supplies, 1946-2015,” *Health Security* 14, no. 1 (February 2016), pps. 19-28.

64. “Agro-Terrorism: Chronology of CBW Incidents Targeting Agriculture and Food Systems 1915-2006,” James Martin Center for Nonproliferation Studies, June 2006, 1915-2006, https://web.archive.org/web/20090202150212/http://cns.miis.edu/research/cbw/agchron.htm.

65. The Global Terrorism Database is maintained by the National Consortium for the Study of Terrorism and Responses to Terrorism, (START) a Center of Excellence based at the University of Maryland and funded by the U.S. Department of Homeland Security.

66. “Global Terrorism Database,” National Consortium for the Study of Terrorism and Responses to Terrorism, accessed June 3, 2018, www.start.umd.edu/gtd; *Codebook: Inclusion Criteria and Variables* (College Park, Md.: National Consortium for the Study of Terrorism and Responses to Terrorism, 2017), www.start-dev.umd.edu/gtd/downloads/Codebook.pdf; Neil G. Bowie and Alex P. Schmid, “Databases on Terrorism,” in *The Routledge Handbook of Terrorism Research*, ed. Alex P. Schmid (New York, N.Y.: Routledge, 2011), p. 295-98; Gary LaFree and Laura Dugan, “Introducing the Global Terrorism Database,” *Terrorism & Political Violence* 19, no. 2 (2007), pps. 181-204.

67. www.start.umd.edu/gtd/search/IncidentSummary.aspx?gtdid=200803260005.

68. This analysis used the downloadable file provided by START.

69. Renee Viellaris, “Official Tests Confirm Harmful Levels - Toxic Shock,” *Courier Mail*, Aug. 4, 2006, LexisNexis Academic.

70. Dalziel, *Food Defence Incidents 1950-2008*, p. 20.

71. Ibid, p. 11.

72. Dr. W. Seth Carus, *Bioterrorism and Biocrimes: The Illicit Use of Biological Agents Since 1900* (Washington, D.C.: Center for Counterproliferation Research, National Defense University, February 2001), pps. 63-65.

73. Carus, pps. 117-18.

74. Ehud Sprinzak and Ely Karmon, “Why So Little? The Palestinian Terrorist Organizations and Unconventional Terrorism,” (June 17, 2007), www.ict.org.il/Article/978/Why%20So%20Little?%20The%20Palestinian%20Terrorist%20Organizations%20and%20Unconventional%20Terrorism.

75. Ibid.

76. “Food Tampering: FDA’s Actions on Chilean Fruit Based on Sound Evidence” (Washington, D.C.: U. S. Government Accountability Office, Oct. 4, 1990), www.gao.gov/products/HRD-90-164.

77. Bruce Ingersoll, “Report Shows Hoax May Have Caused Grape Scare of 1989 - Anonymous Caller Claims He Lied to U.S. About Fruit Being Shipped From Chile,” *Wall Street Journal*, Dec. 23, 1994, Eastern edition, p. B5.

78. Sean P. Eagan, “From Spikes to Bombs: The Rise of Eco-Terrorism,” *Studies in Conflict & Terrorism* 19, no. 1 (1996), pps. 1-18.

79. Carus, *Bioterrorism and Biocrimes*, p. 173.

80. Carus, *Bioterrorism and Biocrimes*, p. 80.

CHAPTER 3

The Mindset of a Terrorist

Dr. Terry Oroszi and Dr. David Ellis

Over the years, the landscape of terrorism in the United States has changed. Prior to the Sept. 11, 2001 attacks, (9/11) domestic terrorist groups like the Weathermen Underground, Black Panthers, Symbionese Liberation Army, and the Jewish Defense League were bombing American infrastructures including civilian, law enforcement, federal locations, and hijacking airplanes in order to protest an event or accomplish a single goal.[1] Since the Sept. 11, 2001, attacks, terrorists have demonstrated their willingness to use a wide range of tactics with a degree of unpredictability to achieve broader goals.

The agricultural system in the United States is highly vulnerable to terroristic attacks known as agroterrorism, and could be devastated by them.[2] The potential use of chemical or biological agents on food sources is a growing concern for regulatory agencies.[3] One way to prevent such an attack is to distinguish the most strategic target and plan for its protection. Another is to monitor the resources necessary for the types of attacks that are gaged to be the most effective. Finally, one could identify individuals with the mindset most likely to perpetrate such an attack and deter or apprehend them.

Recognizing those who are predisposed to commit terroristic attacks requires an understanding of what drives an individual to execute such a devastating crime. This can be achieved by studying those who have already become terrorists, but information rarely comes directly from the criminals themselves. More often, experts report the trends that they find within terrorist populations, and that allows us to understand the mindset of a terrorist.

There is no template that can be used to classify such an individual. Not every fatherless son seeks paternal guidance from criminals, nor do the majority of deeply religious individuals feel the need to kill or wipe the world clean of other religions. There is no singular item that steers an individual down the path of radicalization. Rather, a series of life experiences culminates in a mindset that, in the mind of the individual, morally and ethically justifies terrorism.

The motivation that steers someone toward mass murder differs amongst the criminal populations. Active shooters tend to be angry, attention-grabbing individuals, and serial killers tend to be motivated by sexual deviance. Terrorists are inspired by religious, political, or ideological objectives. The crime of terrorism is the illegal use of force, violence, or the threat of violence to intimidate and coerce a civilian or government entity into changing their beliefs, actions, even their way of life.

One way to better understand the mindset of those who become terrorists, is to examine the demographics of individuals who have been convicted of crimes related to terrorism. Terrorism as a crime is not new, but the laws for prosecuting terrorists are. Most perpetrators are not charged with terrorism, but with related crimes. We previously collected data on 519 American citizens who have been charged with acts related to terrorism since 9/11.[4] The characteristics we identified in that population along with collaborating information from other researchers and additional speculations will be used here to describe the mindset of a terrorist.

Mental Health

We often hope or expect that men and woman who are willing to commit the atrocities associated with terrorism must have a mental illness.[5] The fact is most of them have not been diagnosed with an illness. Only 11 percent of Americans charged with acts related to terrorism were diagnosed with mental illnesses. Humanitarian and researcher Nasra Hassan interviewed 250 Hamas members and found them to be sane and educated, not overly depressed or poor.[6] In fact, large terrorist organizations, can be somewhat selective, and so they are likely to screen out many mental illnesses.

Every organization wants the most capable people, and so anyone perceived as weak or unable to complete tasks are likely to be passed over for membership. Lone wolves, or people acting independently, are reported to be greater than 13 times more likely to have mental illness than terrorists who are sponsored by larger organizations.[7]

Professionals have settled into two camps regarding the psychology of a terrorist. One view holds that no common psychopathology has been found and so there is no set of psychological descriptors to define them. The other, suggests that while a common pathology might not emerge, certain psychological traits may be common among terrorists. Identifying those characteristics in lone-actors might be more meaningful, because they are more likely to act according to their own set of values and emotions. People tend to think, act, and make decision differently if they feel that their group affiliation depends upon it. Then again, organizations try to shape the worldview of their members, and so a person acting alone is still likely to draw from the norms and behaviors of the group they want to be associated with when deciding on their actions.

No common psychopathology or unified psychology has been identified for terrorists, but certain personality traits do tend to be over-represented. Older studies, reviewed by psychologist Jerrold Post,[8] suggest that those who become terrorist tend to be aggressive and action-oriented people who rely on "splitting," by which one regards everything in black and white, good or evil, and projects all evil onto an external enemy. Although splitting is a borderline personality disorder, it sounds much like extremism, in which one idea is moral while the other is unjust. Another recent study of 66 imprisoned terrorists also found that they had more aggression and less recognition of emotion than a control group.[9]

Stephane Baele used a computer program to analyzed the writings of known terrorists in comparison to activists who were known to express anger, but promote non-violent actions, such as Mahatma Gandhi and Martin Luther King, Jr., and against a set of accepted, normalized emotional messages.[10] The lone actor terrorists scored similar to the non-violent activists in resentment, both being significantly greater than the positive control texts. For anger, the activists scored significantly greater than the control, but terrorists had an even greater score, by twofold. Interestingly, the activists and terrorists both scored high with regard to cognitive sophistication, meaning they both expressed logical theories for their ideas.

James Gilligan has asserted that the basic motive for terrorism is a desire to offset an overwhelming feeling of shame and humiliation with pride and honor by effectively transferring the dishonor onto others.[11] This is the motivation of destructive aggression and vengeance, which is directed at individuals when one person feels dishonored or at groups when a collective has been disgraced.

Another potential stimulus involves heroization. By this theory, people are motivated to social action[12] or terrorism[13] by the desire to achieve a higher level of individualization in service to a communal cause. The individual seeks to transcend a meaningless death and become immortalized through some act of perceived heroism. This desire could pull in a potential terrorist who sees an opportunity for personal glory in the struggle of an organization, or it could radicalize someone who is already a member of the community.

A tendency toward aggression, focus on outcome, splitting and externalization of blame, vengeance for dishonor and heroization may help to explain how a person decides to commit shocking acts that result in death and destruction, which most would consider irrational and immoral. Recognizing those traits in potential terrorists may be a challenge.

Economy and Social Status

Economic and social turmoil can result in the radicalization of society.[14] As far back as 1977, it was recognized that terrorists generally come from the middle or upper class.[15] Our study of American citizens showed that about half were middle or upper class.[16] Since they already had the advantage of higher status, this suggests that socioeconomic aspirations are not important for radicalization. The impulse that drives a person toward extremism or increases their susceptibility to terror recruitment is likely not based on economic class, but on some consternation that is common between classes.[17]

Quite a few who are born into the working class will recognize that lifestyle as the norm. They accept their lot in life because it is what they know, and those around them are in the same social situation. Many are happy to work hard, earn their keep, and take care of their families. In addition, if they did not pursue secondary education, they realize it is more difficult for them to rise out of the working class and accept some of the blame for their status. Nevertheless, some strive for a higher status and find that upward mobility is difficult and resisted by those already in the higher class. They become frustrated by what they perceive as an unfair struggle, blaming others for creating barriers against their success.

People born into the middle or upper class are surrounded by those who have already achieved a certain standing in society. A perceived failure to measure up with their peers will cause embarrassment, frustration, even resentment. The aggrieved person may displace the blame for their circumstances onto the community leaders or the government.

Members of any socioeconomic class can suffer from real or perceived inequity in the pursuit of a comfortable life. The greater their level of aggravation, the more likely they are to act out against their presumed obstacle. We submit that a person whose emotions are inflamed in such a way are susceptible to recruitment by terrorist organizations.[18]

Education

Research suggests that advanced education and participation in terror groups have a positive correlation.[19] Most of the terrorists interviewed by Marc Sageman undertook advanced studies in technology and the sciences.[20] Our research found that 61 percent of American male terrorists had some college education, and more than half of those were in science, technology, engineering, and math (STEM) fields.[21] Diego Gambetta and Steffen Hertog also reported a disproportionate number radical Islamists with engineering backgrounds.[22]

We postulate that one possible explanation for the high number of educated terrorists is bitterness over lower prosperity than expected from their efforts. The expectations associated with certain achievements may hold more weight in a person's mind than the actual achievements. After spending the time and money to get an advanced education, one expects positive reciprocity. If a position of respect is not forthcoming, or one's compensation is less than expected, the shortcoming will be blamed on the economy, community leaders, or the government. The dissatisfaction derived from that sense of entitlement and the perceived injustice of not attaining what education should provide, may render people amenable to extreme ideas about inequity.

Poverty

Researchers have debated the influence of poverty on terrorism for several years, but there is very little support in the literature for the idea that poverty breeds terrorism. In fact, if that were true, we would see a great number of terrorists in poverty-stricken areas, but in fact, we see a preference for more prosperous countries. Poverty can lead to corruption and is often used as a tool to repress a population. This will produce the same dissatisfaction and feelings of helplessness already described, which could increase terrorism.

Political Freedom

There is a positive relationship between the rate of terrorist incidents and the lack of political freedom.[23] According to Alan B. Krueger and Jitka Malečková, terrorism derives from a perceived lack of political freedom.[24] Democracies offer their citizens a method to achieve their goals through nonviolent means, but the path is often difficult which can be perceived as suppression or injustice. Autocracies can repress their citizens without fear of overstepping the law, but such actions will also enrage society.

Political freedom is essential to any democracy, and the United States supports it. This freedom implies that every citizen has the right and the ability to influence the way the country is governed, but people often question what impact they can really have. Two political parties have controlled the U.S. government for more than 150 years. These two parties hold opposing views of how the country should be governed and are continually hindering each other's progress. They are also highly dependent on donations to finance their operations, and so there is a general belief that only the wealthy who provide funding for the political parties really have any influence on the government.

All this together creates distrust for the government, and because of that, not everyone uses political freedom as it was designed. Instead of organizing during an election to replace those members of the government with different views than their own, some choose to resist the government by forming militias or patriot groups. In 2009, the number of such antigovernment groups exceeded 1,300.[25] Many factors are involved in the antigovernment movements, but the formation of patriot groups is typically fueled by their perception of increased government regulation or a threat to their right to bear firearms.

Race, Gender, and Sexuality

Committing an act of violence inspired by a person's race or gender is not novel in the United States. Hate groups have had a strong foothold since the creation of the Ku Klux Klan in 1866.[26] The Southern Poverty Law Center estimates that there are 892 white supremacist groups or white nationalist groups in the United States.[27] Anti-Muslim hate groups are relatively new, most of them formed in the aftermath of 9/11. As a country, the United States has increased its acceptance of sexual differences, but this has also spawned new hate groups. The line that separates hate and terrorist groups is narrow and blurred, but if violence or the threat of violence is used to further their goals of political, religious, or ideological superiority, then they are terrorists.

Racial profiling is the exercise of targeting individuals based on their race or ethnicity in the belief that specific demographics indicate who is likely to engage in unlawful behavior.[28] It violates the Fourth Amendment to the Constitution if used to search or arrest an individual without probable cause or proof of criminal activity. It is not a violation, however, to ascertain the race or ethnicity of a suspect from a witness in order to help in capturing that person.[29]

It is common to associate terrorism with men of Middle-Eastern descent. We found, however, that among multigenerational American citizens who were charged with acts related to terrorism, there were more Caucasians than all the other ethnicities combined.[30] About 58 percent of the 519 Americans charged with terror-related crimes since 9/11 were Caucasian. About 64 percent of them were born in the United States and many had parents who were from the United States. The top three countries of origin for naturalized citizens who have become terrorists since 9/11 are Somalia, Pakistan, and Lebanon. Clearly, it is difficult to identify a potential terrorist based on their country of origin or that of their family.

About 90 percent of the American terrorists were male, a historic trend that is also true for international terrorists.[31] Thanks to that overwhelming statistic and our natural tendancy to profile based on trends, female terrorists can avoid suspicion much easier than their male counterparts, allowing them to perpetrate covert, extremely deadly attacks.[32]

Religion

Another misconception is that all terrorists are Islamic militants, but not all the people who join jihadist groups are religious or join for religious reasons. In addition, terrorists who are motivated by religion are also driven by politics, which clouds any attempt at distinguishing the two.[33] In fact, not all religiously motivated terrorists are Muslim. The Army of God is one example of a Christian, domestic terrorist group that believes they are acting on behalf of God. Nevertheless, we found that 81 percent of the Americans charged with terrorist acts were Muslim.[34]

Terrorists motivated by religion, regardless of the faith, believe that their acts are sanctioned by a higher being.[35] That belief that might elevate the fervor of their attack. In 1995, less than 50 percent of foreign terrorist organizations were motivated by a religious agenda, but the death and destruction caused by those groups was greater than any other.

The motivation to join a religious terrorist group may come from the fear of a potential disaster or impending crisis[36] or social inequity.[37] Some religious communities, with no ties to terrorism, offer social services to help economically challenged families, but there are also fundamentalist churches that offer the same services to lure in new members. People who benefit from those services tend to join the organization out of gratitude or a sense of obligation and become indoctrinated to the church's ideologies. Fundamentalist organizations are often driven by extremist views, which do not necessarily promote terrorism, but terrorists certainly hold such views. A progression from fundamentalism to terrorism might easily be implied.

Seeing the Signs

Predicting if an individual has the mindset to become a terrorist is difficult, and the effectiveness of estimating the likelihood of radicalization based on the patterns identified in convicted terrorists is yet unknown. The prediction must rely, therefore, on a systematic study of the demographics of known terrorists to determine reproducible indicators of their character. Those markers can become warning signs that someone is susceptible to becoming or might already be a terrorist.

The classic terrorist profile compiled by Charles A. Russell and Bowman H. Miller in 1977,[38] and reasserted by Brian M. Jenkins[39] and James Dingley,[40] was based on 350 known terrorists from 18 Middle Eastern, Latin American, Western European, and Japanese groups.

Their characteristics of a terrorist include the following:

- They are typically single males, aged 22 to 24.
- Most are from an affluent, middle- or upper-class family.
- Many had some college education, typically in humanities.
- They were probably recruited at the univerisity.

The profile of an American terrorist, which we reported,[41] was based on 519 U.S. citizens who were charged with crimes related to terrorism between September 2001 and December 2018.

American terrorist markers included the following.

- The majority were single males, aged 15 to 40
- Most were from the middle or upper class
- Many were educated
- They were typically raised without an active father figure
- Many were displaced or alienated

While we encourage the use of these markers to identify individuals at higher risk of becoming terrorists, we also realize that not everyone who fits this mold will become a terrorist. Most terrorists will not match all of the markers and we hope that not every individual who matches all the markers will become terrorists. If we use this set of indicators to identify people who might become terrorists, perhaps those individuals can be turned away from extremism and lead down a better path.

Military Terrorists

The men and women of the United States military are some of the most patriotic people in the country. It is difficult to imagine a member or veteran of the U.S. Armed Forces becoming a terrorist, but 40 of the 519 American citizens charged with acts related to terrorism had military experience. Of them, 19 were affiliated with the Army, 10 were Marines, three were in the Army National Guard, seven were in the Navy and one was an Air Force officer.[42]

It is immediately clear that the number of service members in each branch who became terrorists is not correlated with the size of the organizations. According to the Department of Defense (reported by *Statista*[43]) in 2017, the U.S. Army, which had the most terrorists, had 472,047 members, but the Marine Corps, second in terms of terrorists, was the smallest branch with 184,401 members. The Army National Guard was second largest with 345,153. The Navy had 319,492 individuals and the Air Force had 318,580 members.

Interestingly, the profile statistics for home-grown terrorists are different between those with and without training from the U.S. military. The statistics in the following table came from the study of 519 American citizens charged with acts related to terrorism since 9/11.[44] Only 11 percent of non-military American terrorists were diagnosed with mental health issues, while almost half of those from the military suffered from mental illness. A greater proportion of military terrorists were married, and divorced, and affiliated with domestic terror groups, and were American citizens by birth, compared to non-military. Association with international groups and naturalized citizens was less for the military than the non-military.

	Mental Health	Married	Divorced	Domestic	International	Birth	Natural
Military	**48%**	**35%**	**13%**	**18%**	75%	**90%**	8%
Non-Military	11%	18%	3%	9%	**81%**	63%	**32%**

Clearly, the characteristics differ between those with and without military experience, suggesting that the motivations or drivers that radicalize military members and veterans may be different from the non-military. Perhaps the lure the draws military personnel toward terrorist organizations is their apparent similarity with military life, which may aid such a transition.

Brotherhood

What do the military, law enforcement, and firefighters have in common? They work together for a common goal, protecting and saving people, while risking their lives. Many consider them heroes. Terrorists are similar in that they believe in their cause, want to help others who share their beliefs or ideal, and wish to be known as heroes. The youth, who commonly have a feeling of invincibility and desire for heroization, make excellent recruits for such courageous vocations and, unfortunately, terrorist organizations.

Of the 49 American military men charged with acts of terrorism, 67 percent acted alone, 17 percent had partners, and 13 percent operated as part of a larger cell. The status of three percent was unidentified. About 75 percent of the military terrorists aligned with international terror organizations and 18 percent with domestic antigovernment and hate groups. Belonging to a group with a common goal and similar ideals, a brotherhood, appears to be important for the military terrorists.

Trained Killer

Numerous terrorists have admitted to joining the military for training, so they could learn how to be better killers. About 27 percent of the 248 non-military terrorists in our study of home-grown terrorists chose explosives for their weapons,[45] including bombs and grenades, but the majority, 48 percent, did not use weapons. Firearms were the weapon of choice for the military terrorists, having involved them in 45 percent of cases. About 25 percent chose explosives and another 25 percent were not using a weapon when arrested. Violence and the military go hand in hand. For the American terrorists, only 29 percent of overall arrests included an act of violence, but it was involved in 67 percent of military terrorist arrests. A total of 20 percent of the military terrorists killed or injured others. In addition to their training in the U.S. military, seven out of the 40 also attended terrorist training camps abroad.

Lost or Alienated

When service members are released from the military after several years of service, they often feel lost. It is frequently the first time they must take care of themselves. They must plan to pay rent, buy meals, and secure transportation between paychecks. Some military personnel can spend their entire paycheck as soon as it hits their account and still have a home, job, and food on the table. Traditionally, there has been limited training that prepares a soldier for reintegration into civilian life. The pressure to self-learn those life skills along with the embarrassment of failure can place the ex-military people into an economic struggle that may increase their susceptibility to extremist ideas and recruitment into terrorism.

Mental Health

As already noted, almost half of the American terrorists with military experience were diagnosed with mental illness while only 11 percent of non-military terrorists were. The large difference in proportion may indicate that mental illness is a greater factor in turning military personnel to terrorism than non-military. Alternatively, it might have resulted from better access to healthcare in the military so that cases are more likely to be diagnosed. The greater question here is whether recruits entered the military with undiagnosed disorders, or the illness developed while serving. At least 12 of the 40 military terrorists had served in hostile environments including Iraq, Afghanistan, Kuwait, Somalia, South Korea, and Vietnam. Seven of those were diagnosed with mental illnesses.

The U.S. Army Research Institute has developed two noncognitive screening tools to help identify mental disorders and predict the success of military recruits. The Assessment of Individual Motivation (AIM) test has been in use since 2001. It assesses an applicant's behavioral trends and its score has proven useful in predicting retention and the potential for mental disorders.[46] The Tailored Adaptive Personality Assessment System (TAPAS), used since 2009, measures personality traits as they relate to performance motivation.[47] A low score on the TAPAS is associated with early attrition and greater potential for mental disorders. Unfortunately, the cutoff used for acceptance into military service changes with the needs of the military and the volume of applicants. In other words, when the need is high and volume is low, a greater number of recruits with low level concerns will be accepted.

In 2005, recognizing that combat-zone deployment had a significant influence on the mental health status of service members, the Department of Defense mandated use of the Post-Deployment Health Reassessment (PDHRA) to screen returning soldiers for mental health issues.[48] The intent of the effort is to identify personnel who require follow-up treatment to cope with issues that developed during deployment.

In a review of naval practices, Cliodhna Sargent, et al,[49] suggested that individual coping ability should also be assessed during recruitment, because it would aid in assigning the most suitable personnel to jobs with a range of stress levels. They also advocated pre- and post-deployment reviews to more accurately monitor changes in mental health status.

The goal of the Department of Defense in assessing mental health is to cost-effectively cull the recruits who will not complete their commitment due to mental disorders, and to identify and treat those whose service to their country has caused mental health issues. It is currently unknown how much mental illness contributes to radicalization and the turn toward terrorism, but given the unexpected number of home-grown terrorists who served in the military, greater effort may be needed to screen out those who cannot cope with military life and to treat those who have been altered by wartime service. Increased attention on the transition to civilian life may also be necessary to prevent negative backlash and feelings of animosity toward the government to which they were once loyal.

Military Occupational Specialties or Jobs.

Some jobs in the military are not easily translated to civilian careers after leaving the service. Examples of less transferable military occupational specialties (MOS) held by the American, military terrorists include air defense artillery, fire support specialist/artillery, infantry and explosives training, rifleman, tank crew member, and combat engineer. Learning a specific skill in service to one's country and then struggling to find employment post-separation can be infuriating and might alter one's opinion of their country.

Other military occupational specialties held by the military terrorists that are more easily translated to civilian life include psychologist, motor vehicle operator, air-traffic control, supply specialist, translator, engineer, construction, police officer, and airplane mechanic. Remarkably, only the Army psychologist and Air Force airplane mechanic held the same jobs outside of the military.

In total, 30 of the military terrorists were no longer in service to the United States when they committed crimes related to terrorism. They held a variety of civilian jobs, which did not correspond with their military training. Examples include an Army unit supply specialist working as a bodyguard, a Marine infantryman became a construction worker, an Army Patriot launching station enhanced operator/maintainer was a fisherman, combat engineers from the Army and Army National Guard were teaching martial arts and working as security guards.

There are resources available to help veterans transfer their skills, such as the Military Skills Translator at Military.com, but that assistance must be made known to the departing service members. Moreover, in an unfavorable economy, or if their military experience has turned them sour to the translational occupations, the conversion becomes more difficult and may require additional assistance.

Length of Service

The length of service for the American, military terrorists ranged as high as 19 years. However, 67 percent of them served less than five years, and 45 percent were arrested for crimes related to terrorism within five years of their separation. If they entered the military in search of brotherhood, a voluntary short term of service might suggest dissatisfaction with their experience, and they might harbor ill feelings. Discharge due to reduction in force or less than satisfactory service might increase that animosity. This may be an important factor to consider. The bitterness created by such an experience will fall upon the U.S. government and may generate a hate that drives one toward revenge.

Conclusion

The mindset of a terrorist is difficult to describe. The mentality necessary for someone to cause grandiose death and destruction in order to sway the actions or ideologies of others is not yet fully understood. This chapter pointed out several life experiences that may increase one's susceptibility to radicalization. Real or perceived economic or social inequality, lack of political freedom, fundamentalist religious indoctrination, extreme racial bias, and unfavorable experience in the military are examples that may drive such a mindset.

Lacking a unified terrorist psychology, we must use the attributes of known terrorists in order to describe the individuals who are most likely to be converted. Based on the traits presented in this chapter, those most likely to become terrorists are single men, young or middle aged, from the middle or upper class with some college education, but raised without a father figure and alienated in some way. When such an individual tends to be aggressive and externalize blame, their potential to act out increases. Expressing a desire for vengeance or aspiring to champion a cause puts them at the highest risk level.

Chapter 3 Notes

1. Brigitte L. Nacos, *Terrorism and Counterterrorism*, 5th ed. (New York, N.Y.: Routledge, 2016).

2. O. Shawn Cupp, David E. Walker and John Hillison, "Agroterrorism in the US: Key Security Challenge for the 21st Century," *Biosecurity and Bioterrorism: Biodefense Strategy, Practice, and Science* vol. 2, no. 2 (2004), 97-105; Jim Monke, "Agroterrorism: Threats and Preparedness" Library of Congress, Washington D.C. Congressional Research Service, (2006).

3. Terrance M. Wilson, et al, "Agroterrorism, Biological Crimes, and Biowarfare Targeting Animal Agriculture: The Clinical, Pathologic, Diagnostic, and Epidemiologic Features of some Important Animal Diseases," *Clinics in Laboratory Medicine* vol. 21, no. 3 (2001), pps. 549-592.

4. Dr. Terry L. Oroszi and Dr. David H. Ellis, *The American Terrorist: Everything You Need to Know to be a Subject Matter Expert* (Dayton, Ohio: Greylander Press, LLC, 2019).

5. Clare Richardson, "Relative Deprivation Theory in Terrorism: A Study of Higher Education and Unemployment as Predictors of Terrorism," Politics Department, New York University (2011).

6. Nasra Hassan, "An Arsenal of Believers: Talking to the "Human Bombs," *The New Yorker*, vol. 19, Dec. 9, 2018.

7. Emily Corner and Paul Gill, "A False Dichotomy? Mental Illness and Lone-Actor Terrorism," *Law and Human Behavior* vol. 39, no. 1 (2015), p. 23.

8. Jerrold M. Post, "Terrorist Psycho-Logic: Terrorist Behavior as a Product of Psychological Forces" (Washington, D.C., Woodrow Wilson International Center for Scholars, 1990), pps. 25-40.

9. Sandra Baez, et al, "Outcome-Oriented Moral Evaluation in Terrorists," *Nature Human Behaviour*, www.nature.com/articles/s41562-017-0118#supplementary-information.

10. Stephane J. Baele, "Lone-Actor Terrorists' Emotions and Cognition: An Evaluation Beyond Stereotypes," *Political Psychology* vol. 38, no. 3 (2017), pps. 449-468.

11. James Gilligan, "Toward a Psychoanalytic Theory of Violence, Fundamentalism and Terrorism," *International Forum of Psychoanalysis* vol. 26, no. 3 (2017), pps. 174-85.

12. J. Elad-Stenger, "Activism as a Heroic Quest for Symbolic Immortality: An Existential Perspective on Collective Action," *Journal of Social and Political Psychology* vol. 4 (2016), pps. 44-65.

13. Roger Griffin, "The Role of Heroic Doubling in Ideologically Motivated State and Terrorist Violence," *International Review of Psychiatry* vol. 29, no. 4 (2017), pps. 355-361.

14. Magnus Ranstorp, "Terrorism in the Name of Religion," *Journal of International Affairs* (1996), pps. 41-62.

15. Charles A. Russell and Bowman H. Miller, "Profile of a Terrorist," *Studies in Conflict & Terrorism* vol. 1, no. 1 (1977), pps. 17-34.

16. Oroszi and Ellis, *The American Terrorist*, pps. 145-146

17. Oroszi and Ellis, *The American Terrorist*, pps. 83-85

18. Ibid.

19. Claude Berrebi, "Evidence about the Link between Education, Poverty and Terrorism among Palestinians," *Peace Economics, Peace Science and Public Policy* vol. 13, no. 1 (2007); Alan B. Krueger and Jitka Malečková, "Education, Poverty and Terrorism: Is there a Causal Connection?" *The Journal of Economic Perspectives* vol. 17, no. 4 (2003), pps. 119-144.

20. Marc Sageman, *Understanding Terror Networks* (Philadelphia, Pa.: University of Pennsylvania Press, 2004).

21. Oroszi and Ellis, *The American Terrorist*, pps. 71-73.

22. Diego Gambetta and Steffen Hertog, "Engineers of Jihad," (2007).

23. Alberto Abadie, "*Poverty, Political Freedom, and the Roots of Terrorism*," (Cambridge, Mass.: National Bureau of Economic Research, 2004).

24. Krueger and Malečková, pps. 119-144.

25. "Southern Poverty Law Center: Antigovernment Movement," accessed Dec. 15, 2018, www.splcenter.org/fighting-hate/extremist-files/ideology/antigovernment.

26. Stanley Fitzgerald Horn, *Invisible Empire: The Story of the Ku Klux Klan, 1866-1871* (Montclair, N.J.: Patterson Smith Publishing Corporation, 1969).

27. "Southern Poverty Law Center: Hate Map," 2018, www.splcenter.org/hate-map.

28. Jody Feder, *Racial Profiling: Legal and Constitutional Issues* (Washington, D.C.: Library of Congress, Congressional Research Service, 2012).

29. George C. Thomas, "Terrorism, Race and a New Approach to Consent Searches," *Mississippi Law Journal*, vol. 73 (2003), p. 525.

30. Oroszi and Ellis, *The American Terrorist*, p. 92.

31. James Dingley, "The Terrorist-Developing a Profile," *International Journal of Risk Security and Crime Prevention* vol. 2 (1997), pps. 25-37.

32. Laura Sjoberg and Caron E. Gentry, *Women, Gender, and Terrorism* (Athens, Ga.: University of Georgia Press, 2011).

33. Ranstorp, pps. 41-62.

34. Oroszi and Ellis, *The American Terrorist*, p. 95.

35. Mark Juergensmeyer, "The Mind of God," *In Terror in the Mind of God, Fourth Edition: The Global Rise of Religious Violence*, pps. 266-302 (Oakland, Calif.: University of California Press, 2017).

36. Ranstorp, pps. 41-62.

37. Daniel Chen, "Economic Distress and Religious Intensity: Evidence from Islamic Resurgence during the Indonesian Financial Crisis," *American Economic Review* (2003).

38. Russell and Miller, pps. 17-34.

39. Brian M. Jenkins, "The Terrorist Mindset and Terrorist Decision-making: Two Areas of Ignorance," *Terrorism* vol. 3, no. 3-4 (1980), pps. 245-250.

40. Dingley, pps. 25-37.

41. Oroszi and Ellis, *The American Terrorist*, pps. 140-146.

42. Oroszi and Ellis, unpublished dataset.

43. Active and Reserve U.S. Military Force Personnel Numbers by Service Branch and Reserve Component in 2017.

44. Oroszi and Ellis, unpublished dataset.

45. Oroszi and Ellis, unpublished dataset

46. M. E. Gubata, et al, "A Noncognitive Temperament Test to Predict Risk of Mental Disorders and Attrition in U.S. Army Recruits," *Military Medicine* vol. 177, no. 4 (April 2012), pps. 374-379.

47. D. W. Niebuhr, et al, "Personality Assessment Questionnaire as a Pre-Accession Screen for Risk of Mental Disorders and Early Attrition in U. S. Army Recruits," *Psychological Services* vol. 10, no. 4 (November 2013), pps. 378-385.

48. Nancy A. Skopp, et al, "An Examination of the Diagnostic Efficiency of Post-Deployment Mental Health Screens," *Journal of Clinical Psychology* vol. 68, no. 12 (December 2012), pps. 1,253-1,265.

49. Cliodhna Sargent, Cormac Gebruers and Jim O'Mahony, "A Review of the Physiological and Psychological Health and Wellbeing of Naval Service Personnel and the Modalities used for Monitoring," *Military Medical Research* vol. 4 (Jan. 18, 2017).

CHAPTER 4

Response to Agroterrorism by Foreign Animal Disease

Major Kelley J. Williams and Steven A. Schmitt

The agricultural livestock sector of the United States is vulnerable to chemical threats and biological pathogens from the point of origin (i.e., farms, ranches, feedlots) to the point of distribution and consumption (i.e., supermarkets, restaurants).[1] This chapter outlines some of the key stakeholders in response to a potential livestock agroterrorism incident as well as the legal framework surrounding a response. This summary should not be considered comprehensive as each incident will be unique, and the stakeholders and responders may vary greatly based on the situation.

There are currently no known active threats that specifically target the food chain[2] of the United States. However, enemies of the United States are known to have interests in using biological pathogens to infect personnel, animals, and crops. In 2002, Navy SEALs found a list of pathogens and their intended hosts.[3] Photos were later found of al-Qaeda experimenting with pathogens on animals. A similar pathogen list was found at Osama bin Laden's compound in Pakistan after his death in 2011.[4] In 2015, Kim Jong-un released a video showing North Korean dual-use capabilities at the Pyongyang Biotechnical Institute, which could produce both pesticides and offensive biological agents.[5]

Biological threats are commonly found in nature and hold modern agricultural animals at risk. The livestock and poultry sectors of the United States agricultural industry provide food, income, employment, and a source of foreign exchange.[6] Furthermore, the health of agricultural livestock is considered a key factor in promoting food security and human health.[7]

Detecting an Agroterrorism Incident

Detection Challenges

Unlike attacks with guns or explosives, an agroterrorism incident could go unnoticed entirely. A terrorist organization may take ownership of the attack, which would immediately start a federal law enforcement investigation. If no ownership of the attack is taken, detection might come from ranchers, livestock owners, farmers, and various product inspectors between the farm and the table. Agroterrorism incidents are expected to present with disease that is out of season, out of geographic area, or in unusually high frequency. Additional indicators of agroterrorism incidents involve three points of the epidemiological triangle: the host, the agent, and the environment.

Further signs include:

- An unusual event with a large number of affected people or animals
- Higher morbidity or mortality than expected
- Uncommon disease manifestations
- A point-source outbreak
- Multiple endemics[8]

An expected scenario is that ranchers and farmers may notice unusual signs and symptoms of disease in their animals and notify local experts. These experts, such as foreign animal disease diagnosticians (FADDs), may perform a foreign animal disease investigation (FADI) to determine the causative agent. Initially, it may be challenging to determine if an outbreak is natural or malicious. Furthermore, attacks which use endemic pathogens may not be recognized as malicious. Complicating the detection problem, current field investigations are focused on biological signs and symptoms, not necessarily those that may result from hazardous chemicals.

An agroterrorism incident response would likely include a wide variety of civilian and government organizations regardless of the geographic size of the incident. These stakeholders would most likely consist of local, state, tribal, federal, and agricultural industry officials, agricultural experts, law enforcement officers, and emergency management personnel. The state emergency management agency and state animal health emergency response plans may be fully activated. Small incidents may only involve various emergency support functions (ESF) sections at the state level, such as ESF-8 (Public Health and Medical Services Annex) and ESF-11 (Agriculture and Natural Resources Annex).[9]

Foreign Animal Diseases and Transboundary Animal Diseases

Pathogens may exist naturally, be introduced to hosts accidentally or maliciously, remain within one species, or move between animal species and humans. Pathogens are difficult to control when they can survive in numerous hosts and is almost impossible if a pathogen is widespread in wild animal populations or is stable in the environment for long periods.[10]

A study by the U.S. Department of Agriculture National Animal Health Monitoring System (NAHMS) found that more than two-thirds (69.4 percent) of livestock operations vaccinated some portion of their cattle for 21 potential pathogens.[11] Agricultural animal owners cannot protect their animals from all potential pathogens because vaccines are only available for the most common threats based on geographic region, type of operation, and local concerns. The growing threat of antibiotic overuse is also a concern. Since standard vaccination schedules are public knowledge, adversaries could select pathogens for which agricultural animals may not have immunity. Naïve animals would magnify the effects of an agroterrorism incident, which involved a properly selected pathogen.

Foreign animal diseases (FADs) are not endemic to the United States, but are capable of spreading rapidly and causing high numbers of deaths and devastating economic consequences.[12] Some FADs infect only animals (non-zoonotic), such as African or classical swine fevers and foot-and-mouth disease (FMD), while others can also infect humans (zoonotic), such as Rift Valley fever virus, Japanese encephalitis virus, Nipah virus, and the Ebola virus. An animal disease that was previously eradicated, but returns would also be considered a FAD.

Additionally, a transboundary animal disease (TAD) is used to describe FADs further that:

- Represent significant economic, trade and food security importance for a considerable number of countries
- Easily spread between countries and reach epidemic proportions
- Where control or management, including exclusion, requires cooperation between several countries[13]

Many FADs and TADs could cause substantial morbidity and mortality in animals, are potentially zoonotic, and cause economic losses by affecting trade with other countries and states. The novel presence of these diseases may pose considerable harm to farmers, ranchers, and the communities they serve.[14] TADs tend to be more prevalent and pervasive in lower-middle and low-income countries (within) sub-Saharan Africa and Asia and include zoonotic and non-zoonotic pathogens.[15] Zoonotic TADs include highly pathogenic avian influenza, anthrax, Rift Valley fever, Ebola, rabies, and Crimean Congo hemorrhagic fever. Non-zoonotic TADs include Newcastle disease, peste des petits ruminants (plague of small ruminants), and African swine fever.

Foreign Animal Disease Investigations and Resources

Most responses to a suspected FAD will begin at the local level.[16] As such, localities and states often have unique procedures to conduct initial reporting and investigations. The domestic response to potential FAD often begins when a livestock owner or any member of the agriculture and animal health community notices clinical signs in the animals during regular surveillance. The owner should call the local federal assistant district director (ADD) or the state veterinarian's office who will dispatch a foreign animal disease diagnostician (FADD). The FADD performs a foreign animal disease investigation (FADI), which involves visual triage and possibly field diagnostics such as a complement fixation test. The purpose of an FADI is to ensure the health of livestock and protect the nations' food supply at the point of origin.

The FADD may need to send samples from an affected animal for further testing and confirmatory analysis at the National Veterinary Services Laboratories

(NVSL) at Plum Island or Ames, Iowa. The Plum Island Animal Disease Center (PIADC) is the only laboratory in the nation authorized to conduct initial diagnostics for FMD.[17] The FAD work at the FADDL is scheduled to move from Plum Island to the National Bio and Agro-Defense Facility (NBAF) in Manhattan, Kan. in 2022-2023.[18]

Samples that are positive for a FAD will warrant further investigation by a variety of local, regional, and federal stakeholders. Even after confirmation of a FAD, a law enforcement investigation may not take place unless there are suspicious circumstances involved in the FAD outbreak or if the causative agent is highly unusual. Throughout the process, it is common that the local FBI field office remains aware of the potential FAD and stays in communication with the ADD or the state veterinarian's office.

Due to homeland security threats, veterinarians have become a substantial participant within the Homeland Security Presidential Directive-5 (HSPD-5). This requires veterinarians to have awareness training on the National Incident Management System (NIMS) to understand how an incident command system works, and their roles within this framework.[19] Thus, the potential for an agroterrorism event has expanded the knowledge base and responsibilities within the civilian sector. However, the perception of threat and preparedness for this role may be inadequate due to lack of knowledge of emergency management and skills in communication with stakeholders. Thus, veterinarian roles are mostly limited to their technical expertise in the field. They would not necessarily be required to contribute to communication with the media, public, or government on an agroterrorism incident.

Foreign Animal Disease Training

FAD training is intended to safeguard animal health along with food safety for the public. There is a variety of courses for veterinarians, but there are specific courses required to possess a skillset acceptable for agroterrorism events. Held at the National Veterinary Services Laboratories (NVSL) at Plum Island and Ames, Iowa, the Foreign Animal Disease Diagnostician (FADD) Course is the basic instruction in becoming an FADD. The FADD course provides an overview of the clinical signs and gross pathology of 11 FADs and other domestic animal diseases. The course also provides knowledge of PIADC diagnostic procedures and procedures for acquiring and shipping samples to PIADC. Students come from federal, state, military, and academia.

Foreign Animal Disease Diagnostician (FADD)

An FADD is a federal- or state- employed veterinarian who has completed the FADD Course and any continuing education and unique training required. A FADD has three objectives in an FADI. First, to provide a veterinary medical assessment which the FADD provides a possible diagnosis, classifies the investigation, and designs the sample priority. Second, to provide presumptive and confirmatory diagnostic testing to rule out or confirm a FAD possibly. Third, to ensure countermeasures are correctly employed by communicating to local, interstate, or international commerce involved with animals and products. Communication with state ESF-8 and ESF-11 coordinators and law enforcement could begin at this point if unusual circumstances accompany the FADI.

There are three classifications of suspicion for a FAD: high suspicion, intermediate suspicion, and low suspicion.[20] Samples are transported to a NVSL by numerous methods, which may be extreme in the case of a highly suspicious agent. These may include hand-carried and contracted commercial services such as small airplanes. Routine transportation generally consists of services such as FedEx.

Extension Agents

An extension agent carries the unique role of intervening and assisting in the wide range of problems faced by farmers.[21] The history of the extension agents goes back as far as World War I. They initially were used during wartime to assist increasing production in agriculture and animal products. The use of extension agents has evolved into an assistance program for less than two percent of Americans who make a living through farming. The extension agents are based out of public or tribal universities. Generally, there are one or two extension agencies within a state.

There is no specific role an extension agent may provide farmers. Instead, the extension agent may assist with resources and guidance to farmers in a large number of situations. The primary duty of an extension agent is to help farmers overcome agricultural challenges.[22] This includes being a facilitator between the farmer and animal experts in time of crisis. This facilitation is significant if a FAD is confirmed. Agents may provide preparedness training for future problems such as an agroterrorism event. In this case, agents will provide structured guidance and management based on governmental policies, procedures, and information on a state's specific response strategy to an agroterrorism event.

U.S, Department of Agriculture Veterinary Services

The USDA Animal and Plant Health Inspection Service (APHIS) Veterinary Services (USDA/VS) is the federal agency responsible for FADs and is postured for epidemiological investigation during a FAD incident. In the event of an agroterrorism incident, a federal law enforcement investigation would assist with identifying the source of an outbreak. Following notification of a potential FAD, the USDA/VS responds quickly to minimize the incident's negative impact on the agricultural industry. For most FAD incidents, the USDA/VS also serves as the source for federal funding. The USDA/VS follows the FAD Preparedness and Response Plan (FAD PReP) standard operating procedures. FAD PReP integrates and synchronizes the principles of the National Response Framework (NRF) and NIMS by providing stakeholders with FAD outbreak response goals, guidelines, strategies, and procedures.[23]

National Animal Health Surveillance System

The National Animal Health Surveillance System (NAHSS) provides an essential asset to the early detection of an agroterrorism incident. The NAHSS is a comprehensive, integrated, coordinated detection system for events and trends for all stakeholders involved in public, animal, and environmental health.[24] The NAHSS was created after the Animal Health Safeguarding Review in 2001, which stated that the United States must have an animal health surveillance system. The NAHSS is led and coordinated by the Veterinary Services of the USDA. The NAHSS provides protection services for endemic, emerging, and foreign animal diseases that may affect the nation's livestock, poultry, and wildlife populations by (1) facilitating information exchange between surveillance groups, (2) enhancing current surveillance programs, and (3) establishing and maintaining the necessary infrastructure for active and comprehensive surveillance.[25]

NAHSS integrates surveillance efforts included in HSPD-9. The NAHSS objectives include early detection and global risk surveillance of foreign animal disease and emerging diseases.[26] Surveillance programs include aquaculture, cattle, cervids, equine, avian, sheep and goats, and swine. These surveillance programs capture monthly and annual reports of potential threats to animal health.

Although the primary goal of the NAHSS is to prevent, eradicate, and mitigate the spread of disease, these programs are essential to anti-agroterrorism efforts because they identify outlying incidents. While the NAHSS strategic plan does not address specific anti-agroterrorism goals or objectives, it indirectly assists with surveillance for agroterrorism incidents, which supports a rapid response.

Law Enforcement Involvement

Agroterrorism is a threat that cannot be adequately approached by local, state, or federal law enforcement operating independently.[27] Thus, a joint effort between all authorities, along with experts in the field of animal health, would work together in a unified ICS. The FBI is the lead federal law enforcement agency for preventing and investigating agroterrorism. The 56 FBI field offices host agroterrorism workshops to develop relationships between stakeholders across the public and private sectors.[28] Through empowering stakeholders to recognize potential threats, reporting of suspicious activity, and appropriately manage the risk in their facilities, the FBI creates active partners in protecting the nation's food supply.[29]

Once indications point to an agroterrorism incident, the FBI would transition from an awareness and monitoring involvement to assuming jurisdiction over the law enforcement response. Since the response and mitigation efforts would likely disturb evidence, all response and mitigation actions would be directed and approved by the FBI special agent in charge (SAIC) assigned to the incident. In many cases, an FBI Evidence Response Team (ERT) and possibly a Hazardous Evidence Response Team (HERT) would complete evidence recovery operations at involved sites before mitigation efforts.

Legislation and Directives Against Agroterrorism

Several pieces of agroterrorism-related legislation have been introduced by Congress, but most have not become law. The 109th Congress introduced six bills addressing agroterrorism preparedness and coordination in various ways. While these bills were mostly unsuccessful in Congress, they indicated an accelerated interest in safeguarding the nation's agriculture and food supply. Successful implementation of HSPD-9 and other initiatives appear to have rendered many of these individual bills redundant. Additionally, the current crimes listed in 18 U.S. Code on biological weapons (Chapter 10), terrorism (Chapter 113B), and others are likely sufficient to address acts of agroterrorism.

Homeland Security Presidential Directive-9

In 2004, President George W. Bush signed Homeland Security Presidential Directive-9 (HSPD-9), a directive titled Defense of United States Agriculture and Food.[30] HSPD-9 established national policy to defend U.S. agriculture and food systems against terrorist attacks, major disasters, and other emergencies. HSPD-9 built upon and was consistent with HSPD-7, which established the Secretary of Homeland Security as the principal federal official for coordinating the overall national effort to enhance the protection of the critical infrastructure and critical resources of the United States. A critical objective was to establish a coordinated agriculture and food-specific response plan that would be integrated into the National Response Plan (NRP). The directive also called for the development of tools to mitigate the economic and health impact of an agroterrorism incident.

Agroterrorism Prevention Act of 2005

The Agroterrorism Prevention Act of 2005 was intended to amend title 18 of the U.S. Code to criminalize acts of agroterrorism.[31] The act would have authorized funding for USDA and U.S. Department of Homeland Security (DHS) Federal Emergency Management Agency (FEMA) to assist states in developing response plans. It also would have authorized funding for public awareness, the dissemination of farm-level biosecurity guidelines, and mandated further development of a National Veterinary Stockpile and a National Plant Disease Recovery System, primarily mentioned in HSPD-9.

The bill defined agroterrorism as: A criminal act consisting of causing, financing, or attempting to cause damage or harm to, or destruction or contamination of, a crop, livestock, raw agricultural commodity, food product, farm or ranch equipment, a material any other property associated with agriculture, or a person engaged in agricultural activity that is committed to intimidate or coerce a civilian population, influence the policy of a government by intimidation or coercion, or disrupt interstate commerce or foreign commerce of the United States agricultural industry.[32]

The bill also intended to enhance the protection of the agricultural industry and food security of the United States through increasing prevention, detection, response, and recovery planning efforts. The bill was introduced but died in Congress and was not enacted.

Whole Community Approach

The Incident Command System (ICS) should be used during any agricultural disaster and should be planned for accordingly. ICS is regularly used by first responders and emergency managers, which enables effective incident management for any size of incident. ICS is intended to be used throughout the United States for disasters or emergency response in conjunction with the *whole community* approach to emergency management.

The whole community approach is a concept used in preparing and responding to disasters that includes all members of society at the national, state, tribal, territorial levels. Emergency managers are charged with ensuring community members understand the importance of this concept and inclusion with plans for any emergency or crisis. Due to the lack of experience with using ICS by agricultural, veterinarian, other civilian entities, the coordination of regular table-top exercises should be implemented to ensure adequate response to an agroterrorism incident. Although there is some required training on ICS, most of the training is online and only provides a general overview. In a critical infrastructure field without much hierarchical structure, ICS is a very different organizational structure for most agricultural or veterinarians. Most of the relations within this field are ad hoc and not structured for an agroterrorism incident. If the likelihood of an attack were higher, along with more significant consequences, there would be a need for a more structured response system within agricultural and livestock communities.

Defense Support to Civil Authorities During an Agroterrorism Incident

The Department of Defense (DOD) provides support to civilian authorities with military forces, DOD civilians, contractors, and national guard forces, when requested by the DOD secretary and authorized by the governors of affected states.[33] These operations are strictly within the United States, and territories including airspace and waters. The DOD is responsible for homeland defense, which protects sovereignty, population, and critical infrastructures of the United States from external threats. Although the DOD augments homeland security operations, it cannot take command authority during a civilian operation. Instead, the DOD only provides support to the United States government or agency that is responding to a crisis or incident if requested appropriately. DOD augmentation generally occurs when a situation is beyond the capabilities of an impacted state or territory. Governors can request assistance from the president and vice versa.

DOD Directive 6400.04E designates DOD veterinary public and animal health services to support planning and operations with civilian veterinary and public health services.[34] The DOD veterinary services also assist with clinical medicine and diagnostic laboratory capabilities. This asset would integrate into an ICS during an agroterrorism incident when further assistance was needed.

The DOD involvement in assisting with response to agroterrorism is twofold. First, the DOD is mandated to support civil authorities during crises and disasters when requested.[35] Second, an agroterrorism attack could interrupt military operations abroad. This necessity comes from known threats such as the discovery of al-Qaeda caves that contained manuals on the USDA, along with instructions involving agroterrorism operations.[36] Current literature alludes to defense support to civilian authorities (DSCA) involvement in an agroterrorism event. However, many scholars suggest the DOD support capabilities are unclear. This means there is not a clear understanding of what the DOD would do during an agroterrorism incident. Thus, the need to plan for the use of the DSCA is still required.

Potential for Future Involvement of National Guard WMD-CST

The National Guard Weapons of Mass Destruction Civil Support Team program (WMD-CST) is designed as a DOD resource to assist civil authorities in an incident which involves known or suspected weapons of mass destruction (WMD) or chemical, biological, radiological, or nuclear (CBRN) hazards, along with advising on response measures, and assisting with additional support and technical reach back. The mission scope was expanded in 2007 for WMD-CSTs to operate in any natural or human-made disaster within the United States that could result in catastrophic loss of life or property.[37] There are 57 WMD-CSTs spread geographically across the United States and U.S. territories. Each state has at least one WMD-CST, while California, Florida, and New York have two teams. WMD-CSTs have 22 hazardous material (HazMat) technicians and are skilled in sampling and analysis of WMD and CBRN hazards in contaminated areas (hot zones). WMD-CSTs are also trained in the Incident Command System (ICS) and typically integrate with the HazMat Division and Operations Section. Due to *posse comitatus* restrictions, WMD-CSTs are never permitted to assume incident command.

Current WMD-CST doctrine does not permit the collection of clinical samples from humans or animals but does allow for the collection of environmental samples such as soil, vegetation, air, water, and surface swabs. Although FADDs are trained and equipped to conduct field diagnostics and conduct clinical sampling, they do not have the training or resources to conduct mass environmental sampling operations. If an agroterrorism incident involved contamination of food or water or the environmental dispersal of biological agents, WMD-CSTs would be a valuable resource to assist in that mission area.

Active WMD-CST involvement in agroterrorism incidents would be aided by efforts to build relationships between WMD-CSTs and agricultural response subject matter experts. If an agroterrorism incident takes place, the FBI will have jurisdiction over the response. WMD-CSTs often work closely with FBI WMD Directorate. This relationship would be valuable if WMD-CST involvement is required.

Conclusions and Recommendations

Improve interagency response

Current literature and federal guidance indicate that response to agroterrorism requires a highly integrated and multiagency response spanning commercial and government stakeholders. Efforts should focus on increasing awareness of the agroterrorism threat and the generic steps anticipated in an agroterrorism response. These efforts could manifest as a three-pronged approach involving formal instruction and outreach, tabletop exercises, and full-scale training events.

Formal instruction and outreach are needed to provide a unified approach to agroterrorism threats and response activities. This material could be developed by FEMA, USDA, FBI, and industry experts and serve as a framework under NIMS and ICS for agroterrorism training. Alternatively, courses on agroterrorism that exist in academia could be adopted for this use. The material could be delivered through community outreach programs that educate peripheral stakeholders about FADIs, agroterrorism concerns, response measures, and roles that these stakeholders may play during an agroterrorism response. One logical approach would be to add an awareness-level agroterrorism course to the FEMA Emergency Management Institute course catalog and require participation for key stakeholders. This new course would expand on the existing FEMA course, which discusses preventing and reducing the consequences of disasters on livestock. Educational content and distribute through state-level agricultural departments.

Tabletop exercises should be conducted to prepare stakeholders for full-scale exercises and refine roles and responsibilities during a known or suspected agroterrorism response. The tabletop exercises could utilize the associated agroterrorism framework to apply the principles to a hypothetical agroterrorism incident. The lessons learned from tabletop exercises would inform organizational policies and procedures, culminating in full-scale exercises. Full-scale training exercises should be conducted that involve stakeholders such as local farmers, extension agents, FADDs, state ESF representatives, the USDA, the FBI, and the National Guard. These training events should be designed to permit broad application of the lessons learned to other regions and agroterrorism threats.

Develop DSCA to Support Agroterrorism Response

If national leaders decide that the DOD should be involved in agroterrorism response, specific training and capabilities should be adopted to facilitate this requirement. This asset should then be integrated into the three-prong approach of formal instruction, tabletop exercises, and full-scale training events. The involvement of DOD assets in agroterrorism response should be defined and integrated into DOD training. Current literature discusses DSCA involvement in an agroterrorism event, but specific roles and capabilities are not clearly defined.[38, 39] The CBRNE Response Enterprise (CBRNE CRE) consists of personnel and equipment dedicated to responding to WMD/CBRNE incidents. In particular, the National Guard WMD-CSTs have the ability to perform field diagnostic techniques such as polymerase chain reaction (PCR) and electrochemical luminescence (ECL) to detect biological agents and toxins, but they have specific target assays from which to choose.[40] Furthermore, no elements of the CBRNE CRE are specially trained or equipped to respond to agroterrorism incidents involving livestock. The CBRNE CRE possesses the base resources to effectively support agroterrorism response, but much work and expense would be required to effectively meet this requirement.

Chapter 4 Notes

1. Peter Chalk, "Hitting America's Soft Underbelly: The Potential Threat of Deliberate Biological Attacks against the U.S. Agricultural and Food Industry," (Santa Monica, Calif.: RAND Corporation, 2004).

2. Kelly Decker and Mollie Halpern, "Preventing Agroterrorism," *FBI This Week*, 2014, www.fbi.gov/audio-repository/news-podcasts-thisweek-preventing-agroterrorism.mp3/view.

3, Maggie Struck Behnke, "Foreign Animal Disease Threats and the National Bio and Agro-Defense Facility," *Laboratory Equipment: Discovery & Design in the Lab*, 2018, www.laboratoryequipment.com/article/2018/06/foreign-animal-disease-threats-and-national-bio-and-agro-defense-facility.

4. Sara Brown, "Is Agriculture Security at Risk? More than You Realize," *Dairy Herd Management*, December 2017, www.dairyherd.com/article/agriculture-security-risk-more-you-realize.

5. Behnke, "Foreign Animal Disease Threats and the National Bio and Agro-Defense Facility.

6. M. J. Otte, R. Nugent, and A. McLeod, "Transboundary Animal Diseases: Assessment of Socio-Economic Impacts," *Fao*, no. 9 (2004), pps. 1-46.

7. Fernando Torres-Velez, et al, "Transboundary Animal Diseases as Re-Emerging Threats: Impact on One Health," Seminars in Diagnostic Pathology 36, no. 3 (2019), pps. 193-96.

8. Zygmunt F. Dembek, et al, "Epidemiology of Biowarfare and Bioterrorism," in *Medical Aspects of Biological Warfare*, ed. Joel Bozue, Christopher K. Cote, and Pamela J. Glass (Fort Sam Houston, Texas: U.S. Army Medical Department Center and School, Borden Institute, 2018), pps. 37-69.

9. Federal Emergency Management Agency, "Emergency Support Function #11 – Agriculture and Natural Resources Annex," in *NRF: Emergency Support Function Annexes*, 2008, pps. 1-16; FEMA, "Emergency Support Function #8 – Public Health and Medical Services Annex," in *NRF: Emergency Support Function Annexes*, 2008, pps. 1-16, www.fema.gov/media-library/assets/documents/25512.

10. Brian Perry and Delia Grace, "The Impacts of Livestock Diseases and Their Control on Growth and Development Processes That Are Pro-Poor," Philosophical Transactions of the Royal Society B: Biological Sciences 364, no. 1530 (London, U.K.: The Royal Society, 2009), pps. 2,643-55.

11. U.S. Department of Agriculture Animal and Plant Health Inspection Service, "Vaccination of Cattle and Calves on U.S. Beef Cow-Calf Operations," U.S. Department of Agriculture Info Sheet, 2010.

12. U.S. Department of Homeland Security, "National Bio and Agro-Defense Facility: Environmental Impact Statement," 2008, www.dhs.gov/sites/default/files/publications/NBAF Scoping Report.pdf.

13. Otte, Nugent, and McLeod, "Transboundary Animal Diseases: Assessment of Socio-Economic Impacts."

14. South Dakota Animal Industry Board, "Foreign Animal Diseases and Transboundary Animal Diseases," 2016, https://aib.sd.gov/FAD.html.

15. Torres-Velez, et al, "Transboundary Animal Diseases as Re-Emerging Threats: Impact on One Health."

16. Knowles Terry, et al, *Defining Law Enforcement's Role in Protecting American Agriculture from Agroterrorism* (Washington, D.C.: National Institute of Justice, 2005) www.ncjrs.gov/pdffiles1/nij/grants/212280.pdf.

17. U.S. Department of Homeland Security, "Plum Island Animal Disease Center," fact sheet (Washington, D.C.: U.S. Department of Homeland Security), www.dhs.gov/publication/st-piadc-fact-sheet.

18. Ron Trewyn, "National Bio and Agro-Defense Facility," 2019, www.k-state.edu/nbaf.

19. James G. W. Wenzel, "Organizational Aspects of Disaster Preparedness and Response," *Journal of the American Veterinary Medical Association* 230, no. 11 (2007), pps. 1,634-37, https://doi.org/10.2460/javma.230.11.1634.

20. Brian McCluskey, *Policy for the Investigation of Potential Foreign Animal Disease/Emerging Disease Incidents* (Washington D.C.: U.S. Department of Agriculture, 2017).

21. Jim Monke, "Agroterrorism: Threats and Preparedness," *CRS Report for Congress DL32521*, 2007.

22. Gwyn E. Jones and Chris Garforth, "The History, Development, and Future of Agricultural Extension," in *Improving Agricultural Extension: A Reference Manual*, ed. Burton E. Swanson, Robert P. Bentz, and Andrew J. Sofranko, pps. 1998, pps. 1-15.

23. U.S. Department of Agriculture Animal and Plant Health Inspection Service, "Foreign Animal Disease Framework: Roles and Coordination," (Washington D.C.: U.S. Department of Agriculture, 2016), www.aphis.usda.gov/animal_health/emergency_management/downloads/documents_manuals/fadprep_manual_1.pdf.

24. U.S. Department of Agriculture Animal and Plant Health Inspection Service, "National Animal Health Surveillance System," 2019, www.aphis.usda.gov/aphis/ourfocus/animalhealth/monitoring-and-surveillance/sa_nahss.

25. Ibid.

26. Ibid.

27. Terry, et al, "Defining Law Enforcement's Role in Protecting American Agriculture from Agroterrorism."

28. Decker and Halpern, "Preventing Agroterrorism."

29. Terry, et al, "Defining Law Enforcement's Role in Protecting American Agriculture from Agroterrorism."

30. President George W Bush, "Homeland Security Presidential Directive, HSPD – 9 — Defense of United States Agriculture and Food," no. d (2004), pps. 173-77.

31. Sen. Arlen Specter, “S.1532 - Agroterrorism Prevention Act of 2005” (2005), www.congress.gov/bill/109th-congress/senate-bill/1532/text?r=7.

32. Ibid.

33. Department of Defense Joint Chiefs of Staff, *Joint Publication 3-28: Defense Support of Civil Authorities* (Washington D.C.: Department of Defense, 2013), https://doi.org/10.2519/jospt.2012.42.4.A1.

34. Department of Defense, “DoD Directive 6400.04E: DOD Veterinary Public and Animal Health Services;” U.S. Department of Agriculture Animal and Plant Health Inspection Service Foreign Animal Disease Framework — Roles and Coordination, *USDA Manual 1-0*, (Washington D.C.: U.S. Department of Agriculture, August 2017), www.esd.whs.mil/Portals/54/Documents/DD/issuances/dodd/640004e.pdf?ver=2017-08-29-132039-997.

35. DOD Joint Publication 3-28.

36. Jim A. Davis, et al, *Agroterrorist Attack: DoD Roles and Responsibilities* (Maxwell Air Force Base, Ala.: U.S. Air Force Counterproliferation Center, 2006), www.hsdl.org/?view&did=747577.

37. NGB, *NGB-J39 Procedural Guidance: Weapons of Mass Destruction Civil Support Teams*, 2018.

38. Jim A. Davis, et al, *Agroterrorist Attack.*

39. John H. Grote, *Agroterrorism: Preparedness and Response Challenges for the Department of Defense and Army*. (Carlisle, Pa.: Army War College, Civilian Research Project), www.hsdl.org/?view&did=478445.

40. Department of Defense National Guard Bureau, *NGB-J39 Procedural Guidance: Weapons of Mass Destruction Civil Support Teams*, 2018.

CHAPTER 5

U.S. Federal Policies and Programs to Combat Agroterrorism

Henry S. Parker and Janet Marroquin

The United States has the most successful, extensive, and diverse agricultural enterprise in the world. It comprises two million farms, occupies one billion acres, and feeds 300 million Americans and many more global citizens.[1] It provides abundant, nutritious, safe, and affordable food products to its citizens who spend far less of their disposable income on nutrition than most of the rest of the world. Yet, despite these successes, the United States is highly vulnerable to agroterrorism.

From farm to fork, the U.S. food and agriculture (FA) sector accounts for 5.5 percent of the nation's Gross Domestic Product and 11 percent of U.S. employment (nearly 22 million jobs).[2] Furthermore, the United States. exports $140 billion of agricultural products annually.[3] This is a bright exception to the otherwise dismal U.S. trade balance.

About 90 percent of the nation's farms are small farms and more than 90 percent are family farms.[4] Nonetheless, large farms account for three-fourths of the production value of U.S. agriculture.

The U.S. FA sector is more than just food. It also includes beverages, ornamental crops, animal feed, fiber and forestry products, and biofuels (e.g., ethanol). Farmlands and forests incorporate important watersheds and landscapes, and offer recreational opportunities. Inputs (pre-production) to the system include seeds, feed, chemicals, equipment, and services. Post-harvest activities and components include processing, slaughterhouses, packaging, storage, transportation, distribution, retail, wholesale, and institutional sales as well as restaurants, home consumption and imports/exports.

Agroterrorism: Threat and Vulnerability[5, 6]

There are multiple, sometimes conflicting definitions of agroterrorism. Here, we define agroterrorism as intentional attacks or threats against food and agriculture by non-state actors, typically for political or ideological reasons (biological attacks carried out by state actors would constitute biowarfare. Those perpetrated by individuals or small groups for criminal purposes, such as food tampering, would be biocrimes).

Agroterrorism usually connotes use of *bioagents*, such as microbes, macro-organisms including insects and weeds, and biotoxins. However, actors could also employ harmful chemicals, radionuclides, explosives, cyberattacks, or even physical disruption (e.g. derailing a train). Possible targets could include any component of the farm to fork continuum, or even non-food activities like forestry or research. For example, animal rights extremists have attacked research facilities.

There have been few documented cases of agroterrorism. However, the sector's very success, in terms of size and value, means that it is a tempting target, and our largely open farms and facilities are not adequately protected.

Crops and farm animals in the United States are also vulnerable to diseases of both domestic and overseas origin. Limited exposure to exotic pathogens and foreign animal diseases, and narrow genetic diversity reduces immunity to those diseases when they do strike. When infection sets in, symptoms may not show up for several days. Diagnosis can be challenging because of insufficient diagnostic facilities and trained diagnosticians. American farms are often adjacent to natural areas, so nearby wildlife and indigenous plants may be reservoirs or vectors for agricultural diseases. We have few vaccines and pharmaceutical products to prevent or treat diseases.

The corporate nature of U.S. agriculture amplifies vulnerability to diseases. Principally, U.S. animals and products move rapidly across large distances making it hard to contain a disease outbreak or trace its origin. Livestock and crops tend to be concentrated in geographic regions and specific locales (e.g. feedlots), facilitating the rapid spread of disease. Furthermore, U.S. agriculture firms are often vertically integrated, so an introduced pathogen could readily be passed along the production and processing chain. In addition, the FA sector employs large numbers of transient or undocumented workers.

Americans' growing dependence on international foods also creates a significant vulnerability. More than nine million imported food shipments cross the borders of the United States annually at 360 border entry points, but only about one percent is inspected.[7] Finally, Americans largely take their food for granted, leading to complacency about threats to the FA sector.

U.S. Food Defense

As for agroterrorism, there are many, sometimes conflicting definitions of food defense. For our purposes here, food defense comprises the policies and processes to protect the FA sector from intentional attacks or disruption, including from agroterrorism. Food defense may also guard against biowarfare, criminal acts, or food fraud. Food defense is distinguished from food safety in that the latter relates to unintentional contamination.

Prior to the Sept. 11, 2001, terrorist attacks (9/11), the nation was poorly prepared for potential agroterrorism. In fact, the FA sector was not even identified as a critical national infrastructure.[8] Since 9/11, the United States has established a substantial regulatory and policy framework for food defense.[9] The framework comprises both federal legislation and White House policy directives.

Three principal, post-9/11 legislative acts buttressed the nation's capabilities to prevent, prepare for, and respond to acts of terrorism, including agroterrorism. The Homeland Security Act of 2002 established the U.S. Department of Homeland Security (DHS).[10] Regarding food defense, the act transferred certain agricultural import and entry inspection functions from the U.S. Department of Agriculture (USDA) to DHS and turned over operating authority for USDA's Plum Island Animal Disease Center from USDA to DHS.[11]

The Public Health Security and Bio-Terrorism Preparedness and Response Act of 2002, also known as the "Bioterrorism Act," substantially strengthened the nation's ability to counter bioterrorism by amending the Public Health Service Act.[12] This act called for a national preparedness plan to counter bioterrorism, and a strategic national stockpile for drugs, vaccines, and related countermeasures. It also created a national select agents registry (NSAR) program to carefully account for and manage potentially dangerous biological agents and toxins.[13] Finally, it amended the Federal Food, Drug, and Cosmetic Act by giving additional authority to the Food and Drug Administration (FDA) to protect food from contamination or adulteration.

The third significant legislation, the FDA Food Safety Modernization Act of 2010 further amended the FFDCA by providing new authorities to FDA to protect the food supply[14] of the United States. That act emphasizes preventing food contamination, rather than simply responding to it.

Other pertinent post-9/11 legislation included The Animal Health Protection Act of 2002, as amended through 2008.[15] This established a consolidated statutory framework for all animal quarantine and related laws and gave specific authority to APHIS to protect animal health. The Securing Our Agriculture and Food Act of 2017 amended the Homeland Security Act of 2002 by codifying DHS's lead role in coordinating, overseeing, and managing U.S. food defense.[16] The National Defense Authorization Act of 2017 called for the secretaries of the Defense, Health and Human Services, Homeland Security, and Agriculture Departments to jointly develop a national biodefense strategy.[17]

Since 9/11, the White House has issued a number of policy directives, executive orders, and memoranda in support of biodefense and food defense. Homeland Security Presidential Directive-5 (HSPD-5) of Feb. 28, 2003: Management of Domestic Incidents, called for establishment of a single, comprehensive national incident management system.[18] Homeland Security Presidential Directive-7 (HSPD-7) of Dec. 17, 2003: Critical Infrastructure Identification, Prioritization, and Protection, identified sector-specific agencies responsible for protecting the nation's critical infrastructure.[19] This was the first formal recognition that the U.S. food and agriculture enterprise is a critical national infrastructure.[20] HSPD-7 was replaced in 2013 by Presidential Policy Directive21 (PPD-21, see below).

Presidential Policy Directive-8 (PPD-8) of March 30, 2011: National Preparedness, called for establishment of a nationwide "all-hazards" preparedness goal to address preparedness, security, resilience, prevention, protection, mitigation, response, and recovery.[21]

The most significant presidential directive addressing food defense was Homeland Security Presidential Directive-9 (HSPD-9) of Jan. 30, 2004: Defense of United States Agriculture and Food.[22] This set forth, for the first time, "a national policy to defend the agriculture and food system against terrorist attacks, major disasters, and other emergencies." The directive assigned the overall coordinating role to DHS, with USDA and FDA designated as sector-specific agencies, supported by other federal agencies.[23] HSPD-9 is currently under revision.

Homeland Security Presidential Directive-10 (HSPD-10) of April 28, 2004. Biodefense for the 21st Century, called for a coordinated program involving federal, state, local, and private stakeholders to defend the nation against biological threats and attacks.[24] Finally, Presidential Policy Directive-21 (PPD-21) of Feb. 12, 2013: Critical Infrastructure Security and Resilience, laid out an updated, coordinated public and private national policy for critical infrastructure security and resilience, including cybersecurity, with better definition of federal agency roles, functions, responsibilities, and opportunities.[25] PPD-21 has replaced HSPD-7.

Aligned with PPD-21, Executive Order 13636 of Feb. 12, 2013: Improving Critical Infrastructure Cybersecurity focuses on promotion and development of a framework, practices, and regulations to strengthen nation's protection of critical infrastructure cybersecurity.[26] In addition, two relevant National Security Presidential Memoranda (NSPM) were recently issued. NSPM-7 of Oct. 4, 2017: National Security and Defense, supplements U.S. National Security Strategy through strong emphasis on information sharing and collaboration among government sectors at all levels, private sector stakeholders, and the international community.[27] NSPM-14 of Sept. 18, 2018: Support for National Biodefense, provides for implementation of the national biodefense strategy.[28]

Federal Responsibilities, Programs, and Capabilities for Food Defense

While recognizing that the private sector is the first line of defense against agroterrorism, this report focuses on the federal government's role in food defense. Three federal agencies have primary responsibilities: USDA, HHS/FDA, and DHS. Several other agencies, including DOD, also have important roles. Specific missions, responsibilities, and food defense-related programs are as described in the following sections.

U.S. Department of Agriculture

The mission of the U.S. Department of Agriculture (USDA) is to "Provide leadership on agriculture, food, natural resources, rural infrastructure, nutrition, and related issues through fact-based, data-driven, and customer-focused decisions."[29] Overall responsibility for overseeing and managing the USDA counter-agroterrorism efforts resides in the department's Office of Homeland Security (OHS), housed within the office of the USDA secretary.[30] Three USDA agencies have the principal roles for food defense: Animal and Plant Health Inspection Service (APHIS), the Food Safety and Inspection Service (FSIS), and the Agricultural Research Service (ARS).

USDA Animal and Plant Health Inspection Service – The mission of the U.S. Department of Agriculture Animal and Plant Health Inspection Service (APHIS) is "to protect the health and value of American agriculture and natural resources."[31] It accomplishes this by "protecting and promoting U.S. agricultural health, regulating genetically engineered organisms, administering the Animal Welfare Act and carrying out wildlife damage management activities."[32] APHIS and FSIS share responsibility to address both unintentional and deliberate risks and threats to food products. APHIS carries out its food defense-related activities through four programs: Plant Protection and Quarantine, Veterinary Services, Wildlife Services, and the International Service.

Plant Protection and Quarantine – Plant Protection and Quarantine (PPQ) "safeguards U.S. agriculture and natural resources against the entry, establishment, and spread of economically and environmentally significant pests, and facilitates the safe trade of agricultural products."[33]

Under PPQ, the Cooperative Agricultural Pest Survey (CAPS) works with state Departments of Agriculture to surveil select pathogens across the United States.[34] PPQ also endeavors to prevent the entry, establishment, and spread of foreign agricultural pests and pathogens, while ensuring the safe trade of agricultural products.[35] PPQ collaborates with the DHS Customs and Border Protection (CBP) to inspect imported and exported products, and with foreign partners to strengthen early detection capabilities overseas. PPQ's offshore surveillance tools include PestLens, a web-based data integration device that collects and disseminates information on exotic plant pests.[36]

PPQ provides identification and diagnostic capabilities through the National Identification Service and the National Plant Diagnostic Network.[37] These inform quarantine action decisions.[38]

PPQ and Veterinary Services jointly develop response plans to plant and animal disease outbreaks, exercises, emergency response testing, and corrective actions.[39] PPQ uses the National Plant Health Emergency Response Framework for multisectoral collaboration in responding to plant health emergencies, and the *Emergency Response Manual* to guide emergency responders via the Incident Command Center.[40]

Veterinary Services – Veterinary Services (VS) "protects and improves the health, quality, and marketability of our nation's animals, animal products, and veterinary biologics by preventing, controlling, and/or eliminating animal diseases, and monitoring, and promoting animal health and productivity."[41]

VS leads the National Animal Health Surveillance System (NAHSS), an integrated, coordinated partnership among state, local, tribal and territorial (SLTT) entities and the private sector.[42] NAHSS's goal is to "systematically collect, collate, and analyze animal health data and promptly disseminate animal health information."[43]

VS also supports surveillance efforts through integration of information regarding Foreign Animal Diseases (FAD) and uses Emergency Management Response System 2.0 to coordinate FAD investigations.[44]

VS developed the Emergency Preparedness and Response Training/Exercise Strategy and Plan (TEP) to guide responses to agricultural emergencies.[45] VS also assists FSIS with investigations of foodborne illness in humans.[46]

Wildlife Services – Wildlife Services (WS) "provides leadership to resolve wildlife conflicts and create a balance allowing people and wildlife to peacefully coexist."[47] Because many diseases of livestock and poultry may also reside in, and be vectored by, wildlife hosts, WS has an important role in food defense.

International Service – International Service (IS) works with foreign partners to improve technical and regulatory skills to prevent the spread of pests and diseases.[48] The International Technical and Regulatory Capacity Building Center promotes domestic and international training to better protect U.S. agriculture.[49]

USDA Food Safety and Inspection Service – The Food Safety and Inspection Service (FSIS) protects public health by "ensuring the safety of meat, poultry, and processed egg products."[50] FSIS authorities derive from the Federal Meat Inspection Act, the Poultry Products Inspection Act, the Egg Products Inspection Act, and Code of Federal Regulations (CFR), Title 9, Chapter III (Parts 300-500: Meat, Parts 362, 381: Poultry, and Parts 590, 593: Egg Products).[51, 52, 53, 54] FSIS works closely with FDA, which regulates about 80 percent of U.S. food, including almost all seafood. The two agencies recently enacted a formal agreement regarding individual and shared responsibilities.[55] FSIS also has a close working relationship with APHIS.

FSIS conducts vulnerability assessments of agriculture and meat, poultry, and egg-derived food products, then identifies corrective actions and mitigation strategies.[56] FSIS employs sampling programs to detect and identify microbial and chemical contaminants in meat, poultry, and egg products processed domestically and overseas. FSIS also conducts outbreak investigations and manages consumer complaints.[57]

The FSIS Strategic Plan, 2017-2021 supports the agency's mission. The plan includes food defense measures.[58, 59]

Agricultural Research Service – The Agricultural Research Service (ARS) is the USDA principal intramural (federal scientists and facilities) scientific research agency. With a $1.2 billion annual budget, the agency's 2,000 scientists and post-doctoral researchers conduct some 700 projects in nearly 100 locations.[60] Research projects are organized into 16 National Programs of which six (Food Safety, Animal Health, Plant Diseases, Veterinary, Medical, and Urban

Entomology, Plant Diseases, and Crop Protection and Quarantine) directly support food defense.[61] ARS research projects are closely linked to APHIS's mission. ARS also has the capacity to initiate rapid-response research to address outbreaks of high-consequence animal or plant diseases.

The ARS mission is to:

- Provide analytic support to the National Veterinary Stockpile for vaccines and diagnostics.
- Lead the development of the National Plant Disease Recovery System to help withstand high-consequence plant disease outbreaks.[62]

Other USDA Agencies and Programs – The USDA also conducts intramural research in its Economic Research Service (ERS) and the U.S. Forest Service (FS). In addition, USDA administers the National Institute of Food and Agriculture (NIFA).[63] NIFA's research, education, and extension programs involve partnerships among USDA, the Land Grant University (LGU) System, and government, private, and non-profit organizations to address food and agriculture research priorities.

The 2018 Farm Bill authorized the Agriculture Advanced Research and Development Authority (AGARDA).[64] Modeled after other high-risk, innovation-driven programs such as those of the Defense Advanced Research Projects Agency (DARPA) and HHS's Biomedical Advanced Research and Development Agency (BARDA), AGARDA supports high-risk, cutting-edge research to counter threats to agriculture.[65]

USDA's Risk Management Agency manages federal crop insurance to strengthen economic stability after an agricultural incident.[66]

U.S. Department of Health and Human Services

Under the U.S. Department of Health and Human Services (HHS) the Food and Drug Administration (FDA) mission is to protect public health "by ensuring the safety, efficacy, and security of human and veterinary drugs, biological products, and medical devices, and by ensuring the safety of our nation's food supply, cosmetics, and products that emit radiation."[67]

FDA's regulatory responsibilities for food products overlap those of FSIS in ways that sometimes defy logic.[68] While FSIS is responsible for most meat, FDA regulates "meat from exotic animals." FDA also regulates all seafood except catfish, which is under USDA's purview. FDA regulates whole eggs in shells, while USDA inspects egg products. Fresh vegetables and fruit are the responsibility of USDA, but once processed, they are regulated by FDA. USDA regulates milk and dairy products before they are packaged. After packaging, they become the responsibility of FDA. Most confounding are regulations governing multi-component products like pizza and sandwiches. The responsible regulatory authority depends on the pizza ingredients or whether the sandwiches are "open-faced" (USDA) or "closed" (FDA).

Working with USDA/FSIS, FDA uses the Food Emergency Response Network (FERN) to integrate local, state, and federal laboratory data, both public and non-public relating to food safety and food defense.[69] FERN supports analytic capabilities through the Electronic Laboratory Exchange Network (eLEXNET) and via a cooperative agreement program with state laboratories. FERN also contributes to the Integrated Consortium of Laboratory Networks (ICLN), which coordinates chemical, biological, radiological, and nuclear (CBRN) laboratory data under DHS.[70]

Led by FDA, the Food Safety Modernization Act (FSMA) Technical Assistance Network fosters risk awareness among industry stakeholders by providing technical and regulatory information regarding food defense. The FSMA Final Rule requires that industry establish food defense plans.[71] FDA's Food Defense Plan Builder helps owners and operators of food facilities to develop measures to protect against intentional and naturally-occurring FA threats.[72]

FDA established the Office of Laboratory Science and Safety (OLSS) to lead biosecurity and biosafety efforts. The Office of Regulatory Affairs works with OLSS and industry to develop regulations for the FA sector.[73] FDA's Manufactured Food Regulatory Program Standards provide uniformity across the retail industry.[74] FDA also manages the Mitigation Strategies Database, a tool for private industry to protect against intentional food adulteration.[75]

FDA and the Illinois Institute of Technology's Institute for Food Safety and Health created the Food Safety Prevention Controls Alliance to develop training modules and programs for industry and USDA.[76]

FDA's Office of Regulatory Affairs supports the International Food Protection Training Institute in developing and implementing a food safety training system for regulators and public health officials at all levels of government. FDA's Food Related Emergency Exercise Bundle (FREE-B) tool provides scenarios of intentional and unintentional food contamination events for government and public health agencies.[77]

FDA provides subject matter expertise and technical assistance to federal supporting agencies and SLTT entities during the recovery phase of an FA emergency incident. Accordingly, FDA identifies alternate products or sources of alternate products for medical products of critical need and provides guidance to industry to ensure adherence to regulations in a post-disaster environment. FDA also provides post-incident evaluations of responses to emergencies and disasters.[78]

FDA describes its food defense responsibilities and programs at its web site.[79]

U.S. Department of Homeland Security

The U.S. Department of Homeland Security (DHS) coordinates federal activities and programs to defend the FA sector against terrorist attacks, major disasters, and other emergencies. For biodefense, DHS accomplishes this through its Science and Technology (S&T) Directorate, Chemical and Biological Defense division and the newly established Countering Weapons of Mass Destruction (CWMD) Office.[80, 81] Areas of focus include livestock diseases.

DHS also partners with universities, national laboratories, and research organizations to address threats through DHS-supported research programs and projects.[82] These include the Food Protection and Defense Institute, led by the University of Minnesota[83] and the Center for Zoonotic and Animal Disease Defense, at Texas A&M University.[84]

Under the Agriculture Quarantine Inspection (AQI) joint program with USDA, DHS inspects international passengers, cargo, luggage, live animals, and other products to ensure adherence to USDA regulations. DHS also monitors product transit and exports.[85]

The CWMD Office now coordinates DHS food defense efforts through support of Food, Agriculture, and Veterinary Resilience.[86] In addition, the CWMD Office supports the National Biosurveillance Integration Center (NBIC) and the Information Analysis and Anomaly Detection program.[87] The future status and direction of CWMD efforts are currently uncertain.[88]

The DHS National Cybersecurity and Communication Integration Center operates a 24/7 situational awareness, analysis, and incident response center to protect critical infrastructures, including the FA sector, from cyberthreats.[89]

The DHS Science and Technology Office of National Laboratories administers the Plum Island Animal Disease Center (PIADC) to help defend the nation against the intentional or naturally-occurring spread of foreign animal diseases.[90] PIADC research is carried out by USDA. PIADC will soon be replaced by the National Bio- and Agrodefense Facility, described in more detail under "Research Laboratories" below.

The DHS National Center for Biomedical Research and Training offers training courses for emergency responders, including to food emergencies, through CoreSHIELD, a web platform that connects the preparedness efforts of federal, SLLT, and private entities.[91]

The DHS Office of Cybersecurity and Cybercommunications engages with the FA Sector and private sector owners and operators to support cyber preparedness.[92] The Continuous Diagnostics and Mitigation Program endeavors to identify cyber risks to USDA through regular assessments by the Office of the Inspector General and Constellation West, an independent contractor.[93]

The Federal Emergency Management Agency (FEMA) is the primary mechanism for DHS to respond to national emergencies and disasters. FEMA's Disaster Assistance Improvement Program provides guidance and support services, including disaster assistance applications, to disaster survivors.[94] FEMA disaster assistance for FA incidents covers damage to personal property, but not to crops or food animals.[95]

Department of Defense

The Department of Defense (DOD) is directly responsible for inspection and vulnerability assessments of food provided in military installations.[96]

DOD has substantial capabilities in animal health. It conducts a Veterinary Public and Animal Health Services program for military installations, personnel, and families, including veterinary and animal health surveillance.[97] The program could support civilian public and veterinary health services in a national emergency or agroterrorism incident. The U.S. Army Veterinary Corps operates in more than 90 countries.[98] It can assist with animal isolation, quarantine and destruction, decontamination, disinfection and infection control, and disease outbreak investigations.[99] The U.S. Army's Veterinary Laboratory at Fort Sam Houston, Texas, can support sample testing.

DOD's cooperative, interagency role in civilian food defense is defined by Memorandum of Understanding (MOU) 225-16-020 with FDA and HHS.[100] DOD participates in the Food Emergency Response Network and the Electronic Laboratory Exchange Network. The Defense Health Agency Armed Forces Health Surveillance Branch and FDA are jointly responsible for a data-sharing mechanism for food-related events involving the health or safety of military personnel.

DOD can also support civilian risk awareness by leveraging the National Terrorism Advisory System (NTAS) to communicate a domestic incident to the public, when activated by the National Response Plan. DOD's National Guard Coordination Centers can help identify agroterrorism threats and disseminate information for rapid response.

DOD's Defense Intelligence Agency (DIA) administers the National Center for Medical Intelligence, headquartered at Fort Detrick, Md. to monitor threats to the health of military and civilian personnel.[101]

DOD's Defense Threat Research Agency (DTRA) sponsors public- and private-sector research to conduct risk analyses relating to FA security. DTRA's Biological Threat Reduction Program partners with other nations to strengthen biosurveillance and knowledge of pathogen biology, including pathogens of animals and plants.[102] DTRA also works closely with the University of Minnesota Food Protection and Defense Institute.

Internationally, DTRA works with the Food and Agriculture Organization (FAO) of the United Nations to detect and prevent zoonotic and high-impact diseases. In July 2014, DTRA and FAO signed a Collaboration Agreement that led to funding of several relevant surveillance programs.[103]

DOD works with USDA and CBP to preclear agricultural supplies entering the continental U.S. and to expedite exercise, training, and other services to prevent introduction of pests and foreign plant and animal diseases.[104] DOD also conducts agroterrorism-related research at the United States Army Medical Institute of Infectious Diseases (USAMRIID) at Fort Detrick.[105]

Two MOUs between DOD and FDA are relevant to agroterrorism and food defense. MOU 225-16-020 calls for interagency exercises, training events, online training, and joint meetings to support joint development of emergency preparedness plans for food defense and improvement of food defense intelligence.[106] MOU-225-17-015 tasks DARPA and FDA with developing medical countermeasures to biological threats, including against the FA sector.[107] Historically, DOD has collaborated with other federal agencies to develop vaccines for the FA sector. For example, DOD supported USDA-ARS in developing a vaccine for Rift Valley fever.[108]

While DOD does not have a formal, designated role for civilian agroterrorism efforts, it can respond to presidentially-proclaimed national emergencies, including FA emergencies.[109] DOD has unique capabilities that may be applied outside the mandate of the Stafford Disaster Relief and Emergency Assistance Act.[110] For example, the Chemical Biological Incident Response Force (CBIRF) of the U.S. Marine Corps has a strong decontamination capability that can be rapidly deployed for sudden disease outbreaks. CBIRF can also assist with medical triage and emergency medical support.[111]

The Army's 20th Chemical, Biological, Radiological, Nuclear, and Explosives (CBRNE) Command at Aberdeen, Md. exercises mission command over assigned U.S. Forces Command CBRN and explosive ordinance disposal forces.[112]

The Defense Logistics Agency can help dispose of hazardous waste, including carcasses, in cases of widespread animal casualties.[113]

The National Guard can employ Weapons of Mass Destruction Civil Support Teams (WMD-CST), of which there are 57 in the United States, to provide technical and medical advice when activated by a state governor.[114, 115]

Medical triage, emergency medical treatment, and decontamination of human victims can be provided by CBRN Enhanced Response Force Packages (CERFPs).[116]

Joint Publication 3-28 Defense Support of Civil Authorities authorizes the U.S. military to provide consequence management support to another federal agency that is coordinating a federal response. In doing so, DOD must follow the National Response Plan framework and the National Incident Management System.[117] Additionally, *JP 3-28* specifies that DOD may provide assistance to USDA if APHIS requests assistance in responding to an introduced foreign animal or plant disease and/or pest. This request would be facilitated by a MOU between USDA and the General Services Administration (GSA).

During federally declared emergencies, DOD is responsible for continuity of operations and government measures to restore essential government services, protect public health and safety, and provide emergency relief to affected governments, businesses, and individuals.[118] Currently, DOD supports USDA food security initiatives by providing fresh fruits and vegetables to schools and military installations through the DOD Fresh Program. In a significant FA incident, this program can deliver safe food to affected areas.[119]

Research Laboratories

Agricultural research laboratories are a bulwark against plant and animal diseases and food-borne disease. USDA-ARS operates approximately 100 laboratories in this country and overseas. Four existing ARS facilities have a principal food defense focus and a fifth is under development.

Plum Island Animal Disease Center – The Plum Island Animal Disease Center (PIADC), located off Long Island, N.Y., and administered by DHS, conducts research and development on high-consequence foreign animal diseases, including foot and mouth disease and African swine fever.[120] Research is conducted by USDA-ARS, while USDA-APHIS develops medical countermeasures. ARS also collaborates with APHIS's Foreign Animal Disease Diagnostic Laboratory at PIADC to maintain the North American Foot-and-Mouth-Disease Vaccine Bank.[121] The aging facility will soon be replaced by the National Bio- and Agro-Defense Facility (NBAF), under construction in Manhattan, Kan. (see below).

National Animal Disease Center – The National Animal Disease Center (NADC), located in Ames, Iowa, is the largest federal animal disease center in the United States.[122]

U.S. National Poultry Research Center – The U.S. National Poultry Research Center, located in Athens, Ga. (formerly the Southeast Poultry Research Laboratory), develops scientific solutions to national and international exotic, emerging, and endemic poultry diseases.[123]

Foreign Disease-Weed Science Research Unit – The Foreign Disease-Weed Science Research Unit, located at Fort Detrick, Md. on the National Interagency Biodefense campus, conducts research to rapidly detect, identify, and better understand emerging crop pathogens and introduced weeds, in support of risk assessment and disease management strategies.[124] The facility includes a unique Biosafety Level 3 (BSL-3) plant pathogen containment laboratory and research greenhouse facility.

National Bio- and Agro-Defense Facility– The National Bio- and Agro-Defense Facility (NBAF), currently under construction by DHS in Manhattan, Kan., "will be a state-of-the-art biocontainment laboratory for the study of diseases that threaten both America's animal agricultural industry and public health."[125] USDA will own, operate, and manage NBAF. NBAF will include a maximum biocontainment (BSL-4) space to study high-consequence zoonotic diseases affecting large livestock, and will be the first U.S. facility that can house large livestock in BSL-4 laboratory space. This will enable NBAF to study high-consequence zoonotic diseases affecting large livestock. NBAF facilities will also include a vaccine development module.[126]

On June 20, 2019, DHS and USDA signed a Memorandum of Agreement that formalizes the transfer of ownership and operational responsibility for NBAF from DHS to USDA.[127] The facility is currently about 80 percent complete. Commissioning is expected in May 2021 with full operational capability by December 2022.[128]

Extramural USDA Research Facilities

USDA also supports food defense-related research in university laboratories through the National Institute for Food and Agriculture (NIFA). Most of this research is carried out in Land Grant Universities (LGUs). LGUs also receive research support from allocated formula funds, as authorized by the Hatch Act of 1887.[129]

After 9/11 and the subsequent anthrax incidents, DOD decided to upgrade and expand the U.S. Army biodefense research facilities at Fort Detrick to include research facilities and capacities of other federal agencies, and to share infrastructure, foster scientific exchange, and facilitate interagency coordination and communication related to biodefense. This led to the development of the National Interagency Biodefense Campus (NIBC) at Fort Detrick. The NIBC now includes the following agencies and research facilities: USAMRIID, whose aging laboratories are being replaced; the National Institute of Allergy and Infectious Diseases (NIAID) of the National Institutes of Health (NIH), with a new, on-campus Integrated Research Facility; the National Cancer Institute of NIH; the National Biodefense Analysis and Countermeasures Center of DHS; and the Foreign Disease-Weed Science Research Unit of USDA-ARS. NIBC partners established the National Interagency Confederation for Biological Research to foster interagency collaboration.

Other Interagency Mechanisms and Programs for Food Defense

The Strategic Partnership Program Agroterrorism (SPPA) Initiative among USDA, FDA, DHS, the FBI, the private sector, and SLTT governments, created in August 2005, establishes objectives to counter agroterrorism.[130] As part of this process, FSIS has conducted more than 40 vulnerability assessments in private companies and promoted the use of the CARVER assessment tool for self-assessment by industry.[131]

FBI Hazardous Evidence Response Teams collect evidence and coordinate forensic analysis to support risk awareness.[132] FBI law enforcement activities are coordinated with the intelligence community (IC), specifically the Central Intelligence Agency (CIA) and National Security Agency (NSA), through the Information Sharing and Analysis Center (ISAC) confidential network.[133] This integration of information from the IC reduces security risks while facilitating access to sensitive data. Relatedly, the FBI's AgGard program provides a secure network for the agricultural sector for sharing information, including with law enforcement, about suspicious activity.[134]

The FBI and USDA-APHIS, university-based, Animal Plant Health Joint Criminal-Epidemiological Investigations Course provides training on the conduct of joint criminal investigations.[135]

FBI Critical Incident Response Groups work with international, federal, state, and local law enforcement partners, domestically and abroad, to respond to critical incidents including agricultural threats.[136]

HSPD-7, replaced by PPD-21, instructed USDA and FDA to collaborate with federal agencies, SLTT governments, and the private sector in promoting risk management strategies and inspecting domestic and imported food and agriculture, while adhering to National Infrastructure Protection Plan requirements.[137] The directives also prescribe working with EPA on biosurveillance related to animal, plant, and wildlife diseases, and food-related public health, and with the attorney general, DHS, and the IC on intelligence and analysis capabilities related to the FA sector.[138]

To implement the FA-related goals of the National Infrastructure Protection Plan, FDA, DHS, and USDA established a Food and Agriculture Coordinating Council in 2004.[139] The council has two components: The Government Coordinating Council and the Sector Coordinating Council. The councils provide a public-private forum to coordinate agriculture security and food defense strategies, policies, and communications across the FA sector.[140]

A total of 36 federal agencies comprise the Defense Against Agroterrorism Working Group to better understand threats to food and agriculture, avoid duplication of efforts, and facilitate information sharing related to agroterrorism.[141]

The National Animal Health Laboratory Network is a nationwide network and consortium of state and federal laboratories to facilitate a coordinated response to an animal disease outbreak.[142]

In accordance with HSPD-9, the National Veterinary Stockpile was established in 2004, "To provide the veterinary countermeasures animal vaccines, antivirals, or therapeutic products, supplies, equipment, and response support services that States, Tribes, and Territories need to respond to damaging animal disease outbreaks."[143]

The National Plant Diagnostic Network is a "national network of diagnostic laboratories that rapidly and accurately detect and report pathogens that cause plant diseases of national interest, particularly those that could be deemed to be a biosecurity risk."[144]

Summary Table

The summary table below summarizes the food defense-related activities (✓) and unique capabilities (*) of federal agencies, according to the five broad goals of the National Biodefense Strategy.

	Risk Awareness	Prevention	Prepared-ness	Response	Recovery
U.S. Dept. of Agriculture					
Animal Plant Health Inspection Service	✓	✓	✓	✓	
Veterinary Services	✓			✓	
Food Safety Inspection Service	✓				
Agricultural Research Service		✓	✓		✓
Economic Research Service			✓		
Dept. of Health and Human Services					
U.S. Food and Drug Administration	✓	✓	✓		
Dept. of Homeland Security					
Customs and Border Patrol		✓			
Countering Weapons of Mass Destruction Office	✓		✓		
Cyber Security and Infrastructure Agency	✓	✓	✓		
Food and Agriculture Department		✓			
Technology Office of National Laboratories		✓			

Department of Defense					
Defense Advanced Research Programs Agency			✓		
National Coast Guard	*			*	
Marine Corps				*	
Veterinary and Public Animal Health Services	✓			*	
Defense Health Agents Armed Forces Health Surveillance Branch	✓				
Defense Threat Research Agency	✓	*			
Biological Threat Reduction Program	*	*			
United States Army Medical Institute of Infectious Diseases		✓			
Defense Logistics Agency			*		
Intelligence Community					
Central Intelligence Agency	✓				
National Security Agency	✓				
Federal Bureau of Investigation	✓		✓		
International Partners	✓				

Federal Emergency Management Agency					*
Academia	✓	✓	✓		
Private Industry	✓	✓	*	*	*

Cooperative International Programs and Capabilities

Two international organizations, the World Organization for Animal Health (OIE) and the UN-FAO, have global responsibility to protect food and agriculture. They provide opportunities and mechanisms for cooperation, coordination, and communications across the FA sector.

The importance of cooperative international programs is underscored by two highly contagious and economically devastating animal diseases that are endemic in much of the world, but are not yet established in the United States. Foot and mouth disease (FMD) and African swine fever (ASF). U.S. scientists have worked closely with international partners to address these threats. The Global Foot-and-Mouth Disease Research Alliance conducted a gap analysis of FMD research in 2014.[145, 146] Similarly, the Global African Swine Fever Research Alliance works cooperatively to counter ASF.[147]

Despite these successes, the world would benefit from substantially stronger cooperative international programs to prevent and respond to plant and animal diseases and food-borne illnesses. Ideally these should be under the rubric of the Global Health Security Agenda that integrates human health, plant and animal health, and environmental health.[148] After all, most human diseases are of zoonotic origin. Animal diseases may cycle between livestock and poultry, and wildlife and wild birds. An unhealthy environment may be a breeding ground for diseases of humans, animals, and plants. In addition, the diseases themselves may degrade the environment.

In a notable development, the Biological Weapons Convention convened a meeting of experts in Geneva, Switzerland, on Aug. 6-7, 2019. The meeting included discussion of deliberate threats against agriculture and livestock. The United States was represented by an official from USDA Office of Homeland Security who gave a presentation of the American experience.[149]

Relevant Recent Reports, Guidance, and Other Resources

Several recent documents provide important context and guidance for U.S. efforts to combat agroterrorism. Two reports are particularly relevant.

In October 2015, a bipartisan study committee issued, “A National Blueprint for Biodefense: Leadership and Major Reform Needed to Optimize Efforts, A Bipartisan Report of the Blue-Ribbon Study Panel on Biodefense.”[150] This report established the basis for the development of the 2018 National Biodefense Strategy.

In October 2017 a comprehensive report titled "Defense of Animal Agriculture: A Bipartisan Report of the Blue Ribbon Study Panel on Biodefense" identified significant gaps and made important recommendations regarding protection of the U.S. food animal industry from natural, accidental, and deliberate disruption.[151] The report addressed zoonotic diseases and informed the development of the 2018 National Biodefense Strategy which included elements specific to animal agriculture.

In addition, on Nov. 25, 2016, the President's Council on Science and Technology (PCAST) issued a letter to the president titled "PCAST Letter to the President on Action Needed to Protect Against Biological Attack."[152] The letter made a compelling case about the potential threat of advanced biotechnology. It offered several recommendations, including the need for a national biodefense strategy, and that the president should create a new interagency entity for biodefense activities across the IC, DOD, DHS, HHS, and USDA.

In 2008 the FBI, FDA, DHS, and USDA jointly prepared a *Criminal Investigation Handbook for Agroterrorism* to better coordinate food defense-related investigations and activities across federal agencies.[153]

Two recent audits by USDA's Office of Inspector General are particularly pertinent to programs and policies to counter agroterrorism. The audit reports identified several notable shortfalls and provided a number of recommendations. The first report, *Agroterrorism Prevention, Detection, and Response: Audit Report 61701-0001-21* issued in March 2017, evaluated efforts by the USDA Office of Homeland Security and Emergency Coordination (OHSEC) to prevent, detect, and respond to agroterrorism.[154] It presented three key findings: First, OHSEC lacked oversight of the USDA's agroterrorism preparedness. Second, there was insufficient evidence to support USDA's compliance with HSPD-9. Third, the 2015 Food and Agriculture Sector-Specific Plan did not comprehensively represent USDA's efforts to secure the nation's agriculture and food supply.

The second audit report, *USDA Agency Activities for Agroterrorism, Prevention, Detection, and Response Audit Report 50701-0001-21* of September 2018 evaluated efforts by APHIS, FSIS, and ARS to counter agroterrorism.[155]

It identified three important needs for the agencies:

1. Improve processes to aggregate information on agroterrorism preparedness.

2. Improve how agencies communicate and track vulnerability assessments.

3. Improve how agencies track corrective actions from exercises and incident responses.

Since issuance of the audits, USDA has addressed most of the report's recommendations.

National Food Defense Strategies

Since 9/11, the federal government has established a comprehensive framework of national strategies and programs for bioterrorism and food defense. Despite overlap, redundancy, and inconsistencies among strategies and programs, these provide a national roadmap and approach for countering bio- and agroterrorism, and are regularly updated.

There are four relevant overarching federal strategies:

1. National security strategy.

2. National preparedness system and strategies.

3. National biodefense strategy.

4. National agriculture and food defense strategy.

National Security Strategy

Last issued in December 2017, the strategy includes four goals, or "pillars:"

1. Protect the American people, the homeland, and the American way of life.

2. Promote American prosperity.

3. Preserve peace through strength.

4. Advance American influence.[156]

While the strategy does not directly speak to food defense, it does address WMD and combating biothreats and pandemics.

National Preparedness System and Strategies

Coordinated by FEMA, the overarching national strategy and approach to protecting the United States from natural or human-caused disasters, including bioincidents, is embodied in the National Preparedness System.[157] The system is supported by a National Preparedness Goal of, "A secure and resilient nation with the capabilities required across the whole community to prevent, protect against, mitigate, respond to, and recover from the threats and hazards that pose the greatest risk."[158] Significantly, this goal addresses all threats and hazards – natural and human-caused, unintentional or accidental, and deliberate. It emphasizes a "whole community approach." It identifies the need for a Strategic National Risk Assessment, including related to cybersecurity.

The National Preparedness System is organized by five mission areas: prevention, protection, mitigation, response, and recovery. Each of these mission areas is supported by a National Framework for preparedness within that mission area,[159] and additional planning documents within that framework. Each framework also provides specific guidance for food and agriculture.

The frameworks and supporting documents, organized by mission area and with special reference to food and agriculture, are as follows:

Prevention – The National Prevention Framework addresses immediate actions that the entire U.S. community should undertake upon discovery of an imminent terrorist threat to the homeland, based on credible and specific intelligence or operational information about an impending or ongoing terrorist attack.[160]

Protection – The National Protection Framework "focuses on actions to deter threats, reduce vulnerabilities, and minimize consequences of an incident."[161] It encourages partnerships and includes cybersecurity. The framework includes a National Infrastructure Protection Plan (NIPP) which provides comprehensive guidance for an integrated approach to the national community's management of risks to the country's critical infrastructures.[162] Each critical infrastructure, including food and agriculture, has developed its own sector-specific plan to address the NIPP guidance.

The FA sector is guided by the Food and Agriculture Sector-Specific Plan (FA-SSP).[163] Jointly developed by FDA, USDA, and DHS, the FA-SSP describes a collaborative effort among federal and SLTT agencies, non-governmental agencies, and the private sector to "protect against a disruption anywhere in the food system that would pose a serious threat to public health, safety, welfare, or to the national economy." The FA-SSP supports the concepts and processes delineated in PPD8, HSPD-9, PPD-21, and EO13636.

Mitigation – The National Mitigation Framework provides community-wide guidance and describes stakeholder roles for a resilience-based approach to "lessen the impact of disaster by developing, employing, and coordinating core mitigation capabilities to reduce loss of life and property."[164]

Response – The National Response Framework (NRF) provides community-wide, all-hazards guidance to ensure that "the Nation is able to respond effectively to all types of incidents that range from those that are adequately handled with local assets to those of catastrophic proportion that require marshaling the capabilities of the entire Nation."[165]

Implementation of the NRF is through the National Incident Management System (NIMS).[166] NIMS "provides a consistent nationwide template to enable partners across the nation to work together to prevent, protect against, respond to, recover from, and mitigate the effects of incidents, regardless of cause, size, location, or complexity." NIMS provides the *template* for incident management, while NRF provides the structure and mechanisms for response. NIMS employs an Incident Command System (ICS) for coordinated and collaborative incident management and command.

Within the federal government, agency responsibilities for incident response under the NRF are assigned according to the incident type, and organized as agency Emergency Support Functions (ESFs).[167] ESF responses are managed through an ICS.

Responses to a food and agriculture incident are governed by ESF-11, *Agriculture and Natural Resources Annex*, coordinated by USDA which, with the U.S. Department of the Interior, is one of two primary agencies assigned to the function.[168] Moreover, 13 additional federal agencies and eight non-government organizations serve as support agencies.

To support ESF-11, the NRF includes a Food and Agriculture Incident Annex.[169] The annex was promulgated in 2008 and is presently being updated. The annex also informs the development of state food and agriculture incident annexes and assumes close cooperation with the private sector. The primary functions of the annex are to support coordination and communication among federal, state, tribal, local, and international responders, minimize public health and economic impacts of a food and agriculture incident, and "provide transition from response to rapid recovery following a food and agriculture incident."[170]

Recovery – The National Disaster Recovery Framework "establishes a common platform and forum for how the whole community builds, sustains, and coordinates delivery of recovery capabilities."[171]

National Biodefense Strategy

The five-year *National Biodefense Strategy* (NBS), published in 2018, sets forth the overall U.S. policy and approach to address biothreats and bioincidents that could affect the United States.[172] The NBS is aligned with the 2018 *National Security Strategy*, and is required by statute (National Defense Authorization Act for Fiscal Year 2017).[173, 174]

The NBS has five goals:

1. Enable risk awareness to inform decision-making across the biodefense enterprise.

2. Ensure biodefense enterprise capabilities to prevent bioincidents.

3. Ensure biodefense enterprise preparedness to reduce the impacts of bioincidents.

4. Rapidly respond to limit the impacts of bioincidents.

5. Facilitate recovery to restore the community, the economy, and the environment after a bioincident.

Each goal is supported by a number of principal support activities as delineated and described in the NBS.

National Agriculture and Food Defense Strategy

Section 108 of the 2011 FDA Food Safety Modernization Act directed the Secretaries of HHS and USDA, in coordination with DHS, to develop and transmit to Congress a National Agriculture and Food Defense Strategy (NAFDS).[175] Congress required that the strategy include an implementation plan and that, at least every four years, the strategy be revised as appropriate and submitted to relevant congressional committees. The present strategy, currently undergoing revision, was prepared and submitted in April 2015. Congress requires that the strategy be consistent with the National Incident Management System, the National Response Framework, the National Infrastructure Protection Plan, the National Preparedness Goals, and other relevant national strategies. The 2015 NAFDS has four goals:

1. *Preparedness* – Enhance the preparedness of the agriculture and food system by conducting vulnerability assessments, mitigating vulnerabilities, improving communication and training, developing, and conducting exercises, developing modeling tools, and preparing risk communication tools and enhancing public awareness.

2. *Detection* – Improve agriculture and food system detection capabilities by identifying contamination in food products and conducting surveillance.

3. *Emergency response* – Ensure an efficient response to agriculture and food emergencies by immediately investigating animal disease outbreaks and suspected food contamination, preventing additional human illnesses, organizing, training, and equipping emergency response teams, designing, developing, and evaluating training and exercises, and ensuring consistent and organized risk communication to the public.

4. *Recovery* – Secure agriculture and food production after an agriculture or food emergency by working with the private sector to develop business recovery plans, conducting recovery exercises, removing, and disposing of contaminated products and infected plants and animals, decontamination, and restorations of affected areas.

The NAFDS also includes EPA and SLTT entities. Appendix A of the Strategy lists 52 key initiatives and 138 specific activities under each objective of each goal, and identifies the responsible federal agencies (including DOD) and external stakeholders and partners for each activity. Appendix B of the Strategy presents a Coordinated Research Agenda.

Discussion

The United States is still insufficiently prepared for a major agroterrorism incident. This is despite a substantial regulatory and policy framework to counter agroterrorism, extensive government capacity and programs for food defense, and recently improved cooperation and coordination among government agencies and with the private sector.

The principal shortfalls are policy-related, as follows:

1. The various U.S. policies that address food defense are not well aligned.

2. Federal leadership and coordination for food defense is too often fragmented, overlapping, and/or confusing.

3. Key federal players, notably DOD, have substantial capacity for food defense, but are not well integrated into a national policy and programs.

Each of these is addressed below.

U.S. Food Defense Policies Are Not Well Aligned

The 2015 National Agriculture and Food Defense Strategy (NAFDS) is not consistent with, nor well integrated with the National Biodefense Strategy (NBS) of 2018. The four NAFDS goals (Preparedness, Detection, Emergency Response, and Recovery) do not directly match the five NBS goals (Risk Awareness, Prevention, Preparedness, Response, and Recovery). Because the NBS *is* aligned with the U.S. National Security Strategy, it is important that the revised NAFDS (now in progress) track with the NBS. Furthermore, all federal agencies with food defense capabilities, responsibilities, and programs (including DOD), SLTT governments, and the private sector should be fully involved in the NAFDS revision.

Development of a cohesive national strategy is also impaired by a lack of unified definitions for *agroterrorism* and *food defense*. Such definitions should consider threats to the entire FA spectrum and infrastructure, from farm to fork to include farm animals, plants and crops, forestry, specialty products, and market-ready food items. It's also important to recognize that the nature of threats and risks may be biological, chemical, nuclear, radiological, or even physical, and acknowledge that targets may include personnel as well as facilities, products, infrastructure, and support activities.

Federal Leadership and Coordination Remain Inadequate

Food defense across the federal government is insufficiently coordinated and lacks strong, committed leadership. There are several reasons for this.

First, federal statutes and presidential directives assign the overall coordinating authority to DHS (with USDA and HHS as the principal sector-specific agencies). However, DHS's "coordinating" role and associated responsibilities are not well defined by the statutes and directives. Moreover, DHS does not have substantial in-house expertise in food and agriculture.

Complicating matters further, some federal agencies (notably USDA and HHS for food protection and safety) have overlapping and, in cases, mutually overlapping or inconsistent regulatory responsibilities.

The vast array of federal agencies with relevant, but fragmented, capabilities and responsibilities – not to mention state, local, and private sector capacities and programs – presents further challenges to systemwide coordination of food defense. Notably, there is insufficient coordination and cooperation between USDA and the IC and FBI, in part because USDA does not have a strong history in the national security arena and has relatively few high-level security clearances.

Finally, federal funding support for food defense, especially for research, is inadequate and distributed among multiple agencies.

Key Federal Agencies are Not Sufficiently Integrated into U.S. Food Defense

Key federal entities, including DOD, the FBI, and the IC, are not well integrated into a nationwide food defense strategy and programs. DOD in particular has tremendous capacity, important programs, and substantial funding that can – and do – support counterterrorism efforts. Further, a safe and well-protected food supply for military personnel is of paramount importance. Nonetheless, DOD's military mission and statutory authorities have challenged its ability to collaborate with civilian agencies in food defense.

There are signs that this is changing. Notable examples include the National Interagency Biodefense Campus and National Interagency Confederation for Biological Research at Fort Detrick. In addition, USDA has modeled a food defense research program (AGARDA) on DARPA (similar to the HHS BARDA program), and has had an ongoing presence at the National Defense University whose programs include attention to the food and agriculture sector.

Nonetheless, there are significant opportunities for stronger linkages between the defense and civilian communities. Examples include better integration of DOD's veterinary medicine capabilities (including the U.S. Army Veterinary Corps) into national efforts to counter natural or deliberately-introduced animal diseases. Similarly, The National Guard WMD Civil Support Teams could be a key national resource in the event of an agroterrorism incident.

Recommendations

We have several recommendations for improving the U.S. federal government's ability to combat agroterrorism. These fall into three categories: food defense policies, federal leadership and coordination, and better integration of key federal agencies into U.S. food defense.

Food Defense Policies

The United States should develop and implement an integrated national food defense strategy. The vehicle should be a revised version of the existing National Agriculture and Food Defense Strategy (NAFDS). The strategy should ensure close alignment with the National Biodefense Strategy, including new areas of focus such as cyberterrorism and dual use of emerging biotechnologies.

The revised NAFDS should incorporate the entire FA enterprise, including livestock and poultry, farmed seafood, plants and crops, biofuels, silviculture and forestry products, market-ready foods, ornamental products, other specialty products, seeds, and animal feed (including pet food). The strategy should address the entire FA infrastructure. This would include on-farm production, harvesting, processing, and packaging, transportation, and wholesale, retail, and institutional sales. It should also include associated equipment and supplies, supporting research and development activities and facilities, and personnel working in the FA sector.

All federal agencies, including DOD, that have responsibilities, programs, and/or capacities related to food defense should contribute to the revised NAFDS, and the strategy should provide specific direction and provisions for improved coordination and collaboration among federal agencies, SLTT entities, the private sector, as well as the international community. International partnerships are especially important. Therefore, the strategy should be aligned with the Global Health Security Agenda. The strategy should also incorporate mechanisms to reduce duplication and overlap among federal agencies.

Physical security, personnel management and protection, biosecurity, food safety, and food security are all components of food defense and should be integrated into the strategy.

A well-informed public is essential to the prevention of and appropriate response to an agroterrorism incident. Accordingly, the revised NAFDS should include provisions for effective public education and messaging.

Federal agencies must be accountable for implementing the strategy. Therefore, the revised NAFDS should have clear and specific provisions to ensure accountability. To facilitate this, any future revisions of the strategy should be preceded by OIG audits of all federal agencies with significant food defense responsibilities and programs, as well as meetings among relevant government agencies and stakeholders to develop recommendations for the strategy.

Federal Leadership and Coordination

To bolster federal leadership and coordination, and strengthen accountability, Congress or the White House should designate a lead agency for food defense. Although DHS has the overall statutory authority to coordinate counterterrorism activities, that agency does not have substantial experience and expertise in food and agriculture. The Bipartisan Commission on Biodefense determined that White House-level leadership was necessary "to elevate biodefense as a critical national and federal imperative."[176] The commission recommended that leadership be vested in the Office of the Vice President. That office may not have the time, expertise, and resources to provide ongoing, committed leadership to biodefense. With specific regard to food defense, it does not have significant expertise or experience with food and agriculture.

Accordingly, we recommend that USDA be designated as the lead federal agency for food defense. The overall responsibility within USDA should be housed in the department's Office of Homeland Security. Uniquely among federal agencies, USDA's primary mission is to support and protect the national food and agriculture enterprise. It has offices and programs in virtually every U.S. county, works directly with its constituents, and has the history and expertise to provide sustained and effective leadership.

Leadership by USDA would require several important actions and mandates. First, the department must be accountable for ensuring the implementation for a coordinated National Agriculture and Food Defense Strategy that involves all relevant agencies and stakeholders (see previous recommendation for accountability). Second, the department would need dedicated funding to support its leadership role and food defense mission and programs. Third, USDA should be better integrated into the national security arena and agenda.

To address the confusing and duplicative present regulatory framework, we also recommend that federal responsibility for food safety be vested in a single federal agency with overarching statutory authority.

Better Integration of Key Federal Agencies into U.S. Food Defense

Because some key federal entities – notably FBI, the IC, and DOD – are not well integrated into a nationwide food defense strategy and program, we strongly recommend that the FBI, the IC, and DOD be fully involved in the development of a National Agriculture and Food Defense Strategy. In so doing, those agencies should describe in depth their food defense-related capacities and programs and identify specific potential opportunities for better integrating those capacities and programs with those of other federal agencies.

We also recommend interagency details (temporary assignments) among USDA, FBI, IC, and DOD personnel with the requisite expertise and designated responsibilities related to food defense. These short-term assignments could help to build trust and familiarity among the agencies, identify opportunities for collaboration, determine high priority needs in support of food defense, and facilitate more information sharing (including through granting of requisite security clearances) among the agencies. This was successfully done on a trial basis in the late 1990s, but requires a sustained commitment of time and funding from each involved agency.

To facilitate exchange of sensitive information and to better integrate USDA into the national security apparatus, we recommend a sector-based Information Sharing and Analysis Center (ISAC) for Food and Agriculture, similar to the law enforcement ISAC among the FBI and the IC, described earlier in this report. An FA-related ISAC would enable a confidential and collaborative platform for improved risk awareness and prevention regarding agroterrorism. Most Critical Infrastructures in the United States have an operational ISAC that confers with the National Council of ISACs (NCI) for data sharing between the private sector and government. Private sector ISACs help protect companies by sharing risk and threat data with asset owners and operators. Many ISACs have matured beyond information sharing to include operational services for risk mitigation and incident response, as well as providing a platform for technical exchanges and workshops. Given the expansive number of FA stakeholders, information sharing through an ISAC could bridge the gaps among existing data collection efforts and strengthen mitigation strategies.

Finally, Congress and the White House should collaborate on a process to fully identify and delineate food defense-related appropriations and funded programs in all federal agencies, including in DOD, and recommend (or mandate) actions to better integrate these programs with the goal of leveraging capabilities and reducing redundancies or overlap.

Chapter 5 Notes

1. U.S. Department of Agriculture Economic Research Service, *International Macroeconomic Data Set*, (Washington, D.C.: U.S. Department of Agriculture, 2018). www.ers.usda.gov/data-products/international-macroeconomic-data-set.

2. Ibid.

3. Richard Valdmanis, "U.S. farm exports expected to fall $1.9 billion in 2019, led by China: USDA," *Reuters*, Feb. 21, 2019, www.reuters.com/article/us-usa-trade-agriculture/us-farm-exports-expected-to-fall-19-billion-in-2019-led-by-china-usda-idUSKCN1QA1TK.

4. James M. MacDonald and Robert A. *Hoppe*, *Large Family Farms Continue to Dominate U.S. Agricultural Production*, U.S. Department of Agriculture Economic Research Service, (Washington, D.C.: U.S. Department of Agriculture, March 6, 2017), www.ers.usda.gov/amber-waves/2017/march/large-family-farms-continue-to-dominate-us-agricultural-production.

5. Henry S. Parker, *Agricultural Bioterrorism: A Federal Strategy to Meet the Threat*, McNair Paper 65, Institute for National Strategic Studies (Washington, D.C.: National Defense University, 2002), pps. xii, 103.

6. Henry S. Parker. Chapter 8: Biosecurity in the Food and Agricultural Industries, in *Biosecurity: Understanding, Assessing, and Preventing the Threat*, ed. R. Burnette, (Hoboken, N.J.: John Wiley and Sons, Inc., 2013), pps. 129-154.

7. Ibid.

8. Parker, *Agricultural Bioterrorism: A Federal Strategy*, pps. xii, 103

9. Parker, *Biosecurity in the FA Industries*, pps. 129-154.

10. "Homeland Security Act of 2002," Public Law 107-296, *U.S. Statutes at Large*, (Washington, D.C.: U.S. Department of Homeland Security, 2002), www.dhs.gov/xlibrary/assets/hr_5005_enr.pdf.

11. This authority has since been reversed. The U.S. Department of Agriculture will have operating authority for the new National Bio- and Agro-Defense Facility.

12. "Public Health Security and Bioterrorism Preparedness and Response Act of 2002," Public Law 107-188, *U.S. Statutes at Large*, (Washington, D.C.: Government Printing Office, June 12, 2002). www.gpo.gov/fdsys/pkg/PLAW-107publ188/pdf/PLAW-107publ188.pdf.

13. "Federal Select Agent Program," U.S. Department of Health and Human Services, Centers for Disease Control and U.S. Department of Agriculture, Animal and Plant Health Inspection Service, accessed June 26, 2019, www.selectagents.gov.

14. Food and Drug Administration, "Food Safety Modernization Act," Public Law 111-353, *U.S. Statutes at Large*, (Washington, D.C.: Government Printing Office, Jan. 4, 2011), www.govinfo.gov/content/pkg/PLAW-111publ353/pdf/PLAW-111publ353.pdf.

15. "Animal Health Protection Act," Public Law 107-171 as amended through Public Law 110-246, *U.S. Statutes at Large*, (Washington, D.C.: Government Printing Office, May 22, 2008), www.govinfo.gov/content/pkg/USCODE-2012-title7/pdf/USCODE-2012-title7-chap109.pdf.

16. “Securing Our Agriculture and Food Act,” Public Law 115-43, *U.S. Statutes at Large*, (Washington, D.C.: Government Printing Office, June 20, 2017), www.congress.gov/115/plaws/publ43/PLAW-115publ43.pdf.

17. https://uscode.house.gov/view.xhtml?req=granuleid:USC-prelim-title6-section104&num=0&edition=prelim.

18. The White House, “Homeland Security Presidential Directive 5,” *Management of Domestic Incidents*, (Washington, D.C.: U.S. Department of Homeland Security, Feb. 28, 2003), www.dhs.gov/sites/default/files/publications/Homeland%20Security%20Presidential%20Directive%205.pdf.

19. The White House, “Homeland Security Presidential Directive 7,” *Critical Infrastructure Identification, Prioritization, and Protection*, (Washington, D.C.: U.S. Department of Homeland Security, Dec. 17, 2003), www.dhs.gov/homeland-security-presidential-directive-7.

20. Ibid.

21. The White House, “Homeland Security Presidential Directive 8,” *National Preparedness*, (Washington, D.C.: U.S. Department of Homeland Security, March 30, 2011), www.dhs.gov/presidential-policy-directive-8-national-preparedness.

22. The White House, “Homeland Security Presidential Directive 9,” *Defense of United States Agriculture and Food*, (Washington, D.C.: U.S. Department of Homeland Security, Jan., 2004), www.govinfo.gov/content/pkg/PPP-2004-book1/pdf/PPP-2004-book1-doc-pg173.pdf.

23. Department of Defense Joint Chiefs of Staff, *Joint Publication 3-28: Civil Support*, , (Washington D.C.: Department of Defense, Sept. 14, 2007), https://fas.org/irp/doddir/dod/jp3-28.pdf.

24. The White House, “Homeland Security Presidential Directive 10,” *Biodefense for the 21st Century*, (Washington, D.C.: U.S. Department of Homeland Security, April 28, 2004), https://fas.org/irp/offdocs/nspd/hspd-10.html.

25. The White House, “Homeland Security Presidential Directive 21,” *Critical Infrastructure Security and Resilience*, (Washington, D.C.: U.S. Department of Homeland Security, Feb. 12, 2013), https://obamawhitehouse.archives.gov/the-press-office/2013/02/12/presidential-policy-directive-critical-infrastructure-security-and-resil.

26. Executive Order 13626 of Feb. 12, 2013, “Improving Critical Infrastructure Cybersecurity,” *Code of Federal Regulations*, title 3 (Washington, D.C.: Government Printing Office, 2013), www.govinfo.gov/app/details/CFR-2014-title3-vol1/CFR-2014-title3-vol1-eo13636.

27. The White House, “National Security Presidential Memorandum 7,” (Oct. 4, 2017), www.whitehouse.gov/presidential-actions/national-security-presidential-memorandum-7.

28. www.whitehouse.gov/presidential-actions/presidential-memorandum-support-national-biodefense.

29. U.S. Department of Agriculture, *USDA Strategic Plan, FY 2018-2022*, (Washington, D.C.: U.S. Department of Agriculture, May 2018), www.usda.gov/sites/default/files/documents/usda-strategic-plan-2018-2022.pdf.

30. U.S. Department of Agriculture Office of Homeland Security & Emergency Coordination, “National Security Policy Staff,” accessed Oct. 11, 2019, www.dm.usda.gov/ohsec.

31. U.S. Department of Agriculture Animal and Plant Health Inspection Service, "About APHIS," Dec. 20, 2018, www.aphis.usda.gov/aphis/banner/aboutaphis.

32. Ibid.

33. U.S. Department of Agriculture Animal and Plant Health Inspection Service, "Plant Health," accessed June 26, 2019, www.aphis.usda.gov/aphis/ourfocus/planthealth.

34. U.S. Department of Agriculture Animal and Plant Health Inspection Service, *Plant Health Response*, (October 2014), www.aphis.usda.gov/aphis/ourfocus/emergencyresponse/sa_program_overview/ct_plants.

35. U.S. Department of Agriculture, *Agency Activities*, 2018.

36. U.S. Department of Agriculture Animal and Plant Health Inspection Service, *Emergency Management Framework*, (October 2017), www.aphis.usda.gov/plant_health/plant_pest_info/biosecurity/download/PHE-framework.pdf.

37. U.S. Department of Agriculture Animal and Plant Health Inspection Service, *National Plant Health Emergency Management Framework*, (Washington, D.C.: U.S. Department of Agriculture, November 2017), www.aphis.usda.gov/plant_health/plant_pest_info/biosecurity/download/PHE-framework.pdf.

38. U.S. Department of Agriculture Animal and Plant Health Inspection Service, "Pest Identification," (July 9, 2015), www.aphis.usda.gov/aphis/ourfocus/planthealth/pest-detection/pest-identification/ct_pest_identification.

39. U.S. Department of Agriculture, *Agency Activities*, 2018.

40. U.S. Department of Agriculture, *National Plant Health Emergency Management Framework*.

41. U.S. Department of Agriculture Animal and Plant Health Inspection Service, "About APHIS."

42. U.S. Department of Agriculture Animal and Plant Health Inspection Service, "National Animal Health Surveillance System," modified March 26, 2019, www.aphis.usda.gov/aphis/ourfocus/animalhealth/monitoring-and-surveillance/sa_nahss/ct_nahss.

43. Ibid.

44. U.S. Department of Agriculture Animal and Plant Health Inspection Service, "Animal Health Emergency Management," accessed May 2019, www.aphis.usda.gov/aphis/ourfocus/animalhealth/emergency-management.

45. U.S. Department of Agriculture Animal and Plant Health Inspection Service, *APHIS Veterinary Services Emergency Preparedness and Response Training/Exercise Strategy and Plan Fiscal Years 2019-2021*, (Washington, D.C.: U.S. Department of Agriculture, Oct. 15 2018), www.aphis.usda.gov/animal_health/prof_development/downloads/vs-ntep-fy2018-2020.pdf.

46. U.S. Department of Agriculture, *Memorandum of Understanding between the Food Safety and Inspection Service and the United States Department of Agriculture Animal and Plant Health Inspection Veterinary Services*, accessed April 2019, www.fsis.usda.gov/wps/wcm/connect/1e6538de-3e99-4bb6-9831-65836899c410/MOU-FSIS-APHIS-One-Health.pdf?MOD=AJPERES.

47. Ibid.

48. U.S. Department of Agriculture Animal and Plant Health Inspection Service, "International Service," accessed March 2019, www.aphis.usda.gov/aphis/ourfocus/internationalservices.

49. www.aphis.usda.gov/aphis/ourfocus/internationalservices/ trade/trade_capacitybuilding, accessed Dec. 13, 2019.

50. U.S. Department of Agriculture Food and Safety Inspection Service, "About FSIS," Jan. 26, 2018, www.fsis.usda.gov/wps/portal/informational/aboutfsis.

51. U.S. Department of Agriculture Food and Safety Inspection Service, "Federal Meat Inspection Act," Jan. 21, 2016, www.fsis.usda.gov/wps/portal/fsis/topics/rulemaking/federal-meat-inspection-act.

52. U.S. Department of Agriculture Food and Safety Inspection Service, "Poultry Products Inspection Act," Jan. 21, 2016, www.fsis.usda.gov/wps/portal/fsis/topics/rulemaking/poultry-products-inspection-acts.

53. U.S. Department of Agriculture Food and Safety Inspection Service, "Egg Products Inspection Act," Jan. 21, 2016, www.fsis.usda.gov/wps/portal/fsis/topics/rulemaking/egg-products-inspection-act/EPIA.

54. "Chapter III," Food Safety and Inspection Service, Department of Agriculture," *Code of Federal Regulations*, Title 9, (Washington, D.C.: Government Printing Office,) accessed June 26, 2019, www.govinfo.gov/content/pkg/CFR-2010-title9-vol2/pdf/CFR-2010-title9-vol2-chapIII.pdf.

55. U.S. Department of Health and Human Services, Food and Drug Administration and U.S. Department of Agriculture Office of Food Safety, *Formal Agreement Between the U.S. Department of Health and Human Services Food and Drug Administration and U.S. Department of Agriculture Office of Food Safety*, (March 7, 2019). www.fsis.usda.gov/wps/wcm/connect/0d2d644a-9a65-43c6-944f-ea598aacdec1/Formal-Agreement-FSIS-FDA.pdf?MOD=AJPERES.

56. U.S. Department of Agriculture, *Agency Activities*, 2018.

57. U.S. Department of Agriculture Food and Safety Inspection Service, *Report on the Food Safety and Inspection Service's Microbiological and Residue Sampling Programs*, (December 2017). www.fsis.usda.gov/wps/wcm/connect/0816b926-c7ee-4c24-9222-34ac674ec047/FSIS_Sampling_Programs_Report.pdf?MOD=AJPERES.

58. U.S. Department of Agriculture Food and Safety Inspection Service, *Food Safety Inspection Service Strategic Plan 2017-2021*, www.fsis.usda.gov/wps/wcm/connect/317d14d6-1759-448e-941a-de3cbff289e5/Strategic-Plan-2017-2021.pdf?MOD=AJPERES.

59. U.S. Department of Agriculture Food and Safety Inspection Service, "Food Defense and Emergency Response," Aug. 2, 2018. www.fsis.usda.gov/wps/portal/fsis/topics/food-defense-defense-and-emergency-response.

60. U.S. Department of Agriculture Agricultural Research Service, "About ARS," Oct. 25, 2018, www.ars.usda.gov/about-ars.

61. U.S. Department of Agriculture Agricultural Research Service, "Research: National Programs," June 25, 2019, www.ars.usda.gov/research/programs.

62. U.S. Department of Agriculture Agricultural Research Service, "Plant Diseases that Threaten U.S. Agriculture: Identified and Prepared for Under the National Plant Disease Recovery System," December 2018, www.ars.usda.gov/crop-production-and-protection/plant-diseases/docs/npdrs.

63. U.S. Department of Agriculture National Institute of Food and Agriculture, "About NIFA," accessed June 26, 2019, https://nifa.usda.gov/about-nifa.

64. U.S. Department of Agriculture, "Research, Extension, and Related Matters: Title VII," Economic Research Service, February 2019, www.ers.usda.gov/agriculture-improvement-act-of-2018-highlights-and-implications/research-extension-and-related-matters.

65. Laurie Purpuro and Bart Gordon, "Agriculture Advanced Research and Development Authority: New Program Supports Innovation in Agriculture," *K&L Gates*, (Feb. 21, 2019), www.klgates.com/agriculture-advanced-research-and-development-authority-new-program-supports-innovation-in-agriculture-02-21-2019.

66. U.S. Department of Agriculture Risk Management Agency, "Crop Insurance," accessed April 2019. www.rma.usda.gov.

67. Food and Drug Administration, "What We Do," accessed Oct. 11, 2019, www.fda.gov/about-fda/what-we-do.

68. Daniela Galarza, "USDA vs. FDA: What's the Difference?," *Eater Report*, (March 24, 2017), www.eater.com/2017/3/24/15041686/fda-usda-difference-regulation.

69. U.S. Department of Agriculture, *Biennial Report to Congress on the Food Emergency Response Network - 2013*, http://wayback.archive-it.org/7993/20171114122345, www.fda.gov/Food/GuidanceRegulation/FSMA/ucm375711.htm.

70. Ibid.

71. Food and Drug Administration, "FMSA Technical Assistance Network," accessed April 2019, www.fda.gov/food/food-safety-modernization-act-fsma/fsma-technical-assistance-network-tan.

72. Food and Drug Administration, "Food Defense Plan Builder," accessed April 2019, www.fda.gov/food/food-defense-tools-educational-materials/food-defense-plan-builder.

73. Food and Drug Administration Office of Laboratory Science and Safety, *Biosafety and Biosecurity Framework*, March 3, 2017, www.fda.gov/media/116875/download.

74. FDA, USDA, DHS, "Food and Agriculture Sector-Specific Plan 2015," (2015), www.dhs.gov/sites/default/files/publications/nipp-ssp-food-ag-2015-508.pdf.

75. Food and Drug Administration, Mitigation Strategies Database, accessed March 2019, www.fda.gov/food/food-defense-tools-educational-materials/mitigation-strategies-database.

76. Ibid.

77. Food and Drug Administration, "Food Related Emergency Exercise Bundle (FREE-B)," accessed March 2019, www.fda.gov/food/food-defense-tools-educational-materials/food-related-emergency-exercise-bundle-free-b.

78. U.S. Department of Health and Human Services and Food and Drug Administration, *FDA Emergency Operations Plan Version 2.0*, (March 2014), www.fda.gov/media/79493/download.

79. Food and Drug Administration, "Food Defense," accessed Oct. 11, 2019, www.fda.gov/food/food-defense.

80. U.S. Department of Homeland Security, Science and Technology, *Chemical and Biological Defense*, (Washington, D.C.: U.S. Department of Homeland Security, Oct. 11, 2019, www.dhs.gov/science-and-technology/chemical-and-biological-defense.

81. U.S. Department of Homeland Security Countering Weapons of Mass Destruction Office, Oct. 18, 2019, www.dhs.gov/countering-weapons-mass-destruction-office.

82. U.S. Department of Homeland Security, Science and Technology, "Centers of Excellence and Academia," accessed Oct. 11, 2019, www.dhs.gov/science-and-technology/centers-excellence-and-academia.

83. U.S. Department of Homeland Security, Science and Technology, Food Protection and Defense Institute, accessed Oct. 11, 2019, www.dhs.gov/sites/default/files/publications/coe-fpdi-factsheet_190529-508_0.pdf.

84. U.S. Department of Homeland Security, Science and Technology, Center for Zoonotic and Animal Disease Defense, accessed Oct. 11, 2019, www.dhs.gov/sites/default/files/publications/coe-zadd-factsheet_190529-508_0.pdf.

85. U.S. Department of Homeland Security and U.S. Department of Agriculture, *Memorandum of Agreement between the United States Department of Homeland Security and the United States Department of Agriculture*, accessed March 2019, www.aphis.usda.gov/plant_health/moa_dhs/downloads/article1.pdf.

86. U.S. Department of Homeland Security, *Budget Overview Fiscal Year 2020: Congressional Justification*, accessed Oct. 20, 2019, www.dhs.gov/sites/default/files/publications/19_0318_MGMT_CBJ-Countering-Weapons-Mass-Destruction_0.pdf.

87. Ibid.

88. U.S. Congress, *Letter of Correspondence to the Honorable James F. McDonnell*, Aug. 30, 2019, www.hsgac.senate.gov/imo/media/doc/190830_Letter_DHSCWMD.pdf.

89. U.S. Department of Homeland Security Cybersecurity and Infrastructure Security Agency, Cybersecurity Division, accessed Oct. 20, 2019, www.dhs.gov/cisa/cybersecurity-division.

90. U.S. Department of Homeland Security, Science and Technology, Office of National Laboratories, "Plumb Island Animal Disease Center," accessed April 2019, www.dhs.gov/science-and-technology/plum-island-animal-disease-center.

91. U.S. Department of Homeland Security, National Center for Food Protection and Defense, accessed April 2019, www.dhs.gov/sites/default/files/publications/National%20Center%20for%20Food%20Protection%20and%20Defense-NCFPD.pdf.

92. Ibid.

93. U.S. Department of Homeland Security Office of the Inspector General, *Continuous Diagnostics and Mitigation Program Assessment*, (February 2018), www.usda.gov/oig/webdocs/50501-0016-12.pdf.

94. Food and Drug Administration and U.S. Department of Homeland Security, *FDA Emergency Operations Plan*, (July 2019), www.fda.gov/media/79493/download.

95. Federal Emergency Management Agency, “Farm/Agriculture Damages,” accessed June 2019, www.fema.gov/faq-details/Farm-Agriculture-Damages.

96. Department of Defense, “DoD Veterinary Public and Animal Health Service,” *Directive Number 6400.04E*, (June 27, 2013), www.esd.whs.mil/Portals/54/Documents/DD/issuances/dodd/640004e.pdf?ver=2017-08-29-132039-997.

97. Ibid.

98. U.S. Army, “What is the veterinary corps?,” accessed Oct. 11, 2019, www.goarmy.com/amedd/veterinarian/corps.html.

99. Robert Newberry, *Statement Before the Senate Armed Services Committee*, United States Senate 106th Congress, (1999), https://fas.org/irp/congress/1999_hr/991027rn.pdf.

100. Food and Drug Administration, *Memorandum of Understanding between U.S. Department of Defense and the U.S. Department of Health and Human Services, Food and Drug Administration Concerning Food Protection, Food Safety and Food Defense, MOU 225-16-020*, accessed March 2019, www.fda.gov/about-fda/domestic-mous/mou-225-16-020.

101. https://archive.defense.gov/news/newsarticle.aspx?id=118163.

102. Department of Defense Defense Threat Reduction Agency and United States Strategic Command Center for Combating Weapons of Mass Destruction, *The Cooperative Biological Engagement Program Research Strategic Plan: Addressing Biological Threat Reduction Through Research*, (June 2015), www.dtra.mil/Portals/61/Documents/Missions/CBEP%20Research%20Strategy_FINAL_July%202015.pdf.

103. Food and Agriculture Organization of the United Nations, “FAO and the United States’ Defense Threat Reduction Agency collaborate to reduce biological threats,” (Dec. 24, 2014), www.fao.org/ag/againfo/programmes/en/empres/news_241214b.html.

104. Department of Defense, United States Transportation Command, *Defense Transportation Regulation Chapter 506: DOD Preclearance Program Customs and Agriculture Inspections*, , (Feb. 26, 2018), www.ustranscom.mil/dtr/part-v/dtr_part_v_506.pdf.

105. Newberry, *Statement Before the Senate*, 1999.

106. Food and Drug Administration, *MOU-225-16-020*, 2018.

107. Food and Drug Administration, *Memorandum of Understanding between the Food and Drug Administration and the Defense Advanced Research Projects Agency for Development and Assessment of Innovative Medical Products*, (August 2017), www.fda.gov/about-fda/domestic-mous/mou-225-17-015.

108. Newberry, *Statement Before the Senate* 1999.

109. "The Robert T. Stafford Disaster Relief and Emergency Assistance Act of 1988," U.S. Code 42 (2009), www.govinfo.gov/content/pkg/USCODE-2009-title42/html/USCODE-2009-title42-chap68.htm.

110. Newberry, *Statement Before the Senate*, 1999.

111. Department of Defense, *Joint Publication 3-41: Chemical, Biological, Nuclear and Radiological Response*, (Sept. 9, 2016), www.jcs.mil/Portals/36/Documents/Doctrine/pubs/jp3_41.pdf.

112. 20th Chemical, Biological, Radiological, Nuclear, Explosives Command Mission Statement, www.army.mil/20thCBRNE#org-about, accessed Dec. 9, 2019.

113. Defense Logistics Agency, "Hazardous Waste Disposal," accessed June 2019, www.dla.mil/DispositionServices/Offers/Disposal/HazardousWaste/HazWasteDisposal.

114. Tasha Pravecek, Jim Davis, Thomas Berg, *Agroterrorist Attack: DoD Roles and Responsibilities*, (Maxwell Air Force Base, Ala.: U.S. Air Force Counterproliferation Center, 2006).

115. See Williams and Schmitt elsewhere in this volume for more detailed information about WMD-CSTs.

116. Department of Defense, *Joint Publication 3-41*, 2016.

117. Department of Defense Joint Chiefs of Staff, *Joint Publication 3-28 Civil Support*, (2007), https://fas.org/irp/doddir/dod/jp3-28.pdf.

118. Ibid.

119. U.S. Department of Homeland Security Food and Nutrition Service, "USDA DoD Fresh Fruit and Vegetable Program," August 2018, https://fns-prod.azureedge.net/sites/default/files/DOD_FreshFruitandVegetableProgram2011.pdf.

120. U.S. Department of Homeland Security Agricultural Research Service, "Plum Island Animal Disease Center," accessed Oct. 11, 2019, www.ars.usda.gov/northeast-area/orient-point-ny/plum-island-animal-disease-center.

121. Ibid.

122. U.S. Department of Homeland Security Agricultural Research Service, "National Animal Disease Center," accessed Oct. 11, 2019, www.ars.usda.gov/midwest-area/ames/nadc.

123. U.S. Department of Homeland Security Agricultural Research Service, "U.S. National Poultry Research Center," accessed Oct. 11, 2019, www.ars.usda.gov/southeast-area/athens-ga/us-national-poultry-research-center.

124. U.S. Department of Homeland Security Agricultural Research Service, "Frederick, Maryland," accessed Oct. 11, 2019, www.ars.usda.gov/people-locations/people-list-offices/?modeCode=80-44-00-00.

125. U.S. Department of Homeland Security, Science and Technology, National Bio- and Agro-Defense Facility, accessed Oct. 11, 2019, www.dhs.gov/science-and-technology/national-bio-and-agro-defense-facility.

126. Ibid.

127. U.S. Department of Homeland Security, *Memorandum of Agreement Between the U.S. Department of Agriculture Marketing and Regulatory Programs, the U.S. Department of Agriculture Research, Education, and Economics, and the Department of Homeland Security Science and Technology Directorate*, (June 201, 2019), www.usda.gov/sites/default/files/documents/usda-dhs-moa.pdf.

128. U.S. Department of Homeland Security, Science and Technology, National Bio and Agro-Defense Facility.

129. U.S. Department of Homeland Security National Institute of Food and Agriculture, "The Hatch Act of 1887," accessed Oct. 13, 2019, https://nifa.usda.gov/program/hatch-act-1887.

130. Food and Drug Administration, *A Joint Effort of the FBI, DHS, USDA, and FDA to Help Secure the Nation's Food Supply*, (August 2005), www.fda.gov/food/food-defense-programs/strategic-partnership-program-agroterrorism-sppa-initiative.

131. Food and Drug Administration, "An Overview of the CARVER Plus Shock Method for Food Sector Vulnerability Assessments," Sept. 18, 2018, www.fda.gov/food/food-defense-programs/carver-shock-primer.

132. Federal Bureau of Investigation, "Evidence Response Team," accessed June 10, 2019, www.fbi.gov/services/laboratory/forensic-response/evidence-response-team.

133. National Council of Information Sharing and Analysis Centers, "About ISACs," accessed Dec. 8, 2019. www.nationalisacs.org/about-isacs.

134. Congressional Research Service, *Agroterrorism: Threats and Preparedness*, (Aug. 25, 2006), https://apps.dtic.mil/dtic/tr/fulltext/u2/a456167.pdf.

135. www.k-state.edu/comply/aphis-course-17.html.

136. Federal Bureau of Investigation, "Critical Incident Response Group," accessed June 2019, www.fbi.gov/services/cirg.

137. The White House, Homeland Security Presidential Directive, 2003.

138. Ibid.

139. FDA, DHS, and USDA, Food Defense Programs, *National Infrastructure Protection Plan*, (May 21, 2007), www.fda.gov/food/food-defense-programs/national-infrastructure-protection-plan.

140. Ibid.

141. J. Pulz and D. Stiefel, *Food and Agriculture Preparedness and Defense*, Presentation to Georgetown University Department of Microbiology and Immunology, (March 28, 2019).

142. U.S. Department of Agriculture Animal and Plant Health Inspection Service, "National Animal Health Laboratory Network," May 2017, 2019, www.aphis.usda.gov/aphis/ourfocus/animalhealth/sa_lab_information_services/sa_nahln/ct_national_animal_health_laboratory_network.

143. U.S. Department of Agriculture Animal and Plant Health Inspection Service, "National Veterinary Stockpile," May 29, 2019, www.aphis.usda.gov/aphis/ourfocus/animalhealth/emergency-management/nvs/!ut/p/z1/04_iUlDg4tKPAFJABpSA0fpReYllmemJJZn5eYk5-hH6kVFm8X6Gzu4GFiaGPu6uLoYGjh6Wnt4e5mYGBh5m-l76UfgVFGQHKgIAHq7ZJA!!.

144. U.S. Department of Homeland Security National Institute of Food and Agriculture, "National Plant Diagnostic Network," accessed June 29, 2019, https://nifa.usda.gov/national-plant-diagnostic-network.

145. Global Foot-and-Mouth Disease Research Alliance, "GFRA Scientific Meeting 2019: Advancing Global Food and Mouth Disease Research by bridging the gap with novel tools," accessed Oct. 13, 2019, www.ars.usda.gov/GFRA.

146. T .J. D. Knight-Jones, L. Robinson, B. Charleston, L. L. Rodriguez, C.J. Gay, K. J. Sumption, W. Vosloo, "Global Foot-and-Mouth Disease Research Update and Gap Analysis: 2 – Epidemiology, Wildlife and Economics," *Transboundary and Emerging Diseases* 63, no. 1 (June 20, 2016), pps. 14-29, https://doi.org/10.1111/tbed.12522.

147. Global African Swine Fever Research Alliance, "Global African Swine Fever Research Alliance," accessed Oct. 13, 2019, www.ars.usda.gov/GARA.

148. Global Health Security Agenda, "What is GHSA?," accessed Oct. 13, 2019, www.ghsagenda.org.

149. "An integrated approach to preparedness, detection, and response to agricultural threats: The experience of the United States," *Meeting of the States Parties to the Convention on the Prohibition of the Development, Production and Stockpiling of Bacteriological (Biological) and Toxin Weapons and on Their Destruction*, (July 15, 2019), https://undocs.org/BWC/MSP/2019/MX.4/WP.1.

150. Bipartisan Commission on Biodefense, *A National Blueprint for Biodefense: Leadership and Major Reform Needed to Optimize Efforts, A Bipartisan Report of the Blue Ribbon Study Panel on Biodefense*, (October 2015), https://biodefensecommission.org/wp-content/uploads/2015/10/NationalBluePrintNov2018-02.pdf.

151. Bipartisan Commission on Biodefense, *Defense of Animal Agriculture, Bipartisan Report of the Blue Ribbon Study Panel on Biodefense*, (October 2017), https://biodefensecommission.org/wp-content/uploads/2017/10/Defense-of-Animal-Agriculture-03.pdf

152. Executive Office of the President, "President's Council of Advisors on Science and Technology Letter to the President," (November 2016), https://obamawhitehouse.archives.gov/sites/default/files/microsites/ostp/PCAST/pcast_biodefense_letter_report_final.pdf.

153. U.S. Department of Health and Human Services, U.S. Department of Justice, and U.S. Department of Homeland Security. *Criminal Investigation Handbook for Agroterrorism*, (July 2008), www.fsis.usda.gov/shared/PDF/Investigation_Handbook_Agroterrorism.pdf.

154. U.S. Department of Homeland Security Office of the Inspector General, *Agroterrorism Prevention, Detection, and Response: Audit Report 61701-0001-21*, (March 2017), www.usda.gov/oig/webdocs/61701-0001-21.pdf.

155. U.S. Department of Agriculture, *Agency Activities for Agroterrorism, Prevention, Detection, and Response Audit Report 50701-0001-21*, (Washington, D.C.: U.S. Department of Agriculture, September 2018).

156. The White House, *National Security Strategy of the United States of America*, (December 2017,) www.whitehouse.gov/wp-content/uploads/2017/12/NSS-Final-12-18-2017-0905.pdf.

157. U.S. Department of Homeland Security Federal Emergency Management Agency, “National Preparedness System, Jan. 29, 2019, www.fema.gov/national-preparedness-system.

158. U.S. Department of Homeland Security, National Preparedness Goal, Second Edition,” (September 2015), www.fema.gov/media-library/assets/documents/25959.

159. U.S. Department of Homeland Security Federal Emergency Management Agency, “National Planning Frameworks,” Jan. 30, 2019, www.fema.gov/national-planning-frameworks.

160. U.S. Department of Homeland Security Federal Emergency Management Agency, “National Prevention Framework, Second Edition,” (Washington, D.C.: U.S. Department of Homeland Security, June 2016), www.fema.gov/media-library-data/1466017209279-83b72d5959787995794c0874095500b1/National_Prevention_Framework2nd.pdf.

161. U.S. Department of Homeland Security Federal Emergency Management Agency, National Protection Framework, Second Edition,’ (June 2016), www.fema.gov/media-library-data/1466017309052-85051ed62fe595d4ad026edf4d85541e/National_Protection_Framework2nd.pdf.

162. U.S. Department of Homeland Security, *National Infrastructure Protection Plan — NIPP 2013: Partnering for Critical Infrastructure Security and Resilience*, (Washington, D.C.: U.S. Department of Homeland Security, 2013), www.dhs.gov/sites/default/files/publications/national-infrastructure-protection-plan-2013-508.pdf.

163. FDA, USDA, DHS, “Food and Agriculture Sector-Specific Plan,” (2015), www.dhs.gov/sites/default/files/publications/nipp-ssp-food-ag-2015-508.pdf.

164. U.S. Department of Homeland Security, *National Mitigation Framework, Second Edition*, (Washington, D.C.: U.S. Department of Homeland Security, June 2016), www.fema.gov/media-library-data/1466014166147-11a14dee807e1ebc67cd9b74c6c64bb3/National_Mitigation_Framework2nd.pdf.

165. U.S. Department of Homeland Security, *National Response Framework, Third Edition*, (Washington, D.C.: U.S. Department of Homeland Security, June 2016), www.fema.gov/media-library-data/1466014682982-9bcf8245ba4c60c120aa915abe74e15d/National_Response_Framework3rd.pdf.

166. U.S. Department of Homeland Security and FEMA, *National Incident Management System, Third Edition*, (Washington, D.C.: U.S. Department of Homeland Security, October 2017), www.fema.gov/media-library-data/1508151197225-ced8c60378c3936adb92c1a3ee6f6564/FINAL_NIMS_2017.pdf.

167. U.S. Department of Homeland Security Federal Emergency Management Agency, *Overview: ESF and Support Annexes Coordinating Federal Assistance in Support of the National Response Framework*, (Washington, D.C.: U.S. Department of Homeland Security, January 2008) www.fema.gov/media-library-data/20130726-1825-25045-8535/overview_esf___support_annexes_2008.pdf.

168. U.S. Department of Homeland Security Federal Emergency Management Agency, *Emergency Support Function #11, Agriculture and Natural Resources Annex*, (June 2016), www.fema.gov/pdf/emergency/nrf/nrf-esf-11.pdf.

169. U.S. Department of Homeland Security Federal Emergency Management Agency, *Food and Agriculture Incident Annex. AGR-10*, (August 2008), www.fema.gov/media-library-data/20130726-1825-25045-9859/food___agriculture_incident_annex_2008.pdf.

170. Ibid.

171. U.S. Department of Homeland Security, *National Disaster Recovery Framework, Second Edition*, (Washington, D.C.: U.S. Department of Homeland Security, June 2016), www.fema.gov/media-library-data/1466014998123-4bec8550930f774269e0c5968b120ba2/National_Disaster_Recovery_Framework2nd.pdf.

172. The White House, National Biodefense Strategy, (2018), www.whitehouse.gov/wp-content/uploads/2018/09/National-Biodefense-Strategy.pdf.

173. Ibid.

174. United States Congress, "National Defense Authorization Act for Fiscal Year 2017," 6 U.S.C. 104, Public Law 114-328, enacted Dec. 23, 2016.

175. U.S. Department of Health and Human Services and U.S. Department of Homeland Security, *Report to Congress on the National Agriculture and food Defense Strategy Submitted Pursuant to Section 108 of the Food Safety Modernization Act*, Public Law 111-353, (April 2015), www.fda.gov/media/91754/download.

176. Bipartisan Committee on Biodefense, *National Blueprint*, 2015.

177. National Council of ISACs, *About ISACS*, accessed Dec. 8, 2019. www.nationalisacs.org/about-isacs.

CHAPTER 6

Organoleptic Assessments as a Tool for Food Defense Chemical Threat Prioritization

Dr. Nathaniel C. Rice and Dr. Todd M. Myers

The agricultural sector and water supply systems have been identified as critical infrastructures by the U.S. government,[1] and a successful attack on the agricultural sector would have "catastrophic health and economic effects."[2] The agricultural sector is comprised of multiple industries spanning large geographical regions. This vast, complex network contributed more than $1 trillion to the gross domestic product (GDP) of the United States and accounted for 11 percent of American employment in 2017.[3] The size and complexity of the agricultural sector make it difficult, if not impossible, to secure the nation's food supply. A single item may be grown in one location and then pass through multiple intermediary stops before reaching a consumer on the other side of the country. Each step in this process may be with a different vendor, handling some aspect of the supply chain such as rendering, packing, transportation, or preparation.[4] A single item can change ownership multiple times, and the responsible parties, in both public and private sectors, overseeing these vendors may also vary. Similarly, items may be transported through multiple countries, each with different laws applicable to food safety and food defense.

An attack on the nation's food supply is generally perceived as a low-probability, high-impact event. Food and water contamination is one of the easiest ways to expose a large number of people to chemical and biological agents.[5] If an attack were to occur, the rapid and vast distribution system used to transport foods and beverages could be exploited to distribute harmful agents.[6] The Food and Drug Administration (FDA) has also expressed this concern, warning that "if an unintentional contamination of one food … can affect 300,000 individuals, a concerted, deliberate attack on food could be devastating, especially if a more dangerous chemical, biological, or radionuclear agent were used."[7] Prevention of an intentional adulteration event is the ultimate goal and is achieved by safeguards such as personnel management, physical security measures, and engineering controls. The FDA has also recently published the *Intentional Adulteration Rule*, which requires industry partners to conduct vulnerability assessments of their facilities and processes in order to reduce the probability of an intentional adulteration event.[8]

The real-time detection of adulterants or contaminants is a promising technological capability for preventing adulterated items from reaching consumers. These detection methods range from cellular assays[9] to spectrometry,[10] but they are often not suited for mass deployment or are not able to detect a wide range of adulterants. Electronic nose and tongue technologies can be used to test for off-scents and off-flavors,[11] which can be indicative of spoilage, contamination, or adulteration. However, despite continued advancements, these technologies are not suitable for mass deployment. In sum, there exists no real-time detection method that can be implemented to keep U.S. food and water safe from attack from a wide range of adulterants. Until such a technology exists, or in the interim to guide the development of such technology, threat prioritization is needed to identify the adulterants that pose the greatest risk to the U.S. population. This identification will allow for the development of targeted detection methods, will inform medical countermeasure development and stockpiling, and will direct future research and congressional discussions.

How then do we prioritize these threats? Examination of real-world adulteration events is the best way to determine how to assess potential threats. These events inform how an adulterant was selected, the method in which it was used, and when the adulterant was eventually detected. This information can then inform which assessments to conduct in a research setting and which data most accurately predict the risk of a chemical threat being used in a real-world event.

Real-World Intentional Adulteration Events

Food and water supplies have been adulterated for thousands of years, with the first documented case in 590 BCE when hellebore (a toxic plant) was used to poison the inhabitants of a Greek city.[12] In more modern times, intentional food and water adulteration occurs globally and may be economically motivated or meant to cause harm. In 2002, a man in China adulterated the food of a rival restaurant with tetramine (tetramethylenedisulfotetramine, TETS), killing 42 people and hospitalizing around 300 others.[13] In 2013, a disgruntled Japanese employee adulterated frozen foods with malathion, an organophosphate pesticide; 2,800 individuals were poisoned[14] and 6.3 million products were recalled.[15] In 2018, a German man poisoned coworkers with lead acetate by adulterating their lunches, resulting in severe kidney damage to one individual and causing another to enter a persistent vegetative state.[16]

Food adulteration has also occurred in the United States and became a national concern in 1984 after a religious cult in Oregon poisoned salad bars with Salmonella to influence a local election.[17] More than 750 cases were confirmed, and the event was originally considered a food safety issue, as it was assumed the food was contaminated with Salmonella accidentally or incidentally. Adulteration was only considered after a prolonged investigation, and criminal charges were eventually filed 18 months after the event.[18] *Table 1* provides details for a subset of more recent examples of U.S. food adulteration events. In these instances, the adulterants varied, but were predominantly chemicals. Additionally, the majority of the events occurred at the point of service (e.g., food or beverage preparation in a restaurant, volunteer organization, office, or home) or at the point of sale, such as in a grocery store. The agricultural supply chain was not hijacked or exploited in these cases, and events were relatively small-scale and typically only affected local consumers. However, these events also demonstrate that real-time detection technologies would have been unlikely to protect anyone, as the food was immediately given to the consumer (either cooked or to be cooked by the consumer). Most attacks on food and beverages, regardless of the country of origin, are carried out by an individual handling or preparing food for a consumer.[19] Therefore, the only protection that the consumers were afforded was their own ability to detect the adulterants. Although a large-scale event would have real-time detections and other ongoing response measures (such as recalls), the very last opportunity to detect adulteration and prevent consumption of adulterated products will *always* rely on the consumer’s own senses.

Table 1: Examples of intentional (or suspected) food adulteration events in the United States.

1999	Methomyl	Salt	Point of Service/ Sale	107 Injured
2000	Rat Poison	Salsa	Point of Service/ Sale	34 Injured
2002	Nicotine	Ground Beef	Point of Service/ Sale	92 Injured Food Recalled
2003	Arsenic	Coffee	Point of Service/ Sale	11 Injured 1 Dead
2006	Dish Soap	Juice	Point of Service/ Sale	40 Injured
2009	Methomyl	Salsa	Point of Service/ Sale	48 Injured
2015	Cannabinoid	Bread	Point of Service/ Sale	About 40 Injured
2015	Brodifacoum	Cake	Point of Service/ Sale	16 Injured
2016	Sand, Dirt, Soil	Chicken	Food Manu-facture	Food Recalled
2017	Rat Poison	Salad Bar	Point of Service/ Sale	Food Recalled
2017	Viagra	Coffee	Food Manu-facture	Food Recalled
2017	Ricin	Meals	Point of Service/ Sale	1 Injured
2017	Unknown	Candy	Unknown (Imported)	2 Injured
2018	Rat Poison	Cheese	Point of Service/ Sale	Food Recalled

A consumer's ability to detect an adulterant would primarily rely on the organoleptic properties of the adulterant and the consumer's sensory abilities (primarily chemoreceptive). Organoleptic properties (also referred to as organoleptics hereafter) refer to anything that affects a sensory modality. These can include the taste, odor, texture, color, or temperature of an item. Food and beverages already possess important organoleptic properties that consumers attend to. These properties can be used to detect spoilage (e.g., the smell of milk) or to simply discern and decide among the available options. For example, taste, odor, color, and turbidity are how a consumer can judge their drinking water and are important factors that influence the purchase of bottled water.[20] Consumers may also prefer and pay a higher price for grass-fed beef based on the perceived taste. Adulterants also possess organoleptic properties that may be detected by a consumer. If an adulterant is less detectable, then it poses a higher risk as an ingestion hazard because consumers would be more likely to ingest toxic amounts. Organoleptics are primarily investigated in pharmaceuticals, to mask aversive flavors and improve treatment adherence,[21] and pesticide development, to ensure that pests readily consume lethal chemicals.[22] Although these two areas of research are informative, additional research focusing on potential human oral-ingestion hazards *per se* is needed, and, in this regard, the development and use of a laboratory organoleptic and toxicological assessment are warranted.

The majority of food safety and food defense research has focused on biological threats, primarily due to the rate of foodborne illnesses and greater perceived potential impact of a biological event. An estimated 50 million Americans annually will experience a foodborne illness,[23] which has a total economic burden of more than $75 billion,[24] and risk assessments of foot-and-mouth disease infecting livestock estimate billions of dollars in potential damages.[25] Even though these estimates suggest a biological adulteration would be catastrophic, the actual use of biological agents for intentional adulteration has rarely occurred. From 1946 to 2015, chemical agents were threatened or used six times more frequently than biological agents globally,[26] perhaps due to the availability or ease of synthesis of chemical agents compared to biological agents. Some biological agents require special environmental conditions (e.g., specific media and controlled temperatures), whereas chemical agents often remain stable for years under routine storage conditions. Therefore, chemicals may have the strategic advantage of being easier to store, transport, and deliver into foods and beverages. The food adulteration events listed in *Table 1* also primarily involved chemical adulterants. In the United States, more than 80,000 chemicals are in use, and approximately 2,000 new chemicals are introduced to consumer products annually,[27] representing several diverse and distinct mechanisms of toxicity, rendering identification and effective treatment more difficult. Chemicals are also more likely to survive water treatment[28] and food preparation.[29] It is clear that chemical adulterants should be given greater consideration as food- and water-borne threats due to their ease of acquisition and use, number and diversity, and high potency and persistence. The following text will focus primarily on chemical adulterants, though some of the guidance and recommendations may also apply to biological agents.

Chemical Adulterants

The most dangerous adulterants are available or easily synthesized, soluble and stable in food or drink, toxic at small, acute doses, difficult to diagnose or treat, and possess no easily detectable organoleptic properties. Availability is a critical component for potential adulterants, as terrorists, sub-state actors, and even lone wolves will likely choose an adulterant that can be easily obtained. Thus, chemicals requiring licenses or those not freely available to the public are less likely to be used. This was demonstrated in China when attacks using rodenticides decreased after public access to these chemicals was restricted.[30] Analysis of real-world attacks revealed that the choice of agent was primarily determined by availability[31] and not some other factor, such as toxicity. Likewise, if a chemical is easily synthesized, then it can either be made in the requisite amounts or would likely be available for purchase through illegal means. Tetramine is an example of this, as it can be synthesized using common chemicals[32] and is still illegally sold in China, despite a worldwide ban.[33] Availability also needs to be considered for chemicals that are no longer available for public purchase, but once were. Many chemicals are stable over a period of years, and compounds taken off the market may still be available for use at a later date. Black Leaf 40, a pesticide made up of 40 percent nicotine, was used to adulterate ground beef in 2003[34] despite being banned in 1992. This demonstrates that the chemicals “available for misuse” comprise a very broad category that is exceptionally difficult to define.

The solubility or stability of the adulterant in various food and beverage vehicles is also important, though these data typically do not exist since solubility assessments conducted in research settings rarely use foods and drinks as vehicles. An effective adulterant needs to be soluble in drinks or able to be mixed with solid foods and then consumed at toxic concentrations. Some adulterants are not soluble and are only suitable for solid foods, while others adulterants may be highly soluble and are therefore hazards to both foods and beverages. Brodifacoum, an anticoagulant that was deployed in response to warfarin-resistant rats,[35] is demonstrative of the importance of assessing solubility. While ingestion of brodifacoum can lead to injury or death, it is primarily a solid-food threat. Brodifacoum’s solubility in water is quite poor, approximately 0.0038 milligrams per liter (mg/L),[36] which would require a person to consume an unreasonably large volume of adulterated water for it to be life threatening. However, consumption of solid brodifacoum mixed into food can produce severe and prolonged coagulopathy.[37] Whereas selection of an adulterant may be determined primarily by its availability, the solubility and stability of the adulterant are critical factors for determining the potential scope and impact of the adulteration event.

Once an adulterant has been used, it may be consumed chronically or acutely. Chronic exposure often requires long-term access to an individual’s food supply and best describes small-scale, targeted attacks, such as poisoning of a family member over a period of weeks or months. A large-scale attack would most likely involve an acute exposure, with numerous individuals becoming poisoned during a single event. An acute exposure is also more likely in large-scale attacks due to the inevitable intervention from government agencies to remove and destroy the suspected adulterated items to prevent further casualties. As the large-scale scenario involves consumption of the adulterant only once, chemicals that are toxic at smaller doses are more significant ingestion hazards. Unfortunately, although the toxicity of potential chemical adulterants has in some cases been elaborated using multiple routes of exposure, the oral route remains understudied, making it more difficult to prioritize chemical agents as food and beverage adulterants. Given this fact and the importance of understanding *oral toxicity*, use of the oral route for toxicity determinations is discussed in a later section.

Adulterants that are difficult to diagnose and/or treat also represent higher priority threats. In a large-scale, mass-poisoning scenario, medical resources will be strained due to the large influx of patients and worried-well seeking treatment. Adulterants that are difficult to diagnose will prolong the time to effective treatment and will also delay incident response, such as medical countermeasure stockpile deployment. Delayed treatment, particularly in the case of chemical poisoning, is known to increase the severity of injury and probability of long-term complications and death. Delayed diagnosis will impede effective treatment and increase severity of outcomes overall. Once identified, chemicals that are difficult to treat (due to lack of appropriate countermeasures or inadequate dosages) will necessarily place a greater strain on medical resources and potentially exhaust medical supplies and countermeasure stockpiles. The overt toxic signs and symptomology as well as the latency to onset will also differ as a function of the route of exposure. As the oral route of exposure is understudied, the unique or unexpected presentation of signs and symptoms that follow the ingestion of a chemical agent may lead to misdiagnosis or delayed diagnosis, so additional research is needed to understand route-dependent toxidromic effects. In all cases, adulterants that are more difficult to diagnose and treat will likely produce more severe or life-threatening outcomes.

The final and critically understudied aspects of an adulterant are the organoleptic properties. As stated previously, the final defense against ingesting an adulterant is always the consumer’s ability to detect the adulterant. An adulterant that is tasteless, odorless, and otherwise undetectable is a far greater threat than an adulterant that is easily detected and therefore would either not be consumed or consumed in significantly lower amounts. Adulterants might also disproportionately affect vulnerable populations, as the ability to discern flavors and odors decreases with age.[38] This is in addition to the potential physiological vulnerability to chemical exposures,[39] leading to greater toxicity and mortality in older populations. Children might also lack the ability or opportunity to decline adulterated foods, are more likely to consume certain food or beverage items than adults (i.e., milk),[40] and are more likely to consume items that should be avoided, so long as they are packed in an attractive manner. This was observed when young children consumed Tide pods because of the brightly colored packaging.[41] The pods were reformulated to include bittering agents[42] in order to stop children from consuming an entire pod and thereby decreasing the risk and severity of injury. This demonstrates how the organoleptics of a chemical determines the amount consumed and its potential as an agent of terror.

As previously mentioned, the majority of organoleptic research has been conducted in two main areas: pharmaceuticals and baited pesticides.

Pharmaceutical compounds are often bitter, and treatment adherence, especially in children, is an ongoing challenge.[43] Different methods have been developed to mask the excessive bitterness of these compounds and improve patient compliance. Effervescence has been shown to improve oral dosing as well as mask bitterness, as contact time with the taste buds is decreased when a compound dissolves more quickly.[44] Other compounds, such as sodium bicarbonate or artificial sweeteners, can also be added to pharmaceuticals to increase palatability.[45] The pharmaceuticals can also be administered with oils, surfactants, or other vehicles or additives to increase saliva viscosity or coat the taste buds, thereby decreasing the bitterness experienced by the patient.[46] Capsules, microencapsulations, and various coatings can also address bitterness by bypassing the oral mucosae and allowing the compound to dissolve in the stomach or gastrointestinal (GI) tract.[47]

Organoleptics also figure prominently in the successful use of baited pesticides. Pests must consume lethal amounts of a pesticide for them to be effective. If a pest consumes the baited pesticide and subsequently becomes sick, but does not die, that bait will typically be avoided in the future. This phenomenon is called bait shyness,[48] though conditioned taste aversion is a more general term that applies to all consumed items and not just baited pesticides. Laboratory models have repeatedly demonstrated that food consumed immediately prior to intoxication is likely to be avoided in the future and other harmless alternatives are sought out.[49] The avoidance continues even when the once-adulterated food is rendered safe. To counteract this bait shyness, pesticides can be baited with taste additives to make them more attractive[50] or a pesticide with a longer latency to intoxication may be used to increase the likelihood that a lethal dose is consumed prior to intoxication, precluding the development of bait shyness.[51]

The organoleptic research conducted for pharmaceuticals and pesticides is informative, but is primarily focused on ensuring that specific compounds are consumed in very specific vehicles, not determining which compounds may be consumed by humans in a variety of food or drinks. Additionally, pharmaceutical research is focused on treatment adherence and does not significantly contribute to the prioritization of potential chemical adulterants. Instead, laboratory models need to be developed based off the obtained knowledge from these fields and then applied to toxicological examinations and prioritizations of chemical threats. The development of these models, however, requires the use of understudied routes of exposure as well as underutilized behavioral methods.

Experimental Considerations

The prioritization of chemical threats necessarily involves a multi-phase approach to collect threat-specific data regarding availability, solubility, toxicity, and organoleptics. Chemical adulterants are greater threats when they are available, soluble in the target vehicle, acutely toxic at small doses, difficult to diagnose or treat, and not easily detectable before or during consumption. Very few laboratories use solid food items or beverages to deliver chemical adulterants, so while some of these data may be in the literature prior to the start of a project, our experience suggests that very little applicable data are available. If these data, either in whole or in part, are available then replicating the studies is suggested to ensure that the reported values are reasonable. In our assessments of carfentanil we discovered that the existing median lethal dose[52] and bioavailability data[53] were misleading and grossly underestimated carfentanil's potency and toxicity when consumed in our rat model.[54] Careful replication also helps ensure published data are accurate. Food-defense research is scarce, and determining when data are outliers or misleading is more difficult with so few data sets for comparison.

The sections that follow are specific recommendations for conducting laboratory assessments of chemical adulterants and the prioritization of these threats. The assessment of organoleptic properties of chemical adulterants is a critical component of threat prioritization, but the animal model, vehicle, and adulterant must be selected prior to any organoleptic assessment. The solubility of the adulterant then needs to be assessed within the selected vehicle (if applicable) as well as the toxicity of the adulterant when consumed. Much of the guidance presented here outlines these considerations and the steps that must be made prior to the organoleptic assessment to facilitate success and improve the utility of the data.

Vehicle Selection – The organoleptic assessment of a chemical threat necessarily involves the consumption of that chemical in a vehicle. The vehicle of interest should be selected early in the planning process, and solubility of the adulterant must be assessed within that vehicle (if applicable). The vehicle may be a solid food item or a beverage, and vehicle selection should reflect the scenario of interest. If the scenario is the adulteration of a beverage meant to cause harm to any and all civilians, then popular drinks, such as bottled water, juices, milk, and sodas, should be chosen as the vehicle(s). Likewise, the most popular version of these beverages should be selected (i.e., two percent milk).[55] If the scenario is a targeted attack on a specific population, then food more commonly consumed by that population would be the likely choice for a vehicle. If the intent is to damage a specific brand, then food or drinks manufactured under that brand are the obvious choice for a vehicle.

Using multiple vehicles is beneficial in all cases, as the organoleptic properties of adulterants may vary as a function of the vehicles. Our own research has demonstrated that consumption of carfentanil varies when using adulterated water, apple juice, and two percent milk. Rats consumed significantly more carfentanil in juice and milk compared to water,[56] indicating that vehicle selection is critically important in understanding the threat certain adulterants pose and revealing adulterant-vehicle interactions. In the example given above, carfentanil is soluble within each beverage vehicle, but differentially consumed across them. Masking of taste or odor would appear to be the simplest explanation for the increased consumption of milk and apple juice. However, had increased consumption only occurred for milk, such a pattern might suggest that carfentanil is interacting with the protein or fat solids present in milk that are absent in the juice and water. By conducting assessments of adulterants across multiple vehicles, a more robust assessment can be obtained, a more confident conclusion can be reached, and data regarding the masking effects or the likelihood of physicochemical interactions between adulterant and vehicle are obtained earlier. By including diverse vehicles, information gained early in this process can help prevent over-interpretation or misrepresentations about the adulterant in general and may reveal additional considerations to inform scenario and model development (batch sizes, maximum temperatures reached, pH, storage times, etc.) or additional study. For these reasons, inclusion of diverse vehicles early in the process is suggested.

If the vehicle selected for the laboratory assessment is a solid food item, then consideration must be made for how the adulterant will be applied. Solid food items, such as produce, will likely need the adulterant sprinkled onto the item. Obviously, laboratory control of actual exposure level is one of the most important attributes, and this circumstance could undermine precise control due to the increased likelihood of partial dosing and mixed-route exposures. When the adulterant is not suitably mixed or lies primarily on top of an item, it may be removed by environmental exposure, handling, or other movement. Likewise, any handling that occurs may also lead to the adulterant staying on the hands instead of being consumed orally. This scenario would either lead to partial dosing, as not all of the chemical is consumed and was instead removed by handling, or mixed-route exposure, as the chemical may be absorbed dermally. Once on the hands, the chemical can be transferred to the eyes, nasal passages, or various other skin surfaces with differing levels of thickness, vasculature, and thus absorption, further complicating estimates of actual chemical exposure and the timing thereof. With some less solid food items (e.g., cookie dough, peanut butter, ice cream, yogurt), homogeneity of adulteration can be achieved more readily with sufficient mixing.

This approach is preferred over sprinkling the adulterant onto items with no mixing, but homogeneity may not be guaranteed. Handling of the solid food items can again lead to mixed-route or partial exposures, though this method is more likely to produce consistent results than sprinkling the adulterant onto an item. Any error engendered by incomplete mixing is likely to be much lower and obtained exposure level much more consistent both within and between subjects relative to sprinkling the adulterant onto solid foods. While errors in dosing, administration, and consumption cannot be prevented with solid food items, they must be minimized to the extent practicable. In our laboratory, we were able to achieve consistent adulteration by selecting a solvent well-suited to both the chemical poison (tetramine) and the solid food item (a piece of Froot Loops cereal). In our studies,[57] a quantity of tetramine in an acetone solution was applied to the food, and the acetone vehicle was allowed to completely evaporate, leaving only the tetramine on the food morsel. This allowed for near-homogeneous adulteration of the cereal with tetramine and without altering the physical characteristics of the food item (the cereal did not become soggy or lose its sugary coating). Rats were then allowed to eat the poisoned food, which they did promptly and reliably, even at supralethal doses.

Beverages or liquid vehicles are the easiest to use, and measurement of the amount of adulterant consumed is more accurate than with solid foods. Adulterants can be placed into the liquid vehicle of interest and then mixed until a homogenous solution is created. Actual volume consumed can be measured volumetrically or by using the mass (weight) of solution presented minus the amount remaining after consumption is complete, taking into account any additional wastage outside of the container (i.e., spills), if applicable. There are, however, unique considerations for using liquid vehicles. Many beverages consumed in the United States are refrigerated, which will almost certainly decrease the solubility of the adulterant. Likewise, any solids dissolved into the beverage will likely further decrease the solubility. The pH of the liquid also impacts solubility, as many popular drinks are acidic (e.g., juice and soda). Although some of these beverages can be heated to improve solubility and then cooled later, the adulterant might precipitate out, or the scenario may no longer accurately reflect a real-world production or manufacturing process. Regardless of the vehicle chosen, the solubility of the adulterant must be assessed at the temperature to be used in the organoleptic assessment. Adulterants must meet some minimum solubility criterion that is also based on toxicity to ensure that the concentration obtained can produce toxicity in the amount to be delivered or consumed. As mentioned previously, brodifacoum is an example of an adulterant that is a solid-food threat, but not a beverage threat because the solubility is so very low.

Vehicle selection also impacts the form in which the adulterant is delivered. Adulterants may taste and smell differently when delivered as a powder compared to a solution.[58] As solid food items would likely be contaminated by a chemical in solid form (because contamination by a liquid would be obvious), the organoleptics may vary when compared to the same adulterant in a beverage. Unfortunately, there is no way to accurately predict how the organoleptics may vary, so an organoleptic assessment must be conducted to determine if threat prioritization of a chemical adulterant needs to vary for its multiple forms and as a function of the vehicle(s) used. This same logic also applies to different chemical structures of the same chemical (e.g., freebase compared to a salt,[59] or racemic versus enantiomeric forms[60]). However, it is impossible to investigate every combination of adulterant (in its various forms), vehicle, and scenario-specific parameters (e.g., refrigeration). Therefore, research must be targeted primarily at realistic and credible threats, which likely involves parent compounds and idealized conditions.

Toxicity following consumption can also change as a function of the vehicle selected. The fats, proteins, sugars, and other constituents of the vehicle can alter the toxicity of the adulterants. Vehicles that are oily could exacerbate toxicity[61] by enhancing solubility or reduce toxicity by slowing absorption of the adulterant (e.g., corn and cottonseed oil). Lipid solubility and hydrophobic/hydrophilic properties of chemicals must be reasonably understood to make predictions, but typical chemical assessments utilize standard methods (such as the octanol-water partition coefficient) that only partially predict outcomes in more complex situations, such as the chemical adulteration of milk. Our work with aldicarb, a carbamate pesticide, revealed that lethality changed based on the beverage adulterated. Rats that consumed a concentration equivalent to the median lethal dose (LD_{50}) of aldicarb were more likely to die when the aldicarb was delivered in water (five out of 10) compared to juice (three out of 10) and milk (one out of 10). This vehicle-dependent effect was not observed when the concentration was increased to an LD_{99} equivalent.[62]. An exhaustive list of how vehicles change adulterants is not feasible, and while certain aspects of the chemical adulterant may suggest differences in toxicity as a result of the vehicle (e.g., lipophilicity), the most accurate method for assessing vehicle-dependent toxicity is to simply record toxic signs and lethality following consumption.

All of these aspects deserve consideration to ensure that the vehicle chosen maximizes reliability and validity as a laboratory model while also reflecting a real-world scenario as appropriate (or when possible). In all cases, the ability to obtain usable data should be prioritized over realism, because a laboratory model that produces well-controlled exposures and conditions of high internal validity allows extrapolation to a variety of real-world scenarios. Studies overly focused upon specific real-world scenarios seldom achieve data that are internally valid, reproducible, or useful beyond the specific scenarios under which they are framed.

Animal Model Selection – The choice of an animal model is important and needs to be made early in the experiment-planning process. The choice of an animal model affects housing, veterinary and technical staff training requirements, key aspects of husbandry (diet, food, and water regulation), and the equipment and spaces used for toxicological and organoleptic assessments. In sum, the choice of animal model has profound and broad-ranging impacts on the resources needed to complete such studies. The animal model may also affect which vehicles or adulterants are used. Certain animal species may not consume a vehicle of interest or could require significantly more training/experience with the vehicle prior to experimental assessments of the adulterant. Obviously, attempting to train an obligate carnivore (such as the ferret) to consume produce is a poor choice, and selecting an animal species that naturally (or with minimal training) consumes the vehicle of interest will greatly aid in the completion of the organoleptic assessment. Pigeons are likely to consume seeds and grains, whereas ferrets require animal-based food or liquid vehicles (e.g., ground beef, liver, or chicken broth). Omnivores are obviously the most flexible choice and more closely approximate most humans, but not all animals will reliably consume specific foods consumed by humans (e.g., spicy foods or bitter-tasting beverages). Animals may reject completely novel vehicles, so a pilot study to determine if the vehicle and animal model of interest are compatible is advised. The adulterant of interest may also determine the animal model, as some species have markedly different toxicological responses than humans. The goal is to select an animal model that can be comfortably worked with and easily trained to consume the vehicle, and that will assess toxicity in a manner that is predictive of a human response.

One of the more obvious choices for a laboratory animal model is the rat (*Rattus norvegicus*). This species has several diverse and pre-existing chemical and biological data sets to inform experimental planning. The housing requirements are routinely met and easily managed with commercial offerings. Food and water regulation has been accomplished with great success. The laboratory rat requires less housing and laboratory space than larger species, and many laboratory personnel are already trained to work with this species. Many rat strains are also available, so if a particular experimental question requires specific populations (e.g., pediatric or obese subjects), then a commercial solution is likely available. Rats are also cheaper than many other species and can be ordered in larger numbers, so rats can offer greater experimental throughput if personnel and other resources allow.

In addition to the logistical advantages, rats make a good organoleptic model due to their habitat and behaviors. Rats live in the same urban and rural environments as humans. Rats are scavengers and will eat many of the same foods that humans do, meaning that they are a viable choice for many potential food or beverage vehicles. In our own experiments, rats have readily consumed water, apple juice, two percent milk,[63] and liquid eggs[64] when water-regulated. Meats (or blood), grains, eggs, nuts, chocolate, and sugar are common bait additives used to attract rats,[65] further demonstrating the wide array of food items a rat readily consumes with no explicit training.

Rats are also a conservative model due to their neophobia,[66] superb chemoreception, and toxicant resistance. Rats tend to be more neophobic than other species, sampling new foods or drinks to determine if they are safe before consuming large amounts. This makes rats especially adept at determining when vehicles have been adulterated (i.e., have a "new" or different taste). The chemoreceptive abilities of a rat are also superior to those of a human,[67] meaning that an adulterant is more likely to be detected. Therefore, if an adulterant is undetected by a rat, then it likely will be undetected by a human. However, the converse is not necessarily true. Adulterants detected by rats may still be undetected by humans. Rodents are also resistant to some toxicants (e.g., organophosphates),[68] requiring higher concentrations to produce lethality. All of these factors together make for a conservative model. If a rat is not able to detect an adulterant, readily consumes it, and dies, then the adulterant would very likely be lethal to humans under similar conditions. Taken together, the rat is a practical mammalian omnivore with excellent chemoreceptive abilities and reduced sensitivity to many chemical poisons, providing a conservative model for predicting the threats most likely to injure or kill humans.

Toxicity Determination – The toxicity of an adulterant needs to be assessed with an acute, oral dose. An acute exposure is a more realistic large-scale scenario, as consumers are likely to ingest the adulterant a single time before intoxication occurs. Recalls and government intervention will also occur after a mass-casualty event, removing the majority of adulterated items that might remain for sale or were not yet consumed. As such, data from chronic exposures, while useful for assessing chemicals used as pesticides, are not particularly suited for threat prioritization of acute toxicants.

The route of exposure must be *oral*, though this term needs clarification. The "oral route," or PO (*per os*, from the Latin, meaning, "by way of the opening") delivery, is often accomplished with gavage. Gavage is a method that produces accurate and reliable dosing, but does not accurately characterize an oral-ingestion threat. Adulterants would potentially be absorbed by the oral mucosae when consumers ingest adulterated food or drinks.[69] Gavage bypasses these important mucosae, thereby changing the pharmacokinetic profile and potentially altering resulting toxicity.[70] Carfentanil is an example of this, wherein the absorption primarily occurs in the oral cavity (i.e., buccal absorption) and a smaller fraction occurs in the stomach and GI tract.[71] We have confirmed this with our own work by comparing the 24-hour lethality of carfentanil via gavage and voluntary consumption (i.e., drinking from a dish). Lethality was higher than predicted when the rats drank the three mL as opposed to having the fluid placed into the stomach via gavage,[72] indicating that oral absorption is very important for this chemical. However, not all adulterants are readily absorbed in the oral mucosae, and gavage likely serves as a suitable alternative in those instances. The saliva also interacts with the vehicle and adulterant. New compounds and complexes are formed and physical changes can occur (i.e., complexation, enzymatic breakdown, colloidal interactions, and coating/clustering).[73] Importantly, voluntary oral consumption allows for assessments of organoleptics, which is impossible when adulterants are delivered via gavage. In all cases, oral exposures need to be clarified as either occurring via gavage or consumed normally, as the absorption via the oral mucosae is important.

Understanding the onset, severity, and duration of intoxication following oral exposures is critical. Many chemical exposures in toxicology are accomplished via other routes (i.e., IV, IM, IP, SC) and the pharmacokinetics and pharmacodynamics vary between routes.[74] The oral route is likely to be more delayed and variable than other routes, which has implications for emergency medical response, toxidromic analysis/diagnosis, and medical countermeasure administration. The overt signs of intoxication displayed by a patient (or laboratory animal model) may also vary between exposure routes.[75] It is recommended that all adulterants be assessed for their toxicological effects on the laboratory animal model selected. This includes noting which toxic signs occur following oral ingestion as well as the onset, severity, and duration of intoxication. Although the lethality of many chemical adulterants can be assessed with a 24-hour assessment, some chemicals have delayed actions that require more extended assessments. Accurate and reliable dosing is required for this toxicity assessment, and gavage is the recommended route for this, even in spite of the arguments made above. The reliability of the dosing is very important for determining the toxicity of an adulterant, and gavage also bypasses the potential issues of an adulterant being rejected (i.e., not voluntarily consumed). However, even though gavage is likely used for the toxicity assessment, voluntary consumption must occur in the organoleptic assessment, and a reevaluation of the overt signs of intoxication following ingestion are warranted.

Food and Water Regulation/Restriction – Using the oral route for a chemical exposure often requires controlling a subject's food and/or water consumption. Regulation refers to limiting access to food and water, but allowing the total amount consumed per day to remain unchanged.[76] Restriction is when food or water or both are given in amounts lower than ad lib (free access) consumption.[77] When properly implemented, regulation causes no significant changes in body weights, while restriction will decrease body weights proportional to the level of restriction implemented.

Food and water regulation is best accomplished by limiting access time. Food and water can be made available at specific times, during which time the subject can consume its daily allotment. The access time granted to the subject will depend on how easily food can be consumed. If food is difficult to obtain due to specific physical arrangements of the food container (e.g., aperture size of the feeder or presentation of the food within a toy), then longer access times may be needed to achieve comparable levels of nourishment. Likewise, certain food items might also be denser or harder to chew or eat, necessitating longer access time to allow the subject to consume its daily amount. Wastage due to crumbling of the food is typically minimal, but should be accommodated if deemed significant. However, controlling access time rather than providing a measured mass of food greatly overcomes this difficulty. Regardless of the method employed, the investigative and husbandry staff should be diligent in removing all wastage from the cage. We have found that specific bedding materials lend themselves better to detecting excess food in the cage. (Alpha-Dri is white and uniform, providing a high-contrast background to most food materials, and is also non-nutritive, unlike corncob bedding.) Specialized diets such as a high-fat or ketogenic diet will typically present as a paste due to their high proportion of fats, so thorough removal or cleaning of the feeder is best accomplished by a high-pressure wash.

Access time to water is typically more straightforward, so long as the animal has experienced where water is made available and how to operate the mechanism (i.e., water bottle or valve). Obviously, the animal model selected will determine the amount of food and water normally consumed, as will the age and sex of the subjects. Typical values of food and water consumption can usually be obtained from breeders or animal vendors, consultation with researchers experienced with the animal species, or from veterinary and husbandry manuals. If needed, typical consumption amounts can be assessed experimentally by measuring food and water pre- and post-consumption. Limiting food and water access also inherently requires the subjects to promptly begin consumption once the access period begins. Subjects that take longer to begin eating or drinking when food and water is available are more likely to fail to consume their daily allotment. Decreasing the latency to consumption is achieved by making the start of the access time more salient to the subjects. That is, subjects will begin consuming food and water more rapidly when the availability of food and water is clearly signaled (compared to when it is not), for example, by movements of the cage when inserting the water bottle or by the sound of food being placed into the feeder. Importantly, food and water may also need to be concurrently available, as some species (i.e., rats) may not consume food adequately when water is unavailable.[78]

We have implemented water regulation with both ferrets[79] and rats[80] using automated and manual solutions. Ferrets were placed on a water-regulation schedule where access was granted for five hours per day, from 4 p.m. to 9 p.m. This system used a laptop PC running custom software to control water bottle valves. While the valves were always available, the software controlled the flow of water. This system was implemented and used without issue, and all of the ferrets rapidly adjusted to the time-dependent availability of water.[81] The rats were placed onto a similar automated system, wherein water to the rack was controlled by a series of three solenoids, and water was available for two hours per day from 12:30 p.m. to 2:30 p.m. This system was originally implemented with measured feeding (i.e., food restriction to control diets and weights), and the feeding time corresponded to the water access time. The rats were eventually transitioned to *ad libitum* food (food available at all times). This transition to *ad libitum* food also made the start time of the water availability less salient, as the delivery of food no longer coincided with water access, and many of the rats failed to consume their daily amount of water. An audible tone was eventually added to the automated system to signal the start of the water access period, but a significant portion of the rats still failed to consume their daily allotment of water. The automated system was discontinued and a manual solution was implemented. Technicians would move the rat cages toward or away from the water valve at the start or end of the water-access period, respectively. This manual movement of the cages and the perfectly correlated presence of the water valve improved the salience of the water-access period and eliminated most of the water-regulation issues. Adding and removing water bottles to cages functions in a very similar manner. Our experiences highlight the importance of ensuring that the access times of food or water (both start and stop times) are salient. Improving the salience of a signal will likely improve the success of a regulation schedule. We also recommend multiple modalities of signals (i.e., visual, auditory, vestibular) to further enhance signal salience whenever possible.

Food restriction is a procedure often used in laboratory settings, though it is more commonly used with small animal species (i.e., rodents) than with large species (e.g., swine and non-human primates). Whenever restriction (or regulation) is implemented, body weights and health status need to be carefully monitored to ensure the well-being of the subjects. Food restriction is typically implemented with the goal of producing a specific reduction in body weight. While 80 to 85 percent reductions are common in animal research,[82] some institutional animal care and use committees will require substantial scientific justification to approve these restriction levels, particularly when institutes are less familiar with such procedures. If food restriction cannot be used for an assessment, then a food-regulation schedule wherein food is removed for many hours prior to the assessment may suffice. However, if the vehicle selected is not consumed promptly and reliably by the large majority of subjects, then it may be an indicator that food-regulation and food-restriction schedules need to be re-evaluated to optimize successful research parameters.

Food regulation or restriction also factors greatly into the stomach contents of the subjects at the time of exposure. Stomach contents can delay absorption, and chemical exposures (or handling stress) can alter gastric emptying.[83] Ensuring that the stomach is empty at the time of exposure can increase the accuracy and precision (i.e., decrease variability) of a toxicological assessment, as we have observed when rats consumed tetramine on full and empty stomachs. Lethality of consumed tetramine was decreased when the rats had consumed five grams of food within 45 minutes of exposure (LD_{50} = 633.2 μg/kg) compared to rats that were fed approximately 16 hours prior (LD_{50} = 379.2 μg/kg) or had free access to food (LD_{50} = 725.6 μg/kg) (unpublished data). Implementing food and water regulation also helps to ensure that the vehicle selected is desirable. The prompt and reliable consumption of a vehicle is required for an organoleptic assessment, and food and water regulation will likely decrease latency to consumption and increase the amount consumed. If the vehicle used in the organoleptic assessment is a solid food, then food regulation should be implemented. If a beverage has been selected as the vehicle, then water regulation should be implemented. However, consumption of highly flavored, high-caloric, or high-sugar beverages may also be enhanced with food regulation. We have successfully trained rats to consume three mL of water, apple juice, and two percent milk with only water regulation,[84] so food regulation is likely not required for most beverages. We have also successfully trained rats to consume three mL of liquid whole eggs[85], so this water regulation and training regimen may also apply to many liquid vehicles.

In summary, the use of voluntary consumption is the *sine qua non* of organoleptic research, and use of this oral route will often benefit from (or even require) food or water regulation in laboratory animal models. Additionally, stomach contents can change the absorption and toxicity of the adulterants and the vehicle selected for an organoleptic assessment, and acute toxicity is best appreciated when the vehicle is promptly and reliably consumed. Therefore, careful consideration of food and water access should be made prior to the initiation of any toxicological or organoleptic assessments, regardless of the specific animal model(s) and vehicle(s) used.

Organoleptic Assessment

The organoleptic assessment is essentially a choice experiment. Subjects are offered the opportunity to consume (or reject) a particular vehicle with a known amount (or concentration) of adulterant. Amount of vehicle consumed relative to baseline (unadulterated vehicle) and/or to other subjects receiving different concentrations or vehicles provides information regarding likelihood and degree of consumption that cannot otherwise be obtained. Of course, an organoleptic assessment can only occur after an animal model, adulterant, and vehicle have been selected. How the adulterant is placed into the vehicle is of critical importance, and the laboratory should always strive to implement methods that result in high confidence with respect to amount of adulterant consumed. This emphasis on obtained dose is far more important than attempting to model specific exposure scenarios wherein the dose consumed is left largely uncontrolled or is difficult to accurately or reliably estimate.

Toxicity data are also recommended prior to initiating the organoleptic assessments, as it relates organoleptic data to functional outcomes, answering the important questions of whether doses consumed are in the toxic to lethal range. One might reason that toxicity data will be gained within the context of the organoleptic assessment, but an independent toxicity assessment provides critical information that empowers direct and additional comparisons. Specifically, by conducting an initial toxicity assessment using oral gavage, contact with other toxicity research is likely as this route of exposure is common for assessing the oral LD_{50} of most compounds. Additionally, oral gavage bypasses the oral cavity (and most of the esophagus), dispensing the vehicle into the stomach. So, by comparing oral gavage to results obtained under voluntary oral consumption, one can gauge the importance of oral cavity contact, namely, salivary gland interaction and buccal absorption. The other key advantage of conducting an oral gavage toxicity assessment is that it provides toxicity and lethality data that are not confounded by the actual amount consumed under voluntary conditions within the organoleptic assessment. The highest exposure amount that can be achieved in the organoleptic assessment is one that is reliably and voluntarily consumed, whereas gavage allows for much higher concentrations of exposure (limited only by solubility and volume) rather than the highest palatable dose. The knowledge that an adulterant is toxic enough to *potentially* be lethal is very important for prioritizing research in early stages, and oral gavage helps meet these early goals while providing comparative data for appreciating any observed differences in toxicity during organoleptic assessments.

The process we have implemented in our own research has been to first determine the median lethal dose via oral gavage and a fitted probit function, then use a range of functional doses (i.e., concentrations equivalent to the LD_{01}, LD_{10}, LD_{25}, LD_{50}, etc.) derived from the probit in the subsequent organoleptic assessments.[86] This approach affords a considerable time savings, as only concentrations with predictable toxicity above some threshold are assessed. While it is possible to generate a probit of the consummatory response as a function of adulterant concentration, the resources required would be considerably higher. A lethality probit is easier to obtain than an organoleptic probit for two reasons. First, the consumption of an adulterant is not a binary measure like lethality (i.e., survived/died) and is instead a proportion of the baseline amount. Transforming consumption into a binary measure requires either the maximum amount to be consumed (which is unrealistic in many cases), or an arbitrary delineation of amount consumed needs to be selected to indicate when an adulterant was "rejected." Second, properly conducted organoleptic assessments require more training than a lethality assessment, as the animal is trained to voluntarily consume the vehicle. Therefore, an appropriate toxicological profile of the adulterant via the oral route helps to save resources when compared to generating a probit of consummatory response.

Concentration Selection – A range of concentrations will need to be assessed for each compound in each vehicle. Our preferred approach is to begin the assessment with a concentration equivalent to the LD_{50} (assuming an identical weight for all subjects, as organoleptics are unlikely to change as a result of small body weight variations).

The subsequent concentration to be assessed is based on the results. Concentrations are decreased following a rejection and increased following acceptance. The acceptance or rejection of an adulterated vehicle is binary whenever all of the vehicle is consumed, but an arbitrary threshold for acceptance can also be defined (e.g., 2.5 mL out of 3.0 mL). In practice, the actual amount consumed should be the determining factor for selecting future concentrations. As an example, subjects consuming 2.0 mL out of 3.0 mL might count as a "rejection" of the adulterated vehicle, and the next concentration will likely be lower, but that next concentration selected might be higher than if the subjects drank only 0.05 mL. Proper selection of concentrations will more rapidly determine if an adulterant poses any realistic threat, which in turn also reduces the number of animals (and steps) required to complete the assessment.

The concentrations assessed would ideally span a range that produces complete acceptance (i.e., the entirety of the vehicle is consumed and the adulterant can be said to be undetectable or non-aversive) and complete rejection (i.e., subjects consume none of the vehicle). However, in practice, we have found that many chemicals are only accepted at concentrations that are so low they fail to produce any lethality and sometimes fail to produce any overt toxicity. In such cases, further assessing concentrations to determine when acceptance would occur is not worthwhile, as it serves no functional purpose (all accepted concentrations are so low as to be reasonably assumed to be devoid of any toxicity). These data should be evaluated in comparison to human toxicity data, when available, to more appropriately define functional relevance. Doses that are non-toxic in the selected animal model may still be worth evaluating when they are expected to produce toxicity in humans. An adulterant that is accepted only at non-toxic levels is not a high-priority threat, and resources are better spent investigating other adulterants. Many adulterants will be undetectable and will therefore only need to be assessed up to some obviously lethal concentration (e.g., 2x LD_{99}) or will be readily rejected and only consumed at non-toxic concentrations.

The selection of an appropriate volume of liquid vehicle for study is also of key importance. In our studies, we selected a volume of three mL for rats weighing an average of 300 g. This corresponds to one percent of vehicle per body weight and offers several advantages. First, this volume is sufficiently large to work with, as volumes below 100 µL would be difficult to mix, dispense, present, and measure reliably. Moreover, this one percent of body weight volume appears to meet assumptions regarding a realistic volume for liquid consumption in humans. Scaled to a 70-kilogram (154-pound) human, this would be equivalent to a 700 mL (approximately 24 ounce) serving of liquid. This is a sizable, but reasonable volume that also has real-world applicability to serving sizes commonly sold as consumer products (e.g., 12-ounce beverage cans, 24-ounce coffee cup). Specific studies of high concentrations using low volumes would be of interest for acute toxicity studies, but should probably be considered the exception rather than the norm.

Equipment and Context – Conducting an organoleptic assessment is fairly straight forward, but requires training the subjects sufficiently so that the vehicle is promptly and reliably consumed. The vehicle should be presented in a receptacle that is easily accessible to the subject. If subjects have to expend considerable effort to access the vehicle, other factors will become even more relevant (such as palatability of the vehicle and the level of food and water regulation) in affecting vehicle consumption. We have successfully used small, tempered glass dishes as our receptacles, but many other options exist and can be adapted for a variety of animal species. Glass is recommended because it is inert, failing to interact with chemical adulterants, but other material types exist and may be selected based on the vehicle(s) and adulterant(s) used. Tipping or spilling the vehicle makes it more difficult to measure consumption and also adds safety considerations when working with dangerous adulterants, so a mechanism or place to hold the receptacle is recommended and can be something as simple as a carefully sized hole in the floor in which to set a dish.

It is beneficial for the organoleptic assessment to occur in a unique setting, as this will facilitate context-dependent learning.[87] Subjects should consume the vehicle more promptly and rapidly by associating a specific location with the organoleptic-assessment training. Moving subjects out of a colony room and into the lab space is a useful transition, but using a novel cage is also recommended. Administering the organoleptic assessment in the home cage can be done, but might require additional training to reach similar consumption latencies and amounts. We have successfully implemented a novel context by transporting rats from the colony room and into the laboratory as well as moving them to a dedicated cage used only for the organoleptic assessment. This cage has a specialized floor and no bedding, further enhancing the novelty of the context. If training time is especially limited, the vehicle can be introduced into the living space of the subject prior to any training to familiarize the subject with the vehicle (i.e., decrease neophobia). This may speed up the initial session of training, but is not typically necessary under adequate levels of food or water regulation.

Training – A consistent baseline is also required for a proper organoleptic assessment. The detection of organoleptic properties (i.e., taste and odor) is a complex process and there can be significant differences between subjects and also daily variation within the same subject.[88] Water and/or food regulation/restriction can help to overcome some of this variability, as will other properties of the vehicle (such as its palatability). A minimum of one week of training with the vehicle is suggested, though we have found that two weeks is appropriate for water-regulated rats drinking beverages.[89] The length of training should be long enough to ensure prompt and reliable consumption of the vehicle. Subjects should be consistently consuming the vehicle (in whatever amount selected) during training prior to any adulteration. While subjects are not required to consume the entirety of the vehicle, data analysis and selection of concentrations are significantly easier under such conditions. If all subjects consume the entirety of the vehicle, then a maximum volume is known, and test concentrations can be easily calculated to approximate target doses (e.g., the LD_{50}) for every subject based upon this maximum volume. Determining when a subject has detected an adulterant and subsequently failed to consume the vehicle is also significantly easier when the baseline levels of consumptions are at or near the maximum volume presented and are consistent across training sessions.

We have successfully trained rats to drink beverages by starting with larger volumes and longer access times and then decreasing the volumes and times across training days. Our target volume was three mL, and we used the following training schedule (each entry represents one training day/session): 10 mL (10 minutes), 10 mL (10 minutes), five mL (five minutes), five mL (five minutes), five mL (five minutes), three mL (five minutes), and three mL (five minutes). The adulterated beverage was then given with the same parameters (three mL, five minutes). This approach encouraged drinking large amounts of the beverage and then decreased the volumes to the target amount. The longer access times in the first sessions encouraged exploration and adequate sampling of the beverages. We used rats, so overcoming the initial neophobia and exploratory phase was important. This combination of volumes and access times has led to a greater than 99 percent success rate during training. This type of schedule is not required, however, and the same volumes can be used throughout training (e.g., using three mL for training days in our training paradigm). Regardless of the parameters used, the subjects need to be consistently consuming the vehicle, meaning that the amounts and times to consume are not variable between days. Likewise, a baseline control day (or better yet, *multiple* days) should be implemented prior to the adulteration and minimum criteria established for inclusion of subjects. If a subject fails to consume the requisite amount of the vehicle on the baseline control day(s), then that subject should be excluded from any data analysis. This helps to ensure that any changes in consumption are based entirely on the adulterant and not variability between assessments.

Weights – In toxicological research, chemicals are typically assessed as a function of the subject's body weight (i.e., a concentration with mass of chemical as the numerator and body weight as the denominator). This is not necessary for organoleptic assessments, as a subject's ability to detect an adulterant is unlikely to vary as a function of body weight *per se* (but could vary as a function of developmental stage or age, which is often correlated with body weight). Instead, concentrations should be determined as the ratio of adulterant to vehicle. This suggestion, however, is predicated on the assumption that subjects share other characteristics (i.e., age, sex, and strain are all the same). Large between-subject differences in body weights should be avoided whenever possible. This helps to ensure similar health and motivational levels between subjects, and allows the investigator to easily select concentrations for assessment. If subjects are approximately the same weight, then concentrations can be used that correspond to functional outcomes for that average weight. We have used adulterant amounts that were based off of the lethality probit, which were then transformed into concentrations by assuming a 300-gram rat was consuming three milliliters of the adulterated beverage. For example, if the median lethal dose was five mg/kg, a concentration was calculated based on a 300-gram rat consuming that amount (1.5 mg) in three milliliters of beverage (i.e., 0.5 mg/mL).

The importance of keeping body weight consistent is likely less important than that of matching age when assessing organoleptics between different species. However, the differences between a mouse and rat for an organoleptic assessment are obviously less pronounced than the differences between a rat and a non-human primate. Therefore, it is recommended to retain consistency in key features of the organoleptic assessment while also acknowledging and accommodating important species differences, including toxicological response to the adulterant and safety or husbandry requirements that impact the experimental approach. While it may be easy to train a rat to drink out of a dish, a bottle or syringe method is probably better suited for use with non-human primates. Also, non-human primates (like humans) can be more sensitive to the toxic effects of chemicals, so scaling data from rats to primates must be done cautiously.

Data Collection and Analysis – The primary measure of an organoleptic assessment is the amount of the adulterant (and vehicle) consumed. Consumption latencies, such as the start latency (i.e., the time to begin consumption) or the stop latency (i.e., when the subject stops consuming the vehicle), can serve as secondary measures. Collecting latencies can be laborious and may require additional staff and resources. Latencies also need to have a consistent baseline, as was described above for consumption volumes. Latencies are also likely to be more variable than consumption volumes, so additional training may be required to ensure latency data are stable prior to an exposure.

Increased start latencies may indicate the detection of a foul odor. In a related way, a greatly decreased stop latency may indicate detection of a foul taste. Stop latencies are also positively correlated to consumption volumes in many cases, as rejection of an adulterated vehicle will manifest as decreased consumption and an earlier stop time. However, it is possible that a subject repeatedly samples a vehicle, producing stop latencies that are similar to baseline with significantly reduced consumption. This scenario not only makes it difficult to determine when a true "stop" has occurred, as the subject is repeatedly sampling the vehicle, but further illustrates why consumption volumes are the primary measure for an organoleptic assessment.

Once the consumption volume has been measured, a determination of detection (and rejection) of the adulterant can be made. If consumption volumes approximate baseline levels, then detection likely did not occur. Whether a subject can detect an adulterant is a function of the subject's familiarity with the vehicle. A long history with the vehicle should enhance discrimination. A subject that has little to no history with a vehicle will be unable to determine when the vehicle's organoleptics have changed and will therefore consume the vehicle based on its palatability (including the adulterant). The purpose of the organoleptic assessment is to determine the palatability of the adulterant, so the training described above allows the subject to develop familiarity with the vehicle and therefore assess adulterant organoleptics. However, it may be possible that the subject detected the adulterant and then continued to consume the vehicle. We have experienced this when feeding non-human primates carfentanil-adulterated watermelon (unpublished data). At high enough concentrations, the subjects removed the watermelon from the mouth to inspect it, but would often continue to eat the item. Start latencies were unaffected in these cases, but stop latencies (total consumption durations) were often dramatically increased. If latencies are not measured, then it can be difficult to determine if the adulterant was detected, but not rejected. There may be no functional difference, however, since the primary purpose of the organoleptic assessment is to determine if a subject will consume the adulterated vehicle, regardless if detection occurs, but these data serve to extend our understanding of possible adulterant-masking effects and inform the selection of subsequent concentrations for testing.

Whenever consumption volumes were significantly decreased, the adulterant was detected and subsequently rejected. This conclusion is sometimes very easy to make, such as when a subject drinks 0.2 mL instead of the maximum baseline level (e.g., 3.0 mL). However, conclusions are more difficult to draw whenever consumption is *near* baseline levels. If a subject drinks 2.8 mL instead of the normal 3.0 mL (and the subject drank 3.0 mL for multiple days in a row), did detection occur? The subject likely did detect the adulterant, but still drank the majority of the vehicle. Does this then fulfill the purpose of the organoleptic assessment? Unfortunately, we offer no concrete answers. In our own work, we have analyzed consumption volumes both as a continuous variable (i.e., ranging from 0 to 3 mL) and a dichotomous outcome ("acceptance" is ≥ 2.5 mL, while a "rejection" is anything less than that). We have used the dichotomous outcome to assist in determining whether concentrations should be increased or decreased and also analyzed the continuous data for vehicle- and concentration-dependent effects. How consumption volumes are analyzed will necessarily be determined by the scope and aims of the project.

Conclusions

Perfectly securing and protecting the entirety of an agricultural supply chain is an impossible task, and although a large-scale adulteration event has yet to occur in the United States, vulnerability assessments suggest that an event not only is possible, but would strain emergency services and healthcare with a massive number of civilian casualties. While the prevention of these events is the ultimate goal, the mass deployment of real-time detection technologies is not feasible, and a systematic approach to prioritize threats is needed to efficiently and effectively allocate resources (e.g., physical security, detection technology, research funding, pre-positioning of medical countermeasure stockpiles). The most dangerous threats are those that are available or easily synthesized, soluble in liquids or easily placed in food items, acutely toxic/lethal in small doses, difficult to diagnose or treat, and undetectable or easily masked by the food or drink. This last point, the detectability of the adulterant (i.e., its organoleptic profile), is understudied and overlooked in its importance.

Organoleptics have been primarily studied for pharmaceutical development and pesticide bait formulation and are understudied in other areas of toxicology. Organoleptic assessments provide critical data for the prioritization of adulterants, as the consumer's own ability to detect an adulterant is the final opportunity to prevent or limit the ingestion of a toxic compound. Real-world adulteration events in the United States have thus far been small-scale attacks and would not have been detected by any technology, therefore leaving only consumers to protect themselves. While adulteration may be prevented or detected by some technology in a potential large-scale, orchestrated attack on the agricultural system, consumers will again be required to protect themselves should any of those safeguards fail and the attack is even partially successful.

Therefore, organoleptic assessments represent a key conceptual and technical approach for determining which chemical agents would be undetectable by the civilian population when placed into consumer foods or beverages and then consumed in large enough doses to cause grave and widespread harm. The prioritization of potential adulterants must also be data driven. Potential adulterants need to be investigated based not only on up-to-date intelligence, but also on the compound's toxicological profile. This profile is typically elaborated as an adulterant's solubility and toxicity with no regard to its organoleptic properties. We strongly recommend that organoleptic assessments be considered when assessing potential adulterants, as a realistic scenario involves consumers ingesting and potentially detecting these adulterants. Threats that are undetectable and have a high-risk acute oral toxicity profile will need to be prioritized for further research and medical countermeasure development, as well as potentially targeted for real-time detection technologies as they become available.

Chapter 6 Notes

1. John Moteff and Paul Parfomak, "Critical Infrastructure and Key Assets: Definition and Identification," (Washington, D.C.: Library of Congress Congressional Research Service, 2004); David Byer and Kenneth H. Carlson, "Expanded Summary: Real-Time Detection of Intentional Chemical Contamination in the Distribution System," *Journal-American Water Works Association* vol. 97, no. 7 (2005); Office of Inspector General, "The Department of Homeland Security's Role in Food Defense and Critical Infrastructure Protection," (Washington, D.C.: Department of Homeland Security, 2007).

2. George W. Bush, "Homeland Security Presidential Directive 9," *Defense of United States Agriculture and Food*, (Washington, D.C.: Government Printing Office, 2004).

3. Economic Research Service, "Agriculture and Food Sectors and the Economy," (Washington, D.C.: U.S. Department of Agriculture, 2019).

4. O. Shawn Cupp, David E. Walker and John Hillison, "Agroterrorism in the US: Key Security Challenge for the 21st Century," *Biosecurity and Bioterrorism: Biodefense Strategy, Practice, and Science* vol. 2, no. 2 (2004).

5. Ali S. Khan, David L. Swerdlow, and Dennis D. Juranek, "Precautions against Biological and Chemical Terrorism Directed at Food and Water Supplies," *Public Health Reports* 116, no. 1 (2001).

6. Office of Inspector General, "The Department of Homeland Security's Role in Food Defense and Critical Infrastructure Protection;" Khan, Swerdlow, and Juranek, "Precautions against Biological and Chemical Terrorism Directed at Food and Water Supplies;" Charles McKay and Elizabeth J. Scharman, "Intentional and Inadvertent Chemical Contamination of Food, Water, and Medication," *Emergency Medicine Clinics* 33, no. 1 (2015).

7. U.S. Food and Drug Administration, "Risk Assessment for Food Terrorism and Other Food Safety Concerns," Center for Food Safety and Applied Nutrition, Office of Regulations and Policy (2003).

8. "Mitigation Strategies to Protect Food against Intentional Adulteration," in FDA-2013-N-1425-0146, (2016).

9. S. Umesha and H. M. Manukumar, "Advanced Molecular Diagnostic Techniques for Detection of Food-Borne Pathogens: Current Applications and Future Challenges," *Critical Reviews in Food Science and Nutrition* vol. 58, no. 1 (2018).

10. Steven J. Lehotay, Yelena Sapozhnikova, and Hans G. J. Mol, "Current Issues Involving Screening and Identification of Chemical Contaminants in Foods by Mass Spectrometry," *TrAC Trends in Analytical Chemistry* 69 (2015); Simon J. Hird, et al, "Liquid Chromatography-Mass Spectrometry for the Determination of Chemical Contaminants in Food," (2014).

11. Isabella Concina, et al, "Early Detection of Microbial Contamination in Processed Tomatoes by Electronic Nose," *Food Control* vol. 20, no. 10 (2009); Mahdi Ghasemi-Varnamkhasti, Seyed Saeid Mohtasebi, and Maryam Siadat, "Biomimetic-Based Odor and Taste Sensing Systems to Food Quality and Safety Characterization: An Overview on Basic Principles and Recent Achievements," *Journal of Food Engineering* vol. 100, no. 3 (2010); L. A. Dias, et al, "An Electronic Tongue Taste Evaluation: Identification of Goat Milk Adulteration with Bovine Milk," *Sensors and Actuators B: Chemical* vol. 136, no. 1 (2009).

12. Adrienne Mayor, "Chemical and Biological Warfare in Antiquity," in *Toxicology in Antiquity* (Elsevier, 2019).

13. E. Croddy, "Rat Poison and Food Security in the People's Republic of China Focus on Tetramethylene Disulfotetramine (Tetramine)," *Archives of Toxicology* vol. 78 (2004).

14. The Associated Press, "Police Arrest Man in Japan Tainted Food Scandal," *USA Today,* 2014.

15. "Maruha Nichiro Unit Recalls 6.3 Million Packages of Frozen Food," *The Japan Times*, 2013.

16. Christopher F. Schuetze, "German Man Who Poisoned Colleagues' Sandwiches Gets Life in Prison," *New York Times,* 2019.

17. Jean Kinsey, et al, "Consumers Response to a New Food Safety Issue: Food Terrorism" (paper presented at the 13th World Congress of Food Science & Technology 2006); Evelyne Madelaine Maillot, "Terrorism and the Food Chain," in *Threats to Food and Water Chain Infrastructure* (New York, N.Y.: Springer Publishing, 2010); Thomas J. Török, et al, "A Large Community Outbreak of Salmonellosis Caused by Intentional Contamination of Restaurant Salad Bars," *Journal of the American Medical Association* vol. 278, no. 5 (1997).

18. Török, et al, "A Large Community Outbreak of Salmonellosis Caused by Intentional Contamination of Restaurant Salad Bars."

19. Julii Brainard and Paul R. Hunter, "Contextual Factors among Indiscriminate or Large Attacks on Food or Water Supplies, 1946-2015," *Health Security* vol. 14, no. 1 (2016); GR Dalziel, "Food Defense Incidents: 1950-2008," A chronology and analysis of incidents involving the malicious contamination of the food supply chain, Centre of Excellence For National Security, S. Rajaratnam School of International Studies, Nanyang Technology University, Singapore (2009).

20. Zhihua Hu, Lois Wright Morton, and Robert Mahler, "Bottled Water: United States Consumers and Their Perceptions of Water Quality," *International Journal of Environmental Research and Public Health* vol. 8, no. 2 (2011).

21. Harmik Sohi, Yasmin Sultana, and Roop K. Khar, "Taste Masking Technologies in Oral Pharmaceuticals: Recent Developments and Approaches," Drug Development and Industrial Pharmacy vol. 30, no. 5 (2004); Jessica Soto, et al, "Rats Can Predict Aversiveness of Active Pharmaceutical Ingredients," *European Journal of Pharmaceutics and Biopharmaceutics* 133 (2018); Naser M. Hasan, et al, "Flavored Self Microemulsifying Lipid Formulations for Masking the Organoleptic Taste of Pharmaceutical Actives," *Journal of Applied Pharmaceutical Science* vol. 5, no. 11 (2015).

22. Devendra Bhardwaj and Jamil Ahmad Khan, "Effect of Texture of Food on Bait-Shy Behaviour in Wild Rats (Rattus Rattus)," *Applied Animal Ethology* vol. 5, no. 4 (1979); Ghazala Naheed and Jamil Ahmad Khan, "'Poison-Shyness' and 'Bait-Shyness' Developed by Wild Rats (Rattus Rattus L.). I. Methods for Eliminating 'Shyness' Caused by Barium Carbonate Poisoning." *Applied Animal Behaviour Science* vol. 24, no. 2 (1989); M. M. Shafi, et al, "Taste Enhancers Improve Poison Bait Acceptance in Field Rodents Damaging Wheat Crop," *International Journal of Pest Management* vol. 38, no. 2 (1992); M. M. Shafi, et al, "Enhancement of Poison Bait Acceptance through Taste Additives in Rattus Norvegicus," *Journal of Stored Products Research* vol. 28, no. 4 (1992); M. M. Shafi, et al, "Role of Some Taste Additives to Enhance Poison Bait Acceptance in the Black Rat," *International Journal of Pest Management* vol. 36, no. 4 (1990).

23. Elaine Scallan, et al, "Foodborne Illness Acquired in the United States - Unspecified Agents," *Emerging Infectious Diseases* vol. 17, no. 1 (2011).

24. Robert L. Scharff, "Economic Burden from Health Losses Due to Foodborne Illness in the United States," *Journal of Food Protection* vol. 75, no. 1 (2012).

25. Peter Chalk, "Hitting America's Soft Underbelly: The Potential Threat of Deliberate Biological Attacks against the U.S. Agricultural and Food Industry," (Santa Monica, Calif.: RAND Corporation, 2004).

26. Brainard and Hunter, "Contextual Factors among Indiscriminate or Large Attacks on Food or Water Supplies, 1946-2015."

27. U.S. Department of Health and Human Services National Toxicology Program, https://ntp.niehs.nih.gov/go/about.

28. Khan, Swerdlow, and Juranek, "Precautions against Biological and Chemical Terrorism Directed at Food and Water Supplies."

29. Maillot, "Terrorism and the Food Chain."

30. Y. Li, et al, "Tetramine Poisoning in China: Changes over a Decade Viewed through the Media's Eye," *BMC Public Health* vol. 14 (2014).

31. Brainard and Hunter, "Contextual Factors among Indiscriminate or Large Attacks on Food or Water Supplies, 1946-2015."

32. Carlos G. Fraga, Jon H. Wahl, and Stefanie P. Núñez, "Profiling of Volatile Impurities in Tetramethylenedisulfotetramine for Synthetic-Route Determination," *Forensic Science International* vol. 210, no. 1-3 (2011).

33. J. M. Li, et al, "Tetramethylenedisulfotetramine Intoxication Presenting with De Novo Status Epilepticus: A Case Series," *Neurotoxicology* vol. 33, no. 2 (2012).

34. Centers for Disease Control and Prevention, "Nicotine Poisoning after Ingestion of Contaminated Ground Beef-Michigan, 2003," *Morbidity and Mortality Weekly Report* vol. 52, no. 18 (2003).

35. M. R. Hadler and R. S. Shadbolt, "Novel 4-Hydroxycoumarin Anticoagulants Active against Resistant Rats," *Nature* vol. 253, no. 5489 (1975).

36. Toxicology Data Network, "Brodifacoum," (https://chem.nlm.nih.gov/chemidplus/rn/56073-10-0).

37. James A. Kruse and Richard W. Carlson, "Fatal Rodenticide Poisoning with Brodifacoum," *Annals of Emergency Medicine* vol. 21, no. 3 (1992); Brent W. Morgan, Christian Tomaszewski, and Iris Rotker, "Spontaneous Hemoperitoneum from Brodifacoum Overdose," *The American Journal of Emergency Medicine* vol. 14, no. 7 (1996).

38. Susan S. Schiffman and Carol A. Gatlin, "Clinical Physiology of Taste and Smell," *Annual Review of Nutrition* vol. 13, no. 1 (1993).

39. Ryan C. W. Hall, Richard C. W. Hall, and Marcia Chapman, "Effects of Terrorist Attacks on the Elderly-Part I: Medical and Psychiatric Complications of Bombings and Biological, Chemical, and Nuclear Attacks," *Clinical Geriatrics* vol. 14, no. 8 (2006).

40. United States Department of Agriculture Agricultural Research Service, Beltsville Human Nutrition Center Food Surveys Research Group, “Wweia Data Tables,” www.ars.usda.gov/northeast-area/beltsville-md-bhnrc/beltsville-human-nutrition-research-center/food-surveys-research-group/docs/wweia-data-tables, (2016).

41. Amanda L. Valdez, et al, “Pediatric Exposure to Laundry Detergent Pods,” *Pediatrics* vol. 134, no. 6 (2014); S. Huntington, et al, “Serious Adverse Effects from Single-Use Detergent Sacs: Report from a Us Statewide Poison Control System,” *Clinical Toxicology* 52, vol. no. 3 (2014).

42. Serena Ng, “P&G, Other Laundry Pod Makers Agree to New Safety Standard,” *Wall Street Journal* 2015.

43. Jack Y. Zheng and Melissa P. Keeney, “Taste Masking Analysis in Pharmaceutical Formulation Development Using an Electronic Tongue,” *International Journal of Pharmaceutics* vol. 310, no. 1 (2006).

44. Sohi, Sultana, and Khar, “Taste Masking Technologies in Oral Pharmaceuticals: Recent Developments and Approaches.”

45. Ibid.

46. John N. Coupland and John E. Hayes, “Physical Approaches to Masking Bitter Taste: Lessons from Food and Pharmaceuticals,” *Pharmaceutical Research* vol. 31, no. 11 (2014); Martin Kuentz, Peter Egloff, and Dieter Röthlisberger, “A Technical Feasibility Study of Surfactant-Free Drug Suspensions Using Octenyl Succinate-Modified Starches,” *European Journal of Pharmaceutics and Biopharmaceutics* vol. 63, no. 1 (2006).

47. Nguyen-Thach Tung, et al, “Formulation and Biopharmaceutical Evaluation of Bitter Taste Masking Microparticles Containing Azithromycin Loaded in Dispersible Tablets,” Ibid. 126 (2018); Amit K. Nayak, et al, “12 - Drug Delivery: Present, Past, and Future of Medicine,” in *Applications of Nanocomposite Materials in Drug Delivery*, ed. Inamuddin, Abdullah M. Asiri, and Ali Mohammad (Cambridge, U.K.: Woodhead Publishing, 2018); Coupland and Hayes, “Physical Approaches to Masking Bitter Taste: Lessons from Food and Pharmaceuticals.”

48. Naheed and Khan, “‘Poison-Shyness’ and ‘Bait-Shyness’ Developed by Wild Rats (Rattus Rattus L.). I. Methods for Eliminating ‘Shyness’ Caused by Barium Carbonate Poisoning.”

49. Bhardwaj and Khan, “Effect of Texture of Food on Bait-Shy Behaviour in Wild Rats (Rattus Rattus).”

50. Naheed and Khan, “‘Poison-Shyness’ and ‘Bait-Shyness’ Developed by Wild Rats (Rattus Rattus L.). I. Methods for Eliminating ‘Shyness’ Caused by Barium Carbonate Poisoning.”

51. Richard M. Poché, et al, “Development of a Low-Dose Warfarin Bait for Controlling Feral Hogs,” *Crop Protection* 120 (2019).

52. W. F. Van Bever, et al, “N-4-Substituted 1-(2-Arylethyl)-4-Piperidinyl-N-Phenylpropanamides, a Novel Series of Extremely Potent Analgesics with Unusually High Safety Margin,” *Arzneimittel-Forschung* vol. 26, no. 8 (1976).

53. Peng Yang, et al, “Preparation and Evaluation of Carfentanil Nasal Spray Employing Cyclodextrin Inclusion Technology,” *Drug Development and Industrial Pharmacy* vol. 44, no. 6 (2018).

54. Dr. Nathaniel C. Rice, et al, "Organoleptic Assessment and Median Lethal Dose Determination of Oral Carfentanil in Rats," (Aberdeen Proving Ground, Md.: U.S. Army Medical Research Institute of Chemical Defense, 2019).

55. United States Department of Agriculture Economic Research Service, "Fluid Beverage Milk Sales Quantities by Product (Annual)," (www.ers.usda.gov/data-products/dairy-data.

56. Rice, et al, "Organoleptic Assessment and Median Lethal Dose Determination of Oral Carfentanil in Rats."

57. Mark C. Moffett, et al, "Survey of Drug Therapies against Acute Oral Tetramethylenedisulfotetramine Poisoning in a Rat Voluntary Consumption Model," *Neurotoxicology* (2019); Dr. Nathaniel C. Rice, et al, "Behavioral Intoxication Following Voluntary Oral Ingestion of Tetramethylenedisulfotetramine: Dose-Dependent Onset, Severity, Survival, and Recovery," Ibid. 63 (2017).

58. Curt P. Richter, "Taste and Solubility of Toxic Compounds in Poisoning of Rats and Man," *Journal of Comparative and Physiological Psychology* vol. 43, no. 5 (1950).

59. Tetsuo Ogata, et al, "Taste Masking of Propiverine Hydrochloride by Conversion to Its Free Base," *Chemical and Pharmaceutical Bulletin* vol. 60, no. 8 (2012); Masahiro Tamura, et al, "The Relationship Between Taste and Primary Structure of 'Delicious Peptide'(Lys-Gly-Asp-Glu-Glu-Ser-Leu-Ala) from Beef Soup," *Agricultural and Biological Chemistry* vol. 53, no. 2 (1989).

60. Thorsten Meyer, et al, "Taste, a New Incentive to Switch to (R)-Praziquantel in Schistosomiasis Treatment," *PLoS Neglected Tropical Diseases* vol. 3, no. 1 (2009).

61. Jordan Ned Smith, et al, "Comparative Chlorpyrifos Pharmacokinetics Via Multiple Routes of Exposure and Vehicles of Administration in the Adult Rat," *Toxicology* vol. 261, no. 1 (2009); Pasquale Chieco, Mary T. Moslen, and Edward S. Reynolds, "Effect of Administrative Vehicle on Oral 1,1-Dichloroethylene Toxicity," *Toxicology and Applied Pharmacology* vol. 57, no. 2 (1981).

62. Dr. Nathaniel C. Rice, Noah A. Rauscher, Mark C. Moffett, Dr. Todd M. Myers, Organoleptic assessment and median lethal dose determination of oral aldicarb in rats. Annals of the New York Academy of Sciences, Aug. 5, 2020, doi: 10.1111/nyas.14448. Online ahead of print.

63. Rice, et al, "Organoleptic Assessment and Median Lethal Dose Determination of Oral Carfentanil in Rats."

64. Dr. Nathaniel C. Rice, Noah A. Rauscher, Mark C. Moffett, Dr. Todd M. Myers, Organoleptic assessment and median lethal dose determination of oral aldicarb in rats. Annals of the New York Academy of Sciences, Aug. 5, 2020, doi: 10.1111/nyas.14448. Online ahead of print.

65. Shafi, et al, "Enhancement of Poison Bait Acceptance through Taste Additives in Rattus Norvegicus;" Naheed and Khan, "'Poison-Shyness' and 'Bait-Shyness' Developed by Wild Rats (Rattus Rattus L.). I. Methods for Eliminating 'Shyness' Caused by Barium Carbonate Poisoning;" Michael Jackson, Stephen Hartley, and Wayne Linklater, "Better Food-Based Baits and Lures for Invasive Rats Rattus Spp. and the Brushtail Possum Trichosurus Vulpecula: A Bioassay on Wild, Free-Ranging Animals," *Journal of Pest Science* vol. 89, no. 2 (2016).

66. Marilyn E. Carroll, et al, “Demonstrations of Neophobia and Enhanced Neophobia in the Albino Rat,” *Journal of Comparative and Physiological Psychology* vol. 89, no. 5 (1975).

67. Pascale Quignon, et al, “The Dog and Rat Olfactory Receptor Repertoires,” *Genome Biology* vol. 6, no. 10 (2005).

68. Catherine Hofstetter, et al, “Characterization of Serum Carboxylesterase Knockout Mice as a Model for Organophosphorous Nerve Agent Research,” *The FASEB Journal* vol. 29, no. 1 supplement (2015).

69. Nookala Venkala Satheesh Madhav, et al, “Recent Trends in Oral Transmucosal Drug Delivery Systems: An Emphasis on the Soft Palatal Route,” *Expert Opinion on Drug Delivery* vol. 9, no. 6 (2012).

70. Laura N. Vandenberg, et al, “Should Oral Gavage Be Abandoned in Toxicity Testing of Endocrine Disruptors?” *Environmental Health* vol. 13, no. 1 (2014).

71. Theodore H. Stanley, et al, “Oral Transmucosal Fentanyl Citrate (Lollipop) Premedication in Human Volunteers,” *Anesthesia and Analgesia* vol. 69, no. 1 (1989); Jonathan M. Sleeman, et al, “Immobilization of Domestic Goats (Capra Hircus) Using Orally Administered Carfentanil Citrate and Detomidine Hydrochloride,” *Journal of Zoo and Wildlife Medicine* (1997); E. C. Ramsay, J. M. Sleeman, and V. L. Clyde, “Immobilization of Black Bears with Orally Administered Carfentanil Citrate,” *Journal of Wildlife Diseases* vol. 31, no. 3 (1995).

72. Rice, et al, “Organoleptic Assessment and Median Lethal Dose Determination of Oral Carfentanil in Rats.”

73. Ana Carolina Mosca and Jianshe Chen, “Food-Saliva Interactions: Mechanisms and Implications,” *Trends in Food Science & Technology* 66 (2017).

74. Janet J. Diliberto, Joseph A. Jackson, and Linda S. Birnbaum, “Comparison of 2,3,7,8-Tetrachlorodibenzo-P-Dioxin (Tcdd) Disposition Following Pulmonary, Oral, Dermal, and Parenteral Exposures to Rats,” *Toxicology and Applied Pharmacology* vol. 138, no. 1 (1996); Bruce A. Owen, “Literature-Derived Absorption Coefficients for 39 Chemicals Via Oral and Inhalation Routes of Exposure,” *Regulatory Toxicology and Pharmacology* vol. 11, no. 3 (1990); Smith et al., “Comparative Chlorpyrifos Pharmacokinetics Via Multiple Routes of Exposure and Vehicles of Administration in the Adult Rat;” R. Vijayaraghavan, et al, “Differential Toxicity of Sulfur Mustard Administered through Percutaneous, Subcutaneous, and Oral Routes,” *Toxicology and Applied Pharmacology* vol. 202, no. 2 (2005).

75. Patricia L. Meinhardt, “Water and Bioterrorism: Preparing for the Potential Threat to Us Water Supplies and Public Health,” *Annual Review of Public Health* 26 (2005).

76. National Research Council, Guidelines for the Care and Use of Mammals in Neuroscience and Behavioral Research (Washington, D.C.: National Academies Press, 2003).

77. Neil E. Rowland, “Food or Fluid Restriction in Common Laboratory Animals: Balancing Welfare Considerations with Scientific Inquiry,” *Comparative Medicine* vol. 57, no. 2 (2007); National Research Council, Guidelines for the Care and Use of Mammals in Neuroscience and Behavioral Research.

78. Harry R. Kissileff, “Food-Associated Drinking in the Rat,” *Journal of Comparative and Physiological Psychology* vol. 67, no. 3 (1969).

79. Dr. Nathaniel C. Rice, M. C. Moffet, and Dr. Todd M. Myers, "Median Lethal Dose Determination of Subcutaneous Carfentanil in Ferrets," (Aberdeen Proving Ground, Md.: U.S. Army Medical Research Institute of Chemical Defense, 2018).

80. Rice, et al, "Organoleptic Assessment and Median Lethal Dose Determination of Oral Carfentanil in Rats."

81. Rice, Moffet, and Myers, "Median Lethal Dose Determination of Subcutaneous Carfentanil in Ferrets."

82. National Institutes of Health, Methods and Welfare Considerations in Behavioral Research with Animals: Report of a National Institutes of Health Workshop (Washington, D.C. U.S. Government Printing Office, 2002).

83. Dean H. Percy and William D. Black, "Pharmacokinetics of Tetracycline in the Domestic Rabbit Following Intravenous or Oral Administration," *Canadian Journal of Veterinary Research* vol. 52, no. 1 (1988); Claudia Suenderhauf, et al, "Pharmacokinetics of Paracetamol in Göttingen Minipigs: In Vivo Studies and Modeling to Elucidate Physiological Determinants of Absorption," *Pharmaceutical Research* vol. 31, no. 10 (2014); Joseph M. Custodio, Chi-Yuan Wu, and Leslie Z. Benet, "Predicting Drug Disposition, Absorption/Elimination/Transporter Interplay and the Role of Food on Drug Absorption," *Advanced Drug Delivery Reviews* vol. 60, no. 6 (2008); John M. DeSesso and Catherine F. Jacobson, "Anatomical and Physiological Parameters Affecting Gastrointestinal Absorption in Humans and Rats," *Food and Chemical Toxicology* vol. 39, no. 3 (2001).

84. Rice, et al, "Organoleptic Assessment and Median Lethal Dose Determination of Oral Carfentanil in Rats."

85. Dr. Nathaniel C. Rice, Noah A. Rauscher, Mark C. Moffett, Dr. Todd M. Myers, Organoleptic assessment and median lethal dose determination of oral aldicarb in rats. Annals of the New York Academy of Sciences, Aug. 5, 2020, doi: 10.1111/nyas.14448. Online ahead of print.

86. Ibid.

87. Lynn Nadel and Jeffrey Willner, "Context and Conditioning: A Place for Space," *Physiological Psychology* vol. 8, no. 2 (1980).

86. Per-Edvin Persson, "Sensory Properties and Analysis of Two Muddy Odour Compounds, Geosmin and 2-Methylisoborneol, in Water and Fish," *Water Research* vol. 14, no. 8 (1980); John E. Amoore, "The Chemistry and Physiology of Odor Sensitivity," *Journal-American Water Works Association* vol. 78, no. 3 (1986); Morris B. Ettinger and Francis M. Middleton, "Plant Facilities and Human Factors in Taste and Odor Control," Ibid, vol. 48, no. 10 (1956).

89. Rice, et al, "Organoleptic Assessment and Median Lethal Dose Determination of Oral Carfentanil in Rats."

CHAPTER 7

Air Force Capabilities and Technologies to Counter or Mitigate Agroterrorism

William Greer and Dr. Douglas Lewis

Agricultural terrorism has the potential to do great damage and affect many lives yet is not a threat the military specifically develops technologies to counter. While agriculture is essential to our lives, and agriculture has influenced outcomes of past wars, technologies specifically to protect agriculture from terrorist threats has not been a focus within the United States military. Further, the Air Force for its part does not have a specific counter agroterrorism mandate nor acquisition requirements to develop technologies to combat or mitigate agroterrorism. However, threats to agriculture are taken very seriously. With respect to overarching Air Force missions its airmen need a range of capabilities to execute these missions including tools to counterterrorism in its many forms including agroterrorism. Before delving into the technologies some context is needed on factors influencing Air Force mission capabilities. In this section we will briefly touch on potential threats to agriculture, the roles of the military with respect to mitigating threats to agriculture and then what tools and technologies currently exist or are anticipated in the near term. We will also look at military unique technology needs and gaps with respect to a potential dual role as agroterrorism response and as path towards technologies needed to address more general military capability gaps.

With respect to agroterrorism, it is not a new threat as discussed in earlier sections. In the past, it has taken the form of destruction of livestock and crops, but today can also involve introducing a threat that may not destroy the livestock or crop, but rather renders resulting food products unmarketable or toxic. While scenarios can be formulated that might lead to large-scale destruction of agriculture, the time, effort, and resources required suggest terrorists may prefer a more direct and immediate course to meet their objectives. Under this assumption, we can conclude the path terrorists are more likely to follow is to draw from the natural threats as a baseline upon which they might use to develop their terrorism strategy.

To understand why terrorists may seek to build their plan by drawing on natural threats, consider the destruction already caused movement of people and global trade has grown over the centuries. Global trade today encompasses a wide range of products, including foodstuffs and on occasion this trade had resulted in the inadvertent decimation of a local indigenous species of plants or animals by an invasive species. Within the United States, some examples include the unintentional introduction of a number of harmful species such as West Nile virus or chestnut blight, which have spread across the United States. In addition to these microbial threats, animal species such as the South American fire ant, which has established itself across the Southern states and zebra mussels, which are now found in many bodies of water, particularly those directly supporting international trade such as ports and harbors. They are but a few examples of species of animals that have damaged the ecosystems in which they were inadvertently introduced. In addition to these accidental infestations, there have also been intentional introductions such as bamboo, kudzu vine, and house sparrows that were brought in and sold before people recognized the impacts of these species on native species.

More than 6,500 of these harmful, non-native species cause more than $100 billion in damage each year to the U.S. economy. Costly effects include crop decimation, clogging of water facilities and waterways, wildlife and human disease transmission, threats to fisheries, increased fire vulnerability, and adverse effects for ranchers and farmers.[1]

These invasive species are part of what are collectively known as pests and while many such creatures tend to be benign, the examples illustrate some types of organisms can do major harm damaging local ecosystems and causing economic losses in the billions. Further, invasive species are not the only threat. In 2019, for example, a natural African swine flu outbreak has devastated China's swine herds resulting in the loss of roughly 300 to 350 million pigs in 2019.[2] The United States and the Department of Defense (DOD) have long recognized the problem of natural outbreaks and invasive species and over the years have developed tools and implemented protocols to prevent or contain their spread. The U.S. Department of Agriculture (USDA) leads to U.S. research, conducts surveillance programs and develops methods to deal with these species under what is collectively known as pest control and work closely with other federal, state, and local agencies to prevent invasive species from entering the United States. As part of this national defense against pests, the U.S. military services also have in place tools and techniques for pest control associated with personnel and equipment moving in and out of the United States and throughout agricultural regions worldwide.

Should terrorists go down this route, targeting one or more portions of the food chain with microbial attacks is a likely direction that would be difficult to contain and has potential to do damage well beyond the initial targets as evidenced by impact mad cow disease had in the United Kingdom and around the world as well as efforts by China to stop African swine flu and fully restore domestic pork production. Other agricultural attacks also exist. The use of poisons or toxins can be employed, but the impact would be very local and global supply chains can quickly fill a short-term supply gap. Use of insects or other animals or plants to damage food supplies are also possible, but specific, targeted outcomes are highly unpredictable. Further, use of more complex organisms such as insects could result in sporadic damage. However, these creatures may require months or years of unfettered spread to have a major impact. Overall, an agroterror strategy using microbes offers agroterrorists a potential quick strike option that might satisfy their terror objectives and also pose major challenges to authorities' efforts to contain and mitigate the damage to their agricultural sectors.

Today, food protection, crop and animal disease monitoring and pest control measures help the United States maintain safe food supplies within its borders. These measures are not unique to the United States, but are used by nations across the globe. As a result, there is today a significant international infrastructure in place ready to act to protect food supplies and production from a range to risks including from natural threats, unintended introduction of invasive threats and, of course, intentional attempts to damage and/or destroy some part of the agriculture supply chain. The work by the USDA and its agencies along with their counterparts in other nations does not rely on the military for personnel or equipment to protect against agroterrorism. However, should agroterrorism attacks occur or are considered imminent and overwhelm the USDA and its state and local resources the U.S. military may be tasked to provide resources. Likewise, if agroterrorism threatens an ally, the U.S. government may direct the military to provide aid similar to past American responses to natural disasters where the United States has offered assistance to other nations. In the next section, the question of what might the military be called on to provide and what that may involve in terms of technology the military maintains to support its missions and what may exist in terms needs and gaps unique to responding to possible agricultural terrorism.

Air Force Roles and Missions Concerning Agriculture

Potential Terrorist Threats to Agriculture

Before examining the question of what technology needs and gaps exist with respect to agroterrorism responses by the U.S. Air Force, we need to look at the threat in terms of what it might mean in terms of what the military response may be and the tools needed by the Air Force to support such missions. In this section we will briefly consider what todays threat may look like in terms traits of threats that may be exploited rather than specific microbes, pests, chemicals, acts of man, etc.

Loss of food resources whether it involves livestock or crops can be devastating and history offers examples of peoples and civilizations whose collapse or disappearance with the people being no longer able to produce enough to feed themselves. The reasons for these losses varied. Some crops were lost due to weather or warfare, and others suffered invasions of insects or animals, which decimated crops or livestock. From military history, we can find examples where striking at the food source can be devastating to a military campaign. One such example is Napoleon's ill-fated invasion of Russia where his forces, reliant on feeding off the countryside as they march across Europe and into Moscow, were starved and defeated when the Russians destroyed nearby crops and slaughtered livestock leaving nothing for Napoleon's forces to feed themselves. While terrorists today are not likely to model an attack on the actions of the Russians against Napoleon, they may look at recent agricultural events for opportunities. For example, since 2000, outbreaks or avian and swine flu have forced impacted countries to cull millions of poultry and swine and in turn they have had to turn to international trading partners to make up for lost domestic production while they rebuilt their livestock inventories. While these outbreaks in some cases involved culling millions of animals, the global food supply network was able to fill the domestic shortfall and prevent these outbreaks from turning into human tragedies such as regional famines or starvation among the affected population. While it is doubtful a terrorist attack would result in mass starvation there is a real economic impact associated with agricultural diseases. For example, the U.S. government reported that the 2014-15 avian flu outbreak resulted in more than $1 billion in lost exports and a 61 percent increase in domestic egg prices.[3]

Terror groups would likely look at these events today as case studies to allow them to judge whether their attacks may have only limited value in terms of instilling fear in the populous, imposing economic loss, or in weakening the government. Right away, they would see nation's around the globe diligently watch for outbreaks that could harm both people's food consumption choices as well as international trade. Naturally occurring outbreaks are often caught early on and nations can readily draw on a range of existing tools and capabilities to contain and eradicate such outbreaks. In addition to monitoring crops and livestock, the agricultural industry also works to make crops more resilient, which in turn reduces potential vulnerabilities that a terror group might exploit. Modern farming methods such as large "factory" farms for raising poultry and livestock also act as a deterrent by introducing methods that limit animal exposure to possible contagions as well as allowing farmers to more effectively monitor the health of their livestock.

Terrorists may pass on other approaches as well for similar reasons. Causing damage by introducing an invasive species, be it plants, animals or insects can, for example, cause a good deal of harm over time, but that long term impact may not be the result sought by the terrorists. As noted in the introduction, a number of communities have experienced a loss of food production from natural threats that occurred without malevolent intent and have not resulted in the desired public response that a terror group might hope to achieve. Terrorists may desire approaches that have immediate destructive impact and one approach is to employ a highly infective and fast-spreading microbe, fungi, virus or two or more types of microbes targeting both crops and livestock and/or poultry at once. It is possible these microbes could be deployed using insects as infection vectors particularly for crops were insects may be prone to eat and reproduce for as long as there are crop materials to eat. Such a route may also be desirable if the insects and disease it hosts tends to spread quickly once a field is infected. A similar scenario could also be used to carry disease to livestock as well. However, to have a greater impact, the disease(s) would need be able to take a form that will allow the disease to move from plant to plant or animal to animal without a carrier such as an insect vector.

Other options may include use of chemicals to attack and either destroy or render inedible crops or livestock. While this could be effective as a means of inducing terror in a local population, it is also likely to be identified quickly by agricultural monitoring and thereby allow time for officials to take steps to mitigate damage, help local communities recover as well as bring in food to avert famine until new crops are ready to harvest or livestock numbers can recover. Additionally, whereas a biological-based agent can reproduce within the agricultural target the impact of a chemical agent is dependent upon the initial dose. The logistics required for an attack large enough to impact the national level would be well above anything but a state-sponsored terrorist group.

Overall, of these varied threats, those that would be most difficult to counter in today's environment are those involving direct attacks such as poisoning or burning crops and slaughtering livestock as well as those involving disease. Of these, the disease path may be attractive to a terror group as it can be executed covertly. Of greater concern is that with advances in biological sciences, the tools and technologies available to scientists to manipulate an organism's DNA, can also be exploited by a skilled cadre within a terrorist group to modify organisms to make the threat more potent and/or more difficult to contain.

Military Missions and Roles in Countering Agricultural Terrorism

Among the roles and missions of the U.S. military carries out as part of national defense are to defend the nation from various terrorist threats as well as to aid in disaster response and recovery. Within the DOD, Special Operations Forces may, for example, strike at terror groups in remote areas as part of their role in defending the United States and its allies. In addition, the U.S. military maintains far reaching intelligence, surveillance, and reconnaissance (ISR) capabilities that span the globe allowing U.S. forces to gather data that may not be readily available in the public domain. The military also is able to quickly set up logistic chains allowing forces to operate in remote, hostile locations worldwide. In addition, to performing these missions as part of its day to day operations, the military also has robust reserve capabilities and personnel that can on short notice be called upon in times of war and in response to disaster.

As noted in the introduction, agriculture terrorism is not a primary military mission. American forces do practice pest control and works to prevent its forces from inadvertently introducing invasive species into the United States or to other nations where American forces transit or are stationed. These pest management capabilities can for example be used to aid in the detection of a natural threat early on and facilitate appropriate authorities to assess and respond. Should there be indicators such as intelligence indicators that a terrorist group or a particular terror cell is preparing to attack the United States and/or an ally, Special Forces may be called on to track down and stop the threat while military personnel could in principle be asked to assist local authorities watch for and interdict suspicious individuals in sensitive area. Should such an operation collect information suggesting the food chain was being targeted or under attack, appropriate agriculture authorities could then be alerted so that they can determine the next course of action. These scenarios reflect military actions that may impede or thwart an agroterror threat and in terms of the overarching military mission space is in general a supporting role wherein the military is only involved in deterring or defeating a terrorist, but is not specifically geared to defeating agriculture terrorism. While important, such missions would draw on capabilities within existing military infrastructure. They do not drive operational needs for specific agriculture focused technologies by the Air Force in order to carry out the overarching missions it is assigned. Rather, it does suggest a potential need for some Air Force ISR capabilities to be flexible in terms of sensing capabilities to include a wider range of biological and potentially chemical threats scenarios to include sensing of agriculture vice only personnel threats.

The other major role wherein military may be called on is response focused missions where U.S. equipment and personnel are deployed to avert or mitigate a humanitarian disaster. If a terrorist group should succeed in harming significant portions of the agricultural base and in the near term and put some portion of the population at risk, U.S. military forces are likely to be called on as part of a national response. Looking at how the military and Air Force assets have been deployed in the past, a major role the Air Force played is bridging logistics gaps and moving people and equipment where they are needed. However, unlike supporting ongoing missions where infrastructure and controls to prevent the spread of animal, plant or microbial threats can be established and maintained, emergency responses can compel commanders to put military assets, including high value assets such as heavy transport aircraft at risk of contamination in order to save lives. Should that happen, those exposed assets would be restricted until they can be tested and cleared in order to avoid putting the food supplies of the United States and other nations at risk from an infectious agricultural threat. While this does not say there are specific Air Force agriculture disaster response technology gaps, it does suggest Air Force technologies for related response capabilities may also need to cover potential agriculture threats.

Another post attack scenario where Air Force assets might be employed is to aid in containing or stopping the spread of a living threat. If communities find their livestock or crops are infected with a disease, they will seek to stop the further spread of disease using the most cost-effective means available. Common methods used in the United States and abroad include culling animals and burning or plowing under crops. The exact approach employed and how it is executed will depend on the disease itself. While burning a field may be an option against a natural outbreak of a disease, for example, if the terrorist had managed to modify the disease so that instead of killing the threat, it accelerated its spread, then other means such as plowing the crop under or harvesting and destroying the infected plants may be necessary. If large numbers of livestock are infected, culling can present its own challenges in terms of safe and effective disposal of carcasses. For example, culling a large herd of cattle may exceed to capacity of local rendering facilities to process and dispose of carcasses in a timely fashion. In these instances, the logistics of response may require moving heavy equipment to multiple locations in a short period. Whenever possible, the first course of action is not to move people and equipment so as to limit or prevent disease spread. If it is necessary to move resources over the course of the response, decontamination and moving over land would avoid contaminating aircraft or other specialized military equipment. However, terrorists could execute multiple attacks over large areas, or even across borders. Under such a scenario, using heavy lift aircraft to transport specialized equipment to site may be needed and in turn those aircraft may have to also be decontaminated as time constraints may make full equipment sanitization prior to loading impractical. Within such logistics scenarios, aircraft, and other sensitive military equipment (such as unmanned aerial vehicles and sensors) make require detail sampling and potentially decontamination prior to release for unrestricted use. While this may appear to suggest a special agriculture specific technology need, the Air Force and its sister roles and missions include operating in chemical and biological threat environment and in decontaminating equipment.

Overall, threats to the food supply chain can arise from natural threats as well as by intentional acts and the U.S. military roles and missions include executing tasks, which are agriculture sensitive in support of larger national or international organizations. Chief among these are the long-standing threats to agriculture posed by microbes. For its part, the Air Force maintains an ongoing defensive posture through pest control programs working to prevent inadvertent damage to both United States and international agriculture. Should a threat arise, there are several technologies and tools within the Air Force inventory that may be employed to thwart attacks. If such attacks happen and a response requires resources beyond the capabilities of the primary responders, military resources will likely provide the additional people and technologies needed. The Air Force's available technologies, sensing and logistics capabilities can be employed to respond in response to an agricultural attack as well as employing aircraft and other sensitive equipment to support time critical responses. In these scenarios, the current fielded capability to decontaminate personnel and equipment represent a technology need in responding not only to agricultural terrorism, but also to biological threats in general. As outlined in this section, the Air Force has established capabilities it uses to meet its roles and missions to counter terrorists, perform various ISR tasks and meet logistics needs. These operational capabilities and supporting technologies can also be employed to prevent or respond to agricultural terrorism. Based on today's roles and missions, there does not appear to be agricultural unique capability gaps with respect to overarching Air Force roles or missions to drive development of unique agricultural centric technology. Rather, the technologies for defending against and defeating agroterrorist threats will come out of developing technologies to meet overarching needs and gaps that can in turn be leveraged to support lead agencies counter agroterror threats or attacks.

Requirements

Section 2 briefly explored the threat within the context of military and specifically Air Force capabilities. In terms of protecting agriculture and combatting attacks against agriculture, there are capabilities in place designed to protect against natural threats. These pest control tools, along with ISR and logistics technologies can also be employed to mitigate the impact of agroterrorism. In this section, we will discuss requirements that drive Air Force technology development and in turn begin to explore Air Force technologies that can be leveraged as part of building capabilities for countering potential agriculture terrorist threats.

U.S. Department of Agriculture National Invasive Species Management Plan

A specific Air Force agricultural terrorism policy was not explicitly stated when this section was written. Instead, established national policy is captured through DOD and Air Force pest control plans and instructions based on the national framework to address these threats. These policies were put in place to implement Executive Order 13112, which established the National Invasive Species Council in 1999. Executive Order 13751, signed in 2016, amends Executive Order 13112 and directs actions to continue coordinated federal prevention and control efforts related to both intentional and unintentional introduction of harmful invasive species into the United States. The specific focus of this council is to ensure that federal agency activities, including actions by DOD concerning invasive species are coordinated, complementary, cost-efficient, and effective. The DOD in turn established the Armed Forces Pest Management Board, which has published several technical guides (TG) on the subject. These purpose of these guides states:

"Agricultural quarantine actions are taken to safeguard agricultural and natural resources from risks associated with the entry, establishment, or spread of pathogens and pests of humans, animals or plants. This TG provides information on cleaning techniques and inspection procedures for Department of Defense (DOD) personnel responsible for agricultural preparation of personal gear, equipment, supplies and vehicles for deployment and redeployment movement as defined below:

Deployment is the movement of military units from home station, whether in the continental United States or overseas, to a location where they will be employed in operations or exercises.

Redeployment is the transfer of forces and materiel to support an additional operational requirement, or to return personnel, equipment, and materiel to home/demobilization stations for reintegration and out-processing."[4]

This guide talks to the problem and identifies potential routes such as in agricultural produce nursery stick, in timber (such as used for shipping crates), etc. The Armed Force Pest Management Board also published Technical Guide 48 (TG 48), which covers Contingency Pest and Vector Surveillance. The purpose of TG-48 is "… to present the reader with a sound understanding of the principles of vector/pest surveillance in operational environments, equipment use and design, basic vector/pest identification, and personal protective measures."

These technical guides serve as a basis for establishing overarching requirements for tools the U.S. Armed Forces may require to address underlying disease vectors and prevent U.S. forces from inadvertently spreading agricultural disease into the United States or to other nations while deployed or in transit. In the event of an agroterrorism attack, the most likely scenario, which the U.S. Armed Forces might engage, is if U.S. military assets deploy to aid another country. Within the United States, the USDA Animal and Plant Health Inspection Service (APHIS) is charged with leading efforts to surveil and protect U.S. agriculture. APHIS maintains a robust program designed to monitor U.S. agriculture as well as work with customs and border security to prevent introduction of harmful invasive species. APHIS and USDA can draw support from other federal agencies as needed. Their programs have identified and stopped a number of outbreaks over the years using various methods including culling of livestock to eradicate hoof and mouth disease in the United States in the 1930s and on more than one occasion, culling thousands of chickens at farms in the United States to stop the spread of avian flu. Within their response arsenal, they have various tools such crop dusters to treat and stop the spread of crop disease and remedial actions to contain a crop including burning fields or plowing under crops and quarantining the affected areas until it is safe to resume agricultural production.

The U.S. Armed Forces roles in each of these scenarios would not be to lead the response to attacks on agriculture, rather to support the lead agency such as USDA or U.S. State Department if the response involved supporting another nation respond to agroterrorism. If tasked, the likely U.S. Armed Forces part will be responding to these scenarios by providing personnel and equipment to supplement lead agency resources. Additional roles beyond countering the threat include providing humanitarian aid to affected populations as well as decision-making support such as gathering information on the events as they unfold. In terms of countering the direct impact of agroterrorist attacks on the food supply chain, U.S. forces could be tasked to move people, supplies and equipment to forward locations to stop the spread of attacks and may potentially be tasked to cull and dispose of large numbers of animals or destroy contaminated crops if warranted.

In light of these possible roles and the standing guidance for pest control, U.S. Armed Forces employments are unlikely to deploy high-value equipment into area that will likely result in mission-critical systems or equipment being contaminated. If equipment such as trucks or ground transport equipment including trailers and cargo containers entered an infected area, methods to clean the equipment and verify it no longer poses an agricultural risk are required prior to those resources being moved out the area and released for unrestricted use elsewhere.

Standing Requirements to Address Overarching Needs and Capability Gaps

The Air Force has longstanding requirements to ensure the capabilities and procedures are in place to prevent the spread of pests during air operations including those pests and diseases that may harm agriculture. However, as touched on earlier, it is not a specific Air Force requirement to have capabilities specifically to seek out and stop agroterrorists. While it is possible U.S. Special Forces might engage a terrorist group planning to carry out such an attack as part of the broader war on terror, that mission subset would not drive specific counter agriculture terrorism centric technology needs. Rather in general the U.S. military will work to manage pest control and ensure it people and assets do not exacerbate the crisis by spreading the threat. Further, if requested, the services could deploy a variety of in-hand assets to support and assist other U.S. agencies protecting American agriculture as well as work with other nations to ensure no U.S. military assets or operations put that nation's agriculture base at risk.

In addition to pest control, the U.S. Armed Forces and Air Force have standing requirements to equip and train it forces to counter chemical, biological, nuclear, and radiological (CBRN) threats. Chemical and Biological (CB) defense capabilities such a decontamination and detection or sensing of CB threats will likely have some commonality capabilities needed to respond to agroterror threat scenarios discussed earlier. In terms of technologies and needed capabilities, there is realistically little to no difference between a technology to counter chemicals agents or biological organisms targeting people vice those threats that could be employed to target livestock, crops, or other elements food supply chain.

Air Force Specific Technology Requirements

Each day, military missions take people and equipment around the globe to places where they can interact with endemic pests and diseases that, in turn, can be carried elsewhere and threaten native flora and fauna as well as agriculture. The Air Force recognizes agroterrorism can do tremendous harm to U.S. agriculture and economy and that within the federal government the USDA leads development of technologies to protect U.S. agriculture as well developing preparedness capabilities to respond quickly if a threat to agriculture is detected. The DOD and Air Force will support the USDA when tasked and are responsible to ensure its capabilities can be effectively employed when needed and prevent spread of pests while executing its global mission. The DOD and Air Force also work with other nations to help defeat terrorists and if agroterrorism occurs, ensure U.S. forces take steps to prevent the spread of biological threats to other agricultural regions as it executes its global missions. Some capabilities exist today with a majority of the capability residing with the U.S. Army and are used by the Air Force as part of pest management, but as alluded to earlier, and as demonstrated over the past decades, terrorists will look for vulnerabilities and seek to exploit weaknesses in the barriers used to protect people and resources.

Technologies exist today to monitor and mitigate inadvertent introduction of pests that can invade vulnerable ecosystems including attacking agriculture. As part of pest control, the Air Force along with the other services have implemented a number of protocols and use various surveillance tools to identify and track a range of biological, including microbial, threats on a wide variety of military platforms. In terms of what gaps remain to be addressed within the Air Force two key technology areas currently exist, advanced sensing and surveillance technologies designed to meet AF mission needs and broad range decontamination capabilities that are compatible with Air Forces equipment. In terms of threat and technology requirements, the microbial threat as discussed in the introduction poses the most significant challenge as it has the potential, once released, to spread quickly, infecting agricultural operations and compromising local or regional food security. Further, while other agencies will confirm if an outbreak is natural or intentional, U.S. Armed Forces must still have the tools to screen for these threats to are part of ensuring global operations do not put local or regional agriculture at risk.

Potential technologies for countering agroterrorism threats

Two unique Air Force technology areas stand out as capabilities and technologies that can be leveraged to counter or respond to agroterrorism in the United States or in support of other nations worldwide. These are disinfection and decontamination of personnel and equipment and sensing capabilities. While other major Air Force capabilities, such as airlift can, and would likely be leveraged, these capabilities are not necessarily Air Force unique as many air, ground and sea transport options are available from other services and a number of commercial sources as well. Development of other critical response technologies such as tools to eradicate infected or contaminated crops and livestock for example, do not align with other Air Force missions and would instead be addressed by the USDA. The Air Force role with respect to these and related technologies would be to facilitate their movement and to provide other in-stock support equipment, resources and personnel as directed by the DOD. These two areas stand out as the Air Force is already developing and incorporating these capabilities across the Air Force to meet Air Force needs and both technologies can, in collaboration with other agencies, be leveraged to counter agroterrorism.

Disinfection and Decontamination Technologies

Modern warfare covers many threats including CBRN threats. The Air Force trains and equips its forces to operate at fixed sites where an enemy can employ chemical and biological attacks in an attempt to kill personnel or impede operations by forcing personnel to take protective countermeasures. CBRN defense capabilities and general hygiene practices, like pest control, are ingrained in Air Force concepts or operations (CONOPS). The U.S. Armed Forces and Air Force investments in CBRN defense capabilities include several relevant technologies such as detection and surveillance technologies as well as personnel protection and decontamination technologies. Unique among these technologies needed by the Air Force is large-scale mission critical system thorough and/or clearance level decontamination. Thorough and clearance level decontamination concern the hardware's level of cleanliness after treatment. A thorough decontamination level as defined by Mil-STD-3056 is: "Decontamination carried out by a unit to reduce contamination on personnel, equipment, materiel, and/or working areas equal to natural background or to the lowest possible levels, to permit the partial or total removal of IPE and to maintain operations with minimum degradation."[5] For decontamination of biological hazards, the Air Force cleanliness level it needs is to achieve is "clearance" level, which JP 3-11 defines clearance as, "The final level of decontamination that provides the decontamination of equipment and personnel to a level that allows unrestricted transportation, maintenance, employment, and disposal." meaning the equipment or system once treated and certified, can then be used without restriction anywhere in the world.

Mission Critical System Biological Decontamination

The U.S. Armed Forces has developed various methods for killing or inactivating a wide range of biological organisms on personnel and various non-disposable equipment. These include washes, fumigation, sanitizing solutions, autoclaving, etc. For the Air Force, some sensitive equipment such a transport aircraft and other sensitive military equipment, these common biological remediation poses unique challenges. The problem is that many established treatments can achieve a clearance level, but the process involves the use reactive chemicals to sanitize or fumigate contaminated materials and equipment. These treatments are unacceptable for aircraft as the chemicals commonly used are incompatible with some sensitive materials used in military and commercial airframes. One technology developed specifically to treat biological weapon threats and allow aircraft and other select sensitive equipment to return to unrestricted use is referred to as bio-thermal decontamination (BTD) or when used generically with or without use of controlled elevated relative humidity, simply as hot air decontamination (HAD).[6, 7, 8, 9]

HAD and BTD in their simplest forms works to alter the environment of materials, equipment and other military hardware including large weapon systems such as transport aircraft. These items are uniformly heated to temperatures that will kill pest such as insects and animals as well as denature proteins critical to the viability of many microbes and viruses. In the BTD variant, artificially high relative humidity is applied to facilitate inactivation of hardy organisms such as endospores.[10, 11] HAD has been demonstrated as effective in neutralizing many biological pathogens, ranging from vegetative bacteria and molds, to the hardiest biological warfare agents (BWAs).[12] Separate studies are also underway to determine the viability of HAD to desorb and/or decompose several types of toxins and toxic chemicals on a range of common substrates. The technology was proven effective in the laboratory and in the field on several military airframes, including the C-130,[13, 14, 15] C-5, and F-35. HAD is particularly attractive because it only relies on heat and ambient relative humidity to decompose or desorb toxic compounds as well as inactivate many types of organisms including viruses, microbes as well as kill other pests and disease promulgating vectors such as insects. In general, the heat permeates dense, convoluted, and even air-tight spaces that are impenetrable to fumigants, particulates, and radiation/light-based decontamination methods. For this reason, HAD is an effective decontamination technology for aircraft as well as cargo, equipment, and other vehicles. Having demonstrated the decontamination efficacy on large-frame aircraft and jets, application of the technology to staged, embarked, or received cargo is simply a matter of scaling and packaging. HAD can be used to treat cargo in a separate decontamination unit, or even aboard an aircraft or ship, at the point of loading or unloading. With a HAD treatment system, the heat will permeate all forms of secondary containment – wraps, bags, pallets, containers, etc. – ensuring complete kill/inactivation of agricultural threats.

HAD generally refers to decontamination using temperatures above ambient. For military airframes such as the F-35 shown in *Figure 1*, temperatures in the range of 170 to 180 degrees Fahrenheit are recommended, as not to exceed the design limitation of 185 F. For hardy organisms, such as endospores, like *Bacillus anthracis*,[16, 17] these temperatures must be maintained for several days. However, less resistant microbes like a range of viruses and molds, as well as complex organisms such as insects and invasive animal species, lower temperatures (approximately 150 F) can neutralize to kill a host of microbes within just a few hours. The technology is applicable to macro-biology as well, with studies suggesting that invasive species of insects can be neutralized within minutes at temperatures exceeding 131 F. Conceivably, the technology could also be applied to quickly kill other invertebrates (e.g., zebra mussels), vertebrates (e.g., brown tree snakes), and invasive plants (e.g., kudzu), as well.

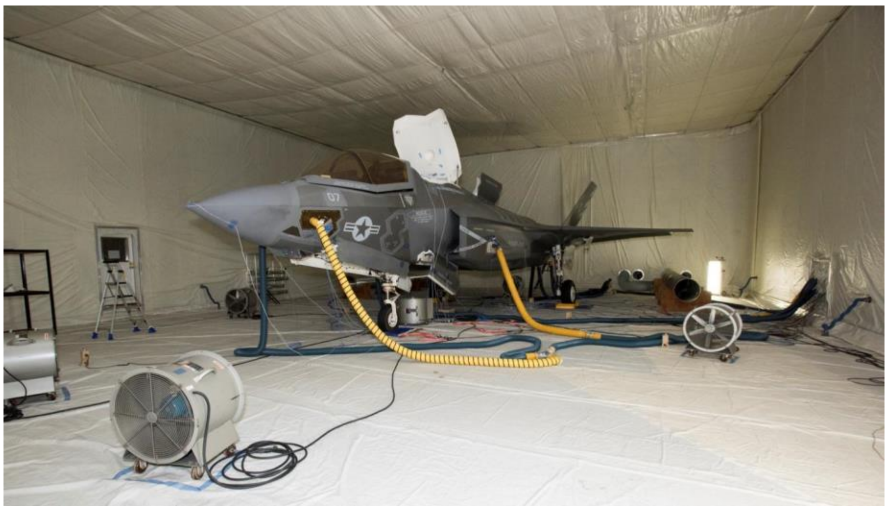

Figure 1. F-35 aircraft prepared to under HAD treatment for chemical and biological contamination.

While the technology is highly advanced for BWAs on military airframes, further development is required to optimize treatment parameters for the other types of biological threats and establish suitable timelines for efficacy in treating materials and equipment potentially exposed to threat organisms should they become part of a shipment of equipment or densely-packed cargo.

Given the broad applicability and flexibility of the technology, there are several CONOPS where this type of decontamination is well suited to support not only large-scale logistics operations, which may be needed to mitigate one or more agroterrorism attacks, but to cover broader operational needs including biological attacks against U.S. armed forces as well as mitigate and contain natural outbreaks such as emerging infectious diseases.

These include:

- Repatriation or in-theater transportation of assets to more than one threatened area where cross contamination poses risks to agriculture outside of an infected area
- Decontamination of equipment and cargo used in humanitarian aid missions such as providing food and recovery supplies where infectious diseases are still prevalent in the area
- Treatment of (retrograde) cargo that becomes infected by the organism or a host vector organism in staging or during transit
- Expeditious movement of assets either to or through countries with existing agricultural and biosecurity limitations for inbound goods and equipment such as Australia

The hot air decontamination technology was designed for BWAs and research continues into it its use as a treatment of other infectious diseases. However, agroterror scenarios includes organisms beyond the list of known biological warfare agents or potential emerging infectious diseases that can threaten humans. However, agroterrorists can draw on a host of fauna or flora diseases in addition the established diseases that infect livestock and crops. While the natural threats to agriculture are fairly well understood and serve as a basis for agroterrorists, the potential for an emerging infectious disease outbreak could require a large-scale response as well as offer agroterrorists an opportunity to exploit a new disease for attacks.

An outbreak of a new strain of avian flu among migrating waterfowl, for example, can pose a major threat agricultural flocks as wild waterfowl often will rest in or near farm ponds on their migration routes. These patterns can facilitate disease spread in the water and infected sites can spread over large areas during migration season making timely movement of resources to contain the spread critical and can drive the need for suitable systems to provide thorough or clearance level decontamination of large equipment and support hardware. Mold and invasive species, on the other hand, are much more common in routine transport missions. For example, Australia's Department of Defence, requires deploying U.S. forces to have their equipment inspected for soil, debris, biological material, and disease that could bring invasive species to the continent that could potentially impact the environment and agricultural sector. "All aircraft, vessels, and military arriving in Australia are subject to an Australian biosecurity requirement. The department inspects all military equipment and the personal effects of military personnel."[18] Aircraft must also undergo disinfection procedures – "health measures taken to control or kill the insect vectors of human diseases present in baggage, cargo containers, conveyances."[19]

In April 2015, for example, nearly 1,150 California- and Hawaii-based U.S. Marines deployed to Australia's Northern Territory for a six-month deployment with Marine Rotational Force-Darwin. Marine spokesperson noted equipment arriving in theater with broken seals or determined to be contaminated by Australian authorities must remain quarantined until U.S. Marine Corps officials decontaminate the gear and resubmit it for inspection. This can be a time-consuming process of equipment breakdown, cleaning, re-examination, inspection, and, if passing, subsequent reassembly once in Australia.

According to U.S. Marine Corps Forces, Pacific, a typical deployment may require:

- 1,500 man-hours of cleaning per aircraft
- 10 to 20 days (12-hour work shifts) per aircraft to complete breakdown, detailed cleaning (pressure washing and vacuuming), inspection, and reassembly of one helicopter
- Marine Heavy Helicopter Squadron's personnel and equipment preparations[20]

In this pest control scenario, HAD could treat all aircraft and equipment with a few hours or days, neutralizing all microbiology and invasive species without disassembly or manual cleaning, saving thousands of man-hours prior to deployment. Responding to a large-scale agroterrorism event using a manual cleaning approach would be impractical as time to treat will likely need to be accomplished in a matter of hours or days, not weeks. Under such time constraints a hand-based treatment would not guarantee more hardy microbes are inactivated nor all pests are killed before aircraft, equipment and people may have to transition to another site. Currently, there are no international standards for this type of decontamination although maturation of scientific data and development of TTPs to establish alternative acceptance criteria and guide new policies that benefit transportation agencies worldwide covering agroterror threats along with the full spectrum of biological threats would need happen in order for U.S. Forces to fully employ this technology globally.

Potential Leveraging Opportunities of Aircraft Decontamination Technologies

The benefit and/or return on investment investing in tools to fight agroterrorism is difficult quantify in terms of an assured dollars and cents number as it is a need driven application. In the example of HAD treatment of equipment and vehicles prior to deployment to Australia, described in above, it could save thousands of hours in manual labor each year for the training deployments alone. The additional effort to run this decontamination for current pest control would pale in comparison to the manual labor required to disassemble and clean a variety of agricultural machinery and tools individually. In addition to these routine deployments, the same technology could be applied prophylactically or in response to suspicion of contaminated cargo in scenarios such as invasive species as well as moving supplies into an out of an area hit by a catastrophic agricultural disease. Presently, if contamination of any sort is suspected, the only recourse is to quarantine, costing time, money, and potentially impacting recovery operations. Finally, the cost avoidance could be in the millions for a pandemic or similar scenario infesting crops or livestock if the diseases were widespread such as what appears to have happened in China with the outbreak of African swine flu. In these rare events of wide spread contamination, there is the potential for other support equipment, cargo or humanitarian relief supplies exposed to an agroterrorist disease(s) during response operations or in transit. In these cases where cross contamination is suspect, a deployable preventative treatment capability could be mission-ready on short notice with personnel who are trained and familiar with the system from the routine uses.

Sensing and Surveillance Technologies

Today in the United States and in other nations, agriculture is critical. Various agencies around the world maintain robust monitoring and surveillance programs to protect foodstuff particularly those products intended for regional and/or international trade. This infrastructure may include teams who visit farms and ranges as well as local or regional labs where technicians test both healthy and suspect samples for possible infestations. The surveillance tools used for collecting potential pests are well developed and field-monitoring professionals are adept at collecting a host of air, ground water and organism samples. In terms of military intelligence, surveillance, and reconnaissance (ISR) sensing and surveillance being leveraged for assessing health of crops and local flora, a gap stands out with respect to indicators stand-off sensors should measure and operators can monitor. Some of these indicators are used today by farmers as well as USDA to monitor crop productivity and health and are discussed further in the sensing section.

Remote Sensing of Crop Status

While the Air Force has limited responsibly for agricultural defense or incidence response, its air platforms and drones could provide a significant wide area surveillance capability if needed. Such capabilities can work hand in hand with people on the ground where farmers and other agricultural specialists observe and sample food crops as well as pasturelands and open ranges for grazing livestock to look for signs of disease or stress. While knowledgeable individuals can identify diseased crops or grazing fields through direct observation, relying on individuals to continually survey fields and open ranges across large rural areas may be impractical for a responsive national defense strategy against agricultural terror attack(s).

Beyond human visual inspection of crops, there are many different technologies that can be used to analyze plant material for the presence of pathogens. Any standard biological detection strategy can be used to look for pathogens. Visual microscopy, culture, antibody binding, protein analysis and DNA analysis are some examples of technologies that can provide highly accurate analysis of suspected diseased plants. These technologies are not unique to the Air Force as any university, research institution, hospital or public health office would have some detection technology that could be leveraged in a national emergency, so in that instance Air Force and DOD assets as a whole could contribute to sample analysis.

However, these techniques can be time consuming, rely upon a physical sample from suspected diseased plants, and would not allow for continuous and widespread surveillance of large fields of crops. One technology that does offer the potential for large-scale continuous monitoring of crops is spectral analysis. Given that the Air Force has a large number of piloted and remotely piloted aircraft that could be modified to provide spectral analysis, the Air Force could provide a significant level of support to a national surveillance and detection effort if directed by command authorities.

Spectral Analysis

Spectral analysis is somewhat of a catch all phrase to describe obtaining information on an item based upon its spectral signatures. By collecting information on the wavelengths associated with a plant (an image may or may not be needed) it is possible to infer the health of the plant. A fundamental spectral analysis conducted by the naked eye would be observing that a leaf has changed from its natural green to brown, indicating the plant was under some form of distress. In fact, aerial image analysis of crop health was first started in 1929.[21] This basic analysis is limited by to the visible spectrum and limited by the ability of the human eye to detect subtle changes in color. As such the human eye may not be able to subtle changes in a diseased plant prior to overt symptoms, nor may it be able to differentiate between diseases.

However, when the human eye is replaced by automated image analysis it is possible to analyze data from many different spectra (visible, infrared, ultraviolet) and use computers to conduct the spectral analysis greatly expanding the amount of information that can be obtained from an image. These advanced capabilities can identify changes in plants early in disease progression, and can identify changes characteristic of a particular disease.

Inherent in this analysis is the idea of detecting changes over time that indicate a stressed situation in a crop of interest. To utilize this type of detection unique spectral signatures of the object (a healthy and stressed crop this instance) need to be generated and analyzed for distinctive and repeatable changes (or signatures) associated with the stressed or disease state. This process involves research where spectral data is gathered from healthy and diseased plants at different stages of growth and disease state. The data is then compared to identify unique changes in the spectra associated with the diseased plants. Generally, the more wavelengths utilized, the greater the resolution and precision of the predicative algorithm.[22] However, as the number of wavelengths analyzed increase there is an increase in optical requirements, computer power, and statistical models used to in the decision process.

Spectral Analysis Capabilities

There is an extensive amount of literature describing the ability to identify plant stress or disease via remote spectral sensing.

Koushik Nagasubramania, et al, demonstrated an ability for machine learning to identify diseased plants without prior knowledge of disease state. In their study soybean stems exposed to charcoal rot. Utilizing upon hyperspectral imaging the AI system was able to classify infection status with 95 percent accuracy as well as identify the most sensitive wavelengths.[23]

Taking a similar capability to the air the FDA was able to detect cotton root rot utilizing both hyperspectral and multispectral imaging systems from an aircraft flying at 10,000 feet.[24] Going even higher in altitude, Han Dong, et al, demonstrated the ability to detect water content in wheat utilizing radar images from satellites.[25]

It is also important to note that many of the observations noted in the literature are dependent on specific laboratory or environmental conditions. A study on grapevines was able to find several spectral signatures indicative of disease, however they were not consistent over soil and weather conditions.[26]

Air Force Sensing Contribution

The USDA as well as other nations currently use drones and imaging for crop and resource management, for example analyzing water content to optimize irrigation usage (*USA Today*, 2019). The USDA, and to a degree other agriculture monitoring agencies worldwide, lead their respective national programs in funding research of spectral analysis as a way to monitor crops for general health, and by extension agroterror. This is not an area in which the Air Force needs to invest. However, the Air Force does possess many aerial systems capable of collecting images capable of being analyzed for spectral content that could be utilized to augment existing platforms owned by other government agencies.

For example, the Predator unmanned aerial vehicle (*Figure 1*) contains a "Multi-Spectral Targeting System, which integrates an infrared sensor, color/monochrome daylight TV camera, image-intensified TV camera, laser designator and laser illuminator." Likewise, manned surveillance aircraft such as the U-2 (*Figure 2*) can carry a number of sensors. "The U-2 is capable of gathering a variety of imagery, including multi-spectral electro-optic, infrared, and synthetic aperture radar products that can be stored or sent to ground exploitation centers. In addition, it also supports high-resolution, broad-area synoptic coverage provided by the optical bar camera producing traditional film products."[27] Given the long loiter time of many Air Force Assets extremely large areas of crops could be monitored.

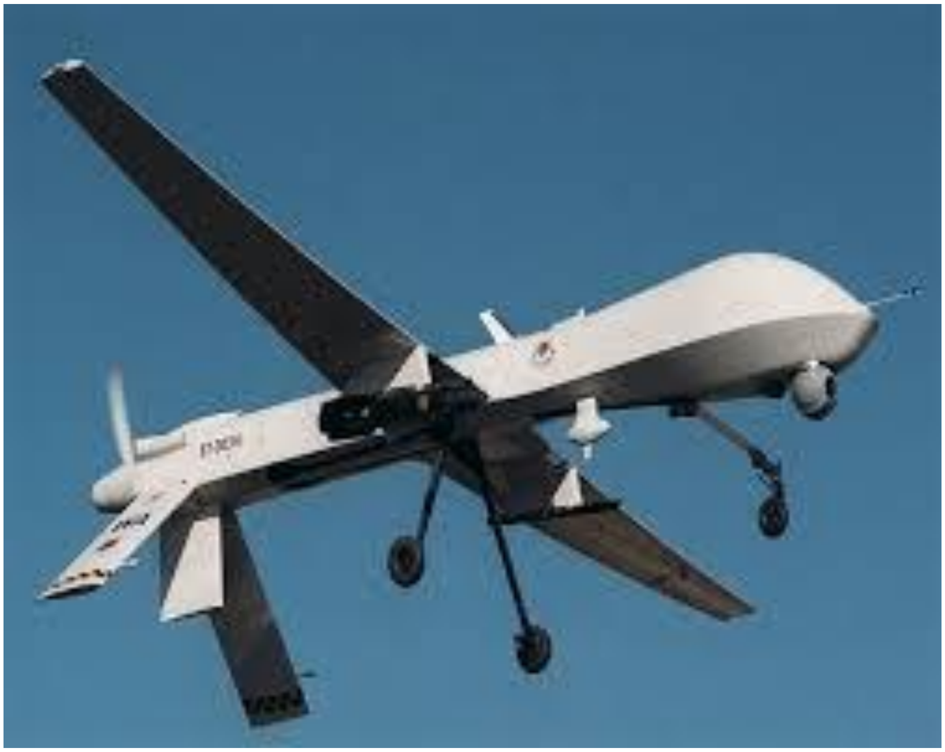

Figure 1. Predator unmanned aerial vehicle (Image from af.mil)

Figure 2. U-2 surveillance aircraft (Image from af.mil)

In the instance of a national emergency these and similar resources could be pressed into service to monitor the health of crops over wide areas of coverage. In such an instance the wavelength data can be collected and transmitted for subsequent analysis. Analysis of this data would most likely not be an Air Force activity, but would be conducted by experts in crop analysis.

A potential gap in the Air Force contribution lies in the need to collect specific the wavelengths associated with a particular crop condition. As demonstrated in the literature cited above, spectral analysis has been applied to identify specific disease conditions and broad crop status. However, each application relies upon a specific set of wavelengths, that exhibit change in response to the condition of interest. It is possible that standard Air Force equipment may not collect information in the correct bandwidth, or may not have the bandwidth resolution needed to identify the condition in question. In this case it may be possible to replace the existing sensors on the platform if they are available in a compatible format, if there is time to make the modifications and if the Air Force operations tempo allows diversion of the asset for the dedicated purpose of crop monitoring.

Alternatively, Air Force assets may be used for general monitoring of crop status that could alert officials as to areas of potential concern, which could be targeted for more intense monitoring and identification efforts. In this scenario existing sensors could be used to monitor crop status for suspicious changes in appearance over an extended period of time. This could be particularly useful if there was threat intelligence that suggested a high probability of an attack. While such monitoring would not necessarily thwart an attack it could detect early indicators an attack took place, hopefully in time to contain the effects.

Capability Maturity and Application

Maturity of capabilities to carry out the various roles discussed in this chapter span a wide spectrum. Global airlift and personnel protection and decontamination are examples of very mature technologies. Within the ISR realm, there are very mature capabilities as well as new capabilities being added, although details concerning any given sensor is either sensitive or classified. As discussed above, non-DOD sensing of crops as well as tools to quickly diagnose a plant or animal disease are well established although employing those systems on DOD platforms may require some integration to ensure seamless functionality during a crisis. Concerning disinfection and decontamination, for many applications there are many approved methods to clean equipment and personnel, which would allow responders to safely move from one site to another without risking cross contamination. As for treating high value assets such as aircraft, the capability to still being matured. It remains to be determined if HAD and/or BTD will be the best method(s) to address more specific agroterrorism response scenarios such as treatment of densely-packed cargo and a broader range of biological targets (e.g., insects and invasive species). Further, while the BTD/HAD technologies are matured, the equipment is designed to treat C-130 aircraft, is bulky and intended to be set-up at a staging base. However, the technology can be scaled down for use at remote site that would support a concept of employment for nonmilitary uses. For non-traditional missions, such as agroterrorism, specific use cases and capabilities must still be determined. For example, decontamination of equipment and cargo employed to counter agro-threats prior to leaving a rural staging area versus performing basic on-site cleaning and potentially transporting still contaminated hardware to a base and then treating prior to loading aircraft.

Future Needs, Gaps and Technology Opportunities

The Air Force will technology development is driven to support mission needs and fill capability gaps. USDA will continue leading development of technologies and capabilities to protect and defend the nation's agriculture. In turn, threats to agriculture, both natural and manmade, will continue and could evolve in ways no one can accurately predict. In terms or agroterrorism there is always a potential that a terror group could damage or destroy the food supply of a population by exploiting a known or emerging natural threat, or by tapping into the rapid advance occurring in the biological sciences for instance. However, it is very unlikely the Air Force will divert limited resources to develop technologies for needs outside of it defined mission areas, specifically technologies and capabilities to defend American agriculture as well as that of other nations from terror attacks. Rather future Air Force capabilities will continue to mature capabilities to defend against a range of threats and work with other organizations to adopt or leverage technologies that can be employed if needed.

In addition to the decontamination and sensing capability area discussed, future mission areas where collaboration or leveraging could apply include strengthening capabilities to thwart terrorists in general through advancing intelligence analysis as well as cyberoperations. Other topic to consider include collaboration on response capabilities. As noted in the introduction, it is possible the military may be called on the cull herds of eradicate crops in order to stop the spread of a highly infectious disease. In these scenarios, USDA and APHIS could collaborate with DOD to ensure the tools of which they may want to use to respond to agroterrorism deploy quickly and also be safely redeployed to respond to multiple sites, or recovered once a threat is stopped. Today's agriculture is already developing and operating advanced sensing technologies. In terms of the gathering wide area surveillance data critical to response decision making, USDA or other non-DOD sensing hardware may need be deployed quickly to assess the conditions of fields at risk of attack or once an attack is identified, map its spread so that a response plan can be executed. These sensing technologies will likely have counterparts with the U.S. ISR architecture and by leveraging DOD sensors along with agriculture focused software and analytic tools, information can be gathered quickly. Having the ability of agencies such as USDA along with the Department of Homeland Security to quickly tap into DOD platforms would quickly aid local, state, and federal responders in the United States and if requested, assist decision makers and responders in other nations as well.

Conclusions

In conclusion, agroterror is not a prime mission of the U.S. Air Force. However, there are still instances where the Air Force may be confronted with agricultural terror. First an agricultural attack is most likely to take the form of a biological agent. As such there is little difference between an agricultural attack or an attack against personnel. As such the detection and decontamination equipment used to defend against a WMD attack would be useful in response to an agricultural attack. This equipment could be used to treat military assets, or could be employed to augment other government agencies or forging governments as needed.

Secondly, the Air Force has a robust manned and unmanned surveillance capability, which could be modified and employed to monitor crop health. While there are other agencies with prime responsibility for this activity the Air Force could be called upon to augment existing capabilities in the case of a large event. Finally, the Air Force fights agroterror on a daily basis in many ways. The nature of the Air Force mission involves movement of personnel, cargo, and equipment across many international borders. As discussed, this movement requires the Air Force take steps to eliminate the movement of invasive species or diseases, which in essence is an extension of agricultural defense. Therefore, while the Air Force will not take the lead in any response to an agricultural attack, it will be able to provide knowledge, and material solutions to support a response if so tasked by national authorities.

Chapter 7 Notes

1. U.S. Geological Survey, www.usgs.gov/faqs/what-invasive-species-and-why-are-they-a-problem?

2. Dan Charles, "Swine Fever Is Killing Vast Numbers of Pigs in China," *National Public Radio*, Aug. 15, 2019, www.npr.org/sections/thesalt/2019/08/15/751090633/swine-fever-is-killing-vast-numbers-of-pigs-in-china.

3. Sam Ramos, Matthew MacLachlan and Alex Melton, "Impacts of the 2014-2015 Highly Pathogenic Avian Influenza Outbreak on the US Poultry Sector," U.S. Department of Agriculture, December 2017, www.ers.usda.gov/webdocs/publications/86282/ldpm-282-02.pdf?v=0.

4. *Pest Control Guide TG31*, Agricultural Preparation of Military Gear and Equipment for Redeployment.

5. Department of Defense, *Joint Publication 3-11, Operations in Chemical, Biological, Radiological and Nuclear Environment*, Figure E-2, Levels of Chemical, Biological, Radiological and Nuclear Decontamination (Washington, D.C.: Department of Defense, Oct. 4, 2013), p. E-3,

6. T. Provens, R. Cahall, M. Shaw, M. Arthur, K. Heater, A. Theys, M. Robertson, *Thermal Inactivation of Bacillus Thuringiensis: Final Report Detailing Results for Thermal Inactivation,* November 2009.

7. V. K. Rastogi, L. Wallace, L.S. Smith, S.S. Shah, and R. Foster. *Laboratory-Scale Demonstration of Hot Moist Air as a Bio-Decon Technology for Large-Frame Aircraft Interior Surfaces*, January 2011.

8. T. Buhr, A. A. Young, D. McPherson, C. Hooban, Z. Minter, D. Shegogue, D. Kota, V. Rozanski, M. Hammon, *Sporicidal Efficacy Testing with Hot Humid Air to Evaluate the JBADS Decon System*, NSWCDL Final Report: Spore Preparations, Environmental Chambers, and Heat Kill of Bacillus Spores (B. anthracis Ames, B. anthracis ΔSterne, B. cereus ATCC 4342, B. thuringiensis Al Hakam). April 7, 2010.

9. M. Sloan, A. Tijerina, M. Woitaske, I. Rosas, J. Kiel, A. De Los Santos, *Validation of Joint Biological Agent Decontamination System Program,* April 2010.

10. T. Buhr, et al. *Sporicidal Efficacy Testing with Hot, Humid Air to Evaluate the Joint Biological Air Decontamination System, Tier II,* April 2014.

11. T. Buhr, et al. *Sporicidal Efficacy Testing with Hot, Humid Air to Evaluate the Joint Biological Air Decontamination System, Tier III,* September 2014.

12. T. Buhr, et al. *Bacillus Spore Decontamination with Hot, Dry Air*, June 2015.

13. T. Provens, K. Heater, A. Theys, M. Arthur, and D. Lorch. Demonstration of C-130 Biological Thermal Decontamination at Little Rock Air Force Base, Ark., October 2011.

14. A. Theys and William Greer. *Analytical Test Report for the Joint Biological Agent Decontamination System Joint Capability Technology Demonstration Operational Utility Assessment,* USAF Contract No. FA8650-13-D-6405, 0002, August 2015.

15. T. L. Buhr, A. A. Young, M. Bensman, Z. A. Minter, N. L. Kennihan, C. A. Johnson, M. D. Bohmke, E. Borgers-Klonkowski, E. B. Osborn, S. D. Avila, A. M. G. Theys, P. J. Jackson, *Hot, humid air decontamination of a C-130 aircraft contaminated with spores of two acrystalliferous Bacillus thuringiensis strains, surrogates for Bacillus anthracis, J. Appl. Microbiology*, vol. 120, no. 4. January 2016.

16. E. J. Prokop, J. R. Crigler, C. M. Wells, A. A. Young, T. L. Buhr, Response surface modeling for hot, humid air decontamination of materials contaminated with Bacillus anthracis ΔSterne and Bacillus thuringiensis Al Hakam spores, AMB Express 4:21, 2014.

17. T. Buhr, A.A. Young, D. McPherson, C. Hooban, Z. Minter, D. Shegogue, D. Kota, V. Rozanski, M. Hammon. *Sporicidal Efficacy Testing with Hot Humid Air to Evaluate the JBADS Decon System*, NSWCDL Final Report: Spore Preparations, Environmental Chambers, and Heat Kill of Bacillus Spores (B. anthracis Ames, B. anthracis ΔSterne, B. cereus ATCC 4342, B. thuringiensis Al Hakam). April 7, 2010.

18. The Australian Department of Agriculture, www.agriculture.gov.au/biosecurity/avm.

19. Australian Department of Agriculture, *Guidelines for Airline and Aircraft Operators Arriving in Australia*, July 2015.

20. Sgt. Sarah Dietz, U.S. Marine Corps, "Marines Work to Send Aircraft to Australia," U.S. Marine Corps, website, March 24, 2005, www.marforpac.marines.mil/News/NewsArticleDisplay/tabid/919/Article/581399/marines-work-to-send-aircraft-to-australia.aspx.

21. Chengai Yang, James Everitt, and Carlos Fernandez, "Comparison of Airborne Multispectral and Hyperspectral Imagery for Mappin gof Cotton Root Rot," *Biosystems Engineering* 107, 2010, pps.131-139.

22. Spectral analysis can be sub defined as spectral, multi-spectral and hyper-spectral. Indicating an increased number of spectral bands analyzed to generate the spectral signature. A generic term "spectral sensing" will be used in this section for all types of spectral analysis.

23. Koushik Nagasubramania, , Sarah Jones, Asheesh Sing, Soumik Sarkar, Arti Singh, and Baskar Ganapathysabramanian, "Plant Disease Identification Using Explainable 3D Deep Learning on Hyperspectral Images." *Pant Methods* vol. 15, 2019, doi:10.1186/s13007-019-0479-8.

24. Chengai Yang, et al, "Comparison of Airborne Multispectral and Hyperspectral Imagery."

25. Han Dong, Shauibing Liu, Ying Du, Xinrui Xie, Linling Fan, Lei Lei, Zhenhong Li, Hao Yang, and Guijun Yang, "Crop Water Content of Winter Wheat Revealed with sentinel-1 and Sentinel-2 Imagery," *Sensors* vol. 19, 2019.

26. Al-Saddik, Hania, Jean-Claude Simon, and Frederic Cointault, "Development of Spectral Disease Indices for 'Florescence Doree' Grapevine Disease Identification," *Sensors*, vol. 17. 2017, p. 2,772.

27. U.S. Air Force, *MQ-1B Predator*, accessed Oct. 1, 2019, www.af.mil/About-Us/Fact-Sheets/Display/Article/104469/mq-1b-predator.

CHAPTER 8

Agroterrorism Policy

Col. (Dr.) Oliver J. Wisco and Paul Imbriano

Agroterrorism, while not a highly publicized topic in the media, is a primary policy concern in the United States. According to U.S. Senator Susan Collins of Maine,[1] "Nothing is more at the heart and core of our economy than our agriculture and food industry. It is a $1 trillion economic sector that creates one-sixth of our gross national product. One in eight Americans works in this sector. It is a sprawling industry that encompasses a half-billion acres of croplands, thousands of feedlots, countless processing plants, warehouses, research facilities, and factories for ingredients, ready-to-eat foods, and packaging, as well as the distribution network that brings food from around the nation and around the world into the neighborhood markets and restaurants via virtually every mode of transportation."

Because of this, it is no wonder that our agriculture was a site of a potential attack for Osama Bin Laden, as discovered in material recovered back in 2002. During exploration of al-Qaeda caves in Afghanistan, many U.S. agricultural documents were recovered that suggested that these were future potential targets of terrorism.[2]

In order to consider the impacts of agroterrorism, we first need to consider the economic and social impacts of agricultural events that occur naturally. Back in 1997, an outbreak of foot and mouth disease of local pigs in Taiwan cost upwards of $4 billion creating an estimated cost of trade embargoes up to $15 billion.[3] In 2001, an outbreak of foot and mouth disease affecting sheep, cattle, and pigs in Great Britain cost an astounding $1.6 billion in compensation, with lost revenue to tourists at an additional $4 billion.[4] In 2002, an outbreak of Newcastle disease (an infection of domestic poultry and other bird species with virulent Newcastle disease virus) in California resulted in grave economic losses and the quarantine of roughly 46,000 square miles of land.

In evaluating these events, we see that losses would not only include the value of lost production, but also include the amount of money it would cost to destroy the diseased products, and the cost of producing drugs, vaccines, pesticides, or other services needed to deal with the biological consequence of the attack. Furthermore, markets of export would be inhibited due to restrictions placed on the United States by countries that imported goods from our nation. Also, multiplier effects would send shock waves through the economy due to the declining sales by businesses dependent on agriculture. Finally, the government would also be affected by significant costs, which would include eradication of the contaminant, and compensation to producers for affected animals. It is easy to see how an attack on agriculture could bring a nation to its knees and why effective policy is needed.

Gaps in Effective Agricultural Policy

In today's world of ever evolving technology and the occasional natural disease occurrence, it is essential that we have established effective policy to address threats of unintentional or intentional attacks on our agricultural industry. However, effective policy is lacking in the United States. The Department of Homeland Security (DHS) identified 16 areas of infrastructure that they have deemed "critical infrastructure" sectors.[5] These sectors are considered to be so vital that if they were incapacitated or destroyed, the country would be seriously crippled.

One of these "critical infrastructure" sectors is food and agriculture. Despite this, the notion that the government watches over our agriculture with an eagle eye is not totally true. In reality, much of the responsibility has been relegated to the private companies that produce the food and water to ensure their product is safe for consumption. For larger companies, the burden of cost and man hours to ensure safety is a hefty, but still affordable price to pay. For the smaller agricultural company, however, this burden increases immensely. Rules and guidelines need to be put into place to help organizations use their resources to the best of their ability. In addition, local government officials should also be trained in what to look for in their communities. From police to emergency medical services personnel in areas of particular risk should not only have extra training in what to look for as warning signs, but also understand the medical signs and symptoms of an agricultural terrorist attack. First responders would be the initial providers for individuals initially affected in a "successful" terrorist attack.

When we look back on the history of both offensive and defensive policy in regards to agricultural attacks, it is evident that there has always been a degree of hesitation on what is thought to be the correct way to deal with these situations. On Sept. 11, 2001, our nation was changed forever. Agricultural policy was no different. According to a Congressional Research Service report, "Appropriations and user fees for the U.S. Department of Agriculture (USDA) homeland security activities have about doubled from a \$156 million "pre-September 11" baseline in Fiscal Year 2002 to \$325 million in FY2004."[6] The Public Health Security and Bioterrorism Preparedness and Response Act was put forth to respond to newly discovered vulnerable areas in this area of critical infrastructure. This act contained provisions with the goals of expanding the Food and Drug Administration's (FDA) authority over the manufacturing and importation of food, tightening the control of biological agents under rules by the Animal and Plant Health Inspection Service as well as the Centers for Disease Control and Prevention (CDC), to increase agricultural security both via upgrades at USDA facilities as well as increase security activities, and also to address the penalties in regards to agroterrorism. The FDA was also told to create or update rules regarding the registration of food processors, notice prior to importation of foods, detention of imported contents, and how they kept their records regarding all of this information. The Homeland Security Act of 2002 also included new policy guidelines regarding agriculture in the post-9/11 United States. It addresses the personnel and responsibility of agricultural border inspections from the USDA to DHS, and also discusses the possession of the Plum Island Animal Disease Center in New York from USDA to DHS. In 2003, the Customs and Border Protection cross-training initiative called for the training of personnel to be able to perform inspections in customs, immigration, and agriculture equally. This was not looked upon favorably by the USDA and other agencies. Because of this, the DHS created a group of inspectors called "agriculture specialists." This very well-trained group undergo an eight-week long training program as well as a two-week long law enforcement training.

As discussed in other chapters, the mechanisms to which an enemy or criminal may try to cause destruction, either against humans or agriculture, vary widely. Due to this wide variation, it is difficult to come up with just one simple standard protocol to follow when dealing with crops or livestock. To further complicate things, when we look back to history for answers, what acts were actually carried out versus what acts were thought to be a hoax seem to have an ill-defined line, and as such, a moderately ineffective response.

Concepts in Agroterrorism Policy Countermeasure Development

If we review the current U.S. national strategy on counterterrorism,[7] we can gain some insight on how best to create a policy regarding agroterrorism. The current policy on terrorism in general can be summarized by several key tactics. First, know your terrorist adversary. In order to most effectively deter or defeat your enemy, you must know what drives them towards their cause. Second, you must prioritize both threats and resources to deal with those threats. It is important to have a team not only to identify suspected threats, but to be trained on how to risk stratify the potential threats and then how to apply the necessary resources for threat mitigation. There is no individual too important or too ground level to be exempt from proper training on threat identification. Third, the current bioterrorism policy further touches upon this idea by discussing the need to modernize and integrate a broader set of United States tools and authorities for counterterrorism and to protect the homeland. Fourth, the new policy requires threats to be pursued to their source – do not stop investigations until the question of the origin of the threat is answered. Fifth, once the threat is discovered, you must isolate terrorists from financial, material, and logistical sources. Without the proper resources, it is difficult for a terrorist individual or group to carry out their efforts. Sixth, we must focus on protecting the infrastructure and enhancing preparedness through a unified front. Infrastructure in the United States is both owned by the government and by private sources. Regardless of ownership, proprietors must be ready for and aware of possible threats since they will be on the front lines. By integrating and improving the preparations for such events through all sectors, both governmental and private, we establish a unified coordinated force to effectively deter and respond to attacks. Seventh, it is important to be aware of mechanisms for radicalization and recruitment of individuals to the terrorist organizations. Knowing the inside workings of these factions will help us to best defend ourselves not only by discovering future threats, but learning the type of individuals that are being targeted. Lastly, but certainly not least, it is important to work with international partners and to share intelligence in order to create a broader network for more rapid and efficient threat detection.

In adopting these current national terrorism policy key tactics to an effective policy on agroterrorism, while the tactics are mostly self-evident, the tactic of understanding who or what organizations are the key threats in agroterrorism and what their rationale is, needs further exploration. All other tactics, given the unique and diverse nature of the Agricultural industry, are based on our understanding of the leaders and their organization behind the threat. As such, our approach through all other tactics will vary depending upon the rationale and desired outcome of the perpetrator. According to Haralampos Keremidis, et al, “Historical Perspective on Agroterrorism: Lessons Learned from 1945 to 2012,” we can classify the attackers within one of following four groups: apocalyptic sects, lone wolves, political terrorist groups, and religious terrorist groups.[8] The specific motives of these groups vary a great deal, but there is one thing they all have at their core – their willingness to do anything, including the use of biological weapons in order to cause changes in the opposing society. In their minds, acts of terrorism that can cause death, fear, or disruption of a society is the best way to reach their goal, making the agricultural industry a unique and important target.

In general, apocalyptic groups believe that the end of days is near and that God himself is giving them orders to act. Groups like these usually are orchestrated by narcistic, but charismatic leaders who isolate their followers from the rest of society. Lone wolves can have many different motives, including political and religious.[9] This group is difficult to prepare for, since it is just one individual with an unknown motive, that individual may easily slip under the radar. However, lone wolves do usually share radical political or religious beliefs with others in society. Political terrorist groups are groups of individuals that carry out attacks with some type of extreme political agenda at their core. Radicalization in political activism is something that needs to be addressed. For example, ecoterrorists and animal rights activists have directed their energy towards attacks on agricultural infrastructure, usually involving violence or vandalism instead of the use of biological agents. Religious terrorist groups carry out terrorism against individuals of opposing religious beliefs because in their minds, their own religion is the only religion. Al-Qaida is an example of one of these groups. While they do at times target the agricultural industry, they typically seek to acquire weapons in order to complete their mission.

If the individual or organization causing the harm is doing so to create some type of “Awareness,” the act may be brought out into the open sooner rather than later.[10] If the goal of the terrorists is to cause more destruction rather than awareness of a particular cause, then a “successful” attack could be one that causes destruction without anyone realizing an attack actually took place. Because of these two extremes, the best way to create policy is to further divide these groups by their actions. The group where the main goal is “awareness of cause” (we will call this group “Awareness”) and the group where destruction is the main goal (we will call this group “Destructive.”) Traditionally, “Awareness” group would be the easier attacker to address. We will start by discussing this group.

Group “Awareness” is defined as an individual or group whose main objective is to create awareness about a particular cause or “injustice” that they believe exists through an attack. Harm to individuals or groups is not the main objective.[11] These groups want their actions known to make the victims “aware” of what they feel are wrongdoings towards the group or “cause” that they represent. You can further classify this group into individual attackers who may represent an individual cause, or group attackers who represent the cause of a nation or particular group. An example of an “Awareness” type group of can be found in a the group known as the “Breeders” who claimed to have bred and spread Mediterranean fruit flies (medflies) in protest to the widespread spraying of the insecticide malathion.[12] This group became known when they threatened that if this new insecticide was released in California in order to combat the medfly damage on local crops, that they would then release their own bred medflies into the population as protest.[13] Although there was a larger than expected influx in medflies during that season, there was not sufficient evidence to show that this terrorist group was the cause.

The next group of agroterrorists, labeled the “Destructive” group, is defined at the group or individual who carry out attacks in order to cause harm to individuals or nations.[14] These groups can have some overlap with the “Awareness” group, wanting their cause to be publicly known, but their main objective is still destruction of opposing groups or individuals. Al Qaeda was a prime example of a terrorist organization that fell into this group. Although they did not carry out an attack on agriculture to our current knowledge, amongst other information gathered from raids the war in Afghanistan, was a book titled *The Prisoner’s Handbook*, which is a pamphlet published right here in the United States that gives extensive details on how to make plant- and animal-derived poisons and to use them for attack purposes.

Local Agroterrorism Response Considerations in Policy Development

From a local perspective on agroterrorism, it may seem that public health officials would be the leaders for responding to an attack on local food supply. However, many state laws require that any agroterrorism events will be handled just like any other crime investigation, putting local law enforcement on the front lines of the attack. Similar to a chemical, biological, radiological or nuclear event, according to research carried out by the National Institute of Justice, the first objective of local law enforcement would be to create and enforce a strict quarantine zone around the area that is affected by the attack.[15] For example, quarantine from a case of foot and mouth disease would roughly cover a six-mile radius and 113 square miles. Quarantine would also have to be enforced for a minimum of 30 days. The next task on the agenda of local law enforcement would be to perform statewide roadblocks to keep the disease contained. Along with state highway patrol, police would stop vehicles at each roadblock, turning vehicles around that have had contact with livestock from the affected area. Some vehicles would be tested for the offending agent on the spot, whereas other vehicles would be sent back to the origin area for testing. In the case of semitrailers, some of them may be allowed to detach their trailer, which would be held to be tested while the cab was decontaminated. Passenger cars would be stopped, and the operators would be interviewed to determine if they had traveled through the affected area or not. Both the vehicle and occupants would have to be decontaminated to minimize transmission risk. In addition, local law enforcement would also be responsible for the investigation of the crime scene until a federal agency were to arrive. This would include the collection of tissue from affected animals, as well as an attempt to identify any suspects responsible for the attack.

Given the complexity of the containment of the response, roles of personnel before an agroterrorism event must be previously established. This also includes who would be responsible for potential disposal of affected animals in the area. Local law enforcement should understand how to work with local livestock producers to gather intelligence on vulnerable farms and feedlots. Once roles have been established, as with mass casualty responses, the established responding agencies, including the local sheriff, farmers, ranchers, truck drivers, meatpackers, feedlot owners, and any additional members of the foot supply chain in that particular jurisdiction, need to create a working group and training protocols to prepare for potential agroterrorism events. Setting up meetings with local livestock association chapters as well as other industry groups will encourage the exchange of ideas that will put the local government at an advantage should such an attack occur. In addition, law enforcement should establish good working relationships with local veterinarians and animal and plant health inspectors.

Discussion of possible threats, roles of personnel, and policy brings us to an important question. How do we make medical threat reduction a policy issue, and not just a public health one? In order to do so, the cost of medical threat reduction would have to be far less than the cost of medical treatment should an attack occur. In other words, the preventive method whether it be a vaccine, antibiotic, antiviral, or similar would have to have such a small cost that it would be a fiscally irresponsible not to add it to the requirements of a personal yearly physical. If we look at what vaccinations are recommended by the CDC as we age, annual flu vaccine, DTaP, MMR etc., these vaccines became policy because the repercussions of not getting the vaccine outweighed the cost of developing and administering the vaccine itself.[16] The cost to society of things like the measles, pertussis, and even the flu is so much of a burden that making their prevention part of medical policy made sense. Although many threats to agriculture would not necessarily involve human disease, increasing research for new vaccines or drugs to veterinarian care regimes would greatly eliminate the number of possible vectors or diseases that could be used in a successful agroterrorism attack. Decreasing the threat means decreasing not only the costly project of recovering after an attack has been carried out, but also decreasing the threat to our nation – the foundation of deterrence.

Agroterrorism Deterrence Policy and Employment

Over the years, there has been countless hours of research and strategy on how to employ terrorism countermeasures. In combating agroterrorism, one of the most effective countermeasures that should be employed is “strategic deterrence.” Strategic deterrence was defined by U.S. Air Force General John E. Hyten as "integrating all capabilities in all domains across all of the combatant commands, government organizations and alongside U.S. allies."[17] While he discussed deterrence mostly in regard to dealing with nuclear threats, the practice of strategic deterrence can still be used as a defense for agroterrorism. Maintaining a constantly evolving technology in both the research of potential causative pathogens and modes of transmission as well as encouraging new innovations to combat such threats would be at the forefront of this tactic. As such, in order for strategic deterrence to work, the technology on the side of the defense has to be ever evolving and always one step ahead of the attacker. Ultimately, deterrence is meant to sway would be terrorists from actually going through with their destructive action. One problem with the use of strategic deterrence though, is the assumption that the attacker is in rational mind. If the use of strategic deterrence were carried out correctly, the cost and effort it would take to surpass the barriers put into place would not be justified by the terrorist. However, if the terrorist has their mind set on doing whatever it takes to accomplish their goal, there is no amount of deterrence that will keep them from pursuing their action.

One particular U.S. governmental organization that is working particularly hard towards protecting the food and water systems is the Auburn University Food Systems Institute (AUFSI) Food and Water Defense Working Group. The group goal is to identify threats to the food and water systems of the United States by developing detection and mitigation techniques and strategies that can be used by corporations, commodities, and utilities. Once these threats are identified and mitigation strategies are developed, the group will disseminate that information to the corporations, commodities, utilities, and also to the general public unless notifying the public would cause further negative effects. As stated by Bob Norton, the chairman of AUFSI, "Threats are not static. They evolve, so the solutions of today might not be appropriate tomorrow. We have to constantly examine the nature of threats and develop robust and adaptable strategies that can be used to counter the threats we identify."[18]

The AUFSI prides itself on being unique compared to other organizations, taking an approach based more on intelligence above all else. What they plan to do is to gather data on potential threats by having a close working relationship with relevant governmental agencies, both at the federal and local level, as well as the Information Sharing and Analysis Centers (ISACs), which are tasked with providing information gathered on threats that involve critical infrastructure. There are a total of 18 ISACs that facilitate the sharing of information between both the public and private sectors of business. One of the goals of AUFSI is to be an advocate for corporations in the food and agriculture sectors, which is a very important and necessary goal to have in today's current hostile climate. Another activity for this group will be to create customized "threat assessments" for specific companies and utilities.

In addition to the work primarily driven by the AUFSI, the policy development on agricultural terrorism post-9/11 has driven the development of new guidelines that better delegate tasks to be carried out if an agroterrorism attack were to occur. In June 20, President Donald Trump signed the Securing Our Agriculture and Food Act.[19] This act formalized multiagency cooperation to protect food and agricultural systems from agroterrorism attacks.[20] One example is the Strategic Partnership Program Agroterrorism Initiative, which is a collaboration of the USDA, FDA, Federal Bureau of Investigation, and DHS.[21] This initiative establishes "centers of excellence," in order to quantify and then correct vulnerabilities that currently exist in the agricultural field.[22] These centers of excellence are modeled after the DHS Fusion Center Network, which are state-owned and operated centers that serve as focal points in states and major urban areas for the receipt, analysis, gathering and sharing of threat-related information between federal, state, local, tribal, territorial, and private sector partners. In addition to this new legislative push to correct vulnerable agricultural soft targets, a National Bio and Agro-Defense facility is also being constructed on the Kansas State University campus, at a cost of $1.25 billion, with the sole purpose of researching how to fight agroterrorism threats.

In addition to the efforts by U.S. based organizations and the U.S. government to combat a potential agroterrorism act, our international partner, the World Health Organization (WHO), mitigates attacks and coordinates responses by using resources from the Global Outbreak Alert and Response Network (GOARN).[23] GOARN was established by the WHO to engage the resources of technical agencies beyond the United Nations for rapid identification, confirmation, and response to public health emergencies of international importance. It currently comprises more than 250 technical institutions and networks (and their members) across the globe. These partners include medical and surveillance initiatives, regional technical networks, networks of laboratories, United Nations organizations (e.g. UNICEF, UNHCR), the Red Cross and Red Crescent Societies, international humanitarian non-governmental organizations, and national public health institutions. Through GOARN, these organizations can pool their resources rapidly to assist affected countries seeking support.

Role of The Department of Defense in Agroterrorism Policy

The specific role of the military in an agroterrorism situation is not currently as established as we would like. According to John Grote Jr., et al, in "Agroterrorism: Preparedness and Response Challenges for the Departments of Defense and Army,"[24] the role for the DOD in an agroterrorism attack specifically is ill defined due to lack of a single document that outlines the specific responsibility of the DOD in such a situation. However, in 2006, the DOD entered into a Memorandum of Agreement with the USDA. This agreement outlined the support that would be provided to the USDA's Animal and Plant Health Inspection Service (APHIS) for a response to diseases of animals. Under the USDA, APHIS has the main responsibility to plan for and coordinate the federal response to any animal disease emergencies. While this is a step in the right direction, this plan is limited in its scope to the provision of veterinary officer support to the USDA at both the national headquarters and at the site where the attack took place. At these locations, the DOD is mostly limited to support with security and to assist with herd culling and the disposal of deceased animals.

Although agroterrorism response is not a primary focus of the DOD, there is opportunity and precedence to partner with the national response network given the DOD's terrorism and mass casualty response expertise. U.S. Northern Command has participated in a series of agroterrorism response exercises, although at a limited scale. High Plains Guardian, an exercise that was conducted in 2004 by the National Agricultural Biosecurity Center at Kansas State University, provided a number of "lessons learned" that could help guide and facilitate the DOD in such an event. The Grote article offers great clarification on these "lessons learned" including the key issues and potential resolutions to identified issues. During these exercises, some of the key issues that were discovered included confusion between multiple jurisdictions, security issues with enforcement of a USDA declared quarantine, vehicle availability, and even confusion between responding agencies that may inhibit response efforts. To correct these issues, it was proposed that the National Guard be used as a primary resource. State National Guard forces are experienced in cross-border coordination, are familiar with local law enforcement, have a cache of resources available on hand at any given time, and have established facilities throughout the United States that can be utilized. Of course, the mission of the National Guard would officially have to be expanded and the appropriate agroterrorism training would need to be employed, but there is precedence for this expansion, as seen with the establishment of the National Guard's development of its Chemical, Biological, Radiological, and Nuclear (CBRN) Response Enterprise.

The Department of Homeland Security (DHS) published the National Response Framework (NRF) in 2008, replacing the outdated National Response Plan. The NRF is a guide to how the United States conducts all-hazards response. The premise is that the national response is built upon escalating scalable, flexible, and adaptable coordinating agencies to align key roles and responsibilities across the United States. The NRF links all levels of government, nongovernmental organizations, and the private sector for all-hazards response.[25] In 2012, recognizing that a stronger unified response policy to unconventional warfare was needed, the Chairman of the Joint Chiefs of Staff Instruction (CJCSI) 3125.01C, Defense Response to Chemical, Biological, Radiological, and Nuclear (CBRN) Incidents in the Homeland was issued. This instruction provides the U.S. military with operational guidance and instructions for a military response to CBRN incidents in the domestic United States. It assigns responsibilities to the Commander of U.S. Northern Command with concern to CBRN response, with the DOD responsibility falling mostly on the National Guard. Now, as agroterrorism becomes a more prominent policy concern, and as much of the potential forms of attack will be through chemical or biological methods of attack, there is an opportunity for the role of the National Guard's CBRN Response Enterprise to be expanded.

Recommendations

Stronger agroterrorism policy development at the national level is critical to protecting the infrastructure and citizens of the United States. There are several agencies already establishing centers and institutes to address this potential threat and there is already DOD precedence through the National Guard to take a lead role. While there are several issues that are present that need to be overcome to integrate agroterrorism policy into the National Response Framework, these issues can be addressed. Previous institute establishment and policy development has paved the way. In particular, the establishment of the CBRN Response Enterprise within the National Guard and through the work of Auburn University Food Systems institute, the key coordinating agencies have emerged to use as a basis for national policy.

Moving forward, key issues that need to be addressed in creating an effective agroterrorism policy include further military engagement, particularly within the National Guard through the CBRN Response Enterprise, the formation of joint surveillance protocols, and the establishment of formal education initiatives to expand the knowledge base of specific agricultural vulnerabilities and forms of attack. In addition, clear leadership roles within the military and civilian agencies need to be established and relationships need to be fostered. Throughout the collaborative response effort, a focus on understanding potential terrorist individuals and organizations that are potentially targeting the agricultural infrastructure is also critical to policy development. As with every potential threat, a focus on deterrence is crucial, but even more so with agroterrorism.

Unconventional warfare is quickly evolving with the rapid growth of technology and innovation. Planning for future threats is essential for national and military leaders. While historically minimized, agroterrorism needs to be on the forefront of policy development and deterrence priorities to persevere in today's rapidly growing and changing world.

Chapter 8 Notes

1. U.S. Senate, "Agroterrorism: The Threat to America's Breadbasket," hearing before the Committee On Governmental Affairs, 108th Congress, 1st session, 2003 www.govinfo.gov/content/pkg/CHRG-108shrg91045/html/CHRG-108shrg91045.htm

2. P.C. Yang, R. M. Chu, W. B. Chung, H. T. Sung, "Epidemiological characteristics and financial costs of the 1997 foot-and-mouth disease epidemic in Taiwan," (1999) *Veterinary Record* vol. 145, pps. 731-734.

3. Claire Bates, "When foot-and-mouth disease stopped the UK in its tracks," *BBC News Magazine*, available at www.bbc.com/news/magazine-35581830.

4. Presidential Policy Directive 21, "Critical Infrastructure Security and Resilience," Feb. 12, 2013, available at https://obamawhitehouse.archives.gov/the-press-office/2013/02/12/presidential-policy-directive-critical-infrastructure-security-and-resil.

5. Jim Monke, "Agroterrorism: Threats and Preparedness," *CRS Report for Congress DL32521*, March 2007. Retrieved Jan. 2, 2020, from https://fas.org/sgp/crs/terror/RL32521.pdf.

6. White House, "National Strategy for Counterterrorism," October 2018. available at www.whitehouse.gov/wp-content/uploads/2018/10/NSCT.pdf.

7. Haralampos Keremidis, Bernd Appel, Andrea Menrath, Katharina Tomuzia, Magnus Normark, Roger Roffey, Rickard Knutsson. "Historical Perspective on Agroterrorism: Lessons Learned from 1945 to 2012," *Biosecurity and Bioterrorism: Biodefense Strategy, Practice, and Science*, vol. 11, no. S1, Aug. 24, 2013, available at https://doi.org/10.1089/bsp.2012.0080.

8. Ibid.

9. Ibid.

10. Ibid.

11. Jennifer L. O. Sheer, "Breeders: A Case Study. Monterey WMD-Terrorism Database Staff," *Encyclopedia of Bioterrorism Defense*, July 15, 2011. https://doi.org/10.1002/0471686786.ebd0019.pub2

12. Arnold M. Howitt, Robyn L. Pangi, *Countering Terrorism: Dimensions of Preparedness*" (Cambridge, Mass.: Massachusetts Institute of Technology Press, 2003).

13. Haralampos Keremidis, et al, "Historical Perspective on Agroterrorism."

14. Glenn R. Schmitt, "Agroterrorism: Why We're Not Ready: A Look at the Role of Law Enforcement," *National Institute of Justice Journal*, Issue 257, June 2007, available at https://nij.ojp.gov/topics/articles/agroterrorism-why-were-not-ready-look-role-law-enforcement.

15. Sachiko Ozawa, Allison Portnoy, Hiwote Getaneh, Samantha Clark, Maria Knoll, David Bishai, H. Keri Yang, Pallavi D. Patwardhan. "Modeling the Economic Burden of Adult Vaccine-Preventable Diseases in the United States," *Journal of Health Affairs*, vol. 35, no. 11 (2016): pps. 2,124-2,132.

16. Terri Moon Cronk, “Strategic Deterrence More Than Nuclear, Stratcom Commander Says,” *Department of Defense News*, April 4, 2017, available at www.defense.gov/Explore/News/Article/Article/1140561/strategic-deterrence-more-than-nuclear-stratcom-commander-says.

17. Auburn Food Systems Institute, Food and Water Defense Group, Auburn, Ala., available at https://aufsi.auburn.edu/food-defense.

18. House Resolution 1238 – Securing Our Agriculture and Food Act, 115th Congress (2017-2018), available at www.congress.gov/bill/115th-congress/house-bill/1238/text.

19. Jacqui Fatka, “Agro-terrorism bill signed by President,” *Feedstuffs*, July 5, 2017, available at www.feedstuffs.com/news/agro-terrorism-bill-signed-president.

20. *Strategic Partnership Program Agroterrorism Initiative: Second Year Status Report July 2006 - September 2007*, available at www.fda.gov/food/food-defense-programs/strategic-partnership-program-agroterrorism-sppa-initiative-second-year-status-report-july-2006.

21. “Disruptive by Design: Why We’re Not Ready to Fight Agroterrorism,” *Signal*, Oct. 1, 2017, available at www.afcea.org/content/disruptive-design-why-were-not-ready-fight-agroterrorism.

22. Glenn R. Schmitt, “Agroterrorism: Why We’re Not Ready.”

23. Col. John H. Grote Jr., MS, John J. Fittipaldi, ODASA, *Agroterrorism: Preparedness and Response Challenges for the Departments of Defense and Army*, (Arlington, Va.: Army Environmental Policy Institute, May 2007), available at www.hsdl.org/?view&did=478445.

24. Department of Homeland Security, National Response Framework, January 2008, available at www.fema.gov/media-library/assets/documents/117791.

25. Chairman of the Joint Chiefs of Staff Instruction 3125.01C, “Defense Response to Chemical, Biological, Radiological, and Nuclear Incidents in the Homeland” (Washington, D.C.: Department of Defense, June 4, 2012), p. 1.

CHAPTER 9

Agroterrorism By Other Means: The Interconnectivity of Critical Infrastructures

Dr. Robert A. Norton and Greg S. Weaver

Concern about the potential effects of agroterrorism on animal and plant agriculture, as well as the safety, security and wellbeing of our nation and economy dramatically increased in the wake of the attacks of Sept. 11, 2001. The subsequent anthrax attacks also firmly influenced the definition of agroterrorism. The Congressional Research Service (CRS) noted, "… agroterrorism is defined as the deliberate introduction of an animal or plant disease with the goal of generating fear over the safety of food, causing economic losses, and/or undermining social stability."[1, 2]

Plant and animal products make up the food supply, which appears a constant to many in most developed nations and especially the United States. The last time malnutrition affected large portions of the United States was during the Great Depression (1929-1941). In that particular instance, the driving factors for malnutrition were poverty, as well as poor farming practices and weather impacts (drought) that lead to significant crop failures.

These same factors, along with war have throughout history proven to be precipitating events inexorably leading to hunger, and in worst cases, starvation. Unfortunately, an increasing number of Americans lack an understanding of how agricultural products (plants and animals) are converted into food. This conceptual disconnect between agriculture and the food supply increases risk, because it can carry through to planning and legislation. Agriculture is food and food is agriculture, domains that are intermeshed and inseparable. When one is imperiled, so are both.

Agriculture creates the inputs to the food supply, whereas the food processing industries produce the outputs that must then be delivered to the consumer through logistics, involving warehousing and transportation. The input and output rates must be harmonized for the food supply to remain available to the consumer. In the simplest terms, agriculture and food processing can be described as complex systems of intermingling systems and subsystems – A "system of systems" (SoS), which is defined as "a collection of systems, each capable of independent operation, that interoperate together to achieve additional desired capabilities."[3] Disruption at any point (i.e. single point of failure) or time, can thereby potentially cause delays in the delivery of food products to the consumer.

Food doesn't disappear when process or logistical delays occur, but its local availability, nutritional value, palatability, safety, and spoilage rate can be dramatically and deleteriously affected.

Agriculture and food are sectors classified as critical infrastructure sectors, as first defined by Presidential Directive-7: Critical Infrastructure Identification, Prioritization, and Protection[4] and subsequently superseded by Presidential Policy Directive-21 (PPD-21).[5] Beyond being tightly connected, food and agriculture are also highly dependent on many of the other critical infrastructures (CIs). Dependencies and connectivity between CIs likewise create an even more highly complex SoS, which when working correctly helps drive efficiency, lower food prices, and help drive a strong economy.

A viable and ever-available food supply also dramatically impacts the health and general welfare of our population. With the interdependencies, also comes risk. Negative effects that begin in one sector can rapidly proceed through or to other CIs causing cascading effects. A cascading effect can be thought of as a single point failure that spreads and magnifies its effects as it moves through other subsystems, causing a larger system failure or failures across multiple systems.

Closer examination of agriculture and food is necessary to more fully understand how cascading effects could be used to advantage by adversaries. As indicated, the food supply is the result of a long series of processes, which start even before an agricultural output (i.e. plant or animal) is grown. The land has to be prepared, using tractors and other equipment that are increasingly guided by the Global Positioning System (GPS). Productivity in agriculture is increased through "precision agriculture,"[6] whereby the rates and location of application of agricultural chemicals, including fertilizers, herbicides and pesticides used on row crops (e.g. corn, soybeans, etc.) are also made possible by GPS.

Pasture and grazing land are likewise treated in many parts of the United States according to exact standards of application for agricultural chemicals, again aided by GPS. Disruption in the availability of GPS would not end the ability to grow row crops, but would significantly complicate farming, potentially causing error in the application of farm chemicals or causing delays in delivery of row crops to grain markets. An attack or coordinated series of attacks on the GPS could cause significant economic impact.

Once grown, grain (e.g. corn, wheat) and other row crops (e.g. soybeans and other legumes), either go directly into the human food chain, or indirectly to humans through its use as animal feed in the production of animal protein (beef, poultry, pork, and fish), or animal protein products (e.g. eggs, milk and milk products). Hay, grass, and silage has to be converted by ruminants (cattle and sheep), before it can be converted into animal protein or animal protein products. Again, here there is potential for negative economic effects caused by delay, if for example the grain products used for animal feed were less available in the quantities needed.

Agroterrorism by current definition can occur at any phase of animal and/or plant production, prior to the arrival of those agricultural outputs to the food processing and packaging systems. Adulteration of the live agricultural outputs (animal or plants) with a pathogen or chemical is by default, agroterrorism, whereas adulteration of an agricultural commodity or food product (animal or plant), occurring within the varied cycles of food processing, transportation and delivery would be defined as bioterrorism. For simplicity sake, agroterrorism will be considered here as a subset of bioterrorism.

The current context of bioterrorism/agroterrorism includes the deliberate introduction of pathogens to plant and animal production systems. Of particular concerns are the Category A, B and C designated agents, which vary in their potential for dissemination. The most serious of the categories are those designated as Category A diseases or agents that can be easily disseminated, result in high mortality, "…have the potential for major public health impact" and "…might cause public panic and social disruption…"[7]

Contrasting the list of bioterrorism agents, are those pathogens categorized as "reportable and foreign animal diseases."[8] As implied, foreign animal diseases (FADs) are those agents not currently present in the United States. Disease outbreaks on this list, if detected anywhere in the world must be reported to the World Organization for Animal Health (OIE).[9] The OIE, which includes membership by more than 160 countries is the global repository of animal disease information related to outbreaks, distribution, animal trade standards, and validated laboratory testing methodologies. Additionally, OIE provides approved protocols for the treatment of diseases, as well as best practice guidelines for the prevention and control of their focus animal diseases.

Some of the FAD agents are duplicative to the CDC's bioterrorism/agroterrorism categories list (e.g. brucellosis), while others are not (e.g. scrapie).[10] FADs have the potential for causing significant mortality and also can potentially necessitate large-scale depopulation of the affected animals. Mandatory reporting of a FAD to the OIE is usually accompanied by significant impacts on agricultural trade, which in turn can potentially lead to severe economic impacts, particularly if the disease spreads to even moderately large numbers of animals.

Like the Select Agents included in the CDC list, FAD agents could be spread by an adversary as part of a large biological attack, or as part of an economic warfare campaign, which can be considered a biological agent attack designed to cause trade disruption and thereby provide trade advantage to the adversarial nation or group. Although, many of the FAD pathogens are not zoonotic, if intentionally dispersed either spatially or temporally, the challenge to the federal government in detection and diagnosis, containment, carcass disposal and remediation would be massive and potentially magnitudes more complex than anything encountered to date in natural disease outbreaks.

The financial, psychological or emotional toll and political fallout from such a deliberate event is likely also to be massive, given the historical experiences that accompanied the naturally occurring foot and mouth disease outbreak in the United Kingdom in 2001.[11] Today, the federal government's emphasis remains primarily focused on the detection, containment, and remediation of pathogenic agents. Although, deliberately dispersed agents can potentially cause of primary effects, (i.e. morbidity and mortality), other equally devastating secondary (economic, trade disruptions, etc.), and tertiary (e.g. suicide, health, and welfare, etc.) effects, can also occur. The economic impacts of the latter two may be greater than the direct costs of the actual outbreak.

Same Effects. Different Means

As a thought exercise, suppose a different type of terrorist attacks occurred on 9/11 and its aftermath, where other types or forms of "terrorism" had been used by al-Qaeda instead of airplanes crashing into buildings. Suppose for instance an attack on the power grid or banking system had occurred. If another kind of attack (i.e. non-bioterrorism/non-anthrax) had been experienced following the plane crashes in New York City, Washington, D.C. and Shanksville, Pa., would we still look at the threat of bioterrorism/agroterrorism in the same way? Possibly not.

The question then arises as to whether the end effects of different types of attacks could be similar or the same, if projected onto U.S. agriculture. In other words, could the social, political, psychological, and economic impacts commensurate with a biological attack be achieved by an adversary, who chose to attack the United States in a different manner? In an increasingly interconnected world, where technology touches all phases of our lives, the answer may be evolving along with the technology. Given that, should we now ask whether the societal effects of bioterrorism/agroterrorism could occur without the pathogen?" Could new or evolved adversaries develop new and thereby unanticipated attack vectors to virtualize agroterrorism? Is virtualized agroterrorism more dangerous to our nation?

Thinking Adversaries

Thinking adversaries evolve in planning attack operations, driven in part by the detection and defensive capabilities of those being targeted. The United States massively mobilized and modified the intelligence and military responses after 9/11. The intelligence community (IC) was dramatically reorganized and other government agencies also evolved to serve the perceived needs of national security. This process continues to evolve even today.

Accompanying the early stages of IC reorganization, decisionmakers may also have begun to modify their view of agroterrorism, as evidenced by the Congressional Research Service report titled, *Agroterrorism: Threats and Preparedness*,[12] which states, "An agroterrorist event would **usually** (emphasis added) involve bioterrorism, since likely vectors include pathogens such as a viruses, bacteria, or fungi. People more generally associate bioterrorism with outbreaks of human illness (e.g., anthrax or smallpox), rather than diseases affecting animals or plants. … The goal of agroterrorism is not killing cows or plants. These are the means to the end of causing economic crises in the agricultural and food industries, social unrest, and loss of confidence in government."[13] The language offers evidence of a subtle, but important intellectual shift, implying perhaps there may be instances when bioterrorism/agroterrorism do not involve pathogens.

The CRS Report lists potential economic consequences including, lost revenue associated with the destruction of diseased or "… potentially diseased products …," lost export markets, the economic ripples into "… agriculturally dependent businesses (farm input suppliers, food manufacturing, transportation, retail grocery, and food service ...," as well as tourism, and the governmental (federal and state) costs of eradication, containment and compensation to affected producers.[14] Again, are there ways that an adversary could accomplish at least some of these goals, without the use of an actual pathogens? Three hypothetical scenarios will be used to further posit the question.

Disruption Scenarios

Special attention is paid here on the background for *Disruption Scenario 1,* "The Seven Sisters," which will be described in more detail below. In this scenario the agent in question is real, but its use live animals or food is not. The adversarial strategy in this example is to use a massive hoax, designed to cause the previously described damages to the economy, disruption of export trade and erosion of public trust in government. This is also an example of information warfare (IW), where social media could be used as the weapon of first choice to spread misinformation (mistaken) and disinformation (intentionally false), so as to stoke panic. The vector for this attack is a lie. This could also potentially be considered hybrid warfare, or as Russian General Valery Gerasimov described it – "Non-Linear War."[15]

In this hypothetical scenario, the agroterrorism agent is a prion. Prions are aberrant proteins that become infectious particles, which if ingested are capable of causing a group of inevitably fatal neurodegenerative diseases in humans and animals.[16] The specific mechanisms by which prions cause disease are not yet fully understood, perhaps an advantage to the adversary operating an IW mission. Suffice it to say, prions have several features that could be exploited to advantage by adversaries wishing to target U.S. animal agriculture, or more directly the actual food supply.

These include:

1. Difficulty to detect infection until manifested during early stages of neurodegenerative disease in animals or humans.

2. Prions are not destroyed by the conventional means used to ensure feed and food safety during processing (e.g. cooking, sterilizing, microwaving, or canning), or even burning, if incineration is not complete.

3. Resulting disease from ingestion or inhalation can take months to years to be manifested. The negative public health and general welfare effects could be significant, if the resulting neurodegenerative diseases became widespread,[17] the psychological effects, also potentially massive and profoundly long-lasting.

Terrorism Scenarios

Terrorism scenarios can be broadly categorized as occurring in two forms, which we shall coin as, "a – monster scenarios" – where the effects of the attacks are manifestly evident, and "b – ghost scenarios" – where the effects of the attacks intentionally remain hidden until manifested at some later time. The effect of a monster scenario is more immediate. A bomb is planted and then shortly explodes killing or maiming. In terms of agroterrorism, an anthrax attack on a herd of cattle could be considered an example of a monster scenario. The herd is intentionally infected by some means (e.g. aerosol) with *Bacillus anthracis*, the causative agent of anthrax in animals and humans, become sick, one to seven days later, (depending on the dose, pathogen strain and other factors), when pulmonary (of the lungs) anthrax[18] is clinically manifested.

The potential psychological effects and social effects – widespread panic and resulting fear of a monster scenario is also relatively rapid, manifesting shortly after the first animals or people become sick. The attacks on 9/11 were also a monster scenario – the terror was rapidly apparent.

On the other hand, ghost scenarios are more surreptitious, intentionally more insidious, where the disruptive psychological and social impacts are protracted and therefore magnified because they remain hidden. Tension continues to build because any particular moment can bring death and destruction – or not! In a ghost scenario, people are not likely to know initially whether they or the animals they have consumed were infected with some agent, since the manifestation of the potential disease has not yet occurred.

Prions are the Golems of terrorism, half monster, but also half ghosts, largely hidden and silent until they begin to kill. The mere mention of prions can promote fear, if people believe they have ingested them. If used as a biological weapon, they infect and lay dormant, until the moment neurological effects are first detected, which could potentially be years. Chronic wasting disease, is an example of a prion disease that occurs in deer, elk, and moose.[19] Bovine spongiform encephalopathy, (BSE), or "mad cow disease" is another example.

Detection of prion diseases are further complicated because they are a multi-agency problem. As CDC points out, the action plan for detection and diagnosis for humans resides with the Department of Health and Human Services and has four major components.

These include:

- Surveillance for human disease is primarily the responsibility of CDC
- Protection is primarily the responsibility of the Food and Drug Administration (FDA)
- Research is primarily the responsibility of the National Institutes of Health (NIH)
- Oversight is primarily the responsibility of the Office of the Secretary of DHHS[20]

Detection of prion diseases in farm cattle on the other hand resides in the U.S. Department of Agriculture, which collects more than 40,000 samples from cattle annually.[21, 22] Carcass disposal in any large-scale animal disease event is logistically complex and very expensive. All procedures for disposal have to be conducted in a way to prevent further spread of the disease agent. Disposal of carcasses from animals infected with prion diseases are particularly problematic. USDA recommends alkaline hydrolysis as the means for disposal. Although, effective in destroying the prion agent, the process is slow, expensive and the equipment involved limited in capacity, making it unsuitable for large-scale events involving many animals.[23]

Large-scale intentional contamination of animals by prions would be difficult, but not impossible, the discussion of which is beyond the level of sensitivity and scope of this chapter. prions are a potentially effective threat agent that could be used in coordinated adversarial information warfare and psychological operations, designed to foster panic and distrust in the government. psychological operations (PSYOPS) have been used to effect by the United States, China and Russia seeking to influence foreign audience perceptions and behavior. In this way prions become more effective because of their asymmetric potential, rather than through the effects of actual agents of disease. Perceptions rather than realities could, as they often do, prevail if adversaries carefully chose their targets and present a plausible threat scenario.

Perhaps surprisingly, weaponization of prions was openly posited by Lt. Col. Jennifer Snow, Dr. James Giordano, and Joseph DeFranco, in the May 9, 2019 post on the *Mad Scientist Laboratory Blog*.[24]

The editor of the blog stated of the post, “Their post sounds a loud and clear klaxon for both the national defense and medical research establishments regarding the possible weaponization of prion diseases and the associated potential for sowing widespread fear across national populations, disrupting global markets, and generating enduring multi-domain, multi-dimensional adverse effects! As Geena Davis tells Jeff Goldblum in the 1986 horror classic, *The Fly*, “Be afraid, be very afraid.” Snow, Giordano and DeFranco indicate, “Thus, to date, prion research has mostly been conducted in general laboratory spaces that are not under federal or international surveillance or bioweapon reporting standards and dictates. However, ongoing developments in prion research suggest – and we argue, support – that such efforts should be regarded as dual use research of concern (DURC), with accordingly appropriate regulation.” The authors point out how prions could be used as an economic weapon, “…to impact targeted markets or widespread animal resources could prompt public fears and serve to disrupt specific regional or global markets to incur disruptive effect(s) in international or inter-industrial competition or adversarial engagement.”[25]

Disruption Scenarios

Scenario 1: "The Seven Sisters," A Ghost Scenario

In this scenario, the adversarial nation-state has access to prion material in small quantities, combined with sophisticated cyber capabilities. A targeted psyops or disinformation campaign is initiated and sustained using the top social media platforms, (e.g. Facebook, YouTube, WhatsApp, Messenger, WeChat, Instagram, and QQ). The threat message indicates that commercial animal agriculture (cattle – beef and dairy, poultry, swine) had been intentionally contaminated with prions using animal feed as the delivery vehicle at seven unidentified locations in the United States. As supposed evidence of the attacks, actual prion material is sent to seven top media outlets in the United States and the world.

The important element to emphasize here is that the food animal contamination did not actually occur. The only things contaminated by prions were the samples sent to the media outlets. Chaos and panic might be expected to occur as word rapidly spread of the potential attack. People could also potentially lose faith in the safety and security of the food supply, calling to mind the Chinese description of Hell, where a sumptuous feast is laid before the dead, who are not able to eat it. Beyond the ensuing psychological and societal impact, this scenario also quickly bleeds into economic warfare. The economy could potentially be severely damaged is suspect meat and dairy imports were stopped by other nations. Food company stock, particularly those corporations unlucky enough to be included in the hoax could also logically expect negative sales impact, for some period of time. This scenario is particularly problematic, because restoration of confidence might entail proving the negative.

Scenario 2: "The Devil's Triangle," A Monster Scenario

In this scenario, the adversary uses cyber to attack the power grid. The failure of the power grid causes poultry houses, dependent on positive pressure air ventilation systems, designed to help maintain proper environmental temperatures, remove dust, humidity, ammonia, and carbon dioxide (CO_2), to use backup generators necessary to power ventilation fans. This very scenario played out when the Iraqi Republican Guards crossed the Kuwaiti border at 2 a.m. on Aug. 2, 1990. The power grid was targeted and those major trunk lines that served the poultry growing region of Kuwait rapidly failed, were intentionally cut or destroyed. Commercial poultry was grown in environmentally controlled housing in Kuwait. Backup generators were available, but were quickly stolen by the invading Iraqi army. Without the generators and without electrical power from the grid, house temperatures rapidly increased and CO_2 from the respiring broiler chickens rapidly built up and large-scale mortality in the chicken houses started with 30 minutes. Most of the Kuwaiti broiler chickens were dead within a few hours.

Given the scale of broiler chicken production in Kuwait in 1990 was magnitudes smaller than what was then or now produced in the United States, the magnitude of economic damage from an intentional widespread power disruption would be catastrophic today.

The National Chicken Council[26] indicates that currently approximately 30 federally-inspected companies are involved in the business of raising, processing, and marketing chickens. The United States has the largest broiler chicken industry in the world and exported approximately 17 percent of production exported to other countries in 2018.

The social and economic impact of broiler production in the United States is massive (*Figure 1*). Americans consume on average more than 93.5 pounds per capita, making chicken the number one animal protein source. Broiler production is primarily concentrated in the South, dramatically impacting state, and local economies.

Number of slaughter/evisceration plants	180
Number of workers directly employed	355,000
Number of workers indirectly employed	1.2 million
Number of family farms growing broilers and/or producing hatching eggs	25,000
Amount of corn used for broiler and breeder feed	More than 1.2 billion bushels
Amount of soybean (meal component) used for broiler and breeder feed	More than 500 million bushels
Amount of mixed feed used	60 million tons
Wholesale value of industry shipments	$65 billion
Consumer retail expenditures for chicken	$95 billion

Figure 1: Basic economic impacts of the broiler chicken industry in the United States – 2019.[27]

A major disruption of broiler production in the United States would cause devastating effects on the social fabric, public health (due to the necessity of replacing poultry protein with some other form of comparable animal protein – currently unavailable at comparable rates) and economy of the nation. Economic impacts would likely not be limited to the loss of the major animal protein source in the United States or the employment effects on those individuals involved in the production, processing, and transportation of poultry products. Other kinds of cascading effects, would also be expected, such as a competition for replacement equipment.

Cascading Implications of Generator Power[28]

Generators have increasingly become the tool of choice for recovering from short to extended power outages, which in the latter case frequently accompanies natural disasters or critical infrastructure disruption events. There are several cascading issues that tend to be overlooked in these scenarios. In the scenario described, the cyberattack would quickly impact the electrical grid in a widespread area, which in turn would impact poultry housing and eventually the food supply. This scenario does not take into full account the biohazard potential or the costs associated with disposal of dead poultry, which would quickly occur with an extended loss of power, normally used to cool the poultry housing facility.

The manpower and resources that would need to be dedicated to that scenario would be quite substantial. Assuming generators are available, there would be significant limitations, given that many commercial grade generators are not designed for continuous heavy loads for prolonged periods of time (weeks to months). Smaller consumer grade portable generators often have a "mean time before failure" (MBTF) of 500 to 1,000 hours, after which they will need parts or in some cases to be rebuilt, whereas larger commercial may have a longer MBTF.

There are some other upstream and downstream supply chain issues that would contribute to this complex, wicked problem as well. Where is the fuel coming from to support the generators? A major power grid failure would be expected to spread into other areas beyond poultry production areas. If for instance hospitals also experienced problems, would there be sufficient fuel to supply both human and animal needs? Who will be monitoring the generators and repairing them upon failure? Will there be spare parts or actual generators to support the ones that could possibly fail? Will the generators be able to support the electrical load of the entire farm? The implications are quite serious. Lost generators could translate into the loss of millions of chickens. If prolonged, this type of scenario would eventually cause disruptions in the food supply.

Scenario 3: "Phantasmagoria," A Scenario Filled With Many Monsters

In this scenario, the adversary simultaneously attacks all or most of the CIs using an electromagnetic pulse. The Congressional Research Service in a Report for Congress characterized the threat stating, "Electromagnetic pulse (EMP) is an instantaneous, intense energy field that can overload or disrupt at a distance numerous electrical systems and high technology microcircuits, which are especially sensitive to power surges. A large-scale EMP effect can be produced by a single nuclear explosion detonated high in the atmosphere. This method is referred to as High-Altitude EMP (HEMP). A similar, smaller scale EMP effect can be created using non-nuclear devices with powerful batteries or reactive chemicals. This method is called High Power Microwave (HPM)." Additionally, the report indicates, "Several nations, including reported sponsors of terrorism, may currently have a capability to use EMP as a weapon for cyberwarfare or cyberterrorism to disrupt communications and other parts of the United States critical infrastructure."[29]

A July 2017 report from the Commission to Assess the Threat to the United States from Electromagnetic Pulse (EMP Attack)[30] further characterized the threat as "existential" stating:

"During the Cold War, the United States was primarily concerned about an EMP attack generated by a high-altitude nuclear weapon as a tactic by which the Soviet Union could suppress the U.S. national command authority and the ability to respond to a nuclear attack – and thus negate the deterrence value of assured nuclear retaliation. Within the last decade, newly-armed adversaries, including North Korea, have been developing the ability and threatening to carry out an EMP attack against the United States. Such an attack would give countries that have only a small number of nuclear weapons the ability to cause widespread, long-lasting damage to critical national infrastructures, to the United States itself as a viable country, and to the survival of a majority of its population."[31]

Executive Order 13865, dated March 26, 2019, further states, "An electromagnetic pulse (EMP) has the potential to disrupt, degrade, and damage technology and critical infrastructure systems. Human-made or naturally occurring EMPs can affect large geographic areas, disrupting elements critical to the Nation's security and economic prosperity, and could adversely affect global commerce and stability."[32]

So how would such a scenario conceivably play out as an agroterrorism event? The most EMP vulnerable animal production systems include intensive poultry and hog operations, where animals are housed in environmentally controlled facilities. An EMP event would severely damage or destroy the power grid supplying electricity to fans and environmental control equipment, but also controller microcircuits, including emergency generators, instantly making them non-functional. Additionally, a wide-reaching EMP would severely damage communication systems (telephones and cellular phones), as well as electrically controlled water pumps, lighting and the circuitry of vehicles and heavy equipment.

Animal deaths would quickly ensue, given the necessity of continuous air exchange, which reduces the level of CO_2, exhaled by the animals. Animals (e.g. cattle and sheep) housed in pastures and outside paddocks would not be directly affected by an EMP and would be expected to survive. Dairy cows would also survive, but could not be milked, since electronically controlled milking equipment would be damaged or destroyed. The disruption and ensuing animal mortality would be massive. Slaughter of dairy cattle could be anticipated.

Subsequent carcass burial would also be severely delayed, given the electrical circuitry in all heavy equipment located in the affected area(s) would be damaged or destroyed. Heavy equipment and other vehicles (trucks, cars, rolling stock, etc.) would have to be brought in from outside this area or region. Decomposing carcasses would within a short period of time also present a potential significant public health hazard.

Entrance into the affected housing would also present significant danger, given the high concentration of CO_2 and noxious or poisonous gases associated with animal decomposition. Personnel entering such areas without independent oxygen sources would be in significant danger. Gas buildup to potentially dangerous levels would be expected within two hours after the initial event, even if houses were opened to outside air (e.g. doors opened).

Sociological Effects – Fear and Distrust

Noted sociology of law scholar and theorist Donald Black suggests that when viewed as a continuum, terrorism situates between violent crime and war, being similar to yet distinct from the others. This somewhat ambiguous position between the respective institutions responsible for criminal justice and national security no doubt makes prevention and response more complex – and even more so when viewed in terms of critical infrastructure of which the food supply and food supply system is a part. Furthermore, Black incorporates the concept of social geometry to suggest how terrorism arises when social distance exists between groups, particularly those in close physical proximity. Social distance can generate and amplify differences, sometimes to the point of conflict. This conclusion is not surprising, given that many acts associated with terrorism are a reaction to a perceived or a real grievance.[33]

Social distance and associated group differences are also important in terms of the perceived or actual threat of terrorism. For example, in the United States – and particularly following 9/11 – terrorism evokes imagery associated with international groups, as opposed to U.S. citizens or domestic groups, even though the latter is likely a greater risk. In short, whether accurate or not, it is commonly believed that terrorism is more likely to occur by the figurative or literal hand of the "other." Concern does not necessarily align with experience. In terms of intentional adulteration or contamination of food, it is widely accepted that the greatest threat is from insiders. This sentiment is similar to attitudes associated with fear of crime. Despite overall decreases in crime rates since the early 1990s, fear of victimization has remained relatively stable. Furthermore, those persons most fearful of being victimized, namely females and the elderly, are less likely to experience it.[34] Concern about harm by young, male (particularly minority) offenders – again "the other" – is present. Once again, concern is not always consistent with events.

Given it is not necessary to carry out an act of terrorism in order to generate fear and or discord, understanding the relationship between threat actors and the social space is extremely important. Returning to the threat scenarios described previously, the "Seven Sisters" hoax would arguably be, in the short term, incredibly disruptive, but would likely erode quickly with passing time. Potential threats of this nature to the food supply are readily connectable to the daily lives of many, but as time passes, concern lessens. While a very different type of example, it could be argued that concerns associated with "Y2K" at the turn of the century ultimately proved to be exaggerated, recognizing there was no doubt real consequences and economic impact. For the "Devil's Triangle" scenario, the impact would be delayed, yet substantial (as the economic consequences become apparent). The social impact for the "Phantasmagoria" scenario would bring consequences so severe, the nation as a whole would likely rapidly devolve into widespread chaos and anarchy and remain so for an extended period, where hunger and starvation could become the norm.

Conclusion

A great deal of governmental attention has focused on the traditional views of agroterrorism – that being scenarios involving the intentional introduction of pathogens into animal and plant agriculture. Additional governmental emphasis has been and continues to be focused on cyber-related defense issues that largely do not consider potential effects on commercial agriculture, the food processing industry, or the combined impact on the U.S. food supply. Thinking adversaries can be expected to evolve in their strategies to adapt and overcome U.S. civil and military defense capabilities. The successful use of intentionally introduced pathogens into agriculture remains complex for the adversary.

Reasons include:

1. *Biological Agent Volume Requirements* – the availability of a sufficient quantity to enable an effective and widespread attack.

2. *Delivery System Requirements* – The ability to disperse the biological agent sufficiently widely, so as to cause a widespread disease outbreak.

3. *Avoidance of Detection in Stages of Planning Through Execution* – Combined these adversarial requirements significantly increase the likelihood of failure. Thinking adversaries may therefore chose to use different strategies and tactics, particularly those that could be leveraged to achieve a greater likelihood of success.

Alternative scenarios, as discussed here provide advantage because they eliminate these requirements, but also offer the distinct advantage of remote implementation. The risk of preoperational detection in which a cyber-vector is used as the attack mode is likewise dramatically diminished. Remote alternative attack scenarios also circumvent many current governmental, agriculture and food industry detection and response capabilities.

Instilling panic and distrust in the government's ability to protect have been common features in previous conflict and will likely remain primary adversarial goals in future warfare. A safe and reliable food supply is one of the primary requirements for maintaining the health and welfare of any society. The complex system of food production and delivery in the United States is second to none in being to consistently deliver a huge diversity of safe, economical, and readily available food stuffs from farm to fork. However, like any complex system of systems, disruptions can occur. Thinking adversaries will likely seek to find the specific nodes that are most vulnerable and then exploit them to advantage.

The past agroterrorism defense strategy relied upon the early detection of biological agents, the quick containment of disease outbreaks (plants and/or animals), followed by assiduous cleanup and remediation. To a degree those kinds of threats will remain in the future. The future of agroterrorism defense strategy will also need to pivot to better focus on the equally serious possibilities that the adversary of the future will choose a different kind of attack vector, but one capable of causing comparable damages – a virtualized, cyber-agroterrorism attack.

Chapter 9 Notes

1. Jim Monke, "Agroterrorism: Threats and Preparedness" Library of Congress, Washington D.C. Congressional Research Service, (March 12, 2007), www.cdc.gov/anthrax/bioterrorism/index.html.

2. U.S. Department of Agriculture, *Agroterrorism Prevention, Detection, and Response*. Audit Report 61701-0001-21. (Washington, D.C.: U.S. Department of Agriculture, Office of Inspector General, March 2017), p. 1, www.usda.gov/oig/webdocs/61701-0001-21.pdf.

3. MITRE Corporation, Systems of Systems – Systems Engineering Guide, McLean, Va., www.mitre.org/publications/systems-engineering-guide/enterprise-engineering/systems-of-systems.

4. The White House, "Homeland Security Presidential Directive 7," *Critical Infrastructure Identification, Prioritization, and Protection*, (Washington, D.C.: U.S. Department of Homeland Security, Sept. 22, 2015), www.dhs.gov/homeland-security-presidential-directive-7.

5. Presidential Policy Directive-21, Feb. 12, 2013, www.dhs.gov/sites/default/files/publications/PPD-21-Critical-Infrastructure-and-Resilience-508.pdf.

6. For more information on Precision Agriculture see, "Precision Agriculture: NRCS Support for Emerging Technologies," Agronomy Technical Note No. 1., U.S. Department of Agriculture, Natural Resources Conservation Service, June 2007, www.nrcs.usda.gov/Internet/FSE_DOCUMENTS/stelprdb1043474.pdf.

7. Centers for Disease Control and Prevention, Bioterrorism Agents/Diseases, (Atlanta, Ga.: Centers for Disease Control and Prevention), https://emergency.cdc.gov/agent/agentlist-category.asp.

8. U.S. Department of Agriculture, *Notifiable Diseases and Conditions* (Washington, D.C.: U.S. Department of Agriculture), www.aphis.usda.gov/aphis/ourfocus/animalhealth/nvap/NVAP-Reference-Guide/Animal-Health-Emergency-Management/Notifiable-Diseases-and-Conditions.

9. World Organization for Animal Health, www.oie.int/en.

10. OIE-Listed diseases, infections, and infestations in force in 2019 can be found on the OIE website. This list of reportable diseases should not be considered comprehensive, since new and emerging diseases may be added, as the list is updated annually, www.oie.int/animal-health-in-the-world/oie-listed-diseases-2019.

11. For more information on the 2001 UK Foot and Mouth Outbreak, see "Origin of the UK Foot and Mouth Disease," Department for Environment, Food and Rural Affairs. June 2002, webarchive.nationalarchives.gov.uk/20130402184227/http://archive.defra.gov.uk/foodfarm/farmanimal/diseases/atoz/fmd/documents/fmdorigins1.pdf, accessed Aug. 8, 2019; Foot and Mouth Disease 2001, "Lessons to be Learned Inquiry Report," Chairman, Dr Iain Anderson CBE, the House of Commons, London, www.jesip.org.uk/uploads/media/incident_reports_and_inquiries/Foot%20and%20Mouth%20Disease%202001%20Inquiry%20Report.pdf, accessed Aug. 8, 2019; "The 2001 Outbreak of Foot and Mouth Disease," National Audit Office, Report by the Comptroller and Auditor General, HC939 Session 2001-2002; June 21, 2002, www.nao.org.uk/wp-content/uploads/2002/06/0102939.pdf, accessed Aug. 8, 2019.

12. Monke, Agroterrorism: Threats and Preparedness.

13. Ibid, p. 5.

14. Ibid, p. 12.

15. Tad A. Schnaufer, II. "Redefining Hybrid Warfare: Russia's Non-linear War against the West," *Journal of Strategic Security* vol. 10, no. 1 (2017); pps. 17-31, http://scholarcommons.usf.edu/jss/vol10/iss1/3, accessed Nov. 14, 2019.

16. For a short history on the discovery of prions as the cause of neurodegenerative diseases see "What Is a Prion? The molecular structure of prions and how they cause infections like Creutzfeldt-Jakob disease," *Scientific American* online edition, www.scientificamerican.com/article/what-is-a-prion-specifica.

17. For more on the public health effects see "The Public Health Impact of Prion Diseases," by Ermias D. Bela and Lawrence B. Schonberger, *Public Health* 2005, vol. 26, pps. 191–212, www.cdc.gov/prions/pdfs/public-health-impact.pdf, accessed July 18, 2019.

18. For more on the types of Anthrax Infections see Types of Anthrax. Centers for Disease Control and Prevention, www.cdc.gov/anthrax/basics/types/index.html.

19. For additional information see Chronic Wasting Disease, see Centers for Disease Control and Prevention, www.cdc.gov/prions/cwd/index.html.

20. For additional information see Centers for Disease Control and Prevention, www.cdc.gov/prions/index.html.

21. For additional information see U.S. Department of Agriculture, www.usda.gov/topics/animals/bse-surveillance-information-center.

22. For additional information see Centers for Disease Control and Prevention, www.cdc.gov/prions/bse/bse-north-america.html.

23. The U.S. Department of Agriculture states: "Alkaline hydrolysis uses high temperature (such as steam heat), pressure and pH (usually strong base like potassium hydroxide or sodium hydroxide) to process carcasses and associated materials. Using this mobile technology, solid byproducts and a sterile aqueous solution are the products of the conversion of lipids, proteins, and nucleic acids. This technology can take place on-site or at a fixed-facility. Alkaline hydrolysis is limited by low carcass material capacity, and is also time consuming, requiring at least three hours to kill microbial pathogens and six to eight hours to deactivate transmissible spongiform encephalopathy (TSE) prions. Because it is one of only a few technologies that can destroy BSE, it remains a viable disposal method. However, the use of alkaline hydrolysis for disposal in a large-scale animal health crisis is significantly limited by its low capacity. In addition, alkaline hydrolysis results in significant quantities of potentially hazardous liquid waste. This hazardous waste, termed effluent, has an extremely high pH and must be discharged in an environmentally safe manner." Source: *FAD PReP Foreign Animal Disease Preparedness and Response Plan;* National Animal Health Emergency Management System Guidelines: Disposal. National Animal Health Emergency Management System (Washington, D.C.: U.S. Department of Agriculture, December 2012), www.aphis.usda.gov/animal_health/emergency_management/downloads/nahems_guidelines/disposal_nahems.pdf, accessed July 19, 2019.

24. Mad Scientist Blog Site (Fort Eustis, Va.: U.S. Army Training and Doctrine Command), https://madsciblog.tradoc.army.mil/about, accessed July 19, 2019.

25. Col. Jennifer Snow, James Giordano, and Joseph DeFranco, "Dead Deer, and Mad Cows, and Humans, Oh My!" Mad Scientist Blog Site (Fort Eustis, Va.: U.S. Army Training and Doctrine Command), https://madsciblog.tradoc.army.mil/143-dead-deer-and-mad-cows-and-humans-oh-my, p. 143, accessed May 9, 2019.

26. www.nationalchickencouncil.org.

27. National Broiler Council, "Broiler Chicken Industry Key Facts 2019, www.nationalchickencouncil.org/about-the-industry/statistics/broiler-chicken-industry-key-facts.

28. This section is the result of extended conversations with C. J Unis, an engineer at Sandia National Laboratory, whose research specialty is cascading engineering in critical infrastructures.

29. Congressional Research Service, "High Altitude Electromagnetic Pulse and High Power Microwave Devices: Threat Assessments," RL 32544, July 21, 2008, https://fas.org/sgp/crs/natsec/RL32544.pdf.

30. The EMP Commission was established pursuant to title XIV of the Floyd D. Spence National Defense Authorization Act for Fiscal Year 2001. The commission is charged with identifying any steps which would better protect its military and civilian systems from EMP attack. For additional information see www.empcommission.org.

31. Electromagnetic Pulse Commission, "Assessing the Threat from Electromagnetic Pulse," *Executive Report*, July 2017, www.empcommission.org/docs/A2473-EMP_Commission.pdf.

32. Office of the White House, Executive Order 13865, March 26, 2019, *Federal Register*, vol. 84, no. 61, pps. 12,041-12,046.

33. Donald Black, "The Geometry of Terrorism," *Sociological Theory*, 2004, pps. 14-25.

34. Nicole Rader, "Fear of Crime," *Oxford Research Encyclopedia, Crime and Criminal Justice* (New York, N.Y.: Oxford University Press, 2019).

CHAPTER 10

Conclusions

Dr. Robert A. Norton

As this book was being prepared, three events occurred, which although not directly related to the topic of agroterrorism, can never the less provide lessons, which hint at the potential magnitude of outcomes, (good and bad), and should such an event actually take place. An agroterrorism event, no matter how large, might never reach the scale of economic and potential psychosocial damage that has occurred in the COVID-19 pandemic. An agroterrorism event, no matter the scale or how widespread will ever truly destroy the entire U.S. food supply. Shortages may occur acutely, some possibly widespread, but the food system as a whole, because of its size, complexity, and diversity of inputs, including food imports, make it resistant to total failure. Nevertheless, an agroterrorism event would be consequential, perhaps devastatingly so and wide ranging, extending beyond agribusiness to become a whole of society event.

The first event was the aforementioned COVID-19 pandemic, which began with a zoonotic infection in China and quickly spread to the world through the global connectivity (air and sea travel), which enables the global economy, and in particular, the two strongest examples, those being the United States and China. One element of that pandemic, which was largely unanticipated, was the resulting effects on agriculture and food. That is where we can begin to see examples of what an agroterrorism event might look like.

Agribusiness is the term used to describe the compendium of businesses and services that make possible the food supply. Food and agriculture are considered critical infrastructures, as designated by Presidential Policy Directive- 21 (PPD-21), meaning they one of 16 critical infrastructures, "…whose assets, systems, and networks, whether physical or virtual, are considered so vital to the United States that their incapacitation or destruction would have a debilitating effect on security, national economic security, national public health or safety, or any combination thereof."[1]

The food supply is not only essential to the welfare of this nation, but also a continuum, made up of inputs (plant and animal agriculture products) and outputs (food products). COVID-19 pandemic illustrated how fragile the system can be. For the first time in a very long time, shortages occurred in meat and dairy products and to a lesser extent, some canned products, fruits, and vegetables. Beyond that, the pandemic also clearly illustrated that events can also cause unanticipated secondary and tertiary events, so called "cascading effects." The human element proved to be the most fragile. People becoming sick rapidly evolved into a food security problem. Animal processing is highly dependent upon people, many of them relatively low paid, who also live and interact inside and outside of work. The COVID-19 quickly moved through the workers, and the processing lines dependent on those people trimming and cutting up the meat began to slow. This in turn caused the continuum to back up, causing in some case the slaughter and burial of animals that could not be accommodated by the processing plants when needed. As a consequence, these potential food products were lost forever, likewise impacting the variety and abundance of food availability. Looking at the problems another way, a localized problem (people getting sick in a food processing plant), quickly evolved and spread across the nation, since the overall meat supply came from a handful of meat processing plants.

The evolving problems illustrated a vulnerability that had previously been considered a strength of the U.S. food supply, that being economy of scale. Food processing is very concentrated, where a few processing plants may be responsible for large percentages of the supply of that commodity. A single plant closing (single point failure) can therefore actually impact to a scale in which the actual food supply as a whole is affected. There is little to no redundancy in food processing, meaning there are no idle plants sitting by in case one or more is shut down for whatever reason. Although, agriculture is more dispersed, similar effects could occur the wake of an agroterrorism event. Much of the farming in the United States is conducted through family farms, many privately held corporations ranging from small to large. In many cattle farming operations, calves are raised on grass and then transported to feed lots, where they are finished up on feed and sent to processing plants.

Cattle feed operations in many parts of the country are massive. One of the largest of these operations houses more than 920,000 head of cattle, which are spread over 11 feedlots, located in six states. A loss of one or two of these operations at this scale would be catastrophic for both the food supply and economy of the nation. Poultry meat is similarly made available through large regionalized operations. USDA estimates the 2020 production will approach 45,600 million pounds.[2] In 2018, the top five poultry producing states in the Southeast (Georgia, Arkansas, North Carolina, Mississippi and Alabama) yielded a staggering 5,199,500,000 broiler chickens.[3] A single agroterrorism event, say for instance using avian influenza (a foreign animal disease) as the potential agent of attack in one of these major broiler producing state could remove a massive quantity of potential meat from the food supply, as well as cause massive carcass disposal and remediation costs.

In such a scenario, emergency government compensation could become very complex. Producer compensation, essentially disaster relief would be anticipated, but in the cases of broiler chickens, the birds are grown by contract, which pay the grower for those services, while the ownership of the flocks is retained by the companies. In an agroterrorism event, the economic impact would spread across the whole enterprise. Producers (i.e. farmers) could potentially lose their contract payments for growing the chickens, have to bury the dead chickens on their property, while company processing plant employees would be laid off, since there would be no broilers to process. The companies would also lose important revenue, ranging according to the magnitude of the event.

Foot and mouth disease (FMD) is another foreign animal disease, not endemic to the United States. It is caused by a highly contagious virus (seven serotypes) that is frequently mentioned as a potential agroterrorism agent that would most likely be used by sophisticated adversaries (e.g. nation-state, proxies, sophisticated terrorist or criminal organizations), who have access to the virus and possess the means to disperse that agent into cattle production areas. Given the nature of the FMD agent, a localized event, would rapidly evolve into a highly impactful state, regional or perhaps even a national event with huge economic cost, given the potential scale of state and federal containment, control and remediation responses.

Beyond that, the impact on the food supply could also be direct and swift. As mentioned previously, the food supply is a continuum and concentrated. Outputs (food products) must come out as inputs (agricultural products) come into the system. There is strength in that it promotes economy and efficiency of scale, but there is also risk because impactful single point failures can occur. Any disruption within a given commodity, beef and dairy cattle being the example, and the food supply would be directly, perhaps dramatically affected. The result could be, and as was the case with COVID-19, panic buying would be an expected short-term consequence, or worse.

Additionally, a considerable psychosocial impact would be expected, achieving one of the primary goals of the terrorist. We must never forget that one of the primary drivers of terrorists is to induce a sense of fear and distrust by the victim. A government that has allowed an agroterrorism event to occur is in a sense a government that has failed in its Intelligence capabilities and its responsibilities to protect the public. Agroterrorism strikes deeper because it strikes everywhere and potentially into every household. Agroterrorism would further severely tax a government perceived as having failed, by requiring massive coordination with states and municipalities, not only in the *detection, response, containment, remediation* phases, but also in its need to find, then deliver alternate food stuffs in a timely manner, before the human casualties would potentially start to mount.

Although, FMD is often referenced as the "best example of a worst-case scenario" in any discussions of agroterrorism, lesser pathogens, chemicals or other means could be used to disrupt the food supply. We should always consider surprises, the so-called Black Swans and Gray Rhinos to occur. Some agroterrorism events could be quite small and have little to no impact on the actual food supply. For instance, a disgruntled employee could introduce an agent that could have catastrophic, but localized consequences. Some agents on the other hand could cause effects that rather than killing the plant or the animal, could instead cause the food products to in some way become unusable or even potentially toxic to the consumer. In such scenarios, animal and commodity disposal could become a huge and costly proposition.

In this way, an agroterrorism event could rapidly evolve into a food defense (intentional adulteration) issue, given that adulteration can occur at any point(s) in the food chain continuum (farm to fork). In this way, the cascading effect begins with the agricultural product, but ends with the actual food product, where the value-added element is most developed. The economic impact in such an event could be quite serious. Beyond that, the safety of the actual food supply could come into question by the public, leading to psychosocial and political effects that might be more impactful than those of the actual targeted commodity.

These kinds of events can also cause what is called as "brand damage," meaning the economic impact of sales and trust of a commodity or food corporation, depending on the scope of that which is targeted. In this way, a given company, say for example, the "X Corporation," could suffer economic damage or even failure if the public becomes distrustful of its ability to deliver a safe and wholesome food product, in the event of an agroterrorism or adulteration event. Likewise, a food commodity (e.g. wheat or milk) could suffer public distrust if the public interprets a threat from an attack on that commodity. Trust in food products is very fragile and subject to rapid shifts. A food security (i.e. food availability) problem can rapidly emerge not only from actual supply problems, but also from trust in that supply. True and perhaps maximal asymmetry could be achieved, by an adversary that does not attack the actual supply, but the trust that is needed for that supply of food to be consumed.

The second event that occurred began as a tragedy and was compounded into a worse one yet. On May 25, 2020, Minneapolis police officers arrested George Floyd, a 46-year-old black man, who had allegedly passed a counterfeit $20 bill, while paying for a pack of cigarettes in a local convenience store. Mr. Floyd was apprehended, allegedly scuffled with the police officers, and was placed on the ground face down. One of the officers, Derek Chauvin, placed his knee on Mr. Floyd's neck, restraining him for eight minutes and 46 seconds, sometime during which Mr. Floyd lost consciousness and expired. The incident caused an instantaneous and guttural national response of disgust and anger, because the events were caught on camera and uploaded to the internet. One might ask, what this has to do with agroterrorism, which on its face seems disconnected. Where the two tragedies, one real and one thankfully only imagined, intersect is in the aftermath of the events. For it is here we see the emergence of what can be called "food deserts" beginning to spread.

The subsequent events that followed Mr. Floyd's tragic death will not be discussed in here, other than to say that the subsequent events in its wake were fed in part by anger and longstanding frustration, which caused first peaceful protests, but later morphed into a lashing out in the form of violence, property destruction and looting. The property destruction was widespread in many cities across the United States. Businesses of all kinds were destroyed and badly damaged. Property theft and destruction also became widespread. People were also attacked, injured, and even killed. Among, those businesses that were attacked, were a variety of food- and beverage-related businesses, including restaurants, grocery stores, bars, and liquor stores, as well as convenience stores, all of which were utilized by the local community.

Although, it is too early to speculate whether any of the businesses will ever return, it is almost inevitable that some, perhaps even a sizeable percentage won't return. Most had already been deeply affected by the lockdowns, accompanying the COVID-19 outbreak. Restaurants in particular had been severely affected, many to the point of bankruptcy. All of these food and beverage businesses served the local community, but will no longer be able to do so, perhaps permanently, or if surviving, perhaps not for an extended period of time. People can no longer walk down the block and be patrons of these establishments. The food that was available there is no longer available. If people, young and old alike, want to continue to eat, they will need to find new food-related establishments, likely farther out from their neighborhoods, increasing the associated transportation costs associated with procuring the food. This is how food deserts, whole blocks or even sections of towns where food is no longer available, are born.

Agroterrorism, like rioting are not abstract acts of violence, but instead very real, with potentially similar results on the variety and availability of the food supply. In this sense, both affect food security. The term food security was developed by the U.S. Department of Agriculture to describe a spectrum of food availability, ranging from "high food security" ("no reported indications of food-access problems or limitations") to "marginal food security." The term "marginal food security" seems appropriate to both the food issues encountered during COVID-19, but also now in the wake of the riots that occurred across the United States. USDA-ERS defines it as "…one or two reported indications – typically of anxiety over food sufficiency or shortage of food in the house. Little or no indication of changes in diets or food intake."[4] Food shortages, regardless of their origins cause anxiety over where one's next meal may come.

Continuing down the continuum, there is found the status of "food insecurity," which contains two subcategories that seem also apropos to the two recent events. The first of the subcategories is "low food security," which is defined as, "Reports of reduced quality, variety, or desirability of diet. Little or no indication of reduced food intake," meaning that which is not accompanied by hunger. Also, there is "very low food security" defined as, "Reports of multiple indications of disrupted eating patterns and reduced food intake."[5] In other words, accompanied by hunger. Like rioting, agroterrorism could lead to both low to very low food security. Agroterrorism might reasonably be expected to have similar impacts like those of rioting. Food deserts could quickly emerge, as food related businesses fail from the lack of income, caused by food shortages. This scenario has certainly also played out in the COVID-19 pandemic. No food – no income – no business – the food desert spreads.

Food related businesses often survive on the slimmest of margins, where volume of product(s), rather than unit markup is the primary contributor to the bottom line. Disruption of the food chain for whatever reason becomes a potential business killer, because it causes patrons to have to range farther and absorb higher costs for acquiring sustenance. Under such circumstances, many will adjust, but to do so, they will have to have access to transportation. A few however, particularly those limited by age, infirmity, or lack of transportation, may not have an immediate alternative to their local food supply contributors. In such cases, disruption could be catastrophic. An agroterrorism event would likely hit hardest those least able to adapt. Most cities have a limited food supply (a few days' worth), which are supplied through "just-in-time" logistics. One of the saddest stories, ancillary to the riots, was that of an elderly handicapped lady, who had depended upon her groceries coming from the neighborhood store, which had been looted and destroyed. She believed it was gone forever, which may prove true. She and many in her apartment building had no transportation and given the violence, the municipal buses no longer travel through the neighborhood. She asked plaintively, "What am I going to do? I have no food. How am I going to live?" Those important questions must be answered first, as government continues to develop strategies that will rapidly detect and swiftly deal with disruptions in the food chain. In this sense food and agriculture defense should most properly be viewed as not protecting an agribusiness with federal and state, but rather as protecting an essential lifeline service, critical to the welfare and survival of our nation.

The third event that occurred as this book was being finished was the successful launch and successful coupling to the International Space Station of the NASA astronauts, Bob Behnken and Doug Hurley in the SpaceX Dragon spacecraft on May 30, 2020. A launch into space might seem a world apart from the topic of agroterrorism (no pun intended). Where the two connect is in the illustration it provides of cooperation between industry and government, rather than the other way around, a subtle, but important distinction. Space Exploration Technologies Corporation (SpaceX) is a privately funded, government assisted endeavor, by which business has entered space. Most of the spacecraft assets and equipment do not belong to the government, but instead to a company founded in 2002 by Elon Musk. His ultimate goal is to colonize Mars. Government, since its last launch in 2011, has proven itself moribund in delivering fully on the promises that were born in 1969, when man first landed on the Moon. The hope of government managed manned space exploration largely perished along with the loss of the Challenger crew (seven astronauts) on Jan. 28, 1986, and subsequent Columbia crew (seven astronauts) on Feb. 1, 2003. The next chapter would be written by business. Business would develop the engineering, while government would provide the means and support system.

Like SpaceX, the government does not own or control the development of agribusiness assets, which are privately mobilized to serve a purpose. The government has no real knowledge of how to grow wheat and corn, cows and chickens and then convert them into food. It knows only how to regulate and tax those that do. In a real sense that is how it should be. Private enterprise, along with government assistance provides the food that is put on the American consumers table. Agriculture and the food supply are not owned by state and federal governments, but instead are regulated or often subsidized by it. Many of the decisions made within agribusiness are therefore influenced, but ultimately not controlled by government. Like in the space race to Mars, in time of crisis, a freer hand is often needed. The goal should be to enable business to develop the fastest and most diverse set of solutions possible to any problems that are presented to our society.

Early in the COVID-19 crisis, a Centers of Disease Control and Prevention official stated that it would be three to four years or longer, before a vaccine could be developed. This was the government way of doing things and also the timeline – their usual way of doing business. The pharmaceutical industry had a very different timeline in mind and upon the easing of liability by the federal government (another example of collaboration), began to immediately pursue more rapid solutions in the form of treatments and vaccine development. We are too early to know whether there will be success. Again, here too the research and development assets are privately owned. In research and development there are often setbacks, but even so, new ways of doing business are being cooperatively developed by government and industry out of necessity. These same kinds of innovations are not only needed to find solutions that make our food supply more secure, but will be essential if agriculture experiences a real attack by adversaries.

Agriculture and food are also national security measures. There is no separate civilian and military agricultural system, nor are our food supplies separate. Like all critical infrastructures, each is shared, so that the agribusiness entity that puts a commodity product on the consumer's table is the same one that puts it on the soldier's, sailor's, or airmen's table. Food has always been and will always remain an element of statecraft and ultimately of war, the strongest expression of that statecraft. The side that controls the food and water supply of the other, has won throughout history. Agriculture and its ultimate outcomes – food, enable projection of force, as surely as do the ships, armaments, and aircraft of our military forces. Agriculture and the food supply can also be a force for stabilization, providing sustenance and even survival for the oppressed or in times of humanitarian crisis.

As has been attributed to both Napoleon and Frederick the Great, "An army marches on its stomach," meaning only a well provisioned military force can prevail. No aircraft carrier can leave port with the holds, freezers and lockers empty of food. No army can leave its barracks without a functional logistics system. Food enables the projection of power around the globe. Agriculture therefore is the essential element that enables that function of power. If a nation-state seeks to go to war with the United States, it would certainly have to cause disruption in the logistical system, which enables food and other essential supplies.

Military Considerations

As we look toward what the future might bring, we cannot discount the global influence, such as some would say domination being sought by China. China is and will remain for the foreseeable future the most capable and persistent adversary of the United States, both economically, diplomatically, and militarily. As stated, agriculture and food remain two essential elements, (among others) that enable force projection around the world.

"The conventional wisdom was that China would seek an expanded regional role – and a reduced U.S. role – but would defer to the distant future any global ambitions. Now, however, the signs that China is gearing up to contest America's global leadership are unmistakable, and they are ubiquitous… There is Beijing's bid to dominate high-tech industries that will determine the future distribution of economic and military power. There is the campaign to control the crucial waterways off China's coast, as well as reported plans to create a chain of bases and logistical facilities farther afield. There are the systematic efforts to refine methods of converting economic influence into economic coercion throughout the Asia-Pacific Region and beyond."[6]

China seems to have learned lessons from the United States in striving to become a superpower. One of the strengths the United States has had for decades is its self-containment in essentials, like agriculture and the food supply. The United States is largely self-reliant in food, because of its massive agricultural industry, which stretches from coast-to-coast. It is certainly true that regions of the United States specialize in certain commodities (e.g. poultry in the South, grain in the Midwest, produce and fruits on the East Coast). Even so, these areas in many cases are not the exclusive source of specific food items. Globalization has certainly changed the nature of many food stuffs, by making them no longer seasonal (e.g. seasonal fruits and vegetables). Although, food items are regularly obtained from other parts of the world in order to promote economy, if displaced, the United States has the capability of pivoting over a relatively short period of time to replace or substitute the lost food stuff. China on the other hand does not have this same self-sufficiency. China must import food. This has caused tensions within China, because it is perceived by some as hindering the goal of self-sufficiency.

"Despite the increase in domestic output, China's role as an agricultural importer has grown. Tensions between market-driven resource allocation and the Chinese objectives of self-reliance continue into the 21st century. Rising imports prompted adoption of a new food security strategy that allows for imports to supplement China's domestic food supplies, but advocates the use of domestic support measures and trade barriers to keep the country self-reliant in food."[7]

In time of war with the United States, it is likely anticipated by China that the United States would seek to disrupt the logistics systems, the very same systems, which enables their food imports. "All of China's leading suppliers of agricultural imports are countries richly endowed with land resources: The United States, Brazil, Australia, Canada, New Zealand, and Argentina. China has been importing more agricultural products from many of these countries, but the United States remains the leader…"[9] It should be noted here that those top tier nations from which China imports food include four of the five nations (the United States, Australia, Canada and New Zealand) that share intelligence in the "Five Eyes Alliance."[9] That fact is surely not lost on China and may therefore be perceived as a significant vulnerability.

China has recently suffered a major loss of their swine herd, due to African swine fever.[10] This has resulted in the loss of one of their major sources of animal protein and a significant increase in food costs. "China used to have 440 million pigs – almost half the world's population – but its herd has shrunk by half or more, according to Rabobank, a Dutch bank with a heavy agricultural focus. Pork prices in China have more than doubled."[11]

"China has long viewed food security as tantamount to national security. It had become essentially self-reliant in pork as well as in rice and wheat thanks to subsidies and aggressive farmland management. The swine fever epidemic will test that commitment to its increasingly affluent people, who more often expect meat at the dinner table."[12]

Perhaps anticipating the increasing need for more pork and the potential for disruption, China through Shuanghui International Holdings Ltd., that nation's biggest meat producer acquired Smithfield Foods, Inc. in 2013 for $4.72 billion.[13]

Although the U.S. government allowed the sale to eventually go forward, concerns were immediately raised by many, given the not insignificant potential that pork raised in the United States might be diverted to China.

The U.S. Senate Committee on Agriculture Nutrition and Forestry held a hearing on July 10, 2013, titling it, "Smithfield and Beyond: Examining Foreign Purchases of American Food Companies,"[14] In the opening statement, The Chairwoman, Senator Debbie Stabenow from Michigan, recognized the potential risks associated with a potentially adversarial nation being able to purchase a major contributor to the U.S. food supply stating, "From the very beginning of human history, we have seen civilizations rise and fall based on their ability to feed their people. That is why food security is absolutely essential to national security, and it is why food and agriculture are such an important and unique part of our American economy."

She then eloquently stated the complexity of the situation: "Not a day goes by that every one of us in this room is reminded of the importance of a safe, affordable, and abundant food supply. It can be easy for Americans to forget that food does not just show up in the grocery store. Sometimes I feel we have to remind people of that. It is a process that requires risk taking, sound business practices, and a whole lot of hard work from the 16 million people whose jobs rely on agriculture.

That is why the news of Shuanghui International's proposed purchase of Smithfield Foods, the largest purchase of a U.S. company by a Chinese firm, raises so many questions. Smithfield might be the first acquisition of a major food and agricultural company, but I doubt it will be the last."[15]

These statements were followed by testimony, including that from Daniel Slane, Commissioner on the United States-China Economic and Security Review Commission, who commented on China's ultimate goals stating:

"Shuanghui's purchase of Smithfield is part of China's far reaching program of foreign investments aimed at gaining as much control of key foreign sources of supply as possible. I remain concerned that many of the largest Chinese enterprises, including Shuanghui, maintains strategic ties to the Chinese government whether through direct ownership or control, preferential access to massive government subsidies, or personal links to the Chinese Communist Party."[16]

Americans are frequently structurally, politically, and emotionally disengaged from their food supply. They are also largely ignorant of how agriculture works or its importance to their wellbeing and the health of the U.S. economy. To many, food comes from grocery stores and not from farms and ranches. In an emergency, food is expected to be there. Many people are therefore unprepared. Disruption has long been considered by the public as so remote as to approach an impossibility. Then, came COVID-19 and the riots and those assumptions were proven false in those areas most acutely affected. The food supply could be disrupted and the American public could experience shortages and increased food costs, due to the diminished availability.

It is too soon to accurate assess the full spectrum of psychosocial, economic, and political effects caused by the disruptions. Local food associated disruptions caused by the rioting were limited geographically and specific to certain parts of affected cities, including neighborhoods, where food establishments were looted and, in some cases, burned. In other words, although emotionally and financially disastrous to the owners, the actual food effects of rioting to the community were limited in scope and did not affect the overall population of the city. The food supply could be accessed in unaffected parts of cities (assuming one had access to transportation), although it could not perhaps be accessed with the same level of convenience. Food security was therefore affected, but not to the degree that would lead to the widespread structural failure of the critical infrastructure. The same limited effects were seen in the food shortages experienced during the COVID-19 pandemic. Local shortages were indeed experienced by the consumer, but were due to two factors:

Demand – people hoarded in expectation of disruption associated with government imposed stay at home orders.[17, 18]

Shutdown – of key meat processing plants shutdown, due to COVID-19, including Smithfield facilities, now owned by a Chinese-based company linked directly to the Chinese Communist Party.[19]

In the scope of things, the disruptions faced by Americans over several months are small in comparison to what could result, should an actual agroterrorism event occur. History has shown that the food and water supplies are vital for prevailing on the battlefield, particularly for sustained combat, which could take place over months or years. Although, the American public largely remains unaware of the criticality of the food supply in many cases, history has repeatedly shown that “He who controls food and water, ultimately prevails.” A sustained conflict in the future with a nation-state, China being the most likely candidate would cause disruptions on a scale unimagined, magnitudes greater than those that took place in even the worst moments of COVID-19 and the riots that followed the death of George Floyd.

If China or any other adversarial nation choses to cross the line with an agroterrorism, the threat to our nation will be on an existential level. In imaging such a scenario, one must consider that a thinking adversary would make a series of attacks, rather than a single point attack, which could be outmaneuvered by the government. Two factors would likely be key elements of the attack strategy – spatial and temporal distribution. A guide to how that might be accomplished and what a full-bore attack might look like is available in history through an examination of the former Soviet Union’s Biopreparat Program. Dr. Ken Alibek, then called Col. Kanatjan Alibekov was the First Deputy Director of Biopreparat from 1988-1992, before defecting to the United States. As such, he has a deep understanding of what capabilities can be developed by a nation-state.

“The problem now is [that] practically all the countries in the world understand that biological weapons are a very serious threat ... a lot of countries are trying to develop biological weapons, and for these countries, the Soviet Union was some kind of role model for developing these weapons, because the Soviet Union was able to develop one of the most powerful and sophisticated programs in the world. A lot of countries are following the Soviet Union's program. I strongly believe that some Asian countries, Arabic countries ... are trying to develop their own offensive program. In my opinion, for them, this country (the Soviet Union) was some kind of example, some kind of role model for these programs' development."[20]

Dr. Alibekov was then asked about the likelihood of a biological weapon attack. His response was chilling, particularly his last statement, "No. Let's analyze the logic of weapons development, the history of weapons development. The problem with biological weapons [is that] they are very complex. But any weapon that has been developed eventually was used in terrorist attacks. Until recently, we hadn't seen anything with applying chemical weapons, but we've seen it recently. Now we can say, if we follow this logic, biological agents, biological weapons could be used in the future. In my opinion, that's not a matter of 'if.' That's a matter of 'when.'"[21]

As for how the logic of why biological agents might be developed by nation-states and terrorist groups, Dr. Alibekov suggested:

"As I said before, the logic of developing weapons and, eventually us[ing] these weapons in terrorist acts, then biological weapons could be undetected. A person or group of people who use it can escape from a place of application, even from a country of application, undetected. In my opinion, biological agents and biological weapons are very terrifying weapons ... we don't have a capability to detect these weapons before they're applied, before they're used. They're very attractive for possible application, they're not very expensive and [they're] relatively easy to manufacture."[22]

The Biopreparat program was divided up into two subprograms, including "…programs to research and develop weapons against humans (codenamed Ferment) and animals and plants (codenamed Ekology).[23] The work of Biopreparat may not ended, following the fall of the Soviet Union.

"We cannot know whether new biological techniques, based on genetic manipulation developed since the Soviet BW program supposedly closed in 1992-1993, have been applied by scientists working in the three-top secret MOD[24] biological institutes to create new or improved weaponized strains of bacteria and viruses. In particular, these techniques could be applied by weapons scientists to develop substances that interfere with genes that control behavior or immunological defense systems."[25]

This open question is particularly concerning given the potential for spillover of pathogens and or capabilities to other potential adversarial nations. Even if not active, there is historical strategic knowledge that could be shared or quickly mobilized if a nation-state to nation-state hostilities were to begin. When asked in 1998 about current Russian capabilities, Alibekov posited, "I don't believe that Russia has biological weapons stockpiled. These weapons were destroyed somewhere at the end of 80s. But if Russia does have a desire to start manufacturing biological weapons, it would take no more than two to three months to start this activity again."[26]

Providing additional details, Alibekov also claimed in the 1998 interview, "Russia has at least four military facilities that could be used for manufacturing biological weapons. These facilities have not been opened for any visits. These facilities could be considered top secret offensive facilities and they have the capability to manufacture biological weapons. In addition to these facilities, Russia continues [running] several facilities, so-called Biopreparat facilities. They were considered mobilization capacities. And we know that Russia stores all production documentation for manufacturing biological weapons. It wouldn't be a big problem to start this production activity if there is desire or if there is an order."

Whether future military cooperation between China and Russia is a real possibility is a question that must be answered quickly.

"China and Russia no longer share a common expansionist ideology, but realpolitik considerations are driving them together. Both recognize that to stand up alone against an established alliance system led by the United States is very difficult, as neither has any truly powerful allies of its own. Yet together they dominate Eurasia and their strengths complement each other. One is a huge land mass with nuclear weapons and hydrocarbons, but it has a modest and shrinking population. The other is an economic superpower and second in conventional military power by most metrics. Some look at this and conclude that China and Russia will become natural allies as time goes on. Others say such an assessment is nonsense given their mutual mistrust and indeed the very proximity that could help them work together."[27]

If the two adversarial nations partnered in a military move against the United States, is an agroterrorism event inevitable? Probably not, although it obviously cannot be ruled out. Although low probability the consequences of coordinated attack has the potential of collapsing the nation's economy and with time and depending on how wide ranging, would at the minimum cause serious disruptions of local food supplies, with the potential of a sustained disruption on the national scale.

Looking Forward

In the wake of 9/11, concern about agroterrorism surged. Many organizations examined various scenarios and the findings were often alarming. The United States was not prepared for major agroterrorism events. Even then assumptions were made that the response would be very similar, although perhaps on a different scale to natural disease outbreaks. One study from the RAND Corporation recognized the potential. It concluded, "Although the consequences of an agroterrorism attack are substantial, relatively little attention has been focused on the threat. Unfortunately, the agricultural and food industries are vulnerable to disruption, and the capabilities that terrorists would need for such an attack are not considerable."[28]

Although, somewhat dated the Rand report identified six key vulnerabilities, all of which still exist to one extent or another.

Those vulnerabilities include:

- Concentrated and intensive contemporary farming practices
- Increased susceptibility of livestock to disease
- Insufficient farm/food-related security and surveillance
- An inefficient passive disease-reporting system
- Inappropriate veterinarian and diagnostic training
- A focus on aggregate rather than individual livestock statistics

It should be made clear that improvements within agriculture and the industry have been made since 2003. Coordination between the relevant intelligence agencies has dramatically improved. That being said, there still remains disconnects between government and agribusiness (although that also has improved), but more importantly within agribusiness itself. Barriers remain between regulatory agencies (having the ability to fine and/or incarcerate) and the regulated, which is all of agribusiness. Beyond that though, unlike most of the other critical infrastructures, agribusiness still lacks an Information Sharing and Analysis Center (ISAC). "Information Sharing and Analysis Centers help critical infrastructure owners and operators protect their facilities, personnel and customers from cyber and physical security threats and other hazards. ISACs collect, analyze, and disseminate actionable threat information to their members and provide members with tools to mitigate risks and enhance resiliency. ISACs reach deep into their sectors, communicating critical information far and wide and maintaining sector-wide situational awareness."[29]

Agribusiness Priority – Establish an Agribusiness Information Sharing and Analysis Center

The reasons that agribusiness still lacks an ISAC are complex and vary by company. Two consistent overarching concerns. First, an unwillingness to share threat information with business competitors (fearing the loss of business advantage). Second, an unwillingness to bear the costs that such an operation would entail. ISACs done right can be economical. Security is an investment for protecting assets (physical, personnel, intellectual property, etc.), but also the brand, the value of which may exceed those of all physical assets combined.

The initial investment for the stand-up entails providing the systems to support both analysis and information dissemination. ISACs vary in capabilities across the critical infrastructures, but the best ones usually employ a group of experienced professional analysts, many of who came from the intelligence community and often still have personal connections with colleagues there. Experience accompanied by a serious rolodex translate to higher costs, as opposed to personnel, who possess less experience and expertise and may not have the connectivity, which can further the quality of the analysis.

Agribusiness frequently references the need for timely information, often called by them as "actionable information." This substantial difference in the agribusiness lexicon to that of the military and Intelligence Community needs to be clearly understood. Both are essential for spotting trends or indicators that something bad is about to happen. What agribusiness means is the need for timely information, which can be used to make business decisions in the short and medium to long terms.

Agribusiness is interested in trends, but also time sensitive information that may give warning for things a company has not yet observed in their facilities or other assets. These interests are unfortunately also accompanied about concerns, both real and imagined, if corporate information is to be shared back to government. These concerns stem from the fact that some of the agencies relevant to agribusiness (e.g. USDA and FDA) have regulatory and enforcement authorities. The concern is that information shared in good faith might somehow come back and be used against the company in litigation. Beyond that, agencies like the FBI, who may share threat information with companies have law enforcement authorities, to which companies may also be sensitive in a general sense, and not motivated by any attempt to hide criminal activities. Realizing these potential sensitivities, DHS has established the Cybersecurity and Infrastructure Security Agency (CISA)[30] to assist Critical Infrastructures, including Food and Agriculture.

CISA, along with USDA and HHS have developed a Sector-Specific Plan. "The Food and Agriculture Sector-Specific Plan[31] details how the National Infrastructure Protection Plan risk management framework is implemented within the context of the unique characteristics and risk landscape of the sector. Each Sector-Specific Agency develops a sector-specific plan through a coordinated effort involving its public and private sector partners. The Department of Agriculture and the Department of Health and Human Services are designated as the co-Sector-Specific Agencies for the Food and Agriculture Sector."[32]

CISA also coordinates for the Food and Agriculture Sector, with other "critical dependencies," that is other sectors, with which agribusiness regularly interacts.

These include:

- Water and wastewater systems, for clean irrigation and processed water
- Transportation systems, for movement of products and livestock
- Energy, to power the equipment needed for agriculture production and food processing
- Chemical, for fertilizers and pesticides used in the production of crops[33]

Although, government can assist with providing more timely threat information, it is incumbent agribusiness to do everything possible to protect itself. The importance of this is made clear in the CISA characterization of the sector, "The Food and Agriculture Sector is almost entirely under private ownership and is composed of an estimated 2.1 million farms, 935,000 restaurants, and more than 200,000 registered food manufacturing, processing, and storage facilities. This sector accounts for roughly one-fifth of the nation's economic activity."[34]

Some in agribusiness have already realized the importance of business intelligence and how it can contribute to business continuity and brand protection. This is a good start, but will need to be expanded, so that more specific threat information can be developed in house. One of the most significant problems with intelligence sharing by government with business is the issues of classified information. Agribusiness also is in many cases multinational, further limiting the exchange of actual government intelligence. In many cases, these are insurmountable problems, thereby the necessity of developing parallel systems. Again here, ISACs can help bridge the gaps, making limited intelligence sharing wherever possible by law. Agribusiness should prioritize an ISAC immediately. A functional ISAC with limited capabilities could be established and disseminating information within two to three months. A more comprehensive threat warning system would take longer, but would be possible, with sufficient buy in from agribusiness in no more than a year. Once in place, it would be the responsibility of the ISAC to foster trust, so that with time, agribusiness would become more willing to share information. Sharing of information does not assure that no attacks will ever occur against food and agriculture, but it does make them less likely, putting an additional level of onus on the adversary, which may cause them to turn away from the sector as a potential target. That alone would make the nation's food supply more secure and better protect our economy, in addition to the wellbeing of everyone.

Recommended Actions

1. Prioritize the development of a robust Agricultural Systems Intelligence Infrastructure (AII) within the Department of Homeland Security, using a model similar to that of the Cybersecurity and Infrastructure Security Agency (CISA). This apparatus will develop and prioritize requirements, coordinate agriculture and food system related intelligence across the IC and states and disseminate findings on a timely basis to state and local agencies and business. This new agency should further be charged with coordinating all civilian and military public health intelligence functions with CISA in order to prioritize protection of U.S. critical infrastructures. Special attention should be paid to the rapid lateral communication of critical findings across whole of society (government, business, and general citizenry). Most importantly the AII should serve an integrative function that crosses all societal boundaries and leverages, not replaces work being conducted by international, federal, state, and local partners, as well as provide appropriate interagency coordination with the Department of Defense. In order to expedite the stand up and integration of this new capability we recommend that this capability be embedded within DHS state fusion centers in order to facilitate appropriate information dissemination at the state and local government levels.

2. Prioritize development of an interagency red team to develop and regularly game a full spectrum of agroterrorism scenarios. Findings from these red team exercises would be used to develop realistic threat and vulnerability assessments, which in turn could assist decision makers in policy development.

3. Prioritize aggregation and analysis of domestic and former terrorist incidents involving agriculture and ancillary targets. This information can be used to further development of profiles of threat actors and groups and indicators, which could in turn be relayed to the interagency to drive requirements and agribusiness, where appropriate.

4. Prioritize integration of foreign animal disease training into the National Guard's CBRN Response Enterprise.

5. Evaluate the implementation of the National Biodefense Strategy for its approach to food defense and agroterrorism.

6. Prioritize collaboration between DOD and National Guard mobility forces, USDA and other relevant federal and state response agencies on concepts and technologies, which could be used to prevent and respond to potential naturally occurring foreign animal or plant disease outbreaks and potential agricultural attacks. Harmonization and clarification of title authorities should be addressed immediately.

7. Prioritize discussions on approaches to deter terrorist from considering attacks on food and agriculture. It is further recommended these discussions approach agriculture and the food supply as critical infrastructures, equivalent to other domains which serve similar impacts on national security, wellbeing, and the economy.

8. Prioritize research designed to develop a better understanding of how the illicit use of cyber tools could be used by state and non-state actors against agriculture and food supply.

Chapter 10 Notes

1. Cybersecurity and Infrastructure Security Agency (2020), "Critical Infrastructure Sectors," www.cisa.gov/critical-infrastructure-sectors.

2. National Chicken Council (2020), "U.S. Broiler Production," www.nationalchickencouncil.org/about-the-industry/statistics/u-s-broiler-production.

3. National Chicken Council (2020), "Top Broiler Producing States," www.nationalchickencouncil.org/about-the-industry/statistics/top-broiler-producing-states.

4. U.S. Department of Agriculture ERS (2019), "Ranges of Food Security and Food Insecurity," www.ers.usda.gov/topics/food-nutrition-assistance/food-security-in-the-us/definitions-of-food-security.aspx.

5. Ibid.

6. Hal Brands and Jake Sullivan, "China has Two Paths to Global Domination, *Foreign Policy*, May 22, 2020, https://foreignpolicy.com/2020/05/22/china-superpower-two-paths-global-domination-cold-war.

7. Fred Gale, James Hansen and Michael Jewison, "China's Growing Demand for Agricultural Imports," United States Department of Agriculture, *Economic Information Bulletin* No. 136. February 2015, www.ers.usda.gov/webdocs/publications/43939/eib-136.pdf.

8. Ibid.

9. Office of the Director of National Intelligence, www.dni.gov/index.php/who-we-are/organizations/enterprise-capacity/chco/chco-related-menus/chco-related-links/recruitment-and-outreach/217-about/organization/icig-pages/2660-icig-fiorc.

10. Keith Bradsher and Ailin Tang, "China Responds Slowly, and a Pig Disease Becomes a Lethal Epidemic," *New York Times*, Dec. 17, 2019, www.nytimes.com/2019/12/17/business/china-pigs-african-swine-fever.html.

11. Ibid.

12. Ibid.

13. John Reid Blackwell, "Chinese firm to buy Smithfield Foods for $7.1B," *Richmond Times-Dispatch*, May 30, 2013.

14. United States Senate Committee on Agriculture, Nutrition and Forestry Hearing, "Smithfield and Beyond: Examining Foreign Purchases of American Food Companies," 113th Congress, July 10, 2013, www.govinfo.gov/content/pkg/CHRG-113shrg87565/html/CHRG-113shrg87565.htm.

15. Ibid.

16. Ibid.

17. Shelley Mesh, “As meat processing slows, Wisconsin grocery stores battle hoarding tendencies amid COVID-19 pandemic,” *Wisconsin State Journal*, May 10, 2020, https://madison.com/wsj/business/as-meat-processing-slows-wisconsin-grocery-stores-battle-hoarding-tendencies-amid-covid-19-pandemic/article_d0ae7f26-c858-5019-8b1c-299069bc8ca0.html.

18. Jaya Saxena, “Costco Limits Meat Purchases to Prevent Hoarding Amid Potential Shortage,” *Eater*, May 5. 2020. www.eater.com/2020/5/5/21247822/costco-limits-meat-purchases-to-three-per-customer-covid-19-hoarding.

19. Jacob Bunge, “Smithfield to Close More Pork Plants Over Coronavirus Pandemic - Top U.S. pork processor says employees at three facilities have tested positive,” *Wall Street Journal*, April 15, 2020, www.wsj.com/articles/smithfield-to-close-more-pork-plants-deepening-coronavirus-farm-crisis-11586990622.

20. *Frontline* interview with Dr. Ken Alibekov, 1998, www.pbs.org/wgbh/pages/frontline/shows/plague/interviews/alibekov.html.

21. Ibid.

22. Ibid.

23. Raymond A. Zilinskas, “The Soviet Biological Weapons Program and Its Legacy in Today’s Russia,” Center for the Study of Weapons of Mass Destruction Occasional Paper, No. 11. (Washington, D.C.: National Defense University Press, July 2016), https://inss.ndu.edu/Portals/68/Documents/occasional/cswmd/CSWMD_OccasionalPaper-11.pdf.

24. Russian Ministry of Defense.

25. *Frontline* interview with Dr. Ken Alibekov, 1998, www.pbs.org/wgbh/pages/frontline/shows/plague/interviews/alibekov.html.

26. Ibid.

27. Michael E. O’Hanlon and A Twardowski, 2019).

28. Peter Chalk, “What Is the Threat and What Can Be Done About It?” *Agroterrorism*, (Santa Monica, Calif.: RAND Corporation, 2004), www.rand.org/pubs/research_briefs/RB7565.html.

29. National Council of Information Sharing and Analysis Centers, www.nationalisacs.org.

30. Cybersecurity & Infrastructure Security Agency, www.cisa.gov.

31. Cybersecurity & Infrastructure Security Agency, Food and Agriculture Sector-Specific Plan – 2015, Feb. 11, 2016, revised May 28, 2019, www.cisa.gov/publication/nipp-ssp-food-ag-2015.

32. Cybersecurity & Infrastructure Security Agency, www.cisa.gov/food-and-agriculture-sector.

33. Ibid.

34. Ibid.

USAF Center for Strategic Deterrence Studies
Maxwell Air Force Base, Alabama

Providing Research and Education on
WMD Threats and Response for the US Air Force