Countering WMD Journal

Biodefense Edition:

- Barriers to Bio Weapons Development: Potential Implications for Pathway Disruption
- Revolutionary Incidents: “Exploiting Naturally Occurring Outbreaks of Disease for Military Gain”
- A Soldier Scientist in the Land of the Rising Sun: Bilateral Biodefense Research with the Engineer and Scientist Exchange Program

Featuring:

- Journal Article Watch
- Book Reviews

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COUNTERING WMD JOURNAL

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Mission Statement

The Countering WMD Journal is published semi-annually by the U.S. Army Nuclear and Countering WMD Agency. It furthers the education and professional development of military and civilian leaders and members of government and academia concerned with the nuclear and countering WMD matters.

Article Submission

We welcome articles from all U.S. Government agencies and academia involved with Countering WMD matters. Articles are reviewed and must be approved by the Countering WMD Journal Editorial Board prior to publication. Submit articles in Microsoft Word without automatic features; include photographs, graphs, tables, etc. as separate files. Please email us for complete details. The editor retains the right to edit and select which submissions to print. For more information, see the inside back-cover section (Submit an Article to Countering WMD Journal) or visit our website at www.usanca.army.mil/.

About the Cover

U.S. Army Nuclear Disablement Team Soldiers and Army Rangers seized and exploited an underground nuclear facility during a training exercise. Nuclear Disablement Team 1 trained with Army Rangers from the 75th Ranger Regiment during operations under simulated fire at the decommissioned pulse radiation facility, June 6. U.S. Army photo by Sgt. Daniel R. Hernandez.

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NOTES FROM THE DIRECTOR

COL. TINA SCHOENBERGER

Greetings to all members of the Countering Weapons of Mass Destruction (CWMD) enterprise and welcome to Issue 28 of the *Countering WMD Journal*.

This issue is built around the timely theme of biodefense. Ever since the onset of the COVID-19 pandemic, our leaders have wrestled both with the operational and strategic implications of biological threats and hazards. Scoping the impact of this ever-evolving threat has always been difficult. In today's world, faced with a rapidly evolving global security environment and growing resource constraints, leaders face even greater challenges as they decide what investments are required to prepare the Department for future threats.

While I'm certain the readers of this Journal don't require convincing, it is no understatement to say that the safety, security, and well-being of our nation, as well as the combat effectiveness of our Army and the Joint Force hang in the balance as we address this rapidly developing and elusive threat. As we think back to the pandemic itself, we can all remember the tremendous impact COVID-19 had on force flow, readiness building, security cooperation activities, and even the basic administrative tasks—schools, assignment cycles, preventive health care—required to keep the Joint Force ready to fight. While the quarantining of the *U.S.S. Theodore Roosevelt* in May of 2020 made headlines, the actual impacts of COVID-19 on the Joint Force were quiet, insidious, and devastating to the long-term readiness of the force.

It is useful at the outset to remember the definition of biodefense which includes "actions to counter biological threats, reduce biological risks, and prepare for, respond to, and recover from biological incidents, whether naturally occurring, accidental or deliberate in origin." The policy implications of known and emerging biological hazards and threats are of keen interest to senior leaders across the Department of Defense.

For much of my career, the discussion of biothreats conjured images of the response to the Amerithrax incidents of 2001. I, myself was called to respond to many "suspect" anthrax calls while I was serving as a member of the 62nd Weapons of Mass Destruction Civil Support Teams in LA, but it took a global pandemic to break us out of our narrow mindset focused on biological warfare agents. The restrictions on movement imposed by COVID-19 forced us to recognize that even naturally occurring biological hazards can be a potent challenge to the strategic mobility that makes the Joint Force such an effective instrument of national power.

While the pandemic highlighted the operational and strategic consequences of failure to counter infectious pathogens, the urgency of the threat is heightened by the rapid spread of biotechnology that is both dual-use and hard to attribute. As you will see in this issue, there is a great deal of work already underway to address this unique challenge. But there remains much more to be done.

At the national level, the 2022 *National Biological Defense Strategy and Implementation Plan* (NBS) envisions a world free from catastrophic biological incidents and lays out a set of objectives to effectively counter the spectrum of biological threats, enhance pandemic preparedness, and achieve global health security.

The DOD's 2023 *Biodefense Posture Review* (BPR), a first-of-its-kind, synchronizes the Department's biodefense planning with the 2022 National Defense Strategy (NDS), the NBS, and the efforts of allies and partners. It aligns with the overarching objectives of the NDS and its priorities support NBS goals and DOD's assigned roles and responsibilities in achieving them. The BPR outlines DOD biodefense missions and priorities, responsibilities, authorities, and needed capabilities, and it establishes several reform initiatives including a strategic approach to biodefense that focuses on Total Force preparedness through rapid response and resilience.

The Army led the way in biological defense when it published its 2021 *Army Biological Defense Strategy* (ABDS), which serves as the Army's guiding document in preparedness and response to biological threats and hazards. The ABDS outlines four Lines of Effort (LOE) that will enable the Army to: expand and share scientific, medical, and operational biodefense knowledge to hedge against strategic surprise; gain and maintain biodefense situational awareness to support decision-making; modernize biological defense policy, research, development, test, and evaluation (RDT&E), capabilities, and force structure; and create readiness to respond to biological incidents while projecting force during competition, conflict, and crisis.

When brought to fruition, the ABDS will permit the Army to recognize operational and strategic risks from biological threats and hazards, demonstrate resilience, protect the Total Army from biological threats, and mitigate the impact of biological incidents.

All these strategic efforts create the framework for our organizations to address the Department's vulnerabilities to a range of biological threat and hazards. But, like any strategic document, the implementation of each is what will determine their impact.

In Issue 28, in addition to our regular material on CWMD policy, science, and technology, you will find articles on barriers to biological weapons development as a pathway disruption, bi-lateral biodefense research with Japan as part of the research and engineering scientist exchange program, operational survivability in a biological environment, and a historical perspective on exploiting naturally occurring biological outbreaks for military gain.

Our adversaries' capabilities and ambitions in biodefense and WMD—while not fully known—are very likely expanding. The work you and your organizations do is vital, significant, and essential. My entire team stands ready to support you as we work together to improve the resilience and readiness of the force. Please do not hesitate to let us know how we can help.

Finally, enjoy this thought-provoking and insightful issue! I learned a great deal from perusing the content and I know you will as well. As always, please send us your comments and ideas on how we can provide better support or improve the *Countering WMD Journal*. ■

REVOLUTIONARY INCIDENTS:
"Exploiting Naturally Occurring Outbreaks of Disease for Military Gain"

ALEXIA GORDON, M.D.[1]

Introduction

"As an expeditionary force, the Army encounters endemic diseases in all areas of the world and operates where the conditions that give rise to emerging disease—globalization, conflict, environmental change—are prevalent. Army forces face adversaries that…are capable of exploiting naturally occurring outbreaks of disease for military gain."[2]

The United States Army published this statement as part of its 2021 *Army Biological Defense Strategy* (*ABDS*), a response to the impact of the COVID-19 pandemic on the United States military. The *ABDS* recognizes the potential impact of biological agents on military operations. However, SARS-CoV2, the coronavirus that causes COVID-19, is not the only biological agent of potential operational significance. The incidence of meningitis caused by the bacteria *Neisseria meningitidis* remains higher in the active-duty military population than in the general population.[3] During World War (WW) I, the U.S. Army experienced a meningococcal meningitis case fatality rate of 39 percent. The fatality rate was lower during WWII but bacterial resistance to the only available antibiotic treatment at the time, sulfa, led researchers at Walter Reed Army Institute of Research (WRAIR) to work toward the development of a vaccine. The U.S. Army introduced the first meningitis vaccine in 1972.[4] In 2010, Dr. Peter Leggat, a physician and professor of public health, noted that despite one hundred years of vaccine and other medical countermeasure development, "vector-borne tropical diseases remain amongst the great problems for operational deployment of military personnel."[5] And the Defense Centers for Public Health—Aberdeen reported a 40 percent increase in syphilis rates from 2020 to 2022.[6]

Although the COVID-19 pandemic has been, perhaps, the most significant since the 1918 influenza pandemic in terms of the disruption it caused, no adversary is confirmed to have deliberately exploited it for military gain. The same cannot be said, historically, for other biological agents of military concern. This paper examines two historical instances when biological agents were exploited for military advantage and, as a result, changed commanders' decisions. Disease outbreaks, and the associated opportunities to use those outbreaks for military gain, played significant roles in the outcomes of both the American Revolution of 1775-1783 and the Haitian Revolution of 1791-1804. During the American Revolution, the British army used a smallpox epidemic to their advantage against the Colonial rebels—countered by General George Washington's eventual mandate to inoculate Colonial troops against the disease. During the Haitian Revolution, the Haitian rebels, under the leadership of François Dominique Toussaint Louverture and his successor, Jean-Jacques Dessalines, exploited a seasonal yellow fever epidemic to enable their defeat of Napoleon's forces. In his play, *The Tempest*, Shakespeare wrote, "Past is prologue." A failure to appreciate the potential impact of infectious disease on military operations risks both the mission and the force.

Smallpox

Smallpox is the disease caused by variola, an orthopox virus. Spread from person to person by respiratory droplets, by contact with fluid from smallpox sores, or by contact with contaminated clothing or bedding, the variola virus comes in two forms. Variola minor causes a mild disease, with a death rate of about 1%. Variola major, on the other hand, causes severe disease and has an overall case fatality rate of 30%. The type of rash developed in cases of variola major further stratifies risk of death. A discrete rash, where the lesions are separated by normal areas of skin, has an associated death rate of 9%. In contrast, a confluent rash has a 62% death rate. Smallpox is highly lethal, only requires a small dose to cause infection, incubates for an average of twelve days before symptoms appear, and is easily spread from person to person, making it an ideal biological weapon.[7] Both variola major and variola minor are included on the Health and Human Services/ US Department of Agriculture Select Agents and Toxins list, a list of pathogens and toxins that "have been determined to have the potential to pose a severe threat to both human and animal health, to plant health, or to animal and plant products."[8]

The smallpox vaccine was not developed until 1796, by physician Edward Jenner. Prior to this, the only protections from smallpox were avoidance and inoculation. Inoculation involved placing infected fluid from a smallpox lesion into an incision in the skin of an uninfected person. That person would develop smallpox but, usually, a mild case.[9] Dr. Zabdiel Boylston, a Boston physician, inoculated hundreds of Bostonians and kept detailed notes of their reactions to the procedure, including severity. One of Dr. Boylston's patients, 18-year-old John Colman, "had a kind and favorable small-pox, as is common in this way, and soon got well."[10] Once patients recovered, they had life-long immunity to the disease. However, because people who underwent inoculation actually developed smallpox, they could spread the disease to others, meaning they had to be isolated until they were no longer contagious.[11] Rarely, an inoculated person died. As Benjamin Franklin noted in a 1752 letter to Boston physician, John Perkins, "Sometime last winter, I procured from one of our physicians an account of the number of persons inoculated during the five visitations of the smallpox we have had in 22 years… the number exceeded 800, and the deaths were but four."[12]

The risk of spreading smallpox associated with inoculation made the procedure controversial, with many jurisdictions banning it outright.[13] Historian Elizabeth Fenn stated in *Pox Americana*, "Inoculation, although permitted at times during the British occupation, had been banned by civil authorities, who feared it would spread the pestilence further."[14] The British Army ignored the civil prohibitions and, as stated by historian Ann M. Becker in "Smallpox at the Siege of Boston," "routinely inoculated [soldiers] if the variola virus was present."[15] Evidence suggests that the British deliberately inoculated people then sent them among the Continental Army troops in the hope of causing a smallpox outbreak.[16] These factors influenced George Washington's decision to maintain a lengthy siege against British-occupied Boston rather than attack the city.[17] Smallpox also contributed to the Continental Army's loss in the battle for Quebec.[18]

Smallpox and the Siege of Boston

In April 1775, British forces engaged Colonial militia at the battles of Lexington and Concord, west of Boston, Massachusetts. The militiamen drove the British back to Boston and, over the next month, surrounded the city. On June 14, 1775, the Continental Congress ratified the Continental Army and appointed George Washington as Commander in Chief. Washington assumed command on July 3, 1775. The British, under General Gage and, later, General Howe, remained in control of Boston and the harbor to the east while the Continental Army remained in control of the surrounding areas on the south and west. The siege of Boston was underway. In a letter to John Hancock, written on 4-5 August 1775, Washington wrote:

> General Gage is making preparations for winter… From the inactivity of the enemy since the arrival of their whole reinforcement, their continual addition to their lines, & many other circumstances, I am inclined to think that finding us so well prepared to receive them, the plan of operations is varied, & they mean by regular approaches to bombard us out of our present line of defense or are waiting in expectation that the Colonies must sink under the weight of the expense or the prospect of a winter's campaign.[19]

Later that month, in a letter to his nephew, Lund, Washington, expressed his frustration over the British refusal to "quit their own works of defense" and "come out" of Boston.[20] "We do nothing," he lamented, "but watch each other's motions all day at the distance of about a mile."[21] Initially, Washington wanted to attack Boston as he "wish[ed] a speedy finish of the dispute."[22] In a September 8, 1775, circular to his general officers, he sought their advice on "whether, in your judgements, we cannot make a successful attack upon

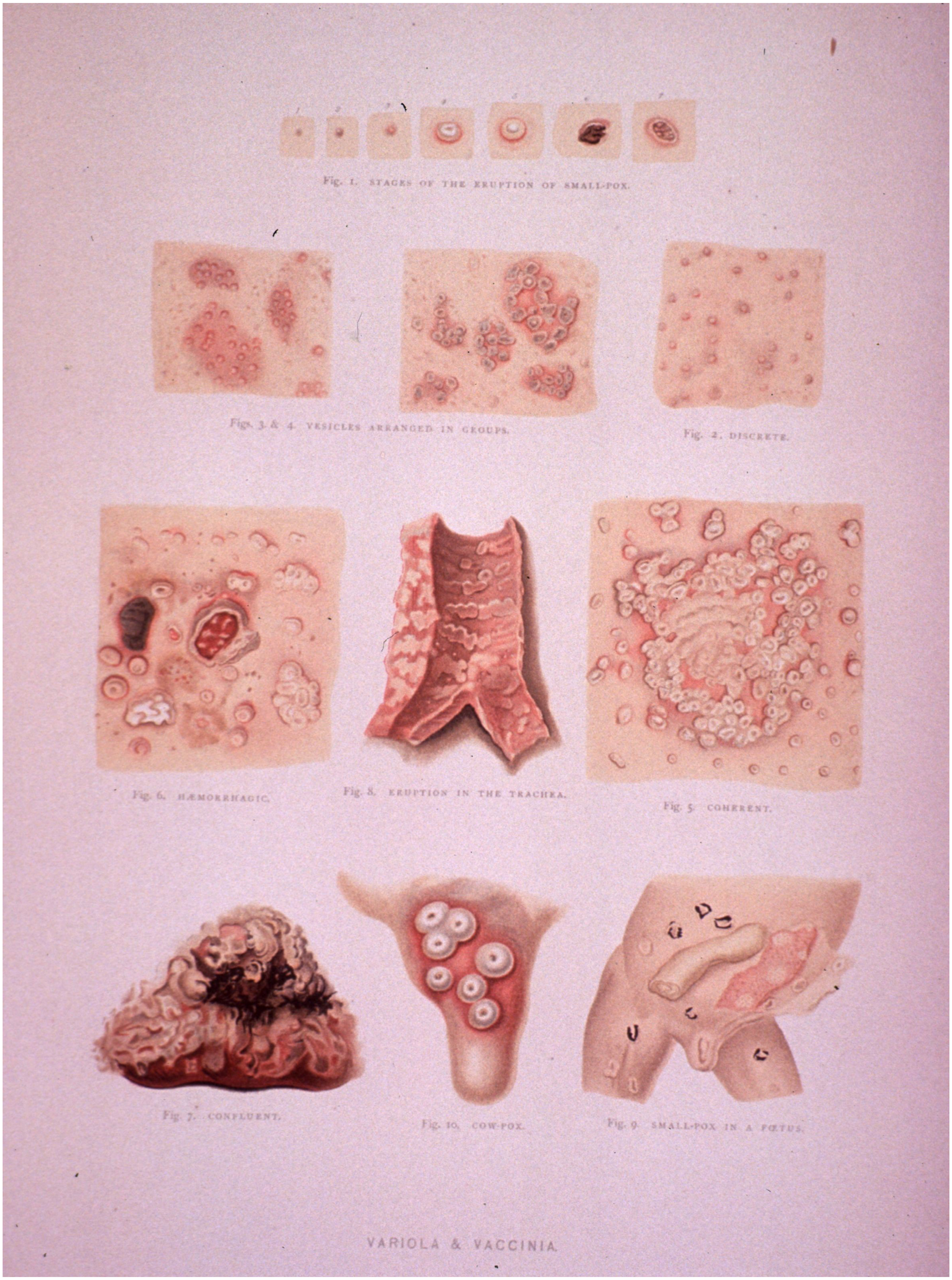

FIGURE 1: Byrom Bramwell. "Small-Pox : Variola & Vaccinia." In Atlas of Clinical Medicine. Edinburgh: 1892. Still image. Images from the History of Medicine. National Library of Medicine. http://resource.nlm.nih.gov/101434083.

the troops in Boston, by means of boats, cooperated by an attempt upon their lines at Roxbury."[23] His concern was for the coming winter weather "when warm and comfortable barracks must be erected for the security of the troops…a very considerable…expense must accrue on account of clothing [and blankets] for the men…"[24] Washington was also conscious that the current troops approached the end of their term of enlistment. "If this army should not incline to engage for a longer term than the first day of January… you must…levy new troops…These things are not unknown to the enemy."[25] Two days later, he expressed his continued frustration and his perplexity at the cause of the British inactivity in a letter to his brother, John Augustine Washington.

> Being…very securely entrenched and wishing for nothing more than to see the enemy out of their strongholds that the dispute may come to an issue. The inactive state we lie in is exceedingly disagreeable especially as we can see no end to it… Unless the Ministerial troops in Boston are waiting for reinforcements, I cannot devise what they are staying there after—and why (as they affect to despise the Americans) they do not come forth and put an end to the contest at once.[26]

However, knowing that smallpox raged through Boston and fearing New Englanders would refuse to fight as a result, Continental leaders "refused to permit nonimmune troops to enter Boston in an effort to prevent the spread of the disease."[27] The smallpox epidemic worsened and there was no attack. The siege continued.

The British used the Continental Army's vulnerability to smallpox to their advantage. Thousands of civilians lived in Boston at the time of the siege. While those loyal to the British crown may have regarded the city as a haven, not all the civilians wanted to remain, especially as supplies in the city dwindled. Allowing civilians to leave Boston benefitted the British by lessening the demand on resources.[28] In November 1775, "on account of the scarcity of wood and provisions [in Boston] …General Howe…issued a proclamation, desiring such of the inhabitants as are inclined to leave the town, to give in their names and a list of their effects."[29] Allowing them to leave also afforded General Howe the opportunity to spread smallpox to Washington's army. In an October 6, 1775, letter to the Massachusetts General Court, Washington reported that the "Winnisimet Ferry [to transport refugees from Boston to Chelsea] which was opened for the relief of the unhappy sufferers at Boston is now turned into a convenience for the enemy."[30] Washington warned that "caution [is] necessary to be used with these people to prevent a communication of the smallpox."[31] In December 1775, Washington reported evidence that "General Howe is going to send out a number of the inhabitants in order it is thought to make more room for his expected reinforcements…A sailor says that a number of these coming out have been inoculated with design of spreading the smallpox through this country and camp."[32] He wrote to John Hancock, "About 150 more of the poor inhabitants are come out of Boston, the smallpox rages all over the town, such of the military as had it not before are now under inoculation—this I apprehend is a weapon of defense [the British] are using against us."[33]

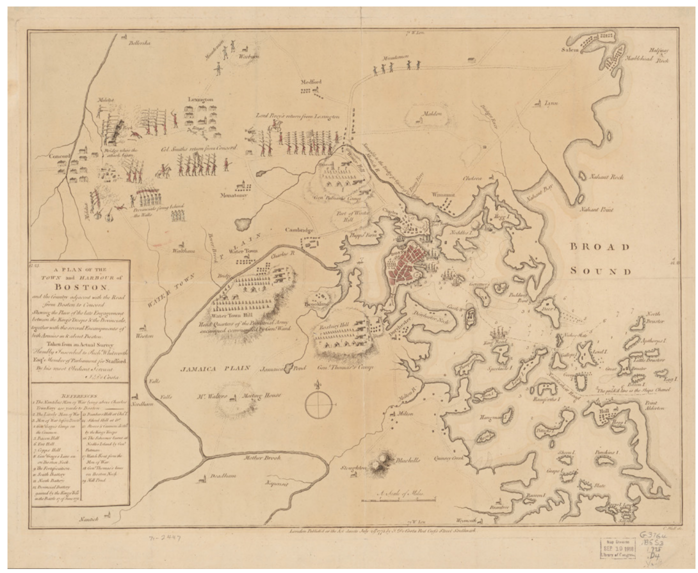

FIGURE 2: De Costa, J, and Charles Hall. "A plan of the town and harbour of Boston and the country adjacent with the road from Boston to Concord, shewing the place of the late engagement between the King's troops & the provincials, together with the several encampments of both armies in & about Boston. Taken from an actual survey. London, 1775." Map. Library of Congress. https://www.loc.gov/item/gm71002447/.

The siege of Boston lasted for almost a year. In January 1776, the Continental Army received cannon and artillery that had been captured at Fort Ticonderoga.[34] This prompted Washington to fortify his position at Dorchester Heights, a hill south of Boston from where the Continental Army could bombard the city. On March 13, 1776, Washington ordered,

> As the ministerial troops in Boston, both from information and appearance, are preparing to evacuate that town: The General expressly orders that neither officer or soldier presume to go into Boston, without

> leave from the General in Chief at Cambridge or the commanding General at Roxbury, as the enemy, with a malicious assiduity, have spread the infection of the smallpox through all parts of the town. Nothing but the utmost caution on our part can prevent that fatal disease from spreading through the army, and country, to the infinite detriment of both.[35]

Howe wanted to attack Dorchester Heights but the risk of suffering casualties on the magnitude of those lost at Bunker Hill, combined with a severe storm that rolled in, changed Howe's plans.[36] He decided to evacuate Boston. Washington agreed to a truce, in exchange for a British promise not to set Boston on fire, and the British left Boston by its harbor on March 17, 1776.[37] Washington ordered General Israel Putnam to "take possession of the [Dorchester] Heights" to prevent the British from returning and recapturing it and gave him command of "a thousand men," restricted to soldiers "who had had the smallpox."[38] Continental brigades that marched into Boston the day after the British evacuated were ordered to "cleanse" the town from smallpox." Other officers and enlisted were forbidden to enter until "the Select Men report the Town to be cleansed from infection."[39] The risk of disease had forced Washington to alter his strategy by choosing a lengthy siege over an attack and continued to impact his decision-making by restricting force flow into the city.

Smallpox and the Quebec Campaign

While Washington besieged Boston, the Continental Congress, heartened by American victory at Fort Ticonderoga, New York, in May 1775, planned an invasion of Canada. They wanted to capture the cities of Chambly, Montreal, and, ultimately, Quebec, thereby delivering Canada into American hands.[40] Initial plans called for General Schuyler to lead the campaign.

FIGURE 3: Faden, William. "Plan of the city and environs of Quebec: with its siege and blockade by the Americans, from the 8th of December to the 13th of May, 1776." [London: S.N, 1776] Map. Library of Congress. https://www.loc.gov/item/gm71005424/.

In an August 20, 1775, letter to Schuyler, Washington wrote, "The design of this express is to communicate to you a plan of an expedition… to penetrate into Canada by way of the Kennebeck River and so to Quebec by a route ninety miles below Montreal— I can very well spare a detachment of 1000 or 1200 men."[41] However, illness prevented Schuyler from leading the campaign, so command fell to General Richard Montgomery. Montgomery marched to Quebec Province in September and captured Montreal in November 1775.

Washington sent another 1000 men to Canada under the command of Colonel (later General) Benedict Arnold. Arnold planned to approach Quebec from the east while Montgomery approached from the west, allowing the Americans to surround the city. On December 5, 1775, Washington wrote to Arnold, "I have no doubt but a juncture of your detachment with the Army under General Montgomery is effected… you will put yourself under his Command and will, I am persuaded, give him all the assistance in your power."[42] Arnold arrived at Quebec in November but, unfortunately, he had lost nearly half of his troops to disease and desertion before he arrived. In a letter written the same day to General Schuyler, Washington wrote, "It gave me the highest satisfaction to hear of Colonel Arnold's being at point Levi, with his men…after their long and fatiguing march, attended with almost insuperable difficulties and the discouraging circumstance of being left by one third of the troops."[43] Montgomery's troops joined Arnold's in early December, giving them a combined force of 1100.

Smallpox also arrived in December, infecting approximately one-quarter of the troops, leaving only about 800 men able to fight.[44] Significantly, the smallpox outbreak put retention at risk. Many of the troops' enlistments ended on January 1, 1776. Fears of smallpox kept them from reenlisting for another term. As Becker stated, "Smallpox broke out in the [Continental] army…In addition to destroying the health of the soldiers in the field…the prevalence of the disease in camp was a factor in the dearth of recruits attracted and reenlistments secured for the Northern Army."[45]

The impending loss of men forced Montgomery and Arnold to attack Quebec on December 31, 1775, despite blizzard conditions. The snowstorm caused confusion, disorientation, and weapons malfunction. Montgomery was shot and killed, Arnold was shot in the leg and forced to give his command to General Daniel Morgan, many Continental troops fled, some retreated, and others were captured. Morgan surrendered to the British commander, General Carleton.[46] Arnold was able to reorganize the remaining American troops and encircle Quebec. His siege lasted until May 1776 when he retreated in the face of continued American troop losses due to disease and the arrival of British reinforcements.

In a June 1776 letter reflecting on "the causes of our misfortunes and miscarriages in Canada," John Adams wrote, "the smallpox, an unexpected enemy, and more terrible than British troops, Indians, or even Tories, invaded our armies and defeated them more than once."[47] Adams wrote to his wife, Abigail, that same month, "The smallpox is ten times more terrible than Britons, Canadians, and Indians together. This was the cause of our precipitate retreat from Quebec."[48] Many believed the smallpox outbreak was a result of the British "inoculating the poor people at government expense for the purpose of giving [the disease] to our army."[49] On July 3, 1776, John Adams again wrote to Abigail, "All these causes [political disagreements leading to delays in the invasion of Canada] …would not have disappointed us, if it had not been for a misfortune which…perhaps could not have been prevented. I mean the prevalence of the smallpox among our troops… This fatal pestilence completed our destruction."[50]

The loss of Canada led to "the first medical mandate in American history."[51] "In January 1777…Washington instituted a new military strategy to protect his troops and sustain the Revolution: systematic troop inoculation."[52]In a February 1777 letter, Washington wrote, "Finding the Smallpox to be spreading much and fearing that no precaution can prevent it from running through the whole of our Army, I have determined that the troops shall be inoculated."[53] He detailed his plan in a February 10, 1777, letter to the New York Convention. He cautioned them to keep the plan "as much a secret as possible" in case the British heard "that many of our men were down."[54] Washington ordered recruits sent to Philadelphia where they would be inoculated "while their clothing and arms and accoutrements are preparing."[55] He also ordered that the recruits be inoculated in tranches to limit the number who were "down at a time," ensuring there would be enough men fit for duty. Hospitals were positioned in easily defensible areas in case the British got word of the inoculations and took advantage of large numbers of men being confined to the hospitals during the required isolation period to attack. Washington assured the Convention that "after the first and second divisions of patients (who should be inoculated at an interval of five or six days) have gone through, the thing [a smallpox outbreak] will become extremely light and of little consequence, whether it is known or not."[56]

Yellow Fever

Like smallpox, yellow fever is caused by a virus. Unlike smallpox, no inoculation or vaccination against the disease existed in the 18th century. A vaccine to prevent yellow fever was not licensed for use until 1938, more than 100 years after Haiti declared its independence.[57]

The yellow fever virus belongs to the flavivirus family. It is classified as a viral hemorrhagic fever, with an incubation period of three or four days before symptoms appear. The illness manifests as high fevers, headache, vomiting, delirium, and pain, followed by liver and kidney failure and massive hemorrhage. Approximately fifteen percent of those who become symptomatic after infection will develop severe disease and between thirty to sixty percent of those who become severely ill will die.[58] Death occurs within one to two weeks of symptom onset.[59] There is no specific treatment for the disease. Yellow fever, unlike smallpox, has not been eradicated. The World Health Organization (WHO) reported 203 confirmed, and 252 probable, cases of yellow fever in the twelve countries of the WHO African Region from January 1 through December 7, 2022.[60] Because it is spread by mosquito bites, rather than by respiratory droplets or contact, yellow fever's bioweapon potential is not as high as smallpox's. But it is not zero. The US Government has declassified and approved for public release reports of "mosquito biting activity" testing done in the 1950s and 1960s. These tests were conducted using *Aedes aegypti*, the species that transmits the yellow fever virus, by the U.S. Army Chemical Corps, which had been tasked with "providing the Department of Defense with adequate CBR weaponry."[61] And yellow fever proved an effective weapon when seasonal outbreaks were capitalized on by Haitian rebels in their fight for independence against the French.

Yellow Fever in the Haitian Revolution

The Haitian Revolution began with a slave uprising in August 1791, when the colony was under French rule and was known as Saint-Domingue. It continued throughout the war between Spain and France, the French Revolution and abolition of the French monarchy, the expulsion of the British from Saint-Domingue, and the rise of Napoleon Bonaparte to power. In January 1801, a little over a year after Bonaparte overthrew the French Revolutionary government and became Consul of France, Toussaint Louverture, the Commander-in-Chief of Saint-Domingue, drafted a constitution that abolished slavery on the island and guaranteed equal rights for the Black and mixed-race ("mulatto") population. Bonaparte, in response, ordered his brother-in-law, General Charles Victor Emmanuel Leclerc, to sail to Saint-Domingue to remove Louverture from power and reinstate French rule.[62] On October 31, 1801, Bonaparte issued secret instructions to Leclerc that detailed a three-stage invasion plan. He authorized a land army of 19,000 soldiers and a fleet of several ships.[63] He expected the mission to last for three months, critically, ending by April. Haiti's rainy season officially lasts from April through October.[64] In France, they knew that the rainy season in Saint-Domingue was deadly. In his history of the Haitian Revolution, *Avengers of the New World*, Laurent Dubois stated, "Bonaparte and his strategists had concluded that in order to be successful his troops must occupy Saint-Domingue before April because later in the year 'the climate of the colonies becomes very dangerous for European troops who are not acclimated to it.'"[65]

FIGURE 4: Le 1er. Juillet , Toussaint-L'Ouverture, chargés des pouvoirs du peuple d'Haïty et auspices du Tout-puissante, proclame la Gouverneur général, assisté des mandataires légalement convoqués, en présenceet sous les Constitution de la république d'Haïty / lith. de Villain, r. de Sèvres No. 11. [Toussaint Louverture reading the Haitian Constitution]. Haiti, 1801. Still image. Library of Congress. https://www.loc.gov/item/2004669332/.

FIGURE 5: Le Rouge, Georges-Louis, and Crépy. "Isle de St. Domingue. Paris, Chez Crepy, 1767." Map. Library of Congress. https://www.loc.gov/item/74691674/.

Yellow fever outbreaks occurred with predictable regularity in Saint-Domingue, fueled by the slave trade, which provided a steady flow of mosquitoes, in addition to human cargo, from areas of Africa where yellow fever is endemic, and by the tropical climate. The mosquitoes that spread yellow fever lay eggs in standing water during hot weather. Crowded port cities during the rainy season provided the perfect setting for the disease to spread.[66] As those who survive the disease are protected against future infections, Africans, and people indigenous to Saint-Domingue, likely had acquired immunity to yellow fever.[67] Those most susceptible to yellow fever were "young men recently arrived from northern climates"—the type most likely to be found in a military encampment or naval vessel in a mosquito infested port.[68] The colony had earned a reputation as a "murderous" "Torrid Zone" and Louverture and the other Haitian rebels would have been familiar with the effects of yellow fever on "young men recently arrived from northern climates."[69] Louverture would have witnessed first-hand the effect of the fever on the British troops he fought against from 1794-1798.

Leclerc landed at Saint-Domingue in February 1802. By mid-February, he had gained control of the southern half of the colony and Louverture had lost half of his troops to defection to the French. Louverture realized that his

> only remaining option was to hold out until the rainy season…with the hope that France's troops would succumb to the tropical climate and fall ill. His strategy was founded in reality: within the first two weeks of Leclerc's arrival, 2,000 European troops were already in the hospital, three-quarters of them

> sick… After three weeks, 500 more soldiers had died and another 1,000 were wounded. Leclerc is forced to request an additional 6,000 troops apart from those already promised and further reinforcement of 2,000 troops per month for the next three months in order for his mission to succeed.[70]

Louverture and the other rebels believed that the French would reinstitute slavery in Saint-Domingue if they were victorious. While "wait[ing] for the 'rainy season that will rid [them] of [their] enemies' through disease," they opted for "destruction and fire," which included burning cities, destroying roads, and fouling the water supply to deny the French the use of these resources.[71]

The tactic succeeded. By April 1802, the beginning of rainy season, "a third of [Leclerc's] original army is incapacitated and… European troops are dying in hospitals at the rate of 30-50 soldiers per day."[72] Despite Louverture's capture in June 1802, the rebels continued to fight. They had gained on Leclerc by September of that year. Thousands of troops and hundreds of ships were sent by Bonaparte to reinforce Leclerc and his successor, General Rochambeau, but, in a letter to Rochambeau, Leclerc complained, "Most of the troops of General Brunet are ill… Reinforcements have now arrived… But illness is ravaging the battalion so badly that I am obliged to send almost all back to France…"[73] In June 1802, Leclerc had written to Denis Descrès, a colonial minister, "If the first consul wants to have an army in Saint-Domingue in the month of October, he must send one from the ports of France, for the ravages of the sickness are beyond telling."[74]

Leclerc, himself, died of yellow fever in November 1802. Rochambeau assumed command and continued waging war against the rebels. However, "the deadly combination of 'yellow fever and an enemy who gave no quarter' steadily undermined Bonaparte's plans for Saint-Domingue."[75] In April 1803, Bonaparte sold the Louisiana Territory to the United States, ending his ambitions for a North American empire. The next month, Great Britain renewed hostilities against France in Europe, which meant that Rochambeau would no longer be able to receive reinforcements. Bonaparte had previously sent 80,000 troops and more than 400 ships to Saint-Domingue.[76] Fighting between the rebels and the French continued until November 1803 when the rebels, under the command of Jean-Jacques Dessalines, defeated the French at the Battle of Vertières. Rochambeau surrendered and negotiated a cease-fire to allow the French to evacuate. "They left behind them upwards of 50,000 dead, the majority of the soldiers and sailors sent to the colony since early 1802."[77] Of the fifty- or sixty thousand who arrived in Saint Domingue from France, only 10,000 survived to return home.[78] Rebels who believed "the prospect of defeat"—in other words, re-enslavement— "was more frightening than the rigors of war," aided by strategic use of a predictable yellow fever outbreak, defeated France and established the independent republic of Haiti.

Conclusion

The American and Haitian revolutions both involved poorly trained, poorly equipped rebel colonists fighting against a world power's larger, better equipped, professional force. Both revolutions were motivated by a mix of economic pragmatism and the idealism of the Enlightenment. And in both, the outcome of events hinged on the knowledge of how to exploit a naturally occurring disease.

The British used smallpox to help them in their fight against the Americans, successfully at the battle of Quebec. However, because a medical countermeasure—inoculation—was available and George Washington was willing to mandate that his troops be inoculated, despite the risks and the opposition, the Americans were able to overcome Britain's efforts to take advantage of a biological incident.

In Saint-Domingue, both the rebels and the French troops knew that if the French were still in the colony during the rainy season, yellow fever would decimate them. Effective medical countermeasures against yellow fever did not exist. A vaccine would not be developed until the twentieth century. The only way to avoid the fever was to avoid Saint-Domingue's ports during the rainy season. The Haitians understood that the way to defeat the French was to keep them in the colony long enough for yellow fever to shift the odds toward their favor. This they did. Effective medical countermeasures against one biological agent and effective exploitation of another led to the creation of the first and second independent republics in the world.

One can interpret "past is prologue" to mean that history repeats. In one sense, this is true. Pandemics and epidemics have occurred throughout recorded history at least since 430 B.C.E. The COVID-19 pandemic will not be the last. The Secretary of Health and Human Services declared COVID-19 a public health emergency (PHE) on January 31, 2020. [79] Since then, the world has experienced a global Mpox outbreak and an outbreak of Highly Pathogenic Avian Influenza. Disease outbreaks will continue to occur. However, an alternate interpretation of "past is prologue" offers a way forward. The past provides context. Lesson learned from the past can shape present actions and future outcomes. As the two examples detailed in this article—smallpox in the American Revolution and yellow fever in the Haitian Revolution—show, disease outbreaks have operational significance for the military. Therefore, military leaders and planners would be wise to heed the lessons of the past and consider how bioincidents, whether naturally occurring, accidental, or deliberate, will affect decision-making during large scale combat operations. ■

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Notes

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BARRIERS TO BIOLOGICAL WEAPONS DEVELOPMENT:
Potential Implications for Pathway Disruption

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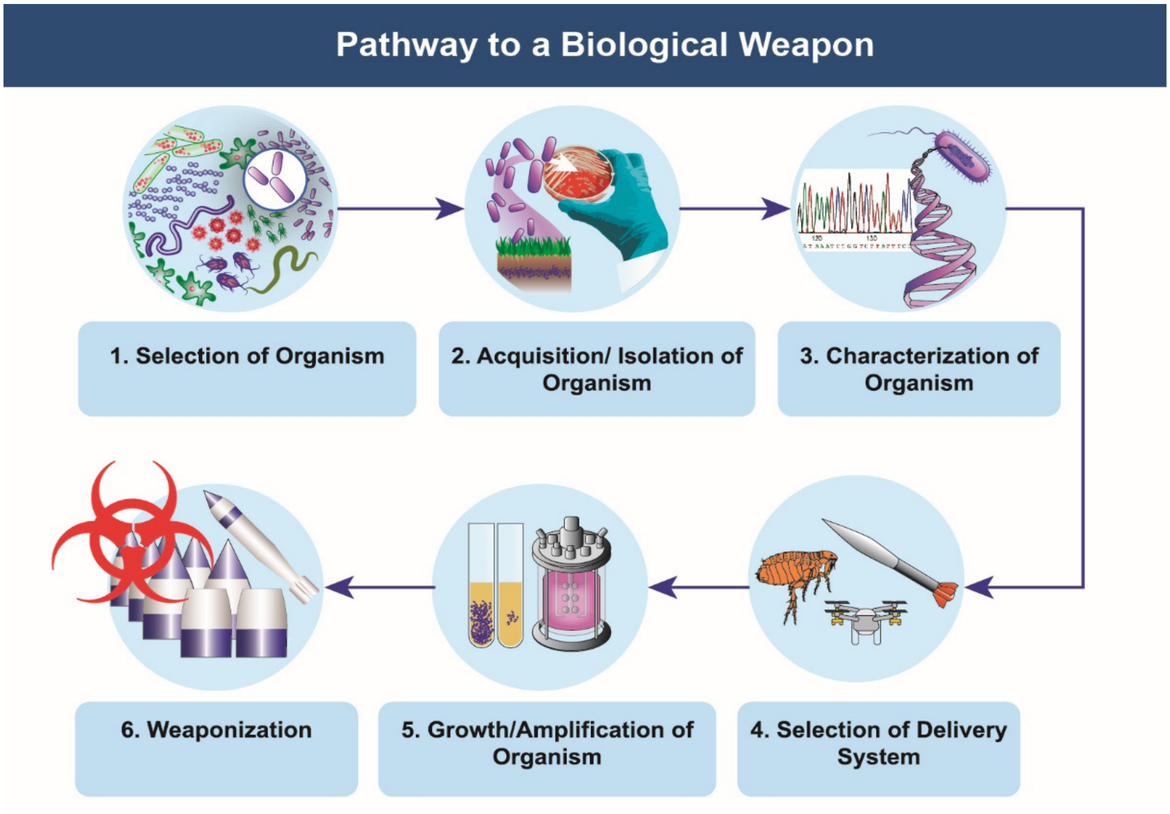
CAPT. SIANG-CHEAN KUA

Introduction

Biological weapons (bioweapons) are a highly complex and diverse group of threat agents.[1] They can be derived from any organism that can cause disease. The complexity of bioweapons arises from the fact that they are living organisms with the ability to grow, replicate, mutate, and evolve.[2] Consequently, bioweapons are more difficult to control and regulate than chemical agents or nuclear weapons.[3] Additionally, they can be produced and distributed with minimal financial and material investment in a largely clandestine manner. [4] A recent example of this fact was provided by the discovery of an undercover biomedical laboratory in Reedley, California in 2023.[5] This facility was found to be storing illegal samples of several of the most infectious diseases including SARS-CoV2, rubella, malaria, dengue, chlamydia, hepatitis, and HIV. It was being operated by a Chinese national with ties to the communist party. Concerningly, local government entities did not know the Reedley lab existed until it was discovered through the chance observations of a local city code enforcement officer. [5] It is also important to recognize to the trained eye, grocery and hardware stores may offer a potential adversary access to nontraditional equipment and reagents that are capable of being used in the production and dispersal of biological weapons. For example, ricin is a biological agent that is capable of rapidly causing death in affected individuals. It is derived from the seeds of *Ricinus communis*, a species of flowering plant that is used to make castor oil (a common laxative).[6] These seeds can be readily procured at a hardware or horticulture store, and if they are used in a home garden setting, they can enable the production of more seeds that can be mashed and processed to extract the ricin in a home laboratory.[7] Despite the ease of and economy of producing these agents in a surreptitious manner, biological weapons are not commonly used during armed conflict. This is because there are numerous barriers to the development, production, and delivery of effective biological weapons.[8] However, the risk of a biological weapons attack will continue to increase as technology develops and knowledge of the life sciences improves and is distributed. Weapon development barriers can be exploited to interrupt the pathway for the production and use of these weapons by potential adversaries. These barriers typically fall into six categories. These can be best described as resulting from the selection of the organism, the acquisition or isolation of the organism, the characterization of the organism, selection of a delivery system, the growth, or amplification of the organism, and weaponization.



ABOVE: The six-step process to bioweapon development. The process begins with the selection of the organism for weaponization and proceeds through the steps of acquisition, characterization, delivery system identification, growth of the organism and final weaponization and combination with the delivery system. Each of these steps represents a barrier to weapon development and key nodes in the development process that can be targeted during counter-weapons of mass destructions operations. (Illustration produced by Ronald Pettit, MSMI)

Selection of an Organism as a Barrier to Bioweapon Development

The first barrier that must be overcome in the pathway toward the development of a bioweapon is the selection of an appropriate organism for the weaponization process. This task is non-trivial as history has shown that sub-optimal selection can lead to a failure in weapon development.[9] Bacterial pathogens such as *Bacillus anthracis*, the causative agent of the disease known as anthrax is the most common agent that has been developed and used as a biological weapon by both state and non-state actors.[10] Bacteria have been described as collections of autonomous biotic systems that are endowed with the ability to self-replicate and self-engineer.[11,12] Correspondingly bacterial growth tends to approximate an exponential function in which one bacterium inoculated into a flask of nutrient broth can produce billions of progeny bacteria within a few hours of growth time if it is given optimum nutrition ideal temperature, and proper gas exchange.[13] This rapid and autonomous reproduction rate was a major factor in the selection of bacteria for bioweapon development by state governments in the early 20th century as it reduced the cost and labor involved in production and enabled large amounts of material to be produced with minimum investment. However, the development of a bacterial pathogen into a bioweapon requires the ability to overcome numerous operational barriers. The first barrier is imposed by the diversity of the bacteria themselves. Bacteria are a tremendously diverse group of organisms. Recent estimates suggest that there are between 800,000 and 1.5 million prokaryotic operational taxonomic units (distinct types of bacteria) worldwide.[14]

To initiate a bioweapons program both state and non-state actors will necessarily have to down select a subset of this diversity for weaponization. This selection must be carried out in such a way as to select organisms that possess a set of predetermined desired characteristics. The most important characteristics of a bacterial bioweapon include rapid growth rate, (to facilitate production and dispersal), a minimal growth media requirement (to ensure economical amplification), low mutation rate (to ensure stability during storage and amplification), stability in dry form (to allow powder formation and aerosol dispersion), and thermal stability (to allow dispersion in the presence of sunlight and dispersion by low-yield explosive). In some cases, this down-selection has inadvertently been performed by academic or industrial scientists and the open-source literature can be utilized to identify strains with the desired characteristics. However, there is diversity within each of the strains themselves that will require expertise in the areas of microbiology and/or biochemistry to ensure that the appropriate organism has been selected, the desired characteristics are present, and that the strain can be grown in large enough quantities to allow tactical or strategic use.

An example of how strain selection can serve as a barrier to weapons development can be found by revisiting the case of the attempted biological attack on Kameido, Japan by the Aum Shinrikyo cult in 1993.[9] In this case, non-state actors attempted to aerosolize anthrax by spraying a liquid suspension containing the organism into the street from the roof of their headquarters near Tokyo. This attack failed to produce the desired effect since the strain of anthrax that they were able to acquire was lacking in a genetic element (that is necessary for pathogenicity).[9] The enormous diversity of bacteria, even within a single group, was not fully appreciated. This lack of understanding led to the selection of an unsuitable agent for weaponization. As a result, the attempt at biological terrorism failed.

Acquisition of Biological Agents as a Barrier to Bioweapon Development

Once an organism has been selected for weaponization the next barrier in the pathway toward converting it into a bioweapon is the acquisition of the organism. The magnitude of this barrier can range from minimal to substantial depending upon the nature of the organism in question. Bacteria and viruses can be acquired from a variety of sources. In some cases, they can be purchased from biological supply companies or acquired from non-profit culture collections.[15] They can also be obtained from academic or industrial research laboratories under the guise of legitimate research and collaboration. Since bacteria are autonomously replicating organisms, large numbers of organisms can be readily produced from a small sample. Actions as simple as furtively touching a bacterial culture growing on the surface of a nutrient plate with the tip of an ink pen can provide ample material for weaponization.[16] Both bacteria and viruses can be cultured from the environment or from infected patients. For example, anthrax is ubiquitous throughout the world, and it can be isolated directly from contaminated soil. Published data concerning regions of the world with high anthrax contamination is available in the open literature.[17] However, there are numerous barriers to isolating bacterial or viral agents from the environment. Using anthrax as an example, these barriers would include determining the form of the agent to be isolated and obtaining the reagents and equipment necessary to initiate the process. First, a decision would have to be made as to whether bacterial spores (the dormant form of the bacteria that has historically been used in aerosol-delivered weapons) or vegetative (actively growing) organisms are to be isolated and then a method would have to be identified to selectively isolate agent from the soil. To give an illustration of the complexity of this process consider that direct spore isolation would require the collection of soil in some type of sample bottle, followed by mixing with a deflocculant (chemical that breaks up large soil particles) followed by shaking and centrifugation at low speed to remove bulk soil.[18] The remaining liquid would then need to be centrifuged a second time at increased speed to collect the spores which will settle at the bottom of the tube. The isolation of vegetative anthrax cells is also a complex process in which a selective nutrient media will be required.[19] Once the soil is plated on this media, it would need to be grown in an incubator capable of maintaining a stable humidity, atmosphere, and temperature for the growth of the organism and then collection of the organism for further expansion would need to be performed in a biological safety cabinet by personnel wearing the appropriate safety equipment to prevent staff contamination.[20]

It is worth noting that techniques have been developed that allow the construction of artificial bacterial genomes that can be inserted into a host cell that has been purged of its native genome.[21] These techniques have been utilized to produce partially synthetic bacterial cells capable of functioning on a minimal genome. In theory, this could allow genes encoding toxin production, environmental stability, spore production, and other factors of pathogenicity to be added onto the minimal genome backbone. These techniques may eventually allow the construction of designer biological weapons that can be tailored to target populations and environmental factors without the need to acquire the organism from an environmental or commercial source. However, this level of biological engineering is accompanied by numerous barriers and would require specific expertise and technical capabilities to include specialized expertise in the fields of bioinformatics, biochemistry, and molecular genetics.[22]

Characterization of Potential Biological Agents as a Barrier to Bioweapon Development

The characterization of a potential bioweapon represents another barrier in the pathway of weaponizing biological agents. This is again due to the extraordinary diversity that can be found in the biological world. Biological organisms (particularly bacteria and viruses) are notoriously difficult to identify and distinguish from one another. Bioweapon development requires specific strains or subgroups of bacteria and viruses that can deliver a pathogenic effect on a given population to achieve a strategic or tactical objective. In the laboratory setting, bacteria are either grown on small circular plates containing a nutrient substrate or they are grown in a liquid broth.[23] Without microbiological expertise, the appropriate equipment, and an appropriate reagent set, identifying strains with weaponization potential would difficult if not impossible.[24] This fact was clearly demonstrated in the Aum Shinrikyo case mentioned above. [9] Microbiological expertise and a well-equipped laboratory would have been necessary for the cult members to determine that the strain of anthrax that they acquired did not have the genetic material for toxin production. They then would have had to select another strain (which would also have to be characterized) or attempt to modify the strains that they had available to confer the desired level of pathogenicity. Characterization of this agent could have been completed by using a selective nutrient media specific for anthrax to verify that they had the correct species of bacteria. This would have been followed up by a confirmatory evaluation to demonstrate the correct microscopic morphology of the bacteria. The presence or absence of the appropriate genetic material could have then been verified by a molecular biological technique known as a polymerase chain reaction that functions by producing numerous copies of the bacterial genome allowing specific characteristics (such as the presence or absence of pathogenicity markers) to be rapidly identified. A more advanced technique known as DNA sequencing would be necessary for complete characterization (determination of all pathogenicity and environmental stability associated genes) of the bacterial genome. This is a technically complicated procedure that relies on a skilled laboratory staff as well as on computational expertise and the availability of networked computer access.[25] It is worth noting that the complexity of characterizing biological agents has decreased in recent years. This is mostly due to the near-ubiquitous availability of DNA sequencing technology, new molecular techniques, and the widespread distribution of bioinformatics tools and analysis pipelines.[26]

Selection of a Delivery System as a Barrier to Bioweapon Development

It has been demonstrated that biological weapons can be delivered using insect vectors, aerosol dissemination, human to human transmission, or by the contamination of food or water.[27] Depending on the characteristics of the organism the selection of a delivery system can represent a barrier to weaponization. Recent experience with anthrax has shown that aerosol dissemination is one of the most likely methods of dispersion to be used by an adversary.[28] This is because an aerosol method would enable maximum casualty generation with minimum resources. Indeed, it has been estimated that a line-source release of 50 kilograms of anthrax spores over two kilometers can potentially lead to 95,000 deaths and 125,000 incapacitations. [27] Aerosol delivery can be accomplished by the release of vegetative (actively growing) cells or spores. As mentioned above, anthrax spores tend to have a higher tolerance for extreme environmental conditions and are therefore the form most likely to be used as strategic or tactical biological weapons. [28] This material can be delivered by industrial sprayer in a fixed location (point-source dissemination), from a moving aircraft such as an airplane or drone (line source dissemination) or by the detonation of an explosive device (point source dissemination).[29] In the Aum Shinrikyo case, industrial sprayers were used by the terrorist cult. However, they proved to be ineffective since the correct strain of anthrax was not selected, characterized, and processed into a usable form. [29] The selection of delivery system will most likely depend upon a rational calculus that will be developed and employed by potential adversaries in such a way as to increase the chance of achieving specific tactical and strategic objectives. Industrial sprayers disseminating a bacterial agent will most likely be used for tactical effect, line source dissemination from a drone or an airplane will most likely be used to generate large numbers of casualties for strategic impact and point source dissemination from explosive devices can be used in both a strategic and tactical manner.

Amplification of the Organism as a Barrier to Bioweapon Development

Agent amplification or expansion can be a significant barrier to weaponization. To produce a viable weapon, it is necessary to produce large quantities of agent for dispersal or to fill munitions. This activity requires knowledge of the growth characteristics of the agent, the selection of appropriate growth media, and the acquisition of the equipment required for growth and containment. In the case of anthrax, growth of the organism in a laboratory setting would require the acquisition or development of a specific growth medium.[30] Typically, such media consists of a liquid suspension of glucose (carbon and energy source), amino acids (carbon and nitrogen sources), and other compounds capable of supporting robust bacterial growth. The optimization of the growth conditions for large-scale production of bacteria in the laboratory setting requires the use of a fermentation system.[31,32] Such devices typically consist of an autoclavable glass reactor vessel (capable of holding several liters of liquid), a bio-controller unit capable of maintaining the pH and temperature of the culture, a motor control unit capable of controlling the activities of a thermo-circulator for the maintenance of aeration, gas exchange and nutrient circulation, and a sterile air source. Production begins by inoculating sterile culture media in the bioreactor with either an overnight bacterial culture or with bacterial spores that will germinate within the system. Growth can be carried out for several hours at a predetermined temperature and monitored with the use of a spectrophotometer.[33] If a bacterial agent is being produced for aerosol dispersion it will be necessary to generate spores. Since spores are the dormant inactive forms of bacterial cells that can survive in conditions of temperature, humidity, and nutrient deprivation that would kill actively dividing cells, they are ideal for aerosol delivery. The acquisition of the required equipment and the development or acquisition of protocols and procedures to use this equipment to produce the quantities of agent necessary for a biological attack will continue to be a rate limiting step in bioweapon production.

Weaponization as a Barrier to Bioweapon Development

With respect to biological weapons, the term weaponization refers to the process by which a biological organism is converted from its native state into a form that can be used to inflict mass casualties, stored for future use, and combined with a delivery system for dispersal. The barriers to this process begin with the conversion of the organism into a form that can be widely distributed in the environment and remain stable long enough to infect the target population. Again, the use of anthrax as a historical precedent for bioweapons development can provide insight into the barriers posed by this process. The spore form of anthrax is the preferred form for aerosol delivery. Producing a concentrated suspension of spores can be technically challenging and require the use of specialized equipment and reagents. This process involves the growth of the selected anthrax strain on nutrient media in a controlled temperature, humidity, and atmosphere environment for at least 24 hours, followed by the growth in a bioreactor of a small portion of the 24-hour culture for amplification and the initiation of spore formation by nutrient deprivation.[35] The resulting spores can be collected from the bioreactor and purified through a series of wash steps and a process known as density gradient centrifugation in which the spores are passed through a medium that allows the separation of the spores from the nutrient media and other contaminants.[36] The purified spores then need to be freeze-dried in a process called lyophilization and then they can either be used without modification or they can be treated with a variety of reagents to alter their electrostatic properties to increase the range of aerosol dispersion.[37] The final step in weaponization is the combination of the biological agent with a munition or delivery system. High concentrations of spores are needed for this purpose. This was demonstrated in 2001 when a series of anthrax-laced letters were sent out to various media personalities and government officials. These events were called the “Amerithrax” attacks and they appeared to have been conducted by someone familiar with biological weapons development. Laboratory analysis indicated that the spore preparations used in the letters contained average of 100 billion spores per gram of material. [37] These attacks were highly successful and even with a suboptimal delivery system (the postal system) they resulted in 5 deaths and 17 non-lethal infections. However, it should be noted that the choice of delivery system will depend upon the goals of the biological attack (strategic versus tactical), and it will not always be chosen for psychological impact or terrorism purposes. For tactical effect, point source or line source dissemination of the agent from a low-yield explosive munition or from a commercial sprayer might be employed. For strategic effects, intercontinental ballistic missiles containing anthrax-filled submunitions might be employed. The primary barrier to the use of strategic biological weapons might be inconsistent shelf-life. Anthrax has been found to lose the plasmids necessary for toxin production during long term storage.[38] Therefore, it might not be possible to stockpile effective biological agents in the same way that strategic nuclear weapons are stockpiled.

Barriers to the Production of Viral Bioweapons

Viruses have been developed as bioweapons in the past. This was illustrated in the late 1970s in the Soviet Union in a case in which approximately 400 grams of a virus known as *Variola* major was released into the atmosphere through a low-yield explosive munition. This release resulted in the death of a laboratory technician working on an unrelated project 15 kilometers from the release site.[39] Significantly, the acquisition and development of viruses for bioterrorism presents several challenges which make their use as bioweapons particularly difficult. Viruses are obligatory intracellular parasites requiring a living cell for replication, this makes their acquisition and mass production more challenging than bacteria since they cannot be readily isolated from the environment, and they require specific animals or animal-derived cells for production. Potentially weaponizable viruses include members of the filoviruses such as Marburg and Ebola, which have a high mortality rate, require low numbers of viral particles for infection, display rapid dissemination, and lack an effective treatment or prophylactic vaccine.[40] The acquisition of these highly virulent viruses is, by itself, an obstacle due to currently limited knowledge regarding their geographic distribution and the identification of all existing animal reservoirs. In addition, there is a limited stock of these viruses in highly regulated and secure BSL-4 laboratories. In fact, the Aum Shinrikyo cult attempted to acquire Ebola virus from the Democratic Republic of the Congo in the early 1990's but they were unsuccessful.[41] Although actual acquisition, propagation, and dissemination of these viruses may be difficult, the mere threat of their use can be employed to incite widespread fear and panic and this threat alone may be an effective psychological weapon.[42] However, it should be noted that it is now possible to synthesize viruses directly from a set of chemical precursors. This was demonstrated in 2002 when researchers were successful in constructing a synthetic polio virus genome resulting in the production of infective virus in animal cells.[43] As this technology is refined, it may become possible for state and non-state actors to develop tailor-made viruses without the need to acquire them from an outside source. There are numerous barriers and challenges to this approach including the acquisition of bioinformatics expertise and the necessary laboratory infrastructure.

Pathway Disruption

At the state level, one of the most common methods of pathway disruption is the development of international treaties as a means of discouraging the production and use of bioweapons by potential adversaries, in 1972 a total of 87 countries signed onto the Biological Weapons Convention (BWC) This treaty initiated an international ban on the production and use of biological weapons development and provided for the disarmament of biological stockpiles.[44] Another means of preventing weapons development is to deny the enemy the expertise necessary to succeed and to divert their interests away from weapons development to public health improvements and other peaceful pursuits. Once a nation-state or terrorist is on the path toward weapons development the focus for disruption must shift to the disruption of the technical aspects of the pathway. This can begin with the six steps outlined in this paper. Organism selection can be disrupted by blocking access to databases and websites containing data on biological agent properties, pathogenicity, and growth characteristics. The acquisition of an organism can be blocked by preventing the shipping of an isolate from commercial source to the group or nation of concern. The isolation of an organism may be blocked by restricting access to websites or databases containing instructions for pathogen isolation, media components, atmospheric conditions, or growth times. It might also be possible to block the purchases and shipping of media, media components, bioreactors, and incubators. Agent characterization is largely a bioinformatics driven effort, and this can be disrupted by blocking access to bioinformatics expertise, bioinformatics software and tools (local or online), and by blocking the acquisition of the necessary computer equipment to carry out the required analytical process to characterize an agent. Defensive cyber operations might be effective in identifying computer systems with bioinformatics capability and removing or interfering with these functions. The ability to grow and amplify a biological agent can be interrupted by restricting access to bioreactors, centrifuges, culture media, culture reagents, or the components to produce these items. From the cyber perspective, it might also be possible disrupt the function of bioreactors and centrifuges using computer worms or other forms of malware targeting the control system. This would be particularly effective during this stage of weapon development since precise growth conditions are required for the large-scale production of an effective agent. The final step in the biological development pathway (weaponization) can be interrupted by preventing access to the components necessary to produce sprayers, missiles, low yield munitions, or submunitions. It can also be interrupted by preventing the storage of biological material by blocking freezer acquisition or interfering with freezer function through cyber operations to prevent the storage of the agent.

Conclusion

Biological weapons are deceptively simple. A cursory review of the literature suggests that they can be easily produced by both state and non-state actors with minimal expertise and material resource investment. While it is true that biological agents are cheaper to produce and easier to acquire than the materials needed for fission-based weapons, there are significant barriers that must be overcome to design, develop, and deploy a reliable biological weapon. These barriers include the selection of an appropriate agent, the acquisition of the agent, the characterization of the agent, delivery system selection, amplification of the agent, and final weaponization. The significance of these barriers is underscored by the fact that effective biological attacks are not common on the modern battlefield and widespread biological terrorism has not been effectively carried out by non-state actors. However, it should be noted that as technology increases and access to knowledge and expertise becomes more universal, these barriers will begin to degrade. Understanding the process of biological weapon development and the barriers to weaponization will be essential to developing tactics, techniques, and procedures for discouraging biological weapons development and disrupting the weaponization pathway. ■

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OPERATIONAL SURVIVABILITY IN A BIOLOGICAL ENVIRONMENT

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Introduction

Throughout history, disease has been a constant companion of warfare, often proving as deadly as the weapons themselves. From ancient times to the present day, the impact of disease on military campaigns remains a significant hindrance to the combat power of troops. Disease outbreaks were common among armies due to crowded living conditions, poor sanitation, and lack of medical knowledge. Epidemics such as the Plague of Athens during the Peloponnesian War and the Antonine Plague during the Roman Empire weakened armies and even contributed to the fall of empires.[1,2] The 20th century saw advancements in medical science, but disease remained a formidable foe in warfare. During World War I, millions of soldiers died from diseases such as influenza and trench fever.[3] World War II saw other diseases like typhus and malaria, which affected troops in various theaters of war.[4] In recent decades, advances in medicine and public health have reduced the effect of disease on military operations. However, infectious diseases such as Ebola, Zika, and COVID-19 continue to pose significant challenges to modern military forces, highlighting the ongoing threat that disease presents in warfare.[5]

The convergence of increasingly complex systems, diseases, and warfare presents a multifaceted challenge in contemporary times. Advancements in technology have led to the creation of interconnected structures, from global transportation networks to digital infrastructure. While these organizations have brought benefits, they have also introduced vulnerabilities in cyber-biosecurity and automation of biomaterial manufacturing that can be exploited by malicious actors. In the realm of public health, the emergence of new infectious diseases and the threat of pandemics are exacerbated by factors such as urbanization, global travel, and climate change; the intersection of complex systems and disease creates new challenges in the context of warfare. As conflicts become increasingly focused on large scale combat operations, the deliberate use of disease as a weapon adds a new dimension to military strategy.

Problem Statement

Deliberate biological weapon attacks, accidental biological leaks, and natural disease outbreaks all create large looming threats in today's world, with potential consequences ranging from localized disasters to global pandemics. Deliberate biological weapon attacks can occur in various settings, from terrorist acts in urban centers to state-sponsored operations targeting military or civilian populations. Accidental biological leaks may occur in high-security laboratories or research facilities, where dangerous pathogens are studied. Such incidents can lead to unintended outbreaks with severe consequences. These events can occur anywhere in the world, but densely populated urban areas, regions with inadequate healthcare infrastructure, and areas prone to political instability are particularly vulnerable.

While military forces have long recognized the biological weapons and natural disease outbreaks, there remains a lack of comprehensive doctrine and operational protocols for conducting military operations in such environments. Although certain documents address strategy and tactics, there is a lack of guidance and implementation to turn strategic goals into successful missions, especially at the operational level. Because of the lack of guidance, as noted in the last CWMD journal issue, current Joint and Service Component staffs face challenges in defining operational CWMD activity when confronting competition from adversaries.[6] Joint Force Staffs are tasked with coordinating strategy to enforce arms control treaties and export controls, operating to track and mitigate WMD capabilities, and preparing tactics to counter WMD use on the battlefield. Joining together these CWMD-related activities into theater-level planning and targeting presents a challenge for the operational staff, as they are primarily focused on other efforts. Many staff officers have limited knowledge of CWMD procedures except for the fundamentals usually found at the strategic and tactical levels of leadership.

Another complication within the CWMD field is that biological diseases behave differently when compared to the other three letters. The other notable CBRN weapons, nuclear, radiological and chemical weapons, have effects that while devastating are relatively straightforward to measure and model once a few conditions are set. The US military has decades of experience with nuclear and chemical tests that form a backbone of health and damage data that models rely upon. Biological models do not have this history of data. Additionally, the biological environment has a different challenge set compared to other environments; it is more difficult to detect production and employment, produces easier, can spread contagiously, uses a variety of delivery methods, needs a much lower dose of agent to be effective, can linger in the environment, has a less straightforward detection and treatment methods, and is cheaper to manufacture.[7]

Measuring the Effects of the Biological Environment

Addressing these interconnected challenges requires a holistic approach that integrates soldier’s health and materiel survivability measures to mitigate the risks posed by the convergence of complex systems, disease, and warfare. To best tackle this problem, the U.S. Army Nuclear and Counter Weapons of Mass Destruction Agency (USANCA) has proposed the merging of two concepts. The first is the operation, which is defined doctrinally as “a sequence of tactical actions with a common purpose or unifying theme or a military action or the carrying out of a strategic, operational, tactical, service, training, or administrative military mission.”[8] The second concept is survivability, which is “all aspects of protecting personnel, weapons, and supplies while simultaneously deceiving the enemy.”[9] Fusing these two terms, the definition becomes “operational survivability” which is the ability of personnel and materiel to survive in and through CBRN environments while solidifying the convergence of the human-materiel interface informing commanders of combat power availability, reliability, and operability, both looking at short- and long-term outcomes.

To understand the impacts of the biological environment on the military’s effectiveness, one must understand combat power. It provides a comprehensive assessment of capability to achieve military objectives across diverse operational environments. Combat power, defined as the total means of destructive and disruptive force that a military unit or formation can apply against the opponent at a given time, serves as a holistic metric encompassing multiple elements of military strength.[10] The concept of combat power embodies the army's ability to bring together its personnel, equipment, leadership, information systems, and supporting infrastructure to achieve mission success. Within its structure, the army contains the capacity for maneuver, firepower, protection, sustainment, and command and control.

Maneuver refers to the movement of forces into advantageous positions relative to the enemy to gain positional advantage and achieve operational and tactical objectives. Firepower denotes the application of lethal and non-lethal force against enemy forces, structures, and systems. Protection involves safeguarding personnel, equipment, and critical infrastructure from enemy threats, including direct and indirect fire, chemical, biological, radiological, nuclear (CBRN) hazards, and cyber-attacks. Sustainment encompasses the army's capability to maintain operations by providing personnel with the necessary logistics, personnel services, and health support. Command and control (C2) incorporates the army's ability to plan, direct, coordinate, and control military operations. By integrating the information systems, communication networks, and decision-making processes, leaders can make rapid and directive decisions.[11]

By assessing combat power, military leaders can evaluate the Army’s readiness, capability, and capacity to conduct operations across the full spectrum of conflict. Such activities can be related to conventional warfare, irregular warfare, stability operations, humanitarian assistance, and disaster relief missions. Biological diseases, however, can significantly degrade combat power by reducing the health and effectiveness of military personnel. Outbreaks of infectious diseases lead to high rates of illness, hospitalization, and death among troops, thereby reducing the army's overall manpower and operational readiness. Moreover, diseases such as influenza, malaria, and COVID-19 can spread rapidly within military units, disrupting training, operations, and logistics. Additionally, the need to implement preventive measures, such as quarantine and social distancing, can further strain military resources and limit the army's capacity to conduct successful operations. Despite advances in the medical sciences, biological diseases can surprise and evolve to pose a significant threat to combat power by undermining the health and readiness of military forces.

Factors in the Pre/Post Sneeze Environment

The operational impacts of biological diseases need to be explored within the context of large-scale combat operations, especially considering advancing medical and biotechnology, as well as other enabling technologies that converge with biomedical advances. Understanding these new potential consequences of biological threats on military operations is essential for preparedness and response. New biotechnologies are poised to significantly influence battlefield operations, offering both opportunities and challenges for military forces. These advances rapidly detect and mitigate the effects of biological threats on the battlefield through newly developed diagnostic tools, next-generation vaccines, and therapeutics. Additionally, developments in biotechnology enable the creation of advanced biosurveillance systems capable of detecting and identifying pathogens in real-time, enhancing situational awareness and early warning capabilities.[12] Moreover, the capability to engineer biological systems may lead to the development of novel materials, fuels, and sensors, as well as the creation of genetically modified organisms for environmental sensing and decontamination. Advancements in genomics and precision medicine also enable personalized medical treatments tailored to individual soldiers, improving health outcomes and resiliency on the battlefield. Biotechnologies such as CRISPR-based detection systems and nanoscale biosensors offer rapid and sensitive detection of biological threats, enhancing force protection and readiness.[13] The integration of biotechnology with big data analytics and artificial intelligence enables the rapid analysis of complex biological data, facilitating decision-making and operational planning.[14] Nature-inspired designs, such as biomimetic materials and bio-inspired robotics, offer innovative solutions for camouflage, sensing, and mobility in diverse battlefield environments.[15] These advancing biotechnologies have the potential to revolutionize military operations, enhancing the army's resources to detect, prevent, and respond to biological threats while also providing new opportunities for innovation and capability development.

Increasing the operational survivability of the Army requires a multifaceted approach that encompasses training and exercises, biosurveillance, early warning systems, planning, fighting in a persistent environment, and understanding the risk to the mission versus the risk to the force. Additionally, the use of protective gear, while essential, presents its own set of challenges. Practical training and realistic exercises are crucial for preparing military personnel to operate in environments contaminated with biological agents. Training should focus on recognizing biological threats, using protective equipment, and implementing decontamination procedures. Regular exercises allow units to practice response protocols and identify areas for improvement, especially for novel or rare diseases. Biosurveillance systems provide real-time monitoring of biological threats, allowing for early detection and rapid response. These systems integrate data from various sources, including medical facilities, environmental sensors, and intelligence reports, to identify potential outbreaks and track the spread of disease.[16] Comprehensive planning is vital for a functional response to biological threats by developing protocols for medical treatment, decontamination, and force protection, as well as coordinating with civilian and industry authorities and international partners. In the contested biological environment, military commanders must weigh the risk to the mission against the risk to the force when operating in biological threat environments, balancing the need to accomplish objectives with the need to protect personnel from exposure to biological agents. Military operations may require personnel to operate in environments contaminated with biological agents for extended periods, which will require specialized training, equipment, and logistical support to ensure the health and safety of personnel. While protective gear mitigates the risks posed by biological threats, it also has downsides. Protective equipment can be cumbersome, impede mobility, and impair communication, making it more difficult for personnel to perform their duties effectively. Additionally, operating in protective gear for extended periods can lead to fatigue and heat-related injuries.[17]

Reactions to an outbreak of disease include prophylaxis, hygiene, physical protection, identification of infection, decontamination, stabilization of health conditions of soldiers, pathways to reentry of the force, and assessment of operational combat power due to losses of materiel and manpower. Prophylactic measures, such as vaccinations and chemoprophylaxis, are critical for preventing the spread of infectious diseases among military personnel. Ensuring that troops are immunized against common biological threats reduces the risk of outbreaks and minimizes the impact on operational

ABOVE: (MOBILE, Al) - Pfc. Raymond Horace III, a guardsman with Task Force 31, fogging the kitchens of Crowne Health Care of Mobile with disinfectant, April 24, 2020. Task Force teams are going to designated facilities throughout Alabama to include nursing homes, veteran's homes and assisted living facilities. (U.S. Army photo by Sgt. Jaccob Hearn)

effectiveness. Maintaining high standards of personal and environmental hygiene through handwashing, proper waste disposal, and disinfection of equipment and living quarters prevents the transmission of infectious diseases. Physical protection measures, such as personal protective equipment (PPE) and collective protection systems, help to minimize exposure to biological agents. PPE, including masks, gloves, and suits, provides a barrier against contamination, while collective protection systems, such as shelters and sealed environments, offer additional layers of protection. Early identification of infected personnel is crucial for preventing the spread of disease within military formations. Training personnel to recognize the signs and symptoms of infectious diseases and implementing surveillance systems for monitoring health status are necessary components of infection control. Prompt and thorough decontamination of personnel, equipment, and facilities is critical following exposure to biological agents. Decontamination procedures, including washing, disinfection, and sterilization, help to remove or neutralize contaminants and prevent further spread of infection. Providing timely and appropriate medical care stabilizes the health conditions of infected soldiers by promptly administering medical treatments, managing symptoms, and preventing complications associated with the disease. Additionally, clear protocols for the reentry of infected personnel back into the force preserves operational readiness by ensuring that personnel are fully recovered, no longer contagious, and have received medical clearance before returning to duty. Finally, assessing the impact of biological threats on operational combat power maintains mission effectiveness through the evaluation of losses from materiel and manpower, identification of vulnerabilities, and implementation of risk mitigation strategies.

Pathways to Mission Success

In those previous discussed areas, modeling and simulation, along with providing decision support with real-time assessments, is crucial for enhancing operational survivability in a biological environment. Modeling and simulation tools allow military planners to simulate various scenarios involving biological threats, including disease outbreaks, contamination events, and response efforts. These tools can simulate the spread of infectious diseases, the effectiveness of medical treatments, and the impact of different intervention strategies. By running simulations, military commanders and staff can better understand the potential consequences of biological threats and develop response plans.[18] Real-time assessments provide military commanders and staff with up-to-date information on the current situation and allow them to make informed decisions quickly. By integrating data from biosurveillance systems, medical reports, and other sources, decision support systems can provide real-time assessments of the spread of disease, the status of affected personnel, and the efficacy of response efforts. Commanders are then able to adjust their plans and allocate resources more appropriately in response to changing conditions. Lastly, multi-component exercises test and refine military capabilities for both known and unknown biological environments. These exercises involve multiple units and components of the military, as well as civilian agencies and international partners. By simulating realistic scenarios involving biological threats, exercises allow military forces to rehearse coordination, communication, and response procedures in a controlled environment. In addition, the testing of medical treatment protocols, decontamination procedures, and logistical support systems are also simulated.

Conclusion

To address the complexities introduced in a biological environment, operational survivability strives to bulwark its force's combat power and to understand the potential impacts of WMD use. WMD-use challenges large-scale combat across time and a geographically distributed space creating two operational environments. Modernization of survivability regulations, processes, and assessment tools reduce the risk of systems and formations becoming combat ineffective following a CBRN event. Deliberate modernization provides the Army with the tools to assess materiel and personnel survivability in real time. Non-computational training environments do not realistically simulate the breadth and scope of biological effects on Army maneuver units. Therefore, the commander is at a loss due to inadequate information contributing to an inability to develop mitigation strategies that enable operational success. However, available materiel test and evaluation metadata combined with known health effects provide a sufficient mechanism to quantitatively estimate and contribute to the operational survivability assessment. Computational codes can be developed to account for varying bio-environmental effects on materiel and personnel. Simulation platforms play a crucial role in life-cycle management by enabling end user understanding of CBRN weapon effects variability with respect to materiel modifications and alternatives.

Therefore, the goals of operational survivability specifically in the biological realm are:

- Assess biological effects on the force to maximize and coordinate the amounts and availability of critical biodefense supplies.

- Predict force degradation from biological weapons by understanding the long-term impacts on combat power from treatment and decontamination of materiel and personnel.

- Provide critical information to commanders to understand and demonstrate the ability to operate in and recover from the effects of biological environment.

By accomplishing those goals, the Army can achieve its end state of fielding a modernized, trained and equipped force able to operate in and through biothreat environments. Understanding bio incident impacts will empower commanders to adjust operational approaches to minimize risk and effectively mitigate vulnerabilities to fully preserve and employ combat power. ■

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A SOLDIER-SCIENTIST IN THE LAND OF THE RISING SUN:

Bilateral Biodefense Research with the Engineer and Scientist Exchange Program

BRADLEY M. KEARNEY, HIROYUKI NAKASHIMA, & MANABU KINOSHITA

Introduction

In the 2022 National Defense Strategy, the concept of "integrated deterrence" emerged as a method for achieving the goals of the Department of Defense in the post-Global War on Terror era.[1] In addition to the preparations across the various warfighting functions to close key capability gaps during the competition phase, the recent COVID-19 pandemic identified vulnerabilities in our response to biological incidents both natural and man-made.[2] To address these shortcomings in our biodefense research, the Department of Defense enterprise must act now to both incorporate lessons learned and to work with treaty allies, such as Japan, and other friendly nations to build a robust, integrated biodefense research program to deter biological weapon attack and mitigate the effects of future pandemics.

Integrated Deterrence and Biodefense

A constant theme in both the National Security Strategy and the National Defense Strategy is that the Joint Force must be ready to operate in a contested multi-domain environment[3] that will likely involve chemical, biological, radiological, and nuclear (CBRN) weapons[4] if the "vital interests or the integrity of [our adversaries] regimes lie in jeopardy."[5] As the Army reorients to these demands, we must both ensure that we synchronize our policies, concepts, and strategies with regional Combatant Command (COCOM) activities during this competition phase while also keeping pace with rapid changes in science and technology.

The impetus to keep pace with the rapid changes in science and technology was directly mentioned in the 2022 National Security Strategy which states that the Department of Defense must "increase the availability of fellowships, internships, and rotational assignments–including in private sector–to grow the skills of our workforce, provide a broad range of experiences, create collaboration opportunities, and carry best practices back to the Department."[6] This sentiment of maintaining a technologically cutting-edge team of Department of Defense scientists is also reflected in joint publications such as JP 3-0 ("with numerous stakeholders in the [countering weapons of mass destruction] mission area, it is critical [to] understand and consider the capabilities and responsibilities of various interorganizational partners when defining command relationships and coordinating interorganizational activities")[7] and JP 3-40 ("Maintaining expertise requires long-term commitment to recruiting, developing, and retaining high quality personnel").[8]

Integrated deterrence is an approach to "advance an international system that is free, and stable, and open" by relying on "partnership and innovation."[9] Although mostly used in reference to rivals of the United States in the geopolitical landscape, this concept can also be used to build a robust defense program against naturally occurring diseases or manmade bioweapons (a recent addition to the long history of civilization and disease).

From the earliest records of modern man, infectious disease limited the growth and expansion of civilizations worldwide. Smallpox, for example, existed long prior to the advent of recorded history, first appearing around 10,000 BC.[10] The tale of modern medicine is analogous to an ongoing arms race between doctors and pathogens.[11] Military strategists also understood how disease could be used as a tool of warfare. The earliest references to biological warfare first appeared in Western history in approximately 600 BC.[12] With the scientific and technological boom in the first half of the twentieth century, CBRN weapons and the Soldier-Scientists were born. As we learned more about how viruses and bacteria work, we also learned how to begin to tinker with these pathogens- to turn them into true bioweapons.

Global healthcare professionals recognized the need for integration to combat naturally occurring pathogens nearly 20 years ago. In 2008, the American Veterinary Medical Association introduced the "One Health" concept.[13] The One Health concept recognizes that public health is the integration of three types of health: human, environmental, and animal health. The One Health concept features prominently in modern Army Preventive Medicine doctrine to mitigate disease and non-battle injuries (DNBI).[14] Just as the One Health concept integrates research and medical experts to combat naturally occurring diseases, the United States government must integrate its efforts in biodefense with both the public and private sectors as well as with our strategic allies and partners. One key enabler for biodefense shaping operations is using our Soldier-Scientists in security cooperation activities with the Engineer and Scientist Exchange Program.

The Engineer and Scientist Exchange Program

The Engineer and Scientist Exchange Program (ESEP) is a US Security Assistance program administered by the Under Secretary of Defense for Acquisition and Sustainment (USD A&S) to promote international cooperation in military research, development, testing, and evaluation (RDT&E). The program is a reciprocal exchange of US military and civilian scientists and engineers working in allied and friendly government organizations with foreign government scientists and engineers working in US defense establishments.

The purpose of the ESEP is to improve insight into foreign military RDT&E techniques and acquisition processes, to facilitate the exchange of ideas and new techniques within the RDT&E community, to enable incorporation of best practices developed in allied and friendly countries, to enhance the professional stature and effectiveness of participants, thus strengthening Department of Defense research and development programs, and to identify and cultivate new areas of technical cooperation of mutual benefit to the host country and the United States.

The ESEP was first authorized by the National Defense Authorization Act for Fiscal Year 97 and its legal authority subsequently codified in Title 10 USC, section 311.[15] The Department of Defense designated the Air Force and Army as executive agents for managing exchanges with approved countries and designated the USD A&S as the authority for international agreements relating to cooperative RDT&E and related personnel exchanges.[16]

For the Army, the Assistant Secretary of the Army (Acquisitions, Logistics, and Technology) manages the ESEP for Department of the Army (DA) Civilians and active-duty service members.[17] Army ESEP participants are predominantly DA Civilians due to assignment billets. For DA Civilians, they can retain their billet at their home Army organization and use the ESEP as a short-term, career-broadening opportunity–one of several available to DA Civilians. For Army Soldiers, however, participating in ESEP is a more complicated venture. ESEP is not a listed program in the Broadening Opportunities Program (BOP) or the Long Term Health Education and Training Program (LTHET). Soldiers, therefore, must fill an authorization on a Table of Distribution and Allowances (TDA) or Modified Tables of Organization and Equipment (MTOE). This requirement hinders program participation by Soldiers and requires continuous advocacy in the Total Army Analysis (TAA) process. Oversight and administration of ESEP prior to arrival in the host country is managed by the Deputy Assistant Secretary of the Army for Defense Exports and Cooperation (DASA DE&C).[18]

There are currently 16 ESEP Memoranda of Understanding (MOU) in place with the following countries: Australia, Canada, Chile, the Czech Republic, France, Germany, Israel, Italy, Japan, the Republic of Korea, the Netherlands, Norway, Poland, Spain, Singapore, and the United Kingdom. Additionally, each country identifies 3-5 areas of strategic research focus to aid in the US placement process.

The ESEP allows the United States and its allies to strengthen their defensive capabilities by promoting scientific exchange to support mutual defense research. Participants work collaboratively with their foreign counterparts to conduct experiments, develop military materiel and technologies, and increase early standardization and interoperability between the U.S. Army and its allies. This collaboration enhances diplomatic efforts through personal contact and military-to-military cooperation. ESEP participants also identify opportunities to establish ongoing collaboration with allies in strategic focus areas, such as protecting the warfighter from chemical/biological attacks.

Biodefense in Japan

As one of our most important treaty allies, Japan finds itself at a nexus for both emerging pathogens[19] and bioweapons. Japanese researchers have long been involved in infectious disease and medical countermeasure research, with Kitasato Shibasaburo co-discovering the infectious agent responsible for the bubonic plague,[20] Kiyoshi Shiga discovering the agent responsible for dysentery,[21] and Hamao Umezawa discovering the potent natural antibiotic kanamycin.[22] Japan also has been the target of several attempted and successful terrorist attacks using chemical[23] and biological[24] agents committed by members of the Aum Shinrikyo cult. The most famous of these attacks was the deadly 1995 Tokyo sarin attack in which 13 civilians were killed and 1,050 injured.[25]

Japan is also centrally located in a region of increasing tension with proximity to three regimes that have been expanding their CBRN capabilities in recent years: the People's Republic of China (PRC), the Democratic People's Republic of Korea (DPRK), and the Russian Federation.[26] As a result, Japan's Ministry of Defense has continuously cited the proliferation and transfer of weapons of mass destruction as an area of growing concern.[27] Additionally, with the advent of technologies such as genome editing using Clustered Regularly Interspaced Short Palindromic Repeats (CRISPR),[28] barriers to non-state actors such as Aum Shinrikyo to produce genetically modified pathogens have been significantly lowered. It should not be surprising that a perennial area of research interest for Japan in the ESEP is chemical and biological defense.

A Soldier-Scientist in Japan - ESEP at the National Defense Medical College

I arrived at the National Defense Medical College in September 2022 as the organization's first ESEP participant. Although I was well-versed in Army doctrine and strategic concepts and had prior foreign-language proficiency in Japanese thanks to a year of study abroad at Hiroshima Shudo University 20 years earlier, I was still nervous to be back in the laboratory. Luckily, my training as a Soldier-Scientist quickly kicked in and I was rapidly integrated into several research projects. I was already aware of the importance of some of the research topics from my brief period as a medical planner–synthetic blood products,[29] for example, is a perennial area of interest to operational medicine. One research topic, however, was at the intersection of biodefense and operational medicine–enhancing the innate immune system to fight off pathogens.

Medical countermeasures for biodefense can be broken down into two general areas. One area of biodefense focuses on countering the pathogen itself. The other area of biodefense enhances a component of the human immune system – innate immunity. The pathogen-specific defense seeks to directly counter a list of known pathogens (the Select Agents and Toxins list codified in 7 Code of Federal Regulations (CFR) Part 331, 9 CFR Part 121, and 42 CFR Part 73) that are highly virulent, easily weaponized, and have high consequences when employed.[30] The success of Operation Warp Speed in developing a vaccine against COVID-19 exposed two weaknesses to this approach. First, there is an inevitable lag period to create a targeted vaccine for a novel virus, including the development period as well as safety and efficacy studies for regulatory compliance reasons.[31] Second, vaccine hesitancy, along with misinformation and disinformation, decreased the vaccination rate and thus protection of the population.[32]

Although targeted medical countermeasures, such as vaccines, are the platinum standard in mitigating infectious disease consequences, a robust biodefense program needs to also provide tools for protection in the absence of a vaccine. The innate immune system, the defense that our bodies developed as part of the ongoing natural arms race with natural pathogens,[33] is therefore a promising target to provide additional protection against bioweapons.[34] Through working with my colleagues at the National Defense Medical College, I have quickly come to appreciate the merits of training the innate immune system.[35] In addition to being a potential countermeasure against sepsis (a leading cause of death worldwide),[36] development of therapies that train the innate immune system may address some of the vulnerabilities identified in the COVID-19 pandemic response.

During my participation in ESEP, the National Defense Medical College has started several partnerships with U.S. Army research facilities–creating with it additional layers of integrated biodefense. I have also been able to work with the Japan Self Defense Force (JSDF) Nuclear, Biological, and Chemical Countermeasure Medical (NBCCMed) unit during its training at the National Defense Medical College and gain valuable insight into how civil authorities would respond to a CBRN incident. This has, thus far, proven to be an extremely beneficial program both for Japan and the United States as we continue to work toward improving mutual understanding of our respective research focuses and to develop a mutually supporting approach to biodefense.

Conclusion

The ESEP is a powerful tool for the U.S. Army to promote integrated biodefense with our treaty partners and other allied nations. Soldier-Scientists bring a unique perspective to the program due to their ability to view problems from a strategic scientific perspective as well as understanding the impacts in translating the research for tactical and operational use. The Army should increase investment in this program to include authorizations at the Army Service Component Command (ASCC) level to enable uniformed Service Members to efficiently and effectively enhance integrated deterrence with allies and partner nations in areas including not only biodefense, but also key research in other areas necessary for multi-domain operations, such as ballistic missile defense, while keeping pace with a rapidly evolving science and technology environment.[37] ■

Disclaimer: The views expressed in this article are those of the author and do not necessarily reflect the official policy of the Department of the Army, Department of Defense, the Army Medical Department, the Japanese Government, or the U.S. Government.

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CONCESSIONS TO THE LIMITED POWERS:

Considerations of Low-Yield Nuclear Weapons, Asymmetrical Capability, and Extended Deterrence

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Introduction

Quite recently, nuclear strategy scholars Kier Lieber and Daryl Press posited that arms' tables have turned, citing the asymmetry of limited nuclear powers as a reboot of the United States (US)-North Atlantic Treaty Organization (NATO) tactical nuclear playbook during the Cold War.[1] Their key message—that "The United States must take seriously the nuclear capabilities and resolve of its foes"—isn't lost on us: we previously called for the need to begin serious counter-weapons of mass destruction (WMD) planning for adversarial use of nuclear weapons below the threshold of Armageddon.[2] We must raise an objection, however, to the assertion that states with limited nuclear capabilities are reprising the US' 20th century strategy of coercion and dissuasion with their handfuls of weapons. Instead, we see a world wherein not only Russia and China, but militarily asymmetrical nuclear aspirants, such as North Korea and Iran, increase their resolve to employ nuclear threats to gain concessions outside previously conceived escalation ladders.

American adversaries—and the foes of US allies under the nuclear umbrella—cannot rationally threaten a massive nuclear strike and expect to benefit militarily after certain retaliation. This classic model of deterring behavior through assured *failure*, if not complete destruction, was emblematic of the dyadic US-Soviet relationship that endured for the Cold War.[3] As Lieber and Press describe in their most recent article, *The Return of Nuclear Escalation*,[4] the US-NATO strategy for so-called "tactical" nuclear weapons in Europe was spawned from a desire to avoid direct intercontinental exchanges, and either dissuade any territorial aggression toward NATO or at least coerce Moscow into halting a conventional campaign. Per that theory, a few short-range, lower-yield weapons would be enough to demonstrate American resolve to alliance commitments without immediately escalating to mutual destruction.

We posit that more so today than in the last century, the rise of the nuclear taboo, at least among Western democracies,[5] and fear of retaliation from even singular nuclear use reinforces the dissuasion of first strike doctrine.[6] The desire to avoid *any* nuclear attacks on one's homeland was determined early in the nuclear age to underpin the fruitlessness inherent in nuclear exchange. At least among those states on parity to exchange volumes of nuclear weapons, certain resort to conventional war was the only rational choice.[7] So arose the Atomic Age mantra of nuclear war as unwinnable from the start, as Bernard Brodie suggested as early as 1946,[8] and a clamoring chorus that "the ever-diminishing plausibility of the nuclear threat and ever bolder challenges to make good on it," as Morgenthau wrote in 1964,[9] itself voids the proposed value of deterrence.

Pyongyang is not NATO—or Islamabad

But North Korean enterprises in the nuclear space are not simply copycat efforts reflective of this dyadic US/NATO vis-à-vis Soviet history. Although Pyongyang's nascent nuclear and conventional capabilities are certainly far weaker than those of the Republic of Korea (ROK)-US alliance, this is an extreme asymmetry, and thus is not nearly comparable to the US-NATO strategy against Soviet territorial aggression in Europe. According to data from the Federation of American Scientists (FAS), the dyadic US-Soviet nuclear inventories were relatively balanced by the mid-1970s, when each held approximately 50% of worldwide warhead stockpiles; prior to this, the US maintained a monopoly on the largest quantity of nuclear arms.[10] It is therefore difficult to compare US/NATO strategies for tactical nuclear weapons to be comparable with the asymmetry contemporary nuclear powers and aspirants who possess limited quantities of weapons have vis-à-vis the United States.

Pakistan is also not North Korea. Lumping together states with small nuclear arsenals or nuclear aspirations implies that comparisons exist beyond quantities alone. A more complex categorical assessment should center on *intent*. Regardless of how many weapons exist, Islamabad has clearer intentions for using nuclear arms to deter neighboring India.[11] More importantly, there's no extended deterrence guarantee from Washington for either side of such an engagement, and the potential for nuclear exchanges remains isolated to these nations based upon their own interactions. North Korea, on the other hand, is poised to engage not just with its neighbor, but a formidable alliance with direct-attack targets that are far from the Peninsula.

Moreover, limited nuclear powers like the DPRK do not possess quantities of weapons necessary to defeat either in-kind nuclear or even conventional retaliation. That's not true for Islamabad, which has openly discussed preparations of nuclear landmines to directly deter troop advances in border regions.[12] At "zero range," Pakistan and India could fight a nuclear war of attrition most akin to the US-NATO strategy that Lieber and Press point to as the basis for limited use in the context of strategic asymmetry. During the Cold War, the Soviet Union held its own reserve of strategic weapons capable of inflicting mutually assured destruction should it either be the victim of aggression, or be embroiled in a protracted war in Europe. North Korea, on the other hand, faces the alliance of both a neighbor and a faraway adversary that could project overwhelming conventional and nuclear force (without even relying on the more than 28,000 troops that are deployable at the North Korean doorstep),[13] and has little recourse to respond with the force that the Soviet Union previously possessed.

Limited taboo, limited use

While the taboo on nuclear use has been concretized among democracies, the behavior of states that reject these currently accepted norms and have little or no dependency on the opinions of their citizenry suggest a lack of internalization for non-use of nuclear arms. We posit that low-yield, high-precision WMD employment strategies which are outside of self-imposed restraints on their use become attractive as effective tools for military operations (in both combat and improved deterrence roles) when the internalization of non-use is limited or wholly lacking.[14] Because technical improvements in weapons' precision and payload miniaturization have effectively upended certain moral qualms that girded any nuclear taboo and sustained its legacy of non-use since WWII,[15] WMD employment that stays within other normalized behavior of the international system of arms' capability becomes a palatable option for those states already wavering on military utility. The United States may still choose not to employ WMD in this way, even when it is a proportional use of force, but global actors who have less internalization of the nuclear taboo may seek to exploit gains from both the US (and its allies') restraint through their own limited use of low-yield nuclear weapons. As survey research has shown, the aversion to nuclear use among ordinary Americans regresses when clear military advantages are shown;[16] why then would we expect despotic regimes with poor track records for the respect of human rights to hold more restraint?

Historic military-technical revolutions (MTRs), correspondingly referred to as the revolutions in military affairs (RMAs), were not immediately recognizable at the time new technologies entered inventory, but became salient only when armies implemented "major changes in the way they prepare and conduct operations in war" for increased effectiveness.[17] The realization of a revolution's gains, therefore, does not necessitate the creation of a new type of weapon or scientific study, rather only the willingness and bureaucratic reform to shift paradigms from existing methods of warfare. Such an envisioned adoption of chemical, biological, radiological and nuclear (CBRN) weapon employment, however, is not equivalent to an erosion of the international norms or ethics that prohibit indiscriminate targeting, disproportionate effects, or gross collateral damages. Instead, the next MTR will be in the realization that CBRN effects—on the battlefield and as tools of deterrence—can favorably limit the feared outcomes associated with this entire category of arms that has injudiciously undergirded their labeling as weapons of "mass" destruction. Indeed, it may be, and we opine is likely, that new generation CBRN agents will be employed for their particular, tactically disruptive effects, which may incur "down-range" destructive manifestations (to economics, infrastructures, socio-political functionality/coherence, as well as public health), but that do not meet regnant criteria for WMDs per se. Changes in international narratives about the viability and value of low-yield nuclear weapons may incur "spill-over" effects upon perspectives, tolerances and thresholds of use of other types of instruments (e.g., novel chemical/biological agents[18] or autonomous weapons)[19] to incur disruptive influence.

Emergence of a new nuclear age

Since the Cold War, the US has maintained a stockpile of nuclear weapons with multi-megaton yields that were intended to deter similarly equipped nuclear weapon-capable states (NWS) from a direct attack on the homeland or allies; but this armamentarium has not been modified to address broader security concerns beyond mutually assured destruction.[20] Such inaction may be traced to perceptions and *ad nauseam* discourses about the characteristically disproportionate and indiscriminate nature of nuclear warfare, which have given rise to the Global Zero campaign and reiterative leadership commitments on non-use.[21] The history of nuclear use and dyadic race to larger, thermonuclear yields made "nuclear" synonymous with "mass destruction" and categorically placed this entire class of technology on a linear path of use avoidance. Meanwhile, the US has accepted liberal use of remotely piloted aircraft (RPA, colloquially called "drones") to prosecute the actual conflicts of the last two decades, lauding their precision and ability to reduce casualties as ethical.[22] Whether in conflict with states or non-state actors, the US has invested in weapons innovations to reduce casualties and increase the range of available response options with discrete effects at longer ranges, from air-launched precision guided munitions during Operation Desert Storm[23] to the Army's latest generation Precision Strike Missile (PrSM).[24] Even against a pacing challenge with the PRC, the US has committed to developing artificial intelligence and autonomous machines of war with a "responsible and ethical approach," as Deputy Secretary of Defense Kathleen Hicks said in introducing the Replicator initiative during a conference in Washington last fall.[25] Yet, the US nuclear stockpile remains chained to the moniker of "mass destruction." Given the very real possibility of facing conflict with an asymmetric nuclear actor, we challenge assumptions that US deterrence remains strong without changes to the status quo stockpile to address militarily feasible, flexible response options afforded by mating nuclear warheads with practical yields to the revolution in precise delivery systems.

Discussing flexibility does not equate to ethical laxation that will violate the nearly 79-year taboo on nuclear use if such weapons were operationally introduced, but should be considered given that the lack of flexibility may instead lead more directly to abrogation of those norms. From the advent of the Nuclear Posture Review (NPR) in 1994, "modernization" of the stockpile has meant de facto "service extension" of existing designs in each restatement. The existing stockpile, however, has done nothing to deter Russian aggression in either Georgia or Ukraine, nor ongoing Chinese assertions about, and threats against Taiwan.[26] None of the previous NPRs established a new pathway for the aging nuclear arsenal to meet contemporary requirements beyond direct/extended deterrence, and the discourse has remained primarily focused upon Russian nuclear capability and threat.

The latest NPR (2022)[27] offers some compromise on acknowledging the need for "flexible" nuclear options, but the cancelation of a nuclear-armed sea-launched cruise missile (SLCM-N) replacement for the Tomahawk falls short of the type and extent of modernization required to address low-yield nuclear threats in the contemporary era of greater multi-polarity.[28] Even the W76-2 warhead for the submarine-launched leg of the Triad, which was deployed on the heels of the previous 2018 NPR,[29,30] raises criticism that it's "low yield" still means "death and destruction, perhaps on a massive and indiscriminate scale," as Ken Olivier and George Perkovich of the Carnegie Endowment rebutted State Department reasoning to support its role in extended deterrence and more flexible response options.[31] Choosing the appropriate posture, however, must not simply equate the contemporary renewal of the Great Power competition of Russia and China[32] with a return to the Cold War paradigm of strategic deterrence alone.[33] Instead, a balanced review could include the need for reliable constraints on Russia, as well as on an emergent China, while concomitantly preventing proliferation of nuclear capabilities among lesser, but iteratively more capable powers —such as Iran and North Korea— in efforts to count the full range of threats outlined in the latest National Defense Strategy (2022).[34]

North Korea's nuclear ambitions offer a non-theoretical lens through which to observe (1) how adversarial use of low-yield nuclear weapons well below MAD thresholds might occur; (2) how the lack of internalization of the nuclear taboo still exists in the global community; and (3) how the current US response options may be insufficient to deter such violations of non-use. While the world in 2024 is consumed with concern that Russia might use a "tactical" nuclear weapon in the Ukraine,[35] that situation is less pertinent to the abrogation of non-use as a global norm: existing deterrence theory has always expected that any NWS suffering significant battlefield loses could seek nuclear weapon options as a last resort. Russia's failures in the Ukraine only support the extant playbook. Although a grave violation of non-use and a deviation from Western commitments never to use nuclear weapons against a non-NWS, Russian propagandizing has set the stage to contain any battlefield nuclear employment to a narrative of existential self-defense—reasons all NWS use to justify sustainment of arsenals against calls for full elimination. Instead, North Korea's potential for low-yield use to achieve limited objectives outside of "last resort" narratives would open a new era of the Third Nuclear Age, wherein flexible options for use are seen as salient, military actions defensible by *jus in bello* principles of proportionality. This is the profound shift in thinking that would revise the international order, setting back decades of peaceful security-building and US-led counterproliferation regimes. How this might materialize requires first an understanding of whether (and to what extent) literature on taboo holds for Pyongyang under scrutiny of its historical relations.

Korea: Nuclear issues; then and now

Contemporary bargaining with Kim Jong Un about nuclear weapons can best be understood in the historical context of longstanding American threats to use overwhelming force against his familial regime. In the clearest expression, President Truman overtly threatened to use "every weapon that we have" (November 1950)[36] in direct response to a press question about atomic weapon deployment in Korea (just five years after their initial use to compel the surrender of Imperial Japan), and subsequently deployed hundreds of air- and ground-launched weapons to the Korean Peninsula between 1958 and 1991.[37] During those post-Armistice decades, the ROK made covert research attempts[38] and the US continued testing of increasingly larger thermonuclear—adding context to North Korea's own ambitions as an independent NWS. In less direct terms, the US demonstrated its conventional capabilities to topple similarly adversarial regimes during numerous military campaigns after the Korean conflict without the single use of a nuclear weapon: Operations Desert Storm, Deliberate Force, Allied Force, Enduring Freedom, Iraqi Freedom, and Odyssey Dawn are exemplary of such actions that occurred after the self-declared American denuclearization of South Korea's territory under President George H.W. Bush.[39]

Thus, whether conventional or nuclear, the United States has retained superiority over North Korea since the international division, strengthened the ROK-US alliance to conduct forcible entry,[40] and articulated warnings of "fire and fury" against the North from the highest level of government as late as 2017.[41]

From this perspective, it is not surprising that Kim Jong Un, as his father and grandfather preceding him, has sought strategic capabilities in an attempt to balance this lopsided equation, and why he is unlikely to trade any deterrent capacity without certainty that his grip on power will not be loosened or lost in the same ways as Mladić, Hussein, or Qaddafi.

A sub-text, however, might be considered as to why the US never used a nuclear weapon in Korea (or China), having done so in Japan only five years earlier, and instead fought a high resource/high casualty war without clear victory. Toward such ends, it may be useful to take a historiographical approach on the record of overt and so-called "back channel" threats to employ atomic bombs against the North during active hostilities between 1950 and 1951,[42] much of which has only become available to researchers in the last decade.[43]

The paradox of suitable targets

Certainly, not all reservations about the use of nuclear weapons in Korea were based on their outright rejection as immoral, given the initial suggestions of Eisenhower and MacArthur days into the war.[44] Within the military establishment, the discussion of atomic use met forcefully along the line of whether the conflict presented any "suitable" targets that would not already be well-serviced by conventional air bombs and artillery[45] or would avoid escalating Soviet involvement, given the USSR's NWS status had been established the previous year. Unlike World War II, which had been defined as total war involving the mobilization of all civilian, industrial, political, and military resources spanning the globe, Korea was viewed as a locally-defined territorial conflict with limited belligerents and a singular objective for reunification. As such, concerns remained over how strategic weapons, which had been used only in counter-population scenarios for compelling an adversary not to risk destruction of its home territory, could be applied to a tactical ground campaign in Korea where unification was sought by both sides.

The extent to which ethical inhibitions and proscriptions on the use of nuclear weapons under any conditions following WWII impacted the selection of "suitable" targets, has been proposed,[46] but remains an unquantifiable unknown. Moreover, in the intervening five years following the Second World War, no major advances had been made in training American infantry to fight in a radiation zone, nor had troops (yet) been equipped with mechanisms for delivering small-yield "tactical" nuclear weapons against constantly moving enemy positions.[47] In effect, the selection of targets would have been hampered by the lack of pre-war planning for employment in such a scenario as Korea because the planning had not been undertaken or had been deemed so implausible as not to warrant sufficient study, even within the military establishment. As of 1950, atomic weapons were exclusively intended for "strategic value" targets with a reserved "special" status, and the Department of Defense had not engaged in operationalizing their use in a limited war against tactical objectives, even as US scientists and weapons' developers were precisely preparing a future class of small-yield, battlefield-ready atomic rounds for such use.[48] For Korea, the shift away from "massive retaliation" strategy toward "flexible response" would not come until the Kennedy Administration.[49]

Instead, the most dramatic change in nuclear policy during the Eisenhower Administration came well-after the July 1953 Armistice, and was oddly proposed as a cost-saving measure rather than to meet a military objective. During a NSC meeting in September 1956, Eisenhower set a directive to reduce the costs of sustaining large numbers of personnel for US Forces Korea (USFK) and funding joint ROK operations––totaling USD$800 million that year, or USD$7.85 billion when accounting for inflation.[50] The options discussed required reducing the troop footprint dramatically, while still keeping a deterrent force on the Peninsula to maintain the Armistice. Despite training and support to ROK military, the NSC concluded in subsequent studies that the withdrawal of USFK would almost certainly encourage the North to abrogate the Armistice and again attempt forcible reunification.

In response, the Eisenhower Administration proposed the deployment of newer, low-yield, tactical nuclear "atomic rounds," which had not been available during the war.[51]

Rather than deploying strategic US B-29 bombers to fly into theater, these new weapons could be pre-stationed with ground forces to enhance their deterrent capacity. By 1958, the first of such tactical weapons arrived on the Peninsula, including 280-mm atomic cannons (artillery shells with low-yield warheads) and Honest John short-range, surface-to-surface atomic missiles.[52] The addition of these weapons achieved what the Joint Chiefs of Staff had wanted the Truman Administration to approve in 1950, but such technology for the US arsenal had not yet been created. These weapons were deemed to be more suitable to a variety of tactical implications because they could be more precisely fired by ground forces, rather than requiring the time-delay of requesting strategic support from the Strategic Air Command (SAC). In addition, their low-yield mass was viewed by some as more ethically acceptable than Mark III or Mark IV air-dropped bombs, because they could (at least theoretically) be limited to a threat radius of only enemy forces, rather than the far more expansive counter-population targeting of civilian cities.[53] This policy of tactical nuclear weapons deployment to South Korean territory continued until December 1991, when President George H. W. Bush ordered their withdrawal.[54]

Pyongyang's nuclear calculus

For whatever long-term costs the overt and back-channel threats to use nuclear weapons in Korea had on the North Korean calculus to pursue weaponization, the deployment of tactical weapons to the Peninsula staged a much more explicit American threat directly across the demilitarized zone (DMZ). From the Armistice in 1953 to the deployment of tactical weapons in 1958, the number of US troops on the Peninsula decreased from around 300,000 to 50,000,[55] thereby reducing the direct threat of a ground assault. Yet, the sustained presence of nuclear weapons allowed the Eisenhower Administration to achieve its objective of cost-savings, while still enhancing the deterrent threat against North Korea; a threat that the North Korean government, military, and populus endured for more than three decades.

In addition to explicitly staring down the destructive power of the US nuclear arsenal opposite its border until 1991, the DPRK has since had access to NSC-68 (declassified 1975), which would have clarified the extent to which the US viewed Korea as a proxy battleground with the Soviet Union, rather than for strategic value or alliance with the ROK alone. The current availability of such documents depicts the rising din of what were once classified internal discussions, attempted strategic messages, and overt threats to use the expanding nuclear force in Korea.[56]

Further, in 2017, the US attempted to bring about North Korean denuclearization, through what may best be regarded as a form of brinkmanship, or as "mad man" theory.[57] When President Trump first met Kim Jong Un in Singapore in 2018, he brought along a video that was part real-estate pitch, combined with a solid amount of strongman-style threatening of the isolation that what would happen if the "hand of peace"[58] was not well-received. Through the Hanoi Summit of February 2019,[59] US threats against North Korea continued at the highest level, even when an agreement on denuclearization was being sought. Despite the desire for something more positively engaging, the second and last Trump-Kim meeting yielded much more of the same, cyclical threats for compelling Pyongyang through renewed conflict, if necessary.

Concessions to the limited powers

North Korea is just one example: outside US-Russia-PRC relations vis-à-vis one another, every nuclear arsenal or aspirant weapons program is asymmetric compared with the US. This iterative ecology of potential nuclear belligerents' pretexts, paces of development and engagement, possible target(s) and intents is presented in Table 1, below.

Pyongyang and regimes with similar programs need not borrow from Cold War playbooks that were rooted in assumptions about dyadic escalation. In contrast, these limited nuclear powers cannot afford "one or two" tactical nuclear weapons to dissuade further territorial aggression or off-ramp a conflict back to the conventional threshold: they would meet certain destruction without secure second-strike retaliatory options even remotely approximate to the scale of the US arsenal. Just one or a few weapons of any size might dissuade attack from a non-nuclear or near peer competitor, as between India and Pakistan, but limited nuclear weapons programs are just as likely to invite a pre-emptive first strike from a Great Power vying to curtail further proliferation.[60] What value, then, can limited powers gain by engaging in nuclear weapons development to compete with the US?

To plan effective deterrence, we must consider that the "WMD" label is truly a misnomer. Lower nuclear yields in the sub-kiloton range—along with chemical, biological, and radiological weapons of true asymmetry—can be delivered on high precision systems with collateral effects below those produced by conventional high explosive ordinance, such as the GBU-43 or roughly 11-ton "mother of all bombs" (MOAB).[61] This strategy is far from the perceived asymmetry that the US and NATO planned against to block or dissuade Soviet territorial expansion into Eastern Europe, when both sides could threaten escalation to both larger yields and direct attacks on each other's homeland territory.

Limited nuclear powers cannot rely on Cold War paradigms because their asymmetric arsenals vis-à-vis the US are incapable of threatening such escalation. With only a few weapons, first strike attempts risk certain retaliation and a high likelihood of taking heavier losses than inflicted on the US. Similarly, holding one or a few weapons to dissuade a direct attack from a much more robust nuclear arsenal lacks rational choice that retaliatory strikes would create winnable terms, echoing Morgenthau's "fruitless" paradoxes that nuclear warfighting is doomed from the start.

Instead, these limited nuclear powers could use low-yield nuclear weapons to garner concessions. Whether held as a reserve threat or actively used, limited powers cannot hope to "win" an already unwinnable war but can bait a stronger NWS to reconsider nuclear restraint. Such a concessions-based scenario is most viable when the likelihood of a stronger NWS violating a deeply entrenched taboo on non-use is low, thereby allowing the limited power to threaten or use one or a small number of weapons without risking swift and assured destruction.

One such scenario where the US/NATO "tactical" weapons playbook could overlap with a limited power seeking to garner concessions would be on the selection of target(s). If regarded as militarily feasible and creating only limited collateral damage, a limited nuclear power could proffer constraints on use that

	Balance	Pretext	Speed	Targets	Intent
US-NATO COLD WAR NUCLEAR STRATEGY VIS-À-VIS SOVIET UNION	Dyad capable of mutually assured destruction	Territorial aggression	Deliberate escalation	Conventional military	Coercion/ dissuasion
REGIONAL NUCLEAR ACTORS VIS-À-VIS PEER/NEAR PEER	Mutual or imperfect symmetry	Territorial aggression	Deliberate escalation	Conventional military	Coercion/ dissuasion
LIMITED NUCLEAR POWERS VIS-À-VIS EXTENDED DETERRENCE	Complete asymmetry (nuclear/ conventional)	None	Unchained provocation	Conventional military	Gain concessions

Table 1

maintains a high bar of restraint by a Great Power. The most feared characteristics of nuclear war, including fallout that can spread beyond the intended operational target theater, have been shown to be mitigated in modeled scenarios assessing a low airburst (10 meters) detonation of a low-yield nuclear weapon of less than a kiloton.[62] For low-density population targets, the discriminate effects of such "WMD" use against a justified military objective would be well-contained, within the destructive parameters of (previously used) current conventional explosive weapons, and could be delivered without adversarial threat (such as that rendered to the type of low-flying aircraft required to drop multiple conventional explosives capable of achieving similar effects). In conclusion, we posit that the nuclear narrative is changing, and it will be vital for the US and its allies to re-address this discourse – and extant postures of deterrence and defense with strict reference to fact(s), so as to proceed pragmatically, accordingly and with prudence. ■

Disclaimer: The view and opinions expressed in this essay are those of the authors, and do not necessarily reflect or represent those of the United States Department of Defense, and/or those organizations and institutions that support the authors' work.

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Soldiers from the U.S. Army Nuclear Disablement Teams demonstrate field use of the Ortec High Purity Germanium (HPGe) detector during a training exercise. U.S. Army photo by Maj. Steven M. Modugno.

ARMY TEAM LEVERAGES EXPERTISE TO INCREASE READINESS FOR RADIOLOGICAL DETECTION MISSIONS

WALTER T. HAM IV

A team of Soldiers and U.S. Army civilians recently came together to design a better backpack. Soldiers from the U.S. Army Nuclear Disablement Teams helped to conceptualize, coordinate and create a backpack that helps them to provide theater-level confirmation and identification of radiological materials in a tactical environment.

The Nuclear Disablement Teams worked with partner organizations, including the Command, Control, Communications, Computers, Cyber, Intelligence, Surveillance and Reconnaissance (C5ISR) Center from the U.S. Army Combat Capabilities Development Command.

Maj. Aaron J. Heffelfinger, the deputy team chief from Nuclear Disablement Team 1, said the new mobile backpack was the result of a six-month project. “The challenge the NDT always had with its Ortec High Purity Germanium (HPGe) detectors was always the deliberate cool down period required for the equipment to be ready, typically in excess of seven hours from a complete shutdown,” said Heffelfinger, a native of Moore Township, Pennsylvania, who previously served as an Air Defense Artillery officer.

Since the detector needs to draw outside air for its internal cooling system and needs to expel this hot air to maintain cryogenic operating temperatures, Heffelfinger said the cases that came with the detector required the equipment to be shut down during transportation. The team members would have to either wait for around eight hours to use their best gamma detector or transport it unprotected with nothing more than a shoulder strap.The backpack enables the NDTs to move faster and provides commanders with greater operational flexibility. “Time is always of the essence. The longer it takes the team to provide the gamma spectroscopy and isotopic assay results to the supported unit, the more constrained the commander becomes,” said Heffelfinger. “If we can provide that information without an 8-hour cooldown first, it can drive the decision-making process that much faster.”

Capt. John M. Prevost, an Army Explosive Ordnance Disposal officer from Nuclear Disablement Team 2, said the power and cooling systems are self-contained and interchangeable with a range of batteries and store power on the backpack. The detector can remain operational almost indefinitely with the new backpack, said Prevost, adding that it can be used anywhere a Soldier can carry it. By allowing the NDTs to carry spectral analysis software on a target downrange, the backpack eliminates the need for reach-back support if communications become degraded.

ABOVE: The newly designed backpack system that helps Nuclear Disablement Teams to provide theater-level confirmation and identification of radiological materials more quickly in a tactical environment. The Nuclear Disablement Teams worked with partner organizations, including the Command, Control, Communications, Computers, Cyber, Intelligence, Surveillance and Reconnaissance (C5ISR) Center from the U.S. Army Combat Capabilities Development Command. Courtesy photo.

“This new backpack provides a protective, continuously-cooling, man-packable solution for bringing our most critical detection equipment to a target,” said Prevost. “The backpack makes our most critical detection and analysis capability smaller, lighter, faster and more ruggedized for expeditionary deployments.” Prevost said the improved backpack was the result of an on-going NDT discussion on existing capability limitations and doctrinal requirements.

“The backpack is proof that the best way to solve complex problems is to assemble teams of experts from varied backgrounds and establish a common vision of success, especially during initial design,” said Prevost, a native of Shelby, North Carolina, and graduate of Wofford College, who served as a platoon leader in the 21st Ordnance Company (EOD), a one-of-a-kind Weapons of Mass Destruction-focused EOD company. “By doing this, you gain varied perspectives on potential problems, existing or innovative design solutions and end-user considerations early in the process,” said Prevost. “Put simply, a small group of motivated experts can accomplish a great deal in an environment where ideas and input are openly traded regardless of rank, education or background expertise where mission success is the sole collective focus.”

Jaywoon Joo was one of the experts who worked on the backpack project.As a U.S. Army civilian project engineer at the C5ISR Center, Joo regularly supports organizations by rapidly prototyping services for them. Originally from San Diego, Joo studied mechanical engineering at the University of Nevada-Las Vegas before moving to Maryland. “My father, Bill Joo, is my main inspiration for becoming an Army civilian,” said Joo. “He has always explained that our work is important - not only because it helps us to win wars - but because it ensures our Soldiers come home safe to their families. I’ve always found that idea to be really inspiring and it’s why I’m working here today.”

The Nuclear Disablement Teams are part of the 20th Chemical, Biological, Radiological, Nuclear, Explosives (CBRNE) Command, the U.S. military’s premier CBRNE formation. The U.S. military’s only Nuclear Disablement Teams — NDT 1, NDT 2 and NDT 3 – are all stationed on Aberdeen Proving Ground, Maryland. As the U.S. Department of Defense’s nuclear subject matter experts, NDTs directly contribute to the nation’s strategic deterrence by staying ready to exploit and disable nuclear and radiological Weapons of Mass Destruction infrastructure and components to deny near-term capability to adversaries. The NDTs facilitate follow-on WMD elimination operations. ■

ABOVE: A Soldier from the U.S. Army Nuclear Disablement Teams conducts a field radiation survey in training while carrying the new backpack designed to carry the Ortec High Purity Germanium (HPGe) detector. U.S. Army photo by Maj. Steven M. Modugno.

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KNOWN UNKNOWNS:
The Psychological Impacts of a Nuclear Battlefield

CADET MAXIMILIAN T. WALSH

The past century has seen impactful evolutions in the technology of warfare. Multiple nations developing nuclear weapons (NWs) are potent examples. Russia and China's efforts on this front have complicated the United States Army's mission of maintaining readiness for Great Power Competition. This challenge is not lost on the Army, as evidenced by Research and Development and Operations and Maintenance activity: modeling fallout, developing radiation protection, and anticipating NWs in combat.[1] However, the question of individual readiness for a nuclear attack is not simply a technological one. Despite the continuing evolution in military technology, the *people* who fight wars remain salient. Victory and defeat alike are products of our actions just as much as the technology we employ. So, we must account for the psychological effects NWs have on warfighters, despite our inability to model them as precisely as traditional NW effects. This project begins that task by considering case studies and psychological literature that may be analogous to the nuclear battlefield. The behavioral patterns drawn from there form the beginnings of our realizing the known unknown psychological impacts of NWs. Accounting for those can begin a new discussion: is our force ready?

Soldiers far enough from the blast to avoid expected weapon effects will suffer purely psychological effects caused by their ignorance toward NW effects. Soldiers close enough to receive direct weapon effects will be susceptible to psychic numbing, a condition characterized by decreased energy and attentiveness. Both states may be significant enough to pose challenges to warfighting capabilities. For both cases, we suggest increasing awareness of NW effects and training with relevant equipment so Soldiers can protect themselves as best as possible.

Clarifying Scope and Diction

As the title implies, this project attempts to address how a nuclear attack will alter behavior. Though bodily effects of NWs like burns and blindness are technically "behavioral responses" as much as feelings of pain, confusion, and fear are,[2] many works have examined those effects (expected NW effects). Fewer have regarding their psychological implications.[3] Our motivating assumption is that people's actions can be altered without an easily detectable cause. Soldiers are not immune to the indirect effects of warfare. Like most people, American troops have preconceived and often fallacious notions of NWs from their portrayal in media, and little is done to change these once Soldiers are in the Army. How Soldiers will react if an adversary uses a NW is not immediately evident. These are the known unknowns.

This project addresses two categories of psychological effects on combatants: proximal and distal, referenced in the second paragraph briefly. What differentiates them is the distance from the blast.

Proximal effects exist solely for those close enough to receive physical weapon effects like burns and radiation. Because expected NW effects are present, proximal effects are plausibly caused by a combination of physiological and psychological phenomena. That is, both bodily and psychological trauma received close to a nuclear detonation cause proximal effects. Distal effects will be present in units far enough from the blast to be safe from expected effects. Because expected effects are absent here, distal effects are causally only due

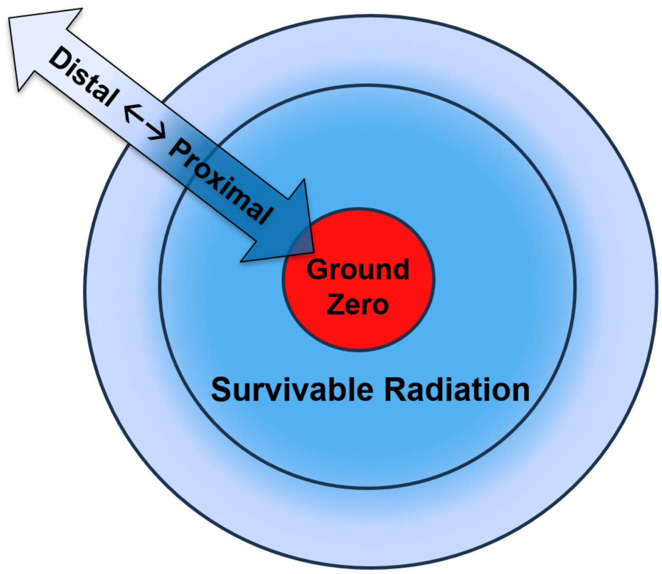


FIGURE 1. Simple depiction of the proximity-based psychological threat model (Author produced graphic)

to psychological phenomena. Overlap is expected. A unit's location could span many distances. However, separating the two is the simplest way to understand the proposed effects.

Psychic numbing – a response to extreme trauma – will be referenced frequently while discussing proximal effects later. Though the term can have other connotations, we mean decreased attentiveness, emotional affect, motivation, and curiosity.[4] The condition is often linked to post-traumatic stress disorder.

The term *psychosocial* will appear when discussing proximal effects. Psychosocial simply connotes an interplay between social factors like roles and responsibilities and individual behavior. A psychosocial effect thus implies social effects, in addition to individual.

Distal Effects: Purely Psychological Casualties

Our evidence for distal effects is drawn from three case studies. The first and last are of populations interacting with chemical, biological, radiological, and nuclear (CBRN) threats at removed distances. For most people, chemical, biological, and radiological threats share a comparable novelty with nuclear threats. In CBRN incidents, it is not always clear when one is affected. The second case study contrasts WWII London's psychological reaction to The Blitz with the V-Weapon bombings later in the war. These examples make clear the high probability that Soldiers under attack from NWs will suffer purely psychological casualties. Those being casualties caused not by physical harm, but by worry and ignorance alone, often referred to as psychosomatic responses. This project labels such effects "distal" because they apply to units far enough from the blast to avoid expected weapon effects but close enough to incorrectly think they are irradiated .

Gas Warfare in World War I

We see parallels between the nuclear battlefield and the first uses of chemical warfare in WWI. Like our modern force's relationship with NWs, most Soldiers 120 years ago were unaware of gas's effects, and troops had yet to encounter it in combat. Opportunities for familiarization beforehand were substantially lacking.

For each Soldier who required evacuation to a field hospital because of actual gas exposure, two more were evacuated who only *believed* they were gassed.[5] That means two-thirds of gas-related "casualties" suffered from purely imagined gas exposure. To understand why that was, let us look at accounts from Soldiers and consider their thought processes:

> "I witnessed from the air the first [chlorine] gas attack in the Ypres Salient. Suddenly we saw to the north of us […] this yellow wall moving quite slowly towards our lines. We hadn't any idea what it was" – Archibald James, an observer in the Royal Flying Corps.[6]

Though Soldiers were initially unsure of this new threat's nature, its consequences were soon made clear:

> "When the gas attack was over and the all clear sounded I decided to go out... [to] see what was happening. But I could hardly believe my eyes... The bank was absolutely covered with bodies of gassed men. Must have been over 1,000 of them" – Lendon Payne, British Sapper describing the Second Battle of Ypres.[7]

Contrast novel CBRN threats with gunfights, where the threat is clear and universally understood. Warfighters usually can tell when someone has been shot, especially the victim. With CBRN weaponry, the situation is more muddled. Soldiers in WWI had yet to become familiar with gas. A review found that in all five examples of widespread gas panic in WWI, "the attacked troops had poor […] training […] in using the gas mask […] or none at all"; in one of the five cases "the men

ABOVE: Men of the 2nd Argyll and Sutherland Highlanders wearing cotton-waste pad-respirators, 1915 (Imperial War Museums)

had no gas masks at all.[8] Many Soldiers suffered imagined effects as a defense mechanism. Psychosomatic response in such a setting is highly adaptive, given how uncertain the threat of exposure seems, and how risk-averse evolutionary processes have made us.[9] When presented with novel threats, the norm is to overreact as a defense mechanism. And in the case of gas warfare, no Soldiers were veterans, no one understood the scope of the threat, and too many had no idea how to use their safety equipment. The Soldiers who *believed* they were exposed unknowingly mimicked symptoms of exposure to receive medical attention. One can imagine how similar casualties may arise in the nuclear context. In that case, too, everyone will be inexperienced when the first bomb drops. Gas warfare early in WWI exposes the importance of training with equipment and understanding the nature of new and novel threats on the battlefield.

V-Weapons in World War II London

Most are familiar with the Blitz: the German bombing of the United Kingdom in WWII from 1940-1941. Fewer are aware that bombing returned later in the war. Soon after the Allies landed at Normandy, Germans began launching V-weapons at London (among other targets).[10] Relative to human and infrastructural damage, the V-weapon attacks on London produced disproportionately more psychological harm than the Blitz. Knowing why that was contributes to our understanding of NW's distal effects and how to combat them. First, evidence that V-weapons produced more psychological harm, despite the Blitz destroying more life and infrastructure, will be presented. Then, we will offer a psychological explanation.

The Imperial War Museums put it simply: "The destruction wrought by the V-weapons was less than that endured during The Blitz of 1940-1941."[11] The Blitz killed 20,000 and injured 25,000.[12] Approximately 2,500 V- weapons landed within the London region, killing 4,840, and injuring 24,500.[13, 14] During the Blitz, one of every six Londoners was homeless at some point, and at least 1.1 million houses and flats were damaged or destroyed.[15] Estimates of houses affected by V-weapons in London vary, but estimates group generally fall in the hundreds of thousands.[16] Despite the larger scale of destruction, Londoners maintained healthier mindsets during the Blitz. The phrase "Business as usual" frequently appeared on boarded-up shop windows.[17] The city reacted differently later in the war – when V-weapons caused more "psychological stress."[18]

In 1971, Jay Weiss found that our ability to cope with pain increases significantly when we can anticipate its coming.[19] In a famous study, one group of rats was administered electric shocks in such a way that they could foresee the impending pain. This group adapted to the stimuli. Another group was shocked randomly, eventually growing ill and weak.

The two groups of rats are analogous to Londoners at both parts of the war. During the Blitz, sirens sounded before the bombs dropped, giving people time to prepare. Londoners had been preparing for air raids for more than two years.[20] Knowing attacks were imminent and taking action boosted morale:

> "The speed with which people in a dazed and bewildered condition could be organized […] determined the rate at which damage could be repaired, production returned to full capacity, and further demoralization in surrounding areas avoided. What was needed, the observers of that time agreed, was a 'much more powerful and imaginative organization' to deal with 'the purely psychological and social effects of violent air attack' [mass observation from 1940]."[21]

The Blitz was set up with a "long conditioning period… [which] served to give the population time to develop coping responses."[22] Contrast these observations with those of Londoners later in the war, who found "V-weapons apparently random strikes […] unnerving."[23]

Comparing the psychological effects of V-weapons to the Blitz in London yields clear takeaways for the nuclear battlefield. First, we might mitigate proximal effects by emphasizing early warning/detection. When encountering NWs is possible, equipping and training units with radiation measurement devices like AN/UDR-13s is a clear step toward boosting detection abilities. Once detected, streamlined communication up and down the chain of command would provide Soldiers with opportunities to employ coping responses. Doing so would boost mental assuredness and lower stress. The advent of V-weapons is analogous to a later development that works against Soldiers in the nuclear context: the proliferation of new NW delivery devices. Adversaries now possess a plethora of ways to employ NWs. These challenges create more ways to surprise Soldiers with a nuclear threat. Educating Soldiers on plausible ways they could encounter NWs is of clear use as well.

Radioactive Material in Goiânia

A famous civilian radioactive materials incident occurred in Goiânia, Brazil in 1987. Like our case studies from World War I and II, the inhabitants of Goniania suffered psychosomatic, imagined effects. Their situation shows on a massive scale how easily people misrepresent contamination in CBRN cases. Though only 250 people were legitimately exposed to the radioactive source, more than 110,000 sought treatments for it.[24, 25] It is unclear to what extent if any the Goiânianese people's stress caused physical symptoms to develop. As sources do not mention any, they likely did not suffer physically to the same extent Londoners did because of V-weapons, and even less likely as much as Soldiers in our WWI case study, who required hospitalization. However, some of the 250 who were irradiated sought treatment for "Tropical Diseases" instead of irradiation, highlighting the general confusion surrounding CBRN incidents with unfamiliar populations.[26] This final case is another that displays the prime cause of psychosomatic responses in CBRN incidents: novelty and unfamiliarity of the threat. It is easy to imagine NWs causing similar reactions in Soldiers if they are left unsure of their level of contamination.

Distal Effects: Takeaways

Anticipating the uncertainty produced by the novel nature of a nuclear attack sets up the discussion of force readiness implications and takeaways. Regarding gas attacks in WWI, the overwhelming presence of psychosomatic responses makes sense, given the Soldiers' lack of training and familiarization with their masks and the unprecedented nature of gas as a weapon. Londoners in WWII were able to develop coping responses and organize as a city preparing for the Blitz, while V-weapons were harder to anticipate. In Goiânia, civilians had no ability to detect radiation and were generally unsure of what, if anything, was wrong with them.

All three case studies indicate that novelty and unfamiliarity are the prime causes of psychological impacts in CBRN incidents. So, training must focus on instilling knowledge of NW effects and familiarization with equipment to minimize negative psychological responses. Before their first encounter with one, Soldiers must understand their effects, be able to independently determine their level of irradiation, and be aware of preventative measures. Implementing even a basic understanding will allow Soldiers to create coping responses and be more lethal on the nuclear battlefield.

Proximal Effects: Depressed Motivation and Psychic Numbing

We first proposed that psychosomatic casualties should be expected in units removed from a NW's expected effects. What about units close enough to suffer these effects? The terrible environment expected close to a nuclear explosion would likely induce psychic numbing in adjacent units. Overcoming the psychosocial implications of these effects will require deliberate, focused preparations for fighting on the nuclear battlefield.

Two case studies are considered here. The first is 9/11 first responders. The second is Hiroshima and Nagasaki. Both are considered relevant for having characteristics that seem analogous to those close to a NW's detonation. We will then speculate about brain irradiation as an exacerbating stimulus of psychic numbing.

First Responders at 9/11

First responders' psychological reaction to 9/11 is relevant to understanding that of combatants in nuclear war. Like a NW in combat, the attack was novel and highly unprecedented, and first responders had not trained for such a situation. Further, like Soldiers in combat, they had a mission to accomplish that was complicated by the environment they had to operate in. Unlike Japanese civilians in our next case study, their behavior was not oriented exclusively toward survival. They had to save lives and work through the horrific circumstances around them.

Three relevant findings exist. Only two weeks after the towers fell, first responders met the threshold for post-traumatic stress disorder (PSTD), six times as often as members of the general population.[27, 28] From this discrepancy, we infer that Soldiers might incur trauma at a greater rate than if they were only concerned with fleeing a NW, like nearby non-combatants. Proximity to the towers was positively related to rates of PTSD.[29, 30] This will likely apply to the nuclear context too, as trauma-inducing incidents are likely to occur proximally, where harmful effects are more prevalent. Finally, in addition to witnessing PSTD-inducing events, personal injury was also positively correlated with PTSD symptoms.[31] This adds to the likelihood that PTSD-like symptoms will occur proximally in nuclear combat, as horror and injury will be abundant. These symptoms may develop at an alarming rate and affect combat readiness before Soldiers are able to seek out necessary mental health resources.

Memories of Hiroshima and Nagasaki

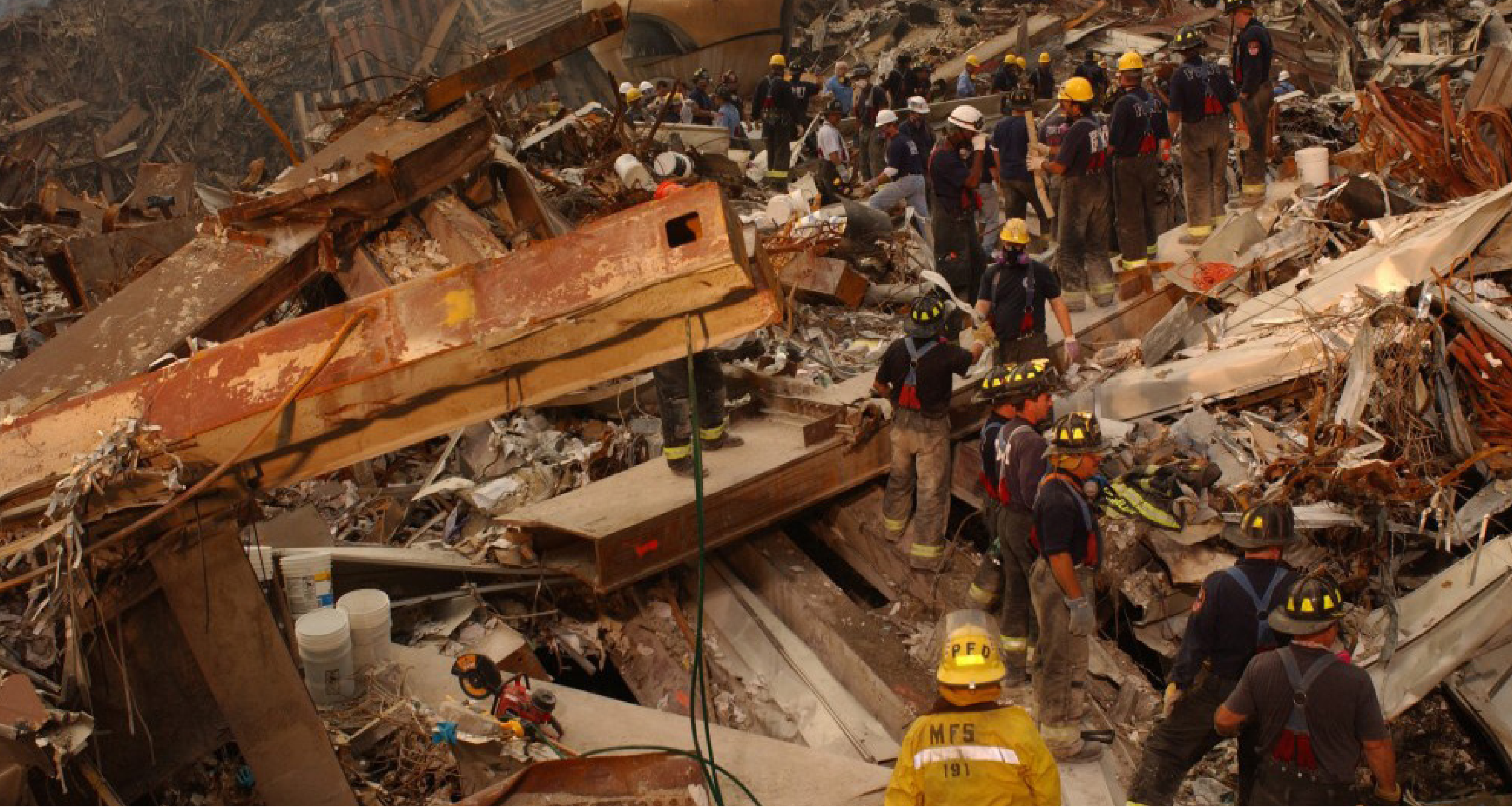
The horrific records from those who survived the attacks in Japan reveal behavioral effects that, if present in Soldiers, will affect combat readiness. In the immediate aftermath of the bombings, one diary remembers victims as "(moving) and (behaving) like automatons."[32] Another more formal source categorizes them as "fatigued," "mentally weak," and "closed off."[33] Robert Lifton coined the term psychic numbing while studying victims in Hiroshima to capture these descriptions in one term.[34] Their psychic numbing and "closing off" make sense, functioning as "defense mechanisms" against the incomprehensible stress their bodies received in such short amounts of time.[35] In the context of ground combat, awareness of and preparation for these threats is needed and could make an incredible difference.

It may be that psychic numbing as a condition increases obedience. In 1989, Andrew Mickley claimed that in Hiroshima numbing led people to be "most likely to pursue the goals established by others."[36] Citing a victim:

> "All the people were going in that direction […] so I suppose I was taken […] and went with them […] I couldn't make any clear decision in any specific way […] so I followed the other people […] I lost myself and was carried away."[37]

Psychosocial implications for a ground unit on the nuclear battlefield are clear. Soldiers will be disengaged and less autonomous, making decentralized command and autonomy tough to employ. Decision-makers must understand the increased importance their commands will have for their subordinates. It may be that more centralized command structures could protect tactical units from psychic numbing leading Soldiers astray on the nuclear battlefield.

In training, small unit leaders must be made aware of the increased importance of their example and directions due to psychic numbing. On the nuclear battlefield, "*Leadership…* the activity of influencing people by providing purpose, direction, and motivation to accomplish the mission" will be more challenging.[38] If a more centralized command structure mitigates psychic numbing's effects, it could justify changing how we fight doctrinally, in a nuclear context.



ABOVE: September 16, 2001, NYFD searching for survivors among the wreckage (Andrea Booher/FEMA)

Possible Neurological Underpinnings for Psychic Numbing

The combined effects of NWs are brutal and damage the mind and body in many ways. Seeing peers and one's surroundings suffer the hellish conditions near a blast will also harm Soldier's psyche. Though we cannot be certain of the extent each effect contributes to psychic numbing, radiation may play a nontrivial role. That is, irradiation may exacerbate psychological harm associated with the nuclear battlefield, specifically psychic numbing. Here we present animal research showing irradiation depresses individual motivation and curiosity in ways reminiscent of the discussed observations from Japan. Radiation's ability to cause neurological damage is "well accepted" at doses "greater than 15 Gy," and "increasing evidence supports radiation-induced brain injury at lower doses."[39] The question then is what are the behavioral effects, and how sure can we be that irradiation plays a causal role?

Behavioral changes seen in primates and mice mirror the discussed changes witnessed at Hiroshima and Nagasaki – where the term psychic numbing was applied. Though some knowledge about specific neurological effects exists,[40] useful takeaways seem too difficult to infer, currently. Some behavioral implications can be generalized, though. Experiments on primates have demonstrated that irradiation suppresses curiosity and attentive behavior.[41, 42] Another found that tasks requiring attention to stimuli in monkeys' periphery suffered from radiation.[43] "Subdued behaviors" have been assessed as "prominent" in irradiated primates, "perhaps mediated in part by some radiogenic Central Nervous System effects."[44] The most powerful data point is from a study done to determine neurotic reactions to the atomic bombings in Japan. Of 7,297 irradiated patients, 533 (7.3%) experienced neurosis-like symptoms; these symptoms were twice as common in patients who also had radiation illness than those who did not.[45] This suggests that radiation may be significantly harmful to psychological well-being, even when accompanied by expected NW effects.

These findings support the possibility that NW's radiation could exacerbate traumatic psychological effects and suppress healthy functioning, though the prime cause of trauma and suppressed functioning likely remains traditional weapon effects.

Proximal Effects: Takeaways

Regardless of the primary cause, psychic numbing is expected in Soldiers facing NWs, as are PTSD-like symptoms. Possible countermeasures for the former could include command centralization: both emphasizing task prioritization and simplifying courses of action. For the latter, behavioral health resources should be ready once Soldiers can be taken off the line.

9/11 first responders' dramatically higher rates of PTSD seem fair to extrapolate to the nuclear context, given the parallels. Trauma and horror seen in nuclear combat will likely cause high rates of stress-related symptoms in Soldiers. The use of NWs in Hiroshima and Nagasaki makes the likelihood that psychic numbing symptoms exist for Soldiers in nuclear combat high, too. Though speculative, experiments on primates and rats and records from Japan suggest that radiation could exacerbate the symptoms of psychic numbing recorded in Hiroshima and Nagasaki.

Conclusions and Looking Forward

Beyond the understood physiological effects, it is clear a nuclear attack will have negative psychological effects on warfighters, though their precise nature is unknown. Distally, our general ignorance of NWs' effects is likely to cause psychosomatic responses. Soldiers far enough to avoid expected weapon effects directly may still be close and poorly trained enough to think they have. It is also worth considering how distal effects might arise in civilian populations. Imagine a scenario in which we employ a tactical NW far enough from a town for the locals to be safe, but close enough for them to see and/or know about the blast. Noncombatants might think they will be irradiated – creating a new set of challenges for damage assessment. Proximally, the hellish conditions closer to the blast will damage Soldiers' bodies and put unfathomable stress on their minds. Psychosocial effects will inhibit Soldiers' focus due to psychic numbing.

Increasing soldiers' training with dose measurement devices like the AN/UDR-13 and familiarization with dose rate effects are two great examples of actions that put control in the force's hands and remove uncertainty. Perceived novelty can also be lowered by exposing units at the National Training Center and the Joint Readiness Training Center to simulated nuclear threats. This would allow them to mitigate surprise and decrease the novel nature of an otherwise never-before-seen threat. Exposure to tools like Mission Impacts of Nuclear Events Software (MINES) and education about NW effects would help too. People frequently overestimate the scope of NW's danger, despite their wild variance in yield and effect radius.

"The degree to which one anticipates a disaster has important bearing upon the way in which one responds…"[46] In his interviews with survivors from Hiroshima, the "predominant tone" Robert Lifton heard was "extreme surprise and unpreparedness."[47] The Army cannot replicate their misfortune; we cannot fail to anticipate NWs in combat. Nor can it fail to adapt doctrinally and prepare Soldiers for their effects.

Future work could examine more case studies that may be analogous to the nuclear context, distally and proximally. Other CBRN incidents and studies done on Soldiers in combat could be considered, as they are the most likely to be similar. Live trainings done with NWs in Nevada during the 20th century are of particular interest. The proposed neurological underpinnings of psychic numbing as it relates to irradiation could be investigated, too.

Psychic numbing and PTSD-like symptoms should be expected in soldiers facing NWs. Possible countermeasures for the former could include emphasizing task prioritization, simplifying courses of action, and centralizing command structures. Training for the nuclear battlefield will allow Soldiers to build muscle memory, which would be useful for combatting psychic numbing's effects on combat readiness. As for PTSD, behavioral health resources should be available, and Soldiers should be aware of its likelihood.

"Are we developing the warrior that the modern battlefield requires?"[48] Army leadership has been and will remain fixated on this question. Our guard can never go down. To be ready for today's battlefield, we must anticipate its having NWs – for the good of our fighting force and of our nation. ■

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RECONSTRUCTING FALLOUT DISTRIBUTIONS:

Using Convolution Neural Networks to Reconstruct Nuclear Fallout Distributions from SCatterable RAdiation Monitors (SCRAM)

CAPT. KEVIN FILIP, MAJ. DAVID FOBAR, MAJ. TYLER HALBERT, & CADET SAMUEL AGUE

Introduction

The potential for conducting military operations in a nuclear environment is at its highest since the Cold War. The UN recognized this fact at a 2023 security council citing Russian plans to relocate nuclear weapons to Belarus as a result of the ongoing war in Ukraine.[1] Geopolitical conflicts,[2] an increasingly capable nuclear China,[3] and the erosion of long-standing arms control agreements[4] all contribute to an operational environment where the risk of nuclear engagement is alarmingly high. Now more than ever, commanders need assets to rapidly analyze the effects from a nuclear weapon employment to inform risk to force while operating in a nuclear environment.

Artificial intelligence (AI) is an ever-evolving asset that could be leveraged to rapidly analyze the effects of a nuclear weapon. In 2023, the Department of Defense (DOD) recognized the increasing prominence of AI and the need for integration with its AI adoption strategy. In this strategy, the DOD cited the requirement to strengthen the decision advantage in warfighting and enumerated two key outcomes of "battlespace awareness and understanding" with "adaptive force planning and application."[5] This strategy admits the need to adopt and embrace AI solutions to maintain the warfighting advantage.

Current nuclear fallout modelling software is robust but relies too heavily on accurate weapon employment information that is unlikely to be available to commanders in real time. Precise point of impact location, blast yield information, and accurate atmospherics may all be unavailable to recreate the fallout field using existing software. Assumptions made in this step could lead to significant error in fallout distribution analysis and this poses a significant risk to force. What if we could predict the nuclear fallout using real time dose rate data and obviate the need for such information?

The goal of this research is to strengthen the decision advantage for operational level commanders by leveraging AI to bridge the information gap that will exist in the nuclear environment. To accomplish this goal, we propose a framework for employing machine learning (ML) algorithms capable of reconstructing nuclear fallout distributions from a network of SCatterable Radiation Monitors (SCRAM). The key components to this framework include the SCRAM system implementation, the nuclear fallout models used as training data, the ML algorithm design, and integration into battle management systems. The SCRAM system is capable of functioning at the division echelon, providing operational commanders vital information to shape the deep fight.

In this article, we provide a brief overview of the SCRAM system, describe the framework for employing machine learning, a brief analysis on potential nuclear fallout models, and demonstrate initial successes in fallout reconstruction using convolution neural networks.

SCatterable RAdiation Monitors (SCRAM)

The SCRAM system is an emerging technology to deliver dosimeters across the area of operations using field artillery, much in the same manner that FASCAM can scatter anti-personnel and anti-tank mines. As envisioned, SCRAM will be shelf stable and rapidly deployable up to 25 miles by artillery. Once emplaced, the detectors will function for a minimum of 96 hours and provide integrated dose measurements as the operational need warrants. Each detector uses a low-power radio transmission protocol that can transmit upwards of 6 miles from its location to listening posts. Multiple listening posts must be established within the 6-mile radio range of the detectors for signal collection. The listening posts will retransmit data and metadata back to a central location (e.g. command post) for aggregation from distances up to 15 miles (25 km) away. Multiple listening posts could be established to extend that range. Using the metadata presented by multiple listening posts, each detector's location can be fixed to within 50 meters, even in a GPS denied environment. Our machine learning algorithm will be employed at the central location to reconstruct the fallout field in real time and provide real time analysis.

The employment of SCRAM could be done via drones where the primary tradeoff is to achieve information faster but lose certainty of information while broadcasting friendly interest in a region. Drones would be programmed to fly to specific areas of interest, sample data and then return for data aggregation. This could obviate the need for listening posts but in that instance would rely on a GPS enabled environment or rely on inertial navigation that could lead to significant position error. The drones would be able to rapidly provide a snapshot in time but the limitations of their range and time on station would reduce the amount of data collected significantly. Ultimately that could lead to uncertainty of results and obviate the purpose of the radiation monitor system. Distributing drones through an area would leave a large audio and visual signature, broadcasting friendly interest in a specific area. While drone employment is feasible the present limitations lead artillery employment to be more desirable.

Machine Learning Framework

The framework for employing machine learning can be broken down into two key phases: training and prediction. During training, an algorithm is constructed and given large volume data sets. The algorithm identifies patterns starting from a sparse collection of point dose rate measurements and reconstructs a continuous wide area radiation field that can be used to predict exposure. The ML model is continually refined to minimize the error in reconstructing the radiation field. Once sufficiently trained, the model can be deployed into battle management systems, given real time dose rate data (from SCRAM), and create a prediction of the expected distribution. Here we will provide an overview of the framework we intend to employ (see Figure 1). The specific ML algorithm design is discussed in the machine learning implementation section of this paper. For further details into the fundamentals of machine learning, see Sarker.[6]

During the training phase in our framework, the ML algorithm undergoes supervised regression learning from one or more of the available fallout models. To create that set of training data, we must consider what data will be available to make predictions in the future and factor those into the training methodology. In our framework, we assume there is a known detonation with approximate locations to employ SCRAM, there are discernable dose rate measurements in that area, some limited atmospheric data is available, and digital terrain elevation data is available. While these assumptions are not final, they inform some initial planning considerations and continue to be refined through the development process.

As with any ML solution, the quality and scale of the training data set establishes the capabilities of the model. While generating data, we varied five parameters: weapon yield, height of burst, ground zero location, wind speed, and wind direction. The complexity of the fallout model dictates the computational requirements and the tradeoffs with ML model accuracy. In the interest of initial model development, simpler fallout models are used to iterate ML solutions. The best performing ML algorithm architecture will experience more robust training and will not substantively change the machine learning approach.

The final critical implementation of this framework is the integration into Tactical Assault Kit (TAK) and other battle management systems to ultimately improve decision advantage for commanders operating in the nuclear environment. However, no amount of training or algorithm design can overcome an inherently flawed fallout model. For that reason, we outline a few fallout models under consideration with a brief analysis of their potential in this framework.

Nuclear Fallout Models for Training Data

The machine learning model can be no more accurate than its training data. The ground truth of the fallout distribution is extremely complex. Numerous techniques for modelling nuclear fallout have been proposed throughout the years with

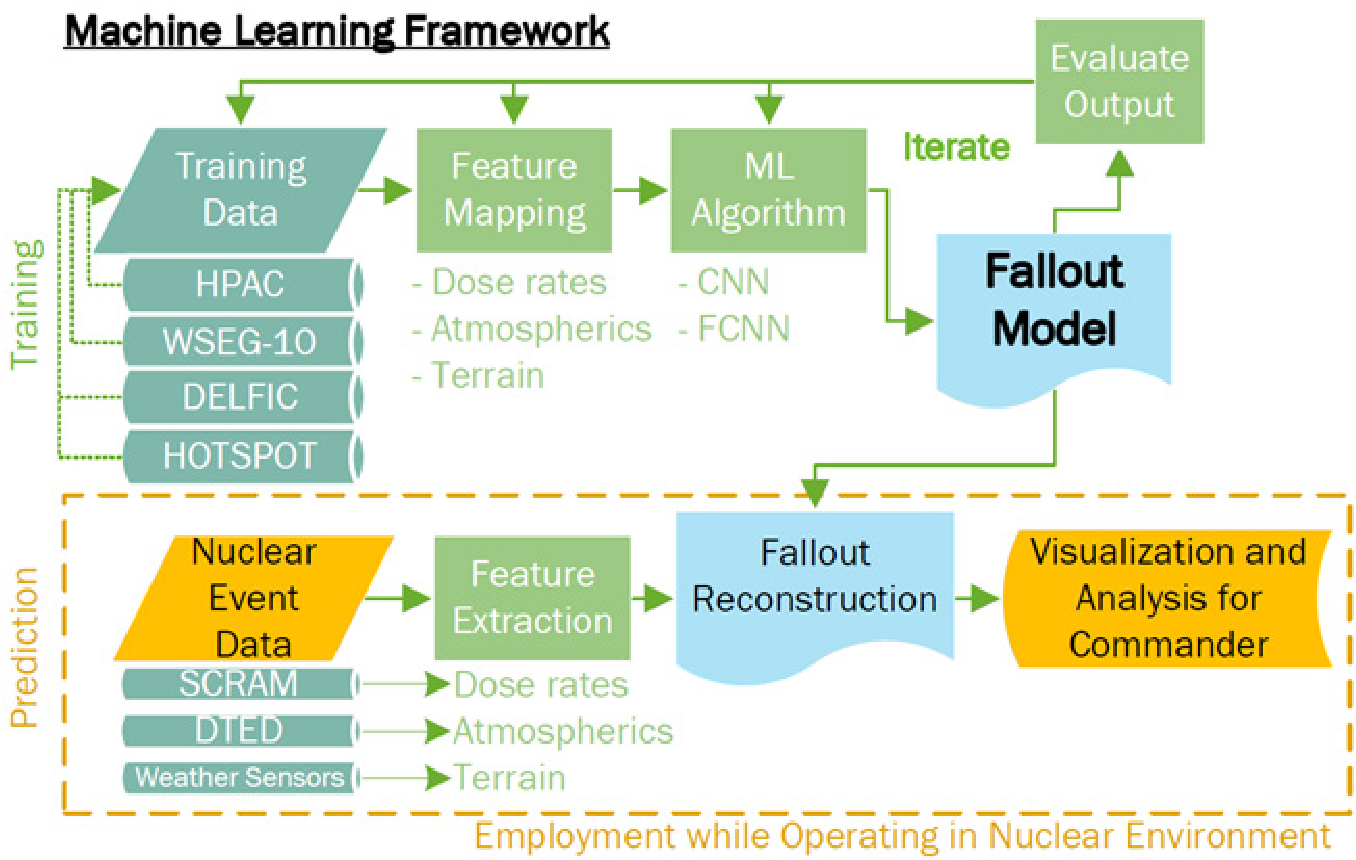

FIGURE 1. The figure above depicts the framework for reconstructing the fallout distribution using ML techniques. The top portion of the diagram is the training component of the ML algorithm while the bottom portion depicts the employment while operating in a nuclear environment.

Glasstone's *Effects of Nuclear Weapons* often referenced as a foundational text.[7] In this section we summarize analysis on the Weapons System Evaluation Group 10 (WSEG-10), HOTSPOT Health Physics Codes, Hazard Prediction and Assessment Capability (HPAC), and Defense Land Fallout Interpretative Code (DELFIC). WSEG-10 is discussed in more detail as this is used to demonstrate the reconstruction capability of the current algorithm design in the final section of this paper.

Weapons System Evaluation Group (WSEG-10)

The WSEG first published this empirically based model in 1959.[8] In 1980, Dan Hanifen wrote a thesis while at the Air Force Institute of Technology, analyzing and refining this model further.[9] In 2016, Edward Geist published a python-based version which digitized the fundamentals of this approach.[10] The python tool built from WSEG-10 assumes a surface burst and is designed for predictions from 1kT to 100 MT. All radionuclide activity is assumed within the fallout cloud and assumes 80% is deposited locally. The radioactivity within the cloud is assumed normally distributed following:

$$p(x,y,h) = \frac{\exp\left[-\frac{1}{2}\left(\frac{x^2+y^2}{\sigma_0^2} + \frac{(h-H_C)^2}{\sigma_h^2}\right)\right]}{(2\,\pi)^{3/2}\,\sigma_o^2\,\sigma_h} \qquad (1)$$

where *x* is downwind, *y* is crosswind, σ_o is the horizontal dispersion, *h* is the height above ground of the cloud, σ_h is the vertical dispersion. This activity distribution gradually falls back to ground as the cloud traverses according to a constant wind speed, direction, and shear. Wind shear in this model is defined as an increasing wind strength per unit of altitude but involves no direction change. The activity deposition is integrated across time and results in a downwind transport function:

$$f_x = Yield \cdot SNC \cdot \phi \cdot g(x) \cdot fission\ fraction \qquad (2)$$

where SNC is a source normalization constant (2×10^6 *R/hr/MT/st.mi*^{2}), ϕ is a normalization function, and *g(x)* represents the final activity deposition function following the cloud activity distribution. The crosswind deposition (f_y) follows a normal distribution along the path of the cloud. The distance and area units of this model are expressed in terms of statute miles, likely due to the era in which this model was published.

Dose from the WSEG-10 model is derived from the crosswind and downwind activity at a point one hour after detonation (figure 2). Integrating this activity across time and accounting for 10% biologically irreparable damage (90% repairable), the model can approximate a 30-day dose (see figure 3 for comparison to HOTSPOT). This biological dose is defined as an 'equivalent residual dose.' It is then refined into a second order approximation, which gives a dose unit in Roentgen/hr despite being used as a measure of total body damage.

Several limitations accompany this model and were noted by Hanifen. WSEG-10 does not account for complex winds, precipitation, and tends to overpredict fallout distribution relative to other models. Additional limitations include the lack of terrain considerations, lack of fractionation, and an antiquated method of estimating whole body dose. All factors considered, the error in this model could compound substantially. Assuming wind patterns are normal and terrain effects are negligible, this model could estimate the contamination area and concentration up to 3-4 times larger than existing models. This is due to its chosen source normalization constant which is used to govern the concentrations and depositions of radioactive fallout. The effects of this are shown in Figure 3 where the areas of contamination are larger when compared to HOTSPOT. This error could be minimized by optimizing the source normalization constant to minimize differences between WSEG-10 and other models if WSEG-10 was chosen as the ideal model to implement in SCRAM.

Bridgeman and Bigelow proposed a fallout model in 1981, which accounts for complex wind patterns and fractionation. It was validated using an analysis of Mt St. Helens ash distribution, yet still falls short of accounting for terrain.[11] Despite limitations, the variance in the degrees of freedom within this model, especially if incorporating source normalization constant as another degree of freedom, could provide a ML algorithm with enough basis to conduct complex interpolations when fit to real world data. Later, we demonstrate the implementation of the WSEG-10 model as a training data set in initial ML algorithms.

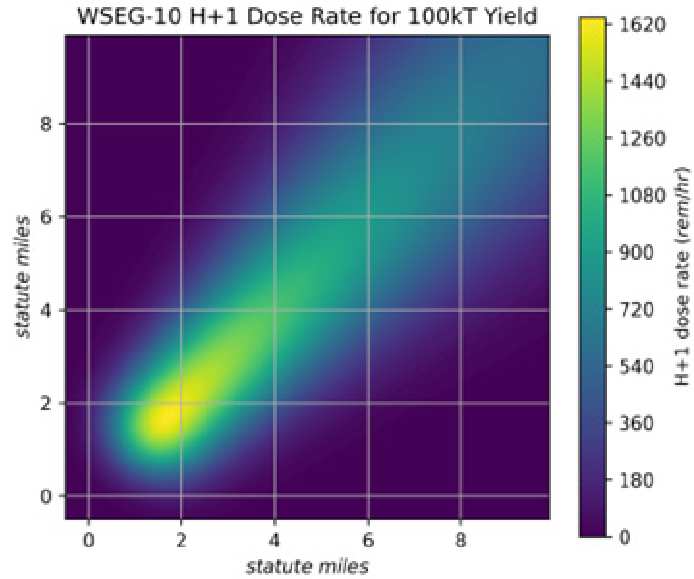

FIGURE 2. WSEG-10 dose rate one hour after detonation for a 100 kT yield, 10 mph winds, 0.23 mph wind speed increase per 1000' of altitude, and a fission fraction of 1.0. The WSEG-10 model's gaussian plume approach offers quick calculation speeds but the assumption of constant winds introduces potential inaccuracies in the spatial distribution of fallout.

HOTSPOT Health Physics Codes

HOTSPOT Health Physics Codes is a tool developed by Lawrence Livermore National Laboratory to provide emergency response personnel with a means to assess radiological hazards.[12] HOTSPOT's fallout modelling is derived from Glasstone and uses a Gaussian plume model (like WSEG-10) to track the movement of the fallout cloud. HOTSPOT accounts for terrain conditions through with a ground correction roughness factor (0.7). The dose estimations from nuclear fallout are assumed to be midline doses with a comparison drawn to Glasstone section 12.108 for whole body gamma dose effects on humans.

Limitations of HOTSPOT are fundamental to the gaussian plume models. The model tracks fallout without accounting for elevation and uses a simplistic assumption of static winds for the duration of the modelling. Model predictions could have significant errors if a major terrain feature exists, or a wind shift occurs during cloud movement. Further, the nuclear explosion tool ignores the dose from the deposition of radioactive particles and does not account for ongoing contamination of an area.[13] To highlight this point, the HOTSPOT Codes documentation states the standard deviation of dose values are approximately a factor of 5, which serve as ample approximation for field portable solutions but are less desirable for a training data set for a machine learning algorithm.[14]

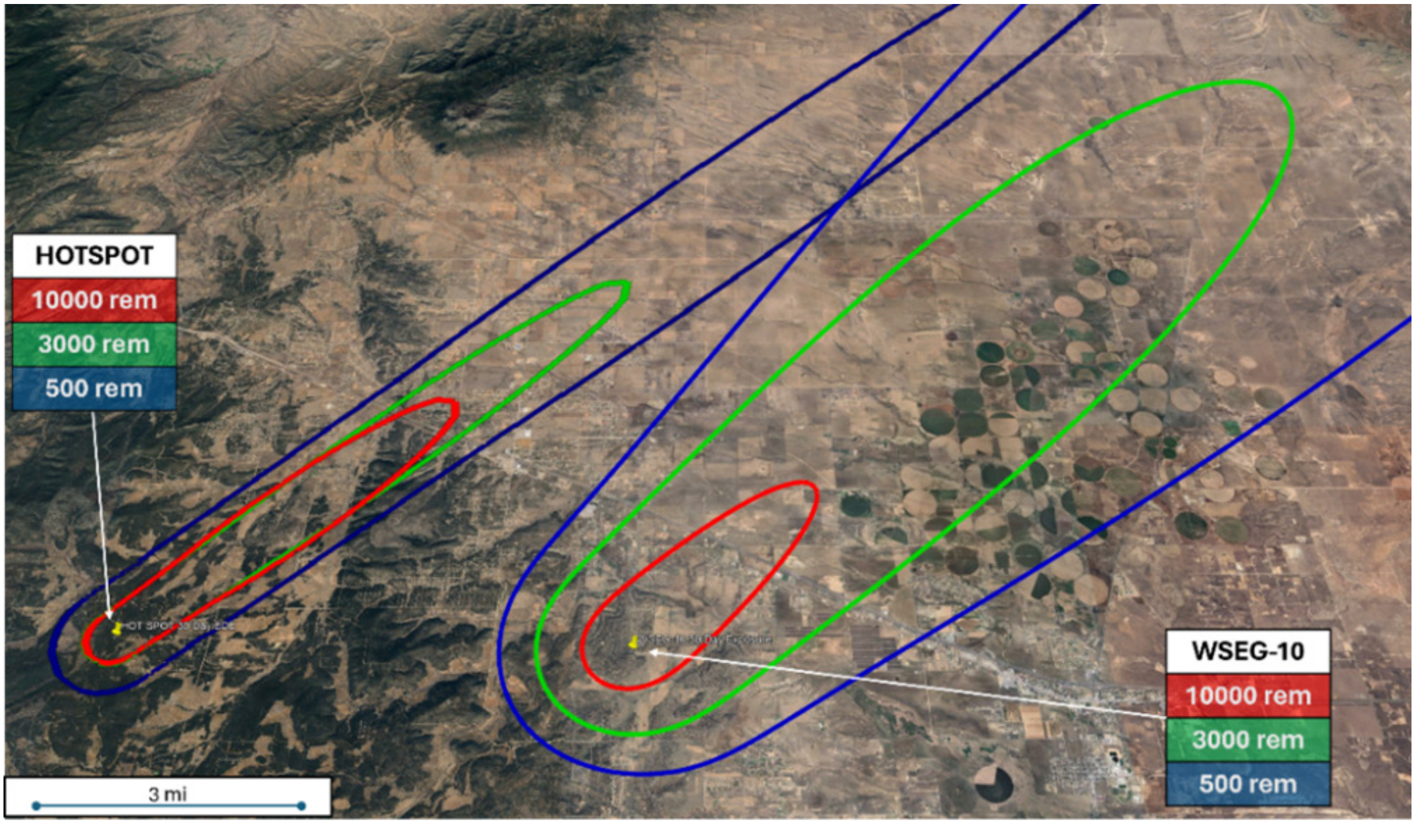

FIGURE 3. Comparison of HOTSPOT Health Physics Codes 30-day effective dose equivalent contours (left) to WSEG-10 python library 30-day dose contours (right) under the same blast yield (100 kT), wind speed (10 mph), and wind direction (225°).

Hazard Prediction and Assessment Capability (HPAC)

HPAC serves as the basis for the DTRA Mission Impacts of Nuclear Events Software (MINES).[15] This probabilistic model uses a second-order puff model which utilizes collections of Gaussian puffs to model mean concentrations of materials. Initial release conditions coupled with ambient airflow, turbulence, and terrain features are all considered to model the fallout cloud movement across time. An additional benefit with HPAC is the inclusion of uncertainty in resulting calculations. That uncertainty could be incorporated into machine learning training to improve statistical certainty in results.

HPAC is a well-rounded solution, though some of the limitations of this model include the terrain resolution and the computational resources to calculate scenarios. Terrain resolution on the scale of 1 km^2 is useful for large scale scenarios but could lose efficacy if used in small scale. If terrain were used to improve our modelling approach, then our machine learning algorithm would need to be trained on a more complex (and larger) data set when considering varying types of terrain. That complexity is further exacerbated when the time to generate the training data set is considered. Suppose we need a data set of 50,000 fallout models and an average calculation time of 5 minutes. In this scenario, the total calculation time becomes roughly half of a year. Based on the rapidly evolving state of machine learning, our goal would be to leverage a data set that enables model retraining within 1-2 weeks of straight computation time at worst case. This time scale gives the flexibility to rapidly retrain and deploy assets to a specific AOR should the need arise for a fine-tuned theater specific model.

Defense Land Fallout Interpretative Code (DELFIC)

DELFIC is a FORTRAN based transport code developed in the 1960's by Oak Ridge National Laboratory and still in use today for modelling local fallout where local is defined by particles that fall within 24 hours of detonation.[16] DELFIC is a dynamic transport code which models the movement, dispersion, and deposition of particles following a nuclear event. This code has gone through many revisions since 1968. One notable update included the inclusion of a wind vector space in the 1990's which leverages real-time atmospherics to improve model prediction accuracy.[17]

DELFIC models particle cloud rise as a bubble of hot air loaded with water and ground material starting at the time the fireball reaches pressure equilibrium with the atmosphere. It uses blast yield, height of burst, and type of soil to create the cloud and the elevation of ground zero, soil solidification temperature, fission yield, altitude of tropopause, fallout particle density, and atmospherics (winds, temperature, humidity, and pressure) to model the cloud rise to vertical stabilization and its subsequent horizontal movement. The particles are transported through the atmosphere and deposited on the ground by individual groups which are combined at the end of calculations. Additionally, DELFIC can calculate the radioactivity of the fallout field through use of the Bateman equation for each individual nuclide present. These values are used to produce the exposure rate for one hour after detonation and then uses a decay factor of $t^{-1.25}$ to calculate the exposure rate for any time frame after one hour. DELFIC is a robust solution for modelling where the main limitation is its format. User interface tools like the DELFIC Fallout Planning Tool exist but challenges exist in preparing training data sets for machine learning.

WSEG-10 Application in Machine Learning

In the next section, we use the WSEG-10 model as training data for our machine learning architecture. The WSEG-10 model was chosen due to its quick calculation speed and ability to generate large training datasets in Python which are easily adapted for machine learning. These features allowed rapid iterative improvements in architecture design that would not be feasible using other models at this stage. We can accept risk on the fallout model accuracy due to the nature of the ML architecture design. In subsequent research, any of the existing fallout models can be applied to this ML architecture to improve the accuracy in results. For now, we will describe one such architecture using the WSEG-10 model as a basis for the training data.

Machine Learning Implementation

Introduction

The fundamental goal of reconstructing fallout distributions can be approached as an image processing task. Neural network architectures are the ideal choice for image processing tasks and their efficacy was investigated. In this section, we demonstrate the results from one machine learning architecture using Convolution Neural networks to spatially reconstruct fallout distributions.

“Neural network” is a broad term which consists of many specialized approaches to machine learning. Two principle design philosophies implemented into our approach are fully connected neural networks (FCNN) and convolutional neural network (CNN). FCNNs are layers of neurons where each neuron in one layer is connected to all neurons in the next layer. Information flows from the input layer through hidden layers to the output layer, with each neuron making connections to the output following activation functions which dictate the value passed between layers. Meanwhile, CNNs handle complex, high-dimensional data through similar hierarchical pattern recognition capabilities. In these algorithms, matrix convolutions are applied as kernels across spatial data to detect patterns, textures, and features. These convolutions can then be summed to detect patterns across layers and map neurons from input to output. While each approach is capable, the most efficient and accurate solution requires hybridization of multiple approaches.

Methods

Our approach involved training the ML model to find connections from sparse dose rate data and atmospherics to the fully formed radiation distribution. From a design perspective, the model should be able to recreate a full spatial distribution with a very limited number of spatially arrayed SCRAM data points and some atmospherics. Both FCNN and CNN design philosophies were incorporated as two parallel branches: the first branch for spatial dose data and the second branch for atmospherics.

The first branch (imaging branch) consisted of CNNs, specifically an encoder/decoder,[18] to encode sparse dose distribution data through a series of convolutions which aggregate the distribution into sequentially lower resolution matrices. At each step of aggregation (encoding), the output of aggregation links to a subsequent layer which de-aggregates (decoding) the data and learning patterns between layers. Our approach consisted of three encoding layers (64,128, and 256 kernels, size 3x3 in each layer) and three decoding layers using a rectified linear unit activation function. The second branch (atmospherics branch) acts in parallel to the first and links wind speed and direction to the output of the first branch. This approach establishes links between sparse data input and atmospherics within the model. This branch then merged with the imaging branch into dense layers of neurons that re-normalize the data into a format that is interpretable. See Figure 4 for a representation of the architecture.

To test this approach, fallout distributions from the WSEG-10 model were generated from 2744 unique combinations of blast yields (0.05 to 1 MT), wind speeds (5 to 25 mph), and directions (equally spaced) within a 1600 sq. mi. area.[19]

The resultant radiation fields from the WSEG-10 dataset were normalized and resized into 256x256 single channel arrays. The TensorFlow API was used to design the architecture in

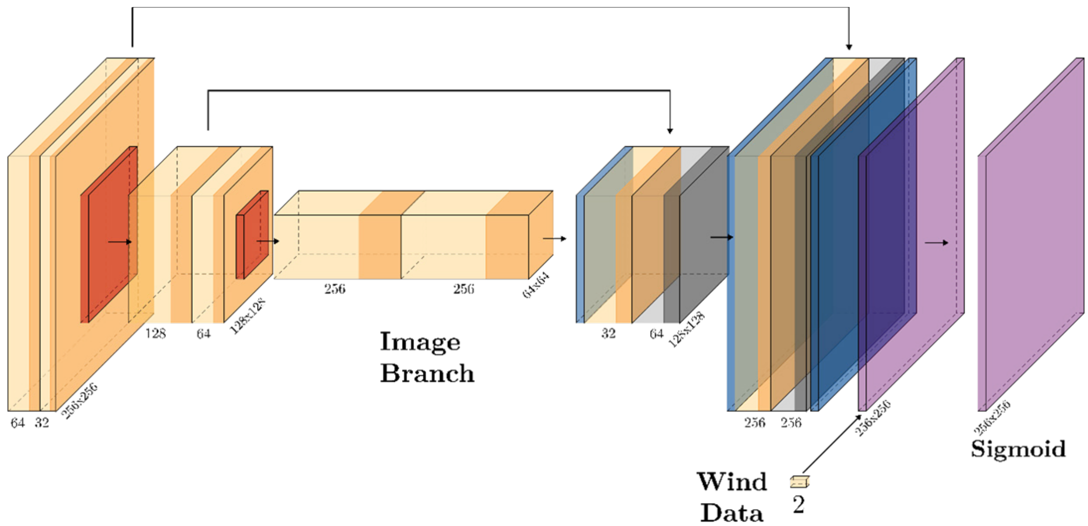

FIGURE 4. Depiction of machine learning encoder decoder architecture with integer wind data incorporated into output of imaging branch. Scaling and resizing of wind input features is not depicted.

Python and was trained following a data reduction training process.[20] This training process used a curriculum training process with progressively smaller data sets which form strong initial pathways and reinforce pattern recognition as data is limited. The model was trained using a curriculum-based training approach by sampling random points from 90% (58,982 points), 60%, 30%, 10%, 1%, and 0.5% (3277 points) of the original distribution. Five epochs were run for each level with a training data set (wind direction, speed, and the incomplete fallout distribution) split 80% for training and 20% for validation using an Adam optimizer (learning rate 0.0003) designed to minimize mean squared error. See figure 5 for the training progress for each data set across training epochs.

The model was assessed by testing predictions using four validation data sets which mirrored expected input data from SCRAM. These data sets consisted of simulated point dose rate data from decreasing amounts of randomly arrayed detectors sampled from a ground truth data set. The wind speed and direction used for validation (5 mph and 110°) represented an approximate value of the ground truth wind speed. For simulated data set, the model predictions were compared against the ground truth. Quantitative assessment was performed using a mean absolute error to compare model training performance and a log scale mean absolute percent error to assess predictive performance. Qualitative assessment was performed through visualization and comparison of the predictive modelling.

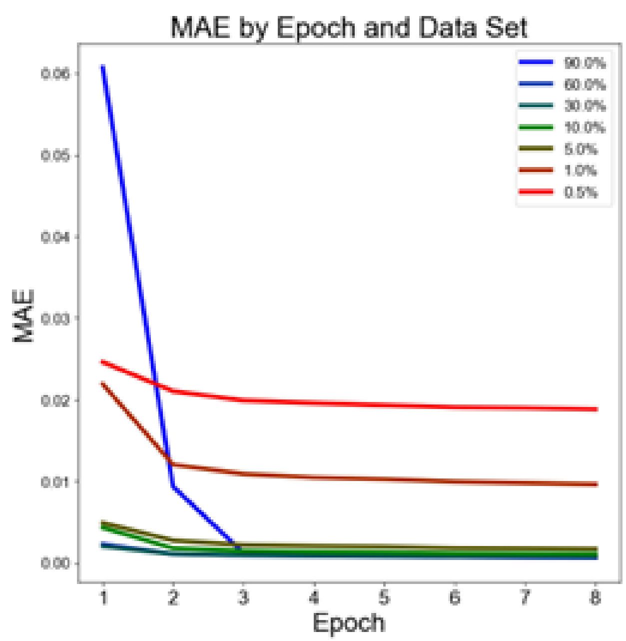

FIGURE 5. Mean absolute error (MAE) across epoch for the described training data methods. Training using a curriculum-based approach caused convergence on a minimized MAE within four epochs. The MAE for all but the 1% and 0.5% training data sets converged due to the sample size being sufficiently large to achieve near 0 error. As sample size decreased to 1.0 and 0.5% the error in prediction reduces, though this curriculum-based approach improved prediction accuracy by a factor of three compared to non-curriculum-based approaches.

Results and Discussion

Figure 5 depicts the mean absolute error (MAE) following training with the model's MAE degrading as training data became more limited. The greatest improvements occurred in the first two epochs and in the first training set (90% complete distributions). The MAE minimized at 5% complete distributions and then increased as distributions were further degraded. For each training iteration, the MAE converged by approximately the fourth epoch and subsequent training epochs resulted in minimal improvements in model accuracy. These results represent a factor of three improvement using the curriculum-based training approach when compared to previous iterations that did not use progressively smaller data sets.

Figure 6 depicts the reconstruction of the fallout distribution alongside the ground truth from the WSEG-10 model. Qualitatively, the shape, intensity, and orientation of the fallout distribution remained generally consistent regardless of the number of detectors. The mean absolute percent error of the predictions stayed relatively consistent ranging from 33% (586 detectors) to 36% (124 detectors). As the number of detectors decreased the general shape, intensity, and orientation of the fallout field remained consistent, though artifacts became more pronounced. The most prevalent artifacts can be seen in the reconstruction using 124 detectors. The gaps in the distribution can expected with convolutions and are exacerbated by the small number of data points. Some amount of image post processing can be done to smooth some artifacts though none was done for this work. Despite these artifacts, the general shape and intensity of the fallout field is apparent.

Results show that the model is learning appropriately but is constrained by the current complexity of the fallout data. Subsequent iterations of this approach will include substantially more than three encoder/decoder layers, additional dense layers, and increases in the spatial resolution. More

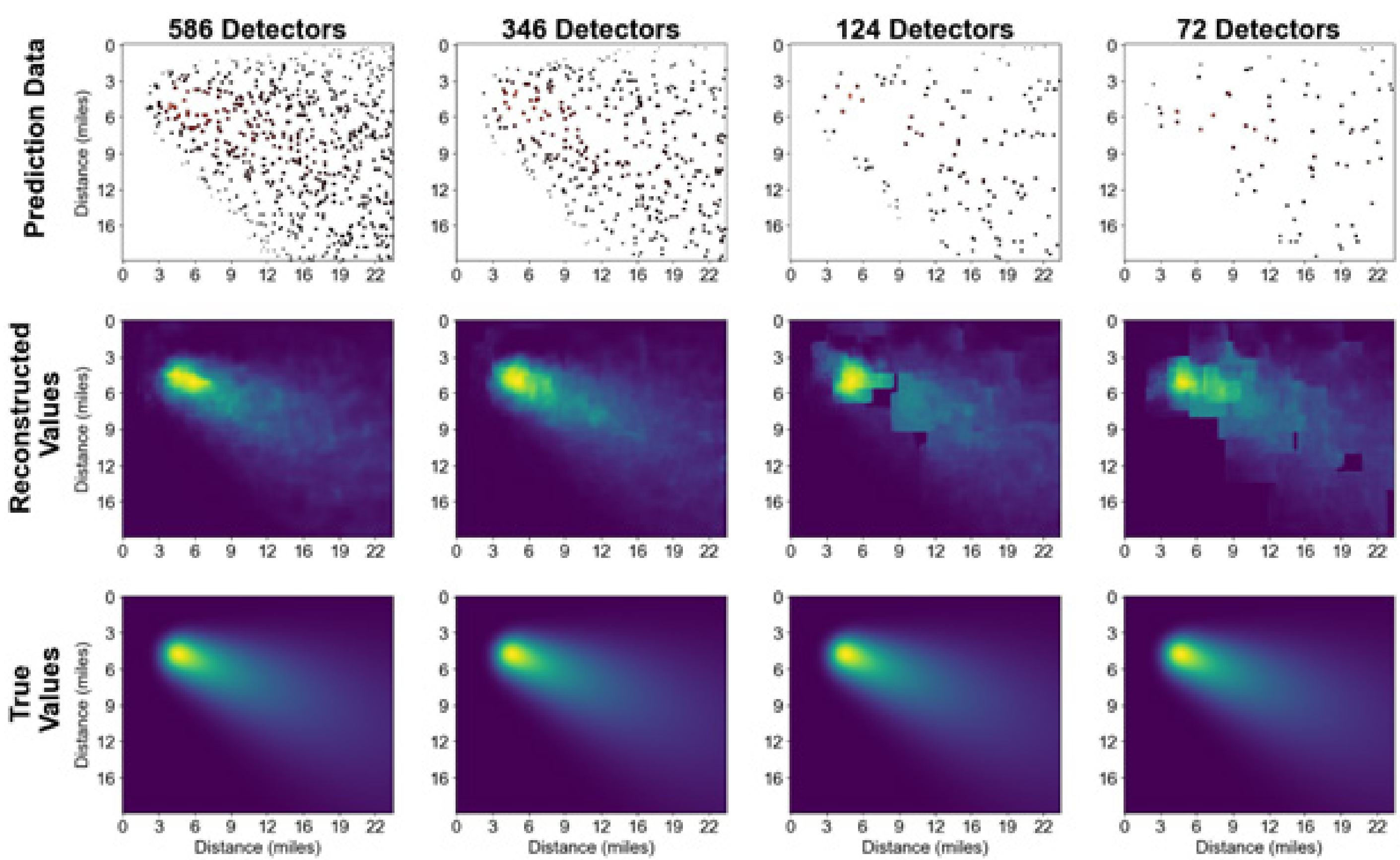

FIGURE 6. A comparison of reconstructed fallout distributions to the "true" distribution based on WSEG-10 modelling (100 kT blast yield, 5 mph winds towards 110°). Pixel intensity value (0 to 1) corresponds to normalized activity one hour after the explosion. The trained model made predictions based off a decreasing amount of randomly assorted, simulated SCRAM dosimeters with approximate wind speed and direction.

encoder/decoder layers could help mitigate the artifacts as the number of detectors decreases. Additional dense layers could help strengthen relationships between dose distributions and atmospherics. Spatial resolution could be increased from a 256x256 array where each pixel represents approximately 12 football fields (63,000 m^2) to a 1024x1024 array where each pixel represents one fifth of a football field (4000 m^2) to improve fidelity in the distribution.

The results shown here prompt a new line of investigation into the minimum threshold of SCRAM detectors while considering the expected dispersion patterns during deployment. Additionally, as new fallout models are integrated new training features like terrain can be incorporated into the input data to further refine the model's predictive abilities.

Conclusion

Our framework for reconstructing the fallout dose distribution following a nuclear event shows promise. The SCRAM system in conjunction with the proposed neural network architecture is shaping to provide commanders with situational awareness which ultimately improves decision advantage. The early results discussed here indicate the feasibility of this approach and give a path for continued development. Of the models reviewed, only one (WSEG-10) was tested and analyzed. Other models must be assessed to determine which provides the most accurate reconstructions based on known limitations.

Significant advancements could be made in the ML algorithm complexity, training, and incorporation of a temporal dimension into analysis. The WSEG-10 model accuracy is the greatest shortfall and seeking a more accurate fallout model is a priority after these initial successes. The source normalization constant used in WSEG-10 is up to four times greater than comparable models which can cause overprediction. Further, the WSEG-10 gaussian plume probability distribution with fixed wind conditions could cause inaccurate interpolation of fallout distribution in spatial reconstruction. This error would depend heavily on the amount and magnitude of wind variability. While the WSEG-10 model is computationally desirable, it lacks the rigor in particle transport models such as DELFIC which track fallout as particles and accounts for variable winds in a vector space. Future work will seek to improve the underlying fallout model training data and machine learning algorithm design. Despite the shortfalls in the WSEG-10 model, the initial results show promise that we can leverage artificial intelligence to strengthen the decision advantage of commanders operating in a nuclear environment. ■

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A PROMPT BOMB EFFECTS CODE

DR. BEHZAD SALIMI

Introduction

In this article, we introduce and highlight the capability of a new software to perform relatively detailed calculations of prompt nuclear detonation environment based on legacy unclassified data. This author also strives to advance towards newer (possibly better) models incorporating more recent data as it becomes available. This article highlights, in graphical mode, the results of the prompt environment for a low-yield nuclear surface detonation scenario. The objective is to offer a qualitative perspective view of the immediate environment of a nuclear detonation phenomenology due to blast overpressure, and nuclear and thermal radiation. Such overall perspectives of the post-detonation environment are useful in understanding the level and the extent of the probable casualty, injuries, and damage to equipment. Understanding and predicting the post nuclear detonation environment is important in consequence analysis for positioning and maneuvering of military forces in battlefield operations. Such a fast, stand-alone digital software tool is ideal for everyday scoping analysis, and it is currently the only tool of its kind available for use on the field and in crisis situations without dependence on third-party access or resources.

Computation Capability

This author has developed a computer program to simulate and function as a fast digital version of the classic circular slide rule "nuclear bomb effects computer" that was included with the original publication of Glasstone and Dolan "The Effects of Nuclear Weapons." Additionally, this computer code includes additional computations of interest beyond what was possible with the mechanical/circular computer. While using the circular slide rule requires no battery, electricity, or data storage, reading numbers from the slide rule requires sharp vision and both physical and mental dexterity to align different scales and read (approximate) numerical values under a hairline on or between tight (sub-millimeter) marker spaces. Usually, the desired value must be visually interpolated between two tic marks. These attempts, no matter how carefully executed, are inevitably prone to user errors and gross approximations.

Circular (mechanical) computers with multiple scales are novel, ingenious inventions, but except in the simplest single conversion scale, they are slow and difficult to use. Surely, they are better than nothing, but they require diligent study and practice to be useful. Moreover, it is highly unlikely that two different people would estimate the same numerical value between adjacent tic marks. Computer programs are much easier and faster to run than mechanical, analog computers, but they can also be misused by wrong users. However, knowledgeable users would be much more efficient and productive with computer programs. Given the same input, when properly maintained, computer programs always compute the same results regardless of the users.

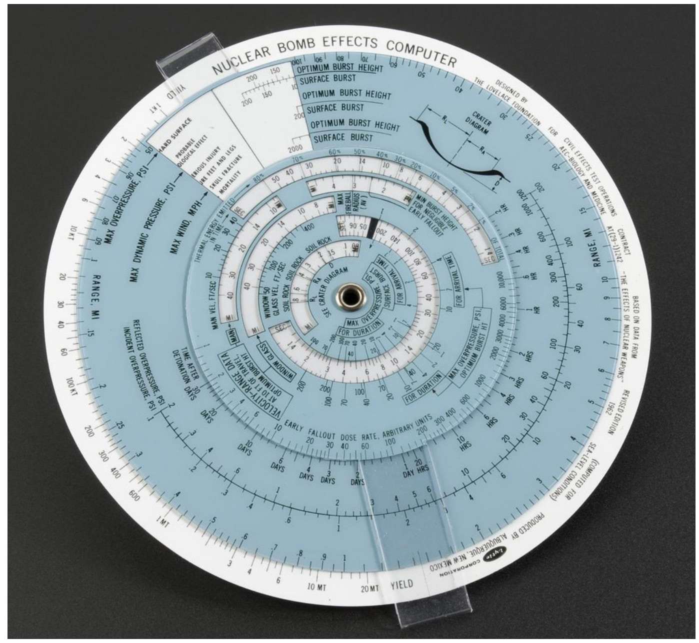
While a well-written computer program requires at least a small computer with battery power and digital memory, it can produce a large volume of numerical results quickly and repeatedly with minimal input. The new computer program developed by this author requires only a one-line input of a few basic global numbers such as the explosion yield and height of burst (HOB). It computes and prints a set of tables including several quantities of interest for a user-specified horizontal range and interval. The computer language for this program is the popular and efficient Python version 3.x (the latest in 2023). It instantly computes and prints nuclear bomb effects for any valid input. It can produce detailed tabular values, and it flags any result that falls outside of the valid scope of the mathematical models. All of the calculations presented in this paper were done at once in one execution run of the program. As a stand-alone tool, this software is self-contained, and it does not require any external libraries or access to the Internet. It can run on any computer platform that has any version of Python-3 installed. Ultimately, this software could serve as an unclassified benchmark analysis tool or a fast, ready alternative to existing, more restrictive (limited operations) tools or in the future.

Sample Scenario Calculations

The following figures illustrate graphically the calculated prompt environment of a 5-kiloton (kt) nuclear surface detonation scenario. The detonation point (ground zero) is at the reference point range=0.0 in the plots. The minimum range for reliable calculation in most cases is usually about 500 meters (m) or 0.5 kilometer (km). The vertical dashed lines in the plots mark the estimated locations as follows:

Black Vertical Line	1 pounds per square inch (psi) overpressure
Red Vertical Line	MSD1 (estimated minimum safe distance 1)
Green Vertical Line	MSD2 (estimated minimum safe distance 2)

See DA PAM 50-7 (PRCC) for formal definitions of MSD1 and MSD2. The typical log-log scale used in many published nuclear effects data makes discerning the perspective of the change of quantities versus distance difficult. Therefore, we plot all calculated values on a linear-linear scale on the axes to make it easier to see how rapidly the prompt nuclear effects diminish with increasing distance from the detonation point.



ABOVE: A mechanical Nuclear Bomb Effects Computer.[1]

Sample Scenario Results

Figure 1 shows the profile for maximum overpressure (pmax).

Figure 2 shows the profile for maximum dynamic pressure (qmax).

Figure 3 shows the maximum wind velocity (umax).

Figure 4 shows all three profiles, overpressure, dynamic pressure, and wind velocity on the same plot, but with different scales. In this plot, it is easy to see that all three profiles are near-exponentially decreasing with distance, and they have similar patterns.

Figure 5 shows the thermal radiation (Cal/cm^2) profile.

Figure 6 shows the total nuclear radiation profile in centi-Gray (cGy).

Figure 7 shows both thermal and nuclear radiation profiles on the same plot with different scales. Similar to blast profiles in Figure 4, thermal and nuclear radiation profiles are also near-exponentially decreasing with distance.

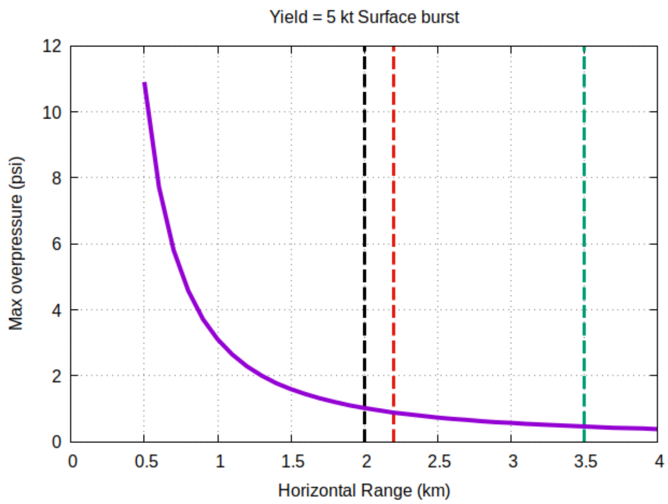


FIGURE 1. Maximum overpressure vs. horizontal range.

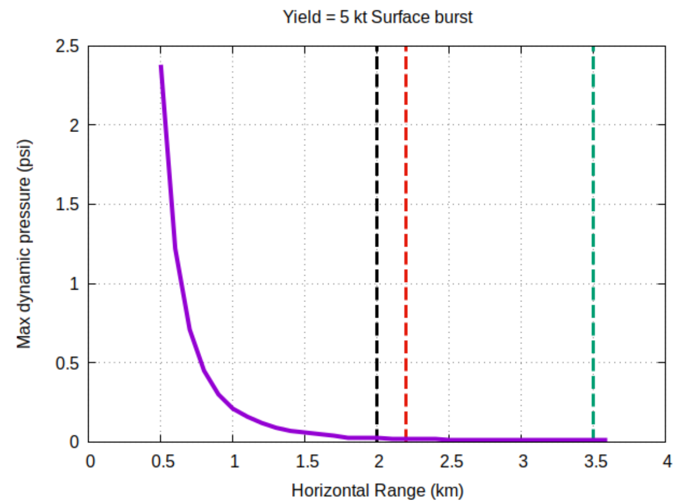


FIGURE 2. Maximum dynamic pressure vs. horizontal range.

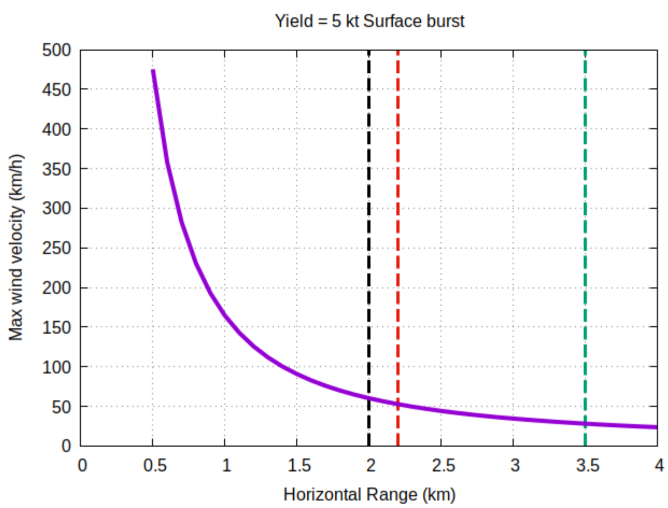


FIGURE 3. Maximum wind velocity vs. horizontal range.

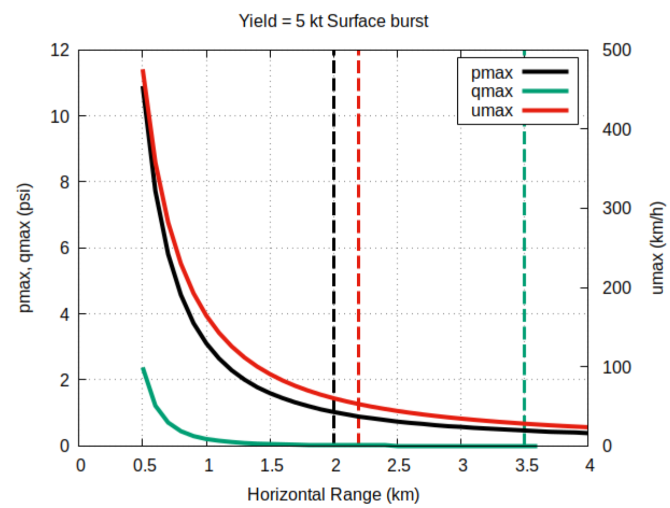


FIGURE 4. Three quantities pmax, qmax, umax vs. horizontal range.

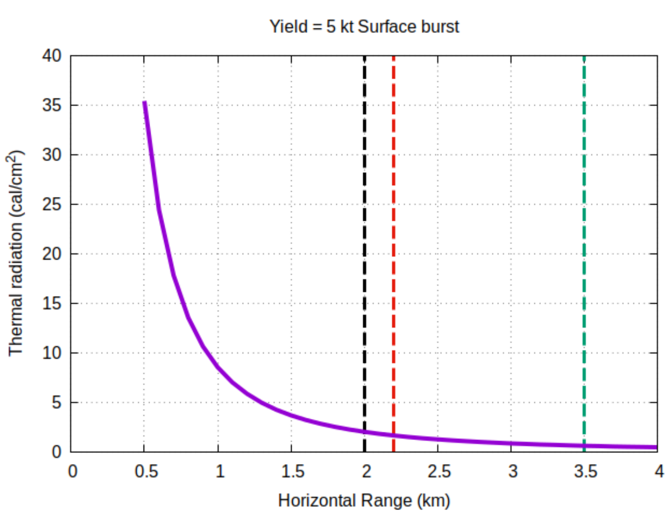


FIGURE 5. Thermal radiation vs. horizontal range.

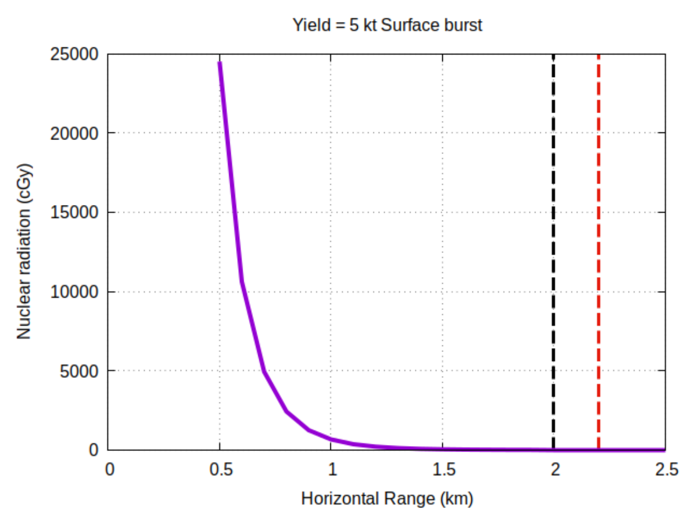


FIGURE 6. Nuclear radiation vs. horizontal range.

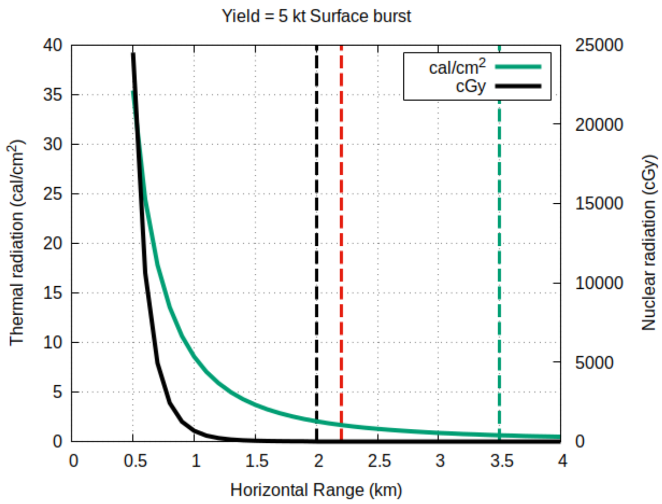


FIGURE 7. Thermal and nuclear radiation vs. horizontal range.

This new software also detects the nominal condition for surface detonations. In this case, it also prints the parameters for the associated crater formation. For the example of 5 kt surface detonation, we find:

Surface Burst Parameters

Crater Lip Diameter	132.0 m (in soil)
	105.6 m (in rock)
Crater Apparent Diameter	66.0 m (in soil)
	52.8 m (in rock)
Crater Lip Depth	19.7 m (in soil)
	15.8 m (in rock)
Crater Lip Height	3.9 m (in soil)
	3.2 m (in rock)
Crater Depth	15.8 m (in soil)
	12.6 m (in rock)

The phenomenology of prompt environment for actual nuclear weapons depends on the weapon type, yield, and height of burst. Therefore, the information contained in these calculations and plots are for overall comparison and scoping analysis. Considering these figures as reasonably accurate and representative, comparison of figures 4 and 7 suggests that all of the prompt effects reduce to safe levels beyond approximately 2.5 km from a nominal 5 kt surface detonation. Flash blindness, retinal burn, and electromagnetic pulse (EMP) effects pose an important risk at greater distances. However, these effects are not included in this brief paper while we continue to further develop and implement efficient methodology and mathematical modeling to address these additional effects.

Although not included in this article, this author is developing simple mathematical models to compute additional estimates of damage to aircraft and certain US Army land equipment of interest in the combat environment. These additional models will be included in future versions of the software.

Conclusion

Most published nuclear effects charts are plotted in “scaled” quantities for the convenient display of data, but they are inconvenient or simply impractical for engineering applications. With this new software tool, we have the computational capability to perform useful and timely analysis of nuclear weapon effects post detonation. This software instantly provides the effects at a point downrange, or effect versus range profiles for blast, thermal and nuclear radiation. We can produce such detailed results for any physically valid and reasonable yield and HOB combination. The numerical values of the nuclear effects phenomenology closely match the data published in Glasstone and Dolan's, *The Effects of Nuclear Weapons*. Therefore, we can provide numerical results much more effectively and accurately than reading values from various mechanical or graphical charts and subsequently using an electronic hand-held calculator to convert them to basic, common, and useful engineering units. This self-contained computational tool is the only known tool available today for use on the field in the absence of Internet in crisis situations.

This fast computational capability can be useful for timely battlefield planning, operations, and logistic of preclusion analysis because the prompt effects of nuclear weapons are minimally (or not at all) affected by ambient atmospheric conditions. Ambient conditions such as humidity, cloud cover, air density, and surface albedo (e.g., snow versus grass) have relatively small effects on some values of the prompt effects. However, these conditions do not change the overall profile of the effects versus distance, and the computed values are typically well within the expected nominal values with associated uncertainties (error bars) in the published legacy data and charts. Therefore, for practical applications, the results of this nuclear bomb phenomenology computer are likely reasonable estimates of the actual expected (nuclear and thermal) radiation and blast environments. Furthermore, using this fast computational capability, we can efficiently compute the prompt effects for different weapon scenarios, and compare the proportional effects and their differences. Such overall prompt effects analysis would be useful in understanding the extent and magnitude of the immediate effects of different nuclear detonations on land component military formations. Future implementation of EMP effects on land and space communication assets, combined with very fast computational capability of this software should provide key information to decision support to estimate and evaluate the consequences of nuclear bomb effects on military maneuver decisions. ■

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CHANCE FAVORS THE PREPARED MIND:
A History of the DoD Cholinesterase Monitoring Program and the DoD Cholinesterase Reference Laboratory

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"Chance favors the prepared mind." (Forte adiuvat animus paratus)

-Louis Pasteur

Introduction

The well-known time-honored quote above from the French chemist, Louis Pasteur, whose contributions were recognized with saving many lives by developing vaccines against anthrax and rabies, can mean several things as it relates to chemical weapon countermeasures. First, it could purport that the better prepared and more knowledgeable a person is, the more that person may be able to benefit from of any chance opportunities or observations. Persons having vision, curiosity, and ability related to the situation may position themselves to exploit any unseen "pearls" initially concealed at the beginning of their inquiry.

Due to the distinctive and extremely volatile nature of chemical warfare nerve agents, the U.S. government established the Department of Defense (DoD) Cholinesterase Monitoring Program, a massive clinical testing and occupational health monitoring program to periodically assess employee's potential exposure to chemical warfare nerve agents. For decades, with the ingenuity of laboratory and specialized personnel using sophisticated laboratory techniques, the program has monitored tens of thousands government military and civilian employees working in chemical weapon storage and destruction depots, as well as in the Chemical Defense industries and emergency preparedness programs. The potential deployment of chemical weapons by Russia and other adversaries have become an undeniable reminder that it is still crucial for the military to maintain and improve a robust cholinesterase activity testing program to better protect Americans and our allies worldwide.

In comparison to other types of chemical weapons, chemical warfare nerve agents have always played a particularly important role in part due to their superior lethality, long lasting effects, excellent survivability in the field environment, and ease in production. The long history of the U.S. government's research on chemical weapon development and countermeasures can be traced back to the WWI era.[1]

After WWII, the government started focusing on the safer-to-handle and easier-to-conceal binary chemical weapons. As a result, a large quantity of traditional chemical weapons and their related munitions were consolidated and delivered to multiple military depots for long term storage or demilitarization (destruction). The process was initiated by the Congress in the 1950s and accelerated during the U.S.-Soviet détente (1969-1979).

Similar to many organophosphate and carbamate pesticides, chemical warfare nerve agents target human cholinesterase by electrophilically attacking the cholinesterase serine residue to render the enzyme inactive.[2, 3] Without cholinesterase-induced breakdown, the neurotransmitter, acetylcholine can quickly accumulate and disrupt the normal acetylcholine synaptic concentration levels. The resulting rapid over-stimulation in the human neuromuscular system can cause acute poisoning and lead to a serious cholinergic crisis. The symptoms of cholinergic crisis are often summarized by the mnemonic 'SLUDGE' (Salivation, Lacrimation, Urination, Defecation, Gastrointestinal distress, and Emesis), in addition to miosis and muscle spasm.[4] 'SLUDGE' is the consequence of excessive exposure to cholinergic neurotransmitters and the resulting over excitation of central nervous system neurons. With high degree cholinesterase activity depression, a person can suffer from flaccid paralysis and respiratory failure, which may eventually result in death.

Unlike commercially available organophosphorus and carbamate pesticides, chemical nerve agents can undergo a fast secondary *in vivo* dealkylating transformation (commonly known as 'aging') to form a significantly more stable agent-cholinesterase complex.[5] The formation of the 'aged' agent-cholinesterase complex cannot be reversed by any conventional medical treatment. Due to these unique and extremely dangerous features, the U.S. government reached to a conclusion that it was necessary to establish a massive clinical testing and occupational health monitoring program to periodically assess employee's potential exposure to chemical warfare nerve agents. This later became the DoD Cholinesterase Monitoring Program.

Scope of the DoD Cholinesterase Monitoring Program Services

The DoD Cholinesterase Monitoring Program started testing government employees in the 1950s. The program significantly expanded in the 1970s through the 1990s. During this period, several DoD cholinesterase testing laboratories were established at or near the nerve agent storage and demilitarization sites. The program experienced peak activity in the mid-1990s through the early 2000s, especially after both the U.S. and Russia signed the treaty under the Chemical Weapons Convention and accepted its obligations in 1993. At the time, there were more than 25 satellite cholinesterase testing laboratories and one Cholinesterase Reference Laboratory under the DoD Cholinesterase Monitoring Program.[6] The program provided direct and crucial support to the Army National Guard Weapons of Mass Destruction Civil Support Teams (WMD-CSTs) in all 50 states, all OCONUS and CONUS DoD medical facilities, the Defense Threat Reduction Agency, the DoD Chemical Surety Program, and numerous auxiliary personnel engaged in missions supporting the nation's destruction of chemical warfare nerve agent munitions. The program has also collected a large amount of testing data and enabled the DoD to establish a normal range of human red blood cell acetylcholinesterase activity.[7]

Analytical Methods for Cholinesterase Activity Testing *in vitro*

Because chemical warfare nerve agents are Cholinesterase Inhibiting Substances, an important biomarker for potential exposure to nerve agents is to evaluate and measure depressed human cholinesterase activity. With the necessity to save lives and innovate, scientists who took Dr. Pasteur's longstanding maxim to heart have developed two widely utilized analytical methods, the electrometric Michel delta-pH method and the colorimetric Ellman method.[8, 9] The Michel method, published by the Army in 1949, measures cholinesterase activity by tracking cholinesterase catalyzed acetylcholine hydrolysis reaction rate in a patient's blood sample *in vitro*.[10] The dissociation of acetylcholine generates choline and acetic acid. The increased acidity of the blood sample is reflected by the decreased pH value. The change of pH can be accurately captured by a calibrated pH meter. Acetylcholine hydrolysis rate over a given time period can thus be calculated as 'delta-pH per unit time period' with a simple mathematical formula. As an alternative, Ellman in 1961 reported a unique method using the sulfur-substituted acetylcholine analog, acetylthiocholine as the substrate.[11] After the cholinesterase catalyzed hydrolysis, the resulting thiocholine reacts with 5, 5-dithiobis-2-nitrobenzoate to produce the highly conjugated chromophores bearing 5-thio-2-nitrobenzoic acid anion in yellow. Therefore, the rate of acetylthiocholine hydrolysis directly links to the color change rate of the reaction mixture and can be accurately measured at 412 nm wavelength (wavelength of the substituted benzene ring absorption light) by a calibrated photometer.

Although the Ellman method has proved to be more sensitive to exposures to extremely low dose nerve agents, the Michel method has significant advantages over the Ellman method for military use. Chief among these is that it requires fewer special reagents with less complex testing procedures. Additionally, although both methods can be applied to a variety of human biological matrices, e.g., red blood cells, serum, and plasma, the Ellman method is prone to be affected by the background colors. Therefore, the DoD decided to adopt the Michel method for the Cholinesterase Monitoring Program. The original Michel method takes about 60 minutes for the hydrolysis to complete. It was later improved by the scientists at the Army Edgewood Arsenal Biomedical Laboratory by markedly shortening reaction time to 17 minutes in 1973.[12] After extensive comparison studies and discussions, the DoD officially designated the 17-minute modified Michel method as the standard methodology for the Cholinesterase Monitoring Program in 1978.[13] The modified method greatly improved testing efficiency by enabling the laboratory to test up to 51 samples every 17 minutes and to shorten testing turnaround time to less than 72 hours.

Quality Management Issues of the DoD Cholinesterase Monitoring Program in Early Days

Rapid expansion also created challenges in quality control and quality assurance. In the early 1970s, the DoD started receiving alarming concerns over a lack of standardized operating procedures across the DoD Cholinesterase Monitoring Program.[14] Although all the testing laboratories used the Michel method, individual laboratories independently purchased their preferred equipment and sometimes even modified testing steps or reaction conditions without proper method validation or verification.[15] In addition, there were no standardized requirements or policies on blood sample collection, submission, and accession. Moreover, none of the cholinesterase testing laboratories under the DoD Cholinesterase Monitoring Program were accredited.[16] The variations in laboratory practices among the laboratories led to inconsistencies, which made it difficult for healthcare providers to interpret results. The inter-laboratory testing result variations at the time were so significant that it was almost impossible to conduct individual cholinesterase activity baseline establishment or long term intra-individual cholinesterase activity monitoring unless all the samples from the individual were tested at the same laboratory.[17] Moreover, even the testing results from the same laboratory were often inconsistent or irreproducible.[18] Another challenge was the absence of proficiency testing program and mandatory requirements to include internal Quality Control samples for each testing batch.[19] At the time, there was no commercial or government reference laboratory to prepare and supply reliable Quality Control materials.[20]

To combat the ‘chaotic’ situation, the DoD tasked the Army to establish a practical and effective program to establish and enforce standardized testing procedures, minimize inter-laboratory testing variations, and improve the overall testing result reliability.[21] In response, the Army Health Services Command started a pilot Quality Assurance program consisted of the cholinesterase testing laboratories at Fitzsimons Army Medical Center (FAMC), Dugway Proving Ground, and Tooele Army Depot in 1974 - 1975.[22] The program included: (a) daily quality assurance testing; (b) periodic proficiency testing; (c) blind batch quality control testing where feasible; and (d) retesting of duplicate samples shipped to FAMC.[23] To minimize systemic bias, the testing equipment across the three testing sites was identical. FAMC was responsible for providing standardized and mandatory training for all testing technicians at the three sites.[24] All reagents and equipment were verified and certified at FAMC prior to delivery to the other two sites.[25] The feedback and results were encouraging, and the Army quickly incorporated these quality management measures in the first official DoD cholinesterase testing regulation, Technical Bulletin (TB) MED 292 in May 1975.[26] The pilot Quality Assurance program later expanded to Rocky Mountain Arsenal in 1976.[27] In the same year, the Army further changed the requirement of testing blind quality control samples in each testing batch from optional to mandatory.[28] Followed by this policy change, the Army developed a practical way to monitor long-term and short-term quality control sample testing result trends. After extensive data review, internal and external inspections, and comparison, the Army selected FAMC as the DoD Cholinesterase Monitoring Program reference testing center in February 1976, and fiscal and manpower resources were gradually implemented through the rest of the year.[29] In 1977, the DoD Cholinesterase Reference Laboratory was officially established at FAMC and became fully functional.[30] The DoD Cholinesterase Reference Laboratory was tasked to: (a) prepare and send out freeze-dried blind quality control samples at least at two (low and high) concentration levels; (b) conduct limited primary cholinesterase activity testing; (c) re-test selected (no less than 20% of) primary testing samples previously tested at and submitted by other testing sites for verification; (d) prepare and provide quarterly proficiency testing samples; (e) provide standardized and centralized training and certification for all testing personnel under the DoD Cholinesterase Monitoring Program. This included initial and annual refresh training; (f) purchase, verify, certify, maintain, and repair major testing equipment used at all testing sites in order to ensure all major equipment was identical and interchangeable among different testing sites; and (g) provide technical support and troubleshooting to other testing laboratories. These efforts greatly improved the DoD Cholinesterase Monitoring Program testing reliability and significantly reduced inter-laboratory testing variations.[31] Consequently, the DoD was able to utilize the large amount of data collected all over the country to establish a general human cholinesterase activity baseline for government employees.[32] Ideally, the individual cholinesterase activity baseline is recommended to be used for every patient due to natural inter- and intra-individual cholinesterase activity variations. However, in reality, cholinesterase activity testing has not been readily available for general population or even all military members. Thus, individual baselines of most people are unknown and it is not economically feasible to include everyone in the long-term monitoring program. As a result, a reliable population-based cholinesterase activity normal range becomes crucial for quick, massive, and early screening for chemical nerve agent-induced acute poisoning for force protection.

Current Operations of the DoD Cholinesterase Reference Laboratory and Cholinesterase Monitoring Program

Under the Base Realignment and Closure Commission's recommendations, the DoD Cholinesterase Reference Laboratory was reassigned to the Directorate of Laboratory Sciences and relocated to the U.S. Army Center for Health Promotion and Preventative Medicine (USACHPPM) at Aberdeen Proving Ground in 1996.[33] In 2008, the DoD Cholinesterase Reference Laboratory moved down to the USACHPPM-South at Fort Sam Houston due to the reorganization of the DoD preventive medicine assets. The USACHPPM-South later became Public Health Command Region-South, which eventually was redesignated as Public Health Command, West (PHC, W) as of October 2023.

Currently, the DoD Cholinesterase Reference Laboratory is under the DoD Food Analysis and Diagnostic Laboratory, PHC, W located at Joint Base San Antonio-Fort Sam Houston. The DoD Cholinesterase Monitoring Program routinely conducts clinical testing and occupational health monitoring for not only federal, state, and local government employees in chemical weapon storage and demilitarization under the Chemical Surety Program, but also government contractors, national research laboratories, certain private sector employees, and local general population in agricultural industries with potential danger of exposure to organophosphate and carbamate pesticides.

In order to maintain high testing reliability, all testing laboratories under the DoD Cholinesterase Monitoring Program have been operated in accordance with updated regulations, e.g., TB MED 590 and DA PAM 40-8.[34, 35] The DoD Cholinesterase Reference Laboratory has been under extensive audits and accredited under the DoD Clinical Laboratory Improvement Program (CLIP) since the early 1990s. Recently, although COVID-19 pandemic caused operational difficulties, the DoD Cholinesterase Reference Laboratory underwent its first ISO 15189:2012 and CLIP combined assessment through the American Association for Laboratory Accreditation (A2LA) and successfully earned dual accreditation in April 2021. Dual accreditation of the laboratory was later re-verified in Summer 2023 and is currently in transition to ISO 15189:2022/CLIP.

Since the U.S. military accelerated chemical weapon demilitarization in the 2000s, many nerve agent storage and destruction sites have been consolidated or closed. This has resulted in a rapid decrease in the number of cholinesterase activity testing sites and human blood specimens processed over the past two decades. In July 2023, the DoD announced the destruction of all U.S. chemical weapons stockpile was completed ahead of the Chemical Weapons Convention elimination deadline.[36] Currently, there are only 7 federal government-owned cholinesterase activity testing sites, including the DoD Cholinesterase Reference Laboratory, for periodically monitoring a population of slightly more than 3,000 people. In comparison, there were still 12 DoD cholinesterase activity testing sites inside the CONUS alone in support of over 25,000 personnel in 2009. Although the reduction in testing sites and samples was logical for economic purposes, it has nevertheless created a potential capability gap in the military protection and sustainment war fighting functions against chemical weapons.

The DoD Cholinesterase Monitoring Program in Future

While the DoD Cholinesterase Monitoring Program and the DoD Cholinesterase Reference Laboratory have downsized with demilitarization of the U.S. chemical weapon stockpiles coming to an end, recent use of chemical nerve agents in terrorist attack in Japan, the Syrian civil war in the Mideast, political assassinations in the U.K. and Malaysia,[37, 38] and current rapidly changing geopolitical situations that may result in peer or near-peer large scale combat operations (LSCO) involving potential enemy use of lethal chemical nerve agents have made us seriously rethink the value and future of the DoD Cholinesterase Monitoring Program in force and general population protection.

As the world's biggest chemical weapon developer and maintainer, Russia (including former USSR) has kept synthesizing, testing, weaponizing, and stockpiling highly toxic nerve agents after it signed the Chemical Weapons Convention in 1993. It has been reported that Russia even secretly used the Western financial aid for chemical weapon destruction in the development of the 4th generation nerve agents, the A-series agents, or ‘Novichoks’ (literal meaning ‘newcomers’) between 1971 and at least up to mid-1990s.[39] Novichok agents were designed to significantly enhance lethality in the field environment in comparison to the traditional G- and V-series agents. As a group, Novichoks possess highly modified substituent patterns while sharing some structural similarities to legitimate organophosphorus pesticides in order to cheat the United Nations and Chemical Weapons Convention inspections that follow molecular fragments. Novichoks have also posed remarkable challenges to chemical analysis and clinical testing communities. Even until today, exact structures and toxicological properties of many Novichok agents remain unknown. The lack of detailed structural elucidation information has created formidable obstacles in developing practical testing panels with modern highly specific technologies, e.g., mass spectrometry for Novichoks induced poisoning detection, identification, and surveillance.[40] Due to the nature of mass spectrometry-based analytical methods, if the target is not on the testing panel, the instrument will most likely miss it. In addition, detecting human metabolites of chemical warfare nerve agents in blood or urine often cannot, in theory provide necessary confirmatory evidence to identify specific nerve agents, since some of them share identical primary or secondary metabolites. This limitation has created noteworthy challenges in forensic, clinical, and toxicology communities. Moreover, mass spectrometry-based methods usually require sophisticatedly designed extraction procedures to minimize matrix effects or interferences.[41] Subsequently, extraction often leads to low instrument responses caused by poor recoveries in addition to difficulty in ionization of certain nerve agent metabolites. In contrast to mass spectrometry methods, the method that the DoD Cholinesterase Monitoring Program currently uses is a broad-spectrum, easy to operate, fast turnaround, and highly cost-effective technology that can readily be applied in the field environment. Instead of chasing specific molecular fragment ‘fingerprints’, the method sensitively and quantitatively measures the affected biological effects caused by cholinesterase inhibiting substances. As a result, knowing chemical structures of the analytes is no longer a prerequisite for testing capability. Due to the unique advantages, the DoD Cholinesterase Monitoring Program has served as a powerful and indispensable tool for screening human potential exposure to cholinesterase inhibiting substances for decades and proved its critical and long-lasting value in future civilian and military applications. ■

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DEPTHS OF DPRK UNDERGROUND NUCLEAR EXPLOSIONS:

Making predictions using Monte Carlo simulations with Bayesian data synthesis

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Introduction

The Democratic People's Republic of Korea (DPRK) conducted six nuclear tests at the Punggye-ri nuclear test site. These tests were conducted in 2006, 2009, 2013, two in 2016, and one in 2017.[1] These tests will be referred to as tests 1-6 chronologically. Information surrounding these tests is limited due to the denied access of the Punggye-ri nuclear test site and the DPRK's lack of reporting. Previous work has reported absolute yield estimations for these tests via extensive seismological data collection and analysis.[2] In this work, "absolute" refers to a non-probabilistic result such as an exact explosive yield or precise location and depth of burst. Similarly, absolute locations of test epicenters have been determined by combining remote sensing techniques such as Interferometric Synthetic aperture radar (InSAR) with precise relative locations (+/- 100 meters) determined by differential seismic arrival time analysis.[3] This estimate was conducted a year after the final test and took a large collective effort to obtain all seismic and InSAR data.

All DPRK tests have been subterranean. The underground test facilitates uncertainty from the international community to determine aspects of the DPRK nuclear weapon technology. The international community has difficulty estimating yield, location, and depth of burst rapidly because of the nature of remote sensing and a lack of a centralized seismic database.[4,5,6] Depth of burst estimations have generally been conducted using analysis of the prior reported absolute locations in tandem with seismic data.[7]

This paper will use methodologies refined by Duncan in his 2021 article, "Predicting depths of burst at denied access sites using Bayesian data synthesis," to determine probabilistic estimates for yield and location utilizing Monte Carlo simulations and seismic data for the DPRK sites located in Waveforms From Nuclear Explosions (WFNE). Bayesian data synthesis will be conducted to improve the precision of the depth of burst estimation for each test utilizing terrain analysis and yield.

Methods

The first step in our methods is to gather seismic data, this is done through access to the WFNE dataset. Users must create an account for the WFNE repository, and then search for the desired test. From the WFNE dataset, you can download the seismic information from each test and sort the body wave magnitude, wave type, and arrival times. From this seismic data, we use the wave data to generate yield and location estimations through Monte Carlo simulations and Bayesian analysis. A Monte Carlo simulation is a method to predict a set of outcomes using a range of possible values for the input parameters. In this work, we use known ranges of values for the geological input variables to predict the what the equations for yield and depth of burst would yield if the DPRK specific constants were known.

Using topographical analysis of the location and depth of burst estimation derived from yield, we can combine our results through Bayes' theorem to arrive at a final depth of burst probability density estimate.[8] Test 1's data from WFNE was not available for analysis. Figure 1 demonstrates a general flow of our methods to arrive at a final analysis of depth of burst.

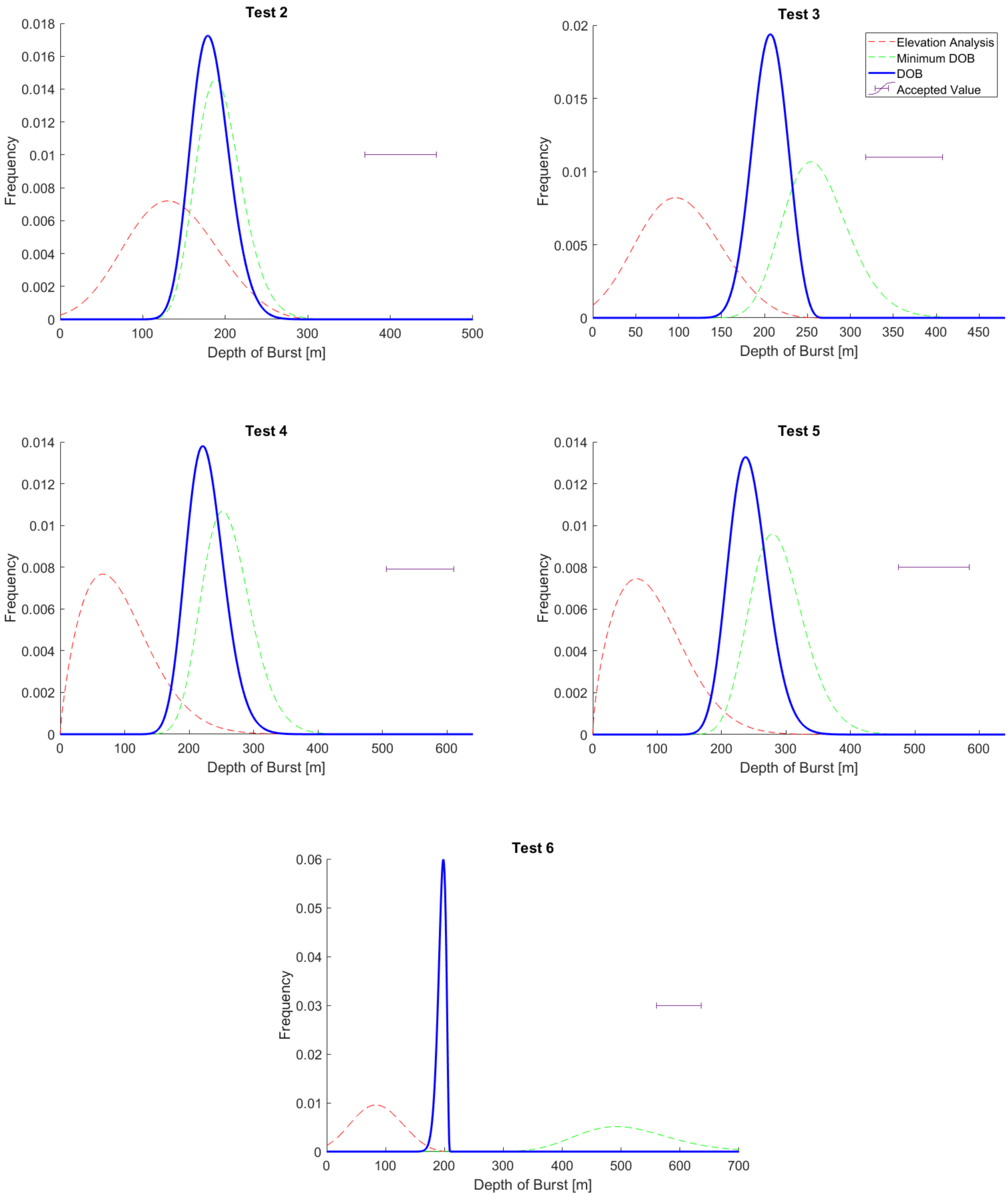

FIGURE 1. The process to estimate yield, location, and depth of burst of an underground explosion (Author Produced Figure).

Yield estimation

From WFNE, we obtain the seismic data for the DPRK tests. The seismic data includes arrival time, amplitude, and wave type from each station. Utilizing the body wave magnitude, of an explosion's seismic data, the yield can be estimated via Equation 1.[9, 10, 11, 12] Where A and B are both geological constants specific to the testing and seismic station sites.

$$Y = 10^{\frac{M_b - A}{B}} \quad (1)$$

Each seismic sensor will generate slightly different values for the body wave magnitude. Using a Monte Carlo simulation, we estimate yield using Equation 1 where we randomly select a body wave magnitude from the WFNE dataset.

The denied access to the DPRK test site results in an inability to provide accurate geological constants, A and B from Equation 1. For the Monte Carlo simulation, we utilize a uniform probability distribution for constants A and B. For both constants, the range used was based on the geological constants for the Nevada Test Site of the United States and the Semipalatinsk test site of the Soviet Union.[13, 14, 15]

100,000 iterations of the Monte Carlo simulation were run utilizing the programing language MATLAB to estimate yield according to Equation 1 to ensure proper randomization. Each iteration of the yield estimate was fit to a histogram of 100 bins. The best-fit curve was selected from MATLAB's 17 native distributions via the akaike information criteria (AIC) in combination with MATLAB's maximum likelihood estimation function using fitmethis version 1.6.1.[16] MATLAB's maximum likelihood estimation function determines the parameters for a probability density function (PDF) that fits the yield histogram. Once this is done for 17 different distribution types, we select the PDF that fits the histogram the best according to the AIC. We utilized MATLAB, but this methodology can be recreated using the Python package SciPy's "norm" function, without requiring proprietary software.

To determine the minimum depth of burst at which a device could be detonated and remain contained, an equation was developed by the Joint Soviet-American Experiment on Verification program (Equation 2).[17, 18]

$$Minimum\ Depth\ of\ Burst\ [m] = C * Y^{\frac{1}{\alpha}} \quad (2)$$

Where Y is the explosive yield in kilotons, C is a proportionality constant, and α is a scaling parameter.

Similar to yield estimations, we used a Monte Carlo simulation using MATLAB to generate a probabilistic distribution for the minimum depth of burst utilizing Equation 2. The simulation was run for 100,000 iterations and used the probabilistic results generated from the Monte Carlo simulation for yield to estimate the minimum depth of burst. Constant C is dependent on the geology of the test site and again due to the lack of site access, must be estimated. For C, the estimate was based on values given in the case of a deep blast with no visible surface deformation generated for the Nevada Test Site and the Semipalatinsk Test Site.[19]

The United States defined the scaling parameter α as 3, and the Soviet Union defined the parameter as 3.4 based on different containment objectives.[20,21,22] No other constraints or assumptions were integrated into the simulation.

Location estimation

Shown in Figure 1, we use the seismic arrival times from the WFNE repository to estimate an underground explosion's location. Within the WFNE dataset, we extract the wave type, wave arrival time, and station location and use this data as input for Bayesian Seismic Locator (Bayesloc). This program utilizes Markov Chain Monte Carlo (MCMC) simulations with travel time corrections to generate a location distribution as an output. This output is a point location with standard deviations in the cardinal directions.[23]

Elevation depth of burst estimation

As shown in Figure 1, we leverage the location estimation to generate a range of possible depth of bursts through topographical analysis of each test region. Utilizing the latitude and longitude generated from Bayesloc, we define a rectangular box whose center coincides with the center of the predicted test locations and whose height and width are taken to be 2.5 standard deviations away from the origin.[24] Elevation data with 30 m spatial resolution within the boxed test location was obtained from the United States Geological Survey (USGS).[25, 26, 27]

We define a 2-D matrix containing the possible depths for each longitude and latitude as:

$$PD(x, y) = Surface\ Elevation(x, y) - Minimum\ Elevation \quad (3)$$

Where x and y represent the longitude and latitude of the predicted region, *Surface Elevation* is a similar 2-D matrix generated from the USGS data, *Minimum*

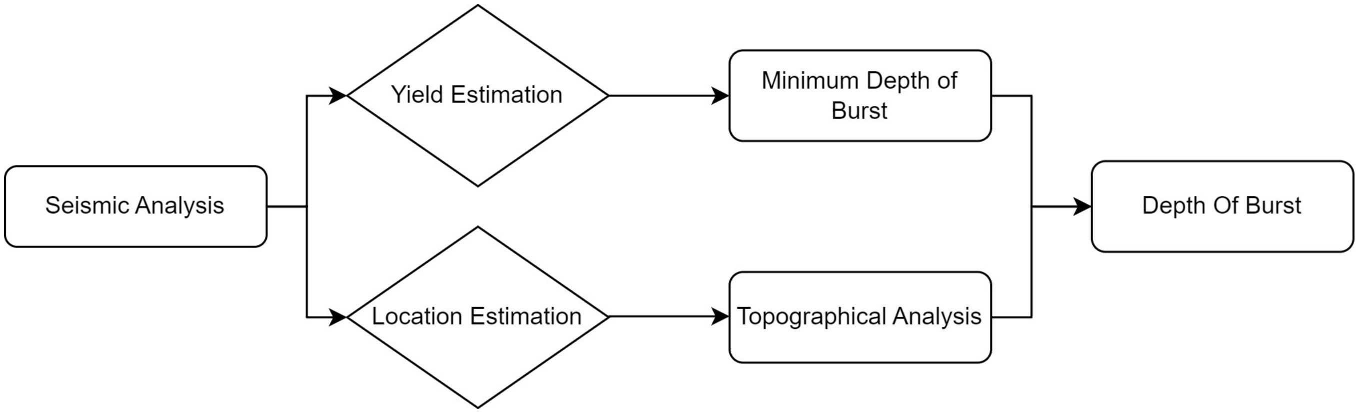

FIGURE 2. Bayesian synthesis for depth of burst for tests 2-6 with accepted depth of burst estimations (Author Produced).

Elevation is the lowest depth of each boxed region,[28] and PD (Equation 3) is a matrix of possible depths at which the explosion could have taken place.

Equation 3 assumes that within each bounded region, the minimum elevation is roughly in line with the water table of that region. For this reason, it is assumed that the test would not be conducted below the water table due to the difficulties in tunnel construction and nuclear explosion testing environment. WFNE and these simple estimation methods can provide accurate, rapid, location estimations for underground explosions within a reasonable error.

Results

Depth of burst

Figure 2 shows the results of the final depth of burst estimations using Bayesian analysis with elevation and the minimum depth of burst. The improved depths of burst are shown with the solid blue line. The current values estimated for these tests are shown by the horizontal bar. Compared to other methodologies for depth of burst which generate uniform distributions, our methodology generates probabilistic distributions.[29]

The similar depths and yields for tests 2-5 were very consistent in both their depths of burst as well as their yields. Test 6 is unique in that the elevation of its placement follows the same range as the previous 4 tests, but the yield is substantially larger. The estimates for depth are all more shallow than previous estimates, which were determined by estimating the overburden necessary to generate the surface deformations recorded by InSAR.[30] For this reason, it appears that test 6 was placed similarly to the previous tests through a horizontal tunnel,[31] but the yield was larger than the DPRK may have expected.

The sudden jump in explosive yield raises concerns over the potential successful detonation of a two-stage thermonuclear device by the DPRK. It is possible that the previous tests were attempts at a two-stage detonation, but without successful fission stages. Test 6, having been emplaced similarly to previous tests and with a drastically enhanced yield, may have been a successful fission explosion generated by a two-stage device.

Conclusions

Using methodologies validated against the United States and Soviet Nuclear Test programs.[32] We were able to determine the possible depth of bursts for the DPRK nuclear tests. This methodology used in combination with WFNE seismic data was able to generate similar signatures for DPRK tests 2-5, indicating likely successful contained fission explosions. However, test 6 has an unusual yield when compared to the previous tests, nearly an order of 10 larger, while still being placed in a similar location and depth. This can be explained by a possible successful two-stage nuclear explosion design. ■

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Lt. Col. Nickolas Duncan

has chosen to withhold biographical information.

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APPENDIX A

Data and Software Availability

Source data

Source data used in this study is taken from the Waveforms From Nuclear Explosions website available at https://www.wfne.info/. The data taken from here was from the region of Korea, DPRK with the date range of 2006-2017. All the data available via WFNE are from open and publicly released sources. All the IMS data contained in this version of the WFNE are from open IMS stations and can be freely accessed and processed by approved users.

A range of options are provided for accessing/downloading these data resources including menu-based and map-based alternatives. For a complete description of the WFNE data resources and access tools, the WFNE User Manual provides an orientation and guide including a summary of what data are available, functionality of various web-based access and display options, and step-by-step examples for several typical WFNE data queries.

Some features of the WFNE website are still being developed or supplemented.

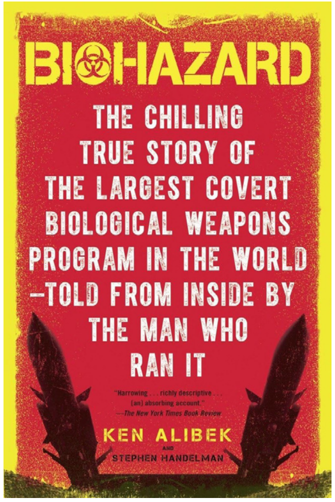
Data information

The WFNE database provides seismic data from the six DPRK nuclear test events. WNFE provides four main components in its data for each event, the descriptions for each of the calculated data files, the calculated data files themselves, the raw waveforms in SAC file format, and the instrument response functions for each station. In this work only the calculated data files were used. These files were generated by WFNE conducting their own analysis on the raw waveforms as well as pulling results from already existing sources. For each test, our methods used to determine the depth of burst were identical, however the number of stations used for WFNEs calculations were variable.

Test 2 used data from 37 stations, Test 3 used 84 stations, Test 4 used 80 stations, Test 5 used 90 stations, and Test 6 used 126 stations.

Software

Archived source code at time of publication:
https://zenodo.org/record/8321978



BOOK REVIEW

BIOHAZARD

The Chilling True Story of the Largest Covert Biological Weapons Program in the World – Told from Inside by the Man Who Ran It

By Ken Alibek and Stephen Handelman

BRICE JOHNSON

An international traveler becomes violently ill from what is initially believed to be flu-like symptoms. Within days, other passengers on the same conveyance become ill and seek medical attention. Several succumb to the illness and die. Soon the illness becomes a world-wide pandemic. The pandemic devastates national and international commerce and economies while challenging nation states as they attempt to protect citizens. The situation is further exacerbated by the fact the pathogen triggering this event is new and of unknown origins. Initially attributed to an unsanitary marketplace, it may have been the result of or human engineering. The medical community works diligently to isolate the pathogen, develops vaccines, and begins inoculation but millions die as the surviving world population gradually begins to develop a natural immunity.

How would the global community address an issue such as this and what could be done to prevent a similar event in the future? To prohibit the development, production, and stockpiling of biological and toxin weapons, in 1972 the United Nations established the Biological Weapons Convention (BWC).[1] The BWC was the first multilateral disarmament treaty that banned this category of weapons of mass destruction. The United States and Russia, then the Soviet Union, ratified the resolution in 1975.[2] China acceded into the BWC in 1984. Today, the BWC includes 183 states.[3]

The BWC, seemingly, would make the thought of developing, maintaining, weaponizing and developing delivery systems for biowarfare agents collectively unthinkable. With America's adversaries bound by this agreement, the threat of biological weapons was greatly reduced. The BWC attempts to diminish the danger that bioweapons present to the world. However, could a state signatory of the BWC continue to research, develop, and create biological weapons? The Book BIOHAZARD, The Chilling True Story of the Largest Covert Biological Weapons Program in the World – Told from Inside by the Man Who Ran It,[4] answers this question with a resounding, frightening, and unequivocal "YES!"

"...biological agents... are almost impossible to detect, which complicates the task of tracing the author of a biological attack. This makes them as suitable for terrorism and crime as for strategic warfare."

- Ken Alibek p.176

After serving as First Deputy Chief of the Soviet Bio-Preparat, the covert Soviet agency responsible for development and production of biological warfare weapons, Dr. Ken Alibek defected to the United States of America in 1992. Upon arriving in the United States, he was alarmed by the level of the western world's ignorance concerning biological weapons. Inspired by his exposure to Soviet biological weapons production and his concern about western misperceptions of this very real threat, Dr. Alibek teamed with Steven Handelman and wrote *BIOHAZARD, The Chilling True Story of the Largest Covert*

Biological Weapons Program in the World – Told from Inside by the Man Who Ran It, a non-fiction book published in 2000. Although the book is not new, recent epidemic events and the rapid spread of inexpensive, dual-use, easy to make, easy to use, and difficult to attribute bioweapons technology make the examination of this subject matter more relevant than ever.

In 21 chapters, spread across approximately 300 pages and including two appendices describing the structure and composition of the Soviet Biological Warfare System, Dr. Alibek provides a compelling and intriguing look at the former Soviet Union's deliberate clandestine program to develop the capacity and capability to deliver biological weapons of mass destruction. Even more riveting is that the Soviets were successful in producing agents with enough quantity and stability to make employment using intercontinental missiles as a delivery mechanism achievable!

As the organizational leader and the Soviet's subject matter expert in all aspects of bioweapons development including selection, acquisition, characterization, weaponization, production, and delivery configuration of biological agents including anthrax, plague, tularemia, smallpox, and Marburg, Dr. Alibek provides a detailed and sobering first-hand account of deliberate and massive violations of the Biological Weapons Convention. His account provides a level of verisimilitude to the frailty, insufficiency, and ambiguities inherent to treaties.

For individuals interested in the inner workings of the former Soviet Union's communist bureaucracy, Dr. Alibek provides a behind-the-curtain look at the Soviet state security apparatus as he describes his intricate navigation of a system rife with overlapping layers of control, enforcement, and distrust. For individuals involved in the design, development, and monitoring of international treaties and conventions, Dr. Alibek's participation in the development of plans and actions to deliberately cover up, deceive, and provide misinformation while hosting inspection visits of representatives from the United States and Great Britain participating in tri-lateral visits to suspected Soviet Biowarfare production facilities will be a great value.

Biohazard is both fascinating and enthralling and a 'must read' for all members of the CWMD enterprise as it addresses subject matter directly related to a very real and constantly evolving threat. I recommend "Biohazard" to all readers with additional emphasis for professionals involved in biological warfare strategy. While some knowledge of biology and disease agents might be useful in better understanding the development and production processes outlined in the book, specialized knowledge in not necessary to appreciate the scale and detail of clandestine Soviet biological weapons development and production. ▪

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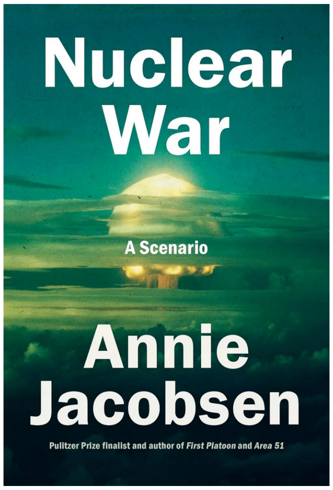

BOOK REVIEW

NUCLEAR WAR
A Scenario

By Annie Jacobsen

ROHIN SHARMA

In her book, *Nuclear War: A Scenario*,[1] national security writer Annie Jacobsen has produced a well written albeit flawed overview of a potential world ending nuclear conflict. Capitalizing on the post Oppenheimer interest in nuclear war, her book is already a New York Times bestseller, with the rights being sold for a possible movie. For those in the nuclear weapons field as well as the general public, I would recommend the book, however, it should be read more as a work of fiction and not a realistic scenario.

Summary

The book is a 72-minute overview of a nuclear strike scenario, starting from a missile launch and ending in a mass nuclear extinction event. The scenario starts with a "bolt out of the blue" North Korean Intercontinental Ballistic Missile (ICBM) strike against Washington DC (there is no reason given for the attack). The strike triggers a series of events, to include radar detection, alert of national command authority, and attempted interception of by ground based mid-course missile defense (GMD) from Fort Greeley Alaska.

When the GMD fails to intercept the North Korean ICBM, the "fog of war" sets in. The U.S. President is grasping at potential response options, while he simultaneously must evacuate himself and his family from Washington. The President is unable to communicate with subordinate commands or other world leaders. Adding more confusion, a second missile from a submarine is detected, heading towards California.

From there, a parade of worst-case scenarios occurs, exacerbating the mass confusion. North Korea launches a Submarine Launched Ballistic Missile (SLBM) at the Diablo Canyon Nuclear Plant in California. North Korea also launches a VX attack against South Korea and an Electromagnetic Pulse (EMP) against the continental U.S. In response, the President launches multiple ICBM attacks against North Korea, with the intent to destroy the Kim regime. In their confusion, Russia believes that the U.S. is launching a nuclear strike against them and immediately launches a strike against the U.S. This in turn forces the U.S. to launch its nuclear weapons against Russia. The scenario concludes 72 minutes after the initial launch with the impact of 1,000 Russian nuclear warheads striking the continental U.S. The remainder of the book discusses the aftermath of the strike and the subsequent nuclear winter that impacts Earth for the next 24,000 years.

The Good

As mentioned, the book is well written, covering issues of nuclear command and control, missile defense, and continuity of government in a way the layman can understand. She weaves in historical anecdotes and explainers that further simplify the issues related to nuclear weapons policy. She also contributes to the "launch on warning" (more accurately labeled "launch under attack") debate that should be considered more broadly by the U.S. public.

The Bad

Many parts of her "scenario" are unrealistic and are scripted to build the end state of a world ending mass nuclear exchange. First, her "bolt out of the blue" North Korean ICBM with no previous escalation or warning is unlikely to happen. The no warning strike contributes to the "fog of war," and the subsequent cascading effects, however this strike is bordering on absurd.

Furthermore, her description of missile defense failures as well as a North Korean SLBM strike are equally unrealistic. A closer read of the book shows that she relies on Dr. Theodore Postal, an MIT professor and defense analyst for much of her analysis. While Dr. Postol has some impressive credentials, he has recently espoused crackpot theories to include:

- Chemical attacks in Syria were launched by the rebels and not the regime.
- The Israeli Iron Dome system is almost ineffective.
- North Korean ICBM designs were essentially the same missiles as Russian ICBMs.

Therefore, his scenario of zero interceptions of a North Korean ICBM as well as North Korean SLBM capabilities should be taken with a grain of salt.

Finally, and most importantly, Jacobsen does not cover the range of options a U.S. President would have in response to a North Korean nuclear strike. In her scenario, the U.S. immediately launches its land-based ICBMs against North Korea, which triggers Russia to launch its massive attack against the U.S. In reality, the U.S. President would have a range of options against Pyongyang, from conventional strikes, to theater based nuclear weapons, to submarine launched ballistic missiles. All of these can be done at a time and place of the presidents choosing, obviating the time clock that is the cornerstone of the scenario. None of these scenarios would likely trigger an immediate massive nuclear strike by our adversaries, as outlined by Jacobsen.

The Ugly

There is one scene that strikes out as me as somewhat offensive. In her historical summary she describes a 1960 planning meeting at Strategic Air Command (SAC) discussing the Single Integrated Operational Plan (SIOP). In the event of nuclear war, the SIOP called for a massive retaliation against all the major cities in Russia and China, resulting in over 600 million deaths. One might argue that this plan represented overkill, targeted too many civilians, bordered on immoral, and was divorced from overall political objectives.

However, Jacobsen takes this a step too far, comparing the SAC planners to the perpetrators of the Holocaust. She goes into specific detail arguing that those that designed the SIOP are like the "German bureaucrats [who} swiftly agreed on a program to exterminate every last Jew they could find anywhere in Europe, using methods of mass extermination more technically efficient than vans filled with exhaust gasses, the mass shootings, or incineration in barns and synagogues uses until then." You can say a lot about General Curtis LeMay, General Thomas Powers etc., but comparing them to senior Nazi leaders strikes me as unseemly.

As I mentioned earlier, I would recommend this book. It is relatively quick read (I read it at Barnes and Nobles in an afternoon), decently written, and covers nuclear weapons policy well enough for the laymen to understand. However, it should be read more as a work of fiction than an actual scenario that could take place. ■

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is currently a policy analyst and strategist at the U.S. Army CWMD and Nuclear Agency as well as an adjunct professor at Georgetown University. He holds a M.A. in Security Studies from Georgetown and a B.A. from Johns Hopkins University. He held previous intelligence positions at the Department of the Army, Defense Threat Reduction Agency, and Department of Homeland Security. He is a former Army officer and combat veteran of OPERATION IRAQI FREEDOM and OPERATION ENDURING FREEDOM.

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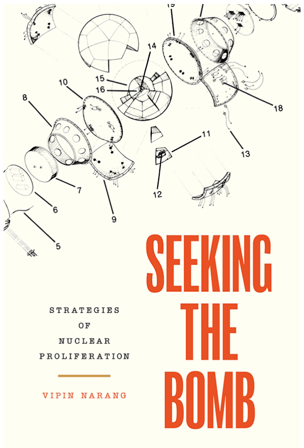

BOOK REVIEW

SEEKING THE BOMB

Strategies of Nuclear Proliferation

By Vipin Narang

MAJ. JOE ATWELL

In *Seeking the Bomb*, Vipin Narang sets out to do three things: identify the ways a state may pursue a nuclear capability, demonstrate the effectiveness of the Proliferation Strategy Theory (PST) framework, and show the impacts of different proliferation strategies. Narang's purpose for the book is to address a gap in proliferation scholarship. According to Narang, prior proliferation scholarship has focused on "why" states choose to pursue a nuclear weapon, ignoring "how" a state acquires a nuclear arsenal. Overall, Narang makes a compelling argument for PST, highlighting where it has successfully predicted a state's proliferation strategy and where it has failed.

The book opens with a discussion on the need to identify "how" states attempt proliferation to develop weapons. Narang identifies four major proliferation strategies: hedging, sprinting, sheltered pursuit, and hiding.[1] Following this introduction, Narang dedicates a chapter to explaining PST, how it is different from the existing theories, and why it is necessary for non-proliferation and counter-proliferation efforts. PST includes three groups of variables a state must consider before pursuing proliferation: security, domestic politics, and current non-proliferation efforts.[2] The chapter also discusses the limitations of the existing theories. His chapter explaining PST is well-written and if readers only read this section, they would be able to comprehend Narang's theory and have a basic understanding of the different proliferation strategies. This chapter does an excellent job laying a foundation for the rest of the book, which includes detailed discussion of the different proliferation strategies and the impacts to non-proliferation and counter-proliferation efforts.

The first strategy Narang delves into is the three types of hedging (technical, insurance, and hard) strategies. Narang describes hedging as taking deliberate steps to shorten the time to develop a nuclear weapon but stopping short of doing so.[3] In this chapter he goes into detail on what differentiates the forms of hedging. It highlights how allies (Japan and Germany) used or are using insurance hedging to maintain US security commitments. Narang also discusses how Argentina and Brazil used technical hedging against each other. The case studies on hard hedging do a good job of showing how even traditionally neutral states (Sweden and Switzerland) have considered pursuing nuclear weapons. However, the highlight of this chapter is the discussion on India which does an excellent job illustrating that a state's proliferation strategy may change given new domestic and/or geo-political circumstances.

The second proliferation strategy addressed in detail is sprinting. Narang defines sprinting as openly seeking and developing a nuclear weapon capability as fast as possible.[4] He highlights that the only states to successfully employ this strategy, from start to finish, are the Nuclear Weapons States authorized under the Non-Proliferation Treaty. The case study on France highlights how a "hedger" may perceive security guarantees as being insufficient, decide to develop its own nuclear weapons program, and then sprint to develop the capability. In the case study on China, Narang touches on how the decision to build a nuclear weapon is mostly a political decision. He does this by highlighting that China, during the Great Leap Forward, which was incredibly disruptive to society, developed a nuclear capability without foreign assistance. While sprinting is a successful strategy, it will probably not be available to most states in the future due to significant advances within intelligence communities and long-range military strike capabilities.

Sheltered Pursuit is the third strategy Narang discusses, using Israel, Pakistan, and North Korea as case studies. The chapter highlights how a proliferant state may take advantage of a unique relationship with a country, possibly due to geography (North Korea) or geo-political circumstances (Israel and Pakistan) to develop a nuclear capability. The point of this strategy is that a larger state already in possession of nuclear weapons can, under the right circumstances, be willing to look the other way and tolerate proliferation to achieve what may be perceived as more important and/or immediate policy objectives. A state using this strategy must recognize that there is only a small window of opportunity to develop a nuclear capability before its protector may deem the relationship less valuable. According to Narang, this strategy might be available to a few select states that have a special relationship with one or more of the current nuclear weapon states.

The last active pursuit strategy discussed is hiding and uses Iraq, Taiwan, and South Africa as case studies. According to Narang, the goal of a state taking this path is to hide its proliferation activities and present a *fait accompli* to the world with a credible claim or a demonstration of capability.[5] He acknowledges the only state to succeed on this path is South Africa, which abandoned its nuclear arsenal shortly after announcing its existence to the world. This method of proliferation is incredibly destabilizing and if the state is discovered prior to developing a nuclear weapon it will probably face economic sanctions, military intervention, or both. Narang identifies that any future "hiders" will already be members of the Nuclear Non-Proliferation Treaty (NPT) and will have to attempt to develop a nuclear capability while being signatories of the NPT. This may make it more difficult to identify hiders in the future.

Following the detailed discussions of the various proliferation strategies and the associated case studies, Narang lays out the impacts to global non-proliferation and counter-proliferation efforts. There is a heavy emphasis on influencing the "domestic political consensus" within proliferant states to either halt or turn-back their nuclear weapons program. He uses the Joint Comprehensive Plan of Action (JCPOA) as an example for how to halt a proliferator. Narang addresses the positives of the JCPOA which, from the data he had access to while writing, suggested that Iran had halted its nuclear weapons program. He highlights this point to show that the sanctions relief was increasing domestic support for moderate political figures who may have been amenable to abandoning a nuclear capability . According to Narang, influencing domestic politics is the best method for convincing a state to abandon proliferation.[6] He admits that this method does not immediately achieve the result of a completely surrendered nuclear weapons program but recognizes that the political leaders of the proliferant state will need to save face and giving concessions, such as sanctions relief, may build support for moderate factions that do not want a nuclear weapons program.

Overall, *Seeking the Bomb* is easy to understand and includes multiple case studies to support PST . It offers a novel framework for assessing how a state may approach nuclear proliferation, addressing a gap in the proliferation literature. Narang's sequencing of variables for PST is logical and results in a fairly accurate methodology, with an 85% success rate for predicting a state's proliferation strategy.[7] I recommend this book for policy analysts, non-proliferation, and counter-proliferation professionals. This book, published in 2022, was written before Narang assumed the Office of the Principal Deputy Assistant Secretary of Defense for Space Policy. It would be interesting to see if and how Narang would modify PST after holding this position. ■

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Notes

1. Vipin Narang, Seeking the Bomb: Strategies of Nuclear Proliferation (Princeton: Princeton University Press, 2022), 3.

2. Narang, *Seeking the Bomb,* 29.

3. Narang, *Seeking the Bomb*, 53.

4. Narang, *Seeking the Bomb*, 127.

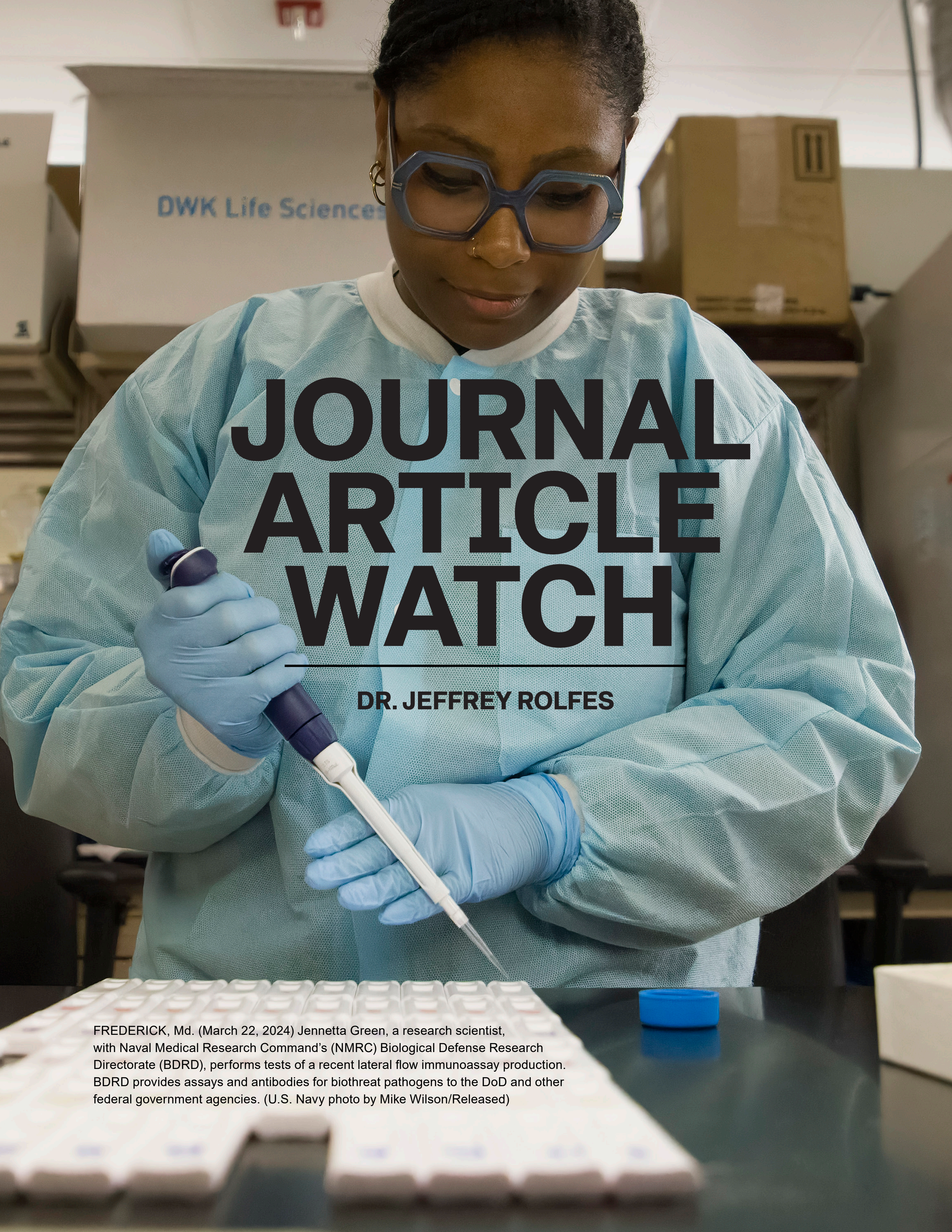
5. Narang, *Seeking the Bomb*, 24.

6. Narang, *Seeking the Bomb*, 339.

7. Narang, *Seeking the Bomb*, 345.

JOURNAL ARTICLE WATCH

DR. JEFFREY ROLFES



FREDERICK, Md. (March 22, 2024) Jennetta Green, a research scientist, with Naval Medical Research Command's (NMRC) Biological Defense Research Directorate (BDRD), performs tests of a recent lateral flow immunoassay production. BDRD provides assays and antibodies for biothreat pathogens to the DoD and other federal government agencies. (U.S. Navy photo by Mike Wilson/Released)

For this issue, the CWMD Journal Article Watch will focus on new research and technologies in the biological arena. Whether the topic is emerging diseases or novel treatments, the pace of new discoveries in this science is exponentially accelerating. Because of the breakneck speed of this inventive force, it is important to stay abreast of all the foundational paradigm shifts that are occurring. Read on for in-depth analysis of ongoing initiatives and thought-provoking pieces that explore the challenges and opportunities related to countering WMDs.

RECENT ADVANCES AND CHALLENGES: TRANSLATIONAL RESEARCH OF MINIMALLY INVASIVE WEARABLE BIOCHEMICAL SENSORS

Summary of research:

Wearable biosensors, which track critical biomarkers, hold great promise for enhancing treatment outcomes. However, the current market lacks widespread availability of wearable biochemical monitors, and many existing options are primarily focused on detecting physical parameters rather than comprehensive biomarker analysis. Despite progress in emerging minimally invasive wearable biochemical sensors (WBS), several challenges hinder their real-world implementation. In this review, the authors focus on studies that have assessed in vivo sensors at technology readiness level (TRL) 4. Their goal is to identify and understand the crucial technological factors and strategies necessary for the practical realization of wearable biosensors, characterized by transducers and target biofluids. Comparative analysis reveals that sensor performance is highly reliant on the design of the detection component. Aspects that affect analysis and operation of the sensor are the choice of bioreceptor, incorporation of nanomaterials, and surface area modifications, which can significantly impact sensitivity, linear range, and stability. While the in vitro sensor method is efficacious for examining biofluids, adapted standardization that relates sensor information to reference techniques is the most accurate technique for measuring biomarker concentrations.

Why it matters to CWMD:

Wearable biochemical sensors have gained significant attention due to their potential in personalized medicine and continuous monitoring of human health. As the materials science and mechanical engineering fields advance, wearable biochemical sensors have been developed to detect various biomarkers such as sweat, saliva, and tears, making them practical for monitoring soldier’s health on base and on the battlefield. Such tech could provide early warning of infections and inform commanders on the real-time health of individuals.

Reference:

Irfani R. Ausri, Yael Zilberman, Sarah Schneider, Xiaowu (Shirley) Tang, "Recent advances and challenges: Translational research of minimally invasive wearable biochemical sensors," *Biosensors and Bioelectronics: X*, 15 (December 2023): 100405, https://doi.org/10.1016/j.biosx.2023.100405.

PRECISION MEDICINE IN THE ERA OF MULTI-OMICS: CAN THE DATA TSUNAMI GUIDE RATIONAL TREATMENT DECISION?

Summary of research:

Precision medicine in cancer is swiftly advancing, embracing a holistic strategy that accounts for various facets of biological complexity to understand cancer progression mechanisms for individual patients. However, this strategy encounters difficulties because of the identification of numerous factors within each tumor. These varied factors make medical decision-making more complex, particularly when considering different treatment choices.

Medication responsiveness relies on the feasibility of specific objectives, their clonal or subclonal origin, and concurrent genomic changes. Recent sequencing endeavors have revealed a broad spectrum of influential factors arising during treatment inefficacy, which might serve as potential targets for clinical trials or drug adaptation. To efficiently prioritize treatments, ranking genomic modifications based on their established feasibility becomes crucial. Beyond primary influencers, the future of personalized medicine necessitates recognizing the spatial and temporal diversity inherent in cancer. Copious intricate biological data mandates leveraging artificial intelligence (AI) algorithms for comprehensive analysis.

Effective personalized medicine cases often rely on identifying core drivers and optimizing drug selection. Additionally, alterations in drug resistance and smaller-scale influential factors have emerged as promising therapeutic targets. Beyond individual contributors, advancing precision medicine necessitates acknowledging the complex spatial and temporal heterogeneity inherent in cancer. Integrating data from various sources provides valuable insights into functional targets and regulatory processes, which are essential for clinical applications. Furthermore, thorough data analysis sheds light on oncogenic mechanisms, enhancing our overall understanding of tumor biology and facilitating the development of comprehensive tumor models.

Why it matters to CWMD:

Precision medicine research not only benefits cancer patients but also informs drug development strategies to mitigate the effects of traditional and novel CBRN WMDs. By leveraging personalized approaches and cutting-edge technologies, the Army can enhance its ability to respond effectively to these complex threats. This field aligns with this multidimensional approach by customizing treatments based on genetic profiles and disease mechanisms.

Reference:

M. Aldea, L. Friboulet, S. Apcher, F. Jaulin, F. Mosele, T. Sourisseau, J.-C. Soria, S. Nikolaev, and F. André, "Precision medicine in the era of multi-omics: can the data tsunami guide rational treatment decision?" *ESMO open* 8, no.5 (October 2023): 101642, https://doi.org/10.1016/j.esmoop.2023.101642.

CONFLATING RACE AND ANCESTRY: TRACING DECISION POINTS ABOUT POPULATION DESCRIPTORS OVER THE PRECISION MEDICINE RESEARCH LIFE COURSE

Summary of research:

The utilization of race in genetic research has been a topic of uneven progress. However, previous research highlights challenges in mobilizing genetic concepts of difference due to broader contextual factors and racialization. These studies hold significant implications within the context of precision medicine research (PMR), which investigates how individual variations in genetics, environments, and behaviors relate to health outcomes. PMR faces a well-recognized deficiency in genomic diversity within biobanks and databases. Studies positioning racial diversity as inherent to their study sites underscore the challenge of moving beyond race and/or ethnicity in genomics research, which can only be resolved by confronting how beliefs about fundamental human differences have long been embedded in practices across the research life course.

Why it matters to CWMD:

Precision medicine research that accounts for racial diversity enhances our ability to respond effectively to CBRN WMDs. As the Army is more racially diverse that the general population, more data needs to be included into these data sets to properly understand the genetic factors that influence a patient's reported race. Another issue to consider is racial populations themselves have a variety of heterogeneity that may be racially different from person to person. Understanding those genetic variations within the population will give scientists and medicine professionals the knowledge to give the correct tailored treatment that is based on an individual's actual genetics and biochemistry, rather than that individual's perceived racial group.

Reference:

Michael Bentz, Aliya Saperstein, Stephanie M. Fullerton, Janet K. Shim, and Sandra Soo-Jin Lee, "Conflating race and ancestry: Tracing decision points about population descriptors over the precision medicine research life course" *Human Genetics and Genomics Advances* 5, no. 1 (September 2023): 100243, https://doi.org/10.1016/j.xhgg.2023.100243.

AN EMERGING HEALTH CRISIS IN TURKEY AND SYRIA AFTER THE EARTHQUAKE DISASTER ON 6 FEBRUARY 2023: RISK FACTORS, PREVENTION AND MANAGEMENT OF INFECTIOUS DISEASES

Summary of research:

On February 6, 2023, earthquakes struck both Turkey and Syria, causing significant structural harm to buildings and infrastructure in densely populated regions of Anatolia. Data collected in the field during this time indicated the existence of risk factors that could lead to the emergence of infectious diseases in the affected residential areas from the very onset of the emergency.

The simultaneous collapse of healthcare facilities, severe winter weather, destruction of critical infrastructure, overcrowding in emergency shelters, substandard sanitation, and adverse socio-economic conditions, compounded by ongoing crises (such as conflicts, pandemics, and epidemics), further worsened the already delicate public health situation. The devastation of local healthcare infrastructure, combined with inadequate emergency preparedness plans, impeded timely management and effective treatment of serious health issues. To address these risks, efficient disease surveillance at local and regional levels became essential for identifying infectious disease outbreaks and managing these crises promptly with medical treatment and supplies.

Why it matters to CWMD:

Natural disasters are apt analogues for WMD events, and the lessons learned from managing the treatment and recovery of people and infrastructure can be applied to similar catastrophic outcomes. Understanding the effects of earthquakes helps in designing resilient infrastructure that can withstand both natural disasters and potential WMD attacks. Earthquakes disrupt sanitation, water supply, and healthcare access; these disruptions mirror challenges faced during WMD incidents. Strengthening infrastructure resilience ensures continuity of essential services during emergencies. This type of recent research provides valuable insights into disaster management, infrastructure resilience, and public health.

Reference:

Maria Mavrouli, Spyridon Mavroulis, Efthymios Lekkas, and Athanassios Tsakris, "An Emerging Health Crisis in Turkey and Syria after the Earthquake Disaster on 6 February 2023: Risk Factors, Prevention and Management of Infectious Diseases ," *Healthcare* 11, no. 7 (April 2022): 1022), https://doi.org/10.3390/healthcare11071022.

EVALUATION OF ARTIFICIAL INTELLIGENCE TECHNIQUES IN DISEASE DIAGNOSIS AND PREDICTION

Summary of research:

Medical conclusions heavily depend on the analysis of images captured by high-tech medical equipment. The incorporation of artificial intelligence (AI) in the examination of medical imagery has led to automated and accurate assessments. As a result, the burden on doctors has lessened, diagnostic inaccuracies and response times have diminished, and the overall efficacy in forecasting and identifying various ailments has increased. Investigations into AI methodologies for medical image processing are pivotal, employing complex computer algorithms for prognosis, diagnosis, and treatment strategies. Machine Learning (ML) and Deep Learning (DL) are the main AI branches used for disease diagnosis, drug discovery, and pinpointing patient risk elements. The recent progress in digital health records and big data solutions have aided the effectiveness of ML and DL algorithms. ML includes neural networks and fuzzy logic algorithms, automating prediction and diagnostic procedures. DL algorithms, in contrast to conventional neural networks, do not depend on expert feature extraction. Their high-performance computations produce encouraging outcomes in medical image evaluation, encompassing fusion, segmentation, documentation, and categorization. Support Vector Machine (SVM) and Convolutional Neural Network (CNN) are the most utilized methods for disease examination and diagnosis. This review research looks at recent AI methodologies for diagnosing and predicting diseases like cancers, cardiac issues, pulmonary conditions, skin ailments, genetic abnormalities, and neurological disorders. These AI techniques exhibit superior accuracy compared to human experts, while also tackling obstacles and restrictions in the healthcare sector.

Why it matters to CWMD:

In the event of a WMD attack or outbreak, the healthcare system may be overwhelmed with many patients requiring medical attention. AI can assist in triaging patients, prioritizing critical cases, and managing resources efficiently during emergencies. During this event, physicians and radiologists may face fatigue or cognitive biases when interpreting medical images manually. AI systems, on the other hand, can process vast amounts of data without fatigue and provide consistent, objective assessments. By reducing human error, AI enhances the accuracy of WMD-related diagnoses and predictions. It is important to note, however, machine and deep learning techniques would struggle to initially process this information if these events were based on novel pathogens due to the lack of data that the system needs to accurately diagnose those pathogens.

Reference:

Nafiseh Ghaffar Nia, Erkan Kaplanoglu, and Ahab Nasab, "Evaluation of artificial intelligence techniques in disease diagnosis and prediction," *Discover Artificial Intelligence* 3, no. 5 (January 2023), https://doi.org/10.1007/s44163-023-00049-5.

A THREE-DIMENSIONAL LIQUID DIODE FOR SOFT, INTEGRATED PERMEABLE ELECTRONICS

Summary of research:

Scientists from Hong Kong have created wearable electronics that are lightweight, stretchable, and exhibit a remarkable 400-fold increase in sweat permeability. These innovative devices enable reliable long-term monitoring of biosignals for biomedical applications. Led by a team from CityUHK's Department of Biomedical Engineering (BME), the research team addressed a critical issue faced by wearable biomedical devices: maintaining stable signal quality over extended periods. Sweat accumulation and air permeability can affect the longevity of signal stability. To overcome this challenge, the team developed a structured material based on a nature-inspired three-dimensional liquid diode (3D LD) configuration that unidirectionally channels sweat away from the adhesion point between the skin and electronics. This novel approach allows for the spontaneous flow of liquids in a specific direction, ensuring seamless monitoring even under sweating conditions.

Why it matters to CWMD:

This new material will now allow for longer term cycles of physiological monitoring. Military uniforms and gear can be equipped with integrated, stretchable wearable electronics, enabling unobtrusive health monitoring for longer time periods and at higher levels of physical activity without compromising mobility or comfort. This new breathable electronic ensures that soldiers can focus on their mission without having to worry about the placement and discomfort of their biosensor.

Reference:

Binbin Zhang, Jiyu Li, Jingkun Zhou, Lung Chow, Guangyao Zhao, Ya Huang, Zhiqiang Ma, Qiang Zhang, Yawen Yang, Chun Ki Yiu, Jian Li, Fengjun Chun, Xingcan Huang, Yuyu Gao, Pengcheng Wu, Shengxin Jia, Hu Li, Dengfeng Li, Yiming Liu, Kuanming Yao, Rui Shi, Zhenlin Chen, Bee Luan Khoo, Weiqing Yang, Feng Wang, Zijian Zheng, Zuankai Wang, and Xinge Yu, "A three-dimensional liquid diode for soft, integrated permeable electronics," *Nature* 628, (2024): 84-92, https://doi.org/10.1038/s41586-024-07161-1.

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TO STRENGTHEN WMD DEFENSES, INCREASE PUBLIC RESILIENCE

LT. COL. NIZAMETTIN GUL

In an era of evolving security threats, the need to fortify America's defenses against Weapons of Mass Destruction (WMD) has never been more critical. Traditional approaches focus on intelligence, surveillance, and consequence management. Promoting public resilience stands as a pivotal and often overlooked component in enhancing the nation's capacity to withstand and counter WMD terrorism.

Currently, consequence management is a crucial aspect of WMD protection, but it falls short in mitigating long-term societal harm and undermining the appeal of mass-casualty WMD attacks to terrorists. Strengthening societal resilience to withstand the consequences of both minor and catastrophic WMD events could significantly enhance current counter-terrorism efforts against WMD-armed terrorists. Although consequence management and public resilience are interconnected, they are distinct and mutually reinforcing.

Public resilience starts at the grassroots level, empowering communities to be vigilant and proactive in identifying potential threats. Engaging citizens in educational programs fosters a collective sense of responsibility, turning communities into active partners in national security efforts. Thus, federal, state, and local governments should implement comprehensive public education campaigns to raise awareness about WMD threats, their potential consequences, and the importance of individual and community preparedness. Further, communities should involve residents in emergency response planning and training exercises to foster a sense of shared responsibility and resilience .

Conventional defense strategies typically emphasize physical structures and service continuity while neglecting human and social factors. The enhancement of societal resilience serves a dual purpose. First, by prioritizing public resilience, response efforts can focus on human and social factors rather than solely on physical structures and service continuity. A resilient public

OPPOSITE: Members of the Combat Readiness Training Center Fire Department, Harrison County Fire Department and Gulfport Fire Department render aid to simulated victims during a disaster exercise at Gulfport-Biloxi International Airport, Gulfport, Mississippi, March 28, 2024. Keesler students volunteered in the exercise, which simulated a mass casualty plane crash that required first responders and airport personnel to respond efficiently, render aid to patients and clear the scene. (U.S. Air Force photo by Airman 1st Class Kurstyn Canida)

RIGHT: Indian Head - U.S. Marines with Chemical Biological Incident Response Force (CBIRF) show the capabilities of CBIRF, along with a demonstration and practical application, to members of the Countering Weapons of Mass Destruction Graduate Research Fellowship Program at National Defense University (NDU), aboard Naval Support Facility Indian Head Annex Stump Neck, Md., on February 11, 2022. This exercise was conducted to provide educational support to NDU faculty and students about CBIRF and how we respond to any type of incident that we could get called to. (U.S. Marine Corps photo by Gunnery Sgt. Kristian S. Karsten/Released)

is less susceptible to the immediate shock and fear induced by WMD incidents, thereby reducing overall vulnerability. We can improve the public response in an attack by cultivating mental preparedness and imparting coping strategies. Second, a resilient society sends a powerful message to terrorists that the desired psychological response to WMD attacks may not be achievable. By showcasing an aware and prepared citizenry, we force would-be attackers to question whether they could achieve their desired ends through such an attack.

Implementing public resilience into counter-terrorism efforts may face challenges arising from the complexity of developing a model based on various types of actions (pre-WMD action, crisis actions) and roles of elements (public roles, leadership roles, etc.). However, through meticulous planning, training, and exercising programs, public resilience can be integrated into ongoing counter-terrorism efforts. Publicizing the involvement of citizens in exercises and actual disaster responses can promote public interest and participation in training programs. Given the hazardous-material aspects of WMDs, providing advanced training and equipment to news crews and role players are also essential.

Promoting public resilience must be acknowledged and pursued as a critical pillar in strengthening America's defense against weapons of mass destruction. By empowering communities, reducing vulnerability, and undermining the strategic appeal of WMD attacks, the nation can create a robust foundation for countering evolving security threats. The integration of public resilience with existing defense strategies not only prepares individuals for the unthinkable but also positions the United States to face the challenges of the future with a resilient and united front. As we navigate an uncertain world, fostering public resilience is not just a strategy; it is an investment in the collective strength of a nation. ■

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LETTER TO THE EDITOR

Dear Editor,

I've read your magazine for years and generally find it to contain decently written, germane articles on CWMD ideas, concepts, and developments relevant to the CWMD community of interest. However, a recent articles series postulating the Army officer corps is at risk due to a lack of educational foundations in Science, Technology, Engineering and Mathematics (STEM) caused me to take great umbrage because the article was written by a small group of STEM officers with the apparent purpose of promoting their own biases and interests.

Briefly, the gist of these articles is that STEM foundations are systemically under-represented in pre- and post- commissioning education and professional military education. STEM officers are more suited to understand the changing dynamics of the battlefield, superior integrators of new science and technology, better at dealing with ambiguity, cheaper and easier to convey complex technical data to, and most disturbing, faster and better at decision making than non-STEM officers. The articles also posit that the Army needs more STEM education, more STEM officers, and more STEM emphasis to remain viable in the face of a rapidly changing information-age environment. There should be quotas to increase the number of STEM officers commissioned. STEM officers should be rewarded with superior ratings based on their advanced STEM degrees vice their demonstrated duty performance.

The authors offer tangentially related research on STEM educated business leaders, inferring business CEOs and Army combat leaders are equivalent. These articles begged the following questions. 1) Are current STEM officers selected for promotion and command at lower rates than non-STEM officers? Is the Army short on billets and advancement opportunities for senior STEM officers? Are STEM related departments at West Point, like the Department of Chemistry, being downsized to enable expansion of non-STEM departments that offer more popular and applicable opportunities for contemporary undergraduate studies?

The Army has spent a great deal of time and energy promoting and advancing diversity. The Army needs all disciplines (business, humanities, social sciences, and some natural and applied science) to attain the diversity of thought and problem-solving skills necessary to meet and overcome the myriad of challenges associated with a constantly changing environment. I acknowledge that STEM related disciplines can contribute to but are not, as the articles imply, exclusive for success on the modern battlefield.

- Concerned CWMD Journal Reader

Has one of our articles resonated with you? We'd like to hear your thoughts to spur further discussion about the articles we print. Write to us by letter or email using the addresses on the inside cover of this journal.

How to submit your work to the

COUNTERING WMD JOURNAL

The United States Army Nuclear and Countering WMD Agency welcomes articles from all U.S. Government agencies and academia involved with CWMD matters. Articles are reviewed and must be approved by the Countering WMD Journal Editorial Board prior to publication. The journal provides a forum for exchanging information and ideas within the CWMD community. Writers may discuss training, current operations and exercises, doctrine, equipment, history, personal viewpoints, or other areas of general interest to CWMD personnel. Articles may share good ideas and lessons learned or explore better ways of doing things.

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Articles submitted to Countering WMD Journal must be accompanied by a written release from the author's activity security manager before editing can begin. All information contained in an article must be unclassified, nonsensitive, and releasable to the public. It is the author's responsibility to ensure that security is not compromised; information appearing in open sources does not constitute declassification. The Countering WMD Journal is published online and is distributed to military units and other agencies worldwide. As such, it is readily accessible to nongovernment or foreign individuals and organizations.

The Countering WMD Journal is published twice a year: Fall/Winter (article deadline is typically 15 September) and Spring/Summer (article deadline is typically 15 March). Send submissions via email to cwmdjournal@army.mil

Additional information about submitting an article to the Countering WMD Journal as well as current and past editions of the Countering WMD Journal are available at our website at www.usanca.army.mil/.

REAR COVER: U.S. Army Nuclear Disablement Team Soldiers and Army Rangers seized and exploited an underground nuclear facility during a training exercise. Nuclear Disablement Team 1 trained with Army Rangers from the 75th Ranger Regiment during operations under simulated fire at the decommissioned pulse radiation facility, June 6. U.S. Army photo by Sgt. Daniel R. Hernandez.

COUNTERING WMD JOURNAL
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U.S. ARMY NUCLEAR AND CWMD AGENCY
Fort Belvoir, Virginia