

United States
Army War College

Implications
of Climate
Change
for the
U.S. Army



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Executive Summary

Implications of Climate Change for the U.S. Army

Current conversations about climate change and its impacts are often rancorous and politically charged. As an organization that is, by law, non-partisan, the Department of Defense (DoD) is precariously unprepared for the national security implications of climate change-induced global security challenges. This study examines the implications of climate change for the United States Army. This includes national security challenges associated with or worsened by climate change, and organizational challenges arising from climate change-related issues in the domestic environment. Given that, the study's starting point is the implications of climate change for the U.S. Army, and the Army is therefore the focus of the analysis and recommendations. That said, much of the analysis involves DoD and other elements of the government, and most of the Army-specific recommendations have parallels that apply to other military services.

The study itself did not involve original research on the nature or magnitude of climate change. The analysis assumes, based on the preponderance of evidence available, that significant changes in climate have already occurred, likely to worsen in the years ahead. The study did not look to ascribe causation to climate change (man-made or natural), as causation is distinct from effects and not pertinent to the approximately 50-year horizon considered for the study. The study does, however, assume that human behavior can *mitigate* both the size and consequences of negative impacts that result from climate change.

Summary of Analysis

Initial findings of the study focus on changes to the physical environment and the human response to those changes.

Sea level rise, changes in water and food security, and more frequent extreme weather events are likely to re-

sult in the migration of large segments of the population. Rising seas will displace tens (if not hundreds) of millions of people, creating massive, enduring instability. This migration will be most pronounced in those regions where climate vulnerability is exacerbated by weak institutions and governance and underdeveloped civil society. Recent history has shown that mass human migrations can result in increased propensity for conflict and turmoil as new populations intermingle with and compete against established populations. More frequent extreme weather events will also increase demand for military humanitarian assistance.

Salt water intrusion into coastal areas and changing weather patterns will also compromise or eliminate fresh water supplies in many parts of the world. Additionally, warmer weather increases hydration requirements. This means that in expeditionary warfare, the Army will need to supply itself with more water. This significant logistical burden will be exacerbated on a future battlefield that requires constant movement due to the ubiquity of adversarial sensors and their deep strike capabilities.

A warming trend will also increase the range of insects that are vectors of infectious tropical diseases. This, coupled with large scale human migration from tropical nations, will increase the spread of infectious disease. The Army has tremendous logistical capabilities, unique in the world, in working in austere or unsafe environments. In the event of a significant infectious disease outbreak (domestic or international), the Army is likely to be called upon to assist in the response and containment.

Arctic ice will continue to melt in a warming climate. These Arctic changes present both challenges and opportunities. The decrease in Arctic sea ice and associated sea level rise will bring conflicting claims to newly-accessible natural resources. It will also introduce a new theater of direct military contact between an increasing-

ly belligerent Russia and other Arctic nations, including the U.S. Yet the opening of the Arctic will also increase commercial opportunities. Whether due to increased commercial shipping traffic or expanded opportunities for hydrocarbon extraction, increased economic activity will drive a requirement for increased military expenditures specific to that region. In short, competition will increase.

The increased likelihood of more intense and longer duration drought in some areas, accompanied by greater atmospheric heating, will put an increased strain on the aging U.S. power grid and further spur large scale human migration elsewhere. Power generation in U.S. hydroelectric and nuclear facilities will be affected. This dual attack on both supply and demand could create more frequent, widespread and enduring power grid failures, handicapping the U.S. economy.

In addition to the changing environmental conditions that will contribute to a changing security environment, climate change will likely also result in social, political, and market pressures that may profoundly affect the Army's (and DoD's) activities. Studies indicate that global society, including in the U.S., increasingly views climate change as a grave threat to security. As the electorate becomes more concerned about climate change, it follows that elected officials will, as well. This may result in significant restrictions on military activities (in peacetime) that produce carbon emissions. In concert with these changes, consumer demands will drive market adaptation. Businesses will focus on more environmentally sound products and practices to meet demand.

The DoD does not currently possess an environmentally conscious mindset. Political and social pressure will eventually force the military to mitigate its environmental impact in both training and wartime. Implementation of these changes will be costly in effort, time and money. This is likely to occur just as the DoD is adjusting to changes in the security environment previously highlighted.

Summary of Recommendations

In light of these findings, the military must consider changes in doctrine, organization, equipping, and training to anticipate changing environmental requirements. Greater inter-governmental and inter-organizational cooperation, mandated through formal framework agreements, will allow the DoD to anticipate those areas where future conflict is more likely to occur and to implement a campaign-plan-like approach to proactively prepare for likely conflict and mitigate the impacts of mass migration. Focused research and early funding of anticipated future equipment and requirements will spread the cost of adaptation across multiple budget cycles, diminish the "sticker shock" and impacts to overall spending.

Finally, the DoD must begin now to promulgate a culture of environmental stewardship across the force. Lagging behind public and political demands for energy efficiency and minimal environmental footprint will significantly hamstring the Department's efforts to face national security challenges. The Department will struggle to maintain its positive public image and that will impact the military's ability to receive the required funding to face the growing number of security challenges.

The recommendations of this study follow.

1. THE ARMY OPERATING ENVIRONMENT

1.1 Problem: Hydration Challenges in a Contested Environment

Recommendation: The Army must develop advanced technologies to capture ambient humidity and transition technology from the United States Army Research, Development, and Engineering Command (RDECOM) that supports the water sustainment tenants of decentralizing and embedded, harvest water, and recycle and re-use.

Implementation Timing: 6-10 Years

Resource Requirement: Moderate

- 1.2 Problem: Lack of adequate preparation and coherence in doctrine, training, and capabilities development to support effective Arctic operations.

Recommendation: *The Army and the Department of Defense must begin planning and implementing changes to training, equipment, doctrine and capabilities in anticipation of an expanded role in the Arctic associated with global climate adaptation.*

Implementation Timing: Now to 10+ Years.

Resource Requirements: Moderate to High.

1. THE ARMY INSTITUTION

- 1.1 Problem: The Lack of a Culture of Environmental Stewardship

Recommendation: *Army leadership must create a culture of environmental consciousness, stay ahead of societal demands for environmental stewardship and serve as a leader for the nation or it risks endangering the broad support it now enjoys. Cultural change is a senior leader responsibility.*

Implementation Timing: Now

Resource Requirements: Low

- 1.2 Problem: Potential disruptions to readiness due to restrictions on fuel use.

Recommendation: *The Army must significantly increase investment in more realistic simulation that incorporates the advances in virtual and augmented reality. It should also continue to invest in the development of lower CO2 emissions platforms and systems.*

Implementation Timing: 6-10 years (Virtual Reality / Augmented Reality), 10+ years (alternate energy platforms).

Resource Requirements: Moderate to High.

2. THE JOINT FORCE AND DoD

- 2.1 Problem: Lack of coordination and consolidation in climate-change related intelligence.

Recommendation: *Advocate for a comprehensive organization, functional manager, technology, and process review study to identify the current state of intelligence community agencies with regard to climate change, with the goal of formalizing Interagency coordination on Climate Change-related intelligence.*

Implementation Timing: Now

Resourcing Requirements: Low

- 2.2 Problem: Lack of Organizational Accountability for and Coordination of Climate Change-Related Response and Mitigation Activities

Recommendation: *Re-commit to the Senior Energy and Sustainability Council (SESC). Add a resourcing element to the council by providing the USA and VCSA with funding across each POM cycle to support climate-related projects that improve readiness and resiliency of the force.*

Implementation Timing: Now, 1-10 Years

Resource Requirements: Low, though potentially moderate through reprogramming.

2.3 Problem: Lack of Climate Change-Oriented Campaign Planning and Preparation

Recommendation: (A) *Develop Bangladesh (worst case scenario) Relief Campaign Plan as notional plan for preparing for broader climate change-related requirements arising from large-scale, permanent population dislocations.* (B) *Work more closely with the CDC to ensure appropriate military support to infectious disease treatment and containment.* (C) *Ensure preparedness for global, regional or local disruptions in logistics that may affect the Army's operations or allies.*

Implementation Timing: Now

Resource Requirement: Low

3. NATIONAL CONTEXT

3.1 Problem: Power Grid Vulnerabilities

Recommendation: A. *An inter-agency approach, coupled with collaboration of the commercial sector, should catalogue the liabilities across the electrical grid and prioritize budget requests for infrastructure improvements.* B. *The DoD should pursue options to reverse infrastructure degradation around military installations, including funding internal power generation such as solar/battery farms and small-nuclear reactors.*

Implementation Timing: Now (A); 6-10, 10+ Years (B)

Resource Requirement: Low (A); High (B)

3.2 Problem: Climate Change and Threats to Nuclear Weapons Infrastructure

Recommendation: *The U.S. Department of Defense, in combination with the U.S. Department of Energy (DOE) should develop a long term 15 to 20 year tritium production plan that accounts for advances in nuclear technology and the possibility of rising climate induced water levels as well as increases to the overall average water temperature used to cool nuclear reactors. This plan should include projections of fiscal resources and military tritium requirements needed to maintain and modernize the U.S. nuclear stockpile. It should also include U.S. government requirements for use of helium-3, a decay product of tritium used primarily for neutron detection when searching for special nuclear material (SNM) and enforcing nuclear non-proliferation agreements.*

Implementation Timing: Now to 10+ Years

Resource Requirement: High

Finally, the study examined the threat climate change poses to the U.S. military's coastal infrastructure, i.e., coastal military facilities and key airports and shipping facilities. Additionally, the U.S. Army Corps of Engineers (USACE) manages the nation's system of inland waterways, and condition of much of that system will be affected by rising seas and changing weather. That said, the study found no basis for additional action. The DoD and USACE have adequate systems and processes in place to track and manage these risks.

Introduction

Current public discourse about climate change and its impacts are often rancorous and politically charged. As an organization that is, by law, non-partisan, the Department of Defense (DoD) is precariously unprepared for the national security implications of climate change induced global security challenges. This study seeks to determine likely national security challenges associated with or exacerbated by anticipated climate change in an effort to craft recommendations for the DoD. Many of the recommendations are specifically targeted at the Army, however the specific recommendation or its parallel can be applied across the military as a whole. The study of climate change as a threat to U.S. and global security is not new to the U.S. Army or DoD.^{1,2,3} This study itself did not conduct specific research on the climate or climate change but assumed through the preponderance of evidence available that climate change is occurring. Additionally, the study did not look to ascribe causation to the climate change (man-made or natural) as causation is distinct from effects and not pertinent to the approximately 50 year horizon considered for the study.

In determining likely national security impacts and providing recommendations for the military, the authors relied upon the Intergovernmental Panel on Climate Change (IPCC) and the Representative Concentration

Pathway (RCP) 4.5. RCP 4.5 is the middle ground prediction of temperature and rainfall variation provided by the IPCC for climate change studies. Use of this model is intended to provide a realistic anticipation of future impacts of climate change without forecasting either extremely dire and catastrophic impacts or minimizing them to such an extent that they are meaningless.

The findings generally are categorized as those relating to anticipated changes in the physical environment and those relating to anticipated changes in the social environment. That is, the authors, using available studies, determined if changes to societal norms would have an impact on the military's ability to execute anticipated missions. The corresponding recommendations consider a near, mid and long term horizon and a low, mid or high level of resources allocated against the challenges. The intent is to provide senior leaders with an easy to understand anticipation of risk associated with each recommendation.

For the purposes of this study the authors chose to use the IPCC definition of climate change. This definition is most compatible as it simply looks at changing climate variables over time without ascribing causation.

Climate Change: Climate change refers to a change in the state of the climate that can be identified (e.g., by using statistical tests) by changes in the mean and/or the variability of its properties and that persists for an extended period, typically decades or longer. Climate change may be due to natural internal processes or external forcings such as modulations of the solar cycles, volcanic eruptions and persistent anthropogenic changes in the composition of the atmosphere or in land use.⁴

1. Werrill, C. and F. Femia. "Chronology of Military and Intelligence Concerns about Climate Change." *The Center for Climate & Security*. 2017. <https://climateandsecurity.org/2017/01/12/chronology-of-the-u-s-military-and-intelligence-communitys-concern-about-climate-change/>.

2. "Report on Effects of a Changing Climate to the Department of Defense." *United States Department of Defense*. 2019. https://climateandsecurity.files.wordpress.com/2019/01/sec_335_ndaa-report_effects_of_a_changing_climate_to_dod.pdf.

3. Werrill, C. and F. Femia. "New Pentagon Report: 'The effects of a changing climate are a national security issue.'" *The Center for Climate & Security*. 2019. <https://climateandsecurity.org/2019/01/18/new-pentagon-report-the-effects-of-a-changing-climate-are-a-national-security-issue/>.

4. "Global Warming of 1.5° C." *Intergovernmental Panel on Climate Change*. 2018. <https://www.ipcc.ch/sr15/>.

An aside on Climate Models and Risk: Uncertainty complicates choices about how to respond to or anticipate the consequences of climate change. Regardless of the cause, climatological data reflects an environment that is always changing. Where the choices lie hinges on whether or not we choose to act. There are four possible scenarios involving climate change and human action to mitigate or prepare for it. (See Figure 1, below.) Each approach carries a level of risk informed by the amount and type of action taken.

The matrix in Figure 1 summarizes payoffs from two different choices (mitigate and prepare or not), given two different contexts (climate change occurring or not). Obviously missing from this matrix is a sense of the probability of climate change itself, which would affect payoff calculations. However, for the sake of the present argument let us make the conservative assumption that climate change is a 50/50 proposition (data and theory indicate that climate change is already occurring).

Figure 1: Climate Change Risk / Response Matrix

		Climate Change Occurring	
		YES	NO
Mitigation and Preparation	NO	Payoff: Catastrophe	Payoff: No change
	YES	Payoff: Avoiding Catastrophe	Payoff: Economic Waste

First, we can assume no climate change is occurring and we can choose to do nothing. If our assumption about climate change is accurate, this is the most appealing option. Second, we can assume there is no change occurring, but that humans choose to act and mitigate human effects to the environment. This option is unappealing in that we will have wasted economic resources, pointlessly regulating and taxing ourselves.

However, if climate change is occurring and we choose to do nothing, we invite catastrophe, though we cannot know just how bad this payoff would be. Finally, if we assume climate change is occurring and undertake mitigation and preparation, we may avoid catastrophe.⁵

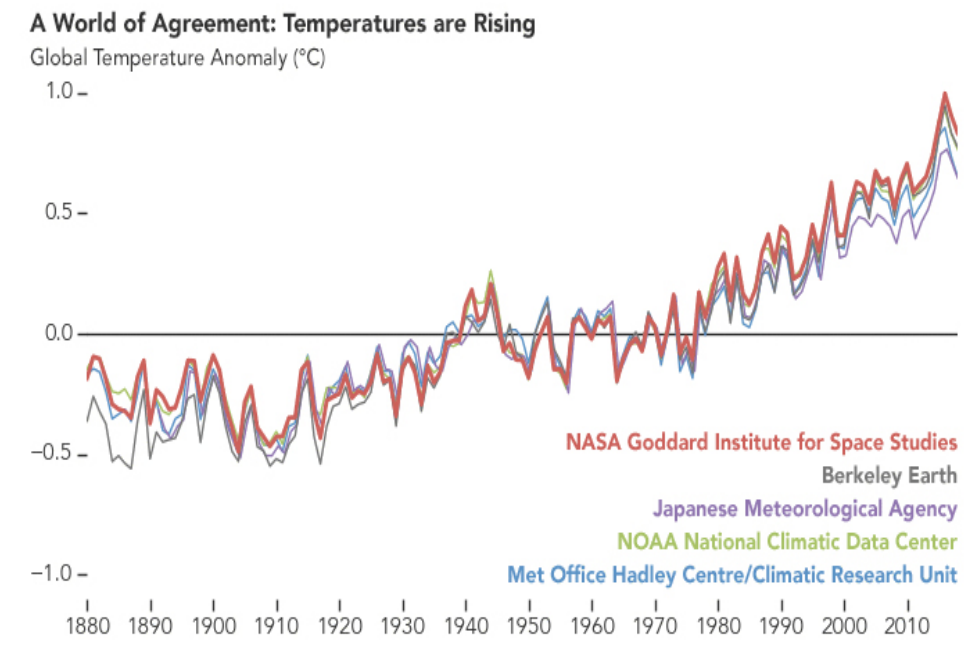
The only justification for doing nothing to mitigate and prepare for climate change is enough certainty that climate change is not occurring to justify the very considerable risk of doing nothing. The strength of scientific arguments in favor of significant warming projections suggests that such certainty is not defensible. (See Figure 2, next page.⁶) Prudent risk management therefore suggests that we should work to avoid the catastrophic outcome and prepare for and mitigate climate change.

Based on this argument, this report accepts as a core assumption the reality of climate change and climate-change related global warming, and therefore focuses on what the Army should do to prepare itself. Regardless of the science behind climatological projections of global warming, climate change is a controversial political issue. For the purposes of this study, we ignore that controversy. We must observe that the planet is warming with a broad range of impacts relevant to the U.S. Army, and we employ middle-of-the-curve projections to guide our analysis of recommendations.

5. Davis, Morton D., and Oskar Morgenstern. *Game Theory: A Nontechnical Introduction*. Mineola (New York): Dover Publications, 2013.

6. "Scientific Consensus: Earth's Climate is Warming." NASA *Global Climate Change, Vital Signs of the Planet*. 2018. <https://climate.nasa.gov/scientific-consensus/> - *.

Figure 2: Temperatures Showing the Last Decade was the Warmest on Record



Part 1: The Challenge of Climate Change

Challenge 1: Climate Change and the Physical Environment

Climate change affects the physical environment of the planet. It therefore affects the conditions in which people live, and the environment in which military organizations operate. The effects of a warming climate with more extreme weather are astonishingly far-reaching. Scientific studies in very diverse fields describe effects that have accelerated over the past 50 years as glaciers, Arctic and Antarctic ice sheets retreat, major weather patterns shift, and demographic, economic and political forces put more people in harm's way, while creating additional multi-dimensional stress on conventional military forces. The trend toward larger, more coherent and integrated research investments, such as the NASA Harvest Consortium, allows science agencies to establish improved and tight interfaces with the DoD on topics relevant to the military that are outside of traditional lanes. This consortium leverages broad international

cooperation and domestic collaborations using NASA earth observations to improve crop yield forecasting with the specific intent to establish tighter and more functional interfaces between NASA Applied Sciences Division and operational agencies, including DoD. Climate change also increases the risk of unrest and conflict globally. Human migration and refugee relocation due to chronic drought, flooding, episodes of extreme, unusual weather or other natural events create an environment ripe for conflict and large-scale humanitarian crises. In 2018, global international migration and internal displacement were estimated at a historic highs by the International Organization for Migration,⁷ bringing increased risk of spread of infectious disease and other public health problems. The fight for dwindling resources along the seams of civilization are harbingers of future U.S. involvement. If the United States is obliged or

7. <https://www.iom.int/wmr/chapter-2>

chooses to respond in a humanitarian or military fashion to alleviate conflict or provide stability, then the importance of recognizing climate-related impacts allows for planners to be proactive rather than reactive in formulating a response.

Rising Seas and Changing Coastal Geography

Coastal flooding is a persistent but acute cause of human displacement. Historically, flood waters recede and people return to their homes. Warming changes this calculus, with rising seas introducing the possibility of permanent displacement of tens, even hundreds of millions of inhabitants of high-risk coastal areas.

The relationship between climate change and international security is not well understood because climate's largest effects on conflict and governance are indirect, mediated through a variety of effects on weather. These sustained shifts in weather in turn produce a wide variety of impacts from one pole to the other and from the sea to the highest mountains. Nevertheless, we can make logical predictions of potential conflict, disruption of trade and humanitarian crises given known risks and exacerbating factors. Consider the case of Bangladesh, a nation with a history of disastrous seasonal flooding. According to one observer, "[Located] in the Ganges Delta, made up of 230 major rivers and streams, 160 million people live in a place one-fifth the size of France and as flat as chapati..."⁸ Almost half of the population of Bangladesh lives at sea level.⁹ As seas rise and huge areas of Bangladesh become uninhabitable, where will tens of millions of displaced Bangladeshis go? How will this large scale displacement affect global security in a region with nearly 40% of the world's population and several antagonistic nuclear powers? For a recent secu-

rity crisis benchmark, look at Syria.¹⁰

The Syrian civil war has been an international disaster with humanitarian and security impacts in the Middle East, Africa and Europe that will continue long into the future. Pre-war Syria had a population of about 22 million.¹¹ Almost five million Syrians have fled the country since the start of the civil war.¹² A host of factors contributed to the outbreak of civil war with causality still a matter of debate. There is, however, no question that the conflict erupted coincident with a major drought in the region which forced rural people into Syrian cities as large numbers of Iraqi refugees arrived.¹³ The Syrian civil war has reignited civil war in Iraq, and brought the U.S. and Russian militaries into close contact under difficult circumstances. The Syrian population has declined by about ten percent since the start of the war, with millions of refugees fleeing the nation, increasing instability in Europe, and stoking violent extremism.¹⁴

By comparison, Bangladesh has *eight times* Syria's population, and a conflicted history as a former part of Pakistan. Bangladesh is a predominantly Muslim nation locked between India and Burma. The latter is already under international scrutiny for its poor treatment of the Rohingya minority, the largest percentage of which have

8. Harris, Gardiner. "Borrowed Time on Disappearing Land." *The New York Times*. 2014. <https://www.nytimes.com/2014/03/29/world/asia/facing-rising-seas-bangladesh-confronts-the-consequences-of-climate-change.html>.

9. Greenfieldboyce, Nell. "Study: 634 Million People at Risk from Rising Seas." *National Public Radio*. 2007. <https://www.npr.org/templates/story/story.php?storyId=9162438>.

10. Some claim that the Syrian civil war resulted from drought-induced migration, a secondary effect of climate change. We do not make that argument here, as recent research questions this relationship. See Selby, Jan, Omar S. Dahi, Christiane Fröhlich, and Mike Hulme. "Climate change and the Syrian civil war revisited." *Political Geography* 60: 232-244. 2017. <https://www.sciencedirect.com/science/article/pii/S0962629816301822>.

11. Barbash, Fred. "U.N.: Nearly half of Syria's population uprooted by civil war." *The Washington Post*. 2014. https://www.washingtonpost.com/news/morning-mix/wp/2014/08/29/u-n-nearly-half-of-syrias-population-uprooted-by-civil-war/?utm_term=.eaa5e39e17b7.

12. "The Syrian Refugee Crisis and its Repercussions for the E.U." *Migration Policy Centre*. 2016. <http://syrianrefugees.eu/>.

13. Hammer, Joshua. "Is a Lack of Water to Blame for the Conflict in Syria?" *Smithsonian Magazine*. 2013. <https://www.smithsonian-mag.com/innovation/is-a-lack-of-water-to-blame-for-the-conflict-in-syria-72513729/>.

14. "The Syrian Refugee Crisis and its Repercussions for the E.U." *Migration Policy Centre*. 2016. <http://syrianrefugees.eu/>.

fled to Bangladesh. India is a nuclear-armed state perpetually on the verge of conflict with its nuclear-armed western neighbor, Pakistan. Indeed, Bangladesh's existence is the result of a war between those two nations. The permanent displacement of a large portion of the population of Bangladesh would be a regional catastrophe with the potential to increase global instability. This is a potential result of climate change complications in *just one country*.

Globally, over 600 million people live at sea level.¹⁵ Sea level rise also poses a direct threat to Army/DoD installations and missions worldwide. The DoD must assess the vulnerabilities to installations and risks to mission at all locations, prioritizing those most at risk. Early recognition of the complex risks will allow planning and implementation to best mitigate the risk and spread costs out over multiple budgetary periods. The 2018 National Defense Authorization Act (NDAA) mandates that the Department of Defense submit a report to Congress with respect to the impact of climate change on DoD missions. Specifically, the NDAA requires that the report include "vulnerabilities to military installations and combatant commander requirements resulting from climate change over the next 20 years."¹⁶ There are currently numerous studies already extant that detail the risks to military installations, some of them executed by government organizations, including the Army Corps of Engineers. Additionally, this report will examine mitigations to the risk associated with climate change impacts.

Opening the Arctic

The Arctic is undergoing some of the most significant and noticeable effects of climate change anywhere on the globe. According to the Intergovernmental Panel on Climate Change (IPCC), since satellite monitoring of the Arctic began in 1979, the Arctic ice extent has de-

creased from 3.5 – 4.1%.¹⁷ Furthermore, the IPCC predicts with high confidence that the Arctic will warm more rapidly than other parts of the globe through at least the year 2100, well beyond the horizon of this study.¹⁸ This warming will cause further diminishment of the Arctic ice, presenting many economic opportunities and security challenges for the United States and its allies.

As the sea ice in the Arctic continues to decrease, there are greater opportunities for all nations to take advantage of new shipping routes between ports in Asia and those in Europe or Eastern North America. According to researchers at the University of Reading in the UK, even if emissions diminish, as proposed by the Paris Accords, by 2050 opportunities for non-modified (that is, ships that are not double hulled or specifically designed for transit through ice prone environments) vessels to transit the Arctic Ocean will double. Furthermore, many of those journeys could take place directly across the pole in international waters, avoiding transit fees.¹⁹ From a money and time saving perspective, these shorter routes will be more and more attractive to shipping companies as the ice recedes. Currently, a typical East Asia to Rotterdam route, transiting the Suez Canal, takes about 30 days. The most conservative estimates of sea ice change estimate non-specialized vessels will be able to complete that route across the Arctic in 23 days and that that route would be available for over half the year.²⁰

Furthermore, according to a 2008 U.S. Geological survey, the Arctic likely holds approximately one quarter of the world's undiscovered hydrocarbon reserves.²¹ Though the United States territorially possesses only a

15. Greenfieldboyce, Nell. "Study: 634 Million People at Risk from Rising Seas." *National Public Radio*. 2007. <https://www.npr.org/templates/story/story.php?storyId=9162438>.

16. "National Defense Authorization Act for Fiscal Year 2018." *115th Congress of the United States of America*. 2017. <https://www.congress.gov/115/bills/hr2810/BILLS-115hr2810enr.pdf>.

17. "Climate Change 2014 Synthesis Report." *International Panel on Climate Change*. 2015. <http://ipcc.ch/report/ar5/syr/>.

18. Ibid.

19. Amos, Jonathan. "Arctic Ocean shipping routes 'to open for months'." *BBC News*. 2016. <http://www.bbc.com/news/science-environment-37286750>.

20. Ibid.

21. Ibid.

small percentage of the Arctic area, estimates are that 20% of those undiscovered reserves are potentially in U.S. territory.²² However, territorial claims in the Arctic are not well established and continue to be disputed amongst the Arctic nations.²³ As the extent of the resources available in the Arctic become more evident, there is a greater potential for conflict. The United States is likely to reach accommodation with allies in the region, but Russia's global pattern of aggression and attempts to reestablish great power status may set conditions for another flashpoint in the Arctic. The Arctic waters may make this evidently a Navy and Air Force issue, however the Army will be tasked with wide area security and reconnaissance roles as part of any joint efforts to secure Arctic interests.

Russia probably has the greatest immediate security concerns as it already earns transit fees from shipping companies using its Arctic waters. Russia has embarked on a rapid build-up in the Arctic, including expensive refurbishment of Soviet era Arctic bases. Russia's current Arctic plans include the opening of ten search and rescue stations, 16 deep water ports, 13 airfields and ten air defense sites.²⁴ (See Figure 3, below.²⁵) These developments create not only security outposts for Russia, but also threats to the U.S. mainland. Russia's recent development of KH-101/102 air launched cruise missiles and SSC-8 ground launched cruise missiles potentially put much of the United States at risk from low altitude, radar evading, nuclear capable missiles.

Figure 3: Map of bases and estimated hydrocarbon reserves in the Arctic



22. "The U.S. Stakes Its Claim in the Arctic Frontier." *Stratfor*. 2015. <https://worldview.stratfor.com/article/us-stakes-its-claim-arctic-frontier>.

23. Millstein, Seth. "Who Owns the Arctic? And Who Doesn't?" *Timeline*. 2016. <https://timeline.com/who-owns-the-arctic-2b9513b-3b2a3>.

24. Nudelman, Mike and Jeremy Bender. "This map shows Russia's dominant militarization of the Arctic." *Business Insider*. 2015. <http://www.businessinsider.com/chart-of-russias-militarization-of-arctic-2015-8>.

25. Ibid.

Russia is not the only nation considering security expansion in the Arctic. Since 2013, the United States Coast Guard has budgeted for the development and fielding of a new Polar Class heavy icebreaker to augment the one heavy and one medium icebreaker they now have in service. To date they have received almost \$191 million in funding toward the acquisition, estimated to cost just less than \$1 billion.²⁶ The FY2018 National Defense Authorization Act authorized the full procurement of the vessel.²⁷

The relatively rapid pace of change in the Arctic will generate opportunities, forecast and unexpected, on which nations around the world will capitalize. However, with any advantage comes the need to secure it. The United States must be prepared not only to seize any opportunities, but also to protect those assets and project power into newly accessible areas. All of these factors suggest that military operations in the Arctic will become more common.

Increased Range of Insect-Borne Diseases

Infectious diseases remain a concern for expeditionary forces and indigenous populations alike. As the climate changes, the distribution and prevalence of endemic diseases will change. Diseases that were endemic before could become altered and mutate to new regions. Extensive research has shown local weather conditions and other related environmental factors strongly influence vector-borne diseases.^{28,29} Diseases caused

by a wide array of pathogens including bacteria, spirochetes, rickettsiae, protozoa, viruses, nematodes and fungi spread through arthropods (i.e. ticks and mosquitoes) are highly susceptible to localized weather conditions.^{30, 31} The 2016 IPCC report and National Climate Assessment concluded there was an increased risk of some vector-borne diseases and that climate variability can alter the incidence of diseases carried by vectors (e.g., mosquitoes, fleas, ticks) through effects on vector geographic distribution, vector and pathogen biology, respectively.³² Indeed, some major vector-borne diseases in the U.S. have doubled or even tripled since 2005.³³ Examples of vector-borne diseases likely susceptible to change include: Malaria, Dengue, Chikungunya, Leishmaniasis, Lyme disease and Zika.³⁴

Consider the case of malaria, perhaps the most lethal infectious disease in the world. In 2015, the World Health Organization reported there were an estimated 304 million global cases and 639,000 deaths.³⁵ While considerable efforts aim at eradicating the disease through vaccine development, the international public health community continues to struggle with the extent of the

26. "Report to Congress on Coast Guard Icebreaker Program." *USNI News*. 2017. https://news.usni.org/2017/12/13/report-congress-coast-guard-icebreaker-program?utm_source=Sail-thru&utm_medium=email&utm_campaign=EBB_12.14.17&utm_term=Editorial-Early Bird Brief.

27. "National Defense Authorization Act for Fiscal Year 2018." *115th Congress of the United States of America*. 2017. <https://www.congress.gov/115/bills/hr2810/BILLS-115hr2810enr.pdf>.

28. "Vector-Borne Diseases Fact Sheet." World Health Organization. October 2017. Accessed December 2017. <http://www.who.int/mediacentre/factsheets/fs387/en/>.

29. Githeko, Andrew K., Steve W. Lindsay, Ulisses E. Confalonieri, and Jonathon A. Patz. "Climate change and vector-borne diseases: a regional analysis." *Bulletin of the World Health Organization* 78,

no. 9: 1136. 2000. [http://www.who.int/bulletin/archives/78\(9\)1136.pdf](http://www.who.int/bulletin/archives/78(9)1136.pdf).

30. Luber, George, and Kim Knowlton. "Human Health." *National Climate Assessment*. 2014. <https://nca2014.globalchange.gov/report/sectors/human-health>.

31. "Ticks and Tick-Borne Diseases." *Medscape*. Accessed December, 2017. <https://reference.medscape.com/slideshow/tick-borne-illnesses-6006369>.

32. Chrétien, Jean-Paul. "Adapting to Health Impacts of Climate Change in the Department of Defense." *Health Security* 14, no. 2: 86-92. 2016. <https://www.ncbi.nlm.nih.gov/pubmed/27081888>.

33. "Illnesses on the rise." *Centers for Disease Control and Prevention*. 2018. <https://www.cdc.gov/vitalsigns/vector-borne/index.html>.

34. Chrétien, Jean-Paul. "Adapting to Health Impacts of Climate Change in the Department of Defense." *Health Security* 14, no. 2: 86-92. 2016. <https://www.ncbi.nlm.nih.gov/pubmed/27081888>.

35. "Fact Sheet: World Malaria Report 2016." *World Health Organization*. <http://www.who.int/malaria/media/world-malaria-report-2016/en/>.

disease.³⁶ Today, the DoD and members of the U.S. Intelligence Community assess the risk of malaria to U.S. forces operating in East Africa³⁷ as high to intermediate depending on the country. A high-risk represents “an operationally significant attack rate (potentially 11-50% per month) could occur among personnel exposed to mosquito bites.”³⁸

The average projected climate changes in East Africa by 2050 show temperatures between 25-30° C. The projected average precipitation shows increased rainfall in select countries. Coupling the generally optimal conditions for malaria carrying mosquitos with the expected climate conditions in 2050, we can conclude that the environment will likely be much more favorable to malarial vectors.³⁹ The temperatures and increase of precipitation may lead to decreasing parasite development, more stable adult populations and increased bite rates.⁴⁰ It is also fair to conclude the more favorable conditions could lead to an increase of the prevalence of malaria.

Decreased Fresh Water Availability and Increased Demand

By 2040, the global demand for fresh water projects to exceed availability. As water availability decreases, the opportunity for social disruption will increase. Although the National Intelligence Council does not predict wa-

ter shortage alone will lead to failed states,⁴¹ the lack of water resources amplifies underlying existing issues such as lack of technology, poor governance, and inadequate economic resilience.⁴² There are several factors contributing to the global water shortage including: population increase, climate change, and poor water management.⁴³ North Africa, Southern Africa, the Middle East, China, and the United States all have areas where the water deficiency is greater than 50%. By 2030, one-third of the world population is projected to inhabit these water-stressed regions.⁴⁴ In several places across the globe, water has prompted cooperative agreements designed to share the scarce resource.⁴⁵ However, there is a growing concern that as demand outstrips supply, water will become a bargaining weapon to accrue power, deprive access to vulnerable populations or even enable sabotage to disrupt supply and achieve desired effects.^{46,47} Rising seas also place coastal fresh water supplies and agriculture at risk, as salt water moves inland, polluting rivers and aquifers, and literally salting the earth.⁴⁸

36. “Malaria.” *Bill & Melinda Gates Foundation*. <https://www.gatesfoundation.org/What-We-Do/Global-Health/Malaria>. Accessed December 2017.

37. The countries in the East Africa region for this study are; Sudan, South Sudan, Uganda, Democratic Republic of the Congo, Tanzania, Eritrea, Djibouti, Ethiopia, Somalia, Kenya.

38. Defense Intelligence Agency, National Center for Medical Intelligence, Infectious Disease Risk Assessment Methodology.

39. Craig, M. H., R. W. Snow, and D. Le Sueur. “A climate-based distribution model of malaria transmission in sub-Saharan Africa.” *Parasitol Today* 15, no. 3: 105-11. 1999. <https://www.ncbi.nlm.nih.gov/pubmed/10322323?dopt=Abstract>.

40. Patz, J. A., and S. H. Olson. “Malaria risk and temperature: Influences from global climate change and local land use practices.” *Proceedings of the National Academy of Sciences* 103, no. 15: 5635-636. 2006. <https://www.pnas.org/content/103/15/5635>.

41. Engel, Rich. “National Intelligence Council Water Research.” *National Intelligence Council*. 2012. [https://www.wilsoncenter.org/sites/default/files/Engel Presentation.pdf](https://www.wilsoncenter.org/sites/default/files/Engel%20Presentation.pdf)

42. “Global Water Security.” *National Intelligence Council*. 2012. https://www.dni.gov/files/documents/Special%20Report_ICA%20Global%20Water%20Security.pdf.

43. “Implications for US National Security of Anticipated Climate Change.” *CENTRA Technology, Inc, and Scitor Corporation*. 2016. [https://www.dni.gov/files/documents/Newsroom/Reports and Pubs/Implications_for_US_National_Security_of_Anticipated_Climate_Change.pdf](https://www.dni.gov/files/documents/Newsroom/Reports%20and%20Pubs/Implications_for_US_National_Security_of_Anticipated_Climate_Change.pdf).

44. Ibid.

45. Ibid.

46. Ibid.

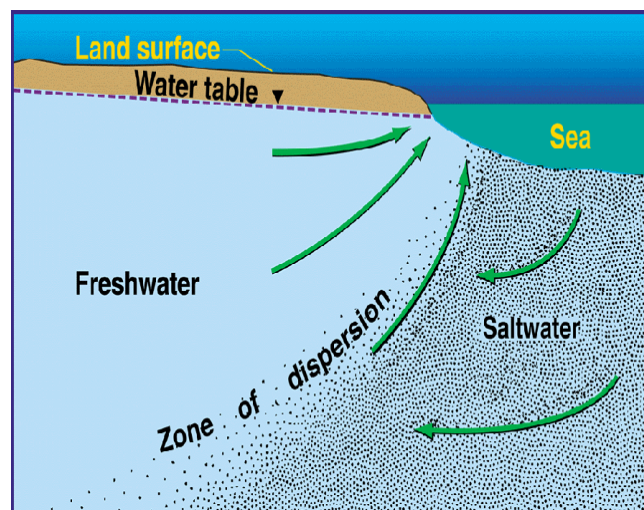
47. Kenney, Carolyn. “Climate Change, Water Security, and U.S. National Security.” *Center for American Progress*. 2017. <https://www.americanprogress.org/issues/security/reports/2017/03/22/428918/climate-change-water-security-u-s-national-security/>.

48. Paris, Aubrey. “Sea Level Rise: Sink or Swim.” *United States Army War College – War Room*. 2017. <https://warroom.armywarcollege.edu/articles/sea-level-rise-sink-swim/>.

The predicted rise in average global temperatures equates to the need for more water to sustain all life. As ambient temperatures rise, so does the risk of raising body temperature. Proper water consumption rates reduce this risk if there is water readily available to consume. As the rigor of activities increases so does the need for increased hydration. Simultaneously as the demand for water increases in a warmer climate, the amount of water readily available for use is reduced due to evaporation.⁴⁹ The combination of expeditionary soldiers fighting in a hot climate with scarce water supplies exacerbates logistical requirements.

Saltwater intrusion is another factor increasing the risk for conflict in coastal areas with large populations. As the need for more water increases, fossil freshwater aquifers are tapped which are not replenished. Reduced water levels in some coastal aquifers can lead to increased salinity as a result of the intrusion of seawater into the aquifer. Typically, a water table in a coastal area pushes fresh water to the ocean, but in this case, the salt water makes its way into the aquifer rendering it unusable. (See Figure 4.)

Figure 4: Ground-water flow patterns and the zone of dispersion in an idealized, homogeneous coastal aquifer⁵⁰



Decreased Food Security and Food System Stability

The United Nations (UN) Food Agricultural Organization (FAO) defines food security as a state when “all people, at all times, have physical and economic access to sufficient safe and nutritious food that meets their dietary needs and food preferences for an active healthy life.”⁵¹ Food security is premised on four components: food availability, food accessibility, food utilization and food system stability.⁵² (See Table 1, next page.) In its broadest terms, food security is the ability to have consistent access to food that is safe and meets dietary guidelines.⁵³

49. “Climate Impacts on Water Resources.” *The United States Environmental Protection Agency*. 2017. <https://19january2017snapshot.epa.gov/climate-impacts/climate-impacts-water-resources.html>.

50. Cooper, H.H. “Saltwater Intrusion.” *United States Geologic Survey*. 1964. <https://water.usgs.gov/ogw/gwrp/saltwater/salt.html>.

51. “The State of Food and Agriculture: Climate Change Agriculture, and Food Security.” *Food and Agriculture Organization of the United Nations*. 2016. <http://www.fao.org/3/a-i6030e.pdf>.

52. “Climate Change, Global Food Security, and the U.S. Food System.” *USDA*. 2015. https://www.usda.gov/oce/climate_change/FoodSecurity2015Assessment/FullAssessment.pdf.

53. “Dietary Guidelines.” *U.S. Office of Disease Prevention and Health Promotion*. 2019. <https://health.gov/dietaryguidelines/>.

Table 1: The Components of Food Security

Component	Definition
Availability	The existence of food in a particular place at a particular time. Addresses the “supply side” of food security, which is determined by food production, transportation, food stocks, storage, and trade.
Access	The ability of a person or group to obtain food. Economic access to food (including affordability) and allocation within society (including intranation and intrahousehold distribution) are integral to this component.
Utilization	The ability to use and obtain nourishment from food. This includes a food’s nutritional value and how the body assimilates its nutrients. Sufficient energy and nutrient intake is also the result of biophysical and sociocultural factors related to food safety and food preparation, dietary diversity, cultural norms and religious practices, and the functional role of food in such practices.
Stability	The absence of significant fluctuation in availability, access, and utilization. When stable, food availability, access, and utilization do not fluctuate to the point of adversely affecting food security status, either on a seasonal or annual basis or as a result of unpredictable events. Weather, political unrest, or a change in economic circumstances may affect food security by introducing instabilities.

Source: “Climate Change, Global Food Security, and the U.S. Food System.” USDA. 2015.

For seven out of eight Americans,⁵⁴ food insecurity is a problem relegated to places far afield from the continental United States. In fact, compared to 113 countries across the globe, the U.S. ranks second on the Global Food Security Index.⁵⁵ The U.S. spends 6.4 % of its income on food compared to countries such as Pakistan, Philippines, and Nigeria where a typical household spends more than 40 % of their earnings for sustenance.⁵⁶ Populations that dedicate more of their income to food are more vulnerable to fluctuations in food commodity prices. Recent effects of price shocks because of food availability have occurred in crisis areas such as Syria and Venezuela. Price fluctuations in food will affect countries differently. Countries that rely heavily on imports will be most affected.⁵⁷ The U.S., in contrast, has

consistently led the world in global agricultural exports, long a source of economic power and global influence.

When food systems fail, whether a failure of agricultural production, a supply chain failure that interferes with food processing or transport, or economic or financial disruption affecting demand, outbreaks of civil conflict and social unrest become more likely.⁵⁸ Global food security hinges on the production of four crops: maize, wheat, rice, and soybeans.⁵⁹ These commodities, along with a long list of foodstuffs moving through both formal and informal channels, are the core outputs of the global food system – the poorly defined, highly dynamic, complex web of transfers and interactions. Climate-in-

54. “Overview: Food Security in the U.S.” USDA. 2018. <https://www.ers.usda.gov/topics/food-nutrition-assistance/food-security-in-the-us/>.

55. “Global Food Security Index for 2017” *The Economist Intelligence Unit*. 2017. <https://foodsecurityindex.eiu.com/Resources>.

56. Gray, Alex. “Which countries spend the most on food? This map will show you.” *World Economic Forum*. 2016. <https://www.weforum.org/agenda/2016/12/this-map-shows-how-much-each-country-spends-on-food/>.

57. “Global Food Security: Market Forces and Selected Case

Studies.” *National Intelligence Council*. 2012. https://www.dni.gov/files/documents/nic/NICR_2012-23_Global_Food_Security_FINAL.pdf.

58. Barbet-Gros, Julie and Jose Cuesta. “Food Riots: From Definition to Operationalization.” *The World Bank*. 2015. <http://www.worldbank.org/content/dam/Worldbank/document/Poverty%20documents/Introduction%20Guide%20for%20the%20Food%20Riot%20Radar.pdf>.

59. Winkler, Elizabeth. “How the climate crisis could become a food crisis overnight.” *The Washington Post*. 2017. https://www.washingtonpost.com/news/wonk/wp/2017/07/27/how-the-climate-crisis-could-become-a-food-crisis-overnight/?noredirect=on&utm_term=.e9f324e6c009.

fluenced impacts on food systems beyond impacts on crop production include interruption of planting or harvest due to adverse weather, rapid freeze-thaw cycles in spring and fall,⁶⁰ soil degradation, depletion of fossil water aquifers, intensified spread of agricultural pests and diseases,^{61,62} and damage to shipping infrastructure as a consequence of flooding.⁶³ During a global food crisis in 2007-2008, social unrest was reported in 61 affected countries.⁶⁴ In war-time, the ability of the U.S. and allies to cooperate through extraordinary institutional innovations delivered under great duress, such as the Combined Food Board, improved provisioning of U.S. and allied war fighters, munitions workers and civilians.⁶⁵ Through the decades since the Second World War, these institutions have been dismantled in the U.S. as the policy of supply management, driven by the U.S. population's needs, shifted to policies that have emphasized agricultural exports as a critical component of the U.S. balance of trade.⁶⁶

Where climate change damages agricultural production, security concerns will likely follow. The world population is expected to increase by 39% between 2005 and 2050, and 95% of that growth will occur in develop-

ing countries that are also food insecure.⁶⁷ Population increases, coupled with the food demand and effects of climate change disrupting crop production will likely result in price instability.⁶⁸ Furthermore, the wild card of weaponized genome editing and, more generally, horizontal environmental genetic alteration agents (HEGAA) applied to agriculture and food systems already under interacting stress from climate change, define a no-analogue future..⁶⁹

Climate change will have diverse impacts on local, regional and global food system stability, far beyond its immediate effects on agricultural production affecting both availability of food and the resilience of underlying ecosystems.⁷⁰ Changes in the length and stability of growing seasons around the world, altered precipitation patterns resulting in droughts, high night temperatures, floods or shifted seasonal patterns will also impact crop production.⁷¹ Some evidence indicates that rising CO₂ levels may increase crop yields to some extent via an effect known as CO₂ fertilization.⁷² However, altered crop growth may affect nutrient composition, especially micronutrients such as zinc and iron, resulting in significant increases in mortality in vulnerable locations, which are those where DoD-supported humanitarian interven-

60. Sinha, Tushar and Keith A. Cherkauer. "Impacts of future climate change on soil frost in the midwestern United States." *Journal of Geophysical Research*, Vol. 115, D08105. <https://doi.org/10.1029/2009JD012188>.

61. Lenne, Jillian. "Climate change, crop plant diseases and future food production." *World Agriculture*. 2018. <http://www.world-agriculture.net/article/climate-change-crop-plant-diseases-and-future-food-production>.

62. Deutsh, Curtis A. *et al.* "Increase in crop losses to insect pests in a warming climate." *Science*. 2018. <http://science.sciencemag.org/content/361/6405/916.editor-summary>.

63. "Extreme Weather" in "National Climate Assessment." *U.S. Global Change Research Program*. 2014. <https://nca2014.global-change.gov/highlights/report-findings/extreme-weather>.

64. Ibid.

65. Roll, Eric. *The Combined Food Board: A Study in Wartime International Planning*. Palo Alto: Stanford University Press, 1956.

66. Collingham, Lizzie. *The Taste of War*. New York: Penguin Press, 2011: 481-501.

67. Alexandratos, Nikos and Jelle Bruinsma. "World Agriculture Towards 2030/2050." *United Nations Food and Agriculture Organization*. 2012. <http://www.fao.org/3/a-ap106e.pdf>.

68. "Global Food Security." *National Intelligence Council: Intelligence Community Assessment*. 2015. [https://www.dni.gov/files/documents/Newsroom/Reports and Pubs/Global_Food_Security_ICA.pdf](https://www.dni.gov/files/documents/Newsroom/Reports%20and%20Pubs/Global_Food_Security_ICA.pdf).

69. Reeves, R.G. *et al.* "Agricultural research or a new bioweapon system?" *Science* 362 (6410): 35-37. 2018. <http://science.sciencemag.org/content/362/6410/35>.

70. "The State of Food and Agriculture: Climate Change, Agriculture, and Food Security." *Food and Agriculture Organization of the United Nations*. 2016. <http://www.fao.org/3/a-i6030e.pdf>.

71. "Climate Change and Food Security: A Framework Document." *Food and Agriculture Organization of the United Nations*. 2008. <http://www.fao.org/3/k2595e/k2595e00.htm>.

72. Kirsbaum, M.U.F. *Plant Phys* 155(1): 117-124. 2011. <https://doi.org/10.1104/pp.110.166819>.

tion is most likely.⁷³ Increased CO₂ levels in the oceans and changes in ocean temperature will alter the availability of fish and could potentially lead to the extinction of certain species.⁷⁴ Changes in temperature will also affect livestock by impacting their ability to thrive and provide adequate amounts of meat and milk.⁷⁵

Increased Incidence of Extreme Weather

Numerous climate models suggest that a warming climate incurs more frequent extreme weather events and intensified weather patterns such as heat domes, polar vortices, super storms, monster ridges, and wider ranges of extremes, especially in spring and fall in temperate climates.⁷⁶ The U.S. Army is directly affected by these extremes, and has obligations connected to disaster recovery efforts related to a changing climate. Not only are Army personnel and installations at risk, the issue compounds when more than one major event occurs in a short interval or where natural disaster occurs where local social, political, and economic infrastructures are not resourced to handle the situation. Attention to a changing climate remains integral to the Army's preparation and response of devastating weather events like recent hurricanes Katrina, Rita, Harvey, Irma and Maria. Hurricane Michael in 2018 was the wettest hurricane on record, reflecting a more general trend of windier and wetter hurricanes.^{77,78} Natural disasters like these will

continue to draw in Army and other DoD resources.

In September 2016, U.S. the Intelligence Community (IC) conducted analysis of possible impacts of climate change on national security over the next 20 years.⁷⁹ Their report highlighted the projected occurrence of more extreme weather and how damaging it may be to natural systems such as oceans, lakes, rivers, ground water, reefs, and forests. Most of the critical infrastructures identified by the Department of Homeland Security are not built to withstand these altered conditions. The lower Mississippi River has sustained 100-, 200- and 500-year floods (meaning the chance is 1% or less that a flood of that magnitude would occur 500 simulations of the current year) in the last 8 years. Between 2016 and 2018, Ellicott City, Maryland sustained two 1,000-year floods.⁸⁰ Because most U.S. agricultural exports (80%) and imports (78%) are water-borne, floods that leave lasting damage to shipping infrastructure pose a major threat to U.S. lives and communities, the U.S. economy and global food security. The U.S. Intelligence Community's 2016 study further emphasized the social and economic implications realized by damaging these systems. The increased urbanization of areas prone to these weather events will only further stress governmental agencies tasked with recovery and support. Additionally, the study captured potential instability of countries, heightened social and political tensions, adverse effects on food prices and availability, increased risks to human health, negative impacts on investments and economic competitiveness.⁸¹

73. Myers, S.S. *et al.* "Increasing CO₂ Threatens Human Nutrition." *Nature* 510(7503): 139-142. 2014. <https://www.ncbi.nlm.nih.gov/pubmed/24805231>.

74. "The State of Food and Agriculture: Climate Change, Agriculture, and Food Security." *Food and Agriculture Organization of the United Nations*. 2016. <http://www.fao.org/3/a-i6030e.pdf>.

75. Ibid.

76. "National Climate Assessment." *U.S. Global Change Research Program*. 2014. <https://nca2014.globalchange.gov/report>.

77. Belles, Jonathan. "Hurricane Florence Was the Nation's Second Wettest Storm Behind Harvey." *The Weather Channel*. 2018. <https://weather.com/storms/hurricane/news/2018-09-19-hurricane-florence-harvey-north-carolina>.

78. "Hurricanes and Climate Change." *Union of Concerned Scientists*. 2017. <https://www.ucsusa.org/global-warming/science-and-impacts/impacts/hurricanes-and-climate-change.html>.

79. "Implications for US National Security of Anticipated Climate Change." *US National Intelligence Council*. 2016. [https://www.dni.gov/files/documents/Newsroom/Reports and Pubs/Implications_for US National Security of Anticipated Climate Change.pdf](https://www.dni.gov/files/documents/Newsroom/Reports%20and%20Pubs/Implications_for_US_National_Security_of_Anticipated_Climate_Change.pdf)

80. Di Liberto, Tom. "Torrential rains bring epic flash floods in Maryland in late May 2018." *Climate.gov*. 2018. <https://www.climate.gov/news-features/event-tracker/torrential-rains-bring-epic-flash-floods-maryland-late-may-2018>.

81. "Implications for US National Security of Anticipated Climate Change." *US National Intelligence Council*. 2016. [https://www.dni.gov/files/documents/Newsroom/Reports and Pubs/Implications_for US National Security of Anticipated Climate Change.pdf](https://www.dni.gov/files/documents/Newsroom/Reports%20and%20Pubs/Implications_for_US_National_Security_of_Anticipated_Climate_Change.pdf)

Stress to the Power Grid

Changing levels of rainfall put the U.S.'s energy grid at risk. Over 7.3 billion people currently inhabit the planet, a little more than half of which live in cities.⁸² In the United States alone, ten cities contain more than one million people, and more than 35 with a population of over 500,000.^{83,84} The power grid that serves the United States is aging and continues to operate without a coordinated and significant infrastructure investment. Vulnerabilities exist to electricity-generating power plants, electric transmission infrastructure and distribution system components. Power transformers average over 40 years of age and 70 percent of transmission lines are 25 years or older. The U.S. national power grid is susceptible to coordinated cyber or physical attacks; electromagnetic pulse (EMP) attacks; space weather; and other natural events, to include the stressors of a changing climate.^{85,86}

Effects of climate abnormalities over time introduce the possibility of taxing an already fragile system through increased energy requirements triggered by extended periods of heat, drought, cold, etc. If the power grid infrastructure were to collapse, the United States would experience significant

- Loss of perishable foods and medications
- Loss of water and wastewater distribution systems

- Loss of heating/air conditioning and electrical lighting systems
- Loss of computer, telephone, and communications systems (including airline flights, satellite networks and GPS services)
- Loss of public transportation systems
- Loss of fuel distribution systems and fuel pipelines
- Loss of all electrical systems that do not have back-up power⁸⁷

The Presidential Policy Directive-Critical Infrastructure Security and Resilience lists 16 critical infrastructures susceptible to power grid failure that directly tie to U.S. national security and the homeland defense mission of the Department of Defense (DoD).⁸⁸ The Congressional Electro-Magnetic Pulse (EMP) Commission, in 2008, estimated it would cost \$2 billion to harden just the grid's critical nodes.⁸⁹ The Task Force on National and Homeland Security calculates an additional \$10 to \$30 billion and many years necessary for a complete grid overhaul.⁹⁰ The EMP Commission further cited that some of the very improvements of network interconnectedness created through the updated Supervisory Control and Data Acquisition (SCADA) network, which control power distribution around the country, introduced additional weaknesses to cyber-attack.⁹¹ The Center for Security

82. Giegengack, Robert. "The Carrington Coronal Mass Ejection of 1859." *Proceedings of the American Philosophical Society*, vol. 159, no. 4: 425-426. 2015.

83. "Ten U.S. Cities Now Have 1 Million People or More; California and Texas Each Have Three of These Places." *United States Census Bureau*. 2015. <https://www.census.gov/newsroom/press-releases/2015/cb15-89.html>.

84. "U.S. City Populations 2018." *World Population Review*. 2018. <http://worldpopulationreview.com/us-cities/>.

85. "Large Power Transformers and the U.S. Electric Grid." *U.S. Department of Energy*. 2012. [https://www.energy.gov/sites/prod/files/Large Power Transformer Study - June 2012_0.pdf](https://www.energy.gov/sites/prod/files/Large%20Power%20Transformer%20Study%20-%20June%202012_0.pdf).

86. "Transmission & Distribution Infrastructure: A Harris Williams & Co. White Paper" *Harris Williams & Co.* 2014. https://www.harriswilliams.com/sites/default/files/industry_reports/ep_td_white_paper_06_10_14_final.pdf.

87. "Space Weather." *Department of Homeland Security*. No date. Accessed November 10, 2017. <https://www.ready.gov/space-weather>.

88. "Critical Infrastructure Security and Resilience." *The White House, Presidential Policy Directive*. 2013. <https://obamawhitehouse.archives.gov/the-press-office/2013/02/12/presidential-policy-directive-critical-infrastructure-security-and-resil>.

89. Graham, William R. *et al.* "Critical National Infrastructures." *Report of Commission to Assess the Threat to the United States from Electromagnetic Pulse Attack*. 2008. http://www.empcommission.org/docs/A2473-EMP_Commission-7MB.pdf.

90. "A Call to Action for America." *Task Force on National and Homeland Security, Secure the Grid Coalition, and Other Partners*. 2017. <https://emptaskforce.us/wp-content/uploads/2017/09/CAA-7-31-17.pdf>.

91. Graham, William R. *et al.* "Critical National Infrastructures." *Report of Commission to Assess the Threat to the United States from*

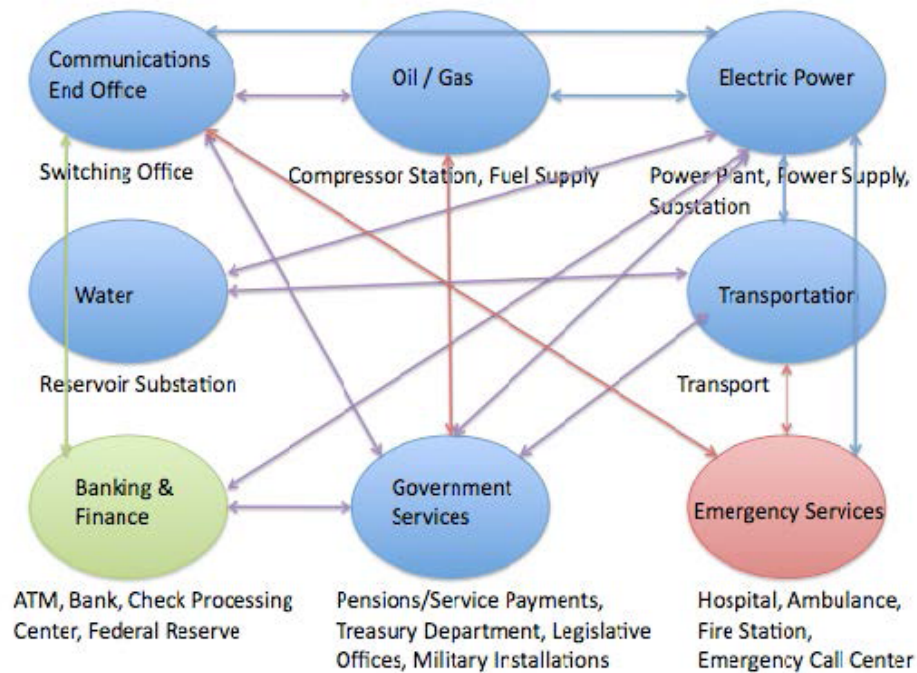
Policy reported that capability and capacity to repair or replace power grid unique infrastructure is reliant on production timelines exceeding a year. Most of these production facilities reside outside the United States, greatly adding to repair times and exacerbating vulnerability.⁹²

Defense of the homeland requires reliable access to power generation capabilities to protect critical infrastructure areas, maintain sovereign security, and provide aid to the nation's population when needed. Department of Defense installations are 99 percent reliant on the U.S. power grid for electrical power generation due to the decommissioning of autonomous power generation capability for budgetary cost saving measures over the last two decades.⁹³

While generators would allow continued operations for a time, a long-term outage of the power grid would rapidly erode the ability to perform numerous missions as resources were diverted toward humanitarian assistance/disaster response operations in the homeland.

Relief efforts aggravated by seasonal climatological effects would potentially accelerate the criticality of the developing situation. The cascading effects of power loss, as depicted below, would rapidly challenge the military's ability to continue operations. (See Figure 5.⁹⁴)

Figure 5: Essential Services Interconnectedness Affected by Power Grid Outage



Electromagnetic Pulse Attack. 2008. http://www.empcommission.org/docs/A2473-EMP_Commission-7MB.pdf.

92. "Guilty knowledge: What the US Government Knows about the Vulnerability of the Electric Grid, But Refuses to Fix." Center for Security Policy. 2014. <https://www.centerforsecuritypolicy.org/wp-content/uploads/2014/03/Guilty-Knowledge-6x9.pdf>.

93. Koppel, Ted. *Lights Out: A Cyberattack, a Nation Unprepared, Surviving the Aftermath*. New York, NY: Crown Publishers, 2015: 216.

94. Jamieson, Isaac. "Addendum – EMP & Cyber Security" in *Smart Meters – Smarter Practices: Solving Emerging Problems*. EM-Radiation Research Trust. 2012. <https://www.radiationresearch.org/articles/smart-meters-smarter-practices-document/>.

While securing the U.S. power grid will take a whole of government approach, the Joint Force's responsibility to defend the homeland is the strongest reason for DoD to prioritize funding towards a solution. The Services must be clear in their assessment of installation vulnerability to an outage of the power grid and the consequences for homeland through missile defense, Defense Support to Civil Authorities, and military response to direct threats. Response delays in any of these areas will impair any effort to stabilize the situation or quickly respond to crisis anywhere in the United States.

Aside from power distribution concerns, our power generation capabilities are also at risk. Due to their water demands, safety requirements, and locations adjacent to waterways, nuclear power stations in the United States are at high risk of temporary or permanent closure due to climate threats, as demonstrated by the example facilities in Connecticut and Tennessee. The U.S. Nuclear Regulatory Commission (NRC) authorizes the current operation of 99 nuclear reactors, including both pressurized and boiling water reactors (PWR; BWR), which supplied 19.7% of the country's utility-scale energy in 2016.⁹⁵ In general, the country's reliance on nuclear energy has increased marginally over time, with a net 1.2% increase in nuclear-generated electricity from 2016 to 2017.

Ultimately, 59 (or 60%) of the country's nuclear reactors exist in regions that are likely to suffer from one or more climate threats. These regions include New England (major risk: sea level rise), Mid-Atlantic (major risks: sea level rise and/or severe storms), South Atlantic (major risks: sea level rise and/or severe storms), and East South Central (major risk: water shortage). Based on their locations, 100% of reactors in New England, 26% in the Mid-Atlantic region, 38% in the South Atlantic region, and 100% in the East South Central region are at risk of experiencing major climate threats.

95. "FAQ: What is U.S. electricity generation by energy source?" U.S. Energy Information Administration. 2018. <https://www.eia.gov/tools/faqs/faq.php?id=427&t=3>.

The dangers facing some of these reactors have not gone unnoticed. For instance, Florida's Saint Lucie Nuclear Power Plant was shut down during Hurricane Matthew in 2016.⁹⁶ Operation of its sister facility, Turkey Point Nuclear Generating Station, was similarly ceased during Hurricane Irma in 2017.⁹⁷ Furthermore, expansion projects at Turkey Point, with proposals and construction spanning the last decade, have been criticized by several South Florida government officials who cite the challenge of rising sea levels.⁹⁸ New Jersey's Oyster Creek BWR will be decommissioned by the end of 2019 because of an unwillingness to construct costly cooling towers;⁹⁹ these structures will become increasingly important for reactors operating in regions where warming trends are apparent. Such complications, critiques, and closures are examples of impending climate change impacts on other nuclear energy facilities in the United States.

While it is true that nearly all types of energy infrastructure may suffer from climate changes unique to their locations, the only *clean energy* facilities likely to suffer as much or more than nuclear plants are their hydroelectric counterparts. In fact, hydropower's reliance on steady water access makes this sector particularly susceptible to climate-induced dryness. Experts expect drought to reduce hydropower generation due to declining reservoir levels, observed in 2007 when drought caused a 30% decrease in hydroelectric capacity in Tennessee.¹⁰⁰

96. Prasad, Nithin. "FPL says Saint Lucie 2 Florida reactor shut ahead of Matthew." *Reuters*. 2016. <https://www.reuters.com/article/us-storm-matthew-florida-nuclearpower/fpl-says-saint-lucie-2-florida-reactor-shut-ahead-of-matthew-idUSKCN1262I5>.

97. Gardner, Timothy. "Florida nuclear plants to shut ahead of Hurricane Irma." *Reuters*. 2017. <https://www.reuters.com/article/us-storm-irma-nuclearpower/florida-nuclear-plants-to-shut-ahead-of-hurricane-irma-idUSKCN1BI2IA>.

98. Staletovich, Jenny. "Mayors make case against FPL nuclear expansion." *Miami Herald*. 2018. <http://www.miamiherald.com/news/local/community/miami-dade/article18627960.html>.

99. Oglesby, Amanda. "Christie: Oyster Creek shutdown schedule." *Asbury Park Press*. 2017. <http://www.app.com/story/news/local/land-environment/2017/10/05/oyster-creek-early-closing/735491001/>.

100. Tennessee River Drought Management Plan, <http://web.knox->

This is consequential due to the nation's increasing demand for hydropower. In 2016, hydropower comprised 6.5% of utility-scale energy generated in the United States, making up the largest component (44%) of the country's renewable energy.¹⁰¹

From 2016 to 2017, a net 10.6% increase in U.S. hydropower generation was recorded. These numbers indicate that the two regions having the second- and third-fastest increase in hydropower usage (i.e., East South Central and West South Central) are also at high risk of future temperature increases and prolonged drought. Currently, 47 and 34 hydropower plants are operating in the East South Central and West South-Central regions, respectively, totaling at least 81 facilities that could suffer from reduced capacity in the near future.

Challenge 2: Climate Change and the Social, Economic, and Political Environment

Most of the preceding discussion of the physical environmental implications of climate change should be familiar. Less commonly discussed are the social, political, and economic effects of human concerns about climate change. Regardless of the actual physical effects of climate change, the belief in climate change as a threat to the earth and its inhabitants is an increasing force in international politics.¹⁰² This suggests that to some extent the debate about whether the planet is warming, or if human activity is the cause, is irrelevant. If a powerful section of the human population believes that the planet is warming, believes that this warming is human-induced and that climate change is a threat, and if that section acts on those beliefs, climate change will have political, social, and economic consequences that the Army will be unable to ignore.

[news.com/pdf/1013draft-drought-management-plan.pdf](https://www.energy.gov/newsroom/1013draft-drought-management-plan.pdf)

101. "FAQ: What is U.S. electricity generation by energy source?" U.S. Energy Information Administration. 2018. <https://www.eia.gov/tools/faqs/faq.php?id=427&t=3>.

102. "China, EU reaffirm Paris climate commitment, vow more cooperation." *Reuters*. 2018. <https://www.reuters.com/article/us-china-eu-climatechange/china-eu-reaffirm-paris-climate-commitment-vow-more-cooperation-idUSKBN1K60TC>.

To understand the impacts of the indirect effects of mobilization around climate change (as opposed to the direct, physical effects), we propose the SMaRT framework: Social, Market, Regulatory, and Technological responses.

Social Responses

Climate change taps into profound fears of insecurity. Humans are highly motivated by symbols, and what more potent symbol is there of human thriving and the fragility of life than the planet itself? A recent Pew survey indicated that climate change trailed only ISIS globally as a security concern.¹⁰³

The population of the United States is also concerned about climate change. Gallup News published a story in March, 2017 titled "Global Warming Concern at Three-Decade High in the U.S."¹⁰⁴ The polling data to support the story showed that, from a post-9/11 low of 51% in 2011, now 67% of the population worry about global warming a "great deal" or a "fair amount".¹⁰⁵ This concern is most prevalent among today's youth, indicating a propensity for the electorate to become more climate sensitive as that demographic ages.¹⁰⁶

Powerful symbols engender social mobilization and change. To have a huge effect on human affairs, these symbols need not be deeply rooted in reality. Conquests of the companions of Mohamed remade the Middle East and North Africa. The Protestant reformation transformed European civilization. The American Revolu-

103. Poushter, Jacob and Dorothy Manevich. "Globally, People Point to ISIS and Climate Change as Leading Security Threats." *Pew Research Center*. 2017. <http://www.pewglobal.org/2017/08/01/globally-people-point-to-isis-and-climate-change-as-leading-security-threats/>.

104. Saad, Lydia. Gallup, "Global Warming Concern at Three-Decade High in U.S." *Gallup News*. 2017. <https://news.gallup.com/poll/206030/global-warming-concern-three-decade-high.aspx>.

105. *Ibid*.

106. "Concern About Climate Change and Its Consequences." *Pew Research Center*. 2015. <http://www.pewglobal.org/2015/11/05/1-concern-about-climate-change-and-its-consequences/climate-change-report-15/>.

tion created a nation that would change the world. All of these phenomena derived much of their power from symbols. Grasping the power of the earth as a symbol requires little imagination compared to the nuances of Mohamed's revelations, Luther's theses, or the American case for independence.

Social mobilization around climate change will have winners and losers. Clear winners will be individuals and organizations perceived to be acting in the collective interest of both humanity and the natural environment. Clear losers will be individuals and entities whose actions are perceived to undermine environmental stability. Increased access to mass communication platforms means that no single entity will control the narrative regarding who these winners and losers are.

What is the current perception of the U.S. Army, the U.S. military, or the U.S. government as a steward of the environment? We have no good data on this question. Anecdotally, the U.S. government is perceived to be an irresponsible actor in the global environment. The U.S. withdrawal from the Paris accords elicited strong reactions in the developed world.¹⁰⁷ By contrast, although China is the largest carbon emitting nation,¹⁰⁸ it has been more thoughtful about how it projects its image globally with respect to carbon emissions, and Chinese clean energy initiatives have been widely publicized in the U.S.^{109,110,111}

107. Shear, Michael D. and Alison Smale. "Leaders Lament U.S. Withdrawal but Say It Won't Stop Climate Efforts." *The New York Times*. 2017. <https://www.nytimes.com/2017/06/02/climate/paris-climate-agreement-trump.html>.

108. "Global Carbon Atlas." *Global Carbon Project*. 2018. <http://www.globalcarbonatlas.org/en/CO2-emissions>.

109. "China Steps Up Its Push into Clean Energy." *Bloomberg News*. 2018. <https://www.bloomberg.com/news/articles/2018-09-26/china-sets-out-new-clean-energy-goals-penalties-in-revised-plan>.

110. Dudley, Dominic. "China Is Set To Become The World's Renewable Energy Superpower, According To New Report." *Forbes*. 2019. <https://www.forbes.com/sites/dominicdudley/2019/01/11/china-renewable-energy-superpower/-9eb1cfa745a2>

111. Forsythe, Michael. "China Aims to Spend at Least \$360 Billion on Renewable Energy by 2020." *The New York Times*. <https://>

The energy and pollution practices of the U.S. military have been subject to less scrutiny both domestically and abroad and have not yet risen to the level of urgency of other issues such as sexual assault. However, as environmental and security concerns increasingly overlap, the international perception of the U.S. as an irresponsible actor could have serious implications for the U.S. military, which relies on allies to maintain its global posture. The U.S. military depends on access to the bases and ports of allies, it enjoys flyover privileges, and other preferential treatment. All of this exists because allies see the U.S. as aligned with their core interests. In the core powers of Europe, in the Commonwealth countries, in Japan, and elsewhere, social mobilization due to perceived climate change has the potential to create a fundamental misalignment between the U.S. and its key allies.¹¹² The U.S. may find itself more internationally isolated than at any times since its repudiation of the League of Nations.

Market Responses

The private sector will play the largest role as it explores ways to respond to society's evolving need to "protect, retreat [from], or accommodate" activities that cause climate change.¹¹³ The market consequences of climate change are complex and ambiguous. Humanitarian and development organizations are also working intensely to build or rebuild markedly more resilient communities with enhanced distributed collective intelligence, decentralized grid structures and other strategies that may improve overall resilience. In general, however, market consequences of climate change are complex and am-

www.nytimes.com/2017/01/05/world/asia/china-renewable-energy-investment.html.

112. Milman, Oliver. "G20 leaders' statement on climate change highlights rift with US." *The Guardian*. 2017. <https://www.theguardian.com/world/2017/jul/08/g20-climate-change-leaders-statement-paris-agreement>.

113. "Technologies for adaptation to climate change." *United Nations Framework Convention on Climate Change (UNFCCC)*. 2006: 13. https://unfccc.int/resource/docs/publications/tech_for_adaptation_06.pdf.

biguous. Highly entrenched economic interests may distort market signals. Global reductions in demand for hydrocarbons means that gasoline, diesel, and jet fuel should become less expensive. On the other hand, reduced demand tends to reduce incentives to explore potential oil fields or build new refining facilities. Much of the U.S.'s domestic oil extraction is unprofitable at oil prices below \$30 a barrel. Technological advances tend to push this number lower, but exhaustion of oil fields tends to push the number higher. In all scenarios, global declines in oil consumption increase the sensitivity of oil markets to the choices of large consumers like the U.S. DoD.

Regulatory Responses

Regulations will play a factor in driving the behavior of both consumers and private sector companies. By establishing standards such as fuel economy, limiting carbon emissions, setting greenhouse gas targets, or providing tax incentives for individuals, the regulatory arm of the government can be a powerful tool over the next 30 years. The United States' participation in Organization for Economic and Cooperation Development (OECD) will continue to provide opportunities to identify shared values with partner nations and set global targets.

Regulatory action often flows from collective interest in change. In the case of climate change, many regulations may create compliance challenges for the U.S. military. We think it unlikely that the U.S. government would restrict military carbon emissions in combat operations, for example. We are less optimistic about the absence of such restrictions on force development. Indeed, we consider it likely that at some point in the next two decades the U.S. government will introduce carbon emissions restrictions that affect non-combat military operations. While the Air Force can quickly increase its reliance on flight simulation, the Army remains wedded to training and practicing in live scenarios. This makes the Army highly susceptible to disruptions in readiness development should the government introduce carbon emissions restrictions.

Technological Responses

To mitigate the effects of climate change, government organizations, non-governmental organizations, and the private sector will need to pursue technological enhancements. These enhancements must be "climate informed" so that improvements do not create unintended vulnerabilities.¹¹⁴

The clearest opportunities for climate-change related innovation are in clean energy production, transmission, and storage. Each of these areas creates risks and opportunities for the U.S. military. The automated, A.I.-enhanced force of the Army's future is one that runs on electricity, not JP-8. More efficient or resilient production of electricity through micro-nuclear power generation or improved solar arrays can fundamentally alter the mobility and the logistical challenges of a mechanized force. Light, quick-charging batteries (super-capacitors) have tremendous value in such a force; so does the wireless transmission of electrical current.¹¹⁵

Innovations such as weather control and weather mitigation techniques may serve to stave-off the worst impacts of climate change. For example, researchers are exploring ways to combat the effects of climate change through geoengineering. This controversial program involves either "capturing and storing some of the carbon dioxide that has already been emitted so that the atmosphere traps less heat or reflects more sunlight away from the earth so there is less heat to start with."¹¹⁶ Other opportunities for technological change include weather

114. Hallegatte, Stephane *et al.* *Shock Waves: Managing the Impacts of Climate Change on Poverty*. 2016. Washington, DC: World Bank.

115. Bakken, Gretchen. *The Grid: The Fraying Wires Between Americans and Our Energy Future*. New York: Bloomsbury, 2016: 201-207.

116. Fountain, Henry. "Panel Urges Research on Geoengineering as a Tool Against Climate Change." *The New York Times*. 2015. <https://www.nytimes.com/2015/02/11/science/panel-urges-more-research-on-geoengineering-as-a-tool-against-climate-change.html?mcubz=3>.

control,^{117*} pollution control, flood management, and agricultural changes.¹¹⁸

The last area of concern regarding weather threats centers around attribution. The United States defends itself daily from activities of rival nations that fall below the level of war but can still negatively target national security. Nations who feel they cannot compete with the United States directly use these methods to level the playing field. As an example, a 2015 DoD Cybersecurity Culture and Compliance Initiative states that the DoD had been the subject of over 30 million malicious attacks to its network in just the short period from September, 2014 to June, 2015.¹¹⁹ Targeted attacks by hackers or computer viruses can leverage naturally occurring events like space weather to disguise their intrusion into U.S. networks as they create effects that mimic space weather threats. By using space weather events or manufacturing events that mimic space weather, adversaries can create a non-attributional attack on vital systems with little concern of detection until it is too late to react.

One such possible event made international news in the Spring of 2016. Swedish air traffic controllers reported widespread and persistent outages of their aviation radar network over the course of five days in November of 2015. Publicly attributed to a solar event, domestic and international flight operations halted while repair efforts searched for the cause of the outage. Anonymous sources pointed towards a more ominous culprit than space weather as further reporting claimed Swedish authorities traced the beginning of the outage to an advanced persistent threat group previously linked to the Russian military intelligence agency, Spetsnaz GRU. The Swedish Civil Aviation Administration later came

back with another announcement that this was a naturally occurring event and no cause for alarm. However, rumors persist that the events engineered over the course of a week had little or nothing to do with a space weather event, but more to do with the Russians testing out their electronic warfare capability.¹²⁰ The fact that a series of geomagnetic storms did occur during this period does create some doubt as to the validity of the rumors, however, that does not preclude the capability exists. That only Sweden's radar network felt the effects of the storm lends credence to other explanations.

While all countries claim a purely scientific interest and capability for experimenting with the natural environment, a prudent strategic leader should look to the dual-use possibilities of such labors and seek mitigation strategies.

Challenge 3: The Army and DoD – Organizational Confusion and Lack of Accountability for Climate Change

No systemic understanding of the wide diversity of climate-change related intelligence.

The section above on the environmental effects of climate change demonstrates the wide variety of stakeholders who are monitoring climate change-related effects. These include public health organizations such as the W.H.O. and the Centers for Disease Control, energy producers and regulators such as the Federal Energy Regulatory Commission, weather observers such as NASA and the NOAA, humanitarian organizations like the World Food Program, national security entities like the U.S. military, and numerous private and public organizations like universities, NGOs, and so on. Climate change is at the center of a complex web of interactions. During this study, we were struck by how much many people knew about parts of the phenome-

117. * See Appendix: Weather Control.

118. "Technologies for adaptation to climate change." *United Nations Framework Convention on Climate Change (UNFCCC)*. 2006: 13. https://unfccc.int/resource/docs/publications/tech_for_adaptation_06.pdf.

119. "Department of Defense Cybersecurity Culture and Compliance Initiative." *Office of the Secretary of Defense*. 2015. <https://dod.defense.gov/Portals/1/Documents/pubs/OSD011517-15-RES-Final.pdf>.

120. Russon, Mary-Ann. "Russia Blamed for Crashing Swedish Air Traffic Control to Test Electronic Warfare Capabilities." *International Business Times*. 2016. <http://www.ibtimes.co.uk/russia-blamed-bringing-down-swedish-air-traffic-control-test-electronic-warfare-capabilities-1554895>.

na, but we were also surprised by the lack of a holistic view of the problem, and a sense of how some areas would relate to each other. Climate change is a common cause linking a disparate set of challenges, but we currently have no systemic view to assess and manage risk. In contrast, in China, systems science and engineering is considered so important to the future of China that this is a course of study required for all cadres in the Chinese Communist Party's Central Party School in Beijing.¹²¹ Thanks in part to some spectacular historical failures and collaboration with the University of Hull, the hard systems approaches have been amended to systematically take into account *wuli* (objective exploration of a problem, facts, futures), *shili* (mathematical and conceptual models used to organize a system), and *renli* (human relationships). The application of these approaches at large scale, coupled with intensive urban surveillance, state-influenced social media, and biometric fintech, have the potential to create very significant asymmetries in resilience between the U.S. and China to climate-induced effects and any other type of attack or disaster.

In the U.S., there are many actions that would be warranted by recent past experience to reduce vulnerabilities of the Army, the DoD and the nation such that the DoD is mobilized under a State of Emergency. No single approach is likely to be adequate to prepare the U.S. Army and the DoD as a whole for altered conditions that are either in place already or virtually certain to occur at some point in the future. In the past two decades, the DoD has been under increasing pressure from Congress to prepare strategies, plans and capabilities necessary to ensure preparedness for the wide array of potential impacts on weather resulting from climate change. The NDAA for 2018 mandated at least two studies to this effect, one focused on climate per se, and one focused on DoD vulnerabilities to disruption of

the global food system. While there have been significant interagency investment and collaboration through the past two decades, there is an ongoing need for improved interagency collaboration between intelligence, defense, and civilian agencies on climate change data collection, analysis, and forecasting. Where not already routine, the intelligence community's analyses would be improved by the systematic inclusion, as a matter of course, of closely synched present day and near-term insights from climate projections, modeling, and weather data into established products and processes. DoD and natural science agencies would benefit from the additional qualitative and quantitative collection, provided by IC platforms, to improve their own processes and products.

The lack of organizational accountability in the DoD and the Army

They say that "what gets measured, gets done." In large, complex, bureaucracies, getting "new" things done often involves adding structure. Especially in long-established organizations, the addition of new structures can engender distress by way of competition for fixed resources and local or general cultural opposition, this can create circumstances where new structures become disconnected from the normal socialization, integration and resourcing processes. Such challenges can arise no matter how justified or important the "new" effort is. In many cases, new administrative structures, staffing and infrastructure are required. Under any circumstances, "best laid plans," can become hard to implement across the organization. Climate change presents the Army with a bureaucratically "new" and complex challenge that must be socialized, integrated, and resourced across the enterprise. Climate change is a national security imperative that cuts across the department and has no single organization wholly responsible for addressing it. But the Army and its sister Services are not alone in wondering how to address climate change. Congress' oversight authority enables it to query the Department of Defense (DOD) about its plans to address the impact of climate change. The 2018 National Defense Authorization Act (NDAA), di-

121. Hvistendahl, Mara. "A revered rocket scientist set in motion China's mass surveillance of its citizens." *Science* 359(6381): 1206-1209. 2018. <https://www.sciencemag.org/news/2018/03/revered-rocket-scientist-set-motion-china-s-mass-surveillance-its-citizens>.

rected the DOD to provide a report on the vulnerabilities to installations and combatant command requirements resulting from climate change over the next 20 years.¹²² The report is required to list of the ten most vulnerable installations, mitigation and cost strategy, and frequency of humanitarian assistance/disaster relief (HADR) missions.¹²³ The Army will task within its organizations for the answer, but short of the occasional request from Congress, is there any organization within the Army that periodically assesses how it is doing across the enterprise? Who is deciding what trades to make, where to invest, what to invest in, or what the Army's priorities should be? The Army is making efforts toward addressing climate change, but who or what body is defining those priorities?

From an organizational structure, the Army does not have a good mechanism for holistically assessing and re-assessing the present and future impacts of climate change on the Army, nor is there a systematic mechanism in place to track present and past impacts on the force. Any new organizing construct within the Army to address the very diverse impacts of climate change across scales and geographies should reflect the Army leadership's objectives. It should provide visibility across the enterprise about what the Army is doing, and the level of readiness or preparedness being resourced. And it should also provide leadership with an understanding of how climate change has and will impact areas such as training, readiness, supply chain, and its future cost implications.

The Environmentally Oblivious Culture of the Army

The Army has thrived despite a culture of environmental oblivion that exists within the force. Conditions may no longer favor this tendency. Trends show that the United States is becoming more environmentally conscious and that the threat of climate change and our impact on the planet is seen as a threat to our national security by a majority of the population.¹²⁴

The Army is not an environmentally friendly organization. Frankly, it is not designed to be. For good reasons, the Army focuses on the most effective means to dominate an enemy on the battlefield. However, in the course of this endeavor, the turbine engines that power helicopters and tanks burn thousands of pounds of JP-8 fuel per hour. Every time one of those turbine engines is shut off almost a pint of jet fuel is dumped overboard onto the ground. The munitions used in training rain lead and explosive residue into range complexes across the country. Armored vehicles churn up the soil in maneuver areas and contribute to erosion and sediment run off into streams. In myriad offices across the force, thousands of pages of PowerPoint presentations are printed off every day, simply to be thrown away after the briefing. In short, the Army is an environmental disaster. Incidentally, this makes the Army a likely target of social mobilization (see above).

Given the magnitude and variety of climate change-related challenges, what specific actions can be undertaken by leaders of the U.S. Army today? We now turn to this question.

122. "National Defense Authorization Act for Fiscal Year 2018." *115th Congress of the United States of America*. 2017:169. <https://www.congress.gov/115/bills/hr2810/BILLS-115hr2810enr.pdf>.

123. "National Defense Authorization Act for Fiscal Year 2018." *115th Congress of the United States of America*. 2017: 169-170. <https://www.congress.gov/115/bills/hr2810/BILLS-115hr2810enr.pdf>.

124. Saad, Lydia. Gallup, "Global Warming Concern at Three-Decade High in U.S." *Gallup News*. 2017. <https://news.gallup.com/poll/206030/global-warming-concern-three-decade-high.aspx>.

Part 2: Recommendations

This section describes recommendations for climate change-related actions by the U.S. Army. We summarize each recommendation in terms of timing of implementation (Now, 1-5 years, 6-10 years, or beyond 10 years), and we characterize the resourcing requirements associated with it. “Low” resourcing assumes no substantive additional resources are required to implement the recommendation. “Moderate” resourcing assumes that some reprogramming is needed, up to \$100 million over a five-year period. “High” means that the recommendation requires substantive appropriations, in excess of \$100 million over a five-year period. All resource projections are estimates.

RECOMMENDATION AREA 1: THE ARMY OPERATING ENVIRONMENT

Problem: Hydration Challenges in a Contested Environment

Recommendation: *The Army must develop advanced technologies to capture ambient humidity and transition technology from the United States Army Research, Development, and Engineering Command (RDECOM) that supports the water sustainment tenants of decentralizing and embedded, harvest water, and recycle and re-use.*

Implementation Timing: 6-10 Years

Resource Requirement: Moderate

Hydration in a Contested Arid Environment

The U.S. Army is precipitously close to mission failure concerning hydration of the force in a contested arid environment. The experience and best practices of the last 17 years of conflict in Afghanistan, Iraq, Syria, and Africa rely heavily on logistics force structures to support the warfighter with water mostly procured through contracted means of bottled water, local wells and Reverse Osmosis Water Purification Units (ROWPU). The Army must reinvest aggressively in technologies both in-house and commercial off the shelf in the next 5-10 years to keep pace with rising global temperatures, especially those arid areas in or poised for conflict. The Army must seek partnerships with industry, other nations, and other militaries currently working on the hydration issue.

The Army must re-examine its planning approach to the hydration issue. The table below comes from the Command and General Staff College Student Text, Theater Sustainment Battle book. The ability to supply this amount of water in the most demanding environment is costly in money, personnel, infrastructure, and force structure.¹²⁵ (See Table 2.) The calculations for water (8.34 pounds per gallon) in an arid environment equates to 66 pounds of water per soldier.

125. Johnson, Michael, CPT and LTC Brent Coryell. “Logistics Forecasting and Estimates in the Brigade Combat Team.” 2016. *Army Sustainment*. <http://www.alu.army.mil/alog/2016/NOVDEC16/PDF/176881.pdf>.

Table 2: Daily water consumption factors in gallons per person¹²⁶

Use	Temperate	Tropical	Arid	Arctic
Drinking water	1.5	3.0	3.0	2.0
Personal hygiene	1.7	1.7	1.7	1.7
Field feeding	2.8	2.8	2.8	2.8
Heat injury treatment	.1	.2	.2	.1
Vehicle maintenance			.2	
Standard planning factor	6.1	7.7	7.9	6.6

Current planning methodologies remain heavily vested in bottled water meaning a more considerable force is needed to transport it. As of the 2017 Modified Tables of Occupation and Equipment (MTOE), most units retain some level of water storage or transportation based on force structure. This structure makes sense and requires continuation. This structure only works through the supplying of potable water by support units or through locally procured methods. Force structure will not fix this problem. Very few Army units have water generation capabilities, and as of 2015, Brigade Combat Teams can no longer organically support their water needs. The additional units needed to support them creates an unsupportable logistical footprint and reduces the speed of the combat units.

Researchers at Ft. Lee, VA, with the Combined Arms Support Command (CASCOT), in the Petroleum and Water Department, believe water generation is one of the leading fields for material approaches in the Capa-

bility Needs Assessment Process. The objective is to develop technologies enabling a logistics transformation in the area of water sustainment by reducing the water distribution and storage load. Without technology advances, water remains 30%-40% of the force sustainment requirement. The reduction encompasses the water storage load on combat platforms, the Soldier, tactical systems, and current and future force water distribution requirements. The Army must develop advanced technologies to capture ambient humidity and transition technology from the United States Army Research, Development, and Engineering Command (RDECOM) that supports the water sustainment tenants of decentralizing and embedded, harvest water, and recycle and reuse. This technology enables water production capability to be embedded in platforms (possibility trailer mounted systems) creating distributed water production that reduces resupply and storage requirements and supports a self-sustainment concept of 3 to 7 days without resupply. The objective is achieving 7 gallons of water produced for every one gallon of fuel used.¹²⁷

The U.S. army must take aggressive steps to manage the risk of emerging technologies. As with any emerging technology, there is a risk. There is a risk in the level of investment of both finances and resources. The amount of time given to the research versus the payoff. The hazard of hydration is identified and through investment, research and development, and partnerships, controls can be emplaced to mitigate, monitor, and ultimately reduce the risk.

The Department of the Army must seek partnerships with foreign regional militaries and organizations who have proven the ability to operate in an arid environment and leverage these techniques and apply them to U.S. military operations. Investments already by the Marine Corps in 2012 proved their worth. The Individual Water Purification System Block II allowed Marines to

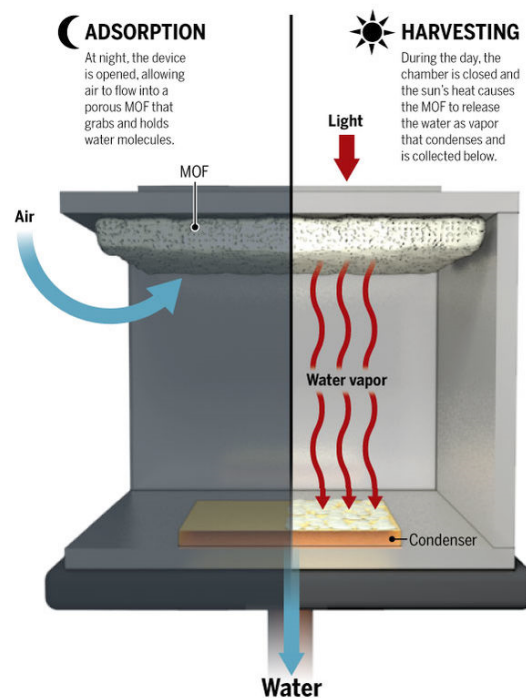
126. Ibid.

127. Burden, Jr., Charles E. Team Leader for Petroleum, Water and Material Handling Equipment, Combined Arms Support Command. Telephone interview by author, April 10, 2018.

self-purify water directly from the source. This system reduces weight and logistics supporting an ever-growing expeditionary force.¹²⁸ In the 2000s in Iraq, over 864,000 bottles of water were consumed each month at one Forward Operating Base (FOB) with that number doubling during hotter months.¹²⁹ Reducing the dependence on bottled water dramatically reduces the number of logistics formations freeing up that force structure for deliberate operations. Further reducing the cost of water was the Army's expenditures in the past for the Lightweight Water Purifier Units. This system developed in early 2002 by MECO Defense cut the price of a gallon of water from \$5.00 to \$.07.¹³⁰

The Army must look at commercial, off-the-shelf (COTS) technologies to create a more self-sufficient warfighter. One of the most recent developments is in the area of atmospheric water gathering. Some researchers estimate there may be as much as 13 trillion liters of water in the air. Previous techniques have proven costly to operate regarding fuel. There is a newer device called a water harvester. Using metal-organic frameworks (MOF), scientists are creating a reaction to force water vapor in the air to condense producing 3 liters of water for every liter of material used.¹³¹ (See Figure 6.)

Figure 6: Illustration of a micro water collector¹³²



Ironically, Dr. Jay Dusenberry and his team at the U.S. Army Tank Automotive Research Development & Engineering Center (TARDEC), as early as 2003, worked on similar technology.¹³³ His opinion is an approach which focuses on multiple technologies such as small unit purifiers, desalinization, and reverse osmosis to supplement an atmospheric water gatherer. This is another capability that allows units to produce their own water. This paired with the water harvesting or mounted on a robot may provide complementary capabilities that would support sustainment for units over a wide range of operational scenarios and environmental conditions. He stresses the goal must be to produce as much water as possible at the point of need.

The U.S. Army continues to make great strides on ways to reduce its dependency on this time-proven supply

128. Browne, Mathuel. "Marines Invest in New System to Purify Water on the Go." *Armed with Science: The Official US Defense Department Science Blog*. 2017. <http://science.dodlive.mil/2017/02/01/marines-invest-in-new-system-to-purify-water-on-the-go/>.

129. Vitter, Scott and Corey James. "In a Position to Lead: How Military Technology and Innovation Can Ease the World's Water Challenges." *Earth Magazine*. 2017. <https://www.earthmagazine.org/article/position-lead-how-military-technology-and-innovation-can-ease-worlds-water-challenges>.

130. Klie, John and Stephen Rome. "US Army Reduces Water Costs with Mobile Purifier Units." *Water and Waste International*. 2005. <http://www.waterworld.com/articles/www/print/volume-20/issue-10/features/us-army-reduces-water-costs-with-mobile-purifier-units.html>.

131. Service, Robert F. "This new solar-powered device can pull water straight from the desert air." *Science*. 2017. <http://www.sciencemag.org/news/2017/04/new-solar-powered-device-can-pull-water-straight-desert-air>.

132. Ibid.

133. Dusenbury, Jay. "Water Treatment and Harvesting Systems." *US Army TARDEC/DARPA*. 2003. <http://www.dtic.mil/dtic/tr/fulltext/u2/a461465.pdf>.

process, but current funding priorities potentially will derail this effort in the areas of research and development. The technologies are appearing in the private sector which requires assimilation into the military formations. Force structure alone will not solve this problem. Soldiers operating in contested arid environments with reduced water sources need the ability to collect water from the atmosphere. Local procurement of water may not be safe or accessible due to conflict. The technology research being recommended could reduce conflict if placed in these water-challenged areas reducing or eliminating the need for U.S. military presence. The issue may well be served by the Cross Functional Teams (CFTs) model to address this dilemma aggressively.

Problem: Lack of adequate preparation and coherence in doctrine, training, and capabilities development to support effective Arctic operations.

Recommendation: The Army and the Department of Defense must begin planning and implementing changes to training, equipment, doctrine and capabilities in anticipation of an expanded role in the Arctic associated with global climate adaptation.

Implementation Timing: Now to 10+ Years.

Resource Requirements: Moderate to High.

Beginning immediately, the Army should implement Arctic training for a greater number of units to increase potential Arctic force capacity. In addition, the Army must focus on immediate doctrine development that will facilitate operations in remote and extreme environments. In the mid-term, over the five to ten-year span, the Army should focus on materiel solutions to operating in environmental extremes, coupled with execution of more environmentally friendly training practices. To enhance operational effectiveness, DoD must increase GPS satellite distribution to augment Arctic coverage and provide enhanced navigation capabilities through the establishment of eLORAN throughout U.S. and allied Arctic regions. Finally, long term focus must be placed

on research, development and fielding of vehicles and equipment that have a decreased environmental impact and are able to transit the Arctic terrain effectively.

In terms of resource allocation requirements for the force, implementation for expansion of Arctic capabilities and capacity is a low to moderate priority in the near to mid-term. This priority increases to high from the mid to long term horizon. Correspondingly, the resources required for implementation of these recommendations also increase over time. Increased training and doctrine development are simply a reprioritization of existing resources, focused on burgeoning capabilities. In the mid-term, materiel solutions and augmentation of navigation capabilities for the Arctic are moderately resource intensive. Finally, the research, development and fielding of low environmental impact equipment with enhanced Arctic capabilities is very resource intensive and will require compromises and a realization of the increased importance of Arctic security.

The Arctic remains at the forefront of the earth's climate adaptation and variances in the global climate are most noticeable in the Arctic region. Increased accessibility to the region for economic activity will consequently increase the security requirements and competition in the region. Currently Russia is rapidly expanding their Arctic military capabilities and capacity.¹³⁴ The U.S. military must immediately begin expanding its capability to operate in the Arctic to defend economic interests and to partner with allies across the region.

The Intergovernmental Panel on Climate Change's 2014 report illustrating the Representative Concentration Pathway (RCP) 4.5 model shows the Arctic Region anomalous temperature change through 2050 from +3 up to +6 degrees Celsius, more than any other area on the globe.¹³⁵ This rapid climate change will continue to

134. Nudelman, Mike and Bender, Jeremy. "This Map Shows Russia's Dominant Militarization of the Arctic." *Business Insider*. 2015. <http://www.businessinsider.com/chart-of-russias-militarization-of-arctic-2015-8>.

135. "Fifth Assessment Report - Synthesis Report." *Intergovernmental Panel on Climate Change*. 2015. <http://ipcc.ch/report/ar5/>

result in increased shipping transiting the Arctic,¹³⁶ population shifts to the region and increased competition to extract the vast hydrocarbon resources more readily available as the ice sheets contract.¹³⁷ These changes will drive an expansion of security efforts from nations across the region as they vie to claim and protect the economic resources of the region.

In this role, the Army must be trained and equipped to operate across vast distances in extremely remote and inhospitable terrain. Choosing not to prioritize resources to this effort puts the Army at substantial risk. Simply put, the competition for resources in the Arctic will increase security requirements and the potential for conflict. The Army will not be excluded from those requirements or any conflict that develops. The Army will simply be unprepared for the mission and the environment in which it will occur. This results in a significantly increased risk to mission as well as to personnel and equipment. Further risk is entailed with respect to service competition for resources. As Russian activity expands in the Arctic, both the Navy and the Air Force will compete for resources to meet the Russian threat. The Army must compete as well, not only to simply gain resources, but, moreover, to be ready to contribute as a member of the joint force.

There are three primary timelines associated with these recommendations: near term (immediate to 5 years), mid-term (5-10 years) and long term (beyond 10 years). Generally speaking, the investment associated with implementing the recommendation corresponds with the timeline, with more immediate recommendations being less cost intensive than longer term ones.

The first near term recommendation is to simply increase the number of soldiers and units exposed to

training in the Arctic environment. The extreme climate and remoteness of the region requires specialized training that is currently available to only a small number of Army soldiers. This expansion in training must be accompanied by development of doctrine that addresses how brigades will fight in remote environments. In a wide area security mission in the Arctic's vast expanse, a brigade will be expected to defend a much wider area, forcing battalions to operate in a more autonomous mode, removed from bases of supply and centralized command nodes. Expanding area coverage requirements will drive the development of advanced persistent sensors, both air and ground based, that can operate in extreme climactic environments to enable the brigades and battalions to detect enemies and maneuver to counter potential attacks.

These near-term recommendations do not require a great deal of immediate investment. Primarily, the Army would need to reprioritize training funding to expand throughput and attendance at Arctic training areas. Additional investment would be required for sensor development, but the current capabilities both in the inventory and in commercial applications are not far removed from those the Army will require to meet near-term needs.

The mid-term recommendations will require close coordination between the Army and other elements of the DoD. The first series of recommendations concerns materials engineering solutions to problems associated with current equipment in cold weather environments. For example, the current rotary wing fleet has many restrictions on cold weather operations concerning battery usage and life as well as requirements for auxiliary power unit (APU) operations and fragility of elastomeric bearings in the tail rotor sections. These restrictions are easily mitigated when conducting operations from controlled environment hangars but will severely hamper maneuver operations from austere locations.

Next, in conjunction with the other services, the Army must expand search and rescue capabilities in the Arctic. An increase in population, economic activity and

[syr/](#).

136. Amos, Jonathan. "Arctic Ocean Shipping Routes 'to Open for Months'." *BBC News*. 2016. <http://www.bbc.com/news/science-environment-37286750>.

137. Keil, Katherine. "The Role of Arctic Hydrocarbons for Future Energy Security." *Nautilus Institute for Security and Sustainability*. 2014. <https://nautilus.org/napsnet/napsnet-special-reports/the-role-of-arctic-hydrocarbons-for-future-energy-security/>.

unit training will increase requirements for search and rescue assets. Recently the Army has abdicated primary search and rescue responsibilities to the Air Force, as the proponent for combat search and rescue. However, the Army should expand capabilities and training to minimize response time for contingencies.

Additionally, in conjunction with the DoD and other services, the Army must invest in expanding Arctic navigation capabilities. Lack of GPS differential, ionospheric storms and low angle satellite intervisibility combine to reduce the effectiveness of GPS at high latitudes.¹³⁸ The DoD can mitigate this risk through augmentation of the GPS satellite fleet that will enable greater GPS differential to increase geolocation accuracy. Furthermore, establishment of eLORAN land-based navigation facilities to augment satellite aided navigation will ensure both accuracy and redundancy for operation in remote Arctic areas. Consideration should also be given to the limitations of satellite aided communications in the Arctic as any geosynchronous platform will experience the same limitations as the GPS satellites.

Finally, in the mid-term the Army must focus on reducing the environmental impact of training. The Arctic will remain a delicate environment that the public looks to as “unspoiled” wilderness. Operations that damage or degrade the environment will foster a negative view of the Army and must be mitigated through careful training execution that minimizes the risk of petroleum spills and localizes training impacts to the smallest area possible. There are further recommendations associated with this challenge for long term consideration.

Taken together, these mid-term recommendations will require moderate investment to bring to fruition. Material solutions to cold weather operating challenges are available for many of the Army’s current platforms, however those materials will need extensive testing to incor-

porate into those platforms. Additionally, it is critical that those material solutions be viable across the spectrum of operational conditions as it is not realistic, for example, to install different batteries, APUs and bearings for different environments across the rotary wing fleet. Expanded search and rescue capabilities and capacity will require investment in both equipment and training. However, the equipment required is available either within other services or is currently in use in commercial applications. The most cost intensive of the mid-term recommendations is augmentation to navigation and communication capabilities. However, these costs can be somewhat mitigated through normal satellite attrition and replacement with upgraded capabilities. Additionally, low earth orbit (LEO) satellite options can be employed that simply augment coverage in the Arctic region. LEO satellites are less expensive to deploy and limited capabilities for a limited coverage area may decrease per unit costs.

The final recommendation considers long-term solutions to the challenge of increased operations in the Arctic. As previously discussed, the austere and remote nature of the Arctic, as well as the vast area under consideration will require units to operate in a much larger area than current doctrine dictates. This will significantly stress the Army’s logistics capability to support those units in an environment with little transportation infrastructure. To mitigate this, the Army must invest in platforms that are far more fuel efficient or that operate off of alternative energy sources. A diminishing reliance on hydrocarbon-based fuels will not only decrease logistical requirements but will also decrease the environmental impact of operations in the Arctic. These developments can put the Army at the forefront of environmental stewardship and ensure that the public remains firmly rooted behind the Army’s efforts.

In conjunction with development of new fuel sources, the Army must explore vehicles more well-suited to Arctic maneuver. Thawing of the permafrost will create large expanses of bogs and marshes across many areas of the Arctic. In addition, though the globe is warming, extreme weather conditions will persist in the Arctic.

138. “Polar Regions.” *The Swedish Club: International Marine Insurance*. Accessed April 16, 2018. <https://www.swedishclub.com/loss-prevention/trading-area/polar-regions/>.

The Army needs to focus on the development of an infantry carrier vehicle with low surface pressure to maximize maneuverability in adverse terrain. An amphibious capable vehicle that has high weight distribution characteristics across the drive (either wheeled or tracked) contact patches will increase the speed of maneuver necessary for units to conduct wide area security across greater coverage areas.

These long-term recommendations will require significant investment to come to fruition. Research and development of new fuels and a new class of vehicles is a long lead time requirement that the Army must begin investing in now. However, the research into new fuels or energy sources can be shared across the services and is already underway in many cases. Commercial companies are also well invested in these capabilities already. Public demand is driving innovation in this field and will help mitigate costs for the Army in development and fielding.

RECOMMENDATION AREA 2: THE ARMY INSTITUTION

Problem: The Lack of a Culture of Environmental Stewardship

Recommendation: *Army leadership must create a culture of environmental consciousness, stay ahead of societal demands for environmental stewardship and serve as a leader for the nation or it risks endangering the broad support it now enjoys. Cultural change is a senior leader responsibility.*

Implementation Timing: Now

Resource Requirements: Low

The Army has attempted some small-scale efforts at environmental stewardship. At installations across the country there are areas that are off limits to training because some endangered species is resident there. In nearly every office there is a blue recyclables trash can and most installations have a recycle program

that awards the unit that brings in the most waste to the recycling facility. This program, however, is a great example of one of the obstacles to environmental consciousness in the Army. In order for a unit to receive an annual award that may amount to \$500 deposited into the unit's Morale, Welfare and Recreation (MWR) fund, every soldier in the unit must make the individual effort to identify those items eligible for recycling, separate their trash and then dispose of that trash in a special receptacle. The unit must then transport that refuse to the post recycling facility for credit. This is a classic example of concentrated costs with dispersed benefits, as demonstrated in Mancur Olson's *Logic of Collective Action*.^{139,140} The reward is distributed to the organization, but not to the individual and therefore the individual does not see the direct benefits of his efforts to recycle. Whatever events may be sponsored from the MWR fund would likely occur anyway. The only benefit of the recycling award is that potentially the soldier may get an extra hamburger at the MWR picnic. This is not much of an incentive. Creating and promulgating a culture of environmental stewardship throughout an organization as vast and diverse as the Army will take years, and the tide of public opinion shows no signs of slowing.

The Army's norms and values must change.¹⁴¹ The Army does not have a set of norms that promotes environmental stewardship or leadership where it is in the best interest of the force. To create these, the underlying assumptions that focus simply on the *ends* must change to consider the *ways*. Edgar Schein maintains that those assumptions are based on deeper dimensions such as

139. Olson, Mancur. *The Logic of Collective Action: Public Goods and Theory of Groups*, 2nd ed. Cambridge: Harvard University Press, 1971. Olson argued that in a large, or what he called *latent*, organization, rewards and punishment used to incentivize a greater good must be administered at the private level to incur direct costs or consequences associated with a given behavior.

140. Congleton, Roger D. "The Logic of Collective Action and beyond." *Public Choice Online* 164, no 3-4: 219. 2015. <https://search-proquest-com.usawc.idm.oclc.org/docview/1727606018?pq-orig-site=summon>.

141. Gerras, Stephan J., Leonard Wong and Charles D. Allen. "Organizational Culture: Applying a Hybrid Model to the U.S. Army." *US Army War College*. 2008: 6.

reality, truth and human activity.¹⁴² These are the same challenges echoed in climate change debates today.

The youth of the military is a powerful potential source of cultural change. If the younger population as a whole is more environmentally conscious in the United States, it stands to reason that the younger members of the military will be as well. However, the military as a highly hierarchical organization is resistant to the adoption of innovative input from lower ranking and younger individuals.

Army leaders can achieve the necessary cultural change through what Schein calls *embedding* and *reinforcing* mechanisms. “Embedding mechanisms emplace the assumptions into an organization,” while “reinforcing mechanisms...support the embedded assumptions.”¹⁴³ Schein’s first embedding mechanism are those things that leaders pay attention to or measure on a regular basis. If Army leaders, for example, rewarded units with the lowest per soldier energy consumption in the barracks, that may create lower energy consumption. To use another embedding mechanism in this example, if the reward was a day room in the barracks outfitted with the latest Xbox or PlayStation, a UHD 70” OLED TV and the fastest Wi-Fi, the soldiers would see the benefit of reduced individual electricity consumption through a reward that they can individually appreciate. Finally, perhaps the most effective embedding mechanism is for Army leaders to put their money where their mouth is. How the Army chooses to allocate future resources will communicate to the soldiers where the real focus lies. Significant increases in the budget for simulations as well as R&D for alternative fuels and energy efficient platforms will help anchor the organizational changes into the long-term culture of the Army.

To support these embedding mechanisms, Schein suggests aligned reinforcing mechanisms, without which “cultural change is much more difficult, if not impossi-

ble”.¹⁴⁴ The first of these is a change to organizational design or structure necessary to support the cultural change. An example of this might be to decrease future investments in logistical support capacity to match decreased support requirements achieved through increased fuel efficiency. These investments could then be redirected into developing additional combat capacity or capability.

Another important mechanism is the design of physical spaces and buildings. A focus on energy efficient design and renewable energy sources will reinforce a sense of conservation and efficiency. Couple this tactic with formal statements of mission and organizational philosophy that include references to environmental stewardship posted on the ubiquitous unit bulletin boards will support the foundational assumptions put in place by the embedding mechanisms.

The Army is at a crossroads. The current administration may have backed out of the Paris Accords, but the majority of the American people believe that climate change is a threat. Steps taken now can put the Army on a path to lead the nation in preparedness and environmental awareness. At the same time, the Army may come to recognize environmental awareness, not as an add-on, but as a core strategy to ensure the force is leveraging all insights possible for war-fighting and U.S. preparedness. Alternatively, the Army can continue its present trajectories, ignoring the myriad existing and potential threats that result from climate change and environmental concerns more broadly, including alienation of youth, allies and voters on whose largesse it depends, hurtling through the night in the belief that it is as unsinkable as the Titanic.

142. Ibid

143. Gerras, Wong, and Allen, 17.

144. Gerras, Wong, and Allen, 19.

Problem: Potential disruptions to readiness due to restrictions on fuel use.

Recommendation: *The Army must significantly increase investment in more realistic simulation that incorporates the advances in virtual and augmented reality. It should also continue to invest in the development of lower CO2 emissions platforms and systems.*

Implementation Timing: 6-10 years (VR/AR), 10+ years (alternate energy platforms).

Resource Requirements: Moderate to High.

The Army must significantly increase investment in more realistic simulation that incorporates the advances in virtual reality. The current resistance to greater simulation in training is primarily based on a lack of simulation realism.¹⁴⁵ However, the technology to perfectly replicate the sights, sounds, smells and feel of weapons, platforms and situations is developing rapidly. The Army is at risk of being left behind.

This change will impact nearly every facet of Army operations today. Nothing is likely to fully replace field training in the foreseeable future. However, the Army must invest now in developing future capabilities. The required investments cross the entire range of activities, from administration to training to combat.

Currently Army investment in virtual training is primarily based on the Virtual Battle Space (VBS) simulation platform that most of industry has already abandoned in favor of the Unity platform, "the engine of choice among virtual reality developers".¹⁴⁶ The Army is not investing enough in simulations to be agile and change with the industry, or to command industry trends. The 2018 Na-

tional Defense Authorization Act authorizes nearly \$700 billion in military spending for the year, yet industry expects the entire U.S. military to invest only \$48.9 billion in simulations through 2025.¹⁴⁷ Greater simulation investment can create overall budget savings. Depending on the airframe, training in flight simulators costs only 5-20% the cost of operating the actual platform.¹⁴⁸ Beyond the environmental impact, increased investment in simulations can result in decreased training costs, longer life for the actual platforms, an increased opportunity for training repetitions and improvements in acquisition through better environments for prototyping and new platform integration.

Finally, the Army's primary platforms, its weapons systems and the vehicles, are not designed for energy and fuel efficiency or to minimize the impact to the environment. Alternative fuel research and new technologies that limit emissions and increase fuel efficiency are expensive. The slow pace of military acquisition ensures that development and integration of these technologies into future platforms will be laborious and incremental. However, if current requirement documents do not reflect an organizational drive to change the environmental footprint of future systems, the Army will remain decades behind the public demands.

145. "Going Virtual to Prepare for a New Era of Defense." *Government Business Council*. 2014. http://cdn.govexec.com/media/gbc/docs/gbc_rc_going_virtual_final.pdf.

146. Tucker, Patrick. "Better Simulation Could Save the Military Millions." *Defense One Online*. 2015. <http://www.defenseone.com/technology/2015/01/better-simulation-could-save-military-millions/104172/>.

147. "Military Simulation and Virtual Training Market: \$15.8B Worth Global Opportunity by 2025." *Cision PR Newswire Online*. 2015. <https://www.prnewswire.com/news-releases/military-simulation-and-virtual-training-market-158b-worth-global-opportunity-by-2025-499209471.html>.

148. "Going Virtual to Prepare for a New Era of Defense." *Government Business Council*. 2014. http://cdn.govexec.com/media/gbc/docs/gbc_rc_going_virtual_final.pdf.

RECOMMENDATION AREA 3: THE JOINT FORCE AND DoD

Problem: Lack of coordination and consolidation in climate-change related intelligence.

Recommendation: *Advocate for a comprehensive organization, functional manager, technology, and process review study to identify the current state of intelligence community agencies with regard to climate change, with the goal of formalizing Interagency coordination on Climate Change-related intelligence.*

Implementation Timing: Now

Resourcing Requirements: Low

To support and improve interagency collaboration in the Intelligence Community (IC), the Office of the Director of National Intelligence (ODNI) should initially assign an office and/or National Intelligence Manager (NIM) with the requisite authority and budget to coordinate and champion climate change endeavors within the IC and greater interagency. This office and/or NIM should manage a comprehensive organization, functional manager, technology, and process review study to identify the current state of IC agencies regarding climate change. Following the completion of the review, an IC-wide Climate Change strategy should be developed.¹⁴⁹

The IC should dedicate collection, targeting, and analysis resources into monitoring global geo-engineering technologies and state-programs. This area of technology focus and growth is expected to continue globally; this topic, therefore, should be added to the National Intelligence Priorities Framework (NIPF).¹⁵⁰

The IC should partner with allied nations on the collection and analysis of climate-related intelligence. This partnership should be included in existing partner engagement programs.

The National Intelligence Council should lead and ensure the reoccurring completion of a National Intelligence Estimate or akin intelligence assessment for use across the United States and partner governments, non-governmental organizations (NGOs), industry, and academic institutions. The Defense Intelligence Agency – in coordination with the Department of Defense – should lead and ensure the reoccurring completion of a Defense Intelligence Assessment on climate change drivers that are expected to affect the security environment globally. Both assessments should identify threats and opportunities for the National Security apparatus.

DoD Combatant Command theater and operational plans could be improved by including climate and related systems which affect the security environment into existing processes like, Joint Intelligence Preparation of the Environment (JIPOE), Infectious Disease Risk Assessments, and Country Cooperation Plans.¹⁵¹ Inclusion of climate change data into existing and complementary intelligence planning processes would improve the Joint Planning Process and meet DoD's statutory requirements.

Initial resourcing for IC expansion to include climate change into existing products and processes is expected to be minimal. IC, DoD and natural science agencies are manned to react to burgeoning national security issues. Sensor improvement that can better collect on climate change and related driver issues can be included in requirement generation for future programs.

In terms of a NIM or like office to champion this issue in the IC, the ODNI may need to provide an initial allotment

149. "Functional Managers." *Office of the Director of National Intelligence: Intelligence Community Directive 113*. 2009. https://www.dni.gov/files/documents/ICD/ICD_113.pdf.

150. "National Intelligence Priorities Framework." *Office of the Director of National Intelligence: Intelligence Community Directive 204*. 2015. https://www.dni.gov/files/documents/ICD/ICD_204_Na-

[tional Intelligence Priorities Framework.pdf](#).

151. Defense Intelligence Agency, National Center for Medical Intelligence, "Infectious Disease Risk Assessment Methodology," in Annex.

of NIP funds for 2-3 years until programmatic can be determined.

The National Intelligence Council identified climate change and related drivers of instability were identified as a global trend with implications for the national security environment by 2035.¹⁵² The IC and DoD are the responsible government-arms to observe, track, assess, and respond to national security threats that are increasingly emanating from climate change drivers.

While climate change and related drivers are expected to increasingly affect and change the global landscape, there is still time. Initial investments in the next 5-10 years will ensure applicable government department and agencies are right fit for the future.

Secretary of Defense Mattis stated, “I agree that the effects of a changing climate – such as increased maritime access to the arctic, rising sea levels, desertification, among others– impact our security situation.” To respond to these security implications he then indicated, “It is appropriate for the Combatant Commands to incorporate drivers of instability that impact the security environment in their areas into planning.” The Chairman of the Joint Chiefs of Staff, General Joseph Dunford, explained military forces may have to be prepositioned globally to respond to natural disasters and other crises that are as a result of climate change.¹⁵³

In June 2016, CIA Director John Brennan spoke at the Council on Foreign Relations, stating, “An Stratospheric Aerosol Injection (SAI) program could limit global temperature increases, reducing some risks associated with higher temperatures and providing the world economy additional time to transition from fossil fuels. The process is also relatively inexpensive—the National

Research Council estimates that a fully deployed SAI program would cost about \$10 billion yearly.”¹⁵⁴

The last two National Defense Authorization Acts and Intelligence Authorization Act noted climate change, food system security and stability, and other related issues that affect the IC and DoD’s missions. These Congressional acts require the IC and DoD to study, analyze, and identify where these emerging areas affect their mission areas and the security environment.

Problem: Lack of Organizational Accountability for Climate-Change Related Activities

Recommendation: Re-commit to the Senior Energy and Sustainability Council (SESC). Add a resourcing element to the council by providing the USA and VCSA with funding across each POM cycle to support climate-related projects that improve readiness and resiliency of the force.

Implementation Timing: Now, 1-10 Years

Resource Requirements: Low, though potentially moderate through reprogramming.

There are a variety of options for rallying an organization around a mission. For enduring issues, the goal should be to institutionalize the thought. In other words, create a culture where military and civilians regularly consider how their mission could be impacted by climate change. The goal for enduring issues should also be to institutionalize the process, so that the mission does not get disconnected from the normal battle rhythm of a bureaucracy. When a disconnection happens, these missions lose visibility, prioritization, and oftentimes, resourcing.

Climate change will present a challenge to the Army and

152. “Global Trends, Paradox of Progress.” *National Intelligence Council*. 2017: 6. <https://www.dni.gov/files/documents/nic/GT-Full-Report.pdf>.

153. “National Defense Authorization Act for Fiscal Year 2018 – Sec. 335.” *115th Congress of the United States of America*. 2017. <https://www.congress.gov/115/bills/hr2810/BILLS-115hr2810enr.pdf>.

154. “Director Brennan Speaks at the Council on Foreign Relations.” *Central Intelligence Agency – News and Information*. 2016. <https://www.cia.gov/news-information/speeches-testimony/2016-speeches-testimony/director-brennan-speaks-at-the-council-on-foreign-relations.html>.

the DoD for decades to come. With readiness as the number one priority, mitigating the disruption caused by extreme weather activity should be included amongst the Army's goals. The Army must be able to train, fight, and win across all domains and in all environments. To do this will take a collective effort to ensure a wide range of missions are able to support the needs of the force.

Considering the challenges presented by climate change, the Army should re-energize the Senior Energy and Sustainability Council (SESC) within the next six to twelve months. This cross-functional council can address complex, ambiguous problems routinely and ensure its recommendations are integrated across the organization. As the proponent for SESC, ASA IE&E already collaborates as-needed across the enterprise. SESC Council of Colonels level meetings are held periodically, but this is not a decision-making forum. A quarterly meeting at the General Officer Steering Committee (GOSC) and a semi-annual meeting with the Under Secretary of the Army and Vice Chief of Staff of the Army, will signal the importance of the issue, improve its visibility, and provide direction on prioritization of efforts. Policy drives resources, and a senior leader-driven council can shape how the Army operates in what will become one of the Army's future challenges. And for the Secretary of the Army and the Chief of Staff of the Army, the SESC will be their center of gravity for "All Things Climate Change." It will provide them with an organization that will: ensure their priorities are being addressed; oversee what the Army is doing to address climate change; and make strategic decisions about where to invest and take risk.

The Army should also add a resourcing element to the council by providing the USA and VCSA with funding across each POM cycle to support climate-related projects that improve readiness and resiliency of the force. The SESC could champion innovation by having funds available for organizations to compete to have climate-related projects. With an ability to resource projects, the SESC has the ability to make tangible changes on the ground that affect the force and local communities. Although it is difficult to predict when an extreme

weather event will occur or how it will affect military operations, the Army must leverage the knowledge and resources it has to build resilience across the force. As retired General Martin Dempsey noted, "[w]e need to act based on the information we have, not remain immobile waiting for 'better options' to emerge."¹⁵⁵ Senior leader involvement will be key in creating a resilient force of the future.

Problem: Lack of Climate Change-Oriented Campaign Planning and Preparation

Recommendation: (A) Develop Bangladesh Relief Campaign Plan as notional plan for preparing for broader climate change-related requirements. (B) Work more closely with the CDC to ensure appropriate military support to infectious disease treatment and containment.

Implementation Timing: Now

Resource Requirement: Low

Bangladesh Crisis Campaign Plan

Climate change is likely to cause an increase in catastrophic climatic events. Some of these events, such as tropical cyclones, will have an acute impact on the affected residents of any given region. Others, such as relative sea level rise and increased desertification, will have a more long-lasting effect. Even acute incidents, given an increasing frequency and severity, may have impacts on the population that are more chronic in effect. The result of these events is likely to manifest itself in increased population migration to escape the destabilization brought on by climate change.

The DoD is unlikely to dedicate significant resources to better preparing the force for humanitarian and disaster response (HADR) missions. However, it should analyze areas where climate change events are likely to exacerbate other political, economic or social issues

155. Dempsey, Martin and Ori Brafman. *Radical Inclusion*. USA: Missionday. 2018: 120.

and where the scale of the potential human migration will tip the balance toward conflict and mass humanitarian strife. In other words, those areas where the United States will be compelled to respond. After an analysis to determine those areas at greatest risks, the Army should develop a campaign plan-like approach to mitigate future risk and to set conditions for a more successful response, if necessary.

The U.S. should immediately initiate a campaign plan to mitigate the effects of future crises and set conditions for more effective assistance. We recommend developing a campaign based on the notional scenario of a massive, permanent dislocation of the population of Bangladesh, rated as the planet's most at risk country from climate change, according to Verisk Maplecroft, a global risk analysis firm.¹⁵⁶ Additionally, Germanwatch, funded by the German Federal Ministry for Economic Cooperation and Development, rates Bangladesh as already the sixth most impacted country from climate events in the last 20 years.¹⁵⁷ Other factors also combine to create an even greater probability that the United States would intervene if a humanitarian disaster struck Bangladesh.

As discussed above, nearly 160 million people live in Bangladesh, nearly half of them at sea level.¹⁵⁸ Sea level rise and alluvial subsidence has resulted in a relative sea level rise for the delta of approximately 1.5 meters since 1960.¹⁵⁹ Both Al-Qaeda and affiliates of ISIS are currently active in Bangladesh.¹⁶⁰ In summary, 80 million

people fleeing an uninhabitable portion of their country in what is already one of the most densely populated countries on earth will have nowhere to go. Bangladesh's neighbor, India, is a nuclear armed country persistently in conflict with Pakistan and with which the United States is trying to forge stronger ties to counter Chinese regional influence. These factors will drive U.S. involvement in any crisis.

This approach is not resource intensive but will significantly reduce mission risk. The military, in conjunction with interagency partners such as the State Department and USAID, should immediately establish liaison teams to work closely with the Bangladeshis to understand their plan to deal with internal migration and the resources they have available. After this analysis the U.S. can offer assistance to strengthen the resilience of government agencies and provide training for the Bangladeshi military. The Army Corps of Engineers, in conjunction with multi-national partners, can assist the Bangladeshis in determining what effective steps to take that can slow the effects of relative sea level rise. Through the State Department the U.S. should work with the Indian Government to establish a crisis response team with Bangladesh to help ensure mass migration does not result in conflict. Humanitarian relief supplies should be prepositioned at Diego Garcia to speed the response effort. In addition to interagency efforts, the U.S. should reach out to multi-national partners to determine what kind of coalition can be built to respond to the region, preventing the inefficient and piecemeal collaboration of an ad hoc coalition.

This is just a short list of the many steps the U.S. can take in an area where future intervention is highly likely. Through analysis, the U.S. can determine where, globally, campaign plans should be instituted so that the response efforts are less the execution of a hastily assembled contingency plan and more the sequenced execution of a resourced and ready plan.

156. "Environmental Risk and Climate Change." *Verisk Maplecroft*. 2011. <https://www.maplecroft.com/about/news/ccvi.html>.

157. Eckstein, David, Vera Kunzel, and Laura Schafer. "Global Climate Risk Index 2018." *Germanwatch: German Federal Ministry for Economic Cooperation and Development*. 2017. <https://germanwatch.org/en/download/20432.pdf>.

158. Greenfieldboyce, Nell. "Study: 634 Million People at Risk from Rising Seas." *National Public Radio*. 2007. <https://www.npr.org/templates/story/story.php?storyId=9162438>.

159. Schmidt, Charles W. "Delta Subsidence: An Imminent Threat to Coastal Populations." *Environmental Health Perspectives*, Vol. 123: 8. 2015. <https://ehp.niehs.nih.gov/doi/10.1289/ehp.123-A204>.

160. "The World Factbook: Bangladesh." *US Central Intelligence*

Agency. 2018. <https://www.cia.gov/library/publications/the-world-factbook/geos/bg.html>.

Infectious Disease Treatment and Containment Support

The research in this report indicates a greater likelihood for outbreaks of vector borne infectious diseases worldwide, including in the United States. The Intergovernmental Panel on Climate Change (IPCC) research using Representative Concentration Pathways (RCP) 4.5 data (the midrange prediction of climate change used throughout this report) predicts areas in the Southeastern U.S. will see an increase in precipitation of .5-.8 mm/day and an increase in average annual temperatures of 1-3 degrees Celsius by 2050.¹⁶¹ This change will likely allow the proliferation of disease vectors (such as mosquitoes and ticks) over a wider area than they currently inhabit and limit Winter kills of the vectors, resulting in a larger population to spread any diseases. This phenomenon is likely to increase the incidence of diseases such as Zika, West Nile Virus, Lyme disease and many others, some of which may be previously unseen in the U.S. As the largest source of potential capacity and capability to respond to widespread disease outbreaks in the United States, the military should be prepared to execute defense support to civil authority (DSCA) missions of this type.

The Centers for Disease Control (CDC) in Atlanta, Georgia undoubtedly has robust and detailed plans for widespread disease response. The Army, through the DoD, must liaise closely with the CDC and the IC to determine the validity of the plans and the expectations of the military in assisting in the response. Response to disease outbreaks generally follows two tracks, containment and treatment. From a military standpoint, containment of the disease resembles wide area security operations, and treatment is a robust logistics effort. The Army excels at these tasks.

To ensure proactive response, the active force, in support of Reserve Component units, should predetermine locations for key logistics nodes throughout the areas

most at risk. These nodes will require APODs, rail links and robust highway systems to speed the deployment of equipment and materials. Appropriate medical facilities should be identified capable of providing patient isolation and those areas lacking that capability must be identified. Army assets can fill those capability gaps in more remote areas.

Climate change is introducing an increased risk of infectious disease to the U.S. population. It is increasingly not a matter of "if" but of when there will be a large outbreak. The U.S. Army will be called upon to assist in much the same way it was called upon in other disasters. Detailed coordination with local, state and federal agencies in the most high risk regions will hasten response time and minimize risk to mission.

RECOMMENDATION AREA 4: NATIONAL CONTEXT

Problem: Power Grid Vulnerabilities

Recommendation: A. *An inter-agency approach, coupled with collaboration of the commercial sector, should catalogue the liabilities across the electrical grid and prioritize budget requests for infrastructure improvements.* B. *The DoD should pursue options to reverse infrastructure degradation around military installations, including funding internal power generation such as solar/battery farms and small-nuclear reactors.*

Implementation Timing: Now (A); 6-10, 10+ Years (B)

Resource Requirement: Low (A); High (B)

The susceptibilities of the power grid to climate effects should drive the DoD to pursue options to reverse infrastructure degradation around military installations and ensure that cutting edge strategies for decentralized power generation and storage are employed. Contracts with utilities, including rural electric cooperatives now thought to be especially vulnerable, should contain requirements that mandate tougher cyber security

161. "Climate Change 2014 Synthesis Report." *International Panel on Climate Change*. 2015. <http://ipcc.ch/report/ar5/syr/>.

protocols to limit damage done by the intensive cyber assaults the grid is currently sustaining, and ideally, to preclude further attack to the US electrical grid. This could reduce exposure to fluctuations in the survivability of military capability.¹⁶² The ability to enable safety protocols like Faraday cages would prevent a massive grid failure in the event of a cascading grid collapse allowing for a logical and orderly redistribution of critical power where needed. The development of new options for replacing crucial extra high voltage large power transformers damaged by age and overload will remain essential due to year-long lead times for construction and production of this unique equipment existing outside the country. Additional infrastructure challenges lie in the lack of heavy lift capacity, bridges, and roadways needed to transport these transformers, given each weighing between 200 and 300 tons.¹⁶³ The development of a domestic production capability for these large transformers or innovative new, lighter technologies for replacing those systems remain a significant barrier to recovery from a widespread power outage. Distributed technologies that are hardened to cyber-attack, such as solar installations, may reduce several major classes of vulnerability simultaneously.

One option that has met with success stems from the Smart Power Infrastructure Demonstration for Energy Reliability and Security (SPIDERS) Joint Capability Technology Demonstration (JCTD). The purpose of the test was to improve cyber security around installations, bolster survivability during a blackout using a microgrid and smart grid technology demo and share that knowledge with the non-military services infrastructure supporting the test locations. Successful test results hold promise for investment on military installations across

the DoD, as well as sharing with vital services supplying the military and the community. Adoption of this concept generates the possibility for integration of renewable, like micro-nuclear reactors, and other distributed energy generation concepts to increase endurance during a natural or man-made widespread outage of the power grid.¹⁶⁴ Addition of a SPIDERS infrastructure extends beyond military installations and local communities as cyber security improvements could also lead to protection of uplink and downlink stations thus improving resilience of space borne assets from infection.

The results of the SPIDERS JCTD highlight the importance of infrastructure investment and decisions at DoD facilities while reducing the unacceptably high risk of an extended outage of the power grid. The original SPIDERS initiative launched under the co-sponsorship of the DoD, Department of Energy (DOE), and Department of Homeland Security (DHS) and demonstrated the survivability of an installation protected by a cyber secure micro-grid, smart grid technologies and investment in infrastructure modifications. The SPIDERS technology delivered capabilities tied to power generation reliability, installation and cyber security, reduction of energy costs while being cost effective, and minimizing environmental impacts, all goals the DoD seeks to achieve.¹⁶⁵

The Joint Staff can further signal their support to Congress by addressing this need through use of the Joint Risk Assessment Framework to develop a prioritized list of critical DoD infrastructure necessary to defend the homeland and execute Joint Strategic Capabilities Plan-directed contingency operations. Upon completion of this list and with SPIDERS funding approval, each affected Service can execute necessary activities to harden their networks, infrastructure, and power generation capabilities thus protecting military installations from cyber, physical, or coordinated attacks; electromagnetic

162. Mehta, Aaron. "Pentagon Weighs New Requirements to Secure Military's Vulnerable Power Grid." *Defense News Online*. 2017. https://www.defensenews.com/pentagon/2017/11/29/pentagon-weighs-new-requirements-to-secure-militarys-vulnerable-power-grid/?utm_source=Sailthru&utm_medium=email&utm_campaign=EBB_11.30.17&utm_term=Editorial-Early Bird Brief.

163. Koppel, Ted. *Lights Out: A Cyberattack, a Nation Unprepared, Surviving the Aftermath*. New York, NY: Crown Publishers, 2015: 95-100.

164. "Technology Transition Final Public Report: Smart Power Infrastructure Demonstration for Energy Reliability and Security (SPIDERS)." *Naval Facilities Engineering Command*. 2015. https://energy.gov/sites/prod/files/2016/03/f30/spiders_final_report.pdf.

165. Ibid.

pulse attacks; space weather; and other natural events.

The SPIDERS implementation across the Services promises to lessen the impacts of a U.S. power grid loss while hardening cyber protections to critical response capabilities. The NORTHCOM and PACOM Combatant Commands, Congress, and the Services' working together in support of this critical initiative enable a change in prioritization of infrastructure security, often overlooked, within the defense budget. The cost is such that, with the proper advocacy, a key vulnerability to the homeland defense mission becomes manageable and the Department of Defense priority of protecting the homeland is realized.

Problem: Climate Change and Threats to Nuclear Weapons Infrastructure

Recommendation: The U.S. Department of Defense, in combination with the U.S. Department of Energy (DOE) should develop a long term 15 to 20 year tritium production plan that accounts for advances in nuclear technology and the possibility of rising climate induced water levels as well as increases to the overall average water temperature used to cool nuclear reactors. This plan should include projections of fiscal resources and military tritium requirements needed to maintain and modernize the U.S. nuclear stockpile. It should also include U.S. government requirements for use of helium-3, a decay product of tritium used primarily for neutron detection when searching for special nuclear material (SNM) and enforcing nuclear non-proliferation agreements.

Implementation Timing: Now to 10+ Years

Resource Requirement: High

The U.S. Department of Defense (DoD) in combination with the U.S. Department of Energy (DOE) should develop a long term 15 to 20-year tritium production plan that accounts for advances in nuclear technology and the possibility of rising climate induced water levels as

well as increases to the overall average water temperature used to cool nuclear reactors. This plan should include projections of fiscal resources and military tritium requirements needed to maintain and modernize the U.S. nuclear stockpile. It should also include U.S. government requirements for use of helium-3, a decay product of tritium used primarily for neutron detection when searching for special nuclear material (SNM) and enforcing nuclear non-proliferation agreements.¹⁶⁶

Currently, the Department of Energy conducts tritium production using 2 to 4 commercial nuclear pressurized water reactors (PWRs) run by the Tennessee Valley Authority (TVA).¹⁶⁷ This commercial capability currently meets the U.S. stockpile tritium production capability; however, due to the overall age of the U.S. nuclear power industry, future PWRs may not be available to continue tritium production.¹⁶⁸ The loss of tritium production directly reduces the effectiveness of the U.S. nuclear stockpile by reducing or hindering the overall yield produced by the nuclear warheads. Without an effective U.S. nuclear stockpile, the U.S. cannot deter peer nuclear competitors and rogue nuclear states increasing the risk to all-out war against the United States.¹⁶⁹

Directly tied to tritium production is the future of the nuclear power industry. It is filled with an aging fleet of reactors built in the late 1960s and 1970s. Most receive a commercial license by the Nuclear Regulatory Commission (NRC) to operate on average 30 years, but many have or are seeking extensions to increase the operations out to 40 and 50 years.¹⁷⁰ The age of the industry

166. Special Nuclear Material (SNM) refers to fissile nuclear material such as uranium 235 or plutonium 239 that is used as fuel in nuclear weapons.

167. *NNSA Expanding Tritium Production at TVA Reactors*. Vol. 245 Access Intelligence, LLC, 2010.

168. Horner, Daniel, "GAO Finds Problems in Tritium Production." *Arms Control Association*. 2010. https://www.armscontrol.org/act/2010_11/GAOTritium.

169. Schelling, Thomas C. *Arms and Influence*. New Haven: Yale University Press, 1966: 22-23.

170. Lester, Richard K. "A Roadmap for U.S. Nuclear Energy Innovation." *Issues in Science and Technology* 32, no. 2:45-54. 2016.

and the lack of new reactors coming on-line creates a significant risk to both the environment and the maintenance of the U.S. nuclear stockpile. "The highest priority of nuclear innovation policy should be to promote the availability of an advanced nuclear power system 15 to 20 years from now".¹⁷¹

Nuclear reactors produce far less atmospheric pollution than fossil fuels and radioactive waste can be minimized and managed accordingly. Reducing carbon monoxide emissions in the near future must include a replacement of the underlying nuclear power production capability in this country. Increasing the underlying U.S. baseline nuclear power generation capability from a mere 20% (and declining) to more than 80% (to cover the 60% coal production capability that currently exists) can significantly reduce greenhouse gases.¹⁷² The government will need to lead this expansion which goes against the fossil fuel business paradigms that have existed for more than 100 years. Any nuclear industry expansion must include a long term review of tritium production requirements and analyze how the government will maintain its required tritium production capability.

The production of tritium directly effects the production of helium-3. Tritium has a half-life of 12.3 years. This means that if you have 10 liters of tritium, 12.3 years later you will only have 5 liters. Every time you hit a half-life milestone (every 12.3 years) the volume of tritium available drops in half. After about 7 half-lives, tritium has decayed away to trace amounts. This affects the amount of tritium needed in our existing nuclear stockpile and will not decrease over the next 50 to 75 years.

An added benefit to tritium decay is the production of helium-3. This direct byproduct currently supports the non-proliferation efforts of nuclear inspectors conducting treaty verification, Special Forces conducting critical lost or stolen SNM search missions, and the U.S.

Army's Chemical, Nuclear, Radiological, and Nuclear (CBRN) Response forces conducting troop health and safety sweeps at suspect nuclear and industrial facilities or identifying the detection of SNM at suspect nuclear weapon production facilities. The Defense Threat Reduction Agency currently has research efforts looking at replacing helium-3 as a detection gas since its availability in the future may come into question. The risk to these programs remains high over the next 5 to 7 years until newer viable research methods reveal stable and reliable neutron detection methods for use by the Army's Special Forces and CBRN response forces in the field. The long-term outcome for neutron detection capability remains low due to these new technologies.

Any expansion of nuclear power should also take into account the stability of tritium production to maintain U.S. national security through a strong nuclear deterrence. The DoD, especially the Army, must consider the consequences if the U.S. nuclear stockpile can no longer maintain its effectiveness. Without an effective strategic nuclear deterrent, the risk of conventional conflict will increase.

The strategic nuclear force is the backbone of U.S. national defense. This is the last-ditch defensive capability designed to keep rational peer adversaries out of the U.S. homeland and out of direct conflict with U.S. military forces. Any erosion of this force or its value in present or future conflict mandates the need to identify alternative deterrence mechanisms at scale. The Army will need to compensate with adding more soldiers or robotic capabilities because countries may try to engage the U.S. more frequently in sub-kinetic or hybrid compelling and coercive actions to halt or dissuade U.S. foreign and national security policy motives around the world. The force may falter under the diversity of threats, with the potential for increased local escalation as a result of other peer competitors. A strong Army must compensate for such actions since it will be called on to hold ground, interact with populations (civilian and military), and advance and take positions to shut down enemy actions. The loss of an effective nuclear capability could overtask the U.S. Army and possibly bankrupt the coun-

<https://issues.org/a-roadmap-for-u-s-nuclear-energy-innovation/>.

171. Lester, 48.

172. Lester, 50.

try in an attempt to maintain U.S. post-Cold War hegemony.

The Army should support the DoD efforts to maintain and replace tritium production levels, especially in any future climate efforts that may change the availability of nuclear power generation in the commercial sector that ultimately effects the effectiveness of the nuclear stockpile.

The Army can achieve this through the Nuclear Weapon Council (a joint DoD and DOE senior decision committee focused on nuclear weapon matters) under the Nuclear Weapon Council Standing and Safety Committee (NWCSSC) (See Title 10 of U.S. Code section 179 for summary of the NWC).¹⁷³ Currently, the Army has a position on the NWCSSC to help review safety, military requirements, and future needs of the nuclear stockpile. The NWCSSC sends its recommendations to the NWC for approval. The Army should maintain an active role on the committee and start pushing for development of a long term 15 to 20 year plan for maintaining tritium production requirements. The Army should consider the consequences to the size and technological makeup of its forces if tritium production changes and reduces overall nuclear stockpile effectiveness. The United States government's ability to deter and dissuade must remain a number one priority in order for the U.S. to continue to push and achieve its national objectives of peace, prosperity, and open market competition for the benefit of the American people.¹⁷⁴ Without a credible strategic nuclear force, the Army and the DoD risks future long term conflicts requiring extensive resources in manpower and equipment.

RECOMMENDATION DISCUSSION: ASSESSED AS REQUIRING NO ACTION

Problem: Port Access Challenges Due to Rising Seas

Recommendation: No action – Continue to Monitor.

Large-scale Army deployments overseas require access to ports in the continental United States. While rising seas are a near-term concern for some ports and shipyards, our research indicated that the major trans-shipping areas used by the U.S. Army are insensitive to the mid-range predictions for sea-level rise and would remain accessible to the Army in those scenarios.

173. "10 U.S. Code § 179 - Nuclear Weapons Council." *Legal Information Institute, Cornell Law School*. No date. <https://www.law.cornell.edu/uscode/text/10/179>.

174. Mattis, Jim. "Secretary's Preface," in *Nuclear Posture Review*. *US Department of Defense, Office of the Secretary of Defense*. 2018: I-III. <https://media.defense.gov/2018/Feb/02/2001872886/-1/-1/1/2018-NUCLEAR-POSTURE-REVIEW-FINAL-REPORT.PDF>.

Conclusion

The implications of significant, global, regional and local change produced by a general warming of the Earth's climate are far too extensive to be addressed by this study. Therefore, the guiding principle of this study was to explore diverse areas of importance for the Army that are or will be likely affected by climate change and to develop reasonable, useful recommendations in connection with those areas. A larger and perhaps even more urgent lesson from this study is the importance of developing regular administrative and institutional structures and processes that allow the Army and the DoD to detect, evaluate, respond and regularly review the implications of systemic risk relevant to the Army's missions and preparedness. Large scale threats like climate change and mass migrations are systemic risks, with emergent features not captured by the simple summation of threat-by-threat-by-threat assessments. The Army must find governance mechanisms that generate greater flexibility, without risk of compromise to the integrity of the force, to deal with the various significant stresses on the Army inherent to a warming climate. These stresses are occurring for military and civilian institutions alike against the backdrop of exponential changes in technology, human population, resource consumption, urbanization, sea level rise, etc.

It is useful to remind ourselves regularly of the capacity of human beings to persist in stupid beliefs in the face of significant, contradictory evidence.¹⁷⁵ Mitigation of new large-scale stresses requires a commitment to learning, systematically, about what is happening.

On 22 June, 1941, the Third Reich launched *Operation Barbarossa*, a massive invasion of the Soviet Union.

The assault, named after the red-bearded ("barba rossa" in Italian) German crusader and emperor Frederick I, involved over 3.5 million Axis troops, killed millions, and almost destroyed the Soviet Union. Although the attack is sometimes called a "surprise," this is misleading. It is more accurate to say that *Barbarossa* surprised the one person who could not afford to be: Josef Stalin. How could a military operation involving about 150 *divisions* have found its political target so unprepared?

Life is full of the unexpected, or the overlooked obvious. The term "black swan event" describes surprises of an especially momentous and nasty type. Popularized by the mathematician Nicholas Nassim Taleb in his 2007 book of the same title, Taleb argued that black swan events have three characteristics: "rarity, extreme impact, and retrospective (though not prospective) predictability."¹⁷⁶ In recent years, the concept of black swan events has gained currency in political, military, and financial contexts.

The black swan has a venerable history as an illustration of the ancient epistemological problem of induction: simply stated, no number of observations of a given relationship are sufficient to prove that a different relationship cannot occur. No amount of white swan sightings can guarantee that a different color swan is not out there waiting to be seen. The discovery of black swans by European explorers in Australia has proven too tempting to ignore as a powerful metaphor for the problem of induction.

However, in emphasizing the importance of anticipation, Taleb's concept of the black swan ignores key facts about history and how it is understood by those who live it. Two characteristics of the strategic environment epitomize this problem.

175. This section adapted from Hill, Andrew: "Red Beard, Black Swan: Recognizing the Unexpected." *US Army War College, War Room*. 2017. https://warroom.armywarcollege.edu/articles/black_swan_red_beard/.

176. Taleb, Nicholas Nassim. *The Black Swan: The Impact of Highly Improbable Fragility*. New York: Random House, 2007: xxii.

First, the list of things that can happen but have not happened yet is long. It is, in fact, infinitely long. For each thing that exists (e.g., cats) we can come up with more variations that do not, to our knowledge, exist (flying cats, cats with gills, six-legged cats, and so on). It is fun to think about all the cataclysmic, history-altering events that might happen, but thinking about those things in a way that appropriately organizes them and informs strategy is extremely hard. That said, techniques used in Systems Thinking, when applied to this concern, often reveal relatively obvious blind spots that obscure even high impact, high likelihood events. The Chinese focus on building universities, programs and initiatives focused on Systems Thinking over the past 20 years, and the inclusion of this curriculum in the training cadets destined to lead China in the future should be notable, as it is may be the basis of large asymmetries with broad implications for the U.S. Army, the U.S. IC, the DoD, and allies.

Second, events that present as tremendous shocks have often taken months, years, or even longer periods to emerge. In the time between weak signals of change and the onset of a deeper crisis, there are often opportunities to prepare and adapt. These opportunities may be much more readily apparent if important “emergent properties” of major concern to the force, especially those resulting in threat that is orthogonal to force strength, are systematically characterized.

The real challenge with black swan events is not accurate anticipation, but timely recognition. While it can be useful to imagine what *might* happen, we should focus more on recognizing what *is* happening as quickly as possible and limiting the damage through timely learning.

The black plague took half a decade to advance from Sicily to the Baltic states. More recently, the 2008 financial crisis is already remembered as a “shock” event

that surprised global finance.^{177,178} However, the truth is more nuanced, and depressing. Notable observers of the system (including Dr. Taleb) recognized serious problems long before the fall of Lehman Brothers in September, 2008 (and the onset of a full-blown banking crisis).^{179,180} Yet this was mostly recognition, not prediction. The clearest early signal of big trouble in the mortgage market came in the March-April, 2007 collapse of New Century Financial, an originator of risky mortgages, almost a year and a half before Lehman’s end, and a year before Bear Stearns was rolled up.^{181,182} What happened in the meantime? In *All the Devils Are Here*, Bethany McLean and Joe Nocera describe two embattled Bear Stearns asset managers who provide a microcosm of the wishful thinking that made the crisis much worse than it needed to be. In the face of mounting evidence that their investment strategy is failing, “the two men simply couldn’t bring themselves to believe that the picture was as dire as the model suggested.”¹⁸³

When the facts do not match our strong theories for how the world works, we prefer to change the facts. How can we more quickly recognize the unexpected for what it really is?

177. Srivastava, Sriha. “On this day 8 years ago, Lehman Brothers collapsed: Have we learned anything?” *CNBC*. 2016. <http://www.cnbc.com/2016/09/15/on-this-day-8-years-ago-lehman-brothers-collapsed-have-we-learned-anything.html>

178. “Crash course: The origins of the financial crisis.” *The Economist*. 2013. <http://www.economist.com/news/schools-brief/21584534-effects-financial-crisis-are-still-being-felt-five-years-article>.

179. Cox, Jeff. “Best and worst predictions of the past 25 years.” *CNBC*. 2014. <http://www.cnbc.com/2014/07/01/best-and-worst-predictions-of-the-past-25-years.html>.

180. “The collapse of Lehman Brothers.” *The Telegraph*. Accessed August 29, 2018. <http://www.telegraph.co.uk/finance/financialcrisis/6173145/The-collapse-of-Lehman-Brothers.html>.

181. “New Century files for Chapter 11 bankruptcy.” *CNN Money*. 2007. http://money.cnn.com/2007/04/02/news/companies/new_century_bankruptcy/.

182. “Bearing all: The fall of Bear Stearns.” *The Economist*. 2009. <http://www.economist.com/node/13226308>.

183. MacLean, Bethany and Joe Nocera. *All the Devils Are Here: The Hidden History of the Financial Crisis*. New York: Penguin, 2011.

In Frank Tashlin's classic children's book, *The Bear That Wasn't*, a bear awakes from hibernation and, exiting his cave, finds himself in a huge factory that has been built over his forest home. Encountering a foreman, the bear is told to get back to work, to which the bear replies, "I don't work here. I'm a bear." Incredulous, the foreman says, "You're not a bear. You are just a silly man who needs a shave and wears a fur coat."

Aside from its entertainment value, *the Bear that Wasn't* provides a humorous example of a profound philosophical problem: When the facts do not match our strong theories for how the world works, we prefer to change the facts. How can we more quickly recognize the unexpected for what it really is? The foreman (along with various executives that the bear meets) has a simple belief: *No bears are in factories*.

If we have a theory of factories that says (among other things), "No bears are in factories," the theory is based on our experiences observing who is in a factory (i.e., human workers). It is an *inductive* theory: every observation to date has been of human workers. We could not arrive at such a theory independent of our accumulated experience. In addition, the more workers we see, the more certain we become (in terms of probability) that all workers are human (and none are bears), but we will never, ever observe every possibility.

Although we should not make the unjustified leap from making a probabilistic statement based on induction to a universal statement based on deduction, we often do it anyway. Our beliefs then shape how we treat the evidence. For example, prior to seeing a non-white swan, we develop the following syllogism:

1. Major Premise: All swans are white.
2. Minor Premise: That bird is a swan.
3. Conclusion: That bird is white.

When we see a black swan, if we are unemotional, Spock-like empiricists, we will immediately recognize that "if swan, then white" is false. That is, we will know that our conclusion, "that bird is white," is false based

on observation that the bird is black *and* a swan. Finding ourselves in a situation in which we believe that our premises are true but our conclusion is false, and therefore *not* entailed by the premises, we will conclude that our major premise must not be true, and therefore reject it.

Here is where human experience departs from the clean abstractions of logic. We are not Spock. We have emotional attachments to our beliefs. This is as true of attitudes towards a changing climate as it was of attitudes towards the financial crisis.

Three maxims can help us avoid dangerous failures of recognition, and speed learning when unexpected things happen.

1. Everything we believe about the world is provisional – "serving for the time being." Adding the words "so far" to assertions about reality reminds us of this.
2. Unjustified certainty is very costly. The greater your certainty that you are right when you are wrong, the longer it will take you to recognize and incorporate new data into your system of belief, and to change your mind. General Douglas MacArthur was a confident man, and this confidence usually served him well, such as when he undertook the risky landings at Incheon in the Korean War. Yet MacArthur's confidence betrayed him when China entered the war. He was certain that this would not happen, and MacArthur's certainty delayed his recognition of a key change, exposing forces under his command to terrible risk. Confidence in your beliefs is valuable only insofar as it results in different choices (e.g., I choose A or B). Beyond that point, confidence has increasing costs.
3. Pay special attention to data that is unlikely *in light of your current beliefs*; it has much more information per unit, all else equal. In this sense, information content is measured as the potential to change how you think about the world. Infor-

mation that is probable in light of your beliefs will have minimal effects on your understanding. Improbable information, if incorporated, will change it.

It is doubtless correct that many awful things that have not happened before will yet happen. Foresight regarding such events would be nice. It would be nicer still if we could recognize more quickly what is happening right in front of us. That is the right starting point for thinking strategically about the warming climate.

Appendix: Weather Control

Weather control is a fascinating and worrying potential technology. If used in with intentionally nefarious intent, its effects could be catastrophic. It is not exactly climate change in the sense that we define it here, but it brings many of the problems of climate change, with the prospect of these problems arising at the time and place of an adversary's choosing.

Naturally occurring terrestrial and space weather events constitute only one set of challenges to national security. The concept of weaponizing the natural environment is nothing new. Congressional testimony dating back to the early 1950s recommends approval of research and development funding for weather modification experimentation. This in response to concerns Russia was beating us in learning how to control the weather and the potential threat that posed to the United States.¹⁸⁴ The United States has already demonstrated the potential to modify the weather in support of combat operations through its efforts in Vietnam. United States' cloudseeding techniques used aircraft to disperse lead iodide into the atmosphere above portions of Southeast Asia to create a super-saturated environment during the Vietnamese monsoon season. The increased precipitation produced significant degradation of Vietnamese logistic capabilities as vehicles, carts, and men remained bogged down on certain roadways and paths soaked by nearly continuous rainfall.¹⁸⁵

Much like the United States, potential rivals already pos-

sess the capability to artificially manufacture effects that manipulate the terrestrial and space weather environment. An example is the superheating of the ionosphere through directed-energy generation. This capability has the potential to disrupt communications, limit capabilities of missile defense or other monitoring radars, and contaminate the ionosphere to such a degree as to prevent use of U.S. space or missile defense systems. Normally these ionospheric scintillation experiments, like those performed at the High Frequency Active Auroral Research Program (HAARP) in Alaska, are benign in nature and used for purely scientific research purposes. However, the U.S. Air Force, U.S. Navy, and the Defense Advanced Research Projects Agency (DARPA) originally developed, designed and operated HAARP as a joint project to perform experiments that manipulate and potentially control the ionosphere to enhance Department of Defense (DoD) command, control and communications capabilities. Experiments ranged from extremely low-frequency waves for submarine communications to over-the-horizon-radar enhancement and even super scintillation events to disrupt or disable space assets in low Earth orbit. The HAARP program transferred to the University of Alaska for educational research after the DoD successfully accomplished their original experimental goals and determined to cut costs by terminating the experiments and HAARP facility.¹⁸⁶

However, the United States is not the sole possessor of a HAARP-like capability. Partner nations, such as Japan and Norway, operate their own antenna farms, as do Russia and China.¹⁸⁷ The use of ionospheric sounders operated by the Air Force make it possible to monitor

184. "Prohibiting Hostile Use of Environmental Modification Techniques," in *Multinational Corporations and United States Foreign Policy: Hearings Before the Subcommittee on Multinational Corporations of the Committee on Foreign Relations*, vol. 3, parts 15-17: 36-37. U.S. Senate Committee on Foreign Relations, Subcommittee on Multinational Corporations: 94th Cong., 2nd sess. 1976.

185. "Weather Modification." *U.S. Senate Subcommittee on Oceans and International Environment of the Committee on Foreign Relations*, 93rd Cong., 2nd sess., March 20, 1974:88-93. <https://www.vietnam.ttu.edu/star/images/239/2390601002C.pdf>.

186. National Research Council. *Opportunities for High-Power, High-Frequency Transmitters to Advance Ionospheric/Thermospheric Research: Report of a Workshop*. Washington, DC: The National Academies Press. 2014: 1,3.

187. National Research Council, 18-19.

when manipulations of the ionosphere occur, so it would be difficult to heat the ionosphere without anyone's knowledge. However, the current distribution of these ionospheric sounders leaves large gaps in coverage exposing them to possible exploitation by an adversary.

Still another artificially induced weather effect manifests through the use of a nuclear detonation to induce an artificial radiation belt. The consequences of such an event would produce significant and far-reaching impacts to U.S. national security. First, the electromagnetic pulse generated during the initial explosion mimics the disastrous costs produced by a Coronal Mass Ejection (CME) induced geomagnetic storm. The United States would witness widespread power grid outages, loss of communication and navigation capabilities, plus long-term modification to the space environment. Damage to space assets in various satellite orbits would vary depending on detonation altitude and a loss of asset capability expected. These concerns do not spring from speculation. On July 9, 1962, the United States exploded the STARFISH PRIME nuclear device in the low Earth orbit at around 400 kilometers. Only 24 satellites were in orbit during the time of this test and subsequent tests that followed, but eight satellites suffered immediate damage during the tests while still others demonstrated shortened life spans from the artificially induced radiation belts. This nuclear testing also impacted communications and changed the space operating environment for decades to follow.¹⁸⁸

A similar detonation in today's congested space environment promises significantly worse outcomes. According to the Union of Concerned Scientists website, the space environment hosts over 1,738 known satellites as of August, 2017. No country has more to lose than the United States if a space-based nuclear detonation occurred. Leading all nations at 803 satellites, the United States has over 476 commercial, 150 governmental (with an additional 159 military), and 18 civil satellites

on orbit at various altitudes above the Earth.¹⁸⁹ While other nations would feel the effects of such an event, they are less likely to feel the level of national security implications when compared to the United States. Concerns over North Korean intentions during recent tests of their growing nuclear capability raise this to a very real threat. There is evidence that North Korea reached back to the early experiments of the United States and the Soviet Union during the late 50s and early 60s to gain insights on their own nuclear program. An atmospheric or space-based test of a North Korean nuclear weapon, designed to demonstrate national power or will on the international stage, would generate substantial disadvantages to U.S. national security as losses of space capability occur across a wide range of possible platforms.¹⁹⁰

Numerous additional examples exist that demonstrate the ability to manipulate the natural environment as an instrument of national power. Commonly referred to as Geoengineering, it is defined by the Intergovernmental Panel on Climate Change as "a broad set of methods and technologies that aim to deliberately alter the climate system to alleviate impacts of climate change."¹⁹¹ However, many of the geoengineering experiments currently underway to combat climate change possess the dual-use potential for weaponization of the natural environment. A report on Chinese efforts in the arena of solar geoengineering call for a variety of terrestrial or space-based options to combat CO₂ concentrations. The various methods discussed could change the physical, chemical or biological characteristics of the Earth's climate system. While some of these options

188. Conrad, Edward E. et al. "Collateral Damage to Satellites from an EMP Attack." *Defense Threat Reduction Agency*. 2010: 11-15. <https://apps.dtic.mil/dtic/tr/fulltext/u2/a531197.pdf>.

189. "UCS Satellite Database." *Union of Concerned Scientists*. 2017. <http://www.ucsusa.org/nuclear-weapons/space-weapons/satellite-database>.

190. Sanger, David E. and William J. Broad. "Prospect of Atmospheric Nuclear Test by North Korea Raises Specter of Danger." *The New York Times*. 2017. <https://www.nytimes.com/2017/09/22/world/asia/north-korea-atmospheric-nuclear-test-risks.html>.

191. "Climate Change 2014 Synthesis Report: Summary for Policy Makers." *Intergovernmental Panel on Climate Change*. 2014:89. https://www.ipcc.ch/site/assets/uploads/2018/02/AR5_SYR_FI-NAL_SPM.pdf.

may reduce greenhouse gas concentrations, they may also potentially create negative effects to an environment where one did not exist previously.¹⁹²

A report examining the United States' history in geoengineering reveals very similar possibilities. A National Center for Atmospheric Research, and Environmental Studies Program explored U.S. weather modification exertions back to 1947 and found a reactionary, checked past. In developing science and technology options, along with the accompanying legislation, weather modification ran the gamut of beneficial and detrimental outcomes across society. The study recommends any plans using geoengineering in climate change mitigation would benefit from a guiding framework of rules and regulations. It further endorses the establishment of a centralizing U.S. federal weather modification governing body to provide proper stewardship of the environment during any experimental development or actual implementation.¹⁹³ Anything less could lead to a broad range of potential environmental, technical, political, and ethical issues.

These very concerns culminated in the United Nations General Assembly holding the Convention on the Prohibition of Military or any Hostile Use of Environmental Modification Techniques (ENMOD) of 1976. The ENMOD Convention was the tool used to capture the spirit of international disarmament law explicitly envisioned to keep the manipulation of the environment out of the armed conflict arsenal. An additional protocol added a further ban on the use of methods and means of warfare that purposefully and excessively damage the environment. The overall language bans the hostile use of the natural environment to wage war and went into force as of October, 1978. The United States, along with 77 other nations, have ratified the treaty and agreed to live by its restrictions.¹⁹⁴ A decision to weaponize weather in the future would carry with it an almost certain international condemnation for any nation willing to undertake the effort. If someone could prove who did it.

192. Cao, Long, Chao-Chao Gao and Li-Yun Zhao. "Geo-engineering: Basic Science and Ongoing Research Efforts in China." *Advances in Climate Change Research*, vol 6: 188-196. 2015. <https://www.sciencedirect.com/science/article/pii/S1674927815000829>.

193. Hauser, Rachel. "Using Twentieth-Century U.S. Weather Modification Policy to Gain Insight into Global Climate Remediation Governance Issues." *Weather, Climate and Society*, vol. 5: 180-191. 2013. <https://journals.ametsoc.org/doi/pdf/10.1175/WCAS-D-11-00011.1>.

194. "1976 Convention on the Prohibition of Military or any Hostile Use of Environmental Modification Techniques." *International Committee of the Red Cross, Advisory Service on International Humanitarian Law*. 2003. <https://www.icrc.org/en/document/1976-convention-prohibition-military-or-any-hostile-use-environmental-modification>.