THE ROLES OF SCIENCE IN NATIONAL SECURITY POLICYMAKING:

A CASE STUDY ON NUCLEAR ELECTROMAGNETIC PULSE

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Preface

Brad Roberts

George Bernard Shaw famously quipped that the British and Americans are two great peoples divided by a common language. The same might be said of policymakers on the one hand and scientists and technologists on the other. Although they communicate with each other in a common language, these two communities often accomplish very little in understanding each other's perspective and building a common understanding of context and implications. As a one-time policymaker, I can report that I was often frustrated with the lack of interest technologists took in the problems I was trying to solve as they tried to explain to me their solutions to technical problems I did not have. I also came to appreciate their frustration from the other side of the divide and to better understand my own responsibility to help create the needed bridge.

This small volume addresses squarely the responsibility of scientists and technologists at this laboratory and elsewhere to create the needed bridge to the policymaker. More than that, it offers practical advice on how to be effective in the policy environment. The monograph grows out of the experience of lab technical staff with programmatic activities at the Center for Global Security Research, where such bridge-building is an ever-present project. It also grows out of their own professional experience serving as advisors, whether formally or informally, to decisionmakers in Washington DC. The authors sift through these experiences for lessons of enduring value to the bridge builders. In making their case, they draw effectively on a case study—the provision of technical advice to policymakers on the threat from electromagnetic pulse weapons. The result should be of value to any member of the laboratory's technical community seeking a better understanding of how to be effective in ensuring that policy judgments are technically sound.

Introduction

Scientific advice is rarely as profound as scientists wish or as decisive as policymakers desire.

This basic observation lies at the core of the difficulty of incorporating scientific advice in effective policy decisions. National security policymaking, like all public policymaking, is an inherently political, value-laden process, a fact that complicates integration of scientific input to that process. In supporting policymaking, the roles of technical advisors range from the "purely scientific" (detached from policy preference) to strong advocacy for a particular policy. Time constraints that dictate national security policymaking and scientific knowledge production are frequently incompatible, as national security decisions may require an immediate response to a threat while science follows an iterative process to reduce uncertainty.

When thrust into a policymaking environment, scientific advisors—isolated from the norms and protocols of their technical fields, and often without policymaking experience themselves—stand to benefit from the guideposts for advising that we identify in this paper. Rather than advocate for specific, formal changes to the structure of existing policymaking institutions, we explore the many roles science advisors can play when engaging on thorny national security topics. While technological progress presents new challenges, many of the difficulties faced by advisors, such as uncertain and limited data, conflicting values and risk tolerances, and potential misalignment between policymaker expectations and scientific reality, have plagued scientific advising since the earliest days of American governance. To focus our exploration, we recruit four idealized technical advisor roles identified by Roger Pielke, Jr. in *The Honest Broker*. In a series of fictional dialogues (rooted in actual Congressional testimony), we examine the threat from high-altitude nuclear electromagnetic pulse, or EMP, a national security topic that lays bare many challenges for technical advisors.

Many facets of national security policy that define the United States' role in the world have depended on trust between policymakers and scientists. The importance of that trust grows in a time of great power competition. In 1939, Albert Einstein drafted a letter to President Roosevelt communicating "some recent work by E. Fermi and L. Szilard," which led to the advent of nuclear weapons. That the United States would become a leading nuclear power was by no means assured—it resulted from the careful coordination between the scientific community and alignment of national security policymakers. The national security landscape of the coming decades may also hinge on how well U.S. policymakers and science advisors communicate. Indeed, addressing challenges in artificial intelligence, quantum computing, cyber security, additive manufacturing, and energy independence will require effective scientific advice. Advisors’ ability to reckon with uncertainty, convey the limits of data, and develop trust with policymakers will shape technology and security to come.

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The Roles of Science in National Security Policymaking

Throughout American government, most decisionmakers recognize that policymaking requires sound scientific and technical input. Why then, does scientific input spark such widespread political debate and polarization? What determines when scientific expertise informs and clarifies debates—and when it muddies the water?

In short, when someone says "trust the science," what do they mean?

The importance of public trust in science and of scientific literacy has already been well established by scientific and professional bodies. Less recognized is that trust in science and in expertise are conditions, but not guarantors, for sound policy. There is an acute need for scientists and engineers to be able to navigate policymaking processes and to leverage their expertise for decisionmakers' benefit.[1] Our goal in this paper is to supply technical experts who are new to scientific advising in national security policy with a set of guideposts. To be effective, they must understand how the role they play can affect policy outcomes. For their part, policymakers can also benefit from developing a better understanding of the point of view of technical experts who, while engaging in policy support, work outside the comfortable norms of their home disciplines and navigate political polarization. Adopting such a perspective can help decisionmakers improve the approach they take towards soliciting technical input, as well as communicate their needs and values to their advisors.

We were motivated to examine the topic of technical advising for policymaking based on our own collective experiences in the fields of national security and science. Above all, we recognize the many reservoirs of expertise—some technical, some non-technical—that must merge for successful policy development. And while increased transparency of expectations, roles, and accountability can strengthen trust in science and scientists, durable policies are rarely crafted based on scientific evidence alone. The COVID-19 pandemic[2] brought into sharp focus the critical contributions science makes to policymaking while simultaneously highlighting how highly politicized policymaking environments can degrade trust in the value that science brings to this process. Effectively delivering thoughtful, well-grounded scientific expertise is particularly challenging due to an expansive digital information environment that

1 Harold Varmus and Elias Zerhouni, "The United States needs a department of technology and science policy," *Nature* 600 (November 30, 2021). https://www.nature.com/articles/d41586-021-03543-x. Accessed May 5, 2022.

2 The development of this paper coincided with the COVID-19 pandemic, which provided a continuous example of scientific advising for policymakers at all levels. However, due to its proximity and our lack of medical expertise, we steer clear of the pandemic in this paper and hope that lessons from COVID-19 will become clearer with the passage of time.

provides nearly unlimited opportunity for anyone to broadcast their opinion. Such competition for policymakers' and the public's attention often involves questionable, misleading, or contradictory information.

Beyond these challenges to scientific authority, there is recognition that the science behind many of today's most pressing policy issues "…is most often complex, multidisciplinary and incomplete."[3] Consequently, simple, unequivocal, and prescriptive scientific direction or guidance is exceedingly rare. It is in such a daunting policy environment that scientists must provide sound input on unresolved technical issues to policymakers. Further, there is also tension between the timeline typical of policymaking and scientific knowledge production. This is because policy development may require rapid decisions, especially if a threat looms, whereas science is more often a prolonged and iterative proposition accompanied by varying levels of uncertainty throughout.

To be effective, technical experts should be aware of these dynamics before they enter policy processes. What political context already exists that they, as a technical expert, may not have considered? How is their advice different from another expert with a similar background—or a dramatically different one? Has the policymaker clearly articulated a preferred outcome or a policy problem to overcome? Can their scientific input really answer a policymaker's question, or will the information they provide only serve as a cover for a debate of values?

To tackle these issues, many past proposals have argued for structural changes in policymaking processes, such as the creation of a Cabinet-level Department of Science and Technology Policy or other top-down approaches.[4] While such changes are worth considering, they do not provide express guidance on how advisors can improve their day-to-day support for policymakers. To fill this gap, rather than advance a one-size-fits-all solution to "fix" the science policy process, this paper is structured as an exploration of the process itself for prospective advisors. First, we examine how historical and contemporary forces constrain scientific input to national security policy. Following this brief survey, we illustrate the various ways scientists can inform or confuse policy architects through a series of constructed (but based on actual events) dialogues on a real national security issue: the potential threat posed by nuclear electromagnetic pulse.

The long record of policy development on EMP mitigation is an ideal example of science advising in security policy, as it is rich in technical complexity and unknowns, has the potential for profound public impact, and is often viewed along partisan political lines.[5] The potential risk from EMP was first appreciated during the nuclear testing era when both the Soviet Union and the United States observed powerful

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3 Science Advice for Policy by European Academies (SEPEA), "Making sense of science for policy under conditions of complexity and uncertainty" (2019). https://doi.org/10.26356/MASOS. Accessed May 5, 2021.

4 Harold Varmus and Elias Zerhouni, "The United States needs a department of technology and science policy," *Nature* 600 (November 30, 2021).

5 Michael Crowley, "The Newt Bomb," *The New Republic* (June 2, 2009).

electromagnetic fields at ground level following high-altitude nuclear tests. Though not directly harmful to people, such EMPs were powerful enough to damage or destroy electrical equipment over a broad area. The physical mechanism for nuclear EMP is well established,[6] but the degree of risk to civilian electrical infrastructure is murkier; consequently, so is the need for policymakers to act. Subsequent studies have modeled (and in some cases experimentally tested) EMP resilience of individual electronic components or systems, but predicting the effects of a hypothetical nuclear EMP at a societal level (such as on regional telecommunication networks) remains fraught with uncertainty. In the absence of incontrovertible evidence, one oft-referenced, real-life example of civilian impact due to nuclear EMP is the Hawaiian Street Light Incident[7] in which the EMP from the Starfish Prime high-altitude test is thought to have induced several electrical failures on the Hawaiian island of Oahu over 1,000 kilometers away.

Since the 1990s, the risk to civil society from a high-altitude nuclear EMP has grown in the public imagination and garnered the sustained attention of Congress over the last three decades. Some parties, including the EMP Commission first created and funded by Congress in Fiscal Year (FY) 2001, warned of an existential risk to civil society and that current national EMP vulnerability would "invite and reward attack if not corrected."[8] In contrast, technical studies on the topic were (and continue to be) most often scoped to answering questions amenable to technical analysis, such as simulation of specific electronic systems within an assumed EMP environment, without assessing the plausibility, likelihood, or political ramifications of such an event. Efforts to develop policy to address this potential threat culminated in a 2019 Presidential Executive Order titled "Executive Order on Coordinating National Resilience to Electromagnetic Pulses."[9] In building a series of fictionalized dialogues (that rely heavily on actual testimony from a real-life policy development process), we do not presume to adjudicate whether the proposed EMP policies are sound or well-aligned with technical realities. Our intent is to lay bare the risks of misalignment when scientists and national security officials work together. It serves both technical advisors and national security decisionmakers to understand what science can and cannot do as an element of policy development.

6 M.K Rivera, S.N Backhaus, J.R. Woodroffe, M.G. Henderson, R.J. Bos, E.M. Nelson, and A. Kelic, *EMP/GMD Phase 0 Report, A Review of EMP Hazard Environments and Impacts*, Los Alamos National Laboratory, LA-UR-16-28380 (2016).

7 C.N. Vittitoe, "Did high-altitude EMP (electromagnetic pulse) cause the Hawaiian streetlight incident?," Sandia National Laboratories (1989). https://www.osti.gov/servlets/purl/6151435/. Accessed May 19, 2022.

8 National Research Council, *Report of the Commission to Assess the Threat to the United States from Electromagnetic Pulse (EMP) Attack, Volume 1: Executive Report* (Washington, DC: 2004).

9 United States Office of the President, Executive Order No. 13865, 84 FR 12041, Coordinating National Resilience to Electromagnetic Pulses (March 26, 2019). https://www.federalregister.gov/documents/2019/03/29/2019-06325/coordinating-national-resilience-to-electromagnetic-pulses. Accessed May 5, 2022.

How Science Has Supported American Governance: A History

Many of the difficulties faced today by scientists, regulators, and legislators seeking to provide the best policy options for the country are not new. Science has impacted American governance since the country's founding, guiding key decisions of political leaders facing similar challenges of bringing sound scientific knowledge to bear on policymaking. Understanding the history and origin of the provision of scientific advice to the government is important if one is to improve and enhance current practices.

The role of scientists in the formulation of U.S. government policy historically has been dominated by three themes:

- The ongoing provision of technically derived societal benefits to the economy and defense, in return for government funding
- Appropriating the role to a class of professional scientists and excluding amateurs
- The provision of advice on explicit societal and regulatory issues with a technical component—"the Fifth Branch of Government"

At the present time we are living through one of the most contentious, politically fraught, and momentous applications of science to public policy: the response to the COVID-19 crisis. Although all three themes mentioned above figure in the country's response to the pandemic, we have deliberately excluded it from this discussion, as it remains an ongoing debate. (We refer the reader to the sidebar on page 19).

Societal Benefits

National crises, especially wars, spur public support and investments in science and technology, including the creation and growth of science agencies in the United States. World War II brought about "Big Science"[10] (and the National Laboratories) as originally conceived and created by Ernest Lawrence in 1934. The paradigm of Big Science, though it originated in the physical sciences with accelerator technology and the nuclear weapons program, has been adopted broadly in the 21st century, including government-sponsored initiatives in biology, environmental science, astronomy, medicine, cybersecurity, and engineering of all stripes.

The first half of the 19th century saw the beginnings of what were to become government science agencies, along with the provision of federal funding to support

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10 Alvin Weinberg, "Impact of Large Scale Science on the United States," *Science* 134, no. 3473 (1961). Big Science refers to very large, government-funded research projects such as the Manhattan Project, the Stanford Linear Accelerator and LIGO (Laser Interferometer Gravitational-Wave Observatory).

applied science (economic growth and defense) and discovery science (e.g., astronomy):

> A predominant agency … must be able to command on the one hand a series of fruitful research results from the scientists and, at the same time, it must command from the general community the means to accomplish its scientific ends.
>
> If the confluence of opinion is strong enough, a predominant agency can convince both of its constituencies—the scientists and the general community represented by such an institution as Congress—that its mission is the most pressing and most attainable one of the age. The first predominant agency was the Coast Survey in the years between 1843 and 1860.[11]

The Coast Survey can thus be seen as the predecessor of the plethora of current day federal science agencies such as the National Science Foundation (NSF), Defense Advanced Research Projects Agency (DARPA), National Institutes of Health (NIH), Department of Energy (DOE), and many others. It is through these agencies that a central function of science-government policy formulation today—that is, providing support to the economy and defense—is accomplished. Then, as now, the dominance of particular agencies rose and fell as they struggled for mission dominance. Their success was and often is as much a function of their technical aptitude as is the political acumen of their directors or contractors.[12]

The Professional Class

The early and mid-19th century also saw the dawn in the United States of the professional scientist and consultant. The word "scientist"—as opposed to natural philosopher—first appeared at this time. Many professional scientific organizations and societies were founded during this period, such as the Columbian Institute of the Scientific Community (1816), the National Institution for the Promotion of Science (1840), the Smithsonian (1846), and the American Association for the Advancement of Science (AAAS) (1848).

> [C]onditions underlying the pursuit of science changed drastically during the nineteenth century. By the middle of the century, the earlier pattern of gentlemanly scientific activity was rapidly becoming obsolete. The amateur was in the process of being replaced by the trained specialist—the professional who had a single-minded dedication to the interests of

11 A. Hunter Dupree, "Central Scientific Organization in the United States Government," *Minerva* 1, no. 4 (Summer 1963). https://www.jstor.org/stable/41821587. Accessed April 29, 2020.

12 Ibid.

> science. The emergence of a community of such professionals was the most significant development in nineteenth-century American science.[13]

Not surprisingly, this professionalism was accompanied by the appearance of a small, very influential group of eminent scientists. The Scientific Lazzaroni, ostensibly a dining club, dominated recommendations for key scientific appointments and the nation's science policy during this period.[14]

From time to time, Congress and the executive branch have established additional non-partisan organizations to provide technical advice on a broad range of topics, notably the National Academy of Science (established by a Congressional act and signed into law by President Lincoln in 1863), the Office of Technology Assessment,[15] the Defense Science Board, the Congressional Research Service, the President's Advisory Council on Science and Technology, and others. Congress also often mandates technical reports such as The National Climate Assessment[16] and funds specialized commissions such as the Fiscal Year 2001 EMP Commission we consider here.

As the professional field matured, actions were taken to develop and maintain the reputation of science and build trust in it. Scientists saw the necessity for standards of conduct in research and the accompanying means to ensure the integrity of their field. Alexander Bache (third President of the AAAS and significantly the director of the Coast Survey) asserted in an 1851 speech that "an institution of science, supplementary to existing ones, is much needed in our country, to guide public action in scientific matters." In 1863, this proposal was to become the National Academy of Sciences.

Bache was concerned about developing and maintaining science's reputation and trust in it. In the 1851 speech, he eloquently stated this goal:

13 George H. Daniels, "The Process of Professionalization in American Science: The Emergent Period, 1820-1860," *Isis* 58, no. 2 (Summer 1967).

14 "But the basic purpose of the group was not gustatory elegance but the control of the institutional form of all real science in America …The Lazzaroni also concerned themselves with combating charlatanism in science and with defending, against the all-too-prevalent political attacks of the time, the work of such central scientific bureaus as the Coast Survey and the Smithsonian. The almost complete dominance of the Lazzaroni in these years is attested to by the fact that in this era almost all the presidents of the American Association for the Advancement of Science were selected from its active members." Leonard Carmichael, "Joseph Henry and the National Academy of Sciences," *Proceedings of the National Academy of Sciences of the United States of America* 58, no. 1 (July 15, 1967). https://www.jstor.org/stable/58163. Accessed April 30, 2020.

15 "Because of the political environment in which it has operated, OTA reports rarely draw definitive conclusions. Rather, in clear and simple language, supported by attractive illustrations, they summarized the technical facts, identified problems, laid out alternatives, and discussed their pros and cons. The reports often placed limits on the range of political debate by laying out what was scientifically feasible. Legislators on opposite sides of contentious issues have often cited the same OTA report as a basis for the lines of argument they have advanced." M. Granger Morgan, "Death by Congressional Ignorance," *Pittsburgh Post-Gazette* (August 2, 1995). https://ota.fas.org/technology_assessment_and_congress/morgan/. Accessed May 25, 2022. OTA was abolished in 1995.

16 The Global Change Research Act of 1990 mandates that the U.S. Global Change Research Program (USGCRP) deliver a report to Congress and the President no less than every four years that "1) integrates, evaluates, and interprets the findings of the Program…; 2) analyzes the effects of global change on the natural environment, agriculture, energy production and use, land and water resources, transportation, human health and welfare, human social systems, and biological diversity; and 3) analyzes current trends in global change, both human-induced and natural, and projects major trends for the subsequent 25 to 100 years" (introduced January 25, 1989). https://www.congress.gov/bill/101st-congress/senate-bill/169/all-info. Accessed May 25, 2022.

> Our real danger lies now from a modified charlatanism, which makes merit in one subject an excuse for asking authority in others, or in all; and, because it has made real progress in one branch of science, claims to be an arbiter in others… This form of pretension leads men to appeal to tribunals for the decision of scientific questions, which are in no way competent to consider them.[17]

In the 1850s, American scientists sought to rectify the issues raised by Bache by gaining control of an "important sector of American scientific publishing" and imposing standards and an early form of peer review on published reports.[18] By 1853, the AAAS had effectively pushed the amateur to the side by controlling publication, even going as far as to "formally disavow" a volume of proceedings edited by amateur scientists.[19]

Regulation

After World War II, the U.S. government became the dominant sponsor of scientific research in the country, and scientists and technologists increasingly impacted U.S. policymaking. This influence drove an awareness of the importance of maintaining trust between the American public and the scientific community—as well as a concern to achieve such trust. Former President Dwight D. Eisenhower's final public speech to the nation in 1961 is perhaps the best remembered (and the most studied) warning of this new relationship between government and science and of the increasing influence of the so-called "scientific-technological elite." Eisenhower acknowledged the critical importance of science and technology for the security and progress of the country and its citizens but emphasized how other values must integrate and shape science in the development of public policy for the betterment of the country.

> The prospect of domination of the nation's scholars by Federal employment, project allocations, and the power of money is ever present—and is gravely to be regarded.
>
> Yet, in holding scientific research and discovery in respect, as we should, we must also be alert to the equal and opposite danger that

17 American Association for the Advancement of Science, "Address of Professor A.D. Bache, President of the American Association for the Year 1851 on Retiring from the Duties of President" https://collections.nlm.nih.gov/catalog/nlm:nlmuid-101172759-bk. Accessed December 29, 2020. See also Joseph Henry, first Secretary of the Smithsonian Institution, "The truth is we are overrun in this country with charlatans, our newspapers are filled with puffs of quackery and every man who can…exhibit a few experiments to a class of young ladies is called a man of science." Quoted in Daniel J. Kevles, *The Physicists-The History of a Scientific Community in Modern America* (Cambridge, MA: Harvard University Press, 1971), p4.

18 John D. Holmfeld, "From Amateurs to Professionals in American Science: The Controversy over the Proceedings of an 1853 Scientific Meeting," *Proceedings of the American Philosophical Society* 114, no. 1 (February 16, 1970).

19 Ibid.

> public policy could itself become the captive of a scientific-technological elite.
>
> It is the task of statesmanship to mold, to balance, and to integrate these and other forces, new and old, within the principles of our democratic system—ever aiming toward the supreme goals of our free society.[20]

To make progress toward these "supreme goals," policymakers increasingly rely on "social" regulation. There is a long history of local, state, and federal government regulation designed to protect the health, safety, and economic well-being of America. The first public health board was created in 1793. Technical-based regulation dates to the early 20th century, when in 1902 Congress passed the Biologics Control Act, described as "An act to regulate the sale of viruses, serums, toxins, and analogous products,"[21] shortly followed by the 1906 Pure Food and Drug Act [which eventually led to the creation of the Food and Drug Administration (FDA) in 1932]. Today, one of the most controversy-plagued roles of the science advisor is that of providing technical support, and sometimes advocacy, for regulation.

Although technically-based regulation dates to the early 20th century, a major impetus for modern regulation began with publication of the book *Silent Spring* in 1962,[22] followed by *Unsafe at Any Speed*[23] in 1965. There followed a spate of legislation (e.g., the National Environmental Policy Act in 1969 and the Occupational Safety and Health Act of 1970), which in turn created multiple new federal regulatory agencies [such as the FDA, Environmental Protection Agency (EPA), and the Consumer Financial Protection Bureau (CFPB)]. These agencies have spawned numerous scientific advisory boards and committees, usually governed by the Federal Advisory Committee Act (FACA), to provide technical advice to their parent agency tasked with implementing regulatory policy. In 2019 there were 957 active FACA committees with 70,253 members—an effort costing almost $400 million. The influence of these un-elected boards, panels, and commissions have become so pervasive that collectively they have been labeled "the Fifth Branch" of the U.S. government.[24] The explosive growth of widely available technical information has further fueled the drive for data-driven regulations.

Regulations often have significant financial and national economic implications. They can also lead to a perception that the government is curtailing individual

20 Eisenhower Library, "Text of the Address by President Eisenhower, Broadcast and Televised From His Office in the White House, Tuesday Evening, January 17, 1961, 8:30 to 9:00 P.M., EST" (January 17, 1961). https://www.eisenhowerlibrary.gov/sites/default/files/research/online-documents/farewell-address/1961-01-17-press-release.pdf. Accessed May 5, 2022.

21 A response to 1901 contamination events involving smallpox vaccine and diphtheria antitoxin.

22 Rachel Carlson, *Silent Spring* (Boston, MA: Houghton Mifflin, 1962).

23 Ralph Nader, *Unsafe at Any Speed: The Designed-in Dangers of the American Automobile* (New York, NY: Grossman Publishers, 1965).

24 Sheila Jasanoff, *The Fifth Branch: Science Advisors as Policymakers* (Cambridge, MA: Harvard University Press, 1990).

liberties, a sentiment that complicates the provision of technical advice for policymakers. In many instances, regulations spark partisan battles, wherein, for example, "…leaders have seen federal regulations and efforts to control environmental toxins or contagions as infringements on liberty."[25] These concerns have led to a heightened scrutiny on the impact of scientific advice when drafting and implementing regulations.

Disputed Authority: Challenges to Professionalism

Often, rather than contest the value of a desired regulatory outcome, opponents question the science—the steps that must be taken to achieve goals that reflect agreed upon values (clean air, clean water, safe workplaces, public health, and national security, for example). These technical debates are further fueled by the reemergence of the internet-enabled non-specialist (Bache's reborn modified charlatan). Whether this softening of expert scientific authority is seen as positive or negative depends on the issue, the commentator, and personal belief. Amid this "proliferation of charlatans," as Bache might have phrased it, government decisionmakers may be even more uncertain about how to proceed.

Concerned about the public's eroding trust in science, in 2019 the American National Academies of Sciences, along with all the Group of Seven (G7) members of the Academies of Science, called for increasing the quality of science dissemination while cautioning against the modern incarnation of charlatans:

> It may be difficult for citizens to distinguish credible scientific information from unfounded claims, an urgent question because of the rapid dissemination enabled by digital technology with considerable expansion of fake news and pseudoscience and their commercial or ideological exploitation. Although people frequently express doubts about scientific facts, they nevertheless often trust blindly in what they find from web searches because they are overconfident about technology, uncritical with respect to the reliability of new sources and misled by the apparent validity of pseudo documents.[26]

As they grapple with these difficulties, scientists and policymakers often reach for the "linear model" for science advising. In this conception of science, facts are first concluded by a detached scientific community in an atmosphere uncorrupted by politics, then subsequently flow downstream into the messy world of policy:

25 Matthew Dallek, "The GOP has a long history of ignoring science. Trump turned it into policy," *The Washington Post* (October 9, 2020).

26 Royal Society, "Summit of the G7 Science Academies March 25-26 2019, Science and Trust" (2019). https://royalsociety.org/-/media/about-us/international/g-science-statements/2019-g7-declaration-science-and-trust.pdf?la=en-GB&hash=32D575A44FA381AB16B9ADF762FA99FB. Accessed May 5, 2022.

> [An] idealized image of the scientific expert involves not simply knowledge, but also a large element of objectivity, of being above politics and partisanship. The idealized policy expert brings the neutral authority of science to bear on politics. Experts derive legitimacy from their ability to appeal to non-political political standards: the use of dispassionate scientific methods of inquiry, validation through peer review rather than mere assertion, and other classic elements of …science.[27]

Despite its appealing simplicity, this picture is often at odds with actual knowledge production processes of the scientific community. Moreover, the claim that policymakers need only seek out dispositive policy answers that flow strictly from "the science," even when that science is settled beyond doubt, is usually a specious one. As stated earlier, the science behind today's difficult policy issues is complex, multidisciplinary, and incomplete. And scientists—in their work as scientific producers of knowledge and especially when solicited for advice—are significantly influenced by individual motivations and values. With the exception of a limited number of well-defined problems—how to build a bridge, for instance, or remove an appendix—most sociotechnical problems are "ill formed" or "wicked" problems.[28] They do not lend themselves to precise measurement, prediction, and control according to a single set of disciplinary standards. However, because multiple reservoirs of knowledge are required, a direct result is

> "…that in many cases, competing interest groups can each find high-quality science advice that supports their political views. The convergence of emerging knowledge, combined with different results produced by different disciplinary perspectives, make it possible for advocates on different sides of an issue to 'cherry pick' whatever scientific claims support their political goals."[29,30]

International scientific organizations have recognized the urgency of this issue and made calls for comprehensive action. In a statement released during the summit of G7[31] science academies in March 2019, member states jointly called for:

- More comprehensive education about the scientific method

27 Bruce Bimber, *The Politics of Expertise in Congress: The Rise and Fall of the Office of Technology Assessment* (Albany, NY: State University of New York Press, 1996), p12, as quoted in Wilhelm Agrell and Gregory F. Treverton, *National Intelligence and Science* (New York, NY: Oxford University Press, 2015), p91.

28 Mark B. Brown, Science in Democracy: *Expertise, Institutions, and Representation* (Cambridge, MA: MIT Press, 2009), p10.

29 Daniel Sarewitz, "How Science Makes Environmental Controversies Worse," *Environmental Science and Policy* 7, no. 5 (2004), as referenced in Brown, p11.

30 Brown, p12.

31 The G7 (Group of Seven) is an intergovernmental organization comprised of Canada, France, Germany, Italy, Japan, the United Kingdom, and the United States.

- Improved dissemination of science to the public
- Communication modes that do not minimize doubts or exaggerate promises
- A requirement for rigor and integrity from scientists and improvements in science assessment emphasizing quality and relevance
- Better dialogue between scientists, social groups, and decisionmakers to inform choices about the major issues facing society[32]

A central premise of the G7's proposed remedies is that a lack of understanding of (or confidence in) science is the primary barrier to better decisionmaking and public policymaking. If this is so, with improved understanding of the relevant science, decision quality would improve, leading to better policy. While it is true that a lack of understanding or confidence in science may be a major, or even a dominant concern, the G7 statement does not address this problem's twin: when a policymaker (or the public) relies inappropriately on scientific authority to arbitrate normative issues. Ultimately, the policymakers are responsible for their decisions—decisions that are ultimately political and will always be informed by more than science alone. Developing and implementing transparent practices that help to ensure delivery of the best scientific input (that has clear limits and is easily understood) is an important element of high-quality decisions.

Selecting Experts

From the professionalization of science in the 1800s to the necessity of rooting out misinformation it the 21st century, scientific influence on policymaking has depended on who is listened to and who is believed. The question of "who deserves a platform" is difficult to answer and bears both on where the boundaries for good-faith scientific discourse should lie and on fundamental issues of freedom of expression. So, too, is the question of who has the responsibility—or the right—to make such a decision. Professional societies? Journalists? University administrators? Social media companies? Scientists who naively expect policy debates to resemble the good-faith discussions of their subfields may "unintentionally [help] to promote controversy and doubt, and that ultimately [impede] an effective... response."[33]

To select experts, policymakers often rely on scientific markers for reliable knowledge production (such as one's membership in relevant professional societies, academic credentials, and association with respected institutions) even though these metrics are not designed to prepare scientists to function effectively to support policy development. On the contrary, these markers of authority indicate that the bearers have spent a great deal of time within dedicated technical communities, often acting

32 See the 2019 G7 science academies' declaration of science and trust: 2019 G7 science academies declaration: Royal Society, "Science and trust."

33 Cecilia Tomori, "Scientists: don't feed the doubt machine," *Nature* 599 (November 4, 2021).

(and disagreeing) in good faith. The normative boundaries and priorities of these communities are not necessarily aligned with the realities of policymaking processes, and politicians must be willing to recognize these normative boundaries as they decide who to ask for expert advice. Scientists must also recognize that in the policy space, scientific standards (such as journal-based peer review and the expectation of academic degree-holding) may come across as suppression of good-faith dissent to actors with differing values. Balancing these two ideals requires trust between both communities.

Recent changes in the United States justice system, which regularly depends on scientific knowledge as embodied in experts, provide a clear example for policymakers. By necessity, courts have a mature framework for designating experts to clarify technical issues in legal proceedings, such as at a trial. The introduction of the Daubert standard for scientific and technical evidence in the 1990s into the Federal Rules of Evidence[34] emerged from a series of landmark Supreme Court rulings on evidentiary admissibility amid a broader concern about so-called “junk science” pervading federal courts. Proponents of a change to the rules of evidence argued that in many cases, shoddy scientific evidence was unduly influencing decisions that might have been different had more “objective” science been admitted.

But as critics of the Daubert standard have argued,[35] imploring judges to "think like scientists" is no more sensible than telling scientists they should "think like judges.” Here, as in national security policymaking, scientific knowledge is an important contributor to a high-quality decision (i.e., a jury’s verdict) but is not necessarily the dominant factor. Even if the science is well understood and certain, a just, fair, and consistent process is itself the primary goal in the courtroom. In the end, the decision and its quality rests fully with the decisionmaker (jury and/or judge) and not the scientist. In certain circumstances, fixating on scientific rigor may make legal decisions worse if this higher priority is ignored, as Supreme Court Justice John Paul Stevens noted in the *Reference Manual on Scientific Evidence*:

> Finally, a court proceeding, such as a trial, is not simply a search for dispassionate truth. The law must be fair. In our country, it must always seek to protect basic human liberties... Any effort to bring better science into the courtroom must respect the jury's constitutionally specified role—even if doing so means that, from a scientific perspective, an incorrect result is sometimes produced.[36]

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34 Cornell Law School Legal Information Institute, “Federal Rules of Evidence, Rule 702: Testimony of Expert Witnesses.” https://www.law.cornell.edu/rules/fre/rule_702. Accessed May 5, 2022.

35 Sheila Jasanoff, “Law’s Knowledge: Science for Justice in Legal Settings,” *American Journal of Public Health* 95, S49_S58 (July 2005). https://doi.org/10.2105/AJPH.2004.045732. Accessed May 5, 2022.

36 Federal Judicial Manual, *Reference Manual on Scientific Evidence, Third Edition* (January 1, 2011). https://www.fjc.gov/content/reference-manual-scientific-evidence-third-edition-1. Accessed May 5, 2022.

Analogous cases are those national security or other public policy issues where science may provide straightforward policy responses but with which the U.S. system of government and commonly held values are at odds (i.e., mass, continuous surveillance of the population to prevent espionage and crime).

For a national security policymaker, it is clear that "trusting science" is necessary for gathering accurate information, but it is also insufficient to completely resolve most policy challenges. Nor can a policymaker simply follow certain very specific formulae for incorporating scientific evidence like those developed by (and hotly debated in) the justice system. Ultimately, while science is uniquely effective at developing knowledge, and knowledge is necessary, it is insufficient by itself for determining decision quality. Both in policymaking and law, a key responsibility of each decisionmaking sphere is then to define quality on its own terms, consistent with underlying social and institutional values. National security policymakers must carefully assess which values they wish to center in their decisionmaking (such as risk minimization, resilience, sustainability, etc.) and design their decisionmaking processes accordingly.

A Note on the Policy Response to the COVID-19 Pandemic

In this paper, we attempt to steer clear of the science and policymaking flurry surrounding the ongoing COVID-19 pandemic. However, given its prominence to science-for-policymaking issues, we feel a brief note is necessary. The pandemic plainly illustrates the difficult positions that scientists are placed in when asked to provide expert input to policymaking, as well as the difficult positions of policymakers who must act in the absence of answers. At the risk of oversimplification, current American debate on proper policy responses to COVID-19 is often framed as a controversy between trust in scientific expertise (case rate data, tracking variants, and the size of vaccine trials, for example) versus trust in other societal values (freedom of assembly, economic stability, education access, for example) as the dominant policy consideration. One result has been a "scientization of politics":[37] those who "trust the science" make special appeals to find and apply neutral, scientific criteria by which the goodness of policies can be decisively decided. As Professor Mark Brown explains, such scientization then contributes to the "politicization of science," increasing demand for neutral experts but weakening trust in them, politicizing expertise which "…increases expert prominence, yet renders expert authority more vulnerable to challenge." On the other side of the framing of the debate are so-called "values trusters" who may respond either by downplaying scientific information about COVID-19 (or implying it is not relevant for decision-making) or by highlighting nuggets of high-quality, but controversial, science to support their preferred policy response.

We offer no scientific or specific policy recommendations on COVID-19 (nor should we, lacking experience in public health policy). However,

37 Mark B. Brown, *Science in Democracy: Expertise, Institutions, and Representation* (Cambridge, MA: MIT Press, 2009), p10.

as we hope our EMP policymaking analysis shows, policymakers cannot afford either to discard expert advice out of hand or to pretend that scientific experts are oracles. Even perfect scientific knowledge—rarely available for policy issues that matter—must be seated within a value system before it can be applied to a particular policy option. For their part, experts have a responsibility both to provide high-quality advice while also deferring to policymaker priorities and values, which are categorically different from technical input. The framing of COVID-19 controversy, pitting a trust in science against a trust in values, is detrimental to a policymaking process that requires both to be effective. As just one example, the degree to which vaccines reduce transmission and hospitalization of COVID-19 is a scientific question, while the question of whether to enact and how to enforce a vaccine mandate is based on values. Mis-framing either of these questions invariably confuses our answers to both.

Dialogues: An Idealized History of EMP

The more than 20-year history of policy development to mitigate the potential national security impact of EMP threats—multiple commissions, at least nine dedicated Congressional hearings, and several high-profile popular treatments[38]—illustrate the challenges policymakers face when addressing highly technical subjects. The record also provides many examples of scientists, committees, and commissions embodying differing roles scientists and other technical experts may play in the policy development process. These roles and their impact on the policy process are important for policymakers, scientists, technical experts, and the public to understand. To frame our investigation into the EMP policy response case, we recruit Professor Roger A. Pielke, Jr.'s helpful construct of four idealized roles for scientists that illustrate the distinct and meaningful options to impact policy.[39] Per Pielke, the effectiveness of each role hinges on two broad features of the policy question at hand: first, whether the policy choices are characterized by both values consensus and low technical uncertainty, and second, whether technical advice expands or restricts the scope of policy choices available. Abridging from Pielke, they are:

- **Pure Scientist:** The pure scientist furnishes decontextualized scientific information to decisionmakers but does not engage the policy question or the process. In the EMP context, a geophysicist publishing academic work mapping variation in Earth's magnetic field would exemplify the role of the Pure Scientist (minimal values controversy and detachment from policy options).

- **Science Arbiter:** The science arbiter directly answers questions the decisionmaker believes to be relevant to policy but attempts to stay above the fray by avoiding normative assertions or preferred alternatives. An aerospace engineer providing information to a policymaker on how a distortion of Earth's magnetic field might impact communications satellites would exemplify the role of the Science Arbiter (minimal values controversy, but explicit engagement with the policymaking process).

- **Issue Advocate:** The issue advocate makes a case (wittingly or unwittingly) for one policy alternative over another. A nuclear physicist arguing for—or against—stricter but expensive EMP hardening requirements in civilian electrical devices would exemplify the role of the Issue Advocate (values controversy and advocacy for one choice among many).

38 The appendix at the end of this paper provides a chronology and references for this policy development period (1995-2019).

39 Roger A. Pielke, Jr., *The Honest Broker: Making Sense of Science in Policy and Politics* (Cambridge, UK: Cambridge University Press, 2007).

- **Honest Broker of Policy Alternatives:** The honest broker engages with specific policy alternatives and policymaker norms, but, unlike the issue advocate, works to expand or clarify the scope of policy choice.[40] A Congressional Research Service staffer contextualizing multiple policy alternatives for EMP mitigation—no change to current regulations, strengthening regulations, or funding an additional experimental facility at taxpayer expense to gather more data—exemplifies the role of the Honest Broker (values controversy and expanded scope of choice).

Each of these roles has a legitimate place in the policymaking process, but they differ in how they limit or expand the scope of choice, uncertainty, complexity, and confidence in outcomes. These variables are all immersed in the context of diverse and often competing political values. In Pielke's prescription, where there is consensus on values and policy outcomes, scientists can play very effective roles as Pure Scientists and Science Arbiters. Without that consensus, these two roles have diminished efficacy and increasingly risk contributing to the politicization of science.[41] In the low-consensus regime, the Honest Broker and Issue Advocate play important roles because they explicitly engage with stakeholder values and support development of policy options for decisionmaker consideration. However, when values consensus is high and scientific uncertainty is low, the Honest Broker and Issue Advocate may be less efficient than the Pure Scientist and Science Arbiter at getting the facts across. If values and facts lead to only a few self-consistent options, then the Honest Broker is less useful.

The historical themes discussed in the previous section also influence the justification provided by advisors and how they jockey for attention. For example, Issue Advocates clearly represent those pursuing societal goals—national defense (protection from a catastrophic attack) and economic benefit (in the form of resilient and affordable infrastructure) to the country. They may or may not also be characterized as amateur scientists. The Honest Broker and Science Arbiter who engage with policymaker questions may be cast as members of the Fifth Branch—unelected individuals potentially determining policy. The Pure Scientist who offers technical advice on subjects where they have unquestioned expertise and who refuses to be drawn into topics on which they are unqualified to respond is laudable, but may also frustrate policymakers with very short timelines who need a workable answer without delay.

Using the EMP case as an example to juxtapose the impact of these roles on policy alternatives, we present three hypothetical dialogues between policymakers and scientists. The dialogues proceed in rough chronological order, following a life cycle for policy development. We chose this format because we feel it allows us to

40 Pielke, pp1-2.

41 Pielke, p53.

explore the many stages at which technical advisors often participate in policymaking environments. The points of view we present should not be taken as endorsement or criticism, implicit or otherwise, of actual EMP policy outcomes or participants in the process. Rather, this should be seen as an exploration of how the contours of policy are affected by the roles that advisors believe they should be playing. For those interested in further detail on historical EMP policy, the Appendix details the history of concern over high-altitude EMP (HEMP) impact on civilian infrastructure. Much of the material requisitioned in the dialogues can be found here in its original context.

While much of the dialogue is fictionalized and written specifically to highlight various roles, many of the statements are drawn verbatim from actual Congressional testimony and the public record (as referenced throughout the paper). All dialogue taken verbatim or paraphrased from public records is set off in italics, with sourcing in the footnotes. The participants in our dialogue are fictional but have comparable backgrounds to the actual participants from the historical record.

Dialogue 1: Understanding EMP

Scenario: Policymaker A, the chairman of the Congressional Military Research and Development Subcommittee of the Committee on National Security, has noticed a considerable uptick in concern over EMP among her constituents. Spurred by this interest, she sought out some popular treatments of EMP, many of which conclude that EMP is a grave but underappreciated risk to national security. To assess professional consensus on the topic, the chairperson has convened a public Congressional hearing on EMP threats to military systems and civilian infrastructure, requesting input from several scientific experts.

Participants

Policymaker: Member of Congress, chairperson of the Military Research and Development Subcommittee, Committee on National Security

Pure Scientist: Professor in Astrophysics at a major private university and chief scientist for a national astronomy observatory, with a PhD in Astronomy

Science Arbiter: Director of a federally funded science and technology research laboratory, with a PhD in Nuclear Physics

Issue Advocate: Deputy Director of Department of Defense's agency responsible for nuclear and advanced weapons expertise, with a PhD in Electrical Engineering

Policymaker: *The subcommittee is meeting here today to explore in more detail EMP effects on our military systems and the civilian infrastructure, how confident we are that we can predict these effects, our potential vulnerabilities, what policies and practices should guide our efforts to protect our systems, and the steps we have taken and can take to ameliorate these vulnerabilities.*[42]

Pure Scientist, I'd like to start by asking you to explain, in generic terms, what is an EMP?

Pure Scientist (testimony): *Electromagnetic Pulse (EMP) is an instantaneous, intense energy field that can overload or disrupt at a distance numerous electrical systems and high technology microcircuits, which are especially sensitive to power surges. A large scale EMP effect can be produced by a single nuclear explosion detonated high in the atmosphere. This method is referred to as High-Altitude EMP (HEMP).*[43] *Studies of electromagnetic pulse (EMP) effects on civilian and military*

42 United States Congress, House Committee on National Security, Subcommittee on Military Research and Development, "Threat Posed by Electromagnetic Pulse (EMP) to U.S. Military Systems and Civil Infrastructure" (July 16, 1997).

43 Clay Wilson, *High Altitude Electromagnetic Pulse (HEMP) and High Power Microwave (HPM) Devices: Threat Assessments*, CRS Report for Congress, Congressional Research Service (Updated July 21, 2008), p2.

systems predict results ranging from severe destruction to no damage. Convincing analyses that support either extreme are rare.[44]

Policymaker: Is EMP merely a hypothetical phenomenon, or has this effect been demonstrated?

Pure Scientist: EMP and its effects were observed during the U.S. and Soviet atmospheric nuclear weapon test programs in 1962. One such observation was after the U.S. Starfish Prime nuclear detonation that occurred at an altitude of about 400 kilometers above Johnston Island in the Pacific Ocean. While not designed or intended as an EMP generator, some electronic and electrical systems in the Hawaiian Islands, 1,400 kilometers distant, were affected, causing the failure of street-lighting systems, tripping of circuit breakers, triggering of burglar alarms, and damage to a telecommunications relay facility. In their testing that year, the Soviets executed a series of nuclear detonations in which they exploded 300 kiloton weapons at approximately 300, 150, and 60 kilometers above their test site in South Central Asia. They report that on each shot they observed damage to overhead and underground buried electrical cables at distances of 600 kilometers. They also observed the burnout of surge arrestors, spark-gaps breaking down, blown fuses, and breakdowns of the power supply.[45]

The Hawaiian streetlight incident associated with the Starfish nuclear burst is the most widely quoted observed damage. We reviewed the streetlight characteristics and estimate the coupling between the Starfish EMP and a particular streetlight circuit identified as one of the few that failed. Evidence indicates that the damage was EMP-generated. The main contributing factors were the azimuthal angle of the circuit relative to the direction of EMP propagation, and the rapid rise of the EMP signal. The azimuthal angle provided coherent buildup of voltage as the EMP swept across the transmission line. The rapid rise allowed substantial excitation before the cancelling effects of ground reflections limited the signals. Resulting voltages were at the threshold for causing the observed fuse damage and are consistent with this damage occurring in only some of the strings in the systems.[46]

Policymaker: Thank you for your testimony, Pure Scientist. As I am not an expert on electromagnetic propagation, I am afraid I will need some more context to understand exactly what we're talking about. Issue Advocate, can you supplement Pure Scientist's description of EMP?

Issue Advocate: Yes. I can assure you, that, unfortunately, EMP is not a hypothetical phenomenon. Any nuclear detonation at high altitude *has as its salient feature the ability to simultaneously bathe an entire continent in EMP. The ability of EMP to induce potentially damaging voltages and currents in unprotected*

44 Charles N. Vittitoe, "Did High-Altitude EMP Cause the Hawaiian Streetlight Incident?" Sandia National Laboratory, SAND88-3341 (April 1989). https://www.osti.gov/servlets/purl/6151435. Accessed May 5, 2022.

45 EMP Commission Executive Summary (2004).

46 Charles N. Vittitoe, "Did High Altitude EMP Cause the Hawaiian Street Light Incident?" (April 1989).

electronic circuits and components is well known. The immense footprint of EMP can therefore simultaneously place at risk unhardened military systems, as well as critical infrastructure systems to include power grids, telecommunication networks, transportation systems, banking systems, medical services, civil emergency systems, and so forth.[47]

All unhardened satellites in low Earth orbit … can be expected to demise … in a matter of days to weeks following one such high-altitude burst. A knowledgeable adversary, armed with a few nuclear weapons, might seek to exploit any such perceived vulnerability, thereby severely degrading the significant U.S. technological advantage built on a foundation of sophisticated electronic systems.[48]

[The] National Security Strategy for a New Century, issued by the White House, warns against the likelihood of an adversary using asymmetric means that avoid our strengths while exploiting our vulnerabilities. To quote from the report, ''Because of our dominance in the conventional military arena, adversaries who challenge the United States are likely to do so using asymmetric means, such as weapons of mass destruction.''[49]

The mandate is clear. Hardening systems to the pervasive effects of high-altitude explosions must be part of an overall strategy to balance asymmetries and to disincentivize the acquisition and use of nuclear weapons by potential adversaries.[50]

Policymaker: Thank you, Issue Advocate. It seems from your testimony that EMP is an incontrovertible, potentially catastrophic phenomenon, but I am still trying to understand what exactly it is and why, if it is so potentially perilous, it has not received urgent attention from Congress in the past. Perhaps I am missing some context—Science Arbiter, can you comment?

Science Arbiter: Thank you, Ms. Chairperson. Yes, some additional context would be in order. We've heard much today already about EMP, HEMP, and the negative impacts they could generate, particularly against our critical civilian infrastructure and military systems. We should note that EMP is not a monolith: there are many varieties of EMP. Local, small-scale EMPs include those created in the vicinity of a lightning strike and those generated by military devices to disrupt operation of an adversary device or facility. Large-scale EMPs include those caused regularly caused by solar storms, which can disrupt electrical power and communications systems for many hours across thousands of miles, and HEMPs, which Pure Scientist and Issue Advocate have already discussed.

It is important to distinguish between an EMP attack and a natural EMP event. An EMP attack typically refers to a scenario where an adversary detonates a nuclear device roughly 40 kilometers in altitude or higher above a target region. Due to the

47 United States Congress, House Committee on National Security, Subcommittee on Military Research and Development, "Threat Posed by Electromagnetic Pulse (EMP) to U.S. Military Systems and Civil Infrastructure" (July 16, 1997).

48 Ibid.

49 Ibid.

50 Ibid.

interaction of the blast with the Earth's atmosphere and magnetic field, a series of pulses, referred to as E1, E2, and E3, propagate downward toward the Earth's surface. Each pulse has a different character and potential impact on electrical devices below.

Contrast this with a natural EMP event called a geomagnetic disturbance, or GMD. These occur during solar storms, and large-scale, potentially devastating events are expected to occur every century or so. GMD is a well-understood scientific phenomenon with potential to damage long power and communications infrastructure, as occurred in the 1989 Quebec GMD incident. In this sense, they are like an earthquake: inevitable in the long run, but difficult to forecast either in terms of timing or damage. A significant difference is that GMDs from solar storms give advance warnings hours—or even days—ahead of time.[51]

Policymaker: I can only conclude that EMP is real, with effects somewhere between a temporary, local blackout and a months-long national catastrophe. Is there any judgment on which end of that spectrum we're more likely to land on? Additionally, it's not even clear who would attempt an EMP attack, or why. I feel like we're drinking water from a fire hose. We're going to need more hearings on this if we're looking to craft any sensible policies. You've convinced me this is a problem worth investigating, but there's no clarity on how to go about solving it.

Scenario Takeaway

In this scenario, the Policymaker enters with minimal information about EMP and has requested a basic introduction. In response, the Pure Scientist provided a description about one type of EMP (HEMP) and some technical details concerning the Hawaiian streetlight incident, a well-documented example of electromagnetic effects on the ground due to a high-altitude nuclear burst. To the Policymaker, it's not clear how relevant these facts are to today's world. Faced with the same question, the Issue Advocate instead detailed some worst-case effects and possible adversary motives, then proposed a course of action—from hardening electrical systems to dissuading adversaries from pursuing nuclear weapons—but has not given any sense of how likely the feared impacts might be. The Science Arbiter provided the Policymaker much-needed context that there are multiple types of EMP, including introducing natural EMP phenomena such as geomagnetic disturbance (GMD), plus some estimates of their attendant uncertainty and risk profile, but deliberately avoided any connection to policy options. The Policymaker leaves with a sense that EMP is a real risk and potentially very harmful, but lacks a bearing on how it could or should be addressed.

51 National Oceanic and Atmospheric Administration, Space Weather Prediction Center, "Current Space Weather Conditions - Alerts, Watches, and Warnings." https://www.swpc.noaa.gov/products/alerts-watches-and-warnings. Accessed May 5, 2022.

Dialogue 2: Assessing and Mitigating EMP Risk

Scenario: After the previous hearing, the Policymaker considers EMP a serious issue that requires a response from Congress. She convenes a panel of experts to assess EMP risk and develop some mitigation strategies, in preparation for drafting legislation.

Participants

Policymaker: Member of Congress, chairperson of the Military Research and Development Subcommittee, Committee on National Security

Pure Scientist: Professor in Astrophysics at major private university and chief scientist for a national astronomy observatory, with a PhD in Astronomy

Science Arbiter: Director of a federally funded science and technology research laboratory, with a PhD in Nuclear Physics

Issue Advocate: Deputy director of Department of Defense's agency responsible for nuclear and advanced weapons expertise, with a PhD in Electrical Engineering

Policymaker: Thanks to the panel of experts convened here today. At our previous hearing, we learned about the phenomenon of EMP and its potentially dire risk profile. Today we will focus on more practical concerns, including assessing acute EMP risks and possible mitigation strategies worth pursuing.

I would like to begin this risk assessment process by asking what is the typical range for an EMP? *I would ask our physicists especially on the panel to respond because they are the experts. You say that an EMP burst would occur at an altitude of 250 miles? Is that the appropriate or optimum altitude for an EMP burst to take place?*[52]

Pure Scientist: *Yes, [for maximum range] you would want to be at about 300 or 400 kilometers, 250 miles, and you would be in the megaton class yield.*[53] Let me refer you to [Figure 1], a typical "Smile Diagram," which shows the relative field strengths that would occur on the ground as calculated from an EMP simulation for using a 1 megaton weapon at 200 kilometers.

Policymaker: Does this mean that most of the country would suffer a blackout? If so, how permanent would that be? What's the difference between the red space and the outer blue edges? I see a scale between 0 and 1.

52 United States Congress, House Committee on National Security, Subcommittee on Military Research and Development, "Threat Posed by Electromagnetic Pulse (EMP) to U.S. Military Systems and Civil Infrastructure"(July 16, 1997).

53 Ibid.

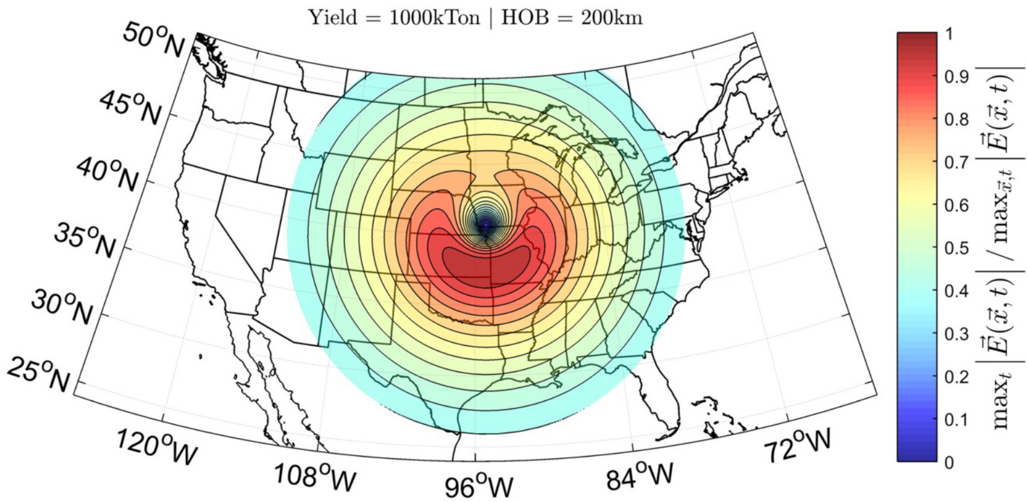

Figure 1. Normalized smile diagram for benchmark 5 (Yield = 1,000 kilotons, Height of Burst (HOB)= 200 km; ground zero location is 40° N, 95° W) Source: Los Alamos National Laboratory, LA-UR-18-23547

Pure Scientist: This chart demonstrates that the impact would be observed by most of the country, but it doesn't explicitly tell what the on-the-ground impact to our infrastructure would be.

Science Arbiter: All I can say with certainty is that things will be worse at higher fields than lower, all other things being equal.

Issue Advocate: That's absolutely right. Most, if not all, of the country would feel the effects of this attack, so we'd need to be prepared at a national level.

Policymaker: Well, would you say with a fairly high degree of certainty that we would experience the impact specifically within our utility systems and our communications systems? Would that likely happen in the pale yellow or only in the dark red? I represent Tennessee. I'd like to address to the entire panel: Can any of you tell me what would happen in Nashville?

Pure Scientist: In this scenario, the people in Nashville would experience about 50% of the peak field strength that people at the epicenter of the blast would experience. There are too many questions about the infrastructure about the city, even some that we don't even know to ask because we have no data on this type of question. There's just no way I can give you an accurate description.

Issue Advocate: The Pure Scientist is right, there's no precedence for this type of attack, so there's no way to be certain how safe the people of Nashville would be if it happened. But, given the potentially catastrophic impact of losing vital infrastructure and services suddenly—and for an extended period of time—we need to hope for the best and assume the worst. I can't promise you that your constituents would be okay.

By comparison, we have substantial impact on our communications and utilities systems from solar magnetic storms which impose far, far lower fields on the long transmission lines and communications systems than, you know, are involved in EMP. And so there would undoubtedly be impact.

Policymaker: I understand your chart is meant to model an adversary's nuclear attack with many uncertainties. How's that related to natural EMPs that have been discussed before? You reference impact from solar storms. Aren't those brief and perhaps better called upsets than major disruptions? Don't we recover from those rapidly?

Science Arbiter: I'd say that's an accurate characterization. We've seen these before and tend to recover quickly. Plus we'd likely have warning. NOAA provides advanced warnings[54] of solar disturbances for the communications and power industry so that they're able to take preventative actions. But in the end there might be very little impact at all on over 90% of the affected area as shown on that map.

Policymaker: I suppose my question was ill posed. What I want to know is: what is the appropriate or optimum altitude for an EMP burst to cause damage? I don't know how to interpret an esoteric quantity like relative strength.

Science Arbiter: No one has such a map—I know of no trusted, predictive way to quantify expected harm-on-the-ground.

Policymaker: Given all this uncertainty, can we look at a historical example of this, or as close as we can get to one? In the background materials this committee's been provided with, you mention the Starfish Prime test and its effects on Hawaiian infrastructure. From our understanding of what happened in Hawaii, can we expect much more widespread impact on electrical infrastructure if an adversary deliberately targets us with HEMP? And what do we need to do to prevent or at least mitigate that impact? Pure Scientist, can you answer that question?

Pure Scientist: We simply don't have enough data to extrapolate any lessons from the Starfish Prime test. It would be irresponsible to draw any firm conclusions from this, especially any lessons that would apply to current-day infrastructure.

Policymaker: It might be irresponsible for you, the Pure Scientist, to draw any firm conclusions for current-day infrastructure, but making firm decisions is my job description. Can you help here, Issue Advocate?

Issue Advocate: In short, *we have found that the EMP phenomenon is very real and is well understood by the nuclear weapons effects community; that our strategic systems and their command, control, and communications infrastructure have been designed and built to survive and operate effectively in such an environment; that there would likely be pronounced effects on the civilian infrastructure from such a pulse; that the magnitude and extent of these effects is difficult even to estimate; and that it is probably not feasible to completely protect the entire infrastructure from the effects of*

54 See reference 51.

such a pulse.[55] In truth, we can't conclusively say that current infrastructure isn't more vulnerable to such a pulse.

How much of the telecommunications systems would fail and for how long, how much of the power grid would be disrupted and for how long, how many cars would stop and/or would not start are things that are extremely difficult to predict.[56] This is one of the few avenues that a foreign adversary could use to devastate Nashville—something that your constituents have rightly picked up on and elevated to your attention.

Policymaker: I think we've made some progress here. Per the expert testimony, I understand why it's difficult to predict the likelihood of severe—or even catastrophic—impact. I'm sure the Pure Scientist's Smile Diagram is technically accurate, but as the Science Advocate clarified, it cannot tell me what I want to know about impact on the ground. The Issue Advocate sees the uncertainty as a reason to act (and providing some tempting political justification for doing so)—but from my point of view, how to act mostly depends on how likely this type of attack would be in the first place, which we've come no closer to determining. Perhaps an intelligence estimate of adversary capabilities is more important than a technical assessment of EMP physics. As we plan for a final hearing, I wanted to leave these two questions for the panel and the rest of the committee: One, what measures could mitigate the impact of such an attack? Two, would federal regulation be the best way to achieve these measures?

Scenario Takeaway

In this scenario, the Policymaker's goals are to quantify EMP risks and identify mitigation strategies. In particular, the Policymaker wants to quantify risk in plain-language terms, something that could serve as robust justification for a policy response. In their answers, the three different experts give three very different impressions of the same technical risk profile, without any of them being intentionally misleading. The Smile Diagram introduced by the Pure Scientist presents a technically sound but very narrow slice of possibilities for the Policymaker. How one interprets it depends on a variety of values, risk perception, and one's own tolerance for risk. Additionally, we see how the Pure Scientist's refusal to offer context or comparison to go along with scientific facts about incidents such as Starfish Prime may do more harm than good if the Policymaker herself doesn't already have an effective contextual framework in which to place the new information. While the Science Arbiter and Pure Scientist demur in the face of direct questioning about on-the-ground harm, the Issue Advocate fills the void with justification for their preferred alternative. The Policymaker concludes that other sources of information, such as intelligence assessments, may be more relevant to their overarching policy goals.

55 United States Congress, House Committee on National Security, Subcommittee on Military Research and Development, "Threat Posed by Electromagnetic Pulse (EMP) to U.S. Military Systems and Civil Infrastructure."

56 Ibid.

Dialogue 3: Enacting EMP Policy

Scenario: The Policymaker has decided to conduct a final hearing on EMP to devise effective policy remedies. To support this goal, she has invited three additional experts, two Issue Advocates and one Honest Broker. The first Issue Advocate is a national security expert and proponent of hardening civilian infrastructure against EMP threats, and the other is a representative from the Electric Power Research Institute (EPRI), an electric industry nongovernmental organization (NGO), which could be impacted by EMP legislation.

Participants

Policymaker: Member of Congress, chairperson of the Military Research and Development Subcommittee, Committee on National Security

Issue Advocate – National Security: Deputy Director of the Department of Defense's agency responsible for nuclear and advanced weapons expertise, with a PhD in Chemistry

Issue Advocate – Electric Industry NGO: Deputy Director of nonprofit NGO performing research studies on the U.S. power grid/power generation capabilities, funded by consortium of electricity providers

Honest Broker: Independent technical expert, extensive research career in physics and former chief scientist and advisor in various executive branch agencies, with a PhD in Physics

Policymaker: As we've planned for this hearing, I've determined there are three questions that we, as a committee, need to address: one, what measures could mitigate the impact of such an attack; two, would federal regulation be the best way to achieve these measures; three: who should pay for it? First, what are we mitigating? What scenario is most likely and which mitigations are most affordable? Lastly, who pays, and how do we develop regulations and enforce them?

Issue Advocate – National Security: I take issue with your question of what's "affordable." Compared to what we spend on other sectors, like entitlements, military budgets, foreign aid, and the F-35, it's clearly worth it to prevent a collapse of our society. The measures required certainly aren't cheap, but they're certainly worth it.

Policymaker: Well, what measures are we talking about? I think it would be worth it to discuss a few options before the committee. Let's give the electric industry NGO representative a chance to talk about the energy sector's research and response to this.

Issue Advocate - Electric Industry NGO: First of all, this is a threat we take seriously. We've conducted research on this and funded studies, and while we've identified mitigation measures, we should also be clear about what our studies show: mainly that the effects of such an event aren't as dire or as widespread as the National Security Issue Advocate makes them out to be. *Assessments using bounding E1 EMP environments showed that this hazard field has the potential to cause disruption or damage to digital protective relays over large areas such as an electrical interconnection. Based on the assumptions made in the assessments, it was estimated that approximately 5% of the transmission line terminals in a given interconnection could have a digital protective relay that is disrupted or damaged by the nominal E1 EMP environment that was simulated, whereas approximately 15% could be impacted by the scaled (up to 50 kV/m at the most severe location on the ground) E1 EMP environment.*[57]

Policymaker: Can you please simplify that a little for me the other members of the committee?

Issue Advocate - Electric Industry NGO: Of course. Basically, the E1 EMP effects described in the EMP research is the main cause of concern. The E2 and E3 EMP effects are not likely to cause as much disruption, and the damage they do will likely result from the combination effects of E1 EMP. In other words: Research suggests that a regional blackout is definitely possible, but the sort of apocalyptic scenario that the National Security Advocate is talking about is extremely unlikely. Our research findings do not support the notion of blackouts encompassing the contiguous United States and lasting for many months to years. This notion of returning to a pre-industrial, Jeffersonian era is scaremongering—pure and simple.

Policymaker: We'll get back to this question of scale in a moment, but I'm curious what your organization identified as realistic mitigation measures.

Issue Advocate - Electric Industry NGO: We've identified several mitigation measures for E1 EMP effects, which our research indicates would be the most harmful. *These include shielded control and signal cables with proper grounding, low-voltage surge protection devices and filters, the use of fiber optics-based protection and control systems, modifications to substation control houses to enhance electromagnetic shielding properties, and other grounding and bonding enhancements. We didn't identify any specific mitigation measures for E2 EMP effects, since our assessments evaluating the potential impacts of E2 EMP indicated that damage to the transmission system is not expected to occur. E3 EMP is similar, with danger coming from the combination of E1 EMP.*[58]

57 EPRI, "High-Altitude Electromagnetic Pulse and the Bulk Power System: Potential Impacts and Mitigation Strategies," EPRI Executive Summary (April 29, 2019). https://www.epri.com/research/summary/000000003002014979. Accessed August 26, 2021.

58 Ibid.

Policymaker: A question to the other experts here: Would these measures work? Are they enough?

Honest Broker: That's a good question, and the answer depends on what you mean by "working." Are we trying to completely eliminate any threat from natural or adversarial EMP? Is it to repair damage done in one of those cases in a timely manner? These are not really the same; neither are they mutually exclusive.

The mitigation measures put forth by the electric power NGO representative are certainly a good start if you want to prioritize resiliency, but they would need to be tested more extensively before we could understand how well it speeds the recovery from such an attack. Pursuing these mitigation strategies is not at odds with further research—it just depends on your funding priorities. If your priorities are broader or you see the risk as less acceptable, there's room for other research, too.

Issue Advocate - National Security: With respect to my fellow panelists, realistic impacts of EMP aren't something you can test. The only "test" that produces the effects we're discussing here would be an actual attack. Separating out specific parts of an intricate system without the broader context gives you partial information, but one misses the cascading nature of the effects. It's analogous to testing an individual relay or power station controller in isolation, but ignoring the possibility of systemic failure, as from a hurricane. The problem is, we're not dealing with risk—we're dealing with uncertainty. Everyone here agrees that we don't have an exact risk calculation for this type of attack—but what we do know are the dire consequences of being wrong.

Honest Broker: It's true that uncertainty is at the heart of this matter, but let me frame this another way. Rather than discuss unknowables, another way of looking at these issues is to think about mitigation strategies. You can try to protect key elements of the grid, which might require research and installing so-called "surge protectors" for key links in grid infrastructure, or you might simply stockpile large amounts of expensive equipment like transformers, even though both are meant to reduce the unknown risk of catastrophic failure. Put simply, would you want to protect the pieces you have, or do you want to have plenty of spares if they do break? What you choose might depend most on your preference for effectiveness versus cost rather than on technical risk. In that case, more research, even if it reduces scientific uncertainty, won't help you make your decision.

Policymaker: If we prepared for every possible scenario because of uncertainty, it would be impossible to manage, and certainly impossible to pay for. I also want to take a moment to remind everyone that we're not saying that an EMP attack would result in "just" a regional grid failure. We take these types of failures seriously, and I hope that no one here believes that we need the hyperbole of systemwide risks to make something a nationwide priority worthy of funding… Well, speaking of paying, who would pay for all of this—all of these mitigation measures that are on the table? The steps we're talking about here would be costly.

Issue Advocate - National Security: I don't care who pays as long as it gets done.

Issue Advocate - Electric Industry NGO: This is a national security issue, so it would make sense for the government to pay for it, rather than have us pass it on to our rate payers.

Policymaker: To be clear, you mean you want the taxpayers in my district to pay for it. However, aren't there things that affect human lives that you're already responsible for repairing? I'm thinking of hurricanes, snowstorms, etc. You're responsible now for mitigating these threats. Additionally, GMD is a natural event. Shouldn't you be prepared for something that's natural and inevitable?

Honest Broker: Electric industry NGO rep, what measures has industry taken to protect against GMD? What additional measures would be needed to be taken to protect against EMP?

Issue Advocate - Electric Industry NGO: Our report I mentioned earlier outlines the steps that we believe should be taken to reduce the risk due to any type of EMP. We also believe strongly that any Congressional mandate to harden our systems should come with appropriate funding from, for example, the Department of Homeland Security, as any imposed costs would impact consumer rates.

Policymaker: It's becoming clear to me that the investment decisions we're talking about are to ensure a rapid recovery, not to completely prevent an attack. So let me ask: let's take a hypothetical scenario, based on the map we looked at in our last session—the Smile Diagram. Let's return to the yellow area in Tennessee, where my constituents are. How long would it take for this area to recover? How long would it take now vs. $1 billion of infrastructure-protection investment from now? Five days? Thirty days? Six months?

Issue Advocate - Electric Industry NGO: It's difficult to give you a strict answer to that question.

Policymaker: Earlier, when you specified the likely effects of the EMP, you mentioned a regional blackout. What do you mean when you say "regional blackout?" Is it something like the blackouts we saw in Texas in 2021? On a scale of four to five days?

Issue Advocate - Electric Industry NGO: Yes. Something like that. Something correctable, but would require time, money, and effort.

Policymaker: Shouldn't you ALREADY be able to do that? If we agree that it was industry's responsibility to repair the grid in Texas, what makes this different?

Issue Advocate - Electric Industry NGO: Hold on for a moment. This is not to say that there wouldn't be unique challenges associated with repairing the damage from an EMP. *Until the transmission system is appropriately hardened against the potential impacts of E1 EMP, recovering from a HEMP-induced blackout may present operators with challenges that have not been experienced following previous blackouts from more traditional causes. These potential challenges are primarily related to unavailable, inoperable, or damaged equipment and impaired situational awareness capability that could occur as the result of E1 EMP-related damage.*[59]

59 Ibid.

Policymaker: What would you need to keep the impact to five days or less? How about 30 days or less? Six months or less? Can we come up with a range of options? Based on experience, what level would you need to keep it at and tells us we can tolerate it?

Issue Advocate - National Security: Honestly, I'm not sure anyone could tell you about an exact solution with an exact price - the research so far on the topic has been too underfunded. There are so many unknowns about this kind of attack, and once you start talking about systemic, cascading failures, recovery efforts are much harder. The most urgent steps are to mandate resiliency standards for the most at-risk types of consumer and communication electronics and to fund a national transformer stockpile that can be used to quickly rebuild the electric grid infrastructure after a widespread blackout.

Issue Advocate - Electric Industry NGO: Again: *Research findings do not support the notion of blackouts encompassing the contiguous United States (CONUS) and lasting for many months to years.... Although E3 EMP is not expected to cause immediate, widespread damage to large power transformers, it may be prudent to evaluate the number of transformer spares that are available to ensure that adequate replacements exist for the number of transformers that are identified as being at potential risk of damage.*[60]

Policymaker: So, I have one person telling me that we're going to back to an agrarian society and I have another person telling me we'd lose power for a few days. I grew up in North Carolina. We have hurricanes all the time. The power goes out, and society doesn't crumble. It seems to me that at that level, this is within the due diligence of the power industry to pay for it and handle it themselves. How is a regional blackout different from a hurricane? I ask this because once you accept the fact that we're not going back to the agrarian age, the funding question gets simpler. If the government pays for the research, as mandated by the 2019 Executive Order, I think that it falls within industry's wheelhouse to take the necessary precautions—to correct a regional failure instead of a country-wide apocalypse—based on what that research finds.

Issue Advocate - National Security: With all due respect, we don't know what it would take to limit it to a few days. I would be very happy with that standard and that solution if we knew how to do it. But we don't. Additionally, we've only been talking about the grid here. Our modern life depends on much more than that. How would we respond if 90% of America's cars suddenly stopped? That means no ambulances, no transport, thousands of accidents. What if 90% of routers went offline suddenly? How would we communicate, or buy goods and services? We're looking at specific trees here, but we live in a forest.

Issue Advocate - Electric Industry NGO: That's correct, I'm only talking about the grid here because that's my—our—responsibility, to the electricity providers of the

60 Ibid., pXII.

U.S., and ultimately, their customers. I can't speak for car manufacturers, and I can't speak for EMS providers. If you want to talk to the chief technology officer of Toyota about EMP shielding, the Policymaker can invite them here. But I can't speak for them.

Honest Broker: I want to interject here: National Security Issue Advocate—can you tell me where you're getting the 90% figure from? If we're uncertain about the effects, couldn't it also be as little as 10%, or even 5% or 1%? Five percent would be bad, but it's not as apocalyptic as ninety. My point is that uncertainty cuts both ways, and assuming the worst isn't necessarily more accurate.

Issue Advocate - National Security: The saying is to prepare for the worst and hope for the best. Not the other way around.

Policymaker: If we summarize everything down over the past few sessions, I think there are some salient points for the committee to consider as we're creating this legislation: It's clear to me that we're going to have to live with some degree of uncertainty here, no matter what this committee decides to do and what funding is allocated and to whom. We're never going to be in a situation to completely eliminate every risk, and assuming that every outcome will be the worst-case scenario isn't going to be productive. Legislating this type of thing is a zero-sum process. Assuming the worst case for one threat is going to mean that we can't fund, study, and protect against another threat that might be less severe, but more probable. We need to get comfortable dealing with uncertainty.

Second, it seems to me that if we're willing to live with a heightened risk—a heightened uncertainty—for the next 10 to 15 years (much as we've done the last 10 to 15 years), we can be spending that time creating new standards for new infrastructure. As our electric industry NGO representative has told us, it's easier and cheaper to raise the safety of new builds than it is to completely retrofit existing infrastructure. If we feel comfortable living some uncertainty until the next generation of infrastructure, we can solve this problem for the next generation of Americans.

Most importantly, whatever this committee decides, I don't think we need another meeting. We have the information we need to write our legislation. We have the facts, now we just need to decide what to do with them.

Scenario Takeaway

In this last dialogue, our Policymaker has developed a command of the basic facts of the EMP threat—enough for her to begin putting the "facts" presented to her by the issue advocates in a broader context. Importantly, she was able to recognize the usefulness of the, at times, biased information presented to her and pick out the relevant information she needed to move forward. Lastly, as we've stated elsewhere in the paper, EMP is not the only priority or threat for which the Policymaker is responsible for guiding debate and legislation. She now has an idea of where this threat falls in her priority list and a general idea of possible mitigation frameworks.

Conclusions

From this case study of policymaking to address to nuclear EMP risk, we draw four broad conclusions about technical advising in the national security decision-making process.

1. The policymaker's values and timeline should dictate how technical advisors can contribute effectively. Scientists need to acknowledge that decisions cannot always wait for dispositive science.

While a policymaker's options can be sculpted by expert input, policy decisions are ultimately theirs to make. In the decisionmaking process, scientific evidence may be a necessary—but not a sufficient—basis for selecting one course of action over another (see concluding remarks of Policymaker in Dialogue 3). This can be contrasted with the pervasive belief that policy should be downstream from the science; that is, that purely scientific results impel certain policies. This picture of science-in-policy may be superficially attractive for both policymakers and scientists, and as such remains a common mental model, even after extensive criticism of this "linear model" by scholars of science.[61] For policymakers, it provides an escape hatch for difficult decisions: if they treat scientific (un)certainty as dispositive for their policy issue, they can justify (in) action or delay, even if the root of controversy is a difference in values, rather than a lack of scientific information. It also permits them to place blame for a poor decision upstream on the science, rather than their judgement. For scientists, the incentives include both better provisioning for additional scientific research, prestige, and a boost to the public standing of the scientific community.

The consequences of the linear model are predictable. A policymaker may request, and accept, scientific advice on a topic for which a given expert has no standing (for example, asking a research physicist, rather than a trained intelligence analyst, about adversary intention with respect to EMP). Alternatively, in a genuine effort to contribute, a scientist may present what they consider essential detail from a scientific point of view (see Smile Diagram in Dialogue 2) but which for a policymaker is overwhelming or useless. An effective advisor will assume different roles depending on how and when they enter the policy development life cycle. When a policymaker is just beginning to understand an issue and what range of policy options are possible, establishing the correct questions to ask may be more useful than advocacy. As policy options take

61 Sheila Jasanoff, "Law's Knowledge: Science for Justice in Legal Settings."

shape, an advisor will increasingly need to incorporate the political context of the issue. Once a policy decision has been made, decisionmakers are less interested in expanding options and more interested in advice that allows for successful policy implementation. Here, a scientist in the role of an issue advocate may be most useful for the policymaker, even if the relevant science is far from settled.

2. Policymakers should not accept the statement "it's too complicated to explain" from their advisors. It is the advisor's responsibility to provide comprehensible and relevant information.

A key advisor function is to filter the vast amount of technical information relevant to a policy decision into digestible portions. In so doing, advisors should be prepared to explain fundamental technical concepts to those with minimal background knowledge without cluttering the decision process with impressive but irrelevant detail (see Pure Scientist's Smile Diagram in Dialogue 2 and ensuing Policymaker confusion). Policymakers should be comfortable asking and repeating basic technical questions without judgment, recognizing that advisors may be forced to reframe questions that are unanswerable or premised on technical misconceptions.

Most policymakers do not have scientific training and may not be able to distinguish reputable scientific evidence from the personal opinion of a scientist. Accordingly, policymakers may conceptualize science as "the answers at the back of the book" rather than an incomplete, iterative mode for knowledge production, subject to social incentives that influence any knowledge production activity. For a policymaker attempting to advance a policy alternative, they may see more value in showcasing an advisor's technical credentials (even if irrelevant to the science in question) than getting critical feedback. Accordingly, scientists should be clear when they are offering opinions outside of their professional technical expertise and avoid lending their imprimatur to policy processes in which they do not fully engage.

3. Overarching unknowns and short deadlines encourage the understatement of uncertainty. At the same time, all should recognize that total certainty is rarely a prerequisite to action.

Development of scientific knowledge is slow but very accurate in the long run. For most emerging technical knowledge, uncertainty is the default state. However, many important policy decisions occur under withering time pressure and limited policymaker bandwidth. Even in this environment, with large technical uncertainties at play, experts can be very effective by bounding uncertainty enough to enable decisionmaking. Policymakers should be willing to accept scientific uncertainty and incorporate it into their policy outlook. A willingness to understand, acknowledge, and accept uncertainty may signal to advisors that it is safe to provide more context to their advice, thus ensuring more accurate information (see Pure Scientist in Dialogue 2, who cautions against drawing direct conclusions from Starfish Prime). This willingness also helps differentiate between “soluble uncertainty”—that which can be resolved with technical work in a reasonable time frame—and the truly unknowable. For this reason, the intelligence community differentiates between capabilities and intent: capabilities can generally be predicted, assessed, or exposed, but intentions are more difficult to discern. Without careful consideration, urgency can masquerade as certainty or amplified risk. Technical advisors should keep a policymaker’s time constraints in mind when communicating uncertainty, as they dictate which scientific roles and information are useful for a policymaker and which are a distraction.

4. Respect both the value of expertise and the limits of any individual expert.

Policymakers should recognize that all experts are biased, but that does not necessarily invalidate the value of their advice, especially when the bias is acknowledged. Expert bias is a well-researched and understood phenomenon.[62] As a European scientific advisory group has noted in its work for supporting policy development, “Scientists are citizens with different ideologies, who may not be able to completely exclude their own convictions from their research, leading to biased observations and biased interpretations. Scientists may also use their authority to provide opinions on issues that fall outside the scope of their expertise.”[63] While policymakers and experts are aware of and often trained to guard against it, personal and professional bias do not (a priori) invalidate expert advice (see Representative, Dialogue 3 and Issue Advocate, Dialogue 1, who is not an expert on adversary intent).

With these issues in mind, policymakers should scope their questions to the appropriate expert, and experts should resist the urge to speak outside their domain of knowledge, even when encouraged by a policymaker (see the Policymaker’s ill-posed questions in Dialogue 2). Is the policymaker seeking to understand the technical fundamentals of a particular issue (e.g., what is electromagnetic pulse?), the potential national security impacts of an issue (e.g., how might EMP impact critical infrastructure?), possible policy responses to an issue (e.g., what options are available to better understand risk from EMP and to mitigate those risks?), or is the policymaker assembling supporting evidence for a particular course of action already decided?

In asking these questions, policymakers should resist the temptation to treat experts as oracles. Rather than make a reliable prediction, an expert may only be able to confidently tell a policymaker that no one can make a reliable prediction—and this may be all that is needed for a policy response. When experts provide a caveat

62 Philip P. Tetlock, *Expert Political Judgment: How Good is It? How Can We Know?* (Princeton, NJ: Princeton University Press, 2005).

63 SAPEA, *Making Sense of Science* (July 9, 2019). https://www.sapea.info/wp-content/uploads/MASOS-ERR-online.pdf. Accessed October 5, 2021.

("This is my best estimate, but..."), it is a policymaker's responsibility to treat the caveat seriously. Generally speaking, experts tend to be very knowledgeable about a narrow range of a topic or technical area. The complexity of many of today's national security policy issues requires a breadth of expertise that is unlikely to be found in one (or even a few) individuals. One of an expert's most useful roles is to identify the boundaries of expertise when orienting a policymaker. Indeed, an expert indispensable for one step of the policy process may be a poor advisor for another.

A Final Word

Science and policymaking have separate goals: science aims to produce knowledge, and policymaking aims to achieve political ends. Nonetheless, technical advice is essential to today's national security policymaking, an arena rife with high impact hypotheticals, uncertain risk profiles, and worst-case contingencies. In this setting, the efficacy of scientific advising hinges on the roles assumed by scientists, the degree of trust between parties to the decision, and most critically, the expectations, constraints, and goals of the policymaker. It is the scientists' responsibility to be transparent about any bias they may hold, and to provide a clear, comprehensible discourse of the relevant technical issues, free of distractions or unhelpful analogies. However, because it is the policymaker's responsibility to make informed and high-quality decisions, they also have a burden to select advisors suited to their process and structure the input they receive for decisionmaking.

With novel and technically complex issues—particularly those involving human actors and their unknowable intentions (including states and non-state actors)—scientific expertise can address only limited aspects of an issue, often with much uncertainty. Despite those limits, policymakers still have the responsibility to act, frequently under demanding time constraints that do not allow for a complete scientific investigation. In some situations, this results in a preferred policy response that prioritizes values irrespective of scientific certainty (e.g., a particular domestic or foreign policy objective).

As in our idealized deliberations above, the demand on decisionmakers for policy action likely will lead to situations where experts are asked to offer input outside of their specific area of expert knowledge. Accordingly, this pull from policymakers for informed judgments or opinions may well encourage experts to exceed the limits of their knowledge, potentially leading to advocacy for a particular policy position—wittingly or not. Such advocacy can be a legitimate role a science advisor can play, but one best done openly and represented as such. The benefits of scientific advice for policy architects is rarely as profound as scientists would wish or as certain as policymakers desire, but better decisionmaking is always possible.

Appendix: History of United States EMP Policy Development

Since the 1950s, and especially following the atmospheric nuclear weapon tests of 1962, American military planners considered HEMP a realistic threat to military resilience and readiness.[64] During nuclear modernization planning in the 1980s, some elements of civilian EMP hardening appeared in Congressional funding discussions and was the subject of significant research attention in the technical community.[65]

Congressional Interest in EMP

Concern about EMP in Congress during the 1990s included both natural and manmade EMP scenarios, but manmade scenarios attracted the most attention. Serious Congressional interest in EMP would not materialize until the first classified hearing in 1995 and the first open hearing in 1997, spurred by Congressmen Roscoe Bartlett and Curt Weldon. Congressman Bartlett's interest in EMP effects apparently was motivated in part by a work of fiction and subsequent discussions with a scientist from a U.S. nuclear weapons laboratory. In the early 1990s, after reading a Tom Clancy novel (presumably *The Sum of All Fears*) featuring EMP emitted from a nuclear detonation, Bartlett contacted the author to discuss EMP. Clancy introduced Bartlett to a contact of his, Dr. Lowell Wood, an astrophysicist at Lawrence Livermore National Laboratory.[66] In subsequent years, Wood would play a central role in providing expert scientific input to Congressional and other governmental deliberations around the EMP threat.

The Congressional hearings of the late 1990s established a particular view of the threat from EMP with a particular focus on HEMP. While the basic physical phenomenology of EMP was never in dispute, other aspects of the issue were. Was the human-generated scenario (i.e., a country or group purposely detonating a nuclear weapon high above the continental United States to generate EMP as a means of attack) realistic? And if so, how could the U.S. government accurately predict and mitigate the consequences?

64 John F. Zych, *EMP Handbook for AFCS C-E-M Engineers* (November 1, 1976). https://apps.dtic.mil/dtic/tr/fulltext/u2/a060435.pdf. Accessed May 5, 2022.

65 See, for example, Kenneth Klein, et al., "Electromagnetic Pulse and the Electric Power Network," *IEEE Transactions on Power Apparatus and Systems* PAS-104, no. 6 (June 1985).

66 See United States Congress, House Committee on Small Business, Subcommittee on Government Programs and Oversight. "Electromagnetic Pulse (EMP): Should this be a Problem of National Concern to Private Enterprise, Businesses Small and Large, as well as Government?" Serial no. 106-17 (June 1, 1999).

Of these three elements (phenomenology, source of EMP, and consequence), the understanding of phenomenology and consequence are most directly impacted by scientific and technical expertise. For geomagnetic disturbances (GMDs) caused by solar activity, there is no scientific question about inevitability; like earthquakes, they are both certain to happen again but are difficult to forecast.[67] However, whether or not humans (countries or groups) have the intention and the capability to launch a successful HEMP attack against the U.S. mainland is only partially informed (likely with much uncertainty) by scientific and technical expertise.

Given the ubiquity of electrical hardware in modern society, damage inflicted by EMP to even a limited number of components could lead to sustained disruption to one or more of the eight "vital national infrastructures" of "telecommunications, electric power systems, oil and gas transportation and storage, banking and finance, transportation, water supply systems, and emergency services such as medical, police, fire and rescue, and continuity of government services," as identified by the 1996 Commission on Critical Infrastructure Protection.[68] Importantly, failures in these networked systems could impair recovery of the electrical grid and of each other, creating a vicious cycle. Below is how the director of the Johns Hopkins University Applied Physics Lab, Dr. Gary Smith, assessed the threat at the 1997 Congressional hearing:[69]

> The coverage and levels that would ensue from an EMP attack are well understood. However, the overall effects on specific terrestrial systems are not as well understood. How much of the telecommunications systems would fail and for how long, how much of the power grid would be disrupted and for how long, how many cars would stop and/or would not start are things that are extremely difficult to predict. However, just consider what would happen if even a small fraction of the cars on the beltway stopped and expand that to all the roads throughout the country.

A common refrain during these hearings was that the power grid, communications, and other networks are sufficiently fragile—that a well-placed HEMP could lead to unprecedented cascading failures with irreversible effects on the country's ability to support its population, leading to mass starvation and death.

67 Unlike earthquakes, however, GMDs do provide short term warnings that might permit significant mitigation measures. See the NOAA Space Weather Prediction Center (https://www.swpc.noaa.gov/products/aurora-30-minute-forecast) for space weather alerts: "The aurora is an indicator of the current geomagnetic storm conditions and provides situational awareness for a number of technologies. The aurora directly impacts HF radio communication and GPS/GNSS satellite navigation. It is closely related to the ground induce currents that impact electric power transition." Accessed July 1, 2022. Also see U.S. Department of Energy, *Geomagnetic Disturbance Monitoring Approach and Implementation Strategies* (2019). https://www.energy.gov/sites/prod/files/2019/06/f64/DOE_GMD_Monitoring_January2019_508v2.pdf. Accessed May 5, 2022.

68 Center for Homeland Defense and Security, *President's Commission on Homeland Infrastructure* (June 1997). https://www.hsdl.org/?abstract&did=487492. Accessed May 5, 2022.

69 United States Congress, House Committee on National Security, Subcommittee on Military Research and Development, "Threat Posed by Electromagnetic Pulse (EMP) to U.S. Military Systems and Civil Infrastructure."

In June 1999, a more prominent full hearing of the House Armed Services Committee considered the EMP threat. Congressmen Weldon and Bartlett made clear their conviction that U.S. adversaries knew about this threat, and that it was real, setting the stage for major future focus on EMP within the policymaker community. This hearing also featured, for the first time, controversy among panelists on the readiness of civilian systems in the face of a HEMP threat. Mr. Stanley Jakubiak, Senior Civilian for Nuclear C3 and EMP Policy, Joint Chiefs of Staff, suggested that the threat of EMP to civilian networks was moderate and not requiring immediate remedy.

> The Office of the National Communications System (NCS) has also done some extensive testing of the commercial public switch network and have found that the public switch network infrastructure is inherently resistant to the effects of EMP. Their studies have shown that the probability of connection of a telephone call under an EMP environment is greater than 90% with normal loading, and greater than 70% when there is panic loading on that system.
>
> The NCS results have also been confirmed by AT&T Bell Laboratories, who reported that their testing of the public switch network also showed that some upset could be expected, but that damage to the system in an EMP environment was not a concern.[70]

In contrast, Dr. William Graham, former science advisor to President Reagan and longtime technical expert on EMP, argued that in general, previous testing of civilian and military systems were overly optimistic and presented a false sense of security:

> So even when tests and analyses have been run on systems, one has to look at the results very skeptically and with the benefit of experience that we have gained in testing systems over many years. I guess I would finally like to say that I have seen major military systems fail as low as in order of magnitude below the level that Mr. Jakubiak showed there, and not failed at all at the highest levels we could produce, depending on whether they had been hardened or not.[71]

In the end, a central conclusion was that huge uncertainties remained in EMP testing of civilian electrical systems—an assertion Mr. Jakubiak agreed with, though he did not consider this inadequacy an Achilles heel in national security policy.

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70 United States Congress, Committee on Armed Services, Subcommittee on Military Research and Development, "Electromagnetic Pulse Threats to U.S. Military and Civilian Infrastructure," H.A.S.C. No. I 106-31 (October 7, 1999).

71 Ibid.

The Resulting EMP Commission

Spurred by the 1999 hearings, Congress established The Commission to Assess the Threat to the United States from Electromagnetic Pulse Attack, or EMP Commission, in Title XIV of the National Defense Authorization Act (NDAA) of fiscal year 2001. The commission drew on input from many of the people of the previous hearings; notably, Dr. Wood, along with Dr. Graham at the helm. Commissioners were to know the "scientific, technical, and military aspects of electromagnetic pulse" and were tasked with evaluating the "nature and magnitude of potential high-altitude EMP threats to the United States from all potentially hostile states or non-state actors... within the next 15 years," as well as the "vulnerability of military and civilian systems to EMP" and the "feasibility of hardening select systems against EMP attack." Seven of the nine commissioners were appointed by the Secretary of Defense and the other two by the Director of the Federal Emergency Management Agency. The charter also mandated consultation with the Chairman and Ranking Member of the House and Senate Armed Services Committee.[72]

EMP Commission Report Abstract[73]

Several potential adversaries have or can acquire the capability to attack the United States with a high-altitude nuclear weapon-generated electromagnetic pulse (EMP). A determined adversary can achieve an EMP attack capability without having a high level of sophistication.

EMP is one of a small number of threats that can hold our society at risk of catastrophic consequences. EMP will cover the wide geographic region within line of sight to the nuclear weapon. It has the capability to produce significant damage to critical infrastructures and thus to the very fabric of U.S. society, as well as to the ability of the United States and Western nations to project influence and military power.

The common element that can produce such an impact from EMP is primarily electronics, so pervasive in all aspects of our society and military, coupled through critical infrastructures. Our vulnerability is increasing daily as our use of and dependence on electronics continues to grow. The impact of EMP is asymmetric in relation to potential protagonists who are not as dependent on modern electronics.

The current vulnerability of our critical infrastructures can both invite and reward attack if not corrected. Correction is feasible and well within the Nation's means and resources to accomplish.

72 Public Law 106-398, Title XIV. https://www.govinfo.gov/content/pkg/PLAW-106publ398/html/PLAW-106publ398.htm. Accessed May 5, 2022.

73 Foster, John S., et al., *Report of the Commission to Assess the Threat to the United States from Electromagnetic Pulse (EMP) Attack, Volume 1: Executive Report 2004* (2004).

The commission published its first findings in 2004 (see boxed text for report abstract[74]) and reported to the House Armed Services Committee the same year. Much of the report echoed concerns presented during hearings of the 1990s, focusing almost exclusively on human-caused EMP scenarios, but referencing GMD events like the 1989 Quebec blackouts as examples of possible harm. The report explicitly references the threats of a non-state actor launching a Scud-type missile from an offshore barge, and the plausibility of a rogue state, or Russia or China, launching an EMP attack on the American homeland. Many other supporting details and themes recur, including an anecdotal HEMP threat made by Russian officials during a 1999 summit[75] and the 1962 Starfish Prime and Soviet K project tests. The report includes multiple recommendations for strengthening the U.S. resistance to EMP strikes.

The Commission's funding was not renewed in the 2008 budget year, officially marking its end. During a Congressional hearing in July 2008, Congressman Bartlett referred to One Second After, a popular disaster novel with a plot where an EMP attack on the United States kills over 90% of the population.[76]

The EMP Commission Interregnum

With the Commission unfunded, private advocacy groups emerged to continue lobbying for increased EMP protection, including Resilient Societies[77] and EMPact America,[78] which included Congressman Bartlett and the EMP Commission's executive assistant Dr. Peter Pry on its board of advisors. At the 2012 EMPact conference, former House Speaker and Presidential candidate Newt Gingrich gave the keynote address. In 2011, the Congressional EMP caucus was founded, organized in large part by Arizona Congressman Trent Franks. Members introduced the SHIELD Act, a piece of legislation designed to implement the grid protection sought by the EMP Commission, but this ultimately failed to gain traction in Congress. In addition, House Resolution 762 was introduced by Bartlett in the 112th Congress. This resolution called for enhanced civil defense and for 20% of electrical generation to be done on a community level; the bill did not advance. In 2012, Bartlett left Congress and relocated to an off-grid farm in West Virginia, where he continued his advocacy.

Advocacy on the EMP threat continued through 2015, followed by another round of Congressional hearings in both the House and Senate. Former director of the Central Intelligence Agency James Woolsey became prominent in these hearings. While Woolsey, accompanied by Pry, did not provide expert technical testimony, he

74 Ibid.

75 See Congressman Bartlett testimony on page 3, "Electromagnetic Pulse (EMP): Should this be a Problem of National Concern to Private Enterprise, Businesses Small and Large, as well as Government?" United States Congress, House Committee on Small Business, Subcommittee on Government Programs and Oversight. Serial No. 106-17 (June 1, 1999).

76 United States Congress, Committee on Armed Services, "Threat Posed by Electromagnetic Pulse (EMP) Attack," H.A.S.C. No. 110-156 (July 10, 2008).

77 Now the Foundation for Resilient Societies, see https://www.resilientsocieties.org. Accessed May 5, 2022.

78 See https://empactusa.org. Accessed May 5, 2022.

did provide his professional assessment to both the committee and to the media.[79] Much of the hearings recapped the threats highlighted by the EMP Commission with testimony focused on the shortfall of the government to react to the EMP Commission recommendations. A U.S. Government Accountability Office official testified at a Senate hearing on the findings of an upcoming status report (requested by Congress) that found many of the EMP Commission recommendations had not been adopted. The threat of an EMP attack from rogue actors was a common theme of the hearing. Senator Ron Johnson pushed for protection of the grid from an EMP attack; following the hearing, he introduced the Critical Infrastructure Protection Act.[80]

Generated by both the Senate and House hearings, increased popular and news media coverage, and perhaps Woolsey's high profile, there was a resurgence in interest in the EMP threat, culminating in the reestablishment of the EMP Commission by the National Defense Authorization Act of Fiscal Year 2016 on November 25, 2015. The upcoming presidential election further raised the profile of EMP defense when some Republican party candidates raised the issue during the 2016 campaign.[81]

Return of the Commission, Government Action, and Executive Order 13865

The reestablished EMP Commission, with several members of the first commission returning and again chaired by Dr. Graham, issued reports in July 2017 following its statutory mandated end in June 2017, in accord with the terms of the fiscal year 2016. Commission members also published several additional related papers during 2017.[82] These reports reiterate the continuing threat of an EMP attack based on the same reasoning highlighted in the previous reports and again recommended actions to harden the power grid against EMP attacks. Newly added were growing concerns about the potential for cyberattacks to damage and disrupt the grid.

Following the Commission's end in June, the NDAA of Fiscal Year 2018 (signed into law in December 2017) established a Commission to Assess the Threat to the United States from Electromagnetic Pulse Attacks and Similar Events. In addition to a slightly different name, the newest commission had its duties expanded and now, in addition to assessing the nature and magnitude of EMP attacks (and similar events) as the original EMP Commission required, it also included assessment of the likelihood of

79 Center for Security Policy, "Jim Woolsey: Electromagnetic Pulse (EMP) is Existential Threat to America" (July 30, 2013). https://www.centerforsecuritypolicy.org/2013/07/30/jim-woolsey-electromagnetic-pulse-emp-is-existential-threat-to-america/. Accessed May 5, 2022.

80 Ron Johnson, U.S. senator, press release, "Johnson introduces Bill to Require Federal Strategy to Protect Electric Grid" (July 23, 2015). https://www.ronjohnson.senate.gov/public/index.cfm/press-releases?ID=6D104A29-F548-4CAA-B5C8-B9CCB249F418. Accessed May 5, 2022.

81 Olivier Knox, "GOP candidates keep warning of an EMP attack. Here's what that is.," Yahoo News (February 19, 2016). https://www.yahoo.com/news/weather/gop-candidates-keep-warning-of-1367993939435574.html. Accessed May 5, 2022.

82 There are many such reports that have been released over the years through various channels. Not all are hosted on the legacy EMP Commission website. Consequently, it is difficult to determine which are officially representing the Commission's work and which are the sole views of the author. For what may be a comprehensive collection of relevant reports, see Michael Mabee, Grid Security Now! website: https://michaelmabee.info/three-new-emp-commission-reports-released/. Accessed May 5, 2022.

EMP attack—a significant expansion of responsibility and complexity. (It is not clear from publicly available sources if the Commission produced any new assessments or reports. However, in January 2019, the Department of Defense reportedly cleared three final reports from 2017 for public release.[83])

By 2018, new national security priorities were emerging in the White House. The new National Security Advisor, John Bolton, had expressed concern about the threat of an EMP attack before and was a panelist at an EMPact America event concerning the possibility of attack by Iran. The NDAA of fiscal year 2019 was signed into law August 2018 containing a provision extending the EMP Commission for one additional year, until 2020.

In October 2018, as required by fiscal year 2017's NDAA, the Department of Homeland Security (DHS) released a document titled "Strategy for Protecting the Homeland Against Threats of Electromagnetic Pulse and Geomagnetic Disturbances."

In contrast to much of the earlier public testimony and commission findings, the DHS strategy took a tone that reflected the many technical uncertainties associated with EMP:

> Extreme EMP and GMD incidents certainly fit into the categorization of "hard problems"—both are low probability/high consequence scenarios that challenge effective policymaking. A major electromagnetic incident caused by either EMP or GMD would pose immediate and simultaneous challenges to national and local decision-makers, Sector-Specific Agencies, private sector critical infrastructure owner-operators, and emergency managers at all levels of government. For example, significant uncertainties exist regarding the likely effects of extreme EMP and GMD events on existing civilian critical infrastructure. HEMP attacks by an adversary with basic nuclear weapons and missile capabilities may be disruptive on a regional scale, but are unlikely to cause catastrophic damage to the U.S. electric grid on a continental scale. Adversaries with highly developed nuclear capabilities might cause widespread harm to U.S. infrastructure with complex HEMP attacks in the context of an escalating international conflict. Space weather phenomena are relatively well understood within the scientific community, but the historical rarity of extreme GMD events limits availability of data useful for predictive analysis. Past events, such as the 1989 solar storm that led to the interruption of power in much of Québec for nearly nine hours, offer proof of the disruptive potential of GMD, as well as their potential to cascade impacts across critical infrastructure sectors and geographic regions.[84]

83 See Michael Mabee, "Grid Security Now!" website. https://michaelmabee.info/unclassified-emp-commission-reports/. Accessed May 5, 2022.

84 Department of Homeland Security, "Strategy for Protecting the Homeland Against Threats of Electromagnetic Pulse and Geomagnetic Disturbances" (October 9, 2018).

The DHS Strategy set three broad goals:

1. Improve risk awareness of electromagnetic threats and hazards
2. Enhance capabilities to protect critical infrastructure from the impact of an electromagnetic incident
3. Promote effective electromagnetic-incident response and recovery efforts

Finally, on March 26, 2019, President Trump issued an Executive Order, titled "Executive Order on Coordinating National Resilience to Electromagnetic Pulses." The Order established guidelines for EMP resiliency research, assigned new reporting duties for stakeholders throughout the executive branch, and directed federal agencies to coordinate their responses to an EMP threat. DHS was ordered to report on the current status of preparedness within 180 days and file a full report within one year,[85] with follow-up reports every two years after. This was to be done in close coordination with the Departments of Defense, State, and Commerce. The Executive Order was meant to create an ongoing process and keep EMP as a major policy focus. In December 2019, the requirement for a Commission to Assess the Threat to the United States from Electromagnetic Pulse Attacks and Similar Events was repealed when the NDAA for fiscal year 2020 became law.

Some notable organizations outside of government questioned the technical basis of the Executive Order. For example, the Electric Power Research Institute, consisting of representatives of the electric power industry who would be responsible for retrofitting private infrastructure if EMP-protection regulations were mandated, released a report rejecting the premise of EMP as an existential risk, as asserted by numerous EMP Commission reports. An excerpt from one of these reports follows:

> Research findings do not support the notion of blackouts encompassing the contiguous United States (CONUS) and lasting for many months to years.... Although E3 EMP is not expected to cause immediate, widespread damage to large power transformers, it may be prudent to evaluate the number of transformer spares that are available to ensure that adequate replacements exist for the number of transformers that are identified as being at potential risk of damage.[86]

In June 2020, the White House's Office of Science and Technology Policy, National Science and Technology Council issued its report, titled *Research and Development Needs for Improving Resilience to Electromagnetic Pulses* to address requirements of Executive Order 13865. The report identified 12 research needs, spanning U.S. critical infrastructure sectors and key areas of knowledge and capabilities needed to develop

85 See Cybersecurity and Infrastructure Security Agency, "Electromagnetic Pulse and Geomagnetic Disturbance." https://www.cisa.gov/publication/emp-program-status-report. Accessed May 5, 2022.

86 EPRI, *High-Altitude Electromagnetic Pulse and the Bulk Power System: Potential Impacts and Mitigation Strategies* (2019), pXII.

sufficient resilience measures. The identified research needs were grouped into the broad research categories of Environment, System Impact, and Remedies.[87]

Finally, in August 2020 DHS issued its Electromagnetic Pulse (EMP): Program Status Report.

> In accordance with Executive Order 13865, [DHS] has identified initial critical infrastructure and associated functions that are at greatest risk from an EMP. It is focusing efforts on the development and implementation of evidence-based and independently tested EMP protection and mitigation technologies and best practices for resiliency. Initial efforts within [DHS], working across the federal interagency, have focused on risk management to both the energy and communications sectors.[88]

87 National Science and Technology Council, "Research and Development Needs for Improving Resilience to Electromagnetic Pulses" (June 2020).

88 Department of Homeland Security, *Electromagnetic Pulse (EMP): Program Status Report* (August 17, 2020).

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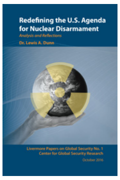

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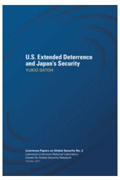

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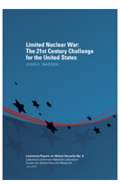

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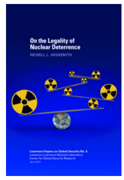

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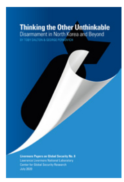

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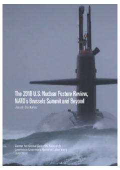

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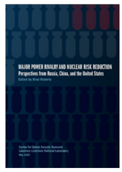

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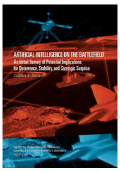

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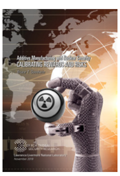

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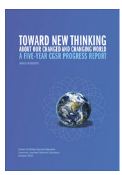

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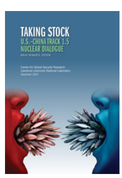

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"The authors have succeeded in a difficult task–writing on a topic of critical importance to both the technical and policy communities in a way that is highly accessible to both. The history of concern and misunderstanding about EMP is a well-chosen example to illustrate the lessons that should be learned and practiced by scientists and policymakers alike."

Miriam John

Vice President Emerita, Sandia National Laboratories

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