TRANSMISSION EXPANSION FOR NATIONAL DEFENSE

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OVERVIEW

This publication presents several concepts for aligning transmission grid investment with national defense, including increasing the size and flexibility of the grid more rapidly, prioritizing specific upgrades to support defense missions, and equipping the Department of Defense (DoD) to engage more directly with grid planning. These concepts were developed through interviews with more than 60 experts from across the electricity industry and the national security enterprise. This paper is intended to encourage conversation between these and other stakeholders about sustaining and expanding the transmission system's national defense capabilities.

EXECUTIVE SUMMARY

- The U.S. electric power grid is a cornerstone of our national defense. Defense missions around the world depend on physical and digital infrastructure located here at home, but our domestic military installations are almost entirely dependent on the civilian power grid. The grid should be viewed as an extension of military missions and weapons platforms from the perspective of national defense.
- Threats from increasingly extreme weather, homegrown violent extremism, and foreign adversaries are revealing that onsite backup power is critical but insufficient. Defense energy resilience requires a focus on the grid in parallel with on-base innovations.
- The transmission grid ensures that electricity from diverse sources can be flexibly and rapidly delivered around the country. The grid's scale and redundancy can absorb shocks that would cause outages in smaller systems.
- The grid also poses national defense challenges. Bulk electric system outages can cause long-duration power outages that exceed DoD planning contingencies, as occurred during recent events such as Winter Storm Uri, Hurricane Ida, and Winter Storm Elliot.
- Winter Storm Uri demonstrated that defense communities are an integral part of military mission capability, and the national defense risk from power outages is regional in nature. The impact of power outages to more than a dozen military installations was compounded by the outages experienced by military personnel and their families, by the defense industry, and by water, gas, and other interdependent utility providers.
- Hurricane Ida demonstrated that older sections of the transmission grid are not built for the current climate and that outage durations beyond DoD's energy resilience planning horizons are a new reality.
- The National Defense Strategy (NDS) emphasizes "deterrence by resilience" as a central strategy to protect critical infrastructure from attacks by foreign adversaries—strengthening systems so that they are not attractive targets. For the electricity grid, deterrence by resilience will require substantial investment and coordination by the government, the military, the utility industry, and many other partners.
- The 2023 National Transmission Needs study highlights the massive transmission investments that will be required to ensure electricity reliability. These investments should be aligned to the greatest extent possible with national defense requirements.
- This publication presents concepts for aligning transmission investment and national defense, with the intent of encouraging conversation between the electricity industry and the national security enterprise. The concepts, which are described here at a high level, are organized into three categories: accelerating transmission expansion, strengthening the grid for critical defense facilities, and empowering DoD as a transmission proponent.

Accelerating Transmission Expansion

- **Accelerate the transmission planning process.** Transmission lines that serve regions with critical defense facilities should be expedited. Transmission projects typically require a lead time of 10-15 years to plan, site, and complete, but the risks to national defense are imminent.
- **Diversify generation access to support DoD.** The transmission system should provide DoD with access to a diverse portfolio of electricity generation to maximize resilience.
- **Build DoD energy loads into grid planning.** DoD energy requirements should be integrated into regional generation reserve margins and supported by interregional transfer minimums.

Strengthening the Grid for Critical Defense Facilities

- **Establish infrastructure design criteria that reflects mission-criticality.** There is a need for hardening and redundancy requirements for transmission assets that serve critical defense facilities.
- **Create a new black start model for DoD.** Grid operators should incorporate critical defense energy loads into black start planning, or create a similar mechanism and criteria specifically for national defense.

Empowering DoD as Transmission Proponent

- **Equip DoD to support grid resilience.** There is an opportunity to provide DoD with the authority to engage in grid planning, and the personnel to effectively do so. DoD legal staff should be fully equipped and authorized to intervene in utility regulatory proceedings as advocates for DoD energy requirements.
- **Understand DoD transmission vulnerabilities.** DoD and electricity industry partners can develop a shared understanding—at the appropriate classification level—of where and how transmission investments would benefit national defense.
- **Host new transmission on DoD land.** DoD can encourage transmission developers to site power lines and other equipment on its land through its enhanced use lease or easement authorities.
- **Integrate grid stakeholders in DoD exercises.** DoD can collaborate more closely with its utility partners in its exercises to jointly investigate grid resilience opportunities.
- **Enable DoD to commit to purchases within planned transmission corridors.** DoD can encourage the development of transmission lines that would support national defense by committing to purchase power from generation projects that would feed into the new lines.
- **Enable DoD to purchase transmission capacity.** DoD can commit to purchasing transmission capacity, either alongside its carbon-free electricity purchases, or on a standalone basis.

INTRODUCTION

"DoD's key problem with electricity is that critical missions, such as national strategic awareness and national command authorities, are almost entirely dependent on the national transmission grid...[which] is fragile, vulnerable, near its capacity limit, and outside of DoD control.[1]"

– Defense Science Board Task Force on DoD Energy Strategy (2008)

For most, the U.S. military may evoke images of combat overseas, reinforced through decades of media showing soldiers and camps in various foreign environments. In reality, national defense hinges on massive networks of physical and digital infrastructure here at home that rely on one shared input—electricity. The U.S. military is a globally networked force, whose missions depend on domestic defense installations. Since almost all bases in the U.S. rely on the civilian electricity grid for power, a resilient power grid directly supports the capability of every major national defense mission.

Defense missions have different electricity service needs, depending on the equipment and personnel needed to execute them. Power failures can impede national defense in many ways. A remotely piloted aircraft operated from a base in the U.S. may fail its overseas mission following even a momentary power outage. Anti-ballistic missile systems and long-range radar represent the first line of defense for direct attacks on the homeland, and they require stable, uninterrupted power to function. Disruptions in electricity can lead to delays in troop movements, given the enormous energy demands of mobilizing thousands of soldiers across the country. Short-term outages can impact rapid air defense response missions—such as those utilized on September 11, 2001—during which fighter aircraft must be launched in a period of minutes to confront imminent threats.

The global interdependence of the U.S. military requires a shift in how the grid is viewed in the context of national defense. The grid must be considered an extension of the very missions and platforms it supports, in part because foreign adversaries already take this view as they develop increasingly effective ways to disrupt our critical infrastructure.[2] In other words, the grid is a cornerstone of U.S. national defense.

The 2022 National Defense Strategy (NDS) states that foreign adversaries such as the People's Republic of China and Russia could "attempt to hinder U.S. military preparation and response in a conflict" by attacking our domestic critical infrastructure. The 2023 Intelligence Community Threat Assessment echoes this point, stating that China would consider cyber operations against critical infrastructure "designed to deter U.S. military action by impeding U.S. decision making, inducing societal panic, and interfering with the deployment of U.S. forces."[3] That active targeting of U.S. critical infrastructure systems has already begun; the Cybersecurity and Infrastructure Security Agency (CISA) issued a warning in 2022 identifying multiple instances where Russian state-sponsored actors have targeted the operations and control systems required for real-time grid operations.[4] The grid is also vulnerable to direct physical attacks. There has been an increase in homegrown violent extremism during the past several years targeting power systems, and several of these have directly impacted the communities that surround DoD installations (Text Box 1).[5]

The NDS proposes deterring such attacks by building resilience—the ability to withstand, fight through, and recover from disruption—into our virtual and physical systems. The NDS focuses on "deterrence by resilience" as a military strategy. When applied to the grid, deterrence by resilience helps sustain operations

1. Office of the Undersecretary of Defense for Acquisition, Technology, and Logistics (2008). Report of the Defense Science Board Task Force on DoD Energy Strategy: "More Fight - Less Fuel".
2. U.S. Department of Defense. (2022). 2022 National Defense Strategy of the United States of America.
3. Office of the Director of National Intelligence. (2023). Annual Threat Assessment of the U.S. Intelligence Community.
4. CISA. (2022). Understanding and Mitigating Russian State-Sponsored Cyber Threats to U.S. Critical Infrastructure.
5. Howard, M.J. (2024). America's Aging Grid Threatens National Security. Here are Some Steps to Fix It. Utility Dive.

Text Box 1.
Physical Attacks on Utilities Serving DoD Installations

The U.S. power grid is suffering a decade-high surge in attacks as extremists, vandals, and cyber criminals increasingly take aim at the nation's critical infrastructure.[6] Several attacks in late 2022 impacted military personnel and their families.

- More than 36,000 people in the defense community around Fort Liberty in Moore County, North Carolina lost power for multiple days after unknown attackers shot two Duke Energy substations in December 2022.[7] Fort Liberty is home to the 82nd Airborne Division, whose mission is to rapidly deploy to any location in the world within 18 hours.
- The lights went dark on Christmas Day 2022 for 14,000 customers in Washington state after four substations were vandalized.[8] The substations are owned by Tacoma Power and Puget Sound Energy, which serve Naval Base Kitsap and Joint Base Lewis-McChord (JBLM), respectively. Naval Base Kitsap is one of two strategic nuclear weapons facilities and has the only dry dock on the West Coast that can handle Nimitz-class aircraft carriers. JBLM hosts the 62nd Airlift Wing, which supports combat and humanitarian airlift missions worldwide with C-17 Globemaster III aircraft.

in the face of a broader range of non-military threats as well, such as extreme weather and physical attacks on infrastructure.[9]

The U.S. already needs to make massive investments to expand and strengthen the grid because of increasingly extreme weather, increased demand from data center growth and transportation electrification, and the rapid build-out of clean energy generation.[10] The U.S. Department of Energy (DOE) estimates that the transmission system will need to expand 60% by 2030 to maintain reliable electric service, and that transmission investment may need to triple by 2050.[11] There are opportunities to accelerate this expansion and do so in a way that contributes to a more integrated approach to deterrence by resilience.

The alignment of national defense and grid expansion will require new conversations between the electricity industry and defense stakeholders, since DoD is no ordinary electricity customer. In addition to the criticality of its missions, DoD is enormous both in terms of its geographic footprint and its energy consumption.

6. Morehouse, C. (2022). Physical Attacks on Power Grid Surge to New Peak. Politico.
7. Cama, T. (2022). Who Shot the North Carolina Power Grid?. Politico.
8. U.S. Attorney's Office Western District of Washington. (2023). Two Charged with Attacks on Four Pierce County Power Substations.
9. Narayanan, A. Welburn, J., Miller, B.M., Li, S.T., & Clark-Ginsberg, A. (2020). Deterring Attacks Against the Power Grid: Two Approaches for the U.S. Department of Defense. Santa Monica, CA: RAND Corporation.
10. Securing America's Future Energy (SAFE) Grid Security Project. (2023). Grid in Peril.
11. U.S. Department of Energy Office of Policy. (2022). Queued Up... But in Need of Transmission.

DoD has approximately 500 military installations spread across 9 million acres of land in every U.S. state and territory, and consumes close to 1% of the nation's electricity.[12]

This publication presents several concepts for aligning transmission grid investments with national defense, including by increasing the size and flexibility of the grid more rapidly, prioritizing specific upgrades to support defense missions, and equipping DoD to engage more directly with grid planning. These concepts were developed through interviews with more than 60 experts from across the electricity industry and the national security enterprise. This paper is intended to encourage conversation between these and other stakeholders about sustaining and expanding the transmission system's national defense capabilities.

This paper is structured as follows:

- **Section 1** reviews the capabilities of the electricity grid that should be sustained, expanded, and strengthened in support of national defense.
- **Section 2** summarizes the risks that bulk electric system outages pose to DoD missions, and explores the potential impacts of large-scale events on DoD through a case study of Winter Storm Uri.
- **Section 3** presents concepts for strengthening national defense through transmission system planning and investment, drawn from interviews with experts and stakeholders.
- **Section 4** discusses next steps and future opportunities.

SECTION 1. TRANSMISSION IS MISSION-CRITICAL FOR EVERYONE

"A robust transmission system is critical to the Nation's economic, energy, and national security."[13]

– U.S. Department of Energy National Transmission Needs Study (2023)

1.1 Grid Overview

While the "grid" is commonly referenced as a single system, it is composed of three discrete elements: generation, transmission, and distribution.

- **Generation.** There are over 11,000 large electric power plants that feed power into the transmission system.[14] The plants generate electricity from a wide variety of fuel sources, such as natural gas, solar, wind, nuclear, geothermal, hydropower, coal, biomass, and others.
- **Transmission.** The transmission system is a high-voltage network consisting of hundreds of thousands of miles of power lines, designed to move power over long distances. Together, the large generators and the transmission system are referred to as the bulk electric system (BES).
- **Distribution.** The distribution system connects the transmission system to neighborhoods, buildings, and homes. There are millions of miles of low-voltages distribution lines across the country. This paper focuses specifically on the transmission system because of its unique role in the current threat environment, and because of the outsized risks to national defense posed by transmission system failures (see Section 2.2). This paper also focuses primarily on physical risks to the transmission system. Cyber attacks pose a significant risk to the BES and to national defense, and are discussed in detail in other reports.[15]

12. U.S. Department of Defense. (2023). Annual Energy Performance, Resilience and Readiness Report Fiscal Year 2022; U.S. Electricity Information Administration. (2023). US Electricity Profile 2022.
13. U.S. Department of Energy. (2023). National Transmission Needs Study, p. 1.
14. U.S. Environmental Protection Agency. (2023). Electric Power Sector Basics.
15. North American Electric Reliability Corporation. (2023). 2023 State of Reliability Technical Assessment; Idaho National Laboratory Mission Support Center. (2016). Cyber Threat and Vulnerability Analysis of the U.S. Electric Sector.

1.2 The Grid's National Defense Capabilities

National defense has been a key driver in the construction of the bulk electric system. In World War II, the U.S. government supported massive new power plants and transmission lines specifically to supply electricity for manufacturing munitions, ships, and airplanes.[16] These wartime investments transformed the energy system, with industrial mobilization driving a 50% increase in U.S. electricity use between 1940 and 1945.[17] The outbreak of the Korean War in 1950 spurred another rapid build-out of power plants and transmission lines under the Eisenhower administration, justified by the view that adequate electric generation capacity was critical to national security.[18]

As discussed above, the nature of conflict has fundamentally changed, and the U.S. is no longer insulated from attack. In the 20th century, policymakers focused on investment in generating capacity to manufacture arms and equipment for U.S. conflicts abroad.[19]

Twenty-first century defense will require investment that takes full advantage of the transmission system. While the transmission system itself is vulnerable, it offers the foundation for a more comprehensive, resilient energy strategy needed to meet the mission assurance requirements of DoD. The unique capabilities of the transmission system that support national defense, as well as electrical reliability more broadly, are discussed below.

"Defense in Depth." The transmission system started as an alternative to single power plants connected to specific end-users on isolated distribution systems. The evolution of the grid followed principles similar to the time-tested military ethos of strength coming from the unit and not the individual, founded on flexibility, diversity, and redundancy. The grid creates multiple pathways for energy to flow, while accessing numerous, redundant generation sources, and increasing the reliability and efficiency of energy delivery.

Scaled to be "Larger than the Risks." The BES operates at a continental scale, with North America divided into the Eastern, Western, and Texas Interconnections. While the Interconnections are not designed to exchange large amounts of electricity with each other, their operating regions connect hundreds of utilities and thousands of generation units. The scale of connectivity between utilities and grid operators creates a collective ability to avoid the outages that occur in more isolated systems through shared reserves and redundant paths for power delivery. The scale of interconnected grids is big enough to absorb and correct for common outage causes, such as severe weather, equipment failures, and maintenance outages, provided that sufficient interregional transmission capacity is available.

Generation Resource Diversification. The grid is designed to access diverse energy sources from dozens of states over large geographic regions as a means of ensuring adequate generation to meet customer demand and mitigate power outages. It can move massive amounts of energy almost instantaneously from where it is generated to its point of use. A single 500 kilovolt transmission line can handle enough power to serve a city of 500,000 people, and grid operators direct the flow of electricity in real-time to maintain balance.

The Black Start Contingency. The transmission system also enables a capability to restart large sections of the grid following major outages, known as "black start."

Rather than relying solely on distribution operators and local generation assets to restore small geographic areas following an outage, black start provides the BES building blocks for grid restoration at a large scale. The black start planning process is centered around a small number of certified generation assets and their corresponding transmission cranking paths.

The transmission grid's capabilities will need to be expanded through policy and investment to effectively support national defense. An energy footprint of DoD's scale and geographic diversity is not conducive to a piecemeal approach to solutions. The next section

16. Kramer G. (2010). Corridors of Power: The Bonneville Power Administration Transmission Network Historical Context Statement. Bonneville Power Administration.
17. Electrical World. (1949). The Electric Power Industry: Past, Present and Future, 1st ed. New York: McGraw-Hill.
18. U.S. Congress Joint Committee on Defense Production. (1952). Defense Production Act Progress Report No. 15: Electric Power Study.
19. McEntire, R.B. (1952). Utility Regulation and the Defense Effort. U.S. Securities and Exchange Commission.

discusses how energy resilience at the installation level, while critical, is not a complete solution. A complementary, grid-based approach is needed to ensure national defense needs are met. This requires a comprehensive expansion of the transmission system to strengthen and further connect the North American grid. Accelerating transmission expansion will benefit DoD installations that depend on civilian electricity infrastructure. At the same time, there are opportunities to reinforce the transmission system in ways that specifically mitigate risks to national defense.

SECTION 2. THE GRID WORKS FOR DOD UNTIL IT DOESN'T

"The Department recognizes that our missions depend on resilient power not just for our bases, but also for the various civilian-owned infrastructure that enable the execution of our essential missions… [W]hen the power goes out, cascading impacts on other critical infrastructure sectors result in second-order and third-order effects that further degrade the ability of the Department to execute its key missions…. A stronger and more resilient grid is a national security priority. A grid that is stronger and more resilient around certain loads, nodes, and communities is the most effective way to manage risk and cost for the Department and in turn the nation as a whole."[20]

– Deputy Assistant Secretary of Defense for Continuity and Mission Assurance's Remarks to the Federal Energy Regulatory Commission (2019)

Despite the importance of electricity to national defense missions and operational capabilities, the risks to the infrastructure serving military installations and their surrounding communities is growing. This section will provide an overview of recent changes to how DoD defines its energy resilience requirements, the prevalence of risks to DoD missions at a regional scale, and case studies of recent events when military installations suffered outages at an unprecedented scale.

2.1 DoD Energy Resilience Requirements

DoD focuses intensively on keeping the power on at its installations to support mission assurance. Under U.S. Code, the general energy policy of DoD is to "ensure the readiness of the armed forces for their military missions by pursuing energy security and energy resilience."[21] In 2021, Congress passed a law requiring DoD to attain a minimum level of 99.9% availability for energy loads that support critical missions by 2030.[22] DoD subsequently adopted guidance specifying even higher availability requirements for certain facility types. Missile fields, cyber operations facilities, and satellite control facilities, for example, must attain a minimum level of 99.9999% availability.[23] This availability requirement translates to a downtime of only 30 seconds per year.

Each of the military departments have also set policy requiring that critical missions be able to operate independently from the grid. The Air Force's critical mission requirement is seven days of independent operation, and the Navy and Army have each established 14-day requirements.[24] The Army has set an additional target to install microgrids at all of its installations by 2035.[25] DoD requires each installation to develop an energy resilience master plan, and encourages installations to pursue backup power and other onsite resilience investments using private capital and its own budget funds.[26]

20. Kosak, C.P. (2019). Cyber and Physical Security, Best Practices, and Industry and Government Engagement. FERC/DOE Security Investments for Energy Infrastructure Technical Conference.
21. 10 U.S.C. 2911.
22. National Defense Authorization Act for Fiscal Year 2021.
23. Office of the Undersecretary of Defense for Acquisition and Sustainment. (2021). Metrics and Standards for Energy Resilience at Military Installations.
24. Assistant Secretary of the Air Force for Installations, Environment and Energy. (2020). Air Force Policy Directive 90-17; Secretary of the Army. (2020). Army Directive 2020-03 (Installation Energy and Water Resilience Policy); Department of the Navy. (2020). Installation Energy Resilience Strategy.
25. Office of the Assistant Secretary of the Army for Installations, Energy and Environment. (2022). United States Army Climate Strategy.
26. Office of the Assistant Secretary of Defense for Sustainment (ASD(S). (2016). Installation Energy Plans; ASD(S). (2018). Policy on Energy Savings Performance Contracts and Utility Energy Service Contracts; Office of the Assistant Secretary of Defense for Energy, Installations and Environment. (2020). Fiscal Year 2026 Energy Resilience and Conservation Investment Program Guidance.

Despite its focus on installation-level resilience, DoD remains heavily reliant on civilian infrastructure.[27] Over 99% of DoD bases rely on the commercial electricity grid for power, and the majority of bases also use civilian natural gas, water, wastewater service, and telecommunications infrastructure. In 2021, DoD reported over 6,200 unplanned utility outages with a combined duration of close to 3,500 days.[28] Although many assume that DoD has sufficient backup power, military diesel generators, microgrids, and other resilience systems are generally not designed for longer duration power outages, or able to support the defense communities upon which DoD depends.[29]

In recent years, the total number of power outage hours in the U.S. has increased significantly, driven by the onset of more frequent "major events"—events that impact a large number of utility customers for a comparatively long period of time.[30] Historically, the average hours of customer downtime from major events was equal to or lower than that from routine outages, but this trend reversed from 2017-2021 when major events caused up to 75% of all outage hours.[31]

Ensuring energy resilience for DoD requires investments in both on-base solutions and grid-scale resilience to adequately mitigate the risk to national defense.

2.2 Grid Outages Impact National Defense at a Regional Scale

Policymakers have increasingly recognized the importance of regional infrastructure to DoD. In 2015, Congress updated the Federal Power Act (FPA) to include an explicit focus on national defense.[32] The FPA, which was passed in 1935, regulates the interstate transmission system. Congress amended the FPA to include a definition of defense critical electric infrastructure (DCEI), which includes any civilian electric infrastructure that serves a critical defense facility. DOE and DoD designated critical defense facilities in 2019 and informed the utilities that serve them of their status.[33] DOE and DoD signed a Memorandum of Understanding (MOU) in 2020 to ensure the energy resilience of DCEI by working with utilities to prioritize national defense in infrastructure planning.[34]

All DCEI elements including distribution, transmission, and generation assets impact national defense in different ways:

- Statistically, the distribution system is responsible for most electricity outages by volume—most frequently caused by weather and equipment failure—but outages of this type are often restored in a matter of hours.[35]
- Transmission system disruptions result in longer-duration outages that impact larger geographic areas than distribution outages.[36] The transmission system represents a unique cog in the larger machine because it serves entire regions, rather

27. Stockton, P. & Paczkowski, J.P. (2019). Strengthening Mission Assurance Against Emerging Threats: Critical Gaps and Opportunities for Progress. Joint Forces Quarterly; U.S. Government Accountability Office. (2020). Climate Resilience: DOD Coordinates with Communities, but Needs to Assess the Performance of Related Grant Programs; Samaras, C. & Willis, H.H. (2013). Capabilities-Based Planning for Energy Security at Department of Defense Installations. Santa Monica, CA: RAND Corporation.
28. U.S. Department of Defense. (2022). Annual Energy Management and Resilience Report (AEMRR) Fiscal Year 2021.
29. CNA Military Advisory Board. (2015). National Security and Assured U.S. Electrical Power. Arlington, VA: Center for Naval Analysis.; Narayanan, A., Knopman, D., Powers, J.D., Boling, B., Miller, B.M., Mills, P., Van Abel, K., Anania, K., Cignarella, B., Jackson, C.P. Air Force Installation Energy Assurance: An Assessment Framework. Santa Monica: RAND Corporation.
30. The Institute of Electrical and Electronics Engineers (IEEE) defines a major event as one that "exceeds the reasonable design and/or operational limits of the electric power system. See, Canadian Electricity Association. (2015). Major Event Day Determination Reference Guide and Stockton, P. (2014). Resilience for Black Sky Days: Supplementing Reliability Metrics for Extraordinary and Hazardous Events. Washington, DC: National Association of Regulatory Utility Commissioners.
31. U.S. Energy Information Administration. (2022). U.S. Electricity Customers Averaged Seven Hours of Power Interruptions in 2021.
32. H.R. 22 (2015).
33. Electricity Advisory Committee. (2022). Strengthening the Resilience of Defense Critical Electric Infrastructure: Recommendations to the U.S. Department of Energy.
34. Office of the Assistant Secretary of Defense for Sustainment and Office of the Assistant Secretary for the Office of Electricity (OE). (2020). Memorandum of Understanding Concerning a Collaboration to Enhance Energy Resilience. The MOU is between DOD and DOE-OE, but DCEI related responsibilities are now within DOE Office of Cybersecurity, Energy Security, and Emergency Response (CESER).
35. Distribution lines are generally smaller and easier to replace.
36. National Academies the Sciences, Engineering and Medicine. (2017). Enhancing the Resilience of the Nation's Electricity System.

than individual customers or neighborhoods. Transmission system components are also more rare, expensive, and difficult to replace than their distribution system counterparts.

- Generation outages are comparatively rare given the volume of reserves available to offset local outages. When generation outages occur, however, they can be dramatically exacerbated by a lack of sufficient transmission capacity to access diverse generation resources.

While distribution system resilience is important, this paper focuses on the transmission system because the primary risks and impacts to mission assurance manifest at the regional level, where transmission is vital. These risks and impacts, detailed below, are used in the next section to structure a case study of Winter Storm Uri's impacts.

Direct Installation Impacts

- **Impacts to individual bases.** Although DoD has set targets for installation resilience (Section 2.1), these targets have not yet been achieved, and installations remain dependent on the grid. Transmission outages pose the risk of lasting beyond DoD's 14-day energy resilience planning horizon (see Text Box 2). Studies of backup generation on DoD installations suggest that the Department cannot rely on its onsite generators in the event of extended grid outages. As summarized in a recent report by the National Renewable Energy Laboratory (NREL), "The Department of Defense realized the current electrical configuration was a vulnerability and tasked the NREL to study the effectiveness of backup power systems used on DoD sites. The study discovered well-maintained generators have a reliability of 80 percent after two weeks of run time. Based on this information, the study determined a single, well-maintained emergency generator cannot guarantee emergency power for critical loads over multi day outages."[37]
- **Impacts to multiple bases.** A small number of defense missions can only be executed at a single location. For the majority of missions, the fallback is to relocate to another location or rely on support from geographically proximate locations. Widespread outages that impact multiple bases in the same region can compromise fallback options and decrease the ability of installations to support one another.

Defense Community Impacts

- **Personnel impacts.** Military installations are closely connected to and affected by the communities that surround them. More than 60% of military personnel live outside the fence line of the installation, along with nearly 100% of civilian personnel who work for DoD.[38] Power outages at the homes of personnel and their families can negatively impact military readiness. Additionally, DoD installations are not equipped to handle a large influx of civilians seeking shelter during emergencies that disrupt services to the general population.[39]
- **Interdependent utilities.** Most DoD installations rely on multiple civilian utilities including water/wastewater, communications, and transportation, each of which depends on the same electricity feeding the base.[40] Since transmission outages can affect larger geographic areas, they increase the chance of cascading failures across utilities that will degrade or disrupt mission capability.
- **Defense industrial base.** The Defense Industrial Base (DIB) is the network of facilities and organizations that provide defense-related materials, products, and services to the U.S. government.[41] This includes research, development, and manufacturing of weapons platforms and armaments, among many other activities that are energy-intensive. The DIB includes organizations with highly specialized capabilities that are important to national defense.

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37. Marquesee, J., Ericson, S., & Jenket, D. (2020). Emergency Diesel Generator Reliability and Installation Energy Security. Golden, CO: National Renewable Energy Laboratory.
38. Bipartisan Policy Center. (2023). Housing America's Military Families.
39. Active duty military installations may provide support to civilian emergency response through DoD's Defense Support for Civilian Authorities (DSCA) role. DSCA support can include a wide range of activities, including providing temporary shelter, depending on the military installation and its capabilities. See Federal Emergency Management Agency Emergency Management Institute. (2011). FEMA IS-75: Military Resources in Emergency Management.
40. U.S. Department of Energy Quadrennial Energy Review Task Force. (2017). Transforming the Nation's Electricity System: The Second Installment of the QER.
41. Congressional Research Service. (2023). The U.S. Defense Industrial Base: Background and Issues for Congress.

The DIB is also important to state economies. In 2021, the defense industry employed 1.1 million Americans across 60,000 companies.[42] In 2023, DoD released its first National Defense Industrial Strategy, which highlights the risks that critical infrastructure vulnerabilities pose to critical defense-related components and technologies.[43]

These risks and impacts to military missions reflect the importance of transmission to energy resilience planning. The next section provides insight into how these risks and impacts manifest themselves at the regional level during grid disruptions, and how investment in transmission could mitigate such risks in the future.

2.3 Case Study: Winter Storm Uri's Impacts and National Defense

This section revisits the case study of Winter Storm Uri from 2021 to explore how transmission availability can impact entire regions. There have been many analyses of the storm and its aftermath. This case study focuses specifically on how regional outages translate into risks for military installations and defense communities. Winter Storm Uri is of particular interest because it came close to resulting in system damage that could have taken weeks or months to repair—long beyond DoD's energy resilience contingency plans. The case study presents information at a high level because power outage impacts on specific DoD missions are not publicly available due to the sensitive nature of disclosing vulnerabilities.

On February 14, 2021, a polar vortex swept through Texas, bringing record-low temperatures across the state. During the 2021 vortex, which became known as Winter Storm Uri, the Electric Reliability Council of Texas (ERCOT)[44] faced several concurrent and colliding challenges. The extreme cold created widespread impacts to generators across the state, forcing more than 52,000 megawatts (MW) of capacity—50% of the state's generation fleet—offline as a result of limited natural gas availability and poor power plant winterization.[45]

At the same time, ERCOT faced record winter demand for electricity, totaling nearly 3,000 MW more than originally forecasted. The demand was driven in part by the 75% of homes and businesses in Texas that use electricity for heating.

Texas is unique within the continental U.S. because its transmission system is effectively "islanded" from the country's Eastern and Western Interconnections. As a result, Texas can only import an amount of electricity equivalent to less than 1% of its installed generation capacity.[46] ERCOT declared emergency conditions and shed 20 GW of its system load on February 15 and 16,

42. National Defense Industrial Association. (2023). Vital Signs 2023. Posturing the U.S. Defense Industrial Base for Great Power Competition.
43. U.S. Department of Defense. (2023). National Defense Industrial Strategy.
44. Electric Reliability Council of Texas (ERCOT).
45. Magness, B. (2021). Review of February 2021 Extreme Cold Weather Event – ERCOT Presentation. Texas Legislative Hearings: Senate Business and Commerce Committee House Joint Committee on State Affairs and Energy Resources.
46. Electric Reliability Council of Texas (ERCOT). (2021). Fact Sheet.

representing the largest single directed load shed in North American history. The storm and the disruption to the system caused power outages across the state from February 15 to the 18, with some parts of the state dark for even longer.[47] The loss of electricity also knocked out water service across large portions of Texas.

Texas is home to 15 military installations that are responsible for operating a broad range of missions, including strategic bombing, global airlift, remotely piloted aircraft, ground combat forces, cyber operations, combat systems repair and overhaul, and headquarters support. Texas is also one of the largest military training centers in the country, with programs for strike pilots, helicopter pilots, medical staff, and intelligence officers. The power failures associated with Winter Storm Uri, and the related water and gas outages, impacted military missions and defense communities in multiple ways, as detailed below.

2.3.1 Direct Installation Impacts

- As a result of Winter Storm Uri, DoD reported more than 1,000 hours of hours of unplanned outages at its installations.[48]
- Twelve of the 15 military installations in the state experienced disruptions to their electricity service. Fort Cavazos, Joint Base San Antonio, Goodfellow Air Force Base (AFB), Naval Air Station Kingsville, and Red River Army Depot closed due to a lack of power access, freezing temperatures, and the loss of water and wastewater services.
- Standalone generators with short-term fuel stockpiles connected to critical facility loads represent most backup power solutions for military installations. Many DoD generators fail to receive proper testing and maintenance, leading to higher-than-expected failure rates even when adequate fuel is present onsite.[49]
- The impacts of Winter Storm Uri tested the capabilities of the military's backup power capabilities both within Texas and across a dozen other states. In North Dakota, a portion of the Minot AFB missile field lost power from its utility during Uri, but the installation's backup generators kept the facility operational.[50] Minot AFB hosts the 91st Missile Wing, which maintains Minuteman III nuclear weapons. At Barksdale AFB in Louisiana, the backup generators functioned as designed, but the base struggled to secure sufficient fuel to keep the generators running.[51] Air Force Global Strike Command, which oversees nuclear deterrence and strike capabilities for the United States, is based at Barksdale AFB. Both Minot AFB and Barksdale AFB are also home to B-52 bomber squadrons, which are part of the Air Force 5th and 2nd Bomb Wings, respectively.
- The failure of the bulk electric system in Texas posed significant risks to national defense by simultaneously knocking out the power to an unprecedented number of installations within the same region. While the power failure partially resulted from the scale of the storm, ERCOT's inability to draw on interregional transmission as a source of backup power exacerbated the damage of the outages. Midcontinent Independent System Operator (MISO) and Southwest Power Pool (SPP) faced operating conditions similar to ERCOT, but they were able to access far more generation capacity through interregional transmission to avoid widespread outages.

2.3.2 Defense Community Impacts

- Winter Storm Uri negatively impacted military personnel, defense civilians, and their families. To put the magnitude of the combined military presence in Uri's path into perspective, 235,000 DoD employees live and work in the state of

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47. Texas Comptroller of Public Accounts. (2021). Winter Storm Uri 2021 Special Report.
48. U.S. Department of Defense. (2022). Annual Energy Management and Resilience Report (AEMRR) Fiscal Year 2021.
49. Marquesee, J., Schultz, C., & Robyn, D. (2017). Power Begins at Home: Assured Energy for U.S. Military Bases. The Pew Charitable Trusts.
50. Allen, J.J. (2021). Statement of Brigadier General John J. Allen, Jr., Commander, Air Force Civil Engineer Center on Installation Resiliency: Lessons Learned from Winter Storm Uri and Beyond. House Armed Services Committee, Subcommittee on Readiness.
51. House Armed Services Committee. (2021). Hearing on Lessons Learned from Winter Storm Uri and Beyond.

Texas[52]—almost 10 times the number of employees working at the Pentagon.[53] Approximately 70% of Texas customers lost power, with the average disruption lasting 42 hours. More than 50% lost running water for multiple days. Over 250 people died, and the economic damage was over $130 billion.

- Winter Storm Uri also highlighted the risk of cascading failures across interdependent utility systems. The combined failure of the power grid, rapidly followed by water system outages due to energy disruptions and freezing temperatures, placed additional strain on DoD installations.
- Some bases closed due to disruptions in water access alone. Dyess AFB, for example, lost water service when the City of Abilene's wastewater treatment plant lost power and shut down operations.[54] The Base is home to the Air Force's 7th Bomb Wing, one of only two B-1 Lancer strategic bomber wings, and 317th Airlift Wing, which performs missions around the world with C-130 Hercules aircraft.
- The base was not directly impacted by the power outages, but the city was unable to provide water for 24 hours, forcing the base to switch to its emergency water tanks. The emergency tanks emptied faster than anticipated because of water line breaks on the installation from the cold weather. The installation stopped using its emergency supply when it dropped to 10% to preserve the remaining water for firefighting.[55]
- Winter Storm Uri also impacted Texas's significant defense industrial base. Texas is the top state recipient of DoD contract spending, with $45.6 billion in FY22.[56] Texas's defense industry employs tens of thousands of people in fields such as aircraft and avionics manufacturing, research and development, and operations and overhaul.[57] Bell Textron, which manufactures helicopters and other vertical lift aircraft, shut down operations for four days during Winter Storm Uri, an unprecedented event in the company's history.[58] Lockheed Martin paused production at its facilities in Fort Worth, Texas as a result of electric grid impacts,[59] and Raytheon experienced business disruptions caused by employees attending to personal property damage or unable to get to work.[60]

Despite the significance of the Winter Storm Uri impacts, these consequences do not represent the worst-case scenario. Winter Storm Uri demonstrated that long-duration, regional disruptions are possible. Within a span of only 30 minutes, the mass failure of generators due to equipment freezing and the loss of natural gas supply caused enough instability in the regional grid that Texas was pushed within 4 minutes and 37 seconds of a full-scale blackout.[61] According to ERCOT, such a blackout would have lasted weeks or months, a duration that far exceeds any DoD planning criteria. This near miss should serve as a warning regarding the unpredictable severity of long-duration outages. While a multi-day disruption to a dozen military installations proved challenging, the risk of a multi-week outage affecting an entire region could undermine national defense more broadly.

Although Winter Storm Uri did not cause outages lasting beyond DoD's planning horizons, other recent events have. In 2021, for example, Hurricane Ida knocked out the transmission system in Louisiana, causing multi-week power outages (Text Box 2). Winter Storm Uri, Hurricane Ida, and other recent extreme events such as Winter Storm Elliott illustrate the new paradigm that DoD is operating in, and highlight opportunities to make bulk electric system investments that strengthen and harden the grid in regions with high concentrations of DoD missions.

52. Texas Military Preparedness Commission. (2022). Military Installations Across Texas.
53. MilitaryInstallations. (2023). Pentagon - Air Force.
54. Thayer, R. (2021). Winter Weather Causes More than a Dozen Military Bases to Close. Stars and Stripes.
55. Allen, J.J. (2021). Statement of Brigadier General John J. Allen, Jr., Commander, Air Force Civil Engineer Center on Installation Resiliency: Lessons Learned from Winter Storm Uri and Beyond. House Armed Services Committee, Subcommittee on Readiness.
56. Office of Local Defense Community Cooperation. (2023). Defense Spending by State: Fiscal Year 2022 (Revised Version).
57. Texas Economic Development and Tourism. (2022). Texas Aerospace, Aviation & Defense Industry.
58. Bell Textron. (2021). Letter in Support of TEAM's Emergency Request. Public Utility Commission of Texas.
59. Lockheed Martin Corporation. (2022). Climate Change 2022. CDP.
60. Raytheon Technologies Corporation. (2022). Climate Change 2022. CDP.
61. Magness, B. (2021). Review of February 2021 Extreme Cold Weather Event – ERCOT Presentation. Texas Legislative Hearings: Senate Business and Commerce Committee House Joint Committee on State Affairs and Energy Resources.

Although many assume that DoD has sufficient on site generation, microgrids, and other sources of backup power, energy resilience for DoD requires specific investments in both onsite solutions and in defense critical electric infrastructure. The role of transmission in regional-scale resilience must also be factored into future planning given the need to support both community resilience and interdependent utilities. The next section provides several concepts that articulate how the principles of deterrence by resilience might guide transmission system planning.

Text Box 2.
Hurricane Ida's Transmission System Damage Leads to Multi-Week Power Outages

In August 2021, Hurricane Ida made landfall in Louisiana as a Category 4 storm. Ida was the second-most intense and destructive storm to hit the state since Hurricane Katrina in 2005. The hurricane knocked out power in Entergy's service territory in Louisiana, resulting in disruptions to 1.2 million customers. Nearly 21 days after the storm—or a full week beyond DoD's maximum outage planning horizon—there were still 100,000 customers without power.[62]

The primary driver for both the scale and duration of outages was the destruction of eight transmission lines in a single corridor, "many of which were built decades ago to withstand much weaker hurricanes. The company had not upgraded or replaced a lot of that equipment with more modern gear designed to survive the 150 mile-an-hour wind gusts that Ida brought to bear on the state."[63] Naval Air Station Joint Reserve Base New Orleans, which houses the 159th Fighter Wing, Coast Guard Air Station New Orleans, and a dozen other tenant commands,[64] lost power and had to switch to backup generators.[65] The 159th Fighter Wing provides air defense and superiority over the Gulf Coast with F-15 aircraft on standby 24 hours a day. Coast Guard Air Station New Orleans has saved more than 13,000 lives since it was first commissioned and is the busiest all-helicopter search and rescue unit in the service. The duration of the outages challenged the success of these and other missions in the region affected by Hurricane Ida, underscoring the need for transmission hardening.

62. Kasakove, S. (2021). Three Weeks After Hurricane Ida, Parts of Southeast Louisiana Are Still Dark. The New York Times.
63. Eavis, P. & Penn, I. (2021). Why Louisiana's Electric Grid Failed in Hurricane Ida. The New York Times.
64. Navy Region Southeast. (2024). NAS JRB New Orleans Tenant Commands.
65. Lamar, B. (2021). NCBC Gulfport culinary specialist reflects on mission to New Orleans following Hurricane Ida. Defense Visual Information Distribution Service.

SECTION 3.
DETERRENCE BY RESILIENCE

"As the velocity and variety of threats [continue] to increase, the Nation must urgently address the energy resilience of military installations and the associated commercial electric grid to achieve national security objectives."[66]

– Department of Defense and Department of Energy Memorandum of Understanding (2020)

Deterrence by resilience can help reduce the likelihood of war by shaping adversary assessments of the costs and benefits of attacking. As stated in 2022 NDS, "deterrence is strengthened by actions that reduce a competitor's perception of the benefits of aggression relative to restraint." Investments in grid resilience can reduce adversaries' confidence that they can achieve their goals by striking the U.S. electric system.

This section presents concepts to build and sustain the national defense capabilities of the transmission system. These concepts emphasize roles for both the private and public sectors, and reflect a "shared responsibility" approach to deterrence, under which grid operators and the military take action to minimize the likelihood of attacks.[67] The concepts focus on expanding the reach and redundancy of the BES, addressing the vulnerabilities of the transmission systems that serve critical DoD installations, and enhancing the ability of DoD to engage with the complex processes of planning the transmission system. Extensive conversations with subject matter experts and reviews of recent grid disruptions highlighted BES improvement strategies that can be grouped into three categories:

- **Increasing the Grid's Reach.** The first strategy is to improve the availability and access to diverse generation resources through targeted investment in transmission infrastructure. The benefits of traditional generation reserve margins are blunted when more than one Independent System Operator or Regional Transmission Organizations (ISO/RTO) is impacted by the same event (natural or man-made), or a substantial number of generators share a common vulnerability related to their fuel source or technical limitations. More transmission can alleviate generation capacity pitfalls.
- **Planning for Mission-Driven Infrastructure.** The second strategy relates to the lack of visibility into specific DoD energy needs in a way that informs electricity infrastructure planning and investment. Current planning models are focused at the level of individual military installations and the distribution utilities that support them. Focus must shift to improve the collective understanding of DoD energy needs at a regional level for incorporation into more targeted BES investments.
- **Engagement for National Defense.** DoD can engage more proactively with its electricity industry partners to accelerate and prioritize transmission investment. This will require an improved means of articulating requirements for infrastructure hardening, redundancy, and capacity expansion to support energy assurance needs. This will also require new engagement mechanisms to incorporate DoD requirements into regulatory and planning processes at the state, regional, and federal levels, and the alignment of DoD energy procurement with grid resilience.

Each of the concepts starts with a "BLUF," or bottom line upfront, followed by a discussion of the transmission challenge that the concept relates to and potential solutions to the challenge.

3.1 Accelerating Transmission Expansion

Massive investments in new generation are planned in the U.S., with a combined 2 Terawatts (TW) of new generation in the "queue" for construction, a number greater than the current total U.S. generating capacity of 1.25 TW, and more than six times larger than the queue in 2014.[68] This generation pipeline will not mitigate the energy assurance risks to DoD on its own. Missing from this equation is the corresponding investment in transmission.

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66. Office of the Assistant Secretary of Defense for Sustainment and Office of the Assistant Secretary for the Office of Electricity. (2020). Memorandum of Understanding Concerning a Collaboration to Enhance Energy Resilience.
67. Aaronson, S. (2021). Protecting the Energy Grid is a Team Sport. Security Magazine.
68. Lawrence Berkeley National Laboratory. (2023). Grid Connection Requests Grow by 40% in 2022 as Clean Energy Surges, Despite Backlogs and Uncertainty.

While transmission experienced an average annual growth rate of 2.3% from 1978-2020, construction has dropped to 1% per year over the past 10 years.[69] This downward investment trend needs to reverse to avoid compromising national defense. Siting for transmission lines generally focuses on supporting large electricity load centers, or reducing congestion on existing lines. When it comes to mitigating national defense risk, planning processes need to be more inclusive of addressing generation diversity considerations as well. Winter Storm Uri and Winter Storm Elliott in December 2022 both exposed vulnerabilities in their heavy dependence on a single resource type (in this case natural gas generators), resulting in unprecedented forced outages and customer disruptions. Each event exposed flaws in current resource planning processes that can be alleviated by transmission expansion resilience to adequately mitigate the risk to national defense.

3.1.1 Accelerate the Transmission Planning Process

BLUF: Transmission projects that serve regions with critical defense facilities should be expedited. Transmission lines typically require 10 to 15 years to plan, site, and complete, but the risks to national defense are imminent.

Challenge: Transmission delays primarily occur in three areas: review of new generation by utilities and grid operators, the transmission expansion planning process, and siting and permitting reviews by federal and state agencies. The siting and permitting process to build transmission assets takes far longer than the construction process itself, owing to the challenge of land availability and use.

Solution: DOE laid a foundation for prioritizing transmission investment with the National Interest Electric Transmission Corridor (NIETC) program.[70] Expedited transmission permitting on its own will support national defense through improved redundancy and reliability. New transmission tools and programs, however, create the opportunity to specifically support DoD. DoD can utilize the NIETC program to identify current and proposed transmission projects with the potential for DCEI benefits (see Section 2.2). By more clearly articulating how defense resilience requirements align with specific transmission opportunities, DoD and its private sector partners can make the case at the federal and state levels to systematically accelerate interstate and interregional transmission projects. High priority national defense projects can also leverage the DOE Transmission Facilitation Program[71] or the Transmission Facility Financing Program[72] to secure funding in an expedited manner. Infrastructure investments with DCEI benefits can also support regulator decision making related to transmission projects at the state level. The Missouri Public Service Commission, for example, cited the national security benefit of the Grain Belt Express Transmission line as a factor in approving the line's construction in 2023,[73] and completing a four-state, multi-year approval process. The Arizona Corporation Commission likewise took national defense and DoD energy resilience into account when approving the Irvington-East Loop Transmission Line, which serves the region surrounding Davis-Monthan AFB.[74]

3.1.2 Diversify Generation to Support DoD

BLUF: The transmission system should provide DoD with access to a diverse portfolio of electricity generation to maximize resilience.

Challenge: Winter Storms Uri and Elliott highlighted the risks associated with the heavy dependence of a grid service territory on generators of a single fuel type and in a limited geography. While generation of all types experienced outages due to the cold weather and operating conditions, the outages were far more

69. Jenkins, J.D., Farbes, J., Jones, R., Patankar, N., Schivley, G. (2022). Electricity Transmission is Key to Unlock the Full Potential of the Inflation Reduction Act. Princeton, NJ: Princeton University Zero Lab.
70. U.S. Department of Energy Grid Deployment Office. (2023). Energy Department Releases Guidance to Identify High-Priority Areas for Transmission Development.
71. U.S. Department of Energy Grid Deployment Office. (2023). Transmission Facilitation Program.
72. U.S. Department of Energy Grid Deployment Office. (2023). Transmission Facility Financing Program.
73. Public Service Commission of the State of Missouri. (2023). Report and Order (File No. EA-2023-0017).
74. Tucson Electric Power. (2023). Irvington-East Loop Transmission Line.

pronounced with natural gas generators. In the case of Winter Storm Uri, "from February 8 through February 20, 2021, of the 1,293 unplanned generating unit outages, derates, and failures to start that were due to fuel issues, 1,121 (87 percent) were due to natural gas fuel supply issues."[75] Winter Storm Elliott saw a similar outcome, where 63% of all generation outages (by MW) were from natural gas fired plants.[76] The generation resource mix is not actively managed by ISO/RTOs for energy resilience benefits, and there is insufficient transmission to actively support supply diversity in regions with heavy concentrations of DoD load.

Solution: Transmission expansion can provide more redundancy and access to reserves over a larger area. More comprehensive evaluations of fuel security are needed to identify the optimal mixture of generation types to reduce the risk of disruptions caused by fuel availability.[77] Transmission planning should prioritize connecting regions with a greater diversity of generation types to those regions with a high dependency on single fuels that could suffer from common-mode failures. Expanded interregional transmission would help alleviate reliability issues associated with, for example, forced outage rates of generation that far exceeded grid operator planning criteria during recent cold weather events. Transmission can also balance weather-dependent intermittent resources, such as wind and solar power.[78] For example, the Grain Belt Express HVDC Transmission line connects three ISOs across 23 states that are home to more than a quarter of all DoD installations.[79] This ability to access regional wind or solar assets and deliver them thousands of miles across multiple grid operators maximizes generation resource availability and flexibility. Section 3.3 explores concepts for how DoD might more directly support transmission lines that provide access to diverse resources in the future.

3.1.3 Build DoD Energy Loads into Grid Planning

BLUF: DoD energy requirements related to mission availability and resilience (Section 2.1) should be integrated into regional generation reserve margins and supported by establishing and meeting interregional transfer minimums.

Challenge: Current transmission planning and operational processes don't explicitly take DoD energy loads into account. Regional grid operators do not identify and aggregate the capacity requirements of DoD installations and their defense communities in their service territory, preventing them from identifying the generation and transmission needed to meet those requirements. Winter Storm Uri forced the Electric Reliability Council of Texas (ERCOT) to shed 20,000 MW of firm load. Neighboring systems including the MISO and SPP had similar weather conditions and substantial generation outages, but their ability to import up to 13,000 MW through interregional transmission ties helped avoid the levels of customer outages experienced by ERCOT. FERC found that "MISO's and SPP's ability to transfer power through their many transmission ties with adjacent Balancing Authorities in the Eastern Interconnection helped to alleviate their generation shortfalls, preventing more severe firm load shed. ERCOT, unlike MISO and SPP, did not have the ability to import many thousands of MW from the Eastern Interconnection."[80]

Solution: Historically, planning processes have emphasized generation reserves as the primary means to address adverse operating conditions and disruption events. However, transmission expansion can play an essential role in addressing these vulnerabilities in a number of ways. The establishment of interregional transfer minimums[81] between grid operators and Reliability Coordinators (RC) can help address this issue

75. North American Electric Reliability Council. (2023). February 2021 Cold Weather Grid Operations: Preliminary Findings and Recommendations. FERC-NERC-Regional Entity Joint Inquiry Into Winter Storm Elliott.
76. North American Electric Reliability Council. (2023). December 2022 Winter Storm Elliott Grid Operations: Key Findings and Recommendations. FERC-NERC-Regional Entity Joint Inquiry Into Winter Storm Elliott.
77. See PJM. (2018) Fuel Security Analyzing Fuel Supply Resilience in the PJM Region: Summary of Results, Conclusions and Next Steps.
78. Bird, L. & Lew, D. (2012). Integrating Wind and Solar Energy in the U.S. Bulk Electricity System: Lessons Learned from Regional Integration Studies. Golden, CO: National Renewable Energy Laboratory.
79. HVDC Transmission: A National Security and Energy Resilience Imperative, 23.
80. North American Electric Reliability Council. (2023). February 2021 Cold Weather Grid Operations: Preliminary Findings and Recommendations. FERC-NERC-Regional Entity Joint Inquiry Into Winter Storm Elliott.
81. Reed, L & Xu, A. (2022). FERC is Coalescing around the Idea of a Minimum Transfer Capacity but Needs Data and Definitions. Niskanen Center.

by bringing more access to capacity located in regions less impacted by a disruptive event. Specific to national security, these transfer minimums (and the generation reserves they can support) should also incorporate national defense electricity loads aggregated at a regional scale to better account for the ability of a grid system to support mission-critical needs.

3.2 Strengthening the Grid for Critical Defense Facilities

Bolstering the grid through transmission expansion provides immediate and lasting benefits for national defense, but additional work is needed to identify and articulate DoD energy resilience requirements for targeted infrastructure investment. The success of that work will depend on the development of a more detailed process for identifying criteria for overall performance of assets that support military installations. Under the DCEI program, DOE prioritizes the electricity systems that serve critical defense facilities. However, this process has not been integrated into the long-term and resource-planning models of utilities or interregional organizations seeking to improve or construct transmission assets. The absence of specific construction criteria for DCEI creates ambiguity regarding how best to align mission requirements with grid investment.

The processes by which construction standards are designed and implemented are also outdated, since they are based on historical experience. As noted in a recent utility industry article, "Retrospective analyses are no longer sufficient for future planning when billion-dollar disasters are rising at a rapid clip."[82] Each utility is responsible for coordinating with its military customers to determine their service needs, and each installation uses their own methodology to assess priorities and potential technical solutions to address energy assurance risk. The result is a patchwork process that varies widely from one utility to the next, and is further varied based on state and federal regulator reviews of proposed infrastructure investments.[83] DoD energy assurance requirements must be systematically addressed through new grid planning and operational processes.

3.2.1 Establish Infrastructure Design Criteria That Reflects Mission-Criticality

BLUF: There is a need for hardening and redundancy requirements for transmission assets that serve critical defense facilities.

Challenge: Not all transmission assets are created equal; their importance is a function of the customers they serve and the generation assets they connect to the grid. The recently published DOE National Transmission Needs Study noted, "resilience is especially important...with an aging transmission system. The number of transmission facilities and associated components in need of maintenance often exceed a utility's ability to service them in a timely manner."[84]

There are no current design criteria for building transmission infrastructure that are informed by national defense resilience requirements, only the consensus-based codes developed by professional associations and the reliability standards set forth by the North American Reliability Corporation (NERC). Addressing risks to infrastructure to support national security requirements is best executed in a manner that maximizes survivability from the broadest set of possible hazards. For example, a mitigation strategy that effectively addresses both sea-level rise and cybersecurity is ideal but not always feasible given the significant differences in hazard types.

Solution: Hardening criteria such as wind or ice ratings, flood elevation, cybersecurity protections, or the addition of ballistic fencing all make critical assets more survivable. A clear and consistent process for identifying criteria for minimum levels of hardening is needed for both new and existing transmission serving DoD installations. A process for assessing whether redundancy is adequate is also needed. Additional transmission lines can create or maximize pre-designated, alternate "paths" to support DoD installations. Targeted investment in transmission hardening should focus on assets that can segment the grid around capable generators and local, mission-critical loads. This would allow for the grid to degrade

82. Thadani, M. (2023). The Elusive 'Value of Resilience': Why Every Utility is Asking for it and Why it's so Hard to Pin Down. Utility Dive.
83. NARUC. (2021). Regulatory Considerations for Utility Investments in Defense Energy Resilience.
84. U.S. Department of Energy. (2023). National Transmission Needs Study, p.72.

while maintaining pockets of service larger than a microgrid but smaller than a full utility footprint.

3.2.2 Create a New Black Start Model for DoD

BLUF: Grid operators should incorporate critical national defense energy loads into black start planning, or create a similar mechanism specifically for national defense.

Challenge: Black start planning creates specialized criteria for power plants that can operate when the grid fails. Black start power plants are designed to stay online and create "islands" of electricity during BES outages to serve as building blocks for restoring the larger system from the inside-out.[85] This requires matching real-time demand using dedicated transmission lines, or "cranking paths" that connect black start generators to designated critical loads. Black start critical loads include nuclear power plants, natural gas system infrastructure (such as compressor stations), and power plants that can rapidly restart if provided with outside power.[86] The black start system, however, is not designed to support specific "retail" loads—such as DoD installations—that are not part of the BES. If an event requiring black start were to occur, it is likely the event would have significant national defense implications that DoD would need to compensate for. This creates a transmission gap where there would not be sufficient infrastructure to support critical national defense energy loads during a black start.

Solution: DOE and DoD committed to ensuring the prioritization of military installations in emergency restoration plans in their MOU.[87] DoD should work with grid operators to ensure that the critical defense facilities are included as black start priorities and transmission assets are identified or constructed to directly support these requirements. This strategy will require a paradigm shift in planning, as current standards do not require grid operators to pre-designate alternate or redundant transmission cranking paths. With foreign adversaries targeting critical infrastructure to disrupt national defense missions, this planning for redundancy can mitigate the risks associated with a "contested restoration," when deliberate attacks coincide with major weather events and system disruptions.[88] As an alternative, grid operators can work with DoD to develop specific programs to support national defense loads, using black start as a precedent and guide. Such programs would support mission assurance priority installations with dedicated transmission cranking paths and capable generation assets. Based on recent lessons learned from extreme weather events, a defense-specific black start system should rely on more than one generation type carried over multiple, redundant transmission lines (see Text Box 3). Given the risk of single-fuel dependency, there are opportunities to determine how renewable energy and storage could diversify the blackstart portfolio, particularly given their dramatic increase in national market share.[89]

3.3 Empowering DoD as Transmission Proponent

Utilities, grid operators, and regulators would play a lead role in the concepts presented above. This section presents concepts where DoD would instead play the lead role. Several of these concepts would implicate new responsibilities for DoD, which may require new organizational structures and new authorities to be created through legislation, executive orders, or DoD policy. This paper does not make recommendations as to the specific pathways through which these concepts could be realized.

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85. National Association of State Energy Officials. The Black Box of Blackstart: Electricity Reliability and Interdependency Considerations for State Energy Offices.
86. PJM. (2023). PJM Manual 36: System Restoration (Revision 33).
87. Office of the Assistant Secretary of Defense for Sustainment and Office of the Assistant Secretary for the Office of Electricity. (2020). Memorandum of Understanding Concerning a Collaboration to Enhance Energy Resilience.
88. Electricity Advisory Committee. (2022). Strengthening the Resilience of Defense Critical Electric Infrastructure: Recommendations to the U.S. Department of Energy.
89. Jain, H., Seo, G-S, Lockhart, E., Gevorgian, V., & Kroposki, B. (2020). Blackstart of Power Grids with Inverter-Based Resources. Golden, CO: National Renewable Energy Laboratory.

Text Box 3.
Black Start Lessons Learned from Winter Storm Uri and Winter Storm Elliott

Extreme weather events from the past several years have highlighted the vulnerability of existing black start power plants. As discussed in Section 3.1.2, dependence on a single type of generation represents a serious vulnerability, which is compounded when there is insufficient transmission capacity to balance and diversify with resources from other regions.[90] Despite constituting 40% of total generation nationwide, natural gas generators represent 60% of registered black start units, and recent performance is cause for concern. During Winter Storm Uri, 82% of ERCOT's 28 black start power plants, comprising 1,418 MW out of a total 1,711 MW of black start capacity, experienced an outage, derate, or failure to start at some point. Similarly, in Winter Storm Elliott, over 150 black start-designated generating units, totaling 19,000MW, incurred outages during the Event, 119 of which were natural gas-fueled generating units (accounting for just under 75% of all MW of black start-designated generation outages).

3.3.1 Equip DoD to Support Grid Resilience

BLUF: There is an opportunity to empower DoD with the authority and capability to effectively engage in grid planning.

Challenge: The DCEI-focused MOU signed by DOE and DoD envisions an active role for DoD providing input into integrated resource plans, infrastructure siting, electricity rates, and the prioritization of generation within transmission queues.[91] DoD, however, is not well-positioned to engage with utility partners or regional grid planners on grid resilience. DoD's energy resilience policy is focused primarily at the installation level and does not specify a role for DoD in civilian utility system planning.[92] DoD also does not have staff in-house with expertise in bulk electric system operations and vulnerabilities. DoD does have staff that engage in state and regional regulatory proceedings, but they typically intervene in the interest of the entire federal government—not DoD's interest specifically—and they focus primarily on keeping utility rates low, rather than on policy issues such as grid resilience.[93]

Solution: In order for utilities and grid operators to effectively support national defense, they will require clear input and sustained engagement from DoD about its energy resilience requirements. DoD has an opportunity to update its energy policy to recognize

90. Federal Energy Regulatory Commission, North American Reliability Council, and Regional Entity Staff. (2023). Blackstart and Next-Start Resource Availability in the Texas Interconnection.
91. Office of the Assistant Secretary of Defense for Sustainment and Office of the Assistant Secretary for the Office of Electricity. (2020). Memorandum of Understanding Concerning a Collaboration to Enhance Energy Resilience.
92. 10 U.S.C. 2911.
93. National Association of Regulatory Utility Commissioners. (2021). Regulatory Considerations for Utility Investments in Defense Energy Resilience.

the need for grid resilience. DoD can also train and authorize energy staff to engage proactively with utility and regulatory partners and support efforts to align grid investment with national defense priorities.

3.3.2 Understand DoD Transmission Vulnerabilities

BLUF: DoD and electricity industry partners can develop a shared understanding of where and how transmission investments would benefit national defense.

Challenge: There is a lack of data and analysis to prioritize defense-related transmission expansion and hardening. Although individual utilities may engage with specific critical defense facilities utilizing traditional contingency analysis modeling tools, there is little information to support decision making within a grid balancing authority or at the national level. Comparing the locations of military installations against NERC's Long-Term Reliability Assessment reveals that there are many important defense facilities located in areas of the grid that have an elevated or high forecasted reliability risk.[94] This level of granularity is not actionable, and decision makers require better information (at the appropriate level of classification) to align transmission investments with national defense priorities.

Solution: The national laboratories and other organizations have tools for analyzing the transmission risks to national defense at different levels of classification. These analyses could include, for example, mapping transmission service to critical defense facilities to identify locations where redundant lines are needed, or conducting more detailed analyses related to DCEI assets in specific locations. Examples of these tools include the EPFast tool from Argonne Laboratory, which simulates how the bulk power system behaves when specific components fail, and the All-Hazards Analysis tool from Idaho National Laboratory, which models failures across interdependent utility systems at a regional level.[95] These tools can support risk-informed decision making for infrastructure investment that directly supports DoD mission assurance.

3.3.3 Host New Transmission On DoD Land

BLUF: DoD can encourage transmission developers to site power lines and other equipment on its land through its enhanced use lease or easement authorities.

Challenge: Transmission developers negotiate easements with property owners, or in some cases purchase the land outright, to secure rights-of-way for transmission corridors. The transaction costs of dealing with different landowners, and the cost of acquiring the right-of-way, can be significant expenses.

Solution: DoD owns close to 9 million acres of land in the U.S., equivalent to roughly the size of the state of Maryland.[96] DoD has multiple authorities that allow it to transfer its land to other parties for development. Under its enhanced use lease (EUL) authority, DoD can lease its property to private sector partners if the lease will support national defense.[97] The private sector entities provide an "in-kind consideration" to DoD in lieu of rent payments. Each of the military services has used EULs in partnership with utilities to site generation on-base. The power plants provide electricity to the grid during normal operating conditions, and are designed to supply the host installation with backup power during outages as the in-kind contribution. Some of these projects have included short transmission line runs to connect the power plants to the grid,[98] but there is an opportunity for DoD installations to host larger parts of commercial transmission lines as well. DoD can also provide rights-of-way specifically for transmission lines, substations, and other electrical infrastructure under its easement authority,[99] as long as the projects take into account DoD's energy resilience requirements.[100]

94. North American Electric Reliability Corporation. (2023). 2023 Long-Term Reliability Assessment.
95. Hruska, R.C., McGillivary, K.E., & Edsall, R.M. (2022). A Functional All-Hazard Approach to Critical Infrastructure Dependency Analysis. Idaho Falls, ID: Idaho National Laboratory; Portante, E.C., Craig, B.A., Malone, L.T., Kavicky, J., Folga, S.F., Cedres, S. (2011). EPFast: A Model for Simulating Uncontrolled Islanding in Large Power Systems. Proceedings of the 2011 Winter Simulation Conference.
96. Congressional Research Services. (2020). Federal Land Ownership: Overview and Data.
97. 10 U.S.C. 2667.
98. Hawaii Public Utilities Commission. (2017). Application. Docket No. 2017-0443.
99. 10 U.S.C. 2668.
100. Office of the Assistant Secretary of Defense for Sustainment. (2020). Guidance on the Use of Easements in Pursuing Energy Resilience.

3.3.4 Integrate Grid Stakeholders into DoD Exercises

BLUF: DoD can collaborate more closely with its utility partners in its exercises to jointly investigate grid resilience opportunities.

Challenge: DoD uses pull-the-plug exercises, also known as energy resilience readiness exercises (ERREs), to identify installation energy resilience vulnerabilities. By law, DoD must perform a minimum of five ERREs per military department per year through 2027.[101] During ERREs, power to the installation is physically turned off.[102] Installation staff then make real-time decisions to maintain operations without power from the grid for up to 24 hours.[103] ERREs allow the installations to test their on-base procedures and equipment, such as their backup generators, under realistic conditions. Without such testing, there is no guarantee that backup power systems will be able to carry mission-critical electricity loads during power outages. ERREs can also reveal assumptions about grid resilience and opportunities to improve it. In several instances, installations have assumed that they are connected to two redundant transmission lines because they are served by two separate utilities, when in fact both utilities feed power through a single transmission line.

Solution: DoD engages with its utility partners during ERREs to alert them, for example, that a substantial amount of the installation load may be taken offline. There are opportunities to work with utility partners to participate more directly in exercises, and to use exercise outcomes to explicitly inform investments in transmission hardening or expansion. In some cases, DoD funding may be available to support new transmission development. In 2023, for example, DoD awarded a $9 million grant from the Defense Community Infrastructure Program to the Northern California Power Agency. The grant is supporting a new 15-mile, 69 kilovolt transmission line and substations to connect the Plumas-Sierra Rural Electric Rural Cooperative with the NV energy grid in Nevada. The new transmission line will eliminate a single point of failure for the Sierra Army Depot and other Plumas-Sierra members.[104] Sierra Army Depot provides a wide range of logistics and sustainment missions. It is responsible for the repair and reset of all Army fuel and water systems, and serves as the primary storage site of equipment used to build F-22 Raptor stealth fighter aircraft.

3.3.5 Enable DoD to Commit to Purchases Within Planned Transmission Corridors

BLUF: DoD can encourage the development of transmission lines that would support national defense by committing to purchase power from generation projects that would feed into the new lines.

Challenge: One of the many challenges to developing new transmission lines is the chicken or egg issue of whether the transmission line will be fully utilized once it is built. Although new transmission lines can open the door to untapped energy resources, developers have little incentive to invest in new power plants without a long-term contract for the electricity they would produce.

Solution: DoD has substantial buying power. In fiscal year 2022, DoD used 28 million megawatt-hours of electricity, roughly equivalent to the electricity consumption of the state of New Mexico.[105] DoD is required by law to produce or procure 25% of its electricity consumption from renewable energy sources by 2025.[106] Executive Order 14057 from 2021 also requires federal agencies to achieve 100% carbon-free electricity by 2030.[107] DoD currently meets these requirements by building power plants onsite, or by purchasing power from offsite carbon-

101. 10 U.S.C. 2920; Office of the Deputy Assistant Secretary of the Air Force for Environment, Safety, and Infrastructure. (2022). Energy Resilience Readiness Exercises.
102. Castillo, A., Judson, N., Bose, S. & Monken, J. (2021). Information Paper: DoD and Industry Black Start Exercises. U.S. Department of Defense.
103. Douglas, A., Pina, A. & Pringle, M. (2022). Exercise Roadmap for Resilience: Requirements, Results, and Resourcing. Combating Threats Exchange (CTX) Journal; Poulin, C., Pina, A., Sack, J. & Judson, N. (2020). Identifying gaps between requirements and capabilities. The Military Engineer.
104. Office of Local Defense Community Cooperation. (2023). Defense Community Infrastructure Program.
105. U.S. Department of Defense. (2023). Annual Energy Performance, Resilience and Readiness Report Fiscal Year 2022. U.S. Electricity Information Administration. (2023). US Electricity Profile 2022.
106. 10 U.S.C. 2911(g).
107. Executive Order 14057. (2021).

free generators. As a complement to its current purchasing strategy, DoD could commit to purchasing electricity from carbon-free generators located within planned transmission corridors, provided that the new transmission lines would create significant national defense benefits. Such commitments would help ensure that transmission lines would be fully subscribed.

3.3.6 Enable DoD to Purchase Transmission Capacity

BLUF: DoD can commit to purchasing transmission capacity, either alongside its carbon-free electricity purchases or on a standalone basis.

Challenge: As discussed above, transmission investors need confidence that their lines will be used before they deploy capital for development and construction. One approach to increasing investor certainty is for public sector entities to pre-buy a percentage of the proposed transmission lines' capacity. Such purchases directly de-risk the project, while encouraging other customers to purchase transmission capacity from the line as well.

Solution: Similar to the previous concept, DoD could use its buying power to directly support transmission development. The Bipartisan Infrastructure Law created a new Transmission Facilitation Program, which authorizes DOE to take out loans to purchase up to $2.5 billion of transmission line capacity.[108] DoD could adopt a similar approach and purchase transmission capacity for lines that would create specific national defense benefits. By law, DoD is required to ensure that its power purchase agreements support energy resilience.[109] Purchasing transmission line capacity to support national defense in parallel with its carbon-free electricity purchases could be a strategy for aligning DoD's power purchase and energy resilience objectives.

108. U.S. Department of Energy Grid Deployment Office. (2023). Transmission Facilitation Program.
109. 10 U.S.C. 2922a

SECTION 4.
NEXT STEPS

The evolving nature of war, the changing climate, and the rapid evolution of the energy industry will require new partnerships, ideas, and modes of cooperation. This paper is intended to support innovation at the intersection of electricity transmission and national defense. The conversation between national defense and electricity industry stakeholders remains nascent, particularly as it relates to the transmission system. At the same time, the stakeholders consulted during the development of this paper expressed keen interest in the topic area and in the need for further dialogue. There are several areas of opportunity that could be pursued in the near-term:

- **Engagement.** There are multiple opportunities to connect stakeholders across the fields of defense and energy. These include, for example, structured engagement between DoD and representatives from transmission system operators, and engagement among the electric industry, defense communities, and the defense industrial base. Engagements such as these could broaden the conversation, validate the need for solutions, and identify opportunities to make progress.
- **Prioritization.** The concepts presented in Section 3 draw on the input of experts from across the energy and defense industries. There is an opportunity for a wider audience of experts to propose additional concepts or approaches, and to help prioritize the full range of concepts according to the concepts' comparative impact and feasibility.
- **Concept development.** The concepts presented in Section 3 are high-level and require additional detail, such as implementation pathways, roles and responsibilities, and required institutional support. Some of the concepts may require new legislation or regulation, whereas others may be accomplished through executive order, private sector action, or public-private partnerships. There is an opportunity to build out more detailed roadmaps for high-priority concepts, and identify strategies to move them forward.
- **Analysis.** To support concept prioritization and development, additional analysis would be beneficial. As discussed in Section 3.3, there are no models or data specifically designed to analyze the national defense capabilities of transmission—or the technical and economic tradeoffs of concepts such as those described above. There are existing civilian analytical approaches, however, which could be adapted to support national defense decision making.

Next steps such as these would bring more definition to the problems, but the optimal solutions for advancing transmission expansion for national defense remain uncertain. What will remain certain is the increasing interdependence between energy and national security. Without rapid and persistent action at the national and regional scales, vulnerabilities to the systems that support our most critical needs will soon outpace our ability to address them.

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