STEPS

SCIENCE, TECHNOLOGY, ENGINEERING, AND POLICY STUDIES

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Robert (Bob) Hummel, PhD
Editor-in-Chief

IN THIS ISSUE

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About *STEPS*

STEPS: Science, Technology, and Engineering Policy Studies magazine is the technical publication of the Potomac Institute for Policy Studies, where scholarly articles of broad interest are published for the policy community. We welcome original article submissions including, but not limited to the following:

- Discussions of policies that either promote or impede S&T research
- Articles that address implications and/or consequences of S&T advances on national or international policies and governance
- Articles that introduce or review a topic or topics in science, technology, or engineering, including considerations of potential societal impacts and influences
- Articles that cover historical developments in science, technology, and engineering, or related policies, and lessons learned or implications going forward
- Non-partisan opinion pieces concerning policies relevant to S&T, to include S&T research trends or research opportunities, and the role of national policies to promote or modify those trends and opportunities

STEPS promotes the mission of the Potomac Institute for Policy Studies, which fosters discussions on science and technology and the related policy issues. Policies are necessary to advance scientific research toward achieving a common good, the appropriate use of human and material resources, and significant and favorable impacts on societal needs. At the same time, the creation of effective policy depends on decision makers being well-informed on issues of science, technology, and engineering, including recent advances and current trends.

Societal changes arising from technological advances have often surprised mainstream thinkers—both within technical communities and the general public. *STEPS* encourages articles that introduce bold and innovative ideas in technology development or that discuss policy implications in response to technology developments.

We invite authors to submit original articles for consideration in our widely-distributed publication. Full articles should be between 2,000 and 5,000 words in length, and should include citations and/or references for further reading. Contributions will undergo in-house review and are subject to editorial review. Short articles of less than 2,000 words, such as notes, reviews, or letters are also welcome.

Please submit articles to **steps@potomacinstitute.org** or contact us if you wish to discuss a topic before completing an article. Please refer to the Instructions for Authors for complete information before submitting your final manuscript.

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About the Potomac Institute for Policy Studies

The Potomac Institute for Policy Studies is an independent, nonpartisan, nonprofit, science and technology (S&T) policy research institute. The Institute identifies and leads discussions on key S&T and national security issues facing our society, providing an academic forum for the study of related policy issues. Based on data and evidence, we develop meaningful policy recommendations and ensure their implementation at the intersection of business and government.

STEPS

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From the CEO

Jennifer Buss, PhD

The Potomac Institute remains committed to addressing the critical science and technology policy issues that shape our nation's future. As emerging innovations accelerate, so too must our ability to anticipate their implications and inform sound, forward-looking policy. In this issue of *STEPS*, the authors explore complex topics that range from cognitive performance and AI risk to strategic defense and economic statecraft. These deeply interconnected issues demand sustained strategic attention.

As challenges grow more complex, the need for informed, nonpartisan analysis becomes increasingly critical. The authors featured here call for a deliberate approach to maintaining the United States' strategic edge by confronting risks with clarity, investing in innovation, and applying systems-level thinking across disciplines. From national security to economic resilience, history has shown that America's greatest advancements stem from bold research, strategic foresight, and effective policymaking.

The Potomac Institute is proud to foster the kind of leadership and dialogue needed to meet this moment. By convening experts, exploring implications, and advancing ideas from concept to policy, we catalyze meaningful change.

I'm grateful to the authors for their insight and dedication, and I invite you to engage with the ideas presented here as we work together to shape a future grounded in innovation, resilience, and national purpose.

Jennifer Buss, PhD
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From the Editor

Robert (Bob) Hummel, PhD

The politics of the moment often obscures the larger issues and policy options. But consideration of the larger issues can reveal policies that might be the most effective long-term benefits to society. Technology, and research leading to new technologies, have been the driver of better lives for individuals and members of collective societies, as well as the key to national security. The United States has prospered due to innovation in both technology and processes fueled by policies that enabled investments in research. That research, whether for national defense, energy policies, health care, space travel, or other endeavors, provides benefits beyond the intended applications while maintaining a vibrant ecosystem of scientific thought and research.

In this spirit, this issue of *STEPS* examines big, bold problems confronting the US, often in the guise of issues of today.

Frank Fanelli (with Tim Welter) looks at our economic struggles dealing with China, but is really concerned with how the US should leverage its advantages in pursuing economic statecraft. Without debating the merits of tariffs, Fanelli casts the global economic competition in terms of China versus the US and an appeal for the US to make use of its assets without amplifying weaknesses.

Bob Gourley is interested in assisting analysts in the intelligence community to perform at peak cognitive and analytic capabilities to maximize the quality of analytic products. Of course, most professions require high cognitive performance for many of their tasks. Cognitive enhancement has become a big business, with both hype and science. We all know we need to get more and better sleep. Gourley's article chronicles many current developments and calls for more concerted research.

Bill Regli tackles the issue of the risks of AI. While dismissing the idea that AI technology will produce competitors to the human race any time in the near future, Regli does offer a rational process for assessing risks that accompany AI applications. He provides a couple of examples of serious risks that must be confronted and mitigated, due to generative AI capabilities. The process, however, applies to new technologies in general.

Before the "Golden Dome" project was formally announced, Potomac Institute affiliates were considering the historical relationship between defense and deterrence. In working with Joe Parrish and Institute staff, these advisors insisted that the Golden Dome must also defend the continental US against a conventional (non-nuclear) strike by long-range hypersonic missiles, and advocates for a non-nuclear rapid response capability. Many different architectures for the dome will be proposed, and this article proposes that the interceptor force should defend the ground sites that require high security.

Gerold Yonas was the Chief Scientist for the Strategic Defense Initiative (known at the time as the "Star Wars" project) to develop a missile defense shield for the entire US. Accordingly, we have been challenged to accomplish a golden dome before. Gerry posted a blog on the topic a couple months ago, and we reproduce that blog here, invoking the memory of the late Freeman Dyson. Clearly, strategic defense requires a complex suite of capabilities.

I am happy to acknowledge the excellent work of those supporting Potomac Institute Press, especially Sherry Loveless and Alex Taliesen.

I hope you enjoy these articles, and we look forward to continuing these discussions.

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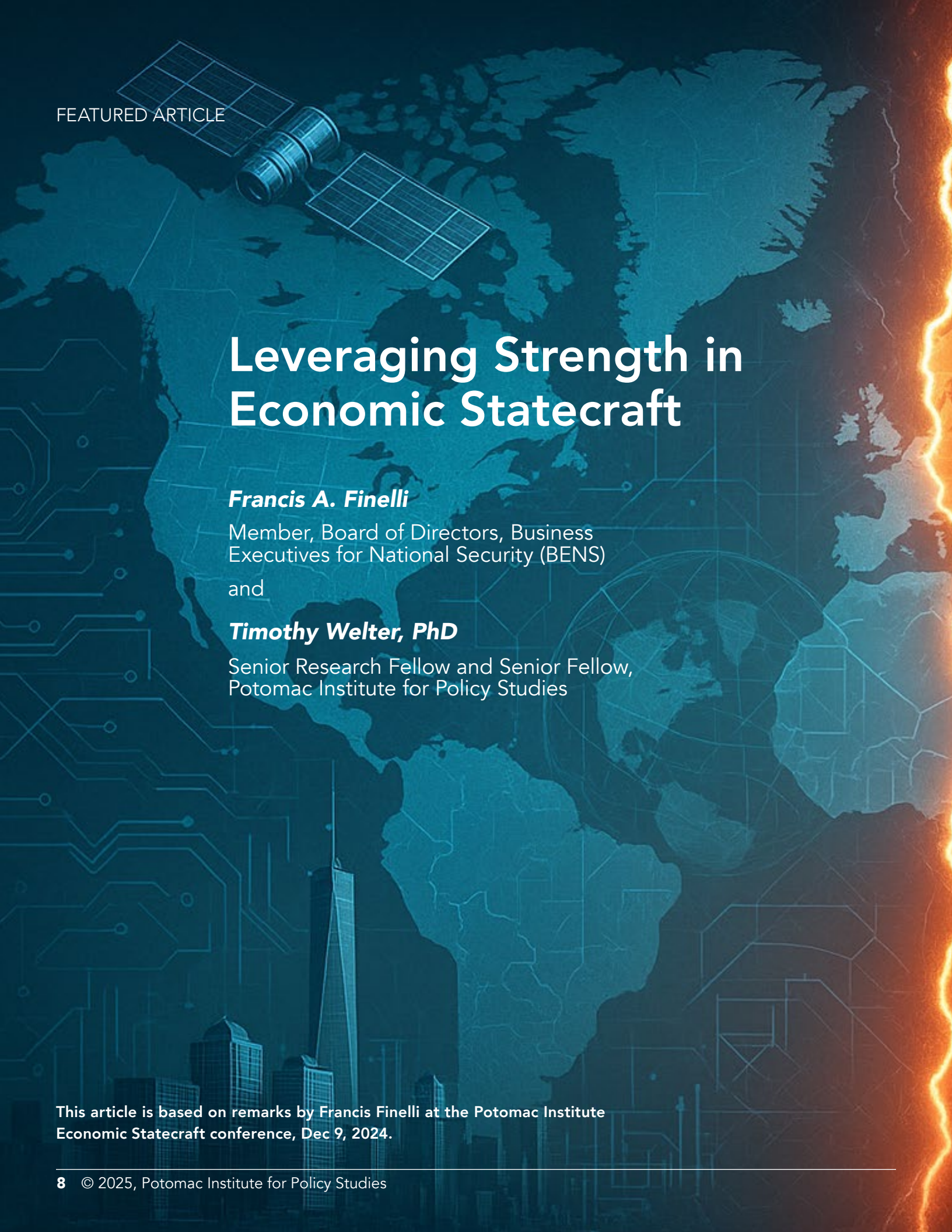

FEATURED ARTICLE

Leveraging Strength in Economic Statecraft

Francis A. Finelli

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and

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This article is based on remarks by Francis Finelli at the Potomac Institute Economic Statecraft conference, Dec 9, 2024.

OVERVIEW OF THE US/ CHINA COMPETITION

There was once a time when it was assumed that China would move toward liberal democratic institutions and, with that, pursue a more open capitalist economy. This assumption was based on the argument that as China grew richer through capital investment and market-driven economic expansion, its population's values and outlook would become more Westernized. However, this assumption, common a couple of decades ago, ignored a critical reality—the Chinese Communist Party (CCP) maintains firm control over China and is dedicated to its own values, including leveraging China's sense of history and destiny to sustain its grip on power. [1] As Jonathan Ward attests in *China's Vision of Victory*, the CCP would never allow a turn to liberal democratic values or institutions.

There was also a time, perhaps just a decade ago, when one could safely assume that China's technological advances in the military or industrial sectors were largely based on stolen or appropriated Western technology, and therefore inferior to the capabilities of the United States and its allies. This assumption also ignores China's deliberate strategic policy to "innovate to dominate."[2]

These assumptions have now been thoroughly debunked, even if some still struggle to internalize the full reality. The current situation and implications are detailed in a series of recent major reports, both official government assessments and independent studies.[3] A listing of some of these studies and reports is provided in "For Further Reading" at the end of this article.

The reality is that US national security relies on a strong economy as well as military strength, while China is engaged in both economic warfare and a military build-up that contest US interests. China has a whole-of-nation, global industrial strategy shaped by an approach of "military-civil fusion."

China is now a near-peer competitor to the United States in some domains, a full peer in others, and, alarmingly, a "super-peer" in too many sectors.[4] China's competitiveness is enabled by its robust industrial base and expansive global supply chains. Furthermore, China is now providing military and economic support to Russia, Iran, and North Korea—forming an "Axis of Upheaval," which acts directly and through proxies to threaten US interests worldwide.[5] While the United States spends more than China on defense (when adjusted for purchasing power),[6] China has had considerable success in military and economic developments, increasing the economic exchange ratio—what it costs the US to respond to the threats posed by China and its Axis of Upheaval. The US needs a strategy to effectively compete with and counter the CCP's momentum toward dominance in both economic and military spheres. Until such a strategy is developed and implemented, China will continue to advance while the United States dithers.

A new US strategy (superseding recent National Defense Strategy pronouncements) must begin with a realistic assessment of the strengths and weaknesses of the rival nations' economic and military might. The strategy must incorporate effective statecraft that leverages America's advantages and requires greater attention to economic statecraft as a core pillar of national security.

CHINA'S ECONOMIC STATECRAFT

China's GDP in 2024 was reported at over $18 trillion, having grown by 5.0% year over year.[7] By comparison, the US GDP stands at $29 trillion, growing at 2.8% per year.[8] However, when adjusted for purchasing power parity (PPP), China's effective GDP surpasses that of the US, according to the CIA World Factbook.[9] This suggests that China, as a nation, has a higher level of economic activity from a production-based accounting of GDP, because similar goods and services cost less in China than in the United States.

Driven by industriousness and strategic decision-making, China now controls over 60% of the world's top 100 ports[10] and dominates in technology supporting operations and logistics management, including software for bills of lading and crane control systems.[11] In networking technology, Huawei holds approximately 35% of the global market[12] and invests heavily in research and development, far beyond its nearest global competitor.[13] The CCP made the strategic commitment to dominate global processing of critical materials, and China currently produces roughly 80% of the world's processed minerals such as tungsten, germanium, gallium, lithium, antimony, rare earth elements, and graphite.[14] Through its "Belt and Road Initiative," China has secured access to key mining assets, with raw materials shipped to China for processing. China processes nearly all global supplies for 30 elements in the periodic table, including 90% of magnesium and 80% of lithium, tungsten, and nickel.[15] Chinese manufacturers secure their supply chains through this vertically integrated strategy, from raw elements to finished systems and subsystems, although they still lack

indigenous capabilities in certain advanced semiconductors—due, in part, to US sanctions. China is considered to have the best commercial nuclear technology for operations at scale, [16] while US nuclear power generation remains flat with no new large-scale commercial projects.[17] However, the United States is making great strides in developing small modular reactors that have great potential for smaller-scale implementations.

China fuels its investment and development by educating large numbers of students in STEM fields, including many who graduate from Western universities.[18] Each year, China produces roughly 80,000 STEM PhDs—both domestically and internationally—more than double the number of US citizen STEM PhDs.[19] China has particularly emphasized robotics and automation enabling low-labor manufacturing, in response to the country's declining fertility rate and population distribution challenges.

According to Jonathan Ward,[20] China's economic statecraft is founded in its ruler's "vision that is geographically and materially grander than anything their forebears could have imagined. Belt & Road is the geographical foundation for their 'Common Destiny for Mankind.' …The Community of Common Destiny for Mankind is not only an economic concept, but also a security concept. It is a concept of international order built around China's comprehensive national power, far reaching international influence, and growing military power."[21] …"China liberalizing in a western manner places the Communist Party on… 'death ground.'"[22]

These investments give China leverage on the global stage to pursue its strategic goals. For example, China has restricted exports of certain materials for military, economic, or retaliatory purposes—essentially employing supply chain warfare.

China's worldwide reach expanded greatly from 2005 to 2025, largely through investments tied to the "Belt and Road Initiative" (BRI).[23] The combined value of these investments, not adjusted for PPP, is around $2.5 trillion over the period, including $200 billion invested in US assets, involving equity in corporations and property, often with controlling interests.[24] Many of these investments are structured as loans collateralized by rights to critical infrastructure. The 10th Anniversary Belt and Road Forum for International Cooperation in Beijing (October 2023) was attended by representatives from 140 nations and 30 global organizations. At the forum, it was claimed that the BRI has lifted 40 million people out of poverty and generated $19 trillion in trade value.[25] These investments give the CCP tremendous leverage through access rights to vast global critical infrastructure—telecommunications networks, ports, transportation networks, and more.

Strategic investments notwithstanding, China has huge challenges—debt, demographics, and deflation (the "three D's").[26] Some have speculated that China has reached its peak.[27] These challenges do not negate the leverage it has already attained, but may bode ill for China's path forward. China's financial challenges only motivate the country to export more, manipulating markets in which it has a dominant position—such as 5G telecommunications and critical minerals—undercutting US competitiveness. The United States, however, faces its own challenges.

THE TOOLS OF US ECONOMIC STATECRAFT

The US GDP ($29 trillion) is the largest in the world. At least 75% of US output is in the services sector: such as healthcare, retail, and hospitality. The United States leads in semiconductor design (though not manufacturing), artificial intelligence technologies, and cloud infrastructure. However, the US lacks a global 5G telecommunications offering, a global port operations company, critical mineral processing capabilities, and robust commercial nuclear development capability—areas it has largely ceded to competitors over the past two decades. Other sectors, such as solar cells and batteries, are also dominated by China, particularly in processed materials and manufacturing. The global auto industry is now aggressively competitive, challenging US exports of automobiles.[28]

The US also faces huge challenges, which can be labeled as 2D-I-S: debt, demographics, inflation, and supply chain risk. US debt includes the $36 trillion national debt and unfunded mandatory spending obligations, such as interest payments, Social Security, and Medicare, which, taken together could approach 600% of GDP—a level far worse than China's.[29] The current US fertility rate is around 1.6 (slightly higher than China's but still well below the replacement rate of 2.1).[30] The inflation rate has declined from multi-generational highs, with the consumer price index averaging 8% across 2022—the highest levels since the early 1980s. Costs have cumulatively increased by around 25% since 2020. Most importantly, the US faces substantial supply chain vulnerabilities—whether due to limited production capacity or restricted access to raw materials—often relying on single-source suppliers, including many from adversarial nations.[31]

The US has attempted to address these challenges, but generally in a reactive manner without an integrated global strategy. For example, the US has identified domestic deposits of lithium ore for supply chain resilience, but the US lacks lithium processing plants and currently produces less than 2% of the global supply of processed lithium.[32] The US has applied export controls to slow China's development of AI technologies, thus incentivizing China to develop its domestic capabilities.[33] Tariffs applied to China give US developers some breathing room to fund their own developments, but success requires an actual competitive product.[34] Tariffs on other countries (e.g., the BRICS) can also encourage them to de-leverage the use of US dollars, influencing global exchange rates and undermining the dollar's status as the world's reserve currency. In the meantime, China has significantly reduced its holdings of US Treasury bonds—from a record peak of $1.7 trillion in 2014 (when total US debt was only $17 trillion) to under $800 billion in 2024—now less than 2.5% of the $36 trillion US debt.[35]

The United States is also in the process of reshoring manufacturing for key industries—such as advanced semiconductor manufacturing (via the CHIPS Act)—by awarding grants to specific companies to subsidize construction.[36] For some sectors, the idea of "friendshoring" has been suggested, for example, as part of the AUKUS agreements or involving industries in Mexico and Canada.[37] However, friendshoring can become an issue if not carefully navigated—for example,

cartel influence in Mexico and China's growing development investment fund in Canada complicate collaborations. All these bilateral and multinational relationships are challenged by tariff policies, which can both promote and frustrate collaborations.

While the US may appear disadvantaged in terms of the tools available for economic statecraft, it retains certain comparative advantages over China. These strengths include a vibrant set of capital markets, a superior technology development ecosystem (innovation), and a diverse network of allies and partners worldwide. The US must develop a coherent strategy that effectively capitalizes on these strengths.

TOOLS BASED ON COMPARATIVE ADVANTAGES

Leverage US Capital Markets

The US has by far the biggest and most mature capital markets in the world, with well over $100 trillion in equity[38] and credit assets.[39] These markets can be leveraged to accelerate the adoption of innovation to rapidly expand military capabilities, scale production capacity, revitalize infrastructure, and reinforce supply chains.

Today, approximately 80% of American research and development (R&D) is conducted by academia and commercial companies.[40] Efforts to tap into this R&D for national security have focused largely on small tech firms co-funded by venture capital. However, much of the national R&D represents investments by large- and mid-size tech companies. Currently, the Department of Defense (DoD) directs a large proportion of its scientific funds for R&D (appropriations 6.1 and 6.2) internally to its own research base—which includes government labs (Research and Development Centers RDECs), and Federally-funded Research and Development Centers (FFRDCs) and University-Affiliated Research Centers (UARCs)—leaving little available for open competition with private technology companies. As a result, DoD underfunds private-sector technology development and transition to production, a shortfall that could be mitigated by effective use of private capital.

Similarly, US national security manufacturing infrastructure is antiquated, and modernizing it has proven slow, even at higher costs. For example, the Shipyard Infrastructure Optimization Program (SIOP) has experienced cost and schedule failures, with costs more than doubling to over $50 billion with a much longer horizon.[41] Poor and outdated test and evaluation infrastructure also causes delays in development and operational testing. Consequently, the fielding of new weapon systems is delayed, and force modernization and warfighter readiness suffers.

To leverage the US R&D advantage driven by private capital, the DoD must compete for capital on a risk-adjusted return basis. It should use its tools to reduce risk and present competitive returns. These tools include long-term contracts, off-take agreements to guarantee future purchases, take-or-pay agreements, and co-investments. In short, the DoD must present projects to the marketplace that can outperform stock buybacks or shareholder dividends and distributions.

De-risk Supply Chains

The US has far too many single-source overseas suppliers, particularly involving companies in adversarial countries. Companies in China are particularly problematic because they can be easily controlled or manipulated by the Chinese government. Sometimes, single-source suppliers are found many layers under the prime integrator—down to the critical materials in a part's chemical composition or lines of software code, whether direct or embedded. This vulnerability is only evident by untangling the bill of materials across hardware, services, and software to identify lower-tier suppliers, thereby exposing the single source.

Manual risk analysis is often too complex and subjective, but automated tools can streamline the process. Many commercial companies use advanced commercial analytical software to assess supply chain risks.[42] Data are assembled into massive databases as supplier decisions are made at all levels. For the DoD, the Intelligence Community, and even commercial firms, it is important to identify hardware and software suppliers controlled by adversarial nations. This could be accomplished through policies and guidelines outlined in a digitized "supply chain risk assurance playbook," made available to program managers, analysts, and program executives. Ideally, this playbook would be harmonized with digital engineering practices, tagging digital twins during the design and manufacturing process. The use of digital engineering techniques is increasingly important in both government and commercial product development.[43]

The digital policy playbook should identify vulnerabilities and suggest risk-reducing alternatives. These might include research objectives to develop new solutions using different components and elements. For example, program officers might identify a vulnerability due to the use of antimony (Sb), which is now subject to a Chinese export embargo. It would be useful to identify suitable alternative materials (e.g., alloys) that do not rely on antimony, and the playbook might even suggest potential alternatives. Additionally, global companies and suppliers can be qualified by the government or tagged with risk factors, while critical materials and specialized supplies could be similarly risk-quantified. The resulting risk analysis would benefit the US government, investors, and the broader industrial base.

At the same time, there need to be faster pathways from R&D to productization for alternative sources. Products and materials need to be tested and qualified, and the United States could expand existing military ranges to permit a wider variety of tests and experiments on federal lands. For example, the nation might establish a "caustic zone" (perhaps within the Southwest Range Complex) where critical mineral processing capabilities are developed and pilot quantities produced for defense programs, supported by expedited environmental permitting on federal land.

Press Allies and Partners to Join In

The US enjoys good relations with many countries, suitable as allies and partners, to serve as a bulwark and deterrent against the "Axis of Upheaval." These US alliances can mutually serve both military and economic goals.

However, the United States generally overestimates the power and commitment of its allies and partners. For example, the European Union's Draghi Report on competitiveness recommended that Europe invest an additional €800 billion per year to reverse its declining industrial base.[44] Europe's real GDP growth has been anemic of late—0.8% in 2024, with a modest projection of 1.2% in 2025.[45] Meanwhile, China's approximately 150 bilateral financial agreements associated with its Belt and Road Initiative—many of which are collateralized by rights to critical infrastructure assets—undercut the commitment of many potential partners, often promoting Chinese exports by establishing markets and manufacturing plants outside China.[46]

The AUKUS accords provide a model for cooperation among US allies on both military and economic affairs,[47] albeit involving only the UK and Australia. Other countries have shown keen interest, including Canada, New Zealand, South Korea, and Japan. Global competition requires expanding these types of accords and making them effective. Pillar Two of the AUKUS agreement is an especially poignant example in its embrace of cooperative activities aimed at developing and fielding advanced technologies and capabilities. These partnerships require following up on the NATO members' commitments to increase defense spending. As an incentive, the US defense industrial base should be expanded to include partner defense industrial base companies as prime contractors and key contributors at various tiers of the supply chain for weapons systems development and procurement programs.

THE STUBBORN FACTS

When considering an assessment of the state of the US industrial base against the Chinese industrial base, one must honestly confront the following facts:

- Despite published reports that state that China's defense budget is less than $300 billion per year compared to the US budget of over $800 billion, the Chinese military out-invests the US military in research and procurement when adjusted for PPP, even without accounting for the intellectual property it steals every year. Additionally, the Chinese defense budget grew by 7.2% from 2023 to 2024, and similarly from 2024 to 2025, during a period of flat inflation. In contrast, US defense spending has grown closer to 2% nominally, which translates to a decline in real purchasing power.
- The US is home to six of the world's top twelve defense companies (by defense revenue), while China has five. Those six US companies generate twice the defense revenue of those five Chinese companies, but the total revenues are comparable when adjusted for PPP.
- However, those five Chinese companies have nearly 50% more total revenue (commercial plus defense) than the six US companies (before PPP adjustment), demonstrating China's success in a dual-use approach under military–civil fusion.
- China's defense industrial base includes multiple development and production programs for equipment in all domains. These efforts are financed, in part, by CCP-provided working capital, effectively giving China a triple-size defense industrial base compared to the US's (in PPP terms).
- China has assured its supply chains in nearly all strategic areas through binding bilateral financial agreements with nearly 150 nations, securing access to global critical materials, which are then processed in mainland China.
- China has also derisked its energy needs by controlling half of the world's exportable oil production through its influence within the expanded BRICS coalition and Russia's dominant role in OPEC. China also holds a dominant position in solar panel and battery production.

To quote again from Jonathan Ward's book (2019),

"The Chinese Communist Party's objective—the objective of one hundred years of national effort—is China's preeminence. This is a vision of a world in which China's comprehensive national power is second to none and unconstrained: A Chinese world order, phrased in the kind and humble terms of peace and stability, but built on the reality of Chinese economic, military, and ideological power. It would mean a world where China has no rival and no peer, and in which China's restoration is at last complete."[48]

LEVERAGING STRENGTHS

So, how does the United States stop China from achieving an objective that is clearly destructive to US interests and society? The answer must be to exercise tools of economic statecraft—effectively and urgently.

The United States needs an overarching national strategy and doctrine for economic statecraft.[49] In crafting the strategy and developing the doctrine, the US needs to recognize its strengths and not amplify weaknesses. These strengths include the world's most advanced technology development ecosystem, large and open capital markets, systems and tools that can identify and analyze supply chains, and allies and partners with deep connections to the US in military and economic affairs. Ultimately, this strategy must be implemented across the government and directed by an organization with the authorities to orchestrate and deploy the full range of economic statecraft tools.

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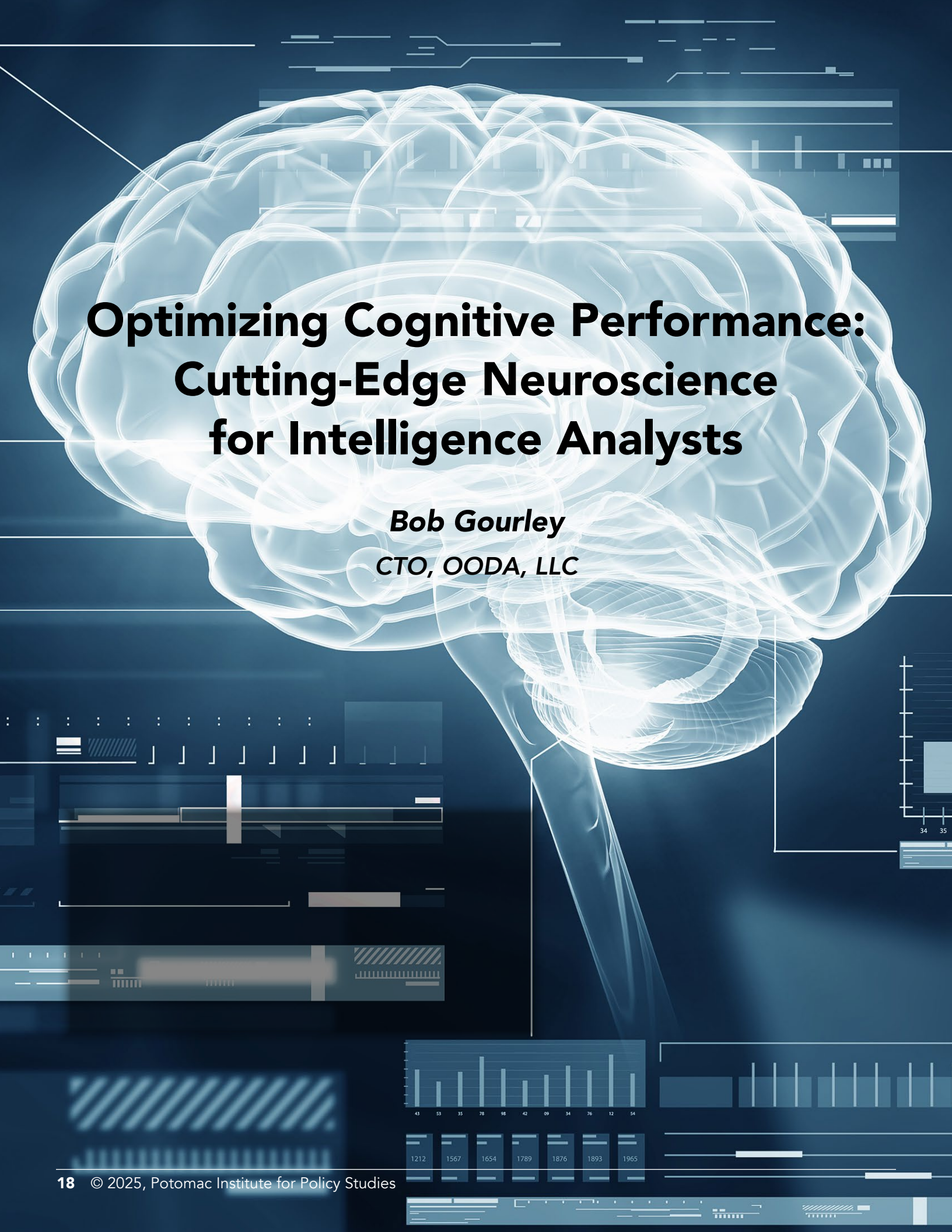

Optimizing Cognitive Performance: Cutting-Edge Neuroscience for Intelligence Analysts

Bob Gourley

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INTRODUCTION

In today's era of relentless disruption, intelligence analysts sit on the front lines of national defense, not with weapons, but with judgment. Faced with an avalanche of data, increasingly deceptive adversaries, and constant geopolitical volatility, their mission is to extract clarity from chaos. When done well, their assessments shape national strategy, thwart threats, and save lives. When missed, the cost can be measured in global consequences. As artificial intelligence, cyber conflict, and information warfare accelerate the pace of change, the demands on analysts are growing more intense, not less. The future of national security hinges not just on technology, but on the minds trained to interpret its signals.

Analysts operate in highly demanding environments characterized by stress, uncertainty, and urgency. They tackle complex, multifaceted problems under intense pressure, often working long shifts and adapting to rapidly changing priorities. Analysts are frequently redeployed to urgent task forces on short notice, where they are thrust into high-pressure situations that require immediate, high-stakes decisions. Their work is often mentally exhausting, marked by rigorous intellectual debate and the need to constantly defend or challenge positions.

Analysts gather information, assimilate it, evaluate, debate alternatives, and ultimately develop conclusions that must be communicated succinctly and accurately. New information technologies and advances in fields like artificial intelligence and information retrieval are intended to assist analysts in their work but, in fact, often exacerbate analysts' cognitive workload.

Over time, analysts have been given access to far more sources of information. More information must be absorbed, reconciled when conflicting information is presented, and evaluated in collaboration with other analysts with varying areas of expertise. The result can be less time spent on manipulating data but more time focused on cognitively demanding analysis. The same evolution in functionality is found in many other occupations in modern society. In the case of analysts in the Intelligence Community, national security depends on analyst efficiency in concert with these new challenges.

This continuous cognitive strain and intellectual conflict can lead to mental fatigue, highlighting the need for strategies that sustain and enhance cognitive resilience.

COGNITIVE LOADING AND THE HUMAN BRAIN

Given the brain's paramount importance to intelligence work, it is remarkable how infrequently it is discussed. Our brains guide us in approaching analytical problems, choosing methodologies, identifying knowledge gaps, and delivering results that drive decision-making. They enable us to lead, manage, and unravel the deepest mysteries of our adversaries in support of national security missions. This vital organ deserves more focused attention in the Intelligence Community.

Fortunately, recent advancements in neuroscience offer opportunities to better understand and optimize brain performance. Research reveals that brain function is not static—it can be improved. This raises important questions: Could greater focus on neuroscience within the Intelligence Community improve analyst performance? Might this lead to faster, better analysis? What would be the impact of significantly enhanced cognitive capabilities among analysts?

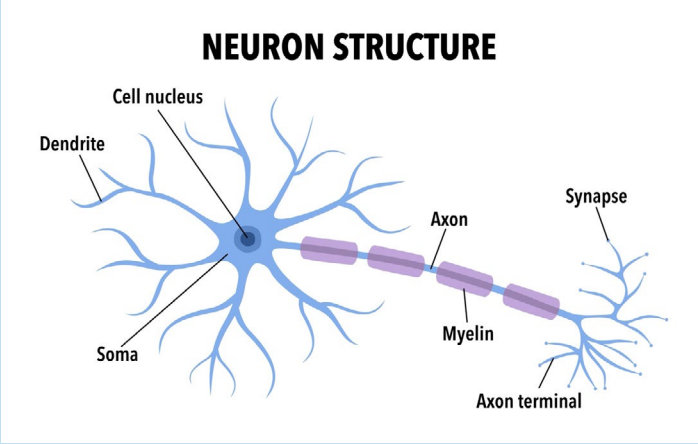
Emerging insights into brain function show how proper sleep, nutrition, supplements, external stimulation, and deliberate habits can significantly elevate cognitive performance and reinforce overall brain resilience. This article distills those findings into actionable strategies tailored to intelligence analysts. We begin with a concise overview of key brain mechanisms and terms, then present clear, evidence-based recommendations for the Intelligence Community. Ongoing research has revealed many inner workings of the brain, including new insights into how neural circuits and synaptic plasticity—the brain's ability to adapt—are influenced by external factors like exercise, nutrition, and sleep (for a brief overview of current thinking about brain function, see ***How the Brain Works: The Basics of Neural Communication*** on page 21).

How the Brain Works: The Basics of Neural Communication

Neurons communicate through complex electrochemical signals. Recent research indicates that the human brain contains approximately 87 billion of these neurons,[1] each connecting with between 100 and 1,000 other neurons. Estimates suggest that the human brain has up to 100 trillion neuron-to-neuron connections.[2] Current understanding holds that these specialized cells and structures are responsible for most brain functions.

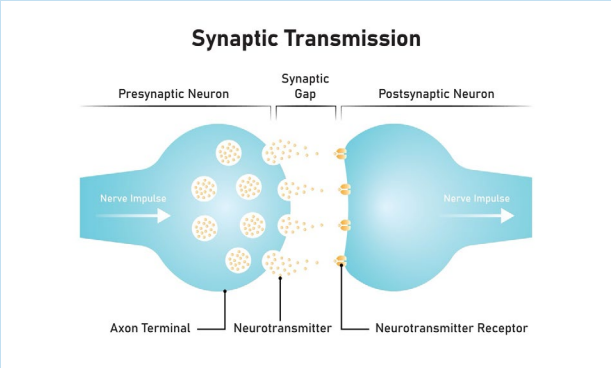
The basic neuron structure contains the **cell body (soma)**, **dendrites**, **axon,** and **synapses**.

- **Cell body (soma):** Contains the nucleus; maintains neuron health and synthesizes proteins.
- **Dendrites**: Extend from the cell body like branches, receiving signals from other neurons.
- **Axon:** A long, slender projection, wrapped in an insulating myelin sheath**,** that carries electrical impulses away from the cell body to other neurons or muscles.
- **Synapse**: A small gap where communication occurs between neurons.



Communication between neurons occurs when an electrical signal caused by charged chemicals, known as an **action potential**, is generated in response to a stimulus. This electric signal travels down the axon to the **axon terminal**, where the neuron connects to another neuron via a small gap called the **synapse**. The electric signal is the result of chemical ion exchanges across the neuron's cell membrane, and then a similar mechanism to reset the neuron after it fires. Neurons fire at rates that vary based on their type—some as slowly as once per second, others up to 500 times per second.

When the electrical signal reaches the synapse, it triggers the release of **neurotransmitters**—chemical messengers stored in small sacs called **vesicles** within the axon terminal. These neurotransmitters cross the synaptic gap and bind to specific receptors on the **dendrites** of the next neuron, either stimulating or inhibiting a new action potential.



The strength and type of response at the neurotransmitter receptor depends on the neurotransmitters involved.

After neurotransmitters are released and perform their function, they are either broken down by enzymes, taken back into the presynaptic neuron through a process known as **reuptake**, or absorbed by other brain cells. Reuptake is crucial for maintaining the balance of neurotransmitters in the brain and ensuring that neurons can fire again quickly and efficiently. Some common medications for anxiety, depression, and other neurological conditions work by slowing reuptake or altering the strength of neurotransmitter activity in the synapse.

There are several major types of neurotransmitters, including:

- **Acetylcholine**: Involved in learning, memory, and attention regulation.
- **Dopamine**: Impacts motivation, reward, and focus.
- **Serotonin**: Regulates mood, memory, and sleep.
- **Glutamate**: The main excitatory neurotransmitter, essential for learning and memory.
- **Gamma-Amino Butyric Acid (GABA)**: The primary inhibitory neurotransmitter, important for calming neural activity and reducing anxiety.

An important aspect of brain function is the **blood-brain barrier** (BBB), a protective shield formed by tightly packed cells lining the blood vessels in the brain. The BBB selectively allows essential nutrients to pass through while blocking harmful substances from entering the brain's environment. However, this barrier also presents a challenge for certain

drugs and nutrients that aim to target brain function, as only specific compounds can cross the BBB to influence neural activity.

The brain both produces and is influenced by a variety of hormones that play critical roles in regulating mood, energy levels, physiological responses, and even cognition. Some hormones are produced in the brain, but most are produced by endocrine glands (e.g., pituitary, adrenal, thyroid, testes, and ovaries). Certain hormones can cross the BBB to affect brain function. However, chemicals circulating throughout the body also influence brain health and function. Maintaining overall physical health is important for supporting healthy brain function.

What causes the brain to feel fatigued after heavy cognitive workloads? Researchers now believe that the tired feeling comes from intense thinking that produces biochemical changes leading to the buildup of the neurotransmitter glutamate in areas of the brain involved in higher-order thought.[3] This buildup makes it increasingly harder to perform complex cognitive tasks.

Neurogenesis is the process by which new neurons are generated in the brain. Proper nourishment and active learning can promote neurogenesis. Synaptic plasticity refers to the brain's ability to strengthen or weaken connections between neurons over time, a process thought to be fundamental to learning, memory, and adapting to new information.

Building Blocks of Brain Health: Essential Foundations for Cognitive Vitality

Overall health is foundational to good brain health. This means eating a good diet, avoiding drugs and alcohol, and getting sufficient exercise should be considered minimum requirements for optimal brain function. While this may seem like common sense, it is strongly supported by extensive research.

For example, a wealth of scientific literature indicates that regular aerobic exercise improves executive function, attention, and processing speed;[4] enhances memory and learning ability; and increases brain volume and neuroplasticity.[5] Even short bouts of moderate aerobic activity can provide an acute boost to cognitive performance.[6]

Research also underscores something many of us overlook during the day—the critical importance of staying appropriately hydrated. Good hydration supports neurotransmitter function and cerebral blood flow; improves performance on cognitive tests; and protects against impairments in attention, memory, and mood caused by even mild dehydration.[7]

Adequate sleep is vital for maintaining sharp cognitive function. Adequate sleep enhances learning and creativity and refreshes the brain for the next day's work. In the accompanying review of brain function, we reference glutamate buildup due to extensive cognitive activity and how it can impede higher-order thinking. While taking breaks during the day can help mitigate this buildup, it is during sleep that the brain performs most of its glutamate recycling, making sleep critically important to intelligence analysts.

Sleep is also one of the most important times for the brain to strengthen (or weaken) neural pathways, making good sleep essential for analysts to learn and retain new information. While everyone is different, most adults are advised to get 7 to 9 hours of sleep per night.[8] Sleep deprivation impairs attention, working memory, and decision-making, so a good night's sleep supports cognitive function, while a poor night's sleep is bad—so bad that it can directly impact an analyst's performance.

External Stimulation for Improving Brain Function

Over the past decade, extensive research has examined the potential of noninvasive external brain stimulation techniques to enhance cognitive functions, improve memory, and support neurological rehabilitation. This interdisciplinary field brings together insights from neuroscience, cognitive psychology, and bioengineering. Although many approaches remain experimental, recent evidence has begun to inform clinical practice and open new possibilities for cognitive enhancement in healthy individuals, making it a field that should be of high interest to the Intelligence Community.[9]

Techniques such as transcranial stimulation using magnetic fields or low-current electrical signals have been suggested not only for cognitive enhancement but also for treating mental disorders, delaying cognitive decline and diseases such as Alzheimer's,[10] and improving sleep effectiveness. The US Food and Drug Administration (FDA) has approved several devices for treating anxiety, depression, and other disorders, including those that use low-voltage alternating current stimulation.[11] DARPA has investigated peripheral

nerve stimulation in conjunction with training in its TNT ("Targeted Neuroplasticity Training") program to boost neurochemical signaling in the brain and enhance neural plasticity.[12]

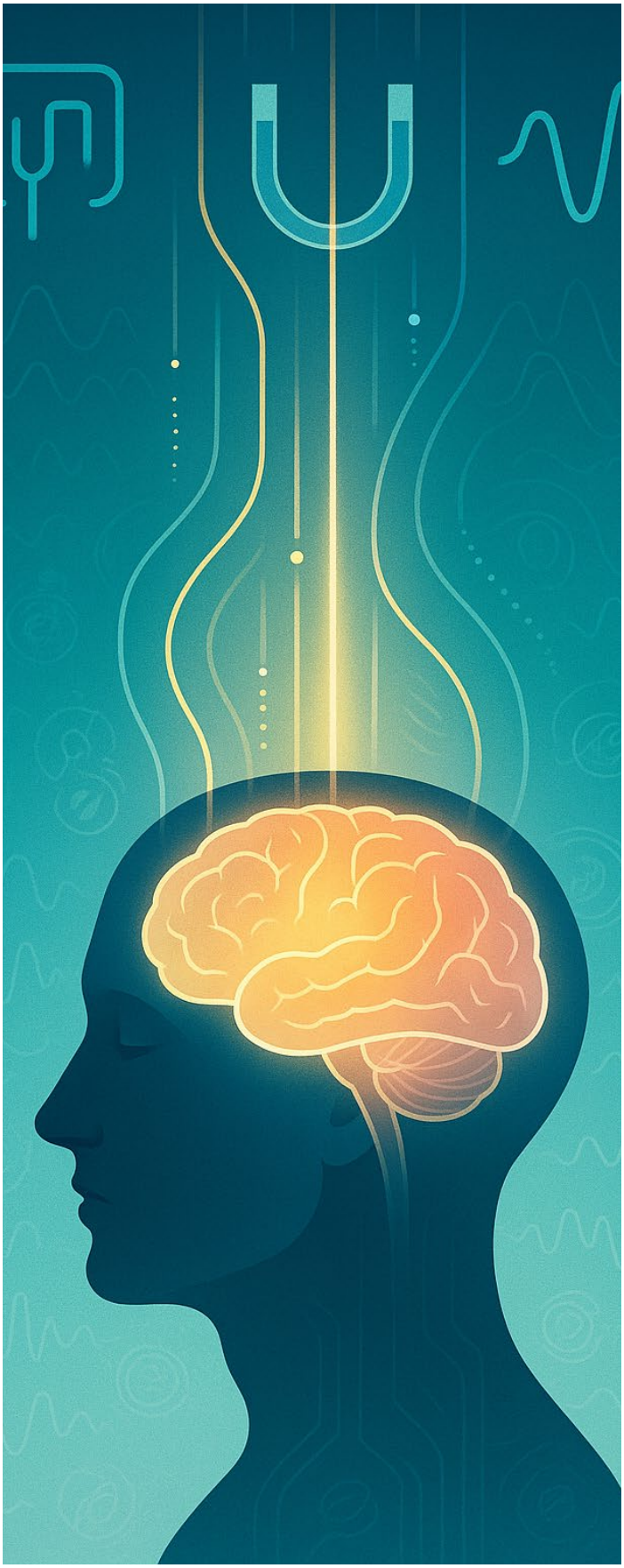
Transcranial magnetic stimulation (TMS) has a well-established history in clinical applications, having been approved for treatment-resistant depression. Beyond its therapeutic use in mood disorders, TMS research is expanding into cognitive enhancement, examining whether repetitive stimulation can boost memory recall.[13] Other methods with extensive research include low-intensity ultrasound[14] and near-infrared light; researchers hypothesize that the positive results of the latter may stem from enhanced mitochondrial metabolism and increased cerebral blood flow.[15]

Additionally, a large body of research has focused on non-invasive brain stimulation using low-level currents delivered through scalp-mounted electrodes.[16] Both direct current and alternating current approaches have been examined.[17] Some findings suggest improvements in working memory, memory consolidation, language processing, and learning rates—particularly when enhancing slow-wave neural activity such as that seen during slow-wave sleep (certain portions of deep sleep)[18] while using neurofeedback techniques to optimize brainwave entrainment.[19]

Despite these promising developments in using external stimulation to enhance brain function, critical challenges and controversies remain.[20] Individual responses to external brain stimulation vary considerably, influenced by factors such as genetics and lifestyle variables. Furthermore, questions remain regarding the longevity of observed cognitive benefits and the safety of repeated stimulation sessions.[21]

Nourishing the Mind: Vitamins, Minerals, and Nootropics for Cognitive Performance

In recent years, researchers have focused increasingly on how vitamins, minerals, and other compounds influence brain function. While many of these substances have been recognized for centuries, ongoing studies provide clearer evidence of their specific mechanisms and potential impact on cognitive performance. Nonetheless, research continues for these and many other compounds. New findings are developed regularly, and professional nutritionists maintain currency. The Dietary Supplement Fact Sheets maintained by the National Institutes of Health provide up-to-date information.[22]



Vitamins and Minerals: Supporting Cognitive Health

A well-balanced diet should theoretically provide sufficient vitamins and minerals. But in the modern world, maintaining a well-balanced diet is challenging for most people—especially for intelligence analysts working in the high-stress environments of our intelligence agencies. It is reasonable to assume that few intelligence analysts maintain optimal nutrition. An overview of recent research into the mechanisms by which vitamins and minerals support cognitive health is presented in ***Research on the Function of Vitamins and Minerals****, below*.

Research on the Function of Vitamins and Minerals

Certain vitamins and minerals have clear mechanisms explaining their potential effects on cognition. Most of these components can be obtained from a healthy diet, but deficiencies can exist. Here, we briefly note some of the brain-related functions of common vitamins and minerals.[23]

Vitamin B1 (Thiamine): Thiamine plays a key role in glucose metabolism in the brain, ensuring that neurons have the energy to function optimally. It is crucial for acetylcholine synthesis, impacting memory and cognitive processing speed. B1 is also important for long-term brain health, and studies suggest that thiamine use can stave off long-term cognitive decline and diseases like Alzheimer's.[24]

Vitamin B6 (Pyridoxine): Pyridoxine is involved in the synthesis of key neurotransmitters like serotonin, dopamine, and GABA. It plays a direct role in mood regulation and cognitive function. Sufficient B6 has been correlated with maintaining cognitive abilities and preventing mood disorders.[25]

Vitamin B9 (Folate): Folate is necessary for neurotransmitter synthesis and DNA synthesis and repair, which is particularly important for neurogenesis and synaptic plasticity, meaning it is involved in learning, memory, and the brain's ability to adapt to new information or experiences.[26]

Vitamin B12 (Cobalamin): Vitamin B12 is essential for synthesizing myelin—the protective covering around nerve fibers—and for producing neurotransmitters. The importance of B12 to cognition has been shown by studies of B12 deficiency, which can lead to cognitive impairments and memory issues.[27]

Vitamin C: Vitamin C protects the brain against oxidative stress and is involved in the synthesis of norepinephrine, a neurotransmitter important for mood and cognitive function. Higher vitamin C levels are linked to better cognitive performance and a reduced risk of cognitive decline.[28]

Vitamin D: Vitamin D exists in several forms and is crucial in many ways, including its role in cognition. Vitamin D receptors are present throughout the brain, particularly in areas involved in cognition, decision-making, and memory, including both long-term and short-term memory performance. Vitamin D deficiency can contribute to feelings of fatigue and brain fog, affecting an individual's ability to focus, analyze data, and make timely assessments. Proper vitamin D levels help sustain mental clarity and energy. Research has linked vitamin D deficiency with cognitive impairment and a higher risk of dementia.[29]

Vitamin E: As an antioxidant, vitamin E protects neurons from oxidative damage. This neuroprotection is beneficial for maintaining high levels of analytical reasoning, situational awareness, and complex data processing.[30]

Magnesium: Magnesium plays a role in synaptic plasticity, the brain's ability to adapt and form new connections. It regulates portions of neurons involved in learning and memory. Magnesium supplementation has been shown to improve cognitive functions, particularly under stress.[31]

Zinc: Zinc is important in modulating communication between neurons (especially via glutamate and GABA). Zinc deficiencies have been linked to cognitive dysfunction and mood disorders, and in some cases, certain types of cognitive decline can be reversed with Zinc supplements.[32]

Nootropics: Enhancing Focus and Mental Agility

A nootropic is a substance believed to enhance cognitive function, particularly in areas like memory, focus, creativity, and overall mental performance. Nootropics can include natural substances, synthetic compounds, or prescription medications. They are often used to improve learning capacity, mental clarity, motivation, and attention, and some are thought to protect the brain from age-related cognitive decline.

Many types of nootropics exist. ***Research on the Function of Common Nootropics***, on page 26, reviews common nootropics whose mechanisms are well understood through research and warrant serious consideration. However, many others—widely sold in drug stores or available online—have had zero credible research backing their claims, relying solely on marketing from the vendors who produce them. This includes some of the most popular and heavily advertised products claiming to improve memory and brain function.

A Public Service Warning: Buyer Beware!

Always consider the science behind any advertised nootropic, and avoid the products if you do not understand the mechanism by which they work. Be very careful—you may not only waste your money but also put your health at risk![33]

Research on the Function of Common Nootropics

Amid much hype and marketing, certain nootropics are known to boost brain cognitive functioning. Caffeine, for example, is pervasive. In most cases, however, more large-scale independent research and testing is needed to adequately assess appropriate dosing and trade-offs.

Caffeine: Caffeine blocks adenosine receptors, preventing drowsiness and promoting alertness. It also increases dopamine and acetylcholine activity, enhancing attention, memory, and reaction time. Caffeine's cognitive benefits are well-documented, particularly in improving short-term memory and focus.[34] Continuous caffeine consumption results in the body producing more adenosine receptors, mitigating the impact of the caffeine. Caffeine also interferes with good sleep, which is critical to cognitive function.

Omega-3 Fatty Acids: Omega-3 fatty acids are among the most extensively studied nutrients in medical literature. However, there is significant debate regarding their effects on brain function; while some studies show notable cognitive benefits, replication of these results is often inconsistent, suggesting the need for further research.[35] Despite these conflicting findings, it is well established that omega-3s play vital roles in cognitive health. Two key fatty acids, eicosapentaenoic acid (EPA) and docosahexaenoic acid (DHA), are particularly notable. DHA is crucial for maintaining neuronal membrane structure, while EPA has anti-inflammatory properties that protect against oxidative damage. Together, EPA and DHA enhance synaptic plasticity, facilitate communication between neurons, and support learning and memory through neurogenesis.

Since studies suggest that omega-3 supplements may help slow long-term cognitive decline and contribute to other aspects of health, they are likely a prudent addition to a balanced diet. However, there is no current evidence that taking omega-3s has a direct impact on brain power. More research is necessary to fully understand their role in cognitive enhancement and overall brain health.

L-Theanine: Humans have recognized the benefits of green tea for thousands of years[36] and have studied the science behind its effects. L-Theanine promotes relaxation without drowsiness by increasing levels of GABA and dopamine, two key neurotransmitters involved in mood regulation. It has been shown to improve attention and cognitive performance, particularly in tasks requiring focus and calmness.[37]

Flavanols: Flavanols are the main flavonoids found in cocoa and chocolate and can be especially abundant in certain cocoas. Research has shown many health benefits from flavanols, including antioxidant effects and improved vascular function. Research, including MRI studies, has shown flavanols can increase blood flow to the brain and improve overall cognitive performance for many tasks.[38] The research performed by commercial vendors, however, uses doses that are far higher than those consumed in chocolates.[39]

Resveratrol: Resveratrol, a polyphenol found in red wine, red grapes, blueberries, peanuts, and dark chocolate, has antioxidant properties and is known to protect brain cells from oxidative damage. It is also widely promoted in supplements. Resveratrol has been shown to reduce mitochondrial impairment in brain cells, supporting cognitive function and slowing age-related cognitive decline.[40]

Nicotine: The nicotine found in tobacco has been known and studied for years. There are now synthetic nicotine products that do not come with the many carcinogens of tobacco. The FDA regulates synthetic nicotine. Its full mechanism is unknown, but it acts as a cognitive enhancer by stimulating acetylcholine receptors, which seems to improve attention, learning, and working memory. However, nicotine's addictive properties and harmful long-term effects, even in synthetic form, are a major cause for concern.[41]

Creatine: Known for its role in muscle energy production, creatine also supports brain energy metabolism by providing additional phosphate groups to help regenerate adenosine triphosphate (ATP), the brain's primary energy molecule. Studies show creatine supplementation can improve working memory and cognitive performance, especially during demanding mental tasks.[42]

Tyrosine: Tyrosine is a precursor to dopamine and norepinephrine, neurotransmitters critical for motivation, focus, and mood regulation. Supplementation with tyrosine has been shown to improve cognitive performance under stressful conditions, such as sleep deprivation or cognitive overload. It is a plentiful amino acid that is produced by the body, so supplementation might be contraindicated.[43]

Prescription Compounds

Prescription medications have been shown to improve mental focus, alertness, and sustained attention—critical qualities for analysts. These drugs are legally available only to individuals diagnosed by a treating physician (for example, to manage Attention Deficit Hyperactivity Disorder [ADHD]). Some of the most effective intelligence analysts are neurodivergent, including those with ADHD, whose unique perspectives often drive innovative insights. However, these individuals may rely on prescription medications like Adderall, which primarily influence dopamine and norepinephrine levels. By limiting the reuptake of these neurotransmitters into neurons, these medications increase their availability in synapses and can enhance functions of the prefrontal cortex.

Prescription treatments are also available to mitigate some of the impact of the rise in Endocrine Disrupting Chemicals (EDCs) in the environment, a concern that no doubt affects many intelligence analysts. EDCs are chemicals that interfere with the endocrine (hormonal) system and can impair brain function, including reducing visual and verbal memory.[44] Research has advanced to the point that we can probably recommend that workspaces for analysts be inspected to minimize exposure to EDCs and that analysts be trained on how to reduce dietary exposure. When warranted, medical professionals familiar with the effects of EDCs will know what to look for and can order blood tests to assist with appropriate diagnosis and treatment to help reverse cognitive impacts. EDC exposure in the body may, for example, result in significantly decreased levels of critical hormones such as testosterone and estrogen, which can affect analysts' performance. In such cases, medical professionals can prescribe appropriate treatments.

At the same time, many self-proclaimed "biohackers" experiment with compounds that promise cognitive gains, but the scientific evidence behind these products varies widely. Some substances show initial promise; others are supported by little more than marketing claims and/or carry significant risks. Several are even illegal in the United States and pose real dangers, making them wholly unsuitable for professionals in the Intelligence Community. Rather than leaving analysts to navigate these dubious options independently, agencies should proactively endorse evidence-based, medically approved enhancers and establish clear policies discouraging the use of unverified or prohibited substances. Resources such as the DoD-supported Operation Supplement Safety provide guidance on identifying and avoiding high-risk products.[45] However, we recommend that analysts receive individual attention from professionals with expertise in pharmacology and familiarity with these resources.

RECOMMENDATIONS FOR INTELLIGENCE COMMUNITY ACTION

It is time for the Office of the Director of National Intelligence (ODNI) to launch a concerted, community-wide initiative aimed at enhancing cognitive performance across the Intelligence Community. Current efforts to research and promote best practices in brain health are fragmented across multiple agencies and offices, resulting in inconsistencies and gaps in knowledge. A centralized approach can unify these efforts, establish clear guidelines, and ensure that proven, science-based strategies are available to all analysts.

Building on existing neuroscience research, the Intelligence Community should take proactive steps to encourage healthy foundational habits. Sleep stands out as a critical factor in high-level analytical work, yet erratic schedules often compromise the rest analysts receive. Implementing flexible work hours, dedicated break areas, and an institutional culture that values sufficient sleep can dramatically improve sustained attention and complex reasoning. Physical fitness is similarly vital; both aerobic and strength training exercises have been shown to bolster cognitive endurance. By providing on-site gym facilities, structured exercise breaks, and practical incentives, agencies can help analysts maintain the mental clarity needed for complex tasks. Nutrition is another key element. Offering balanced meals on government campuses and access to nutritionists for individualized dietary planning can help analysts stay focused throughout demanding work cycles. Just as important is ready access to medical professionals who can tailor regimens for stress management and respond to questions about supplements—ensuring that analysts receive personalized guidance without resorting to unverified or risky over-the-counter products.

To expand beyond these foundational steps, intelligence organizations should bolster dedicated expertise. Staff nutritionists and physicians, supported by professionals specializing in neuroscience and brain health, can offer ongoing evaluations and tailored interventions designed specifically

for the pressures of intelligence work. These experts can educate analysts on cutting-edge cognitive science and guide everything from meal planning to discussions about potential nootropic use. Rather than applying a one-size-fits-all approach, these experts can create individualized programs that recognize each analyst's unique physiology, medical history, and cognitive demands.

Above all, the ODNI should lead efforts to unify and expand applied neuroscience research to directly benefit intelligence analysis. Pilot programs and controlled studies on emerging techniques, like noninvasive brain stimulation, should be centrally coordinated and shared across the Intelligence Community. A more coordinated strategy would also help reduce burnout by integrating mental health services, team-based support structures, and policies that promote a healthy work-life balance. By addressing both the organizational framework and the science of cognitive optimization, the Intelligence Community will not only support its analysts' immediate needs but also build a more resilient, forward-looking workforce—one poised to tackle the ever-evolving challenges of modern intelligence.

For intelligence analysts working in high-pressure environments, optimizing cognitive performance is crucial. By taking a comprehensive, policy-driven approach—encompassing exercise, nutrition, hydration, sleep, cognitive-enhancing interventions, and ongoing research—organizations can set the stage for a more resilient, high-performing intelligence workforce. These efforts, informed by science and continuously refined through evidence-based research, will help ensure that analysts remain fully prepared to meet the rigorous demands of the intelligence mission.

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ASSESSING THE RISKS OF AI: *Haven't We Been Here Before?*

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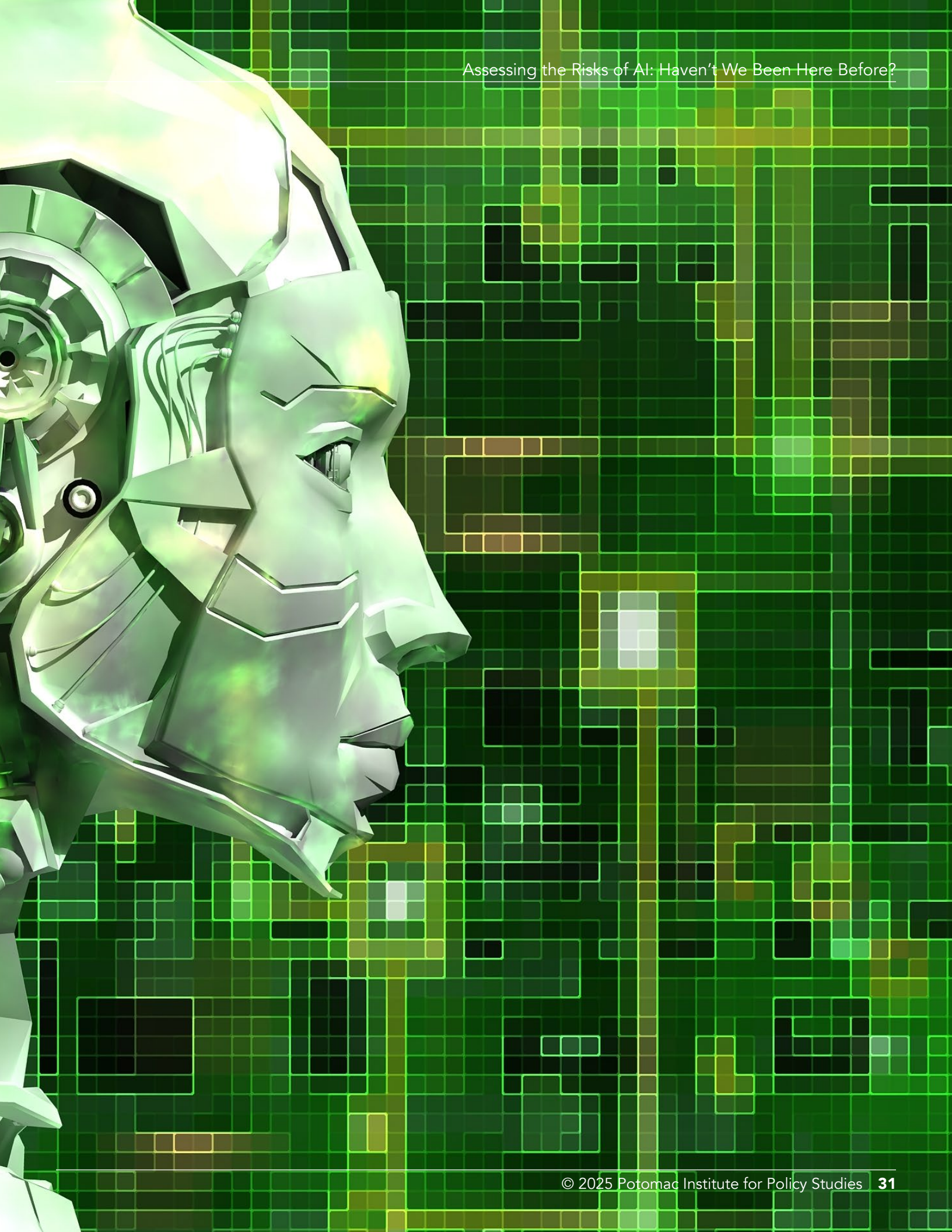
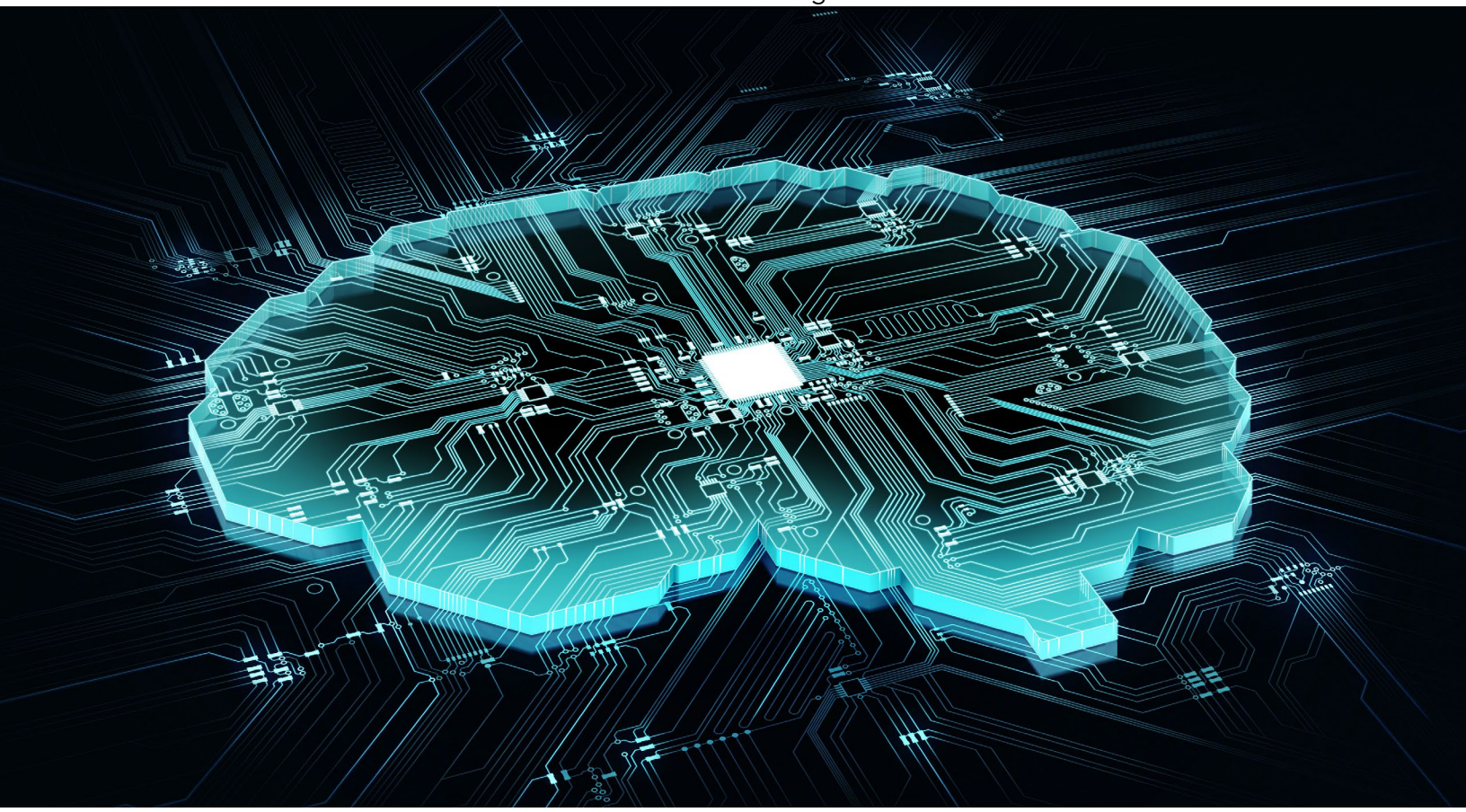


Will artificial intelligence (AI) technology empower a magnificent future, or will the risks of AI manifest themselves in a way that threatens human existence? Wall Street and Silicon Valley (i.e., many of whom are "AI boomers") mostly believe that AI will make us productive, rich, and prosperous in a transition of our future that portends super-charged productivity and applications that eliminate worry and tedium. Others (i.e., those who are the "AI doomers") have argued that unfettered AI will supersede humans and pose risks to human civilization.[1] Between these two extremes, people worry that AI will exacerbate global climate change through power consumption, displace human workers, and enable new dystopias.

As with all new technologies, there are benefits and there are risks. We understand some risks and some are new—a product of the new technology. Risks must ultimately be recognized and managed to maximize the benefits of a technology. We do this in everyday life, for example, with transportation. We have safety standards and rules of the road; we mandate seat belts and certify airworthiness. And yet, we still put up with costs due to risks (i.e., accidents, insurance, infrastructure). With information technologies, we now confront cyber threats, and we have realized that we must establish processes and procedures to mitigate cyber-enabled harm such as phishing, denial-of-service attacks, and financial frauds. As risks are presented to individuals, organizations, and society, we have established procedures and methods to manage risks in each case, whether through education, training, or engineering solutions.

When it comes to AI, thinking about risk requires answering two questions. First, what is AI? There is a wide variety of opinions about what constitutes AI. Second, if we can agree on what AI is, what new threats does it pose, and how should we categorize them? Existential risk scenarios receive inordinate attention due to their dramatic nature, but this focus can crowd out more realistic assessments of likely impacts and the harms they might cause. We are the proverbial frog in gently warming water—focusing too much on the existential risk which is, in itself, a risk, and whereby we may overlook the more mundane issues that are gradually raising the temperature. Here, we will highlight several practical threats posed by AI technology as examples of a process for assessing realistic risks.



WHAT IS AI?

First, understand that AI technology, whatever it is, is not a risk. Risks depend on how the technology is applied. Only within the context of specific applications can risks be assessed, understood, or even discovered. And because the ways in which AI will be used are still evolving, some risks are inevitably yet to be determined—and some will come as surprises.

AI means different things to different people. Some equate AI with recent developments in "generative AI," most significantly large language models (LLMs) and deep machine learning. These trillion-parameter systems have enabled companies and organizations to produce large-scale "approximation engines" driven by the data and images drawn from the Internet.[2] However, AI also includes a body of algorithms and techniques developed with the earliest introduction of computers, using theories developed by Alan Turing and expanded in the mid-1950s with the introduction of the term "artificial intelligence." This body of work includes heuristic search, constraint propagation, perceptrons, expert systems, old-school symbol-processing Lisp machines, and circumspection, among many other concepts and developments. In the broadest sense, AI can refer to any program that senses the world (generating inputs) and acts in the world (producing outputs). How this sense-act loop is implemented in a computer determines the nature of the computed function. With recent developments in AI, the nature of this function is becoming increasingly complex, abstract, and potentially cognitive.

Risks associated with expert systems, for example, are more manageable than those associated with LLMs' applications because the workings of expert systems are better understood. In contrast, the inner workings of LLMs—graphical models with networks of nodes and interconnection weights— are "black boxes," making it difficult to explain their outputs. What we can discern, however, is that AI systems have migrated from dealing exclusively with raw data to processing information based on statistics and patterns learned from training datasets. As the richness of training data increases, the patterns that these algorithms learn become harder to discern. For example, understanding how a search algorithm selects a chess move is relatively straightforward, whereas understanding how an LLM generates a Shakespearian sonnet about the wonders of CRISPR/Cas9 is not.[3]

In the knowledge management community, the "DIKUW Hierarchy"[4] of data—information, knowledge, understanding, and wisdom—serves as a useful framework. AI systems have broached the "knowledge" and "understanding" levels, at least in terms of how humans perceive their outputs. These systems can reason about problems, break down queries, and generate surprising outputs that seem to reflect human ingenuity. However, while people might *perceive* the AI as demonstrating understanding or even wisdom, these systems are still fundamentally function-approximators. Our perceptions of them are heavily biased by our own built-in wiring and a Theory of Mind.[5]

The key tenet is that AI exists in a context. On its own, an LLM or expert system does nothing. However, in interacting with AI or placing the AI's sense-act system into the context of an application, we introduce risk.

These applications of AI will involve using autonomy to amplify abilities: AI can enable faster and more accurate decision-making, whether for good or bad. Vectors of amplification include those areas where complexity of action is enabled by computer analysis, providing action at scale in real-world situations. AI can "read" and summarize massive amounts of heterogeneous data; it can perform duties requiring speed, persistence, or endurance, enabling the development of systems that remain vigilant when humans might falter. These capabilities drive applications of AI situated within a context. From the application context comes the risk.

AI RISK

New AI applications will deal with increasingly complex situations. Marketable uses might include combating disinformation, analyzing financial analysis systems, dealing with market data, deploying chatbots, or enabling hyper-customized systems that respond to individual interests and recommend courses of action among many alternatives. Applications that integrate massive amounts of heterogeneous information will include sophisticated search engines and "recommender systems," medical data processing, and systems for science discovery. For persistence and endurance, we can envision surveillance systems, systems to counter cybercrime or financial crimes, and systems that monitor market forces to set prices and optimize profit.

Notably, none of these applications involve creating sentient AI systems that can threaten physical harm to humans. For any given risk, there is generally an initiating event or development that must occur—each with some probability of occurrence—and a measure of the potential severity of harm if it does. To manage the risk, we can control the probability of that development or we can attempt to reduce the impact. A far more plausible risk than sentient machines seeking to harm humans is that an autonomous drone equipped with a lethal weapon could misidentify and attack an unintended target. Approaches to mitigating this risk might include ensuring that a human is in the decision-making loop or requiring multiple verification steps prior to weapon deployment.

For a system to pursue ill intent toward humans, it must develop far greater agency than is present in current AI systems. What is more urgent, however, is that AI amplifies human capabilities, enabling individuals or groups to cause harm more efficiently or that harm may arise indirectly as an unintended externality of pursuing other goals using AI.

EXTERNALITIES

Sometimes, new technologies are accompanied by changes that can cause harm indirectly related to the developments. The development of nuclear weapons has created an expensive need for cleanups. For example, the cleanup of the Hanford Site in Washington State will take centuries and cost tens of billions of dollars.[6] The use of fossil fuels for generating power has led to smog and pollution that harm people's health and has required measures to clean the environment. In many cases, these externalities could have been predicted but were ignored until real harm had been incurred.

For AI, we know that power consumption requirements to train certain machine learning systems are immense and may require new electric generation plants, whether nuclear or fossil fuels or renewables. These power needs will compete with other commercial and residential needs and can result in higher prices, environmental warming, greenhouse gas emissions, and land utilization with concomitant pollution, as well as other indirect harms. Finding options for AI systems (and data centers) that require less power is thus desirable not only to reduce operational costs but also to limit externality harms.

Another negative externality for generative AI systems today is the harm inflicted upon intellectual property and copyright material. Much like energy, generative AI systems have a vast need for data, and they do not care who created the data or who might own it. As such, the value of intellectual property to those who hold it is under threat, literally.[7]

Some externalities can be predicted in advance, but others may not become apparent until later—hopefully not too late.

IDENTIFYING REALISTIC RISKS

We cannot, by definition, anticipate the "unknown unknowns." But there might be risks that can be anticipated where we fail to consider how to deal with them until harm has occurred. To capture and mitigate such risks and to develop mitigation strategies, we might take a cue from the policies established around cyber threats and security engineering.[8] This entails:

1. Identifying use cases, or in this case, how AI might be applied, especially in emerging applications;
2. Identifying the threat vectors: ways in which things could go wrong, either through bad actors or unforeseen circumstances. These threat vectors will depend on the specific type of AI being used (i.e., depending on the application, some types of AI are going to prove riskier to use than others); and
3. Determining mitigation strategies for each threat vector, either to reduce the likelihood of the vector being employed or to reduce its potential impact.

We offer a couple of examples of implementing this process. However, a similar process could reveal many other potential risks of AI applications.

Risk: Generating Language that Appears to Come From a Human

ChatGPT® and other language models have shown an ability to generate text in response to prompts, and the resulting text can be realistically mistaken for human writing. This could greatly aid productivity as people generate text according to their instructions and relay that text as information to others. At the same time, now that AI can generate language and stories, it has become an active participant in human discourse—whether we like it or not.[9]

Consider the following scenario. The government often issues "requests for comments" to solicit opinions from the public. The Army Corps of Engineers, for example, listens to public comments before engineering projects. The Environmental Protection Agency considers pros and cons to regulations and solicits information from those who might be affected. Now consider an actor wishing to conduct a denial-of-service attack using human language. They might produce many instances of various texts and comments that would seem to come from many different people but, in fact, reflect the opinion of a single person or a single point of view. Using language generation capabilities, someone could generate hundreds, thousands, or even millions of responses, effectively crippling the bureaucracy that is soliciting human input. To mitigate against such an attack, governments will need mechanisms to authenticate comments and verify that they are from humans.

From a broader perspective, we see that our governance systems, which collect information from people and organize and deliver information to those who need it, are not yet prepared to deal with massive text generation capabilities. Many threat vectors can be envisioned that would endanger our bureaucracies, or at least their effectiveness. The ability of AI to generate material that seemingly comes from humans but is merely the result of a statistical process based on a selected corpus of training data, threatens to upend the hierarchical foundations upon which societies have organized themselves for efficient production. In this sense, the bureaucracies that emerged from economic and societal revolutions (post-Middle Ages) are now at risk of being undermined by AI language generation systems.[10]

Addressing such threats will require new scientific tools and human processes to contain AI. These might include developing ways to measure organizational and management effectiveness, methods to track changes over time, and tools to simulate and analyze the effects of AI language generation on an organizational system. Business processes will need to be re-engineered to be "AI Robust," including aligning organizational incentives with actions, and providing ongoing education and training for personnel (and perhaps the AI systems, as well) in a way that might resemble today's routine training for cybersecurity awareness.

Risk: Directed Cognitive Manipulation

It is well known that AI can generate text, images, and videos that can influence people to gain their approval and confidence. In this way, actors with widely varying goals (commercial, political, criminal, anarchist, etc.) can influence the cognitive processes of an individual through simulated friendship, collegiality, hostility, or other means presented in a way that is hyper-tailored to the recipient.

Consider the scenario in which a hostile actor uses this AI capability to gain the confidence of an individual (or organization) to commit financial crimes such as financially fleecing the victim, as in current online scams. Sometimes called "pig butchering," there are scammers who gain the confidence of their mark (fattening the pig) before stealing their money or disrupting an organization's financial system.[11] With AI, bad actors could become more proficient at such scams, using AI to target individuals, to generate synthetic voices and media of relatives and affections, and to create hyper-realistic scenarios with extraordinarily low cost at great scale. Synthetic AI phone calls from your children needing bail money or other forms of digital blackmail can be readily imagined.[12]

Remediation of the harms in this scenario might not involve any technological change to AI systems but rather require processes that stop the opportunities or mitigate potential effects. We do this now in the financial system through processes such as daily withdrawal limits, account co-signers, fraud insurance, and verification of wire transfers. However, we can begin to envision a large risk landscape requiring both technological advances (i.e., content verification and authenticity) and societal process innovation.

MANAGING RISK IN THE CONTEXT OF A HUMAN/MACHINE SYSTEM

AI systems, like all technological systems, will necessarily experience failures. They will fail even in the most rigorous of settings, and failures cannot be eliminated. However, failures reveal limits that drive the creation of new capabilities to improve performance. This happened, for example, with the introduction of railroads, which led to time zones and train signaling systems in the nineteenth century.[13]

One of the positions of this paper is that focusing solely on fixing AI technology is a largely specious goal. AI will always be used within a context—at minimum, a social context in which a user interacts with an agent. The main causes of future failures of such AI+human systems stem from their amplification of humans. For example, we have difficulty understanding and mitigating bias among human actors, and AI systems, even the best of them, will tend to amplify human flaws. When a human instructs an agentic AI to achieve a task, the resulting actions may create collateral damage or negative effects. The key to mitigating AI risks is to conceive of the AI in the full context of a human-machine team and to build the necessary controls and processes around that team.

A bit of good news is that AI itself may be able to help us scan and manage these risks. Many believe AI will accelerate scientific discovery and, hence, AI may be one of the key technologies required to build better AI+human systems. The objective is not to become overly risk averse, as we may miss opportunities. Instead, we can learn from past lessons on how to best design and build reliable and robust systems out of components that may not be fully reliable.[14]

While much public discussion centers on potential AI eventualities and fanciful AI risks that might occur if "AI scaling"

continues unabated and "AGI" comes to pass, this focus seems to serve as a distraction from the more immediate externality and amplification of AI risks. We must not be distracted from the immediate business of considering how emerging AI technologies are already creating serious capabilities that pose realistic, present-day risks.

ENDNOTES

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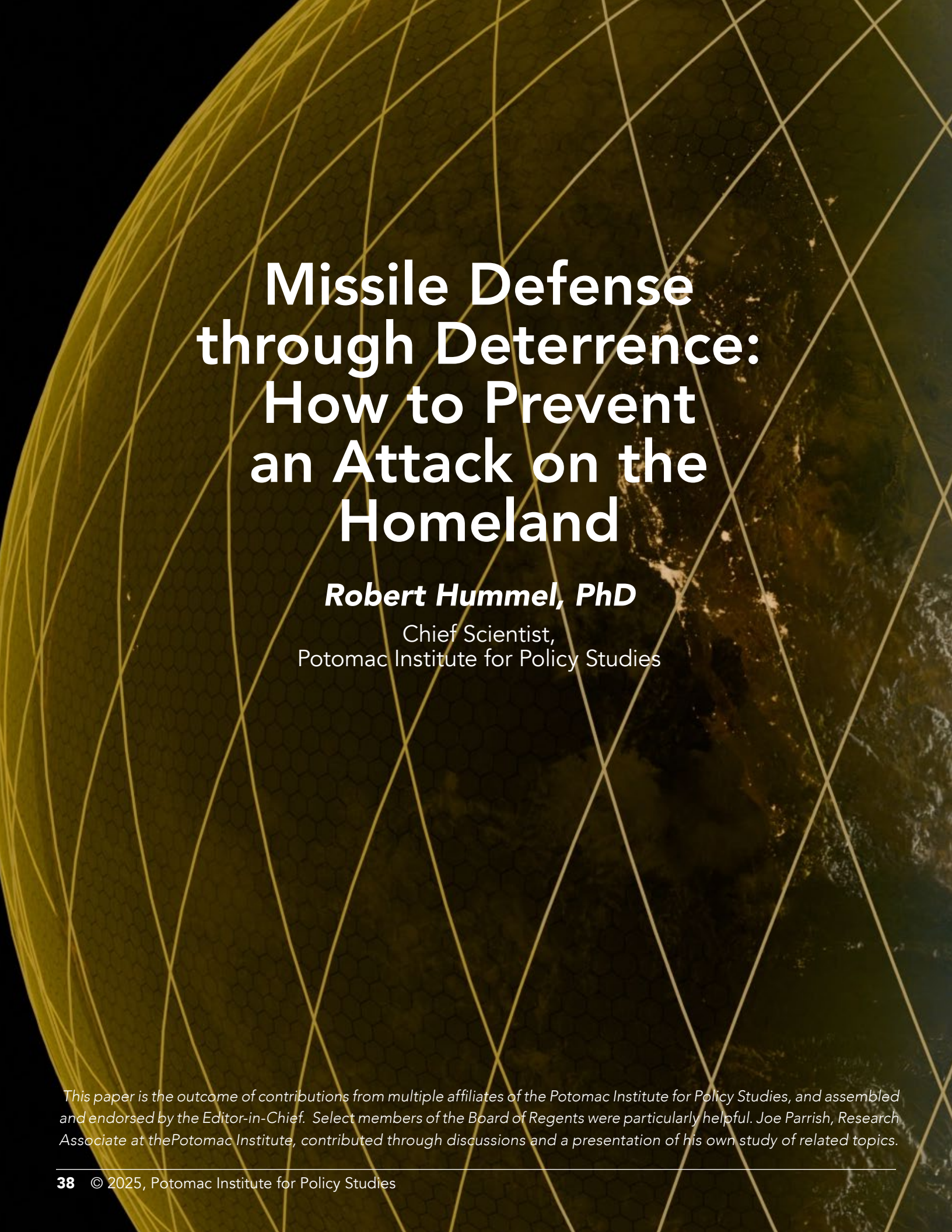

Missile Defense through Deterrence: How to Prevent an Attack on the Homeland

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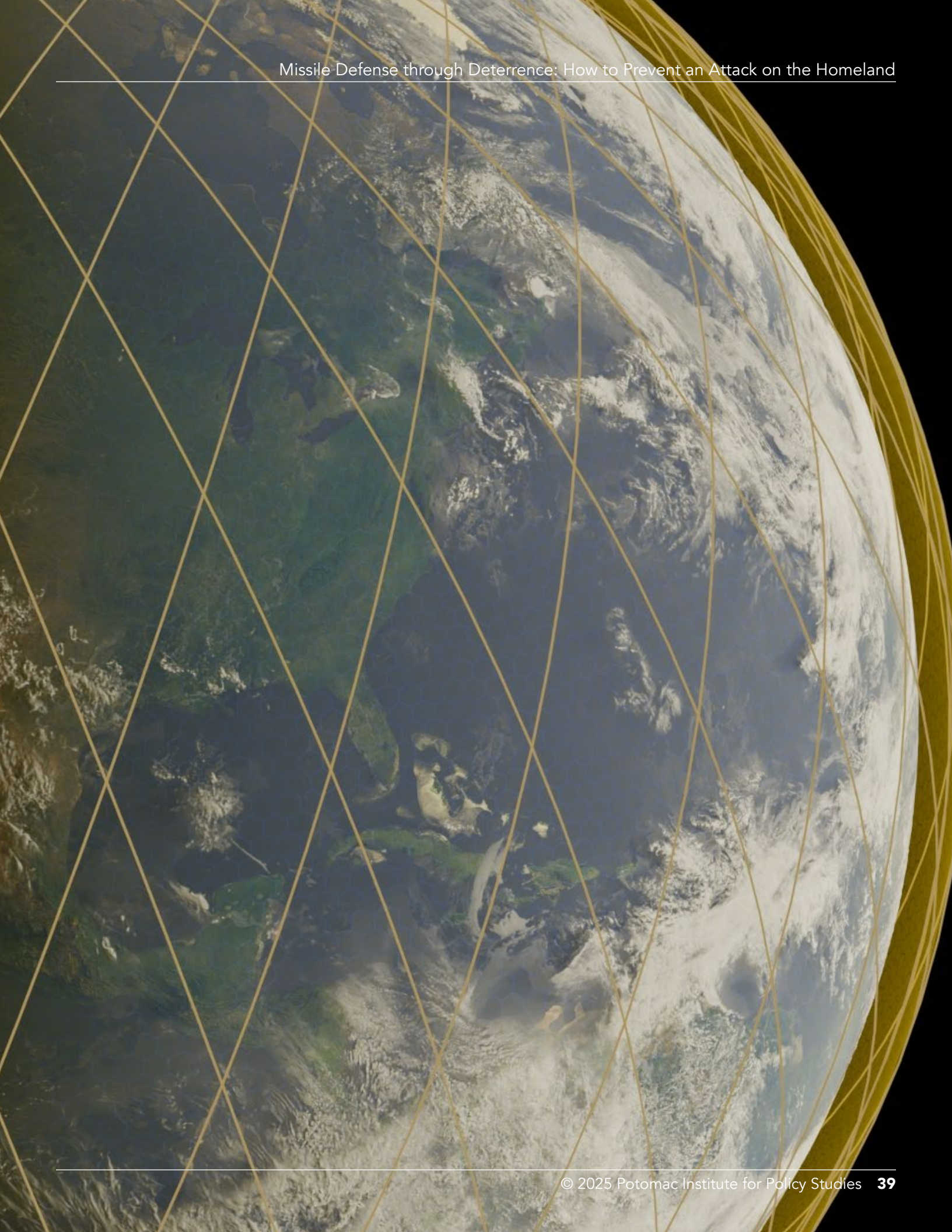

INTRODUCTION

Missiles are flying over the Middle East and Europe, of many different types and with both offensive and defensive purposes. At one time, the US assumed that the only danger to the continental US was from intercontinental ballistic missiles, most likely nuclear-tipped. Thus, was born concepts of strategic nuclear defense based on mutually assured destruction; at the same time, there was continuously a search for an alternative. The Strategic Defense Initiative (the "Star Wars Program") of the 1980s was a program seeking to render nuclear weapons "impotent." But now, new missile and strike technologies have brought new threats. They include stealth bombers and missiles, commercial assets turned into weapons, maneuverable hypersonic boost glide weapons that can carry conventional or nuclear weapons, and killer preplaced drones. It is time to re-examine the elements of missile defense.

While the "Golden Dome" program will play an important part in the development of new elements of US national missile defense, it is not likely to replace existing defense elements nor to provide the sole means of missile defense. This article is not about Golden Dome, an architecture for Golden Dome, nor the technologies that need to be developed for Golden Dome. Instead, this article calls for using ongoing developments to strengthen the nation's deterrence posture. Those developments need to be accelerated, reinvigorated, and managed with greater urgency. The result would not only save investment dollars, but it could deter a costly war, either in the homeland or elsewhere. The defense of the US must continue to involve a strong deterrent capability.

DEFENSE THROUGH OFFENSE

Historically, the assurance that the United States will not be attacked by any "rational" nuclear power has been based on deterrence. Any nation that values its right to exist will not dare attack the US. The US maintains a strategic force that stands ready to respond rapidly and massively. This nuclear force is embodied in the triad of land, sea, and air-based assets capable of responding to a nuclear attack. And it has worked! No nuclear attacks have occurred against the United States.

While the nuclear triad (the "Triad") has guided the defense of the continental United States for over 75 years,[1] its viability both real and perceived has diminished in recent years. Potential vulnerabilities in the Triad and concerns about the reliability and safety of the stored arsenal of weapons has increased uncertainty. The emergence of near-impervious adversarial hypersonic weapons threatens aspects of the Triad. Further uncertainty stems from the Sentinel program to modernize the land-based portion of the Triad through replacement of the Minuteman III missiles. That program has stalled with cost and schedule overruns.[2] Moreover, it is not certain that the US would actually commence Armageddon in response to a conventional (non-nuclear) or limited attack.

So, how must the United States change the deterrence calculation back in its favor?

A logical answer is the defense of both the nuclear triad and a non-nuclear arsenal through land and sea-based terminal-phase interceptors, as well as a demonstrated non-nuclear prompt strike capability as a deterrent to a non-nuclear attack. Implementing this solution requires the development and deployment of an enhanced ground-based local interceptor-based defense, and conventional hypersonic strike weapons capable of being launched from the US to strike any target on the planet within an hour. In doing so, we enhance the credibility and viability of US deterrent forces using "Defense through Offense." It would ensure that the US could deter an attack, with or without the use of nuclear weapons, and that any foreign aggression directed against the US and its allies could not result in a viable win for the aggressor.

DEFEND THE US NUCLEAR DETERRENT

One component of maintaining a strong deterrent is a defense of the nuclear Triad.

The Triad is the one component of the US defense system that employs its personnel and its most lethal weapons systems on a 24/7 basis, without break or stand-down, focused on a singular mission. The bombers, land-based ICBMs, and sea-based SLBMs are on constant alert. For some 75 years, from the 1950s to today, men and women in uniform have ensured that no nation on this planet dare attack the United States of America. The contributing elements include the Strategic Air Command (now STRATCOM),[3] the Global Strike Command,[4] and the numerous service members operating aircraft, submarines, and missile silos in support of the deterrence mission.

Over the years, we assured ourselves that these weapons would be launched in retaliation before their destruction, that some would survive a first strike, and it may even be

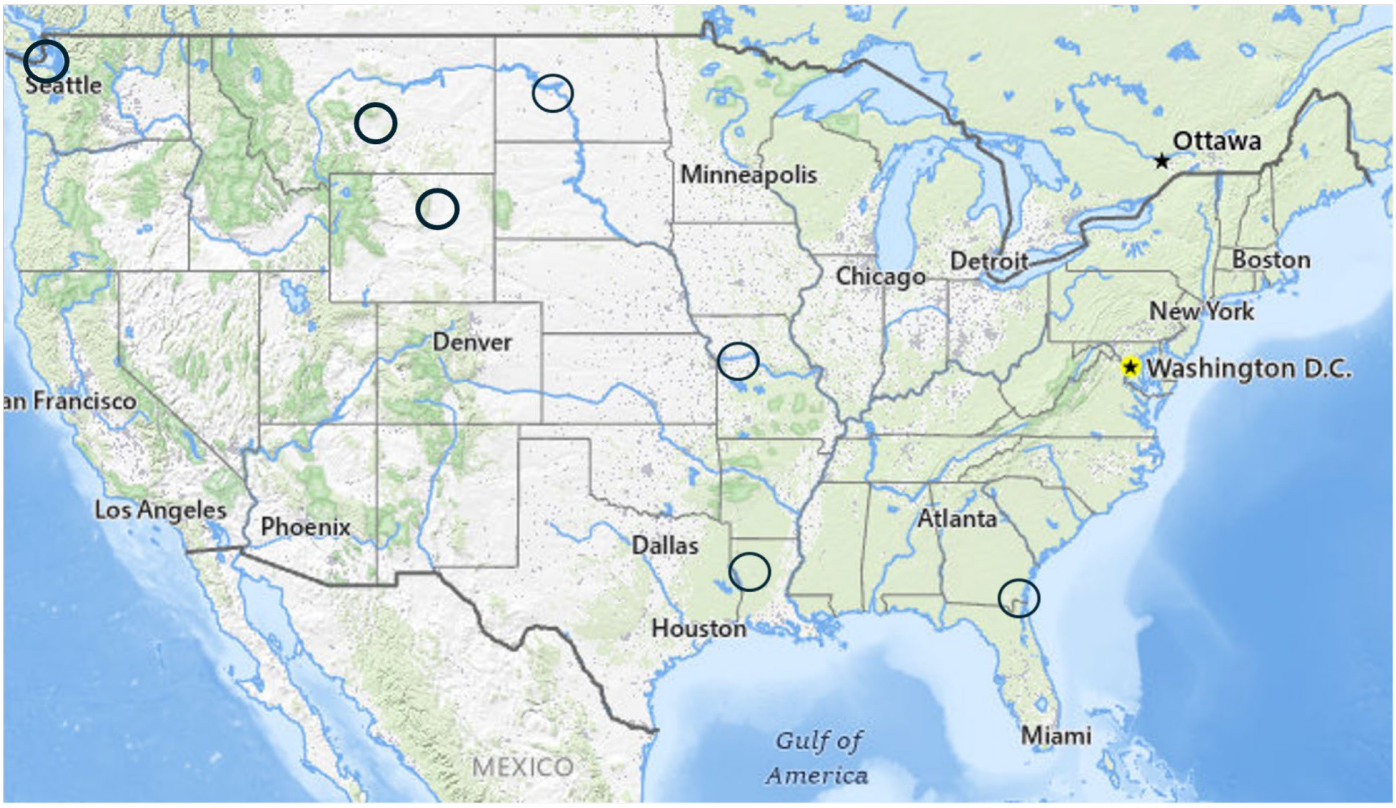

Figure 1. Approximate and notional locations and areas requiring defense for the CONUS-based nuclear deterrent force. Each circle represents roughly 3,000 square miles. Command and control centers and weapons assembly sites are not included. Source: Underlying map from USGS. Circles are estimates based on open-source reporting. Source: Underlying map from USGS.

possible to protect them against ballistic reentry vehicles using long-range land- and sea-based radars and Arctic-based interceptors. Moreover, the land-based portion of the Triad would serve as a magnet for much of an initial attack.

New threats have emerged. With the advent of precision-strike Mach 20+ hypersonic intercontinental boost-glide weapons now pursued by US adversaries (Russia and China), the Triad can no longer be considered secure.[5] Whether nuclear or not, there is less assurance that a sufficient portion of the Triad would survive an attack.

One way to enhance the deterrence of the Triad would be to better defend its fixed CONUS sites. Fixed launch sites, ports, and storage locations are depicted on the US map (to the extent they are known publicly) and must be defended to be considered viable. While difficult, it would be technically feasible to defend the required areas using interceptors.

Ground-Based Interceptors

The US has a long history of developing and fielding "theater ballistic missile defense systems." Current deployed systems include the land-based Patriot Advanced Capability (PAC-3)[6] and the Terminal High Altitude Area Defense (THAAD) system,[7] and the sea-based Aegis system.[8] The Navy and the Missile Defense Agency (MDA) have developed a ground-based system appropriately named Aegis Ashore, which mimics the at-sea Aegis system of interceptors and radar.[9] Aegis Ashore batteries have already been deployed in Eastern Europe and could serve as a model for an "arsenal defense" system within the United States.

The history of theater ballistic defense began with the Safeguard Program announced in 1971, which aimed to protect ICBM missile bases using megaton-yield nuclear-tipped anti-missiles as part of an anti-ballistic missile (ABM) system.[10]

Besides involving air burst nuclear detonations, this defense concept was ahead of its time technologically and could be overwhelmed by massed attack and decoys.

The number of sites needing defense (as seen on the map) has changed little in the 60 years since the concept was first envisioned. Perhaps some command-and-control centers and weapons assembly sites would also need to be included. Some sites could be consolidated to reduce the size of the defended regions. Today, however, defending this limited number of sites is more feasible.

Today's ground-based interceptor programs are focused on "midcourse defense" to defend large territorial regions.[11] An updated, non-nuclear interceptor approach for defense of a local territory (to defend the arsenal) now would require ground-based conventional interceptors and radars. Localized defense systems would need to be able to defend against maneuverable hypersonic vehicles.

Similar to a souped-up Aegis Ashore system, the SM6 missile and AEGIS SPY-1 radar system (and its upgrades) could be configured to provide localized defense. Such terminal-phase ground-based interceptors have begun to demonstrate effective intercept capability.[12] These intercept tests were executed against both live-fire ballistic reentry vehicles and simulated hypersonic maneuvering glide vehicles.

It might be attractive to rely on terminal guidance using space-based sensors, which would lessen interceptor cost and on-board sensor complexity. It is technically possible to achieve the required "fire control quality" tracking from space-based sensors as is demonstrated by Hubble and James Webb telescopes. However, communication latencies are likely to render endgame "in-flight updates" unworkable. An interceptor must rely on its sensors for autonomous terminal guidance to close in on the attack vehicle. In the "terminal phase" of flight, the aggressor missile (whether a reentry vehicle or hypersonic glide vehicle) will have acquired and committed to its target, which increases the predictability of the flight path and the ability of a smart terminal homing system to intercept the missile.

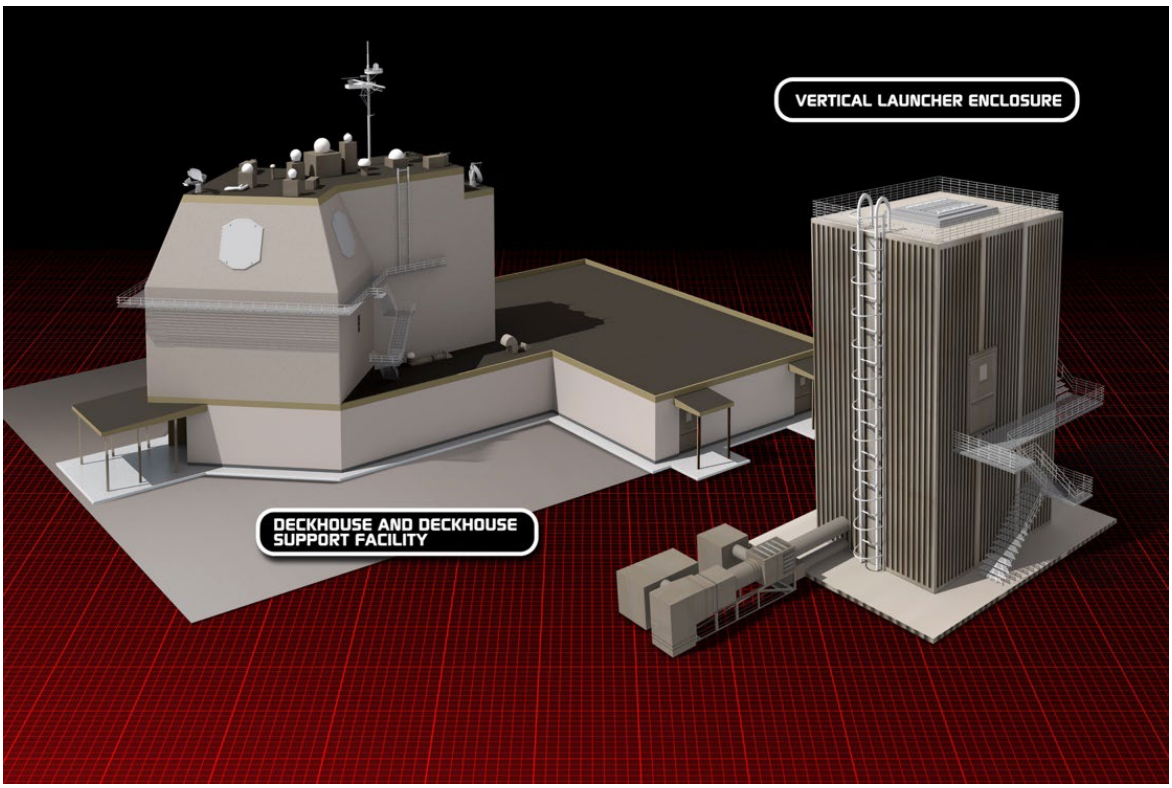

Figure 2. Aegis Ashore Site.
Source: Missile Defense Agency.[13]

Space-based surveillance and control systems

The defense of the arsenal will also require global surveillance and control systems, even though the interceptors have their own sensors. However, the hypersonic threat vehicles fall into two types: ballistic-hypersonic and aero-hypersonic platforms.

Early warning of ballistic hypersonic vehicles is being addressed in the Next Generation OPIR program[14] and other developments. The program, however, has had delays and is expected to launch its first satellites in 2026.[15]

The aero-hypersonic vehicles can travel at relatively low altitudes, so they require a different space-based surveillance system. Several small satellite developments from the US Space Force's Space Development Agency (SDA) are planned as part of the Proliferated Warfighter Space Architecture Program.[16] The first "tranche" of hundreds of command, control, and communications satellites—scheduled to begin launching in 2025—will become the backbone of the "Joint All-Domain Command and Control" (JADC2) concept.[17] Data communications for hypersonic and ballistic missile tracking will be provided by a future tracking layer (Tranche 2) of satellites. This tracking layer is expected to contain 54 to 74 satellites for tracking hypersonic and ballistic missile threats. But the total system capability is not operational yet.

Until the SDA satellites can provide the needed surveillance, the existing Hypersonic and Ballistic Tracking Space Sensor (HBTSS) program provides a constellation of two prototype satellites designed to track aggressor's hypersonic missiles. The two HBTSS spacecraft were launched in February 2024 and recently demonstrated a successful simulated hypersonic intercept with the "Standard Missile" SM-6 in the loop.[18] However, the HBTSS approach to surveillance may be far more expensive than the small satellite approach.

The history of space-based tracking programs is sobering. The "Brilliant Eyes" concept of the late 1980s and early 1990s evolved into the SBIRS-Low program in the early 2000s but was canceled after the GAO cost estimate ballooned from $2.5 billion to $23 billion.[19] Similarly, SBIRS-High, initially estimated at $5.6 billion in 1996 with an expected first satellite launch in 2002, ended up costing $20.3 billion, with its first launch delayed until 2011—a nine-year slip.[20] These programmatic failures are independent of the technical feasibility of providing a space-based surveillance and communications network capability.

MODERNIZE THE NUCLEAR DETERRENT

While defending the triad is important, its viability is also important. With an aging stockpile and aging infrastructure, the credibility of the nuclear deterrent has waned.

There are programs to renew the stockpile, without renewed testing. There are programs to build new submarines, and to maintain the bomber fleet. Of the elements of the triad, the ground based fixed launchers are important but arguably the least important, due to their vulnerability. Of course, their vulnerability is intentional, but because they can be attacked by conventional (non-nuclear) means, the missiles might be considered the portion of the triad where less focus might be given to its modernization.

And yet the Sentinel Program to replace the launchers and rockets is expected to cost over $141 billion (and climbing) and is years over schedule.[21] While a land-based component of the triad is important, one can again question the wisdom of directing large resources to a lesser priority.[22]

CONVENTIONAL GLOBAL STRIKE

The US nuclear deterrent is not credible against the use of conventional weapons to attack US assets in CONUS or located outside the United States, including its holdings, territories, or allies. Such an attack might come from a near-peer aggressor to confound a US response. US nuclear forces can successfully deter nuclear war. However, they are unlikely to be used in a conventional war.

How can the United States credibly deter a conventional weapons strike on its assets?

To deter an assault on US assets and/or allies, the United States must broaden the ability of STRATCOM and Global Strike to hold strategically valuable targets at risk with the equivalent psychological impact on adversaries as nuclear forces, but without the use of nuclear weapons.

To deter non-nuclear aggression, the United States must develop the capability that assures aggressors that any of their attempts to attack will fail. This degree of assurance requires the ability to strike targets with impunity anywhere in the world with massed, non-nuclear weapons delivered with the same speed and inevitability as a nuclear attack. While ballistic ICBMs can deliver conventional payloads, a launch is subject to misinterpretation, and adversaries may have developed their own ground-based interceptors against ballistic missiles.

To deliver conventional weapons against a well-defended foe, intercontinental hypersonic boost-glide weapons can be tailored to execute the mission. Uniquely added to STRATCOM and Global Strike, these weapons would form part of the deterrent forces, strictly distinct from US tactical forces. An intercontinental boost-glide weapon uses a multi-stage booster rocket to reach extremely high speeds exceeding Mach 20, exiting the tangible atmosphere before reentering the upper reaches of the atmosphere. At an altitude between 20 and 80 km, it glides potentially thousands of miles, performing evasive maneuvers before descending to precisely hit its target.

While the United States is investing heavily in the development of hypersonic missiles, progress toward developing prototype intercontinental-class hypersonic boost-glide weapons are delayed.[23] The US defense industry has the technical ability to build such weapons. The investments require greater urgency.

THE SIGNIFICANCE OF A CREDIBLE DETERRENT

In 1991, during the Gulf War, Iraq fired scud missiles against Israel and Saudia Arabia. There was great fear in Israel that the missiles would contain chemical weapons. Iraq did indeed have large stores of chemical weapons, as verified by the UN after the war.[24] But none of the scuds used chemical weapons.

It was reported, but not acknowledged if true, that US impressed on the Iraqi Foreign Minister, Tariq Aziz, in a meeting on January 9, 1991, (the failed Geneva Peace Conference), the consequences of Iraq's use of WMD in the war that followed.[25] If so, deterrence worked.

At the outbreak of the Russo-Ukrainian war, Vladimir Putin openly threatened the use of nuclear weapons.[26] He later claimed that Russian nukes (their triad) are more advanced than US nuclear weapons.[27] The US did not respond by invoking the US Triad and threatening retaliation. Was the US unwilling to back up a threat if it had issued a belligerent response? That may never be known; however, the onset of the Russian attack against Ukraine in 2022 came soon after the declaration that the Russian ICBM-class boost-glide nuclear weapon, the Avangard, was now operational.[28] Our silent response to the Avengard is that we are working on ground-based interceptors. Just like we are working on a replacement for the Minuteman III missiles.

The US credibility, and its ability to influence outcomes, is on the line. More than just investing money in new systems, a strategy and effective implementation plan are required. While some of the technical challenges will require experimentation and testing, the technical feasibility is assured. The true challenge is the will to press the urgency, and to manage the development with technical and programmatic skill.

SUMMARY

Ensuring protection of the United States, overseas assets and territories, and critical interests requires a credible deterrent against both conventional and nuclear attacks. The best way to achieve this requires a nuclear triad defended against a first strike, including a first strike that could involve non-nuclear hypersonic weapons. A credible deterrent also involves an arsenal of conventionally armed, precision-guided, maneuverable hypersonic boost-glide weapons that can overcome adversary defenses to provide prompt response.

As with the Strategic Defense Initiative and the more recent Golden Dome initiative, establishing a broad area defense is a worthwhile goal. It should not, however, diminish attention to maintaining a strong deterrent capability. Many of the components of a reinvigorated deterrent are under development, managed by the US Space Force, the Missile Defense Agency, and other Pentagon offices. So while the need for a deterrent is not being neglected, neither is it being pursued and coordinated with the vigor that reflects its importance.

One possibility is to establish a new organization with a national mandate and fiscal commitment to build this capability and thus fully deter any attack by current or future adversaries. Whether an existing or new organization, this is a national imperative that will require commitment by government and industry alike, in partnership. Deterrence is perhaps less exciting, in that the hope is that the associated weapons should never be used, but deterrence has preserved the US for decades and is an essential element of defense for the future.

"For only when our arms are sufficient beyond doubt can we be certain beyond doubt that they will never be employed" [29]

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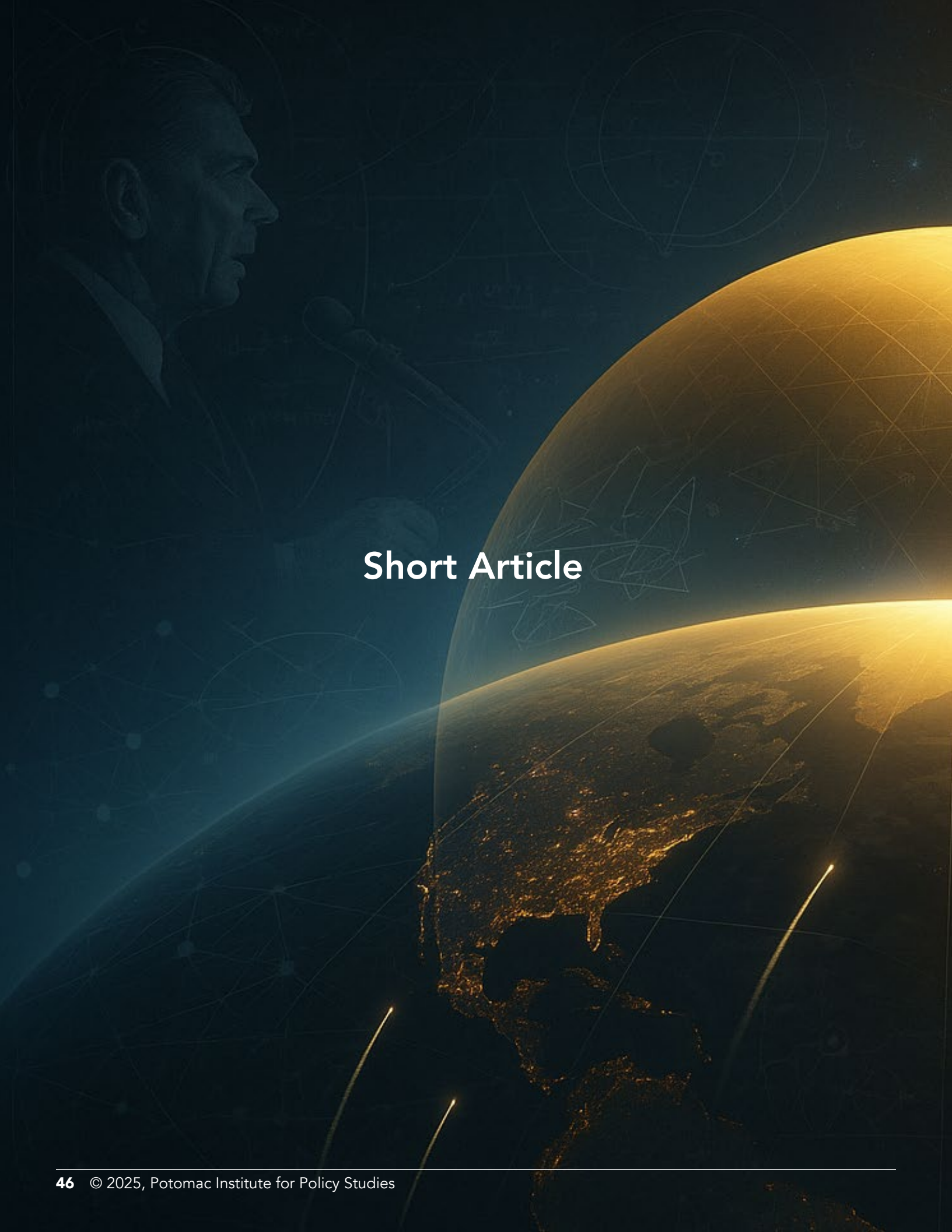

Short Article

Can Trump's Golden Dome Make us Safe?

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Last year, Donald Trump announced that "we must be able to defend our homeland, our allies, and our military assets around the world from the threat of hypersonic missiles, no matter where they are launched from." After his election, he called for a program labeled the Golden Dome and requested a plan with no limit on cost to achieve his goal. This brought back many memories from 40 years ago.

Although I had been involved—and often frustrated—for many years with the rather slowly advancing R&D related to space-based missile defense, I became intrigued by new ideas after a lunch conversation with the brilliant and creative physicist Freeman Dyson. I had become convinced that the tactics and technology needed to counter a massive missile attack would always fail. I was sure that the offense would always have the advantage. Dyson introduced me to a more interesting way of looking at this complex issue. He told me about his concept of a quest that would "allow us to protect our national interests without committing us to threaten the wholesale massacre of innocent people." He argued on moral grounds for "a defensive world as our long-range objective … and the objective will sooner or later be found, whether the means are treaties and doctrines or radars and lasers."

This quest became my full-time occupation after the March 23, 1983, speech by President Reagan in which he called for a program "to make nuclear weapons impotent and obsolete." As a result, I was asked by Harold Agnew, the former head of Los Alamos Lab, to help put together a plan to implement the President's challenge. The plan, delivered to the President in September 1983, consisted of a collection of poorly defined technologies and called for a five-year, $25 billion investment to answer the question of whether there could someday be a defensive approach to missile defense. Because I had helped create the plan, I was asked in 1984 to become the chief scientist for Reagan's Strategic Defense Initiative, working with Director James Abrahamson. I found my assignment was primarily public relations, as the actual research work was dominated by the question "Will it make us safe?" I spent many days and weeks trying to explain to the detractors what "it" was.

During this time, I often found myself in debates with notable opponents. I vividly remember my debate with Hans Bethe, Nobel Laureate in physics, who also happened to have been my quantum mechanics professor in 1961 at Cornell University. Our debate was published in *Science Digest* in an article titled "Can Star Wars Make Us Safe?" Bethe answered no, and he was joined in his opinion by practically all of the academic scientists at the time. They argued that we had no plausible way to accomplish what they believed was Reagan's goal—to protect all of us from the threat of nuclear-tipped ballistic missiles. I argued that the answer was yes, but I redefined the goal to be more in keeping with my understanding of what Reagan really wanted, and in keeping with the wisdom of Dyson. Today, the demands for protection against threats are much more complex, including hypersonic missiles, cruise missiles, anti-satellite weapons, and cyber-attacks. In fact, one of the scariest threats would be contagious bioweapons spread by swarms of crop sprayers launched from submarines near our coasts. But my answer to the question, "Will 'it' make us safe," is still in the affirmative.

As before, arms control experts have spoken out to explain that "it" just cannot be done. They repeat the same old arguments that it won't work, it is too expensive, and it will create entirely new strategic instabilities. The question I asked at the time was "What is it?"—and I think that is still the right question to be considered now.

So, what about now? Are we still arguing about "it" without understanding what it is? In my view, it is not about how to win the ultimate global war using space-based weapons, but rather how to prevent war. Maybe, with the recent advances in technology, we can find new ways to accomplish that through a new approach to deterrence that involves a shared approach to a stable combination of defensive and offensive tech weapons development. We will need to first accomplish a breakthrough in vastly improved trusted communication and decision-making in the face of confusion, chaos, threats, and fundamental disagreements. With the proliferation of advanced offensive weapon technology, we need to try to find a new more hopeful path. Maybe there could be some stable system to prevent war through technology enhanced information sharing, reduced offensive threats, and deterrence that will prevent the initial steps toward war.

But I recall Bethe's final argument in our debate was that any defense could not be trusted since it could not be tested under realistic conditions. I argued that we already have learned to live with deterrence that cannot be realistically tested, since that has to be a question of psychology involving human decision making. It is conceivable that complex reasoning-based information management and decision making can be assisted through AI that could carry out

simulated tests of a semi-infinite number of complex combinations of events and human decision making.

I remember when Harold Agnew asked me to lead the group to deliver a plan for the beam weapons component of the SDI. He said in a hushed tone that I had to take very seriously his warning that the job would be "very, very dangerous." He said I could easily be trampled by the stampede of contractors going after funding. He was not encouraging, to say the least, and in a matter of weeks he walked away from involvement. He never understood the Reagan goal for the program and he was definitely opposed to any thought of nuclear weapons abolition. His concept of safety was the threat of destruction.

The "it" is still hard to define and has not become easier, but President Trump says there should be a way to protect us, and there should not be any limit to the amount of investment. Maybe the "it" is a safe future world, and then the question is… can the Golden Dome make us safe? Let's see what "it" is in the plan that needs to be developed.

FEATURED AUTHORS

Robert (Bob) Hummel, PhD

Chief Scientist, Potomac Institute for Policy Studies
STEPS, Editor-in-Chief

Bob Hummel is the Chief Scientist at the Potomac Institute for Policy Studies, the Washington D.C. metro area think tank focused on science and technology issues related to national policies. He is also Editor-in-Chief of STEPS. The Institute supports US government clients and US national S&T policy issues.

While at the Potomac Institute, he served on assignment at the National Geospatial-Intelligence Agency. Previously, Dr. Hummel was a program manager at DARPA, managing projects related to automated target recognition, sensor systems, multisensory exploitation, computer science and AI. He is the recipient in 2005 of the Director's Award for Personal Achievement. He worked with DARPA strategy teams, elements of the DoD Joint Staff, and with NGA.

He is a co-founder of the US Technology Leadership Council, a non-profit industry association. Prior to joining DARPA, he was a tenured university professor at the Courant Institute of Mathematical Sciences at New York University. His area of research is in computer vision and information fusion, publishing in object recognition, image processing, parallel computing, uncertainty reasoning, information fusion, connectionism, and mathematics. He has a PhD in mathematics from the University of Minnesota and a bachelor's degree in mathematics from the University of Chicago.

Mr. Francis A. Finelli

Member, Board of Directors,
Business Executives for National Security (BENS)

Mr. Frank Finelli is a Senior Advisor to The Carlyle Group, a global private equity firm, having retired from the firm in March 2024 after over 25 years, culminating in his role as a Partner and Managing Director focusing on investments in the defense and aerospace sector. He led numerous acquisitions and developed Carlyle's cross-portfolio purchasing and functional value creation initiatives. Previously, Mr. Finelli served as a legislative assistant for then-Senator Dan Coats (R-IN), member of the Armed Services Committee and Select Committee on Intelligence. Before retiring as an Army Lieutenant Colonel, Mr. Finelli served as a Special Assistant to the Chairman of the Joint Chiefs of Staff for the first Quadrennial Defense Review (QDR) in 1997. He also worked for the Vice Chairman in restructuring the Joint Requirements Oversight Council (JROC), where he also coordinated reviews of communications and intelligence programs. A Field Artillery Master Gunner, Mr. Finelli served in the 82d Airborne, 1st Armored, and 3rd Infantry Divisions. Mr. Finelli is a distinguished graduate of the U.S. Military Academy. He holds a Master of Sciences in Finance and Operations Research from the Sloan School of Management at Massachusetts Institute of Technology and a Master of Military Arts in Strategy from U.S. Army Command and General Staff College. Mr. Finelli also serves as a Director for Army Emergency Relief (AER) and Business Executives for National Security (BENS), as well as the MIT Sloan School Executive Board, and is on the Advisory Board for the Reagan Foundation's Economic Security Forum. His military awards include the Defense Superior Service Award, the Legion of Merit with Oak Leaf cluster, the Honor Cross of the German Armed Forces in Silver, the Ranger Tab, and Master Parachutist badge.

Bob Gourley

CTO of OODA LLC

Bob Gourley is an experienced enterprise CTO with extensive past performance in optimizing technology in support of global businesses. Bob is the former CTO for the Defense Intelligence Agency. He is the CTO of OODA LLC where he leads engagements focused on improving the security and functionality of enterprise IT. At OODAloop.com he leads analysis into Quantum Computing, Quantum Security, Cybersecurity and operational intelligence.

William Regli, PhD

Professor, University of Maryland

Dr. William Regli is a professor in the computer science department at the University of Maryland. He is a computer scientist who has focused his career on interdisciplinary and use-inspired problems spanning engineering, artificial intelligence and computational modeling and graphics. Dr. Regli's interests include computational tools to exploit the properties of advanced materials, additive manufacturing systems and enabling new paradigms for design and production. His research has spawned two start-up technology companies (one focused on mobile communications for public safety, the other on information management in edge networks) and resulted in five foundational U.S. Patents in the area of 3D CAD search.

From 2014 to 2017 Regli served on the leadership team of DARPA, as Deputy Director and then Acting Director of the Defense Sciences Office (DSO). During his tenure, DSO initiated programs in areas as diverse as artificial intelligence, design and manufacturing, social science, applied mathematics, physical sciences and advanced sensing technologies. Regli's other government service includes as a Scientific Adviser to the U.S. Department of Energy's (DoE) National Nuclear Security Administration (NNSA) in the areas of information technology and manufacturing and as a National Research Council Postdoctoral Fellow at the National Institute of Standards and Technology (NIST).

Regli was the founding Executive Director of the University of Maryland's University-Affiliated Research Center, the Applied Research Laboratory for Intelligence and Security (ARLIS). During the 2023-24 academic year, Regli served in the White House Office of Science and Technology Policy (OSTP), as a Senior Advisor for AI Risk for the National AI Initiatives Office.

Dr. Regli holds a Ph.D. in Computer Science from the University of Maryland at College Park and a Bachelor of Science degree in Mathematics from Saint Joseph's University. He is a Fellow of the American Association for the Advancement of Science (AAAS); an elected senior member of the Association of Computing Machinery (ACM) and of the Association for the Advancement of Artificial Intelligence (AAAI); and a Fellow of the Computer Society of the Institute of Electrical and Electronics Engineers (IEEE).

Timothy Welter, PhD

Senior Fellow, Potomac Institute for Policy Studies

Dr. Tim Welter is a Senior Fellow at the Potomac Institute for Policy Studies where he leads the Global Competition Project. Having worked in the private sector, the military, and on Capitol Hill, Tim brings valuable experience in national security and defense policy to the Institute. After serving on active duty in the Air Force for several years, he worked on Capitol Hill as Legislative Director for two different Members of Congress and later as a Professional Staff Member with the House Veterans Affairs Committee. Upon leaving the Hill, Tim worked with the foreign and defense policy research team at the American Enterprise Institute. He later completed a research fellowship at the National War College during which he finished his Ph.D. dissertation in Political Science with the University of Missouri, writing about the political nature of defense policy in Congress. A U.S. Air Force Academy graduate, Tim holds Master's degrees in Political Science, National Security Strategy, and Management. Just prior to joining the Institute, as a reservist, Tim served in the Pentagon where he helped stand up an organization dedicated to future force design and the development of capabilities and concepts required to meet emerging national security challenges.

Gerold Yonas, PhD

Senior Fellow, Potomac Institute for Policy Studies

Gerold Yonas, PhD has had a long and distinguished scientific and managerial career. He worked as a staff scientist at JPL from 1962 to 1967 and was Manager of Electron Beam Research at Phys Intl from 1967 to 1972. He worked at the Sandia National Laboratories (SNL) from 1972 to 2009 where he initiated the pulsed power fusion program, served as vice president of Systems, Science and Technology, and later became SNL's principal scientist. He also served from 1984 to 1986 as the acting deputy director and chief scientist of the Strategic Defense Initiative (SDI).

He joined the University of New Mexico's (UNM's) Mind Research Network in 2009 as the director of neurosystems engineering. There he dedicated himself to develop this new field, linking advances in neuroscience with systems engineering through interdisciplinary teams that focused on the development of solutions to complex system problems.

He has also served on several defense boards and is a Senior Fellow at the Potomac institute for Policy Studies. He has also taught in the Department of Electrical and Computer Engineering at UNM, and has published extensively in the fields of intense particle beams, inertial confinement fusion, strategic defense technologies, technology transfer, and "wicked engineering." He has authored the mostly-fictional novels "The Dragon's CLAW" and "The Dragon's Brain," and the non-fiction book "Death Rays and Delusions" (with Jill Gibson). Dr. Yonas received his PhD in engineering science and physics at the California Institute of Technology and bachelor's degree at Cornell University.

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