Securing Defense-Critical Supply Chains

An action plan developed in response to
President Biden's Executive Order 14017

February 2022

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Foreword from the Deputy Secretary of Defense

The Department of Defense (DoD) is aligning its priorities and capabilities to enhance our readiness. By modernizing our approach to supply chain resilience, DoD can deliver decisive advantages to our Warfighters in a dynamic threat landscape.

In an effort to improve supply chain resilience and protect against material shortages, President Joseph R. Biden Jr. signed Executive Order (E.O.) 14017, America's Supply Chains. In response to the EO, this report provides DoD's assessment of defense critical supply chains in order to improve our capacity to defend the Nation.

Our recommendations focus on how we can increase domestic production capacity and renew the sources of our economic security. We will continue investing in the production and manufacturing capabilities that will enable a modern, technology-enabled defense industrial base. Because we know that workers animate supply chains, we will foster development of an industrial workforce to ensure the right skillsets are available as needed to meet our requirements. We will also contribute to our national defense stockpile and utilize it to provide flexibility in the case of disruptions or emergencies.

This report reinforces our commitment to American values and underscores the importance of a free, open, and rules-based market. We will prioritize collaboration with our allies and partners to build a network of secure global supply chains. Further, we will safeguard global market integrity to ensure that industry can continue to provide superior products and services to our force.

Our plans include a strong commitment to cooperation with all who have a stake in our national security: our interagency collaborators, Congress, private industry, the American people, and our allies and international partners. By emphasizing teamwork, this report delivers a whole-of-Nation approach to national security and invites greater industrial collaboration with our friends across the globe.

Our work to build resilient, competitive, and sustainable supply chains will be a longterm campaign. Given the complexities of our defense supply chains, the plans in this report are bold and ambitious in their scope. We will continue to iterate on our approach. Our prioritization of expanded and new supply chain capabilities will help us face the challenges of the 21st century with fortitude.

Dr. Kathleen H. Hicks

United States Deputy
Secretary of Defense

Executive Summary

Executive Summary

The Department of Defense (DoD) requires healthy, resilient, diverse, and secure supply chains to ensure the development and sustainment of capabilities critical to national security. The ongoing COVID-19 pandemic highlighted vulnerabilities in complex global supply chains in very real ways to the public, government, and industry. Beyond COVID-19, supply chain disruptions have become more frequent and severe overall.

In order to strengthen the national industrial base during times of disruption, President Joseph R. Biden, Jr. signed Executive Order (E.O.) 14017, *America's Supply Chains,* on February 24, 2021. The E.O. calls for a comprehensive review of supply chains in critical sectors, including the defense industrial base (DIB). This report provides DoD's assessment of supply chains in the DIB and articulates the Department's plans to ensure security of supply for items vital to national security.

The national resolve to strengthen America's supply chains is not limited to the Executive Branch. Congress has demonstrated a commitment to renewing and strengthening U.S. manufacturing through the Bipartisan Infrastructure Law (BIL) and the House Armed Services Committee (HASC) critical supply chain task force. The DIB and related trade associations have outlined myriad actions and are actively engaging with government at all levels to build resiliency.[1] The DoD is committed to strengthening the industrial base and establishing a network of domestic and allied supply chains to meet national security needs.

Given the breadth and scale of defense supply chains, the one-year effort prioritized four areas in which critical vulnerabilities pose the most pressing threat to national security. These focus areas are:

- **Kinetic capabilities:** current missiles systems and advanced and developing missile capabilities, including hypersonic weapons technology, as well as directed energy weapons
- **Energy storage and batteries:** high-capacity batteries, with a particular focus on lithium batteries
- **Castings and forgings:** metals or composites developed into key parts and manufacturing tools through high-intensity processes
- **Microelectronics:** State-of-the-Practice (SOTP) and legacy microelectronics, as well as State-of-the-Art (SOTA) microelectronics

1. National Defense Industrial Association, *The Health and Readiness of the Defense Industrial Base.* February 2022. *https://safe.menlosecurity.com/doc/docview/viewer/docNCFF7F14465DBf21220840d3330e2a40ffe2aa8a8a1606143d25262da1d46a8be6a685f2e24e7*.

This report also provides an update on the implementation of recommendations in DoD's Review of Critical Minerals and Materials, included in the 100-day response to E.O. 14017 published on June 8, 2021.[2]

Underpinning all four key focus areas are strategic enablers that are required for mission success. Fragility or gaps in these enablers create operational and strategic risk, and addressing the challenges in each is critical to building overall supply chain resilience. The strategic enablers are:

- **Workforce:** trade skills through doctoral-level engineering skills
- **Cyber posture:** industrial security, counterintelligence, and cybersecurity
- **Manufacturing:** current manufacturing practices, as well as advanced technology like additive manufacturing
- **Small business:** the role of key members of DoD supply chains

This report provides a strategic assessment of these focus areas and enablers, as well as the steps that can be taken to mitigate identified threats and vulnerabilities and build resilience.

Across all focus areas and enablers, the Department identified certain foundational recommendations to enhance and grow the industrial base. These cross-cutting recommendations underpin the sector specific recommendations outlined in subsequent sections of this report and are critical to the Department's overall ability to make strategic informed acquisition and sustainment decisions. These recommendations are:

- **Build domestic production capacity:** For those supply chains that are critical for national defense, the U.S. is committed to ensuring reliable production access within the defense industrial base, both domestic and allied.
- **Engage with partners and allies:** The U.S. is collaborating with its international partners and allies to develop policies and arrangements that strengthen our defense industrial bases and improve supply chain resilience.
- **Mitigate Foreign Ownership, Control, or Influence (FOCI) and safeguard markets:** The Department is committed to protecting its supply chains and the defense industrial base from adversarial FOCI by scaling efforts to identify and mitigate FOCI concerns.
- **Conduct data analysis:** DoD will continue to build on previous efforts to expand its visibility into supply chains by collecting and organizing key data.
- **Aggregate demand:** The Department will signal to industry what the likely total demand is across multiple programs, so industry can better anticipate number of orders from year to year.
- **Develop common standards:** To leverage commercial sector innovations, and to embed modernizing technologies in weapon systems, the DoD will work, where possible, to limit its use of military-unique requirements when developing performance requirements.
- **Update acquisition policies:** DoD should engage in efforts to develop a whole-of-government strategy and implementation plan to engage with industry and Congress to determine which policy and regulatory changes would encourage expansion of capabilities.

The above actions and sector specific recommendations will provide DoD with a strategic roadmap to renew the DIB and maintain its position as the world leader in innovation well into the 21st Century.

2. United States, White House, *Building Resilient Supply Chains, Revitalizing American Manufacturing, and Fostering Broad-Based Growth*, 100-*Day Reviews Under Executive Order 14017.* June 2021.

Introduction

Introduction

To defend the Nation and deter America's adversaries, the DoD works to ensure that our armed forces have reliable access to every advantage. DoD has the responsibility to ensure that the Nation is prepared to—with all possible speed—manufacture and deliver defense platforms and weapons systems to the armed forces. Increasingly, the DoD is building domestic capacity, cooperating with allies and partners, and safeguarding against adversarial influence to build capabilities that can defend the nation's democratic values and the rules-based order on which global prosperity relies.

Meeting that mission requires a healthy DIB built on resilient, diverse, and secure supply chains. On February 24, 2021, President Biden signed Executive Order (E.O.) 14017, America's Supply Chains, which called for a comprehensive review of critical supply chains in key sectors. In this report, the DoD provides a sector-by-sector assessment of the DIB and articulates the DoD's plan to ensure security of supply.

American Resolve in Securing Defense Supply Chains

Although the COVID-19 pandemic created a supply chain shock of unparalleled global scope and scale, supply chain disruptions have become more frequent and severe overall. Companies must now address the consequences of everything from wildfires and power outages to cyberattacks and acute workforce dissatisfaction. U.S. armed forces rely on the commercial sector to design and produce many necessary capabilities and materials, so these disruptions pose significant risks to national security.

The risks of disruption have grown in tandem with the increasing complexity of U.S. defense supply chains. The average American aerospace company relies on roughly 200 first tier suppliers. The second and third tiers have more than 12,000 companies.[3] With the globalization of supply chains, these suppliers and their goods come from a wide array of places. Some foundational industrial supply chain sectors, like optical instruments, mechanical gears, welding equipment, and printed circuit boards source a large part of their components from outside North America.

3. Mckinsey & Company, *"Why Now is the Time to Stress-Test Your Industrial Supply Chain,"* 27 July 2020.

Disruptions to these complex global supply chains cause significant costs to industry and diminish competitiveness. The 2021 power outages in Texas, for example, cost one semiconductor fabricator more than $100 million and a month of lost wafer (a component of semiconductors) production.[4]

Because supply chain resilience is critical for U.S. national security and economic strength, a clear national consensus—bolstered by public, private, and social sector prioritization—has emerged around the need for bold action in support of supply chain security.

Consequently, supply chain resilience has become a top-of-mind issue in a way it has not been for decades. CEOs and company boards are moving the private sector to modernize supply chains rapidly. In Congress, numerous proposals and laws have signaled an intent to build domestic industrial capabilities and work with allies and international partners to build resilience. In July 2021, the House Armed Services Committee's bipartisan Defense Critical Supply Chains Task Force released a report that concluded, "It is now incumbent on the U.S. Government, in concert with industry and allied nations, to mitigate critical defense supply chain risks, increase surge capacity, and enhance resilience by increasing the diversity of sources."[5]

The DoD has likewise taken important steps to build supply chain resilience. The Department established an enterprise-wide Supply Chain Resiliency Working Group in August 2021 to guide its supply chain strategy and initiatives. Furthermore, the DoD delivers an annual Industrial Capabilities Report (ICR) to Congress that assesses the health of the DIB and places an annual spotlight on important concerns. Numerous components of the DoD continue investing in the DIB and warfighter capabilities through powerful DoD authorities, such as the Defense Production Act and the Industrial Base Analysis and Sustainment (IBAS) program. In addition, the United States has increasingly worked to deepen defense industrial cooperation with allies and international partners. Many of these efforts are captured in reports and studies in response to Executive Orders 13806, 13817, and 13953.

This report serves as a roadmap for addressing the DoD's supply chain challenges. It details how the DoD—in coordination with other U.S. Government agencies, industry, and international partners—will address supply chain challenges that will improve America's overall national and economic security.

Building Resilient Defense Supply Chains

The DoD and its partners have significant assets to build resilience in the face of supply chain risks and constraints, including national resolve around supply chain resilience; a renewed focus within the Executive Branch; resourced programs for industrial base challenges; unrivaled information resources; interagency information sharing; co-development, coproduction, and leveraged resourcing with allies; capital-driven markets with patriotic suppliers; the American spirit of entrepreneurship; and an innovation ecosystem for cutting-edge research and development (R&D).

The DoD's research and procurement revolve around broad-based stakeholder coalitions and public-private partnerships that catalyze economic growth across many communities, creating family sustaining jobs. Despite current supply chain challenges, this market-based approach will outpace adversaries' reliance on state directed command-and-control for their innovation and production capacity.

4. Kara Carlson, *"NXP Could Lose $100 million due to weather shutdown of Austin Plants"* Austin American-Statesmen, 12 March 2021. https://www.statesman.com/story/business/2021/03/12/nxp-could-lose-100-million-due-weather-shutdown-austin-plants/4664621001/.
5. United States, House Armed Services Committee, *Report of the Defense Critical Supply Chain Task Force,* 22 July 2021.

Americans have every reason to be confident about the future of defense supply chains. American industry still leads the world in innovation and production. American entrepreneurs and small businesses power an unrivaled capacity to create everything from cars and satellites to airplanes and robots. The U.S. military is still the most trained and capable force in the world. The Nation's internal capacity to create value for consumers is unmatched, especially when working in concert with allies and partners. The U.S. military enables global markets that are free, stable, and open.

Because of its sophistication, diversity, and capacity to innovate, the U.S. DIB remains the envy of the world. Still, a new age of technology is transforming the global economy and the way that DoD does business. The hallmarks of the Fourth Industrial Revolution, like additive manufacturing, analytics, connectivity, artificial intelligence, and robotics are digitizing production and have created opportunities for the United States to build new competitive advantages.

Focus Areas and Strategic Enablers

To scope the one-year effort to assess defense supply chains, the DoD prioritized four focus areas of particular importance to national security. These focus areas were identified with input from the Services, senior leaders from the Office of the Secretary of Defense, and guiding strategies and policies such as the Defense Planning Guidance and E.O. 14017. The areas are:

- **Kinetic capabilities:** current missiles systems and advanced and developing missile capabilities, including hypersonic weapons technology and directed energy weapons.
- **Energy storage and batteries:** high-capacity batteries, with a particular focus on lithium batteries.
- **Castings and forgings:** metals or composites developed into key parts and tools through high-intensity processes.
- **Microelectronics:** State-of-the-Practice (SOTP) and legacy microelectronics as well as State-of-the-Art (SOTA) microelectronics

This report also provides an update on the implementation of the recommendations in DoD's Review of Critical and Strategic Materials, included in the 100-day response to E.O. 14017 published on June 8, 2021.[6] Though this supply chain remains a high priority, this report does not go in depth on critical and strategic materials, since the June report covered this area.

Underpinning all four key focus areas are strategic enablers that are required for mission success. Fragility or gaps in these enablers create operational and strategic risk and addressing the challenges in each is critical to building overall supply chain resilience. The strategic enablers are:

- **Workforce:** trade skills through doctoral-level engineering skills.
- **Cyber posture:** industrial security, counterintelligence, and cybersecurity.
- **Manufacturing:** current manufacturing practices, as well as advanced technology like additive manufacturing.
- **Small business:** the role of key members of DoD supply chains.

6. United States, White House, *Building Resilient Supply Chains, Revitalizing American Manufacturing, And Fostering Broad-Based Growth, 100-Day Reviews Under Executive Order 14017.* June 2021.

The national security significance of each focus area and strategic enabler is detailed in subsequent sections, along with core challenges in each area and strategic recommendations to mitigate those threats and vulnerabilities.

Recommendations Framework

To structure its supply chain efforts, the DoD developed a framework to organize its planning into four actionable groupings. Because resilience requires cooperation, this report aligns its recommendations to efforts centered on internal, interagency, international, and industry initiatives. Figure 1 outlines this framework.

Figure 1. DoD's Supply Chain Resilience Framework

This report therefore provides a comprehensive, strategic review of critical defense supply chains and the steps that can be taken to build resilience in each—in collaboration with DoD organizations, the interagency, international allies, and industry partners.

Cross-Cutting Recommendations

Cross-Cutting Recommendations

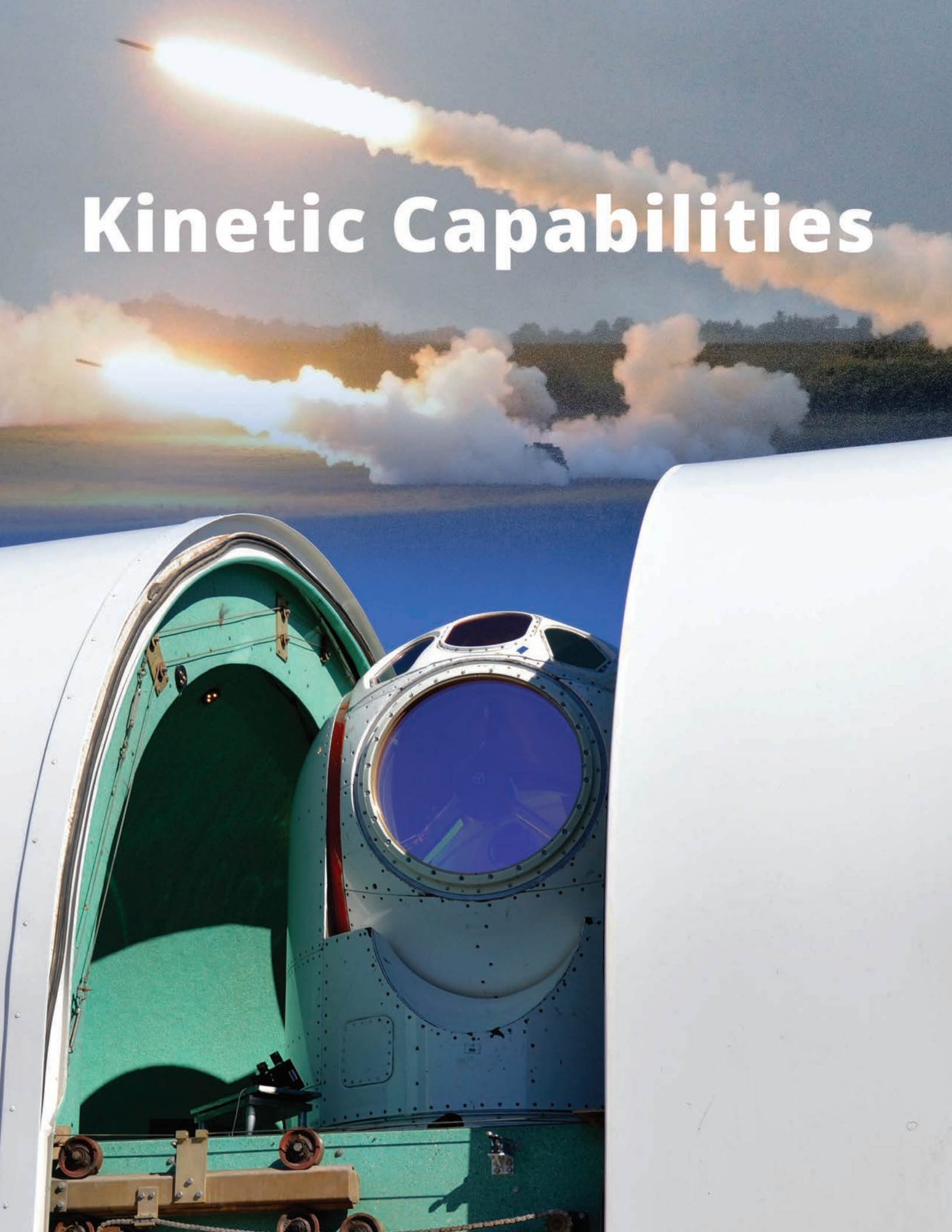
The DoD examined the focus areas and strategic enablers, and developed recommendations that address the core sector challenges in each, organized into the supply chain resiliency framework. During this process, consistent recommendations emerged across the focus areas and strategic enablers. Because they appear across the supply chains highlighted in this report, it is clear that these are critical recommendations for strategically building resilience in the defense industrial base. DoD must take an enterprise-wide approach to effectively address these broad-reaching recommendations, and work with the appropriate partners to coordinate and act on these recommendations:

- **Build domestic production capacity:** Working in close partnership with industry and the interagency, DoD will further develop acquisition strategies and contracting mechanisms that favor domestic sources and collaborate with international allies to diversify domestic and allied supply chains to support the on-shoring and ally-shoring of critical supplies. For those supply chains that are critical for national defense, the U.S. is committed to ensuring reliable production access within its defense industrial base. The DoD will invest, as needed, to ensure defense production can withstand supply chain disruptions.
- **Engage with partners and allies:** The U.S. is collaborating with its international partners and allies to develop policies and arrangements that strengthen our defense industrial bases and improve supply chain resilience. Over the past several years through Reciprocal Defense Procurement Agreements, bi-lateral engagements, and continued dialogue, DoD and its partners have identified opportunities to collaborate and share information. Additional actions DoD will pursue over the next year include: strengthening channels of information sharing through bilateral agreements and establishing working groups to pursue joint actions.
- **Mitigate Foreign Ownership, Control, or Influence (FOCI) and safeguard markets:** DoD is committed to diversifying its supply chains through collaboration with its partners and allies. The Department is just as committed to protecting its supply chains and defense industrial base from adversarial FOCI. This effort requires a front-end assessment of a program's acquisition strategy to ensure a resilient supply chain. Early identification of any FOCI concerns enables mitigation before contract or grant awards. The Department will scale its efforts to identify and mitigate FOCI in supply chain decision-making to ensure investments are not degraded through counterfeit, compromise, or theft.

- **Conduct data analysis:** Over the next year, DoD will continue to build on previous efforts to expand its supply chain visibility. This effort will begin with evaluating the data needed to inform real-time supply chain management decisions. Collecting and organizing key data will position the Department to maximize the use of analytic tools and mitigation strategies to proactively identify and address trends, vulnerabilities, and disruptions.
- **Aggregate demand:** Despite the Department's considerable resources, it still struggles to secure reliable supply at reasonable cost. This is driven in part by the small market size for many defense requirements and DoD's program-driven procurement cycles. Since each program consumes a small portion of total demand, it is difficult for industry to anticipate the number of orders from year to year. DoD can better signal to industry what the likely total demand across multiple programs in the near term.
- **Develop common standards:** To leverage commercial sector innovations and to embed modernizing technologies in weapon systems the DoD should, where possible, work to limit its use of military-unique requirements when developing performance requirements. These efforts include collaborating across the Services, as well as with industry, to understand and align standards where practicable and gain the benefits of competitive commercial markets.
- **Update acquisition policies:** DoD's procurement and budget policies create a challenging business environment for industry, especially small businesses. DoD should advocate for and be an active participant in efforts to develop a whole-of-government strategy and implementation plan to engage with private industry (small, medium, and large businesses), industry associations, capital providers, and stakeholders to determine which policy and regulatory changes would encourage expansion of capabilities. Further, DoD will work with Resource Sponsors and Program Offices during program review to develop smoother procurement cycles. Finally, DoD will continue engaging with Congress to present options to minimize the effect of uneven procurement funding on the defense industrial base.

These themes emerged in most, if not all, of the focus area discussions on supply chains in this report. They are important foundational recommendations that underlie and support the more tactical recommendations in each section and that will require collaboration internally, and with the interagency, international allies, and industry partners.

Kinetic Capabilities



Kinetic Capabilities

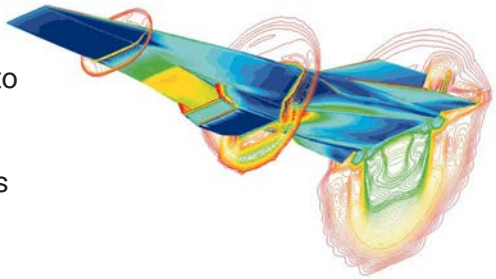
National Security Significance

As missile technology matures and proliferates among potential adversaries, the threat to the U.S. and its deployed forces, allies and partners is growing. Kinetic capabilities are increasingly essential to deterring America's adversaries. These capabilities include missiles systems, as well as advanced and developing missile capabilities, including hypersonic weapons technology and directed energy weapons systems. Adversary military buildup in conventional, strategic, cyber, and hypersonic capabilities poses an acute challenge for the United States.

> *"We're determined to deter aggression, and to prevent conflict, and to establish common sense guardrails."*
>
> - Secretary of Defense Lloyd Austin III

For the last 20 years, the DoD's procurements for kinetic weapons have focused on meeting current operational needs (e.g., Operation Inherent Resolve) and reducing inventory shortfalls incurred from the counter-Islamic State of Iraq and Syria (ISIS) operations. The result has been a conflict-driven pattern of procurement that runs counter to the sustainment of the DIB.[7]

Current and future kinetic capabilities required to prosecute combat operations are intrinsic to U.S. national security. Resilience of prime integrators and their sub-tier suppliers is key to this defense-unique sector of the economy. Current efforts focus on addressing critical vulnerabilities in supply chains for existing operational platforms and those required for future fights, such as hypersonics, a key element of the DoD's modernization activity.



7. See: *Industrial Capabilities Report to Congress: 2020 Annual Report*, pg. 85. https://www.businessdefense.gov/Portals/51/USA002573-20%20ICR_2020_Web.pdf?ver=o3D76uGwxcg0n0Yxvd5k-Q%3d%3d.

Sector Challenges

There is no commercial market for kinetic capabilities (e.g., precision guided munitions, hypersonics, directed energy), as demand for these weapons is sustained solely through defense requirements. However, the commercial market drives the development cycles and production capabilities for some commodity items (e.g., electronic and electrical components, rare earth elements, chemicals, etc.) used in integral subcomponents such as guidance and control systems. Increasing the resiliency of other DIB sectors (as discussed in the following sections) will enable and support the kinetic industrial base. This section outlines four key challenges within the kinetic sector.

Sub-Tier Supply Chain Vulnerabilities

The industrial base for kinetic capabilities faces persistent sub-tier supply chain vulnerabilities, from raw materials and chemical shortages to critical subcomponents produced by fragile suppliers. For several decades, the DoD has entrusted supply chain visibility and risk management to companies in the private sector that provide it with defense capabilities. Consequently, the DoD has limited visibility into some sub-tiers of defense supply chains and does not track these vulnerabilities as they impact weapons programs. As supply chains have become more global in scale, prime contractors have lost some visibility into the sub-tiers of their supply chains, especially below third-tier levels. Multiple categories of programs depend on a strained supplier base—conventional missiles and munitions, hypersonic development, and strategic systems modernization—which exacerbates the issues.

Foreign and Sole Source Dependency

U.S. reliance on sole-source suppliers and foreign sources poses risks to domestic capability and capacity to produce kinetic capabilities. Over time, many domestic suppliers have lost business and/or exited the market due to unstable DoD procurement practices and competitive pressure from foreign nations, particularly China. For example, China's lower production costs make importing materials more profitable than producing the same material domestically. It also reduces the likelihood of U.S. private capital investment, leading to erosion of the profitability and competitiveness of U.S. manufactured materials and resources.

DoD Acquisition Processes

Producers benefit from steady or predictable orders, so the DoD's inconsistent procurement and concurrent production ramps (both increases and decreases) exacerbate the challenges suppliers face across the DIB. DoD revises procurement quantities annually based upon annual appropriations, since DoD priorities and congressional markups impact procurement plans. Sub-tier suppliers, particularly smaller or specialized suppliers with capital constraints, are significantly impacted by these fluctuating procurement budgets and by delays in annual fiscal appropriations and subsequent contract award delays due to continuing resolutions. Because of these postponements and lack of a commercial customer base to sustain business during downturns, industry struggles with forward-planning, especially with respect to workforce and raw material requirements.[8]

Hypersonics Industrial Base Development

As hypersonic programs transition from prototype to acquisition programs, production throughput may be hampered by a number of issues. These issues include suboptimal manufacturing processes (e.g., highly labor-intensive processes, strict manufacturing tolerances, etc.) and higher performance

8. Office of the Under Secretary of Defense (Comptroller)/Chief Financial Officer, Defense Budget Overview: United States Department of Defense Fiscal Year 2022 Budget Request, May 2021 Pgs. 22-23 (listed as 2-11 and 2-12) *https://comptroller.defense.gov/Portals/45/Documents/defbudget/FY2022/FY2022_Budget_Request_Overview_Book.pdf*.

requirements compared to conventional missiles due to the harsh environments in which these systems will operate. This means the programs are limited by existing material solutions, and new material solutions must be identified or developed to meet requirements. To drive the business case for industry to self-invest, a clear procurement forecast must be shared with industry partners.

Summary

There is no commercial market for missiles, and the defense sector alone cannot drive demand for components. Therefore, the DoD must engage where it can to promote a healthy DIB for component parts that have commercial applications and ensure steady demand signals and funding to support bespoke DoD needs. The recommendations below, and throughout this report, will outline how DoD can continue to offer this type of support. Improvements in other DIB sectors—energy storage, castings and forgings, microelectronics, critical materials, etc.—will enable and support the production of the kinetic capabilities required for the U.S. national security mission. Note that the challenges above may affect aspects of missile production in combination. As an example, the acquisition of chemicals critical to the production of these systems— in particular, those used to produce explosives and propellants—are also affected by fragile suppliers, sole-source dependencies, foreign sourcing, limited supply chain visibility, outdated Government guidance, and limited demand. These are the types of challenges the DoD is focused on addressing in the near term.

Recommendations

Internal

Recommendation K1.1: Address supply chain vulnerabilities to critical chemical supply. DoD's Critical Energetic Materials Working Group (CEMWG) continues to identify the most critical chemicals required for kinetic production. The prioritized list should be used to inform fiscal year (FY) 2023 and future DoD funding (Service, Defense Production Action Title III, IBAS, ManTech, etc.) and stockpiling decisions.

Recommendation K1.2: Update material specifications. Many specifications are decades old with antiquated production and quality testing requirements out of line with modern industrial practices. Updating these specifications may encourage alternative sourcing and increase completion by lowering the barrier of entry for the production of materials. Over the next 12 months, CEMWG's first priority should be to identify chemical specifications to be updated and develop funding options to inform FY 2024 budgets.

Recommendation K1.3: Invest in the hypersonic industrial base. DoD is developing a hypersonics industrial base roadmap to inform investments over the next five years, which will guide investment decisions over this period. The roadmap will address sub-tier supplier development, and where appropriate, develop and retain competition that enables affordable production. It should be used to help guide and inform procurements by the Military Services to optimize synergies within the DIB.

Additional internal recommendations on data collection and analysis for supply chain visibility are captured in the Cross-Cutting Recommendations section.

Interagency

Recommendation K2.1: Collaborate with Department of Commerce (Commerce), Department of Energy (DOE), National Aeronautics and Space Administration (NASA), and Federal Trade Commission (FTC). DoD should continue to work with other interagency partners to (1) leverage collective demand to help support a healthy industrial base and reduce supply chain disruption, (2) review mergers and acquisitions that may reduce supply chain security within the DIB, and (3) to annually review the state of competition within the DIB.

International

Recommendation K3.1: Identify and develop allied and partner capabilities. DoD should, over the next six months, identify partners and allies with capabilities to aid in the development and expansion of its hypersonics supply chain, especially for materials and components where domestic sources may not exist. Over the next 12 months, the Department should collaborate with allies and partners to secure identified sources, where possible.

Industry

Recommendation K4.1: Partner with industry to identify and mitigate supply chain issues. DoD should, over the next 12 months, expand existing capabilities and develop new tools for an industrial base analytic capability that better inform and enable DoD decision-makers to identify supply chain challenges, communicate specific concerns to industry, and mitigate risks as appropriate. The focus of the tools should be on identifying sub-tier production limitations.

Table 1 maps the recommendations against the four challenge areas for kinetic capabilities.

Table 1. Challenges and Recommendations for Kinetic Capabilities

		Sub-Tier Supply Chain Vulnerabilities	Foreign and Sole Source Dependency	Foreign and Sole Source Dependency	Hypersonics Industrial Base Development
Internal	**Rec K1.1: Address vulnerabilities to critical chemical supply**	✓	✓		
	Rec K1.2: Update material specifications		✓	✓	
	Rec K1.3: Invest in hypersonic industrial base				✓
Interagency	**Rec K2.1: Collaborate with Commerce, DOE, NASA, and FTC**	✓	✓	✓	✓
International	**Rec K3.1: Identify and develop allied and partner capabilities**	✓	✓	✓	✓
Industry	**Rec K4.1: Partner with industry to identify and mitigate supply chain issues**	✓	✓		✓

Energy Storage and Batteries

Energy Storage and Batteries

National Security Significance

The *"Large Capacity Batteries"* section of the 100-day report laid out in extensive detail the numerous supply chain challenges associated with lithium battery production that the United States currently faces.[9] The *"Defense Annex on Advanced Batteries"* of the 100-day report outlines defense and deterrence impacts for battery supply chains and provides five recommendations for improvement:[10]

1. Coordinate a DoD-wide approach to establishing a battery strategy.
2. Identify mechanisms for measuring defense supply chain risks, such as diminishing manufacturing and material shortages in legacy system batteries, and for addressing these risks, such as transitioning to newer, safer, and higher energy capabilities.
3. Establish DoD-wide cataloguing of advanced batteries for current and future applications.
4. Define future battery supply chain requirements and further assess opportunities to leverage the commercial industry.
5. Assess opportunities to leverage commercial industry.

Relatedly, on June 8, 2021, the *National Blueprint for Lithium Batteries 2021-2030* ("National Blueprint") was released by the DOE.[11] It established five clear goals for the Federal Government to achieve, with national security as a foundational element (see Figure 2). These goals address the pillars of the battery supply chain: mining, materials processing, cell and pack production, and recycling. Inclusive of these goals is the need to ensure workforce development supports the growth and technical leadership of the U.S. lithium battery industry.

9. United States, White House, *Building Resilient Supply Chains, Revitalizing American Manufacturing, And Fostering Broad-Based Growth, 100-Day Reviews Under Executive Order 14017.* June 2021.
10. United States, White House, Defense Annex, *Building Resilient Supply Chains, Revitalizing American Manufacturing, And Fostering Broad-Based Growth, 100-Day Reviews Under Executive Order 14017.* June 2021.
11. United States, Office of Energy Efficiency & Renewable Energy, *National Blueprint for Lithium Batteries 2021–2030,* June 2021.

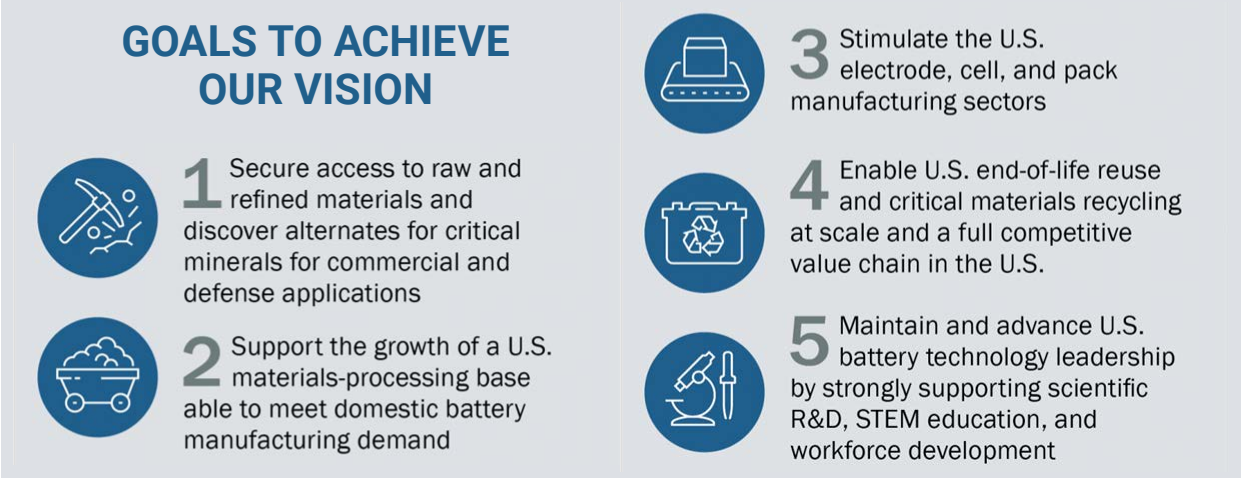


Figure 2. Federal Consortium for Advanced Batteries National Blueprint Goals.

The recently signed Bipartisan Infrastructure Law (BIL) provides domestic investments in the supply chain to tackle the goals in the National Blueprint, presenting an opportunity to pursue dual-use (i.e., commercial and defense) investments, which strengthen the U.S. commercial sector while closing supply chain gaps affecting national security.[12]

Sector Challenges

The global lithium battery market is highly dynamic with technological advancements and policy adjustments creating massive shifts in capital investment planning—sometimes in weeks and months rather than years and decades. To secure its access to supply in the context of this rapidly evolving commercial sector, DoD's approach to addressing the following sector challenges must be flexible and adaptive to evolve with the market.

China's Supply Chain Dominance

By far the largest challenge for securing the supply of lithium batteries for DoD is the power of China's industrial base. China dominates the global advanced battery supply chain, including lithium hydroxide (94 percent), cells (76 percent), electrolyte (76 percent), lithium carbonate (70 percent), anodes (65 percent), and cathodes (53 percent).[13, 14] Even materials and components manufactured domestically often have reliance on China-produced precursors or are fragile suppliers and single point failures within the supply chain. As electrification is expected to accelerate dramatically by 2030, reliance on China will grow and China's relative cell dominance is projected to remain stable.[15] As DoD pursues initiatives to address battery sector challenges, second and third order effects should be studied to ensure reliance on China's cells and material does not inadvertently grow.

12. United States, Congress, Public Law 117-58, *https://www.congress.gov/bill/117th-congress/house-bill/3684*.
13. Benchmark Mineral Intelligence. *Benchmark Mineral Intelligence Report*, Battery Components Manufacturing Asset Map 2019.
14. National Minerals Information Center, *Mineral Commodity-Specific Supply Risk Mitigation Framework*, PowerPoint Presentation June 10th 2021 Minerals Resource program, USGS referencing S&P Global Market intelligence, Roskill, Bloomberg NEF, International Energy Outlook and BCC Research data.
15. Benchmark Mineral Intelligence, *Lithium-Ion Battery Megafactory Assessment*, March 2021. Accessed April 12, 2021. Note: projected capacities vary by source/assessment.

Custom Design Standards

DoD components currently use custom designs that are generally not standardized with commercial-use batteries. For example, the shape and size of cells produced for electric vehicles (EVs)—which are driving the vast majority of domestic cell production growth—are not presently well-suited for many DoD applications. The proliferation of specialty batteries disaggregates demand, impedes the DoD's ability to influence industry standards, and increases the risk of obsolescence across weapon systems. Since the DoD represents a small portion of total battery requirements, low demand and high production costs for DoD-specific standards disincentivize industry from producing for defense needs and inhibits adoption of high-volume commercial batteries. Therefore, commercial battery makers shape the battery industrial base on which DoD depends. This gap in standards creates a barrier for leveraging the $515 billion in active global auto industry investment (in EVs and EV batteries through 2030).[16] Ford and General Motors (GM) are expected to invest a combined $60 billion through 2025, deciding individually which areas to invest the money.[17] For supply chain security, the DoD is already positioning itself to take advantage of the automakers historic commercial investments in electric vehicles.

Acquisition Policy

DoD's acquisition policies further exacerbate battery standardization and market challenges. Despite a preference for domestic sources, present acquisition regulations provide limited mechanisms for prioritizing domestic or allied sources in solicitations for commercial solutions. Even in a best value source selection, the incentive to provide systems at the lowest practicable cost often leads to selection of low-cost cells produced in China with inherent environmental and human rights concerns. The challenges can be even greater with sub-tier suppliers. Building out domestic capacity in battery production without establishing demand will not resolve this challenge because the existing procurement methods may drive contractors towards lowest cost.

Supply Chain Data

Inadequate data management practices hamper DoD's standardization efforts, investment planning, and the development of key supplier relationships. Without knowing the full catalog of batteries DoD needs and uses, the Department will not be able to develop or adopt solutions that meet broader requirements and strategy. DoD would benefit from aggregating its demand signal. This would enable industry to establish long-term relationships with their material suppliers and encourage long-term capital and workforce investments that increase profitability and lower costs to DoD.

Infrastructure

As advanced batteries grow larger and more complex, the DoD should mature its battery safety testing and certification processes for qualifying the increasing numbers of fielded systems and future systems. Additional facilities are required to enable the DoD to characterize battery failures and performance attributes of large systems intended for use in current and future applications.

Organization and Structure

Historically, no existing central organization or entity was responsible for addressing battery challenges within DoD. To date initiatives to build resilience in battery supply chains have been service-specific, sporadic, and difficult to coordinate with limited success. This decentralized and siloed approach complicates engagement with industry and hinders DoD's ability to reliably source necessary batteries.

16. Paul Lienert and Tina Bellon. *"Exclusive: Global carmakers now target $515 billion for EVs, Batteries."* Reuters November 2021. https://www.reuters.com/business/autos-transportation/exclusive-global-carmakers-now-target-515-billion-evs-batteries-2021-11-10/, accessed 10 December 2021.
17. Paul Lienert and Tina Bellon. *"Exclusive: Global carmakers now target $515 billion for EVs, Batteries."* Reuters November 2021. https://www.reuters.com/business/autos-transportation/exclusive-global-carmakers-now-target-515-billion-evs-batteries-2021-11-10/, accessed 10 December 2021.

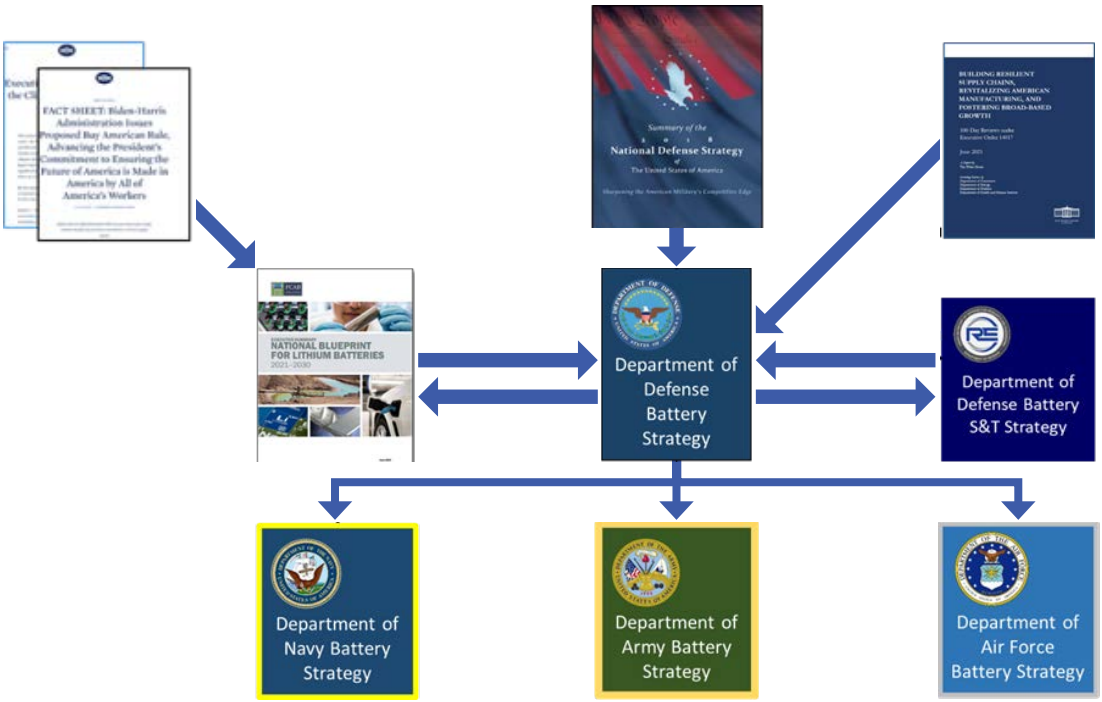


Figure 3. **Department of Defense Battery Strategy Integration.**

Recommendations

While the aforementioned challenges have already led to significant action, the following DoD recommendations require flexibility in the face of a fluctuating battery market and a need to continuously reassess and reevaluate ongoing initiatives to make necessary adjustments.

Internal

Recommendation B1.1: Develop a defense-specific lithium battery strategy. The DoD will develop a lithium battery strategy linking U.S. Government priorities outlined in the National Blueprint to national security priorities, including the National Defense Strategy. This alignment will maximize the value of U.S. Government investment and action in support of national defense (see Figure 3, above). The strategy is scheduled to be completed by the first quarter of FY 2023.

By aligning the DoD strategy to the National Blueprint, DoD will work across the interagency, leveraging efforts initiated within the Federal Consortium of Advanced Batteries (FCAB) by partner agencies such as the Departments of Commerce, DOE, and State, focused on tackling the National Blueprint goals. While the National Blueprint goals are broadly focused on U.S. Government needs, success in any or all of the five goals would improve the security of the DIB for advanced batteries.

Recommendation B1.2: Develop a prioritized plan to resolve battery infrastructure and analytic gaps. Over the past eight months, DoD assessed the scale of the standardization, analytics, and infrastructure problem. Over the next 12 months, in support of the strategy development, DoD will establish a prioritized plan to begin resolving the battery standardization, analytic, and infrastructure gaps. This includes exploring opportunities to adopt supply chain management best practices, such as centralizing information on the type, volume, and future projections of internal battery demands.

Recommendation B1.3: Use DoD investment authorities to leverage commercial investments. In support of DoD's lithium-ion battery strategy development, DoD should develop an implementation plan identifying joint investment opportunities that team industry with the DoD to jointly solve workforce and training issues, improving communication on standards, certification, and procurement approaches to enable better planning and out-year investments.

Interagency

Recommendation B2.1: Work with the DOE and interagency partners to develop integrated investment plans. DoD should work with DOE to convey national security interests as the distribution of the BIL resources are planned and decided. The law contains $3B of investment between FY 2022 and FY 2026 in the area of mineral and material mining and battery materials processing, and $3B focused on battery cell and pack production and recycling. DoD plans to use the FCAB to work with its interagency partners, such the Department of Commerce and Department of Transportation, to coordinate investments across different authorities.

Recommendation B2.2: Coordinate recycling initiatives with DOE. DoD should leverage advancements in battery recycling technology, being led by DOE, and to the greatest extent practical, return battery materials to the domestic supply chain to further reduce reliance on foreign sources.

International

Recommendation B3.1: Enhance interoperability and supply chain coordination. DoD's battery experts should focus on standardization and establish formal objectives and milestones. Ongoing discussions in multilateral organizations, such as the Military Power Sources Committee and the National Technology and Industrial Base (NTIB), should be leveraged to advance this recommendation.

Industry

Recommendation B4.1: Standardize and aggregate battery demand. Standardization and aggregation of demand is central to DoD's approach to bolstering battery supply chain resilience, but it must be done in coordination with and alignment with the efforts of industry partners. This begins with conducting a cross-Service collection of type and quantity of batteries utilized to develop a consolidated inventory of batteries used in DoD systems. With this internal visibility, DoD should then collaborate with industry to understand and align standards – both within DoD, and with commercial standards wherever practicable – to ensure future defense requirements can be produced affordably, while meeting warfighter needs. Additionally, this will ensure DoD can fully leverage the substantial domestic investments in EV battery production, testing and grid energy storage, and maintain a continual technological advantage from the batteries we employ.

Additional industry recommendations focusing on leveraging commercial capital, innovation, and standards are captured in the Cross-Cutting Recommendations section.

Table 2 (next page) maps the recommendations against the six challenge areas for batteries and energy storage.

Table 2. **Challenges and Recommendations for Batteries and Energy Storage.**

		China's Supply Chain Dominance	Custom Design Standards	Acquisition Policy	Supply Chain Data	Infrastructure	Organization & Structure
Internal	**Rec B1.1: Develop a defense-specific lithium battery strategy**	✓	✓	✓	✓	✓	✓
	Rec B1.2: Develop a prioritized plan to resolve battery infrastructure and analytic gaps				✓	✓	✓
	Rec B1.3: Use DoD investment authorities to leverage commercial investments	✓					
Interagency	**Rec B2.1: Work with the DOE and interagency partners on integrated investment plans**				✓		
	Rec B2.2: Coordinate recycling initiatives with DOE	✓					
International	**Rec B3.1: Enhance interoperability and supply chain coordination**	✓	✓				
Industry	**Rec B4.1: Standardize and aggregate battery demand**		✓			✓	

Castings and Forgings

Castings and Forgings

National Security Significance

Cast and forged (C&F) parts are critical to the development, procurement, and sustainment of all major defense systems by the DIB, including, where applicable, the organic industrial base (OIB). They are used in almost all platforms (e.g., ships, submarines, aircraft, ground combat vehicles, spacecraft, etc.), kinetic weapons and weapon systems (e.g., guns, missiles and rockets, bombs, ammunition, artillery pieces, etc.), and many supporting systems (e.g., vehicles, powered support equipment, etc.). In 2020, the Defense Logistics Agency (DLA) identified 30,061 out of 32,597 specialized end items that contain C&F maintenance, repair, and operations (MRO) parts. Many of these parts are high importance/low-volume and minimal demand items[18] that support "critical go-to-war weapon systems and platforms that affect military readiness."[19] C&F products are essential components of the machine tools and other equipment used to produce and sustain fielded systems and forgings are found in 20 percent of the products representing the gross domestic product of the United States.[20]

Organic Defense Industrial Base (OIB)
The OIB includes government-owned government-operated (GOGO) and government-owned contractor -operated (GOCO) facilities that provide specific goods and services for the DoD.

Casting and Forging
Casting is the process used to create geometrically complex parts by pouring molten or high-temperature metal or composites into a mold.

"About Metalcasting." American Foundry Society

Forging is the process used to develop metal parts by pounding, pressing, or squeezing metals under great pressure; the metals are often preheated before working but are never melted.

"Forging Facts: What is Forging?" Forging Industry Association

Manufacturers use C&F capabilities to provide specific material properties in intermediate products[21] and end items that cannot be produced by other manufacturing processes. Production of C&F parts often includes

18. United States, Defense Logistics Agency Industrial Capability Program, "*2019 Castings Summit & Industry Review*," February 26, 2020.
19. *Ibid.*
20. Forging Industry Association, Vision of the Future, https://www.forging.org/producers-and-suppliers/technology/vision-of-the-future, accessed December 8, 2021.
21. *Ibid.* The vision says, *"The industry is a key link between critical manufacturing segments--metal suppliers (both ferrous and nonferrous) and end user industries. Forgings are intermediate products used widely by original equipment manufacturers in the production of durable goods. They range in size from less than an ounce to more than 150 tons and are found in the machines, vehicles and equipment used to generate our industrial economy."*

heat treatment to ensure specific material properties and machining to produce precise shapes and finishes. The resulting products are long-lived, rugged, and can withstand high temperatures, pressures, and stresses. Although people have produced cast and forged products for thousands of years, the relevant processes, equipment, and technologies continue to evolve and improve.

Dependence on foreign sources for key materials and production capabilities can introduce FOCI threats and presents a strategic vulnerability that increases the time and cost to deliver new systems and maintain current capabilities, especially if global transportation channels are backlogged or threatened. The United States needs a robust and secure C&F industry and supply chain to provide reliable, timely delivery of the parts used in DoD's operational systems and to produce and sustain new systems.

Sector Challenges

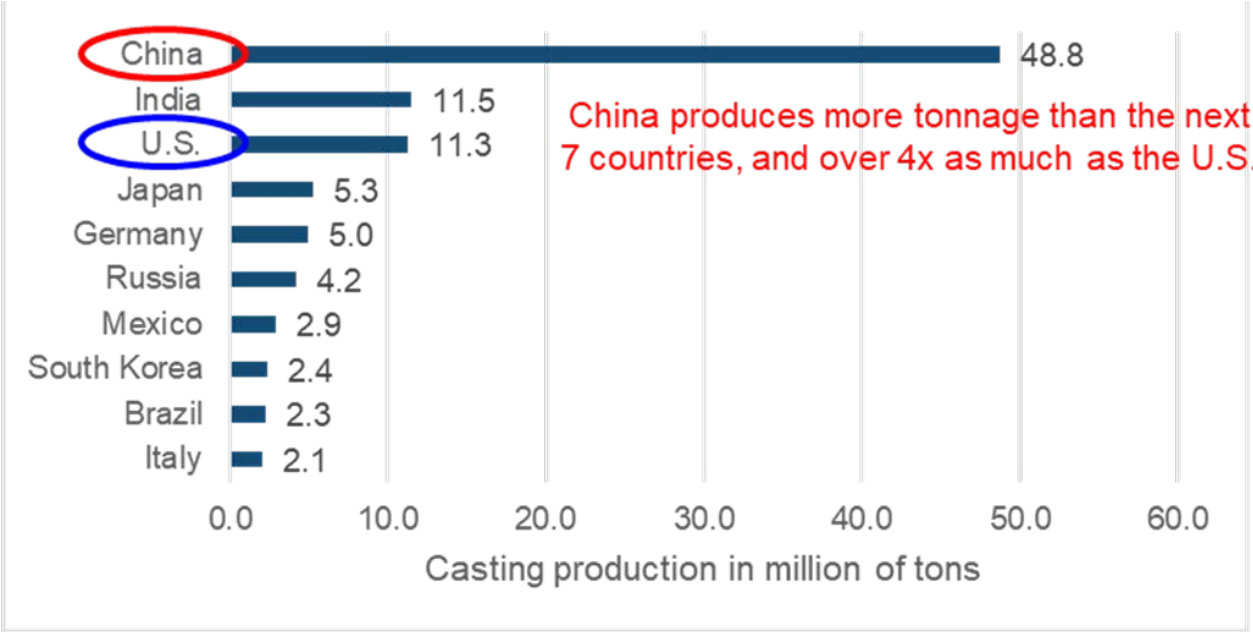
The U.S. C&F industry faces challenges related to capability and capacity, workforce, and U.S. Government policies. Like all businesses, domestic producers need predictable demand, costs, and returns to compete successfully for global market share. In some cases, DoD product needs involve specialized, often low-density requirements that can only be addressed by a small portion of the casting and forging market. Furthermore, the variability of DoD funding (timing and amount) creates challenges for businesses trying to satisfy DoD needs. Industry currently prefers to pursue commercial work. Obstacles to expanding DoD's sources of supply in this area lie in the complex Federal contracting process, the need for improved technical data requirements, and the requirement to modify plant capabilities to support the manufacturing of products that meet military specifications.

Capability and Capacity

The Military Services have experienced casting and forging capability and capacity challenges that can be attributed in part to the impacts of offshoring and waves of industry consolidation since the mid-20th century. For example, the United States has only one foundry that can produce the large titanium castings required for some key systems. The Army has also identified shortfalls in production and heat treatment of specialty alloys that are mission critical.[22] The Navy has documented C&F capacity and quality issues affecting many facets of shipbuilding.[23] The Air Force has identified needs for the ability to cast single crystal turbine blades and large thin-wall titanium components, an additional source for an extrusion press used for powder nickel super alloy billets, and downstream post-processing capacities and capabilities—including heat treating, coating, hole drilling, machining, and hot isostatic pressing to help eliminate unwanted voids and provide increased strength in cast products.[24] Although some suppliers have updated equipment over time in an attempt to meet the Services' needs, many commercial and OIB C&F plants have aging equipment or are limited by existing facilities, infrastructure, and, for commercial firms, state and federal operating permits.[25]

22. Army inputs to September 2021 Deputies Management Action Group briefing. The closure of key West Coast heat treatment facilities has significantly lengthened schedules and added costs due to the need to repeatedly ship parts to suitable heat treatment facilities in other places during the manufacturing process.
23. A government-only 2021 analysis for the Navy reported the need for reliable production of extremely large C&F parts is such a high concern to DoD that the Navy added an NTIB firm to produce large cast shapes for shipbuilding due to domestic suppliers' capacity and quality issues.
24. Air Force Research Laboratory, *USAF View of Military Supply Chain Concerns (Castings and Forgings),* 25 October 2021.
25. For example, the Army recently invested over $65M to upgrade a critical rotary forge at Watervliet Arsenal, NY.

Figure 4. **Statista Research Department, Volume of the Global Casting Production in 2019, by Country, 23 March 2021.**[26]



U.S. supply chains currently involve significant materials and products from foreign manufacturers. Multiple U.S. sources report that China and other foreign suppliers can often deliver a completed item for the same cost that a U.S. forge will pay for the raw materials needed to produce the parts of an item. As shown above in Figure 4, China is the world's leading producer of cast products by a wide margin. DoD counts on foreign countries, including China, for very large cast and forged products used in the production of some defense systems and many machine tools and manufacturing systems in which the DoD is reliant.[27]

As domestic capacity and overall market share erode, fewer U.S. and allied firms can afford improvements to equipment and processes. Limited access to capital for America's small and medium size producers has hindered their ability to invest in the necessary technologies. This includes the adoption of innovative processes and complementary technologies such as additive manufacturing, robotic automation, and digital engineering to support reverse engineering of aging parts.

Acquisition and Program Protection Policy

Low-volume work driven by U.S. Government and DoD procurement practices incurs high startup costs and produces limited profits. Many small and medium sized manufacturers find it challenging to create sustainable businesses or production lines in this space. Although many trade policy actions are conducted pursuant to specific authorities and designed to remedy injury to domestic industry and respond to unfair or unreasonable foreign trade practices, participants in DoD industry listening sessions reported that tariffs on raw materials used in U.S.-made C&F parts made U.S. products significantly more expensive than parts made in China, driving U.S. suppliers out of business.[28] Other challenges included traditional concerns about non-standard technical data packages, complex contracting process, burdensome accounting system requirements, small and unreliable demand, and a slow Government sales cycle.[29]

26. Figure 4 Source: *https://www.statista.com/statistics/237526/casting-production-worldwide-by-country/*
27. The Navy uses an English firm to supplement domestic suppliers of large parts required for shipbuilding.
28. DoD Castings & Forgings Industry Listening Session, *op cit.*
29. United States, Defense Logistics Agency Industrial Capability Program, *2019 Castings Summit & Industry Review, February 26, 2020.*

Technical Data Policy

Vendor control of detailed technical data for C&F parts can constrain DoD's ability to acquire affordable replacement parts, especially for long-lived systems. This is especially true if the original vendor no longer has the capability or desire to manufacture the part. It also makes it difficult for DoD to enable new manufacturers to produce replacement parts using specific geometries, materials, and manufacturing methods that can be constrained by lack of technical data or data rights.

In some such cases, DoD could create and use detailed, Government-developed technical data (i.e., product specifications including manufacturing equipment specifications and a detailed manufacturing "recipe") to address such issues. Experience at Oak Ridge National Lab's Manufacturing Demonstration Facility indicates that detailed Government-owned tech data can provide the following:

- Expand the supplier base ("democratize manufacturing") by licensing on a non-exclusive basis to as many manufacturers as needed that could afford to compete for defense work, reducing prices and pricing practices (i.e., opening non-commercial pricing).
- Increase speed and reduce the cost of first-part certification and acceptance (requires the IP to include a sufficiently complete manufacturing "recipe", which manufacturers must follow scrupulously). This reduces cost-based barriers to entry for new suppliers, increasing the size of the supplier base (including smaller businesses) that could afford to compete for defense work, thereby reducing prices and vendor lock.
- Contribute to development of a creative, competent workforce able to deliver next-generation solutions efficiently, as further discussed in the Workforce strategic enabler section.

Recommendations

Internal

Recommendation C1.1: Develop a C&F strategy. DoD is developing a cross-service C&F strategy to inform policy and investment decisions over the coming the years. The strategy will leverage market research evaluating DoD's casting and forging demand and the commercial sector's ability to meet DoD's requirements. Current plans call for publication no later than the end of the second quarter of FY 2023. The strategy will make recommendations concerning the following:

- Establishing C&F centers of excellence.
- Identifying other specific measures to improve the OIB's capabilities.
- Prioritizing DoD research into:
  - New C&F processes.
  - Alternatives to C&F, such as new subtractive and hybrid methods.
  - Expanding use of additive manufacturing and digital production capabilities as a tool to enhance traditional methods, such as 3D printing sand cores, and for direct manufacturing.
  - Identify specific opportunities requiring the development of Government-owned technical data.

Recommendation C1.2: Invest in the C&F industrial base. Based on the strategy developed in Recommendation C1.1, DoD should create and support a persistent C&F working group to guide execution of the investment plan and research activities, which will address sub-tier supplier and workforce

development, competition that enables affordable production, and designs and procurements that optimize synergies within the DIB.

Interagency

Recommendation C2.1: Expand government and industry partnerships. Guided by the strategy, DoD should continue to expand its current partnership, America's Cutting Edge (ACE), with DOE's Oak Ridge National Laboratory to refine ways to supplement C&F capabilities, including additive and hybrid manufacturing processes and metrology.[30] DoD should also leverage and build on the activities and capabilities of organizations like the American Metalcasting Consortium[31] and Forging Defense Manufacturing Consortium[32], among others, to share information, identify and fulfill research and development opportunities, and identify new sources of supply to support DoD's need for cost-effective, high-quality cast and forged parts. DoD should progressively expand its network of relationships to include other interagency partners.

International

Recommendation C3.1: Identify and develop allied and partner C&F capabilities. Guided by the investment strategy developed as part of the cross-service study from Recommendation C1.1, DoD should coordinate with its international partners to scope, develop, and implement plans to develop and coordinate C&F capabilities, including key aspects of the supply chain such as critical minerals and materials (and therefore in alignment with those recommendations and initiatives outlined in the 100-day review responding to E.O. 14017). Where appropriate, DoD should support the development of international agreements to develop and protect key technologies related to C&F (and suitable alternatives), machine tools, and industrial controls.

Additional international recommendations are captured in the Cross-Cutting Recommendations section.

Industry

Recommendation C4.1: Engage industry to develop domestic capacity. In developing its C&F strategy, DoD will engage the National Institute of Science and Technology's Manufacturing Extension Partnership to develop its understanding of industry's perspectives on building commercially viable domestic capacity.

Table 3 (next page) maps the recommendations against the three challenge areas for castings and forgings.

30. ACE is a national initiative for machine tool technology development and advancement. It has developed a computer numerical control (CNC) machining training program in collaboration with IACMI — The Composites Institute and Oak Ridge National Laboratory.
31. *https://amc.ati.org/cast-it/*
32. *https://www.ati.org/collaboration/fdmc/*

Table 3. **Challenges and Recommendations for Castings and Forgings.**

		Capability and Capacity	Acquisition and Program Protection Policy	Technical Data
Internal	**Rec C1.1: Develop a C&F strategy**	✓	✓	✓
	Rec C1.2: Invest in the C&F industrial base	✓		✓
Interagency	**Rec C2.1: Expand government and industry partnerships**	✓	✓	✓
International	**Rec C3.1: Identify and develop allied and partner C&F capabilities**	✓		
Industry	**Rec C4.1: Engage industry to develop domestic capacity**	✓		

Microelectronics

Microelectronics

National Security Significance

Microelectronics are critical for a wide variety of commercial and defense products—from cell phones, cars, and kitchen appliances to precision guided munitions, hypersonic weapons, and satellites. Defense, commercial, and critical infrastructure sectors are all dependent on a diverse supply of microelectronics products manufactured in a global ecosystem. Microelectronics technologies are a central component to DoD's advanced capabilities. Although most of DoD's current systems are reliant on State-of-the-Practice (SOTP) and legacy microelectronics, State-of-the-Art (SOTA) microelectronics are DoD's primary differentiator for asymmetric technology advantage over potential adversaries. Thus, access to measurably secure microelectronics is vital to the national security and economic prosperity of the United States.

Microelectronics products that contain silicon die chips are typically described as being manufactured at a specific technology node, such as 45 nanometers (nm) or 130nm, with the number typically referring to the dimension in nm of the smallest element in a transistor. Many technology nodes exist, ranging from 3nm up to 1 micrometer (μm) and above, and many variants exist within specific technology nodes. Grouping technology nodes, as illustrated on Table 4, is often done to facilitate clarity, but note that such groupings are subjective, and many others exist.

Group Name	Technology Node Range	Primary Use by Sector
State-of-the-Art (SOTA)	<10nm	Consumer Electronics, Advanced Computing[33]
State-of-the-Practice (SOTP)	10nm to 90nm	Commercial, Automotive, Defense
Legacy (Extant)	>90nm	Limited Commercial, Defense

Table 4. General Technology Node Grouping.

33. Advanced computing including datacenters, supercomputers, artificial intelligence, and other similar applications that use SOTA chips.

Microelectronics technology continually advances, and as new technology nodes supplant previous-generation technology, today's SOTA will become SOTP and legacy in the future.

The manufacturing flow of microelectronics is extremely complex. Wafer fabrication alone involves 500 processing steps with an associated lead time of 14 to 16 weeks.[34] Microelectronics products fabricated on silicon die typically follow a generalized manufacturing flow:

- **Product design:** e.g., facilitated by Electronic Design Automation (EDA) tools.
- **Fabrication:** lithographic patterning and manufacturing of silicon die on a common substrate or wafer.
- **Packaging and assembly:** singulation of silicon die, integration of die into package.
- **Final test and quality control:** electrical testing to ensure product functionality and reliability.

The microelectronics supply chain is global in nature. Although manufacturing is centralized in the Asia-Pacific region, the ancillary industries that support manufacturing are globally dispersed. For example, in 2019, 74 percent of the EDA industry resided in the United States.[35] Production of semiconductor manufacturing equipment is led by corporations located in the United States, the European Union, and Japan. Chemicals and starting materials, such as blank wafers, are sourced from multiple nations including China, South Korea, Japan, and France. The size and complexity of the global microelectronics supply chain can be inferred from the fact that there are over 10,000 large microelectronics distribution companies dispersed globally that serve as distribution points for over 500,000 microelectronics components.[36] In terms of revenue, the market is also very large. As of December 2021, the Semiconductor Industry Association (SIA) estimated a global market revenue of $553 billion in 2021, which is up 25.5 percent compared to 2020 sales totals.[37]

However, 88 percent of the production, and 98 percent of the assembly, packaging, and testing of microelectronics is performed overseas—primarily in Taiwan, South Korea, and China (with China aggressively pursuing a larger market share).[38] In 1990, the U.S share of global semiconductor manufacturing capacity stood at 37 percent. In 2020, the U.S share had declined to 12 percent.[39] Figure 5 (next page) illustrates the global wafer capacity through 2020.

34. International Federation of Automatic Control. *"Supply Chain Complexity in the Semiconductor Industry: Assessment from a System View and the Impact of Changes"*. Elsevier/Science Direct. 2015.
35. Boston Consulting Group (BCG), "*Strengthening the Global Semiconductor Supply Chain in an Uncertain Era*." April 2021. *BCG-x-SIA-Strengthening-the-Global-Semiconductor-Value-Chain-April-2021_1.pdf (semiconductors.org)* (Ex. 1 on p. 5).
36. Can Sun, Thomas Rose, et al., *"Best Practice Sharing for Complexity Management in Supply Chains in the Semiconductor Industry"* 48th annual CIRP Conference on Manufacturing Systems. Elsevier/Science Direct. 2015.
37. Semiconductor Industry Association, "Global Semiconductor Sales Increase 24% Year-to-Year in October; Annual Sales Projected to Increase 26% in 2021, Exceed $600 Billion in 2022." Semiconductor Industry Association Press Release. 3 Dec 2021 *https://www.semiconductors.org/global-semiconductor-sales-increase-24-year-to-year-in-october-annual-sales-projected-to-increase-26-in-2021-exceed-600-billion-in-2022/*.
38. BCG, *"Strengthening the Global Semiconductor Supply Chain in an Uncertain Era."* April 2021. *BCG-x-SIA-Strengthening-the-Global-Semiconductor-Value-Chain-April-2021_1.pdf (semiconductors.org)* p. 38.
39. Boston Consulting Group/Semiconductor Industry Association, *"Government Incentives and U.S. Competitiveness in Semiconductor Manufacturing"*. Presentation. 2020.

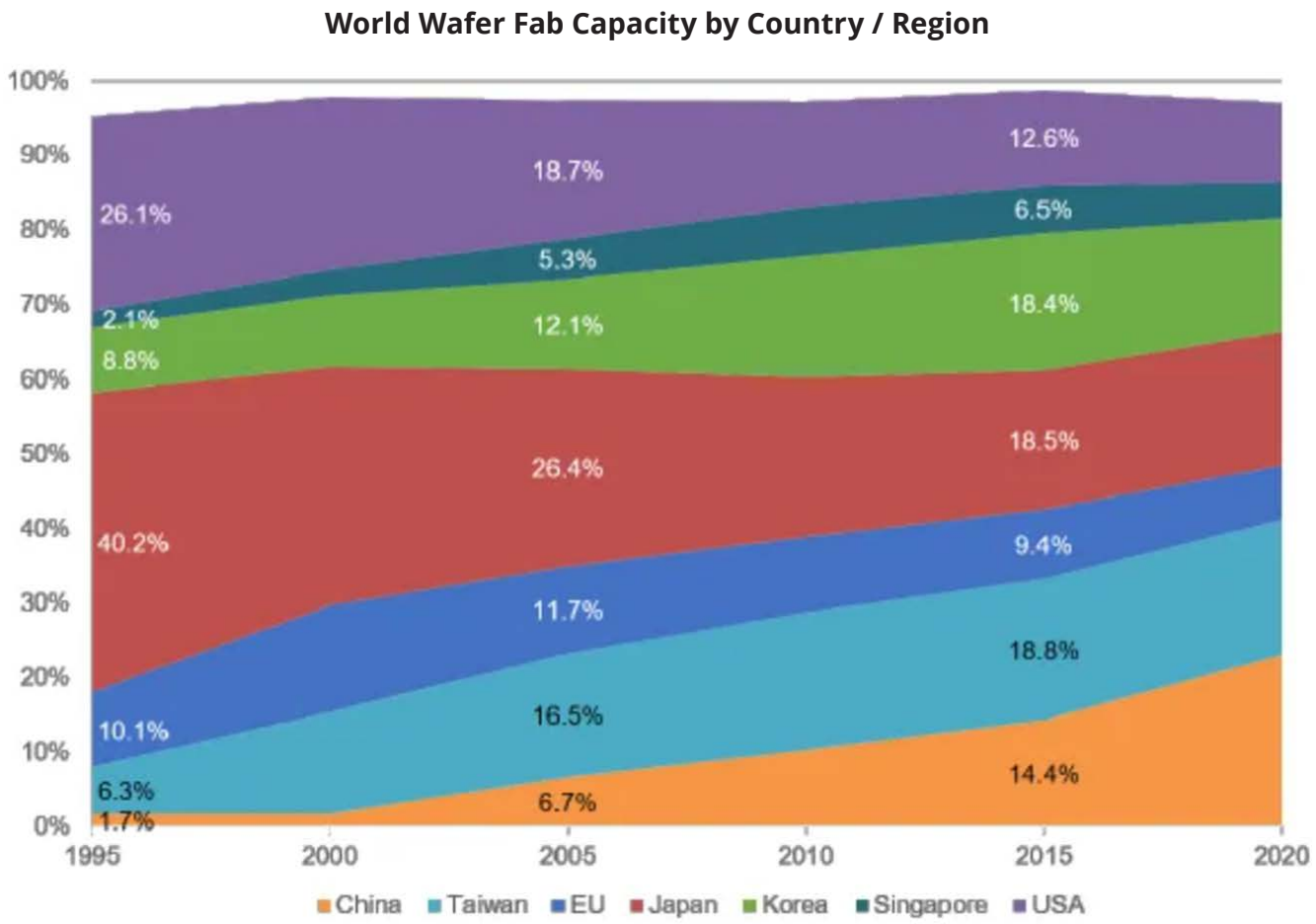


Figure 5. Global Semiconductor Manufacturing by Location (In Percent).[40]

The migration of semiconductor manufacturing to the Asia-Pacific region, and the subsequent decline in domestic manufacturing, represents a substantive security and economic threat for the United States and many allied nations.

The production capability at remaining domestic manufacturing facilities has fallen behind foreign counterparts. For example, U.S. manufacturers do not currently manufacture at the leading-edge 5 nm technology node for commercial production. Access to domestic sources of advanced semiconductor technology is an important component of DoD technology development efforts. Several domestic semiconductor manufacturing corporations have elected not to fabricate product at SOTA technology nodes due to the exorbitant capital required to build SOTA manufacturing facilities and engage in the R&D required to remain competitive. The slow pace of technology implementation occurring in U.S. facilities, coupled with the aforementioned risk-averse position adopted by domestic manufacturers, has led to increased consolidation of SOTA manufacturing technology in foreign nations. These foreign manufacturing facilities are able to fulfill the commercial markets' advanced technology requirements. As semiconductor manufacturing technology advances below the 5nm technology node, reducing the pool of suppliers who manufacture at those levels, ancillary industry sectors such as semiconductor manufacturing tools have also contracted in size. A notable example is the high-tech company ASML (Netherlands), which is currently the sole source for extreme ultraviolet (EUV) lithography tools that

40. European Semiconductor Industry Association, "Trends in Worldwide Semiconductor Production Capacity," 17 June 2021. *https://www.eusemiconductors.eu/sites/default/files/ESIA_PR_WWCapacity_2021.pdf*.

are required to mass produce semiconductor die in technology nodes below 7nm. Such consolidation increases sole-source risk in the global microelectronics supply chain.

Onshoring microelectronics production, packaging, and testing capability will be challenging and expensive, but it would help mitigate national security threats. The cost for a new fabrication facility can be in the tens of billions of dollars.[41] Many Asian countries, including Taiwan and China, subsidize their microelectronics industry, making it difficult for the U.S. to establish domestic capability that is cost-competitive and sustainable.[42] The small share of the market created by unique defense requirements (1–2 percent of the total U.S. market) makes DoD's ability to influence microelectronics suppliers difficult. Any strategy adopted to increase domestic microelectronics manufacturing capacity must be cognizant of the influence of commercial drivers. Unless the commercial microelectronics market is willing to support domestic manufacturing by steering demand to U.S. producers, any DoD investment in this area will be unsuccessful. Thus, the proposed investment strategy could examine incentives as a component in order to increase the likelihood of commercial participation. Such incentives should also be tied to relevant Federal policy goals (e.g., greenhouse gas reduction) that are also of strong interest to industry, such as greatly increased energy efficiency. In addition, the global market is continuing to evolve, so any strategy should consider the policies and incentives proposed and adapted by other nations, to the best extent possible.

Sector Challenges

Supply Chain Visibility

DoD is still building visibility into the sub-tiers of the microelectronics supply chain; until there is greater visibility, it will be difficult to identify certain supply chain threats, vulnerabilities, and risks. Visibility is further eroded by system-level (next-level assembly comprised of multiple microelectronics components) manufacturers who simply seek the lowest cost producers and are source agnostic.

Foreign Dominance in Commercial Production of Semiconductors

The United States is currently manufacturing 10nm semiconductors for commercial production, while Taiwan, the world's largest manufacturer of logic semiconductors, is producing them at 5nm, and is rapidly moving to 3nm. The lack of a stable domestic industry for smaller logic semiconductors impacts next-generation capability development.

Measurably Secure Microelectronics Sources

Procuring measurably secure microelectronics sources is challenged by the potential for China, or countries under the influence of China, to tamper with or insert malicious functionality into microelectronics products. This challenge is further exacerbated by the introduction of counterfeit microelectronics components into the global supply chain from either international or domestic sources. Counterfeit microelectronics components represent a serious safety and national security threat due to their degraded reliability. Counterfeit microelectronics components have been identified in multiple DoD systems.[43]

41. Mark Lapedus, "*5nm Vs 3nm*". Semiconductor Engineering. 2019.
42. United States, Congressional Research Service, *China's New Semiconductor Policies: Issues for Congress*, April 20, 2021.
43. Senate Armed Services Committee Report on Counterfeit Components in the DoD Supply Chain, # 112-167, 21 May 2012.

Non-Market Competitive Practices

Nations such as China and Taiwan provide lavish levels of subsidization to their microelectronics industry, often approaching 30 percent of a company's revenue.[44] These subsidies include support not typically granted in other nations such as preferential equipment lease rates, access to credit and below-market loan rates, and direct state equity investments.[45] These subsidies significantly handicap U.S. companies attempting to compete on a cost basis.[46]

China pursues dominance in all microelectronics areas with purchases of key microelectronics companies and technology, intellectual property theft, and aggressive talent recruitment.[47] DoD and the U.S. Government must make improvements to identify threats and vulnerabilities and protect cutting-edge technology.

Obsolescence

DoD systems have long lives; for example, most weapons systems take 10 to 15 years to design and field. The systems then remain in operation for about 10 to 30 years. Subsequently, many DoD systems are fielded with previous generation technology. Microelectronics technology advances at a much more rapid pace, with new technology nodes introduced approximately every 2.5 years.[48] As microelectronics parts age and become obsolete, sourcing becomes increasingly challenging and expensive. Companies are not willing to sustain production for commercially nonviable microelectronics. This can result in DoD pursuing suboptimal procurement strategies, such as end-of-life buys of specialty semiconductors before production ceases. In addition to maturing technology, some components, such as leaded solder, no longer meet changing commercial and international standards—driving additional systems into obsolescence and low-volume production.

DoD Procurement Practices

The economic viability of the microelectronics industry is predicated on high-volume manufacturing of products designed to meet commercial and automotive reliability requirements. These components are expected to function in relatively mild environments (e.g., climate fluctuations and driving on rough roads). Many DoD microelectronics applications require much more stringent reliability criteria and operate in harsh environments, such as space. In addition, all DoD applications have low production volumes in comparison to commercial applications, such as cellular communications. DoD-unique requirements and associated low volumes de-incentivizes companies from producing microelectronics for DoD.

Recommendations

Internal

Recommendation M1.1: Leverage investment authorities. The DoD should leverage the Defense Production Act (DPA) and other investment authorities to maintain national defense critical capabilities, such as domestic production of strategic radiation-hardened electronics.

44. Boston Consulting Group/Semiconductor Industry Association, *"Government Incentives and U.S. Competitiveness in Semiconductor Manufacturing"*. Presentation. 2020.
45. Boston Consulting Group/Semiconductor Industry Association, *"Government Incentives and U.S. Competitiveness in Semiconductor Manufacturing"*. Presentation. 2020.
46. Semiconductor Industry Association. *"Taking Stock of China's Semiconductor Industry"*. White Paper, July, 2021.
47. Senate Armed Services Committee Report on Counterfeit Components in the DoD Supply Chain, # 112-167, 21 May 2012.
48. Mark Lapedus, *"5nm Vs 3nm"*. Semiconductor Engineering. 2019.

- Investments should target increasing resiliency to combat unfair competitive practices. Efforts could include the following:
  - Provide R&D funding to commercial microelectronics companies producing DoD microelectronics products to offset revenue loss due to cost-cutting tactics used by foreign competitors (which reduces revenue for domestic companies that can be put toward R&D).
  - Investment in capacity expansions to lower domestic product manufacturing costs. This is particularly applicable to domestic producers of commodity microelectronics products such as discrete components.

Recommendation M1.2: Develop measurably secure microelectronics. The DoD should develop practices and techniques to independently evaluate the security of microelectronics components used in systems. Common approaches available to both commercial and DoD entities can be encapsulated in commercial standards, increasing the security of commercial microelectronics devices within critical U.S. infrastructure. The Department is examining this concept within its Measurably Quantifiable Assurance (MQA) program.

Recommendation M1.3: Use microelectronics digital engineering and engineering prototypes. The DoD should leverage digital engineering to plan the progression from design to use of advanced microelectronics. Furthermore, DoD should utilize prototypes for defense applications to effectively test and transition systems to advanced microelectronics, which will dramatically reduce future obsolescence for DoD systems.

Recommendation M1.4: Drive domestic microelectronics ecosystem innovation through program-relevant prototype investments. The DoD should collaborate with commercial and DIB companies to develop domestically designed and manufactured microelectronics that are prepared for adoption within DoD programs. The ecosystem investments should prepare the DoD innovation base to capitalize on on-shoring investments provided under the semiconductor funding initiatives, and ensure energy efficiency improvements are included for continued performance advancements in conjunction with the federal microelectronics strategy. The Department has been supporting efforts in this area through programs such as the Rapid Assured Microelectronics Prototypes (RAMP).

Recommendation M1.5: Track and prevent counterfeit microelectronics in supply chains. The DoD should extract lessons learned from the Naval Air Systems Command's robust counterfeit program, and use them to establish similar programs that ensure all Military Services are monitoring, documenting, and reporting on counterfeit microelectronics found within the supply system. Additionally, to ensure an acceptable supply, microelectronics procurement should include a counterfeit parts management plan that monitors and notifies of procurement from non-authorized independent distributors.

Internal recommendations on data collection and analysis for supply chain visibility are captured in the Cross-Cutting Recommendations section.

Interagency

Recommendation M2.1: Fund the Creating Helpful Incentives to Produce Semiconductors (CHIPS) Program. DoD should recommend that the Administration request Congress to appropriate the $52 billion authorized in the FY 2021 National Defense Authorization Act to fund the CHIPS Program to reverse the decades-long decline in domestic semiconductor fabrication. To prepare for an eventual CHIPS Program appropriation, DoD should also continue to coordinate with the Department of Commerce and other interagency stakeholders in advance of Congress appropriating funds for the CHIPS Program.

Recommendation M2.2: Support the Department of Commerce implementation of the E.O. 14017 100-Day Semiconductor Report recommendations. The DoD should support the relocation of semiconductor production from overseas to the United States, and provide focused support for domestic chip production related to national security needs.

- DoD should coordinate on the analysis of Single Event Effects (SEE) test requirements to determine whether additional investments are needed for construction of new SEE test facilities.
- DoD should increase investments to upgrade SEE testing capacity at existing facilities to meet demand and purchase block-buys of SEE testing.
- DoD should invest in radiation hardened microelectronics data collection, storage, and analytics services to support coordinated, centralized DoD SEE test resource management activities.

Recommendation M2.3: Continue/expand the advancement of STEM careers and education. DoD should continue to increase their efforts to encourage careers and education in STEM fields, horizontally and vertically through other Federal Government agencies and through state and local governments, including school districts. Government and contractor personnel can be given incentives and/or recognition for reaching out to their local schools to talk to students about the interesting aspects and rewards associated with STEM careers.

International

Recommendation M3.1: Leverage international interest in microelectronics collaborative efforts. DoD should undertake collaborative efforts with allied nations to remediate identified deficiencies, such as lack of domestic ME manufacturing capacity. Taiwan and South Korea are planning to make large investments in SOTA manufacturing facilities located in the United States. DoD should endeavor to leverage this capacity expansion as a potential source for SOTA ME product.

DoD is collaborating with the Department of State to pursue opportunities to use existing or establish new assured sources of microelectronics supply in international ally and trusted partner nations. Other potential areas of collaboration, such as collaborative semiconductor R&D efforts should be explored. This leverages the historic strength of The United States in R&D, and can serve to offset the high cost of R&D associated with advanced semiconductor technology.

International Microelectronics Collaboration

Many countries have expressed interest in, or have already begun building capability in the U.S. in order to decentralize production, and to efficiently service the U.S. microelectronics market. Samsung (South Korea), has announced construction of a $17 billion manufacturing facility in Texas. TSMC (Taiwan) has begun construction of a $12 billion facility in Arizona. Japan has expressed interest in exploring collaborative manufacturing efforts.

Industry

Recommendation M4.1: Align DoD investment authorities to support domestic supplier base. DoD should continue regular engagements with microelectronics suppliers to understand barriers to entry in working with the Department. The DoD should then align funding opportunities to reduce these barriers, and review procurement policies to improve the business environment for electronics suppliers working with the DoD.

Recommendation M4.2: Collaboratively develop standards. DoD should work with industry partners to develop assurance and security standards for microelectronics that address both industry and DoD interests. Aligning these types of standards would help ensure the mutual security and resiliency of commercial and DoD microelectronics supply chains.

Recommendation M4.3: Expand industry outreach efforts to identify capabilities and opportunities for partnership. The DoD should engage with industry, including smaller technology development companies, to understand industry capabilities and identify new opportunities for partnership. This could include committing to touring more facilities and holding regular industry roundtables.

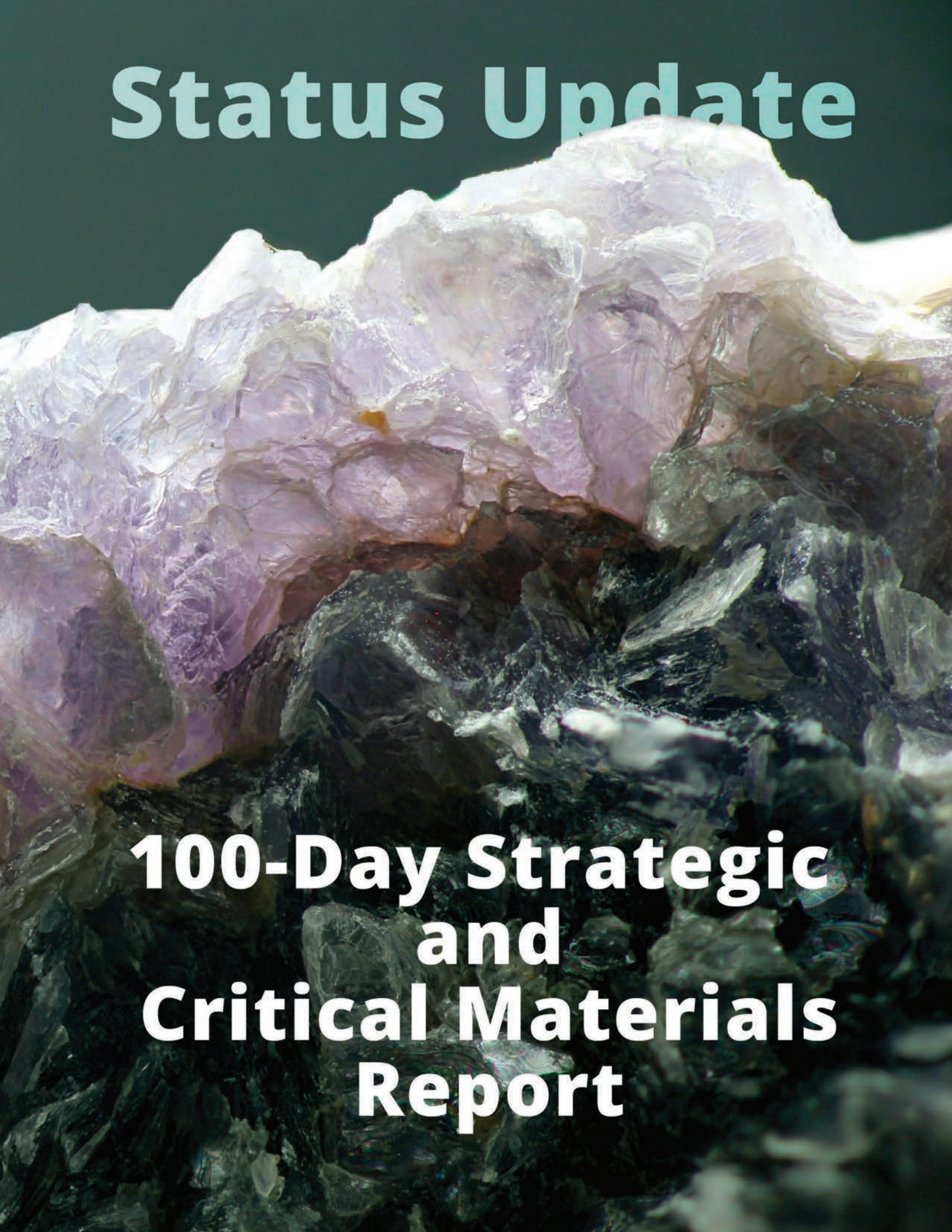
Recommendation M4.4: Leverage industry best practices. DoD should work with industry to understand their best practices in microelectronics design, development, and implementation, and leverage these insights to reduce technology deployment timelines. Similarly, DoD should analyze commercial data to better understand the trends, challenges, and opportunities in the commercial market, and use these insights to improve DoD's position as a customer and partner.

Recommendation M4.5: Share roadmaps to increase visibility. DoD should share technology development roadmaps with industry to increase industry's visibility into DoD's future technology needs (and vice versa, industry should do the same with DoD so the Department knows where industry is headed). This sharing and visibility also facilitates early identification of technologies-of-interest, and opportunities for alignment and collaboration. Sharing roadmaps is also useful for determining the pace of technology refresh in DoD programs to mitigate potential obsolescence issues.

Table 5 (next page) maps the recommendations against the seven challenge areas for microelectronics.

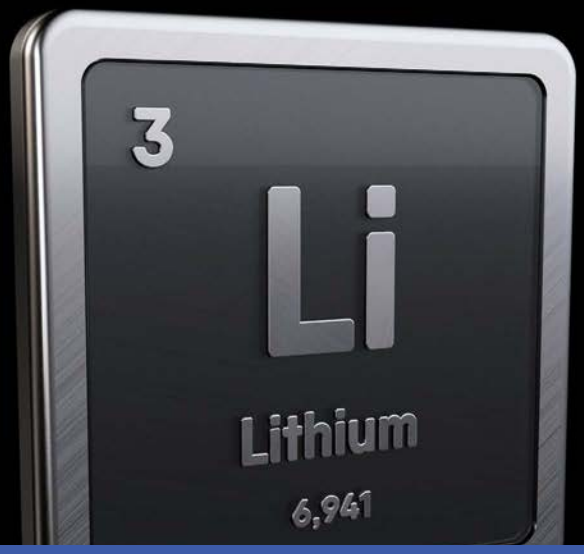
Table 5. **Challenges and Recommendations for Microelectronics.**

		Supply Chain Visibility	Foreign Dominance	Measurably Secure Micro-electronics	Non-market competitive practices	Obsolescence	DoD Procurement Practices	Declining Workforce
Internal	Rec M1.1: Leverage investment authorities			✓	✓	✓		
	Rec M1.2: Develop measurably secure microelectronics	✓		✓				
	Rec M1.3: Use microelectronics digital engineering and prototypes					✓		
	Rec M1.4: Drive domestic microelectronics ecosystem innovation		✓	✓				
	Rec M1.5: Track and prevent counterfeit microelectronics			✓			✓	
Interagency	Rec M2.1: Fund the CHIPS Program		✓	✓	✓			
	Rec M2.2: Support Commerce on EO 14017 100-Day Report implementation	✓	✓	✓	✓			✓
	Rec M2.3: Continue/expand the advancement of STEM careers and education	✓						✓
International	Rec M3.1: Leverage international interest in microelectronics collaboration	✓		✓	✓			
Industry	Rec M4.1: Align DoD investment authorities to support domestic supplier base	✓		✓	✓		✓	
	Rec M4.2: Collaboratively develop standards			✓		✓		
	Rec M4.3: Expand industry outreach efforts to identify capabilities and opportunities for partnership	✓	✓	✓		✓		
	Rec M4.4: Leverage industry best practices		✓			✓	✓	
	Rec M4.5: Share roadmaps to increase visibility	✓				✓	✓	



Status Update

100-Day Strategic and Critical Materials Report



Status Update: 100-Day Strategic and Critical Materials Report

This section provides an update on the 100-day response to E.O. 14017—Review of Critical Minerals and Materials. The DoD was responsible for assessing supply chain risks for critical minerals and materials and proposing a set of recommendations to mitigate those challenges. Since the publication of the report in June 2021, the DoD has been working to implement those recommendations. This section provides an overview of the critical mineral and material supply chains, supply chain risks and an update on the progress made in implementing the recommendations from the 100-day review.[49]

National Security Significance

Strategic and critical materials are foundational for value-added manufacturing and the delivery of essential services throughout the global economy. In addition, strategic and critical minerals are critical to the global clean energy transition, with application in areas as diverse as high efficiency magnets for offshore wind, stationary and electric vehicle batteries, and coatings and alloys. Sustainable and economic access to these minerals and materials will support a rapid evolution to a resilient and clean energy economy.

In civilian sectors, strategic and critical materials are essential to countless manufactured goods, ranging from personal electronics to home construction and critical infrastructure preservation. When access to strategic and critical materials is reliable, the global economy tends to expand and quality of life improves. Economic and social benefits also come from cleaner and low emission energy sources, including reduced emissions and a reversal of adverse impacts on disadvantaged communities who lived in proximity to traditional energy sources and infrastructure.

In the DIB, strategic and critical materials enable the unique combat capabilities of U.S. weapon systems and those of our allies, while providing the essential inputs to expand the industrial base in an emergency and maintain technical overmatch against our adversaries. Without these materials, history shows that industrialized nations have been compelled to accept performance tradeoffs—such as

49. United States, White House, *Building Resilient Supply Chains, Revitalizing American Manufacturing, And Fostering Broad-Based Growth, 100-Day Reviews Under Executive Order 14017.* June 2021.

ammunition rationing and resource scarcity-driven production shortfalls—which contributed to their defeat on the battlefield.[50]

Though domestic strategic and critical materials production represent only a small fraction of total U.S. employment and gross domestic product (GDP), downstream manufacturing and related service sectors support substantially greater economic output and jobs. For example, annual domestic mining activities, valued at $90.4 billon, enable more than $3.3 trillion in domestic value-added industry sectors. This contribution to downstream manufacturing and service sectors is indicative of the incredible derivative value of strategic and critical materials.[51]

Risks to the Supply Chain

DoD assesses risk in the strategic and critical materials sector at and below the level of armed conflict. DoD models the former on a biennial basis, in accordance with its duties as the National Defense Stockpile Manager under the *Strategic and Critical Materials Stock Piling Act of 1939* (50 U.S.C. 98 et seq.), and DoD published an unclassified list of shortfall materials in the 100-day report under E.O. 14017, *America's Supply Chains.*

Though the magnitude of harm from market disruptions during armed conflict is high, the underlying causes of these market disruptions are not new. Instead, conflict imposes a uniquely intense set of requirements upon an already fragile market, not unlike the COVID-19 recovery market for many strategic and critical materials. Core drivers of this fragility in the strategic and critical materials sector include the following risk factors:

- Concentration of supply
- Single-source suppliers
- Price shocks
- Human capital gaps
- Conflict minerals and organized crime

100-Day Report Recommendations

In the 100-day reporting exercise for strategic and critical materials under E.O. 14017 the DoD highlighted four key pillars to the U.S. Government's approach to increasing the resiliency of this sector:

1. **Drive Demand.** Develop new sustainability standards and update existing ones for strategic and critical material-intensive industries and incorporate these standards into Federal procurement.
2. **Stimulate Supply.** Expand sustainable production and processing, including recycling and nontraditional mining, such as reclamation of mine wastes.
3. **Hedge Risk.** Strengthen U.S. stockpiles.

50. United States Air Force, *The United States Strategic Bombing Surveys (European War) (Pacific War),* Maxwell AFB University Press, 1987.
51. U.S. Geological Survey, *Mineral Commodity Summaries 2022 (January 31, 2022),* https://pubs.usgs.gov/periodicals/mcs2022/mcs2022.pdf.

4. **Promote Equity.** Work with allies and partners to increase traceability and transparency in global supply chains.

In the eight months since the release of the 100-day report, the DoD and the interagency have cleared a series of interim objectives against these national priorities. With respect to sustainability standards, the Environmental Protection Agency (EPA) and DOE are leading this effort within the Federal Government. There is an initial focus on incorporating criteria that incentivize recycling and the reuse of critical materials in consumer electronics through the Electronic Product Environmental Assessment Tool (EPEAT) eco-label. EPA has also released a National Recycling Strategy. DoD also intends to coordinate with DOE on critical minerals issues which impact the clean energy supply chain and domestic manufacturing sectors. For allies and partners, since the release of the 100-day report, the interagency have held more than five senior-leader engagements with allies and partners to drive tangible diversification of supply chains.

Though DoD plays a contributing role in each of the above areas, the DoD is the lead component for strengthening U.S. stockpiles. The thinness of private sector inventories, related to wide-spread industry adoption of "just-in-time" delivery practices and a diminished National Defense Stockpile, are critical vulnerabilities in the Nation's preparedness. Fortunately, through a combination of congressional and executive action, the DoD achieved many of its near-term objectives to reverse this trend (see Table 6, below).

Objective	Status (Action)	Class (Vehicle)
Executive Order delegating National Defense Stockpile release authority	**Complete**	FY 2021 – Executive
Reinstate the biennial modeling requirement for strategic and critical material supply chains	**Complete**	FY 2022 – NDAA[52]
Authority to loan material to other Federal agencies to mitigate peacetime disruption risk	**Complete**	FY 2022 – NDAA
Obtain direct-hire authority for the National Defense Stockpile and mobilization programs	**In Progress**	FY 2022 – Executive
Obtain new appropriations for the National Defense Stockpile	**In Progress**	**[TBD]** FY2022 – Appropriations Law
		[TBD] FY2023 – Budget Request
Grant the National Defense Stockpile the authority to acquire shortfall materials	**Rejected**	FY 2022 – NDAA
	In Progress	FY 2023 – NDAA
Reform to the Strategic and Critical Materials Stock Piling Act of 1979	**In Progress**	FY 2023 – NDAA

Table 6. U.S. Stockpile Objectives

However, the critical path to strengthen U.S. stockpiles depends upon appropriate legislation from Congress. DoD regularly submits legislative requests for such authority, including for the Fiscal Year

52. United States, Congress, H.R. 4350 National Defense Authorization Act for Fiscal Year 2022.

(FY) 2022 National Defense Authorization Act,[53] with the most recent request covering rare-earth oxides and permanent magnets, titanium, and high explosives for missiles and munitions.

DoD intends to resubmit requests for acquisition authority for these materials and others in the National Defense Authorization Act (NDAA) for FY 2023 and, if ultimately submitted, the DoD welcomes the opportunity to engage with Congress on these requirements.

Looking forward to FY 2022 implementation of E.O. 14017, DoD intends to focus its efforts on (1) executing actions authorized in FY 2021, (2) advancing priorities for the FY 2023 legislative cycle, and (3) developing a pilot program to facilitate business-to-business (B2B) ties, domestically and with allies, to mitigate vulnerabilities in the strategic and critical materials sector.

Table 8 maps actions to date to each of the recommendations in the E.O. 14017 100-day review of critical minerals and materials.

Recommendation	Actions To Date	Lead Component
1. Developing and Fostering Sustainability Standards for Strategic and Critical Material-Intensive Industries	EPA is leading interagency comment submissions and development of criteria under the EPEAT eco-label for • Chemicals of Concern • Sustainable Use of Resources • Climate Change Mitigation • Low-embodied Carbon Criteria for Photovoltaic Modules	Environmental Protection Agency (EPA) in partnership with DOE
2. Expanding Sustainable Domestic Production and Processing Capacity, Including Recovery from Secondary and Unconventional Sources and Recycling	Interior is prioritizing the critical minerals list for risk mitigation by the inter-agency Interior is leading work with other federal agencies on developing principles and an engagement strategy for comprehensive mining law reform DOE is using new authority and funding to:[54] • Establish a new Critical Material Consortium to develop substitutes and promote resource efficiency • Support pilot plants to extract rare earths from alternative feedstocks, such as coal or mine waste • Promote battery recycling and value-added processing of battery materials	Department of Interior and DOE
3. Deploy the DPA and Other Programs	DoD is awaiting FY 2022 appropriations to resource industrial base investment projects and initiate new-starts POTUS to release a Determination pursuant to DPA Title III to support battery mineral production	DoD
4. Convene Industry Stakeholders to Expand Production	DoD will develop a pilot program to facilitate B2B risk mitigation	Multiple
5. Promote Interagency Research & Development to Support Sustainable Production and a Technically Skilled Workforce	DOE, in partnership with DoD and other agencies, is leading the development of an R&D roadmap to address critical minerals and materials needs for the Nation	DOD
6. Strengthen U.S. Stockpiles	See Table 6	DOE
7. Work with Allies and Partners and Strengthen Global Supply Chain Transparency	State has led over 5 senior-leader engagements with allies and partners	Department of State

Table 7. Summary of Implementation for Recommendations in E.O. 14017 Review of Critical Minerals and Materials

53. United States, Office of General Counsel, Office of Legislative Counsel, *"DoD Legislative Proposals,"* https://ogc.osd.mil/DLSA-Offices/Office-of-Legislative-Counsel/DoD-Legislative-Proposals-2022/, accessed 9 December 2021.
54. Such as *The Energy Act of 2020* (P.L. 116-260) and the *Infrastructure Investment and Jobs Act* (P.L. 117-58)

Supply Chain Strategic Enablers

Supply Chain Strategic Enablers

Workforce

National Security Significance

Workers are a critical component of supply chains and make them possible. A vibrant industrial and logistics workforce enables significant resilience throughout supply chains. To compete globally, the Nation's defense capabilities require a skilled workforce to produce products, build and sustain systems, and conduct research and development. Recent reports from the Ronald Reagan Institute Task Force on National Security and U.S. Manufacturing Competiveness and the House of Representatives Defense Critical Supply Chain Task Force found that a vibrant, highly skilled workforce is vital to strengthening and enhancing the United States' industrial base supply chains.[55]

The Nation is facing a skilled labor shortage, which is undermining its productivity and innovation. Today, the United States has the smallest population coming into the labor force since the Civil War.[56] As a result of these lower numbers, changing worker expectations, and a lack of interest in manufacturing, the labor pool of traditional manufacturing employees is decreasing.[57] This labor shortage is combined with a manufacturing skills deficiency where "the labor market [is] unable to find workers who have the manual, operational, and highly technical skills, knowledge, or expertise to take the open positions."[58, 59] The skills deficiency impairs U.S. manufacturing, including the DIB, and is exacerbated by a lack of effective job training and ongoing retirement of experienced baby boomers.[60]

55. United States, House Armed Services Committee, *Report of the Defense Critical Supply Chain Task Force*, 22 July, 2021. https://armedservices.house.gov/_cache/files/e/5/e5b9a98f-9923-47f6-a5b5-ccf77ebbb441/7E26814EA08F7F701B16D4C5FA37F043.defense-critical-supply-chain-task-force-report.pdf and variety of industry reports also support these findings.
56. Bill Conerly, *"The Scariest Chart For Business In The Coming Decade: Workers Not Available,"* Forbes, Mar. 25, 2018. https://www.forbes.com/sites/billconerly/2018/03/25/the-scariest-chart-for-business-in-the-coming-decade-workers-not-available/?sh=59f55f4e3de9.
57. O'Rahilly, Patrick, *"Redefining the Future of Manufacturing to Plug the Skills Gap,"* Forbes Business Council Post, Forbes, June 21, 2021. Retrieved on January 5, 2022.
58. Propel PLM, *"The Manufacturing Skills Gap: What is it?"* Manufacturing. The Manufacturing Skills Gap: What Is It? | Manufacturing.net.
59. Deloitte's 2021 Manufacturing Talent Study found increasing difficulty finding the right talent, particularly for middle-skilled manufacturing occupations, based on a survey of over 800 U.S. manufacturing executives across all sectors. (Source: Stepahanie Nell, *"Manufacturing Skills Gap Widens in the Wake of COVID-19,"* OEM Magazine, 23 June 2021. https://www.oemmagazine.org/oem-issues/workforce-development/article/21521025/manufacturing-skills-gap-widens-in-the-wake-of-covid19).)
60. "America's population is graying rapidly, with 10,000 baby boomers reaching retirement age every day for the next 19 years." Source: Korn-Ferry, *"Future of Work: The Global Talent Crunch,"* April 26, 2020.

This is not a new trend; the skills deficiency has been growing for decades[61] and DoD previously outlined the threat of a diminished labor force to the health of the DIB in its response to E.O. 13806 in 2018.[62]

The global COVID-19 pandemic has complicated efforts to attract larger numbers of highly skilled workers to key sectors, like manufacturing, but at the same time has accelerated industry's adoption of automation and other advanced manufacturing practices to offset the loss of labor. Even as the Nation recovers from the recession caused by the pandemic, the number of open positions (11.0 million in the nonfarm sector as of October 31, 2021) continues to outpace annual net employment gains (5.7 million workers from October 2020 to October 2021), demonstrated by the most recent reporting from the U.S. Bureau of Labor Statics (BLS). Although these numbers are generally a magnitude less for manufacturing specifically, industry faces similar relative shortfalls to the overall labor market.[63]

Challenges

The U.S. and DoD workforce challenges are driven by major trends.

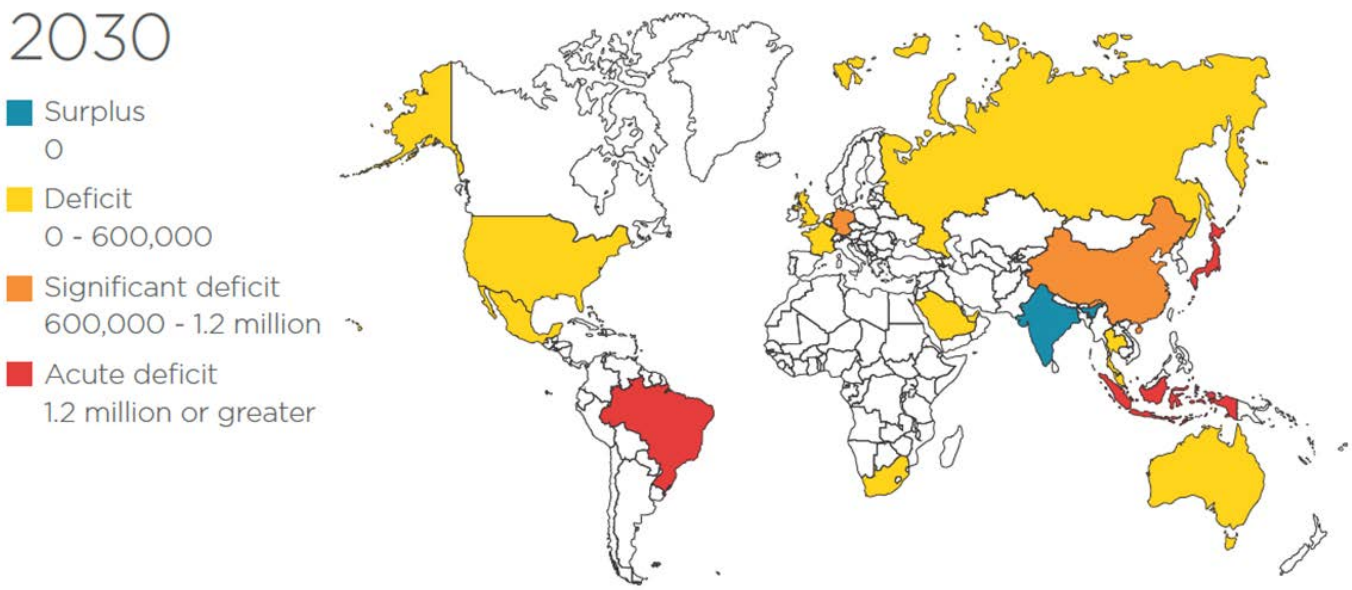
Persistent and Growing Workforce Gaps

In U.S. manufacturing, the gap between open positions and available workers is not expected to close, with an "estimated 2.1 million unfilled jobs by 2030"[64] and a 2030 deficit of 383,000 highly skilled workers—over 10 percent of the highly skilled workforce.[65] Defense manufacturing will be competing with all industrial sectors for increasingly scarce workers.

The worker shortage is not limited to the United States; globally the number of skilled workers is outstripped by the number required to fill current and projected needs. A 2020 Korn-Ferry study estimates the global talent shortage in manufacturing will be 7.9 million by 2030.[66] As shown in Figure 6, many U.S. allies, including Germany and Japan, will also have significant skilled worker shortages in manufacturing, while Russia and China will lose their surplus of highly skilled manufacturing workers by 2030.

Productivity improvements from automation and other technological advances will not offset the global talent shortages caused by demographic changes, tightening immigration, under-skilled workforces, and global growth.[67]

61. O'Rahilly, Patrick, "Redefining the Future of Manufacturing to Plug the Skills Gap," Forbes Business Council Post, Forbes, June 21, 2021. Retrieved on January 5, 2022. *https://www.forbes.com/sites/forbesbusinesscouncil/2021/06/21/redefining-the-future-of-manufacturing-to-plug-the-skills-gap/*.
62. DoD Industrial Policy, *Assessing and Strengthening the Manufacturing and Defense Industrial Base and Supply Chain Resiliency of the United States: Report to President Donald J. Trump by the Interagency Task Force in Fulfillment of Executive Order 13806*, September 2018.
63. United States, Bureau of Labor Statistics, "Job Openings and Labor Turnover Survey News Release," 8 December 2021. https://www.bls.gov/news.release/archives/jolts_12082021.htm.
64. Paul Wellener, et al., *"Creating pathways for tomorrow's workforce today."* Deloitte Insights, accessed December 16, 2021. Manufacturing industry diversity | Deloitte Insights.
65. This study assessed trends for all skill levels (highly skilled, mid-skilled, and low-skilled workers). Korn-Ferry, *"Future of Work: The Global Talent Crunch,"* April 26, 2020.
66. Korn-Ferry, *"Future of Work: The Global Talent Crunch,"* April 26, 2020.
67. Korn-Ferry, *"Future of Work: The Global Talent Crunch,"* April 26, 2020.



The acuteness of an economy's deficit is based on its overall shortage of workers, not accounting for the size of its total workforce.

Figure 6. Global Manufacturing Talent Deficit by Economy.[68]

Defense manufacturers face significant challenges as they attempt to adapt to these workforce trends and the combination of micro- and macro-economic forces that drive industry's decision-making—such as short-term returns, unstable customer demand, and the portability of in demand skill sets. Original equipment manufacturers (OEMs) are generally better positioned to attract and train workers than the small and medium manufacturers (SMMs) in their supply chains.[69]

Taken together, these DIB workforce challenges constitute a major headwind for the development of supply chain resilience. The DoD is committed to working across Government to address these education and training needs.

Reduced Recruitment and Retention

In the past, manufacturing provided middle income jobs that supported local economies and provided stability to American families. This is no longer the case across all manufacturing skill levels. Wage growth depends on worker productivity growth, which depends on capital investments to adopt advanced manufacturing technologies and processes. U.S. worker productivity growth from 2010 to 2020 fell below 1 percent.[70] There is also a 40 percent productivity gap between large and small manufacturing firms,[71] which is exacerbated by SMMs' more limited access to capital and the highly skilled workers needed to implement productivity-enhancing systems. The McKinsey Global Institute found that for manufacturing production workers (the lower-tier, lower-skilled workers), real wages "rose by only 0.1 percent since 1990."[72] The lack of any meaningful increase in real wages in manufacturing jobs makes it more difficult to attract entry-level workers, imperils worker retention, and threatens the manufacturing industry with all the ails associated with increased turnover.

68. Korn-Ferry, *"Future of Work: The Global Talent Crunch"*, April 26, 2020, p. 22.
69. Many DIB companies, particularly SMMs, have thin operating margins and lack access to operating capital for workforce development and investment capital for modernization to improve productivity.
70. The Ronald Reagan Institute, *"A Manufacturing Renaissance: Bolstering U.S. Production for National Security and Economic Prosperity,"* Report of the Task Force on National Security and U.S. Manufacturing Competitiveness, November 2021.
71. McKinsey Global Institute, *"Making it in America: Revitalizing US Manufacturing,"* November 2017.
72. *Ibid.* Making it in America, Revitalizing US Manufacturing.

SMMs in the DIB strive to retain and upskill (teaching new skills to) their workers, and to improve their competitive position through automation and other upgrades—all of which benefit the business and its workforce. However, it has become increasingly difficult for defense supply chains to compete with commercial industry for workers based on wages due to the contractual environment and typically low-volume, high-variety work required by most defense contracts. In the DIB, SMMs frequently end up competing with OEMs for highly skilled workers, increasing the workforce-related cost and schedule risks to these supply chains.

Erosion of Skilled Manufacturing Workforce Development Pipelines

The increased employment opportunities in other sectors and the dwindling entry-level population continue the long-term erosion of the career and technical education (CTE) pipeline. This shortfall contributes to and perpetuates skilled worker gaps. For example, the inability to fill key middle-skill roles looms large for manufacturing companies. Deloitte estimates that over 400,000 middle-skill roles such as assemblers, inspectors, and welders will open over the next decade.[73]

A 21st century economy requires a workforce with a variety of high-tech skills and STEM knowledge. Many of the proposed advanced manufacturing and technology solutions to workforce shortages (particularly automation) and manufacturing issues (including additive manufacturing, hybrid manufacturing, and digitalization) require a higher level of baseline skills. To implement these solutions, individuals must be trained and able to work in teams that combine deep engineering expertise with data analytics and policy knowledge to enable innovation and transform the manufacturing space.[74]

To close these skills deficiencies, defense manufacturing must attract a larger proportion of new high school graduates along with adult workers—including veterans, underserved populations, women, minorities, and workers from other industries. Companies are just beginning to tap into new demographics and communities to recruit workers, but as illustrated in Figure 7 (next page) , there is room to improve workforce diversity, and attracting new demographics can help to fill more jobs.[75] CTE and STEM must also be expanded into middle and high school education to attract and prepare candidates for advanced manufacturing at all levels—from engineering to the factory floor.

Lack of Visibility into Manufacturing Workforce Supply and Demand

Sufficiently representative and detailed data are not yet available to understand and assess changing DIB workforce needs. While research has been done on current and future gaps in labor skills—like the Deloitte study mentioned above—the DoD is beginning to develop the program-specific and regional knowledge needed to shape workforce development solutions. Generally, data on skills deficiencies and workforce trends needs to be compiled from industry, regional, and interagency resources, and analyzed and synthesized to support training and retaining the right workforce. This effort is complicated by industry sensitivities to workforce shortfalls, OEM's lack of visibility into workforce within their

73. Paul Wellener, et al., *"Creating pathways for tomorrow's workforce today."* Deloitte Insights, accessed December 16, 2021. *Manufacturing industry diversity | Deloitte Insights.*
74. The National Academies of Sciences, Engineering, and Medicine (NASEM) and the National Materials and Manufacturing Board (NMMB), Convergent Manufacturing Virtual Workshop, November 2021.
75. In 2020, women made up 25 percent of the skilled manufacturing workforce and minorities filled 32 percent of jobs. (Source: U.S. Bureau of Labor Statistics, *"Labor Force Statistics from the Current Population Survey: 2020 Household Data Annual Averages, Employed persons by detailed industry, sex, race, and Hispanic or Latino ethnicity for durable goods manufacturing."* Retrieved on August 6, 2021 from https://www.bls.gov/cps/cpsaat18.htm.)

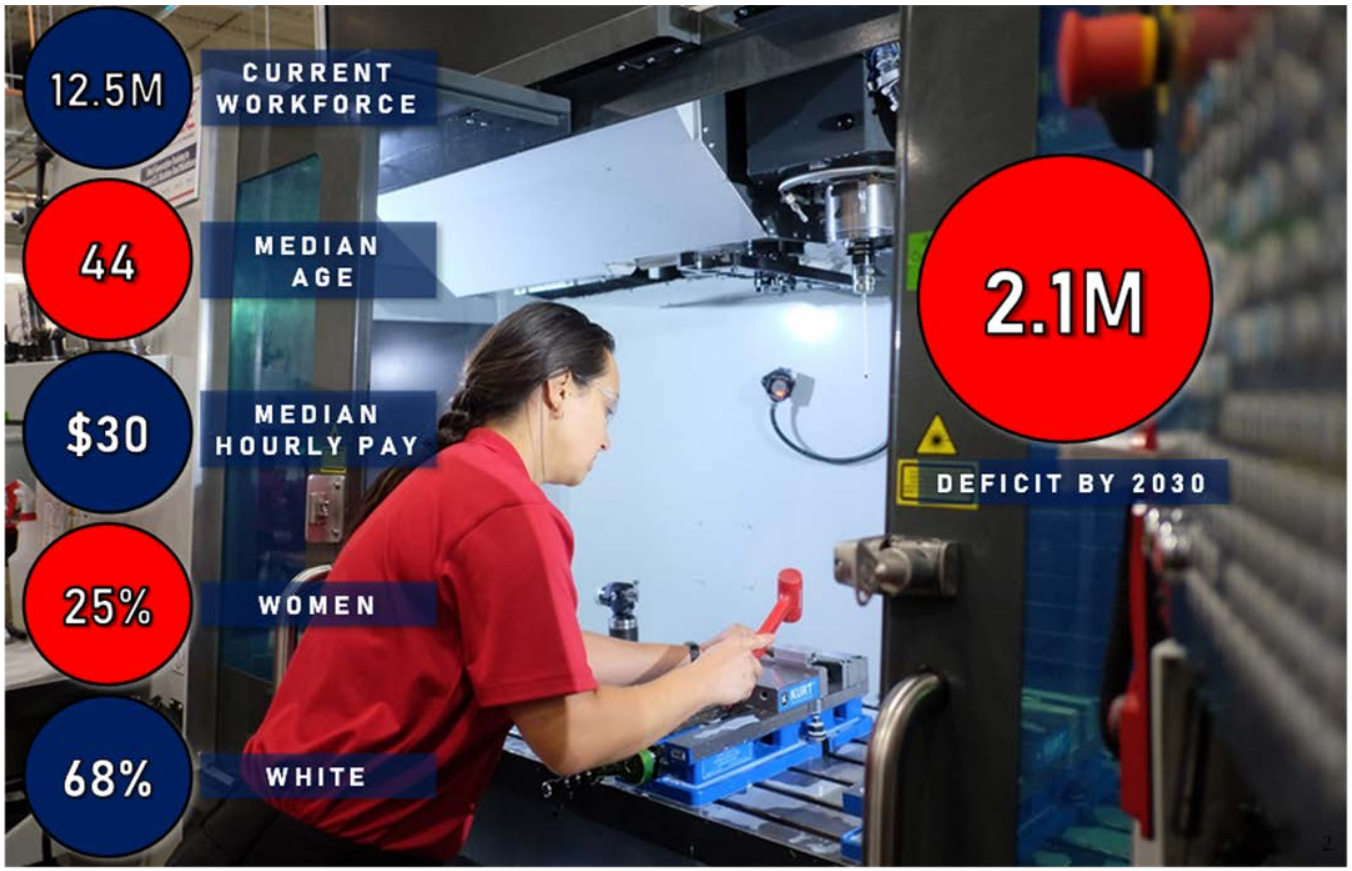


Figure 7. The skilled workforce supply chain must grow to meet the projected deficit.[76]

supply chains, and the rapid pace of changes to position requirements. Government data resources typically document the recent past (1 to 10 years) and provides labor data based on occupation descriptions (which are updated every 10 years). The lack of definitive data on what labor skills are needed today—or more importantly, what will be needed in the next 5 to 10 years—makes it difficult to prevent future gaps.

Recommendations

The challenges listed above are a result of decades of societal, policy, and budgetary factors that contributed to the decline of U.S. manufacturing and related training. This section identifies specific, actionable recommendations to shape stakeholder investments in the American industrial workforce to help resolve these systemic challenges. Similar to the priority focus areas, addressing workforce challenges requires a holistic approach with recommendations that span the internal, interagency, international, and industry framework.

The following recommendations address the challenges outlined above: closing persistent and growing industrial workforce gaps, revamping recruitment and retention to meet a modernizing world, strengthening enduring workforce development, and developing the data needed to inform industrial workforce investment strategies. The intended outcome of these recommendations is to enable the workforce supply chain to become a foundational part of defense supply chain resilience by delivering both the types and volume of talent needed.

76. United States, U.S. Bureau of Labor Statistics, *Manufacturing: NAICS 31-33*. https://www.bls.gov/iag/tgs/iag31-33.htm.

Internal

Recommendation W1.1: Develop programs to expand DIB recruitment to underserved communities. DoD should expand efforts, such as the National Imperative for Industrial Skills (NIIS) initiative, to make targeted investments to improve workforce skills in key regions. DoD should review its recruitment programs for its OIB workforce to include apprentice programs to find, attract, and hire minority and female employees. Closing workforce gaps will require expanding recruitment from recent high school graduates to adults looking to change careers. Similarly, the DoD must contribute to shaping positive public attitudes around industrial work to create an environment where more people see value in preparing for and working in industrial jobs.

Recommendation W1.2: Prioritize attracting military veterans to careers in the DIB. Transition assistance programs should emphasize careers in the DIB by advertising these opportunities at local, regional and national levels. TAP can also help to link DIB employers with service members transitioning out of the military, and advanced manufacturing workforce development programs should expand outreach and accessibility to departing military personnel and veterans. Existing programs, such as DoD's Transition Assistance Program (TAP) and the workforce development components of the Manufacturing Innovation Institutes, could be expanded to help increase the number of defense-experienced personnel entering the DIB as skilled workers.

Recommendation W1.3: Implement DoD specialized curriculum. The DoD should expand and develop specialized curriculum for its unique needs and establish an academic network to implement the curriculum. This should include a partnership between the public sector, private sector, and academia to train the domestic STEM workforce needed to meet DoD's highly specialized microelectronics requirements. The Department has been working aspects of this via its Scalable Asymmetric Lifecycle Engagement Microelectronics Workforce Development (SCALE) program.

Interagency

The Federal Government has the mission, authorities, and resources to address the endemic challenges that are outside the scope of any industry, region, or educational institution. To succeed, the Federal Government—including DoD—must create and support a whole-of-nation strategy that leverages the capabilities at all levels of Government, in close coordination with industry and academia.

Recommendation W2.1: Collaborate with interagency partners to close workforce gaps for SMMs. DoD should actively work to formalize interagency coordination in workforce training and development programs, and to develop a blueprint to close skilled workforce gaps. The blueprint should encompass the following:

- Develop a public service campaign to attract more young people, and adults transitioning careers, to manufacturing and skilled trades—with a focus on underserved communities, women, and minorities.
- Strengthen the alignment of the Department of Labor's (DOL's) Veterans' Employment and Training Service (VETS) programs to target the full range of DIB labor needs. This includes, but is not limited to, expanding the use of the G.I. Bill to cover on-the-job training, CTE programs, and registered apprenticeships.
- Evaluate the Federal Pell Grant and other Federal education programs to ensure funding opportunities are available for certification programs as well as four-year university degrees.
- Leverage the Hollings Manufacturing Extension Partnership (MEP) organizations, and other similar programs, to understand the needs and challenges the skilled workforce experiences across the

lifecycle of critical defense systems. Use these insights to strategically identify, shape, develop, and test solutions to these challenges.

- Promote apprenticeships and other training options to develop the skilled workforce for today and tomorrow.
- Explore immigration policies to ensure that talented individuals will choose to study and stay in the United States.

International

Recommendation W3.1: Identify and develop opportunities for collaboration and resilience. The United States reaffirms commitment to bolster supply-chain resilience through workforce development, and in furthering strategic cooperation through new and existing forums on mutual workforce initiatives with international allies and partners. As DoD moves to prioritize and implement recommendations in this report, the Department should work closely with allies to identify what forums and opportunities for collaboration will be most effective in addressing the core challenges facing industrial base workforces.

Additional recommendations to collaborate with international allies and partners are captured in the Cross-Cutting Recommendations section.

Industry

Recommendation W4.1: Attract, recruit, and train the industrial workforce needed to build and sustain defense capabilities. DoD and defense industry associations can join forces in defense-dense regions to address workforce challenges on behalf of SMMs. DoD should take the initiative to address recruitment, training, and retention challenges by actively partnering with industry to do the following:

- Ensure industrial skills training programs are aligned with industry needs.
- Connect local and regional training programs to improve and expand recruiting pipelines, including to non-traditional manufacturing workers in underserved communities.
- Share best practices to improve retention.
- Promote manufacturing careers early and often in the Kindergarten through high school education pipeline by showcasing industrial skills training programs.

Table 8 (next page) maps the recommendations against the four challenge areas for the DIB workforce.

Table 8. Challenges and Recommendations for the DIB Workforce.

		Persistent and Growing Workforce Gaps	Reduced Recruitment and Retention	Erosion of Skilled Manufacturing Workforce Development Pipelines	Lack of Visibility into Workforce Supply and Demand
Internal	Rec W1.1: Develop programs to expand DIB recruitment to underserved communities	✓	✓	✓	
	Rec W1.2: Prioritize attracting military veterans to careers in the DIB	✓			
	Rec W1.3: Implement DoD curriculum				✓
Interagency	Rec W2.1: Collaborate with interagency partners to close workforce gaps for SMMs				✓
International	Rec 3.1: Identify and develop opportunities for collaboration and resilience	✓			
Industry	Rec W4.1: Attract, recruit, and train the industrial workforce needed to build and sustain defense capabilities	✓			

Cyber Posture

National Security Significance

Secure supply chains and information and communications technologies (ICT) enable American prosperity and national security. Suppliers and ICT/networking supply chains are increasingly targeted by adversaries. Therefore, cybersecurity standards and enforcement mechanisms that recognize shared national interests need to be developed. This perspective is highlighted in Executive Order 14028, *Improving the Nation's Cybersecurity.*[77] Identifying FOCI and other supply chain risks through industrial security, both commercial and DIB, needs strengthening to ensure investments are not lost through insertion of counterfeit/compromised materials, IP theft, the embedding of malicious logic into microelectronics, or malicious programming impacting DoD networks.

A focus on Cybersecurity-Supply Chain Risk Management (C-SCRM) should be an overarching priority for supply chain cyber resilience. C-SCRM efforts manage supply chain risk by identifying susceptibilities and vulnerabilities to cyber-threats throughout the supply chain and developing mitigation strategies to counter those threats whether presented by the supplier, the supplier's products and its subcomponents, or the supply chain (e.g., initial production, packaging, handling, storage, transport,

77. United States, *Executive Order 14028: Improving the Nation's Cybersecurity*, 12 May 2021

mission operation, and disposal). The National Institute of Standards and Technology (NIST) Special Publication 800-161: Cybersecurity Supply Chain Risk Management Practices for Systems and Organizations provides an in-depth description of the core process required for an organization to implement C-SCRM.

The DoD relies on entrepreneurial companies and their innovative and hardworking employees to create cutting-edge capabilities for warfighters. Through procurements from private sector sources, the DoD leverages the best technologies and innovations of the commercial sector to give warfighters the battlefield advantages they need to decisively win whenever called upon to fight. Therefore, DIB cybersecurity is and will remain an expanding priority for the DoD. More than 220,000 companies provide value to the DoD's force development, and the DIB is now facing increasingly sophisticated and well-resourced cyberattacks that must be stopped.

Often backed by adversaries, these cyberattacks threaten the United States and the rules-based order on which the global economy relies. Markets cannot function effectively in an environment where adversarial countries are leveraging their national power to steal intellectual property, sabotage commercial activity, and threaten supply chains.

Recent examples of malicious cyberactivity, such as the Colonial Pipeline ransomware attack and the SolarWinds espionage campaign, have shown that U.S. supply chains face adversaries who continue evolving their exploitation of cyberspace to steal sensitive information and disrupt systems. These highly capable adversaries are maneuvering to infiltrate where they can, especially where they see weak links in supply chain cybersecurity. The size and complexity of defense procurement activities offer numerous pathways for adversaries to access sensitive systems and information. New entry points for U.S. adversaries are created daily as companies use technologies in new and innovative ways across supply chains.

Cybersecurity objectives go beyond protecting data confidentiality. Objectives include ensuring data integrity and availability of the information technology (IT) and operational technology (OT) that operates the Defense Critical Electric Infrastructure, factories, manufacturing environments, and platforms (e.g., trucks, planes, etc.) that companies depend on to conduct business and create the products and services upon which DoD relies.

Challenges

The range of cyberactors and their evolving tradecraft have the potential to hold critical supply chains at risk through a range of cybereffects that can impact data confidentiality, data integrity, and availability of the IT and OT stacks (set of technologies and systems) that enable organizations to function. OT stacks include the hardware and software used in industrial control systems and logistics nodes.

Cyberactors with the potential to cause the most damaging cyberattacks include nation-states and cybercriminals employing ransomware. The potential for a cyberweapon employed by a nation-state to have collateral damage outside the intended area of operations of employment was demonstrated when the "NotPetya" malicious code was employed by the "Fancy Bear" hackers in Ukraine. This cyberattack caused over $10 billion in damages worldwide and significantly degraded the operations of major global enterprises, including Merck, FedEx, Saint-Gobain, Maersk, Nabisco, and Cadbury.[78] In the case of Maersk, their global corporate network consisting of 4,000 servers and 45,000 personal computers was rendered operationally ineffective in minutes.[79]

78. Eduard Kovacs, Security Week Network, *"NotPetya Attack Costs Big Companies Millions,"* 17 August 2017.
79. Charlie Osborne, ZDnet, *"NonPetya Ransomware Forced Maersk to Reinstall 4000 Servers, 45000 PCs,"* 26 January 2018.

Companies that provide critical components to the DoD must take steps to ensure supply chain security and protect their enterprises against cyberattacks. Cyberattacks could impact data integrity, causing key industrial processes to produce products with the wrong “mix” of components or impacting IT/OT integrity that could degrade commercial functioning. This occurred in the recent ransomware attack on Colonial Pipelines. Companies need to develop resiliency to cyberattacks by developing plans to mitigate and recover as well as gain access to reserve IT/OT components that would enable a more rapid recovery from attack.

Recommendations

Internal

Recommendation CP1.1: Expand resources for cybersecurity. DoD should continue expanding resources for DIB cybersecurity and streamlining the operating model for collaboration with industry. This would support cybersecurity efforts to address integrity and availability of critical cyber resources.

Recommendation CP1.2: Develop C-SCRM best practices to support implementation of DoDI 5000.90. DoD should develop a C-SCRM best practices guide aligned with NIST Special Publication (SP) 800-161 to enhance the practice of C-SCRM in alignment with DoDI 5000.90, "Cybersecurity for Acquisition Decision Authorities and Program Managers" which identifies cybersecurity as foundational to the Defense Acquisition System and an intrinsic program manager responsibility when a program uses any acquisition pathway of the Adaptive Acquisition Framework as described in DoDI 5000.02.

Recommendation CP1.3: Enhance the conduct of cybersecurity SCRM. DoD should enhance C-SCRM, especially for companies that support the production of missiles and munitions, by identifying which companies in the supply chain are most important in alignment with DoDI 5200.44 "Protection of Mission Critical Functions to Achieve Trusted Systems and Networks (TSN)." To the extent authorized by and in accordance with applicable acquisition regulations and DoD policies, DoD Program Offices are working to enhance assessment of the cybersecurity practices of the highest priority suppliers and integrators and are working to improve the cybersecurity monitoring of priority suppliers and integrators.

Recommendation CP1.4: Enhance the quality of Cyber Threat Intelligence. DoD should enhance the quality of Cyber Threat Intelligence that is provided to Program Offices by improving the cyber threat components of Validated Online Lifecycle Threat (VOLT) Reports and providing quarterly Cyber Threat Intelligence Briefings to Program Offices and key acquisition decision makers.

Recommendation CP1.5: Expand cybersecurity information sharing. DoD should grow the DoD Cyber Crime Center (DC3)'s Defense Collaborative Information Sharing Environment (DCISE) and enhance the National Security Agency's Cybersecurity Collaboration Center to share crowdsourced threat intelligence at both unclassified and classified levels.

Recommendation CP1.6: Ensure the use of mature cybersecurity practices. To the extent authorized by and in accordance with applicable acquisition regulation and DoD policies, DoD should conduct cybersecurity assessments of companies that make up critical DoD supply chains to ensure that they have transparency and awareness and mature cybersecurity practices.

Recommendation CP1.7: Enhance cybersecurity of critical companies. DoD should enhance the cybersecurity of critical companies in DoD supply chains by requiring timely and complete incident reporting, including threat information and intelligence sharing, cybersecurity technical assistance and collaboration, clear requirements, and assessment mechanisms.

Interagency

Recommendation CP2.1: Facilitate cyberthreat sharing and coordination on defending mission-critical cyber terrain. DoD should augment efforts to facilitate greater acquisition-focused supply chain and cyberthreat sharing and increase partnership activities related to implementation of E.O. 14017- and 14028. DoD should work with its interagency partners to identify and aggressively defend mission-critical cyber terrain from advanced cyberthreats for the highest priority companies providing critical supplies.

International

Recommendation CP3.1: Develop international cybersecurity approaches. DoD should leverage ongoing international engagements to develop cybersecurity approaches for DIB companies that work across international boundaries and build upon the four existing tenets of incident reporting: (1) threat information and intelligence sharing, (2) cybersecurity technical assistance and collaboration, (3) cybersecurity requirements, and (4) assessment mechanisms.

Industry

Recommendation CP4.1: Enhance DIB cybersecurity information management. DoD should work to enhance the ability of DIB companies to get information on cybersecurity. It should be oriented with the DIB company experience in mind and provide useful information on cyber readiness, including a special focus on enhancing information sharing with small and medium enterprises, which tend to have few cyber professionals on staff.

Additional industry recommendations are captured in the Cross-Cutting Recommendations section.

Table 9 (next page) captures the core challenges and recommendations for cyber posture.

Table 9. **Challenges and Recommendations for Cyber Posture.**

		Threat of cyberactors holding critical supply chains at risk
Internal	Rec CP1.1: Expand resources for cybersecurity	✓
	Rec CP1.2: Develop C-SCRM best practices	✓
	Rec CP1.3: Enhance the conduct of cybersecurity SCRM	✓
	Rec CP1.4: Enhance the quality of Cyber Threat Intelligence	✓
	Rec CP1.5: Expand cybersecurity information sharing	✓
	Rec CP1.6: Ensure the use of mature cybersecurity practices	✓
	Rec CP1.7: Enhance cybersecurity of critical companies	✓
Interagency	Rec CP2.1: Facilitate cyber threat sharing and coordination on defending mission critical cyber terrain	✓
International	Rec CP3.1: Develop international cybersecurity approaches	✓
Industry	Rec CP4.1: Enhance DIB cybersecurity information management	✓

Small Business

National Security Significance

The nearly 30 million small businesses in the United States account for over 40 percent of U.S. GDP and provide critical goods, services, and technologies for the manufacturing industry and defense supply chains.[80] The DoD has a strategic interest in leveraging small business innovation and capabilities to address global challenges and ensure mission success. A strong, dynamic, and robust small business industrial base is vital to national security and is an important pillar in the DoD's ability to utilize the most cutting-edge technologies and advanced capabilities. The DoD has spent over $80 billion in prime contracts to small businesses over the past two fiscal years, and the DoD recognizes small businesses are key to ensuring U.S. technical dominance.[81]

Challenges

Despite their importance, small businesses face an uphill battle in participating in defense procurements. Government business practices can create barriers and reduce incentives for the most innovative businesses that may be able to supply the DoD with goods and services critical to national security. Some of these practices include having multiple or ambiguous points of entry into the defense marketplace, unclear communication of opportunities for small businesses, lack of access to information on requirements for bids and the complexity of Federal contracting requirements. Over time, this leads to a deterioration in capabilities and innovation to the detriment of the small business sector and the DIB.

Furthermore, the broader industrial and supply chain challenges faced by the United States disproportionately impact small business suppliers. An erosion of industrial capabilities over the last several decades has diminished critical prime contractor suppliers and impacted the sub-tiers of domestic supply chains. These vulnerabilities mainly impact small businesses, which represent a majority of prime and sub-tier defense suppliers. By recognizing these vulnerabilities now, DoD can respond by leveraging a diverse set of small business suppliers to strengthen domestic supply chains, reduce reliance on sole-source supply, and ensure the United States continues to lead in innovation.

The United States' most innovative small businesses are under increasing threat from attempts by foreign actors to influence or disrupt them through adversarial capital, cyberespionage, or a direct cyberattack. DoD is working to develop additional self-assessment and training resources for small businesses to support cyber compliance.

Recommendations

In his October 2021 memo to DoD leaders, *DoD Small Business Contracting,* Secretary of Defense Austin provided guidance on how to address challenges in the small business industrial base. He urged all DoD components to leverage their small business professionals to ensure small businesses are provided maximum practicable opportunities to participate in DoD acquisition, and give increased focus on reducing barriers to entry for new businesses to help expand the DoD's industrial base, cultivate new and vital capabilities, and increase outreach to underserved communities. To address these objectives and more, the DoD is focusing on several lines of effort.

80. Harvard Business Review. April 13, 2020 "*A Way Forward for Small Businesses,*" A Way Forward for Small Businesses (hbr.org). Accessed December 15, 2021.
81. United States, Department of Defense. October 14, 2021 *"Why Small Businesses Are Essential to U.S. National Security."* *https://www.defense.gov/News/News-Stories/Article/Article/2810965/why-small-businesses-are-essential-to-us-national-security*, Accessed December 15, 2021.

Internal

Recommendation SB1.1: Increase access to the defense marketplace. To improve clarity of small businesses opportunities DoD should to develop and update the DoD Office of Small Business Programs (OSBP) website (*https://business.defense.gov*) and the small business websites of DoD Components into one-stop shops for small businesses to access information on small business programs, resources available to small businesses, and toolkits on how to do business with DoD. This will integrate the work of ninety-six (96) Procurement Technical Assistance Centers (PTACs), which provide counseling support to small businesses that are looking to compete for DoD contracts or perform on current contracts, with DoD's acquisition workforce for unity of effort. These PTACs help overcome the barriers to small businesses that struggle to meet DoD-specific contracting procurement practices and requirements. The Department intends to create processes that would enable DoD Small Business Professionals to leverage PTACs in conducting targeted market research and assistance efforts to support specific acquisitions.

Recommendation SB1.2: Implement a more unified management structure and better resourcing for Department's small business programs. The Department should create a unified management structure of small business programs to ensure long-term planning that better enables small businesses to participate in DoD's programs and have a streamlined entry point into the defense marketplace. To implement unified management of small business programs, the Department is working to improve resourcing of the Offices of Small Business Programs. This unified management effort will help establish better communication between the Department and small businesses regarding DoD priorities and opportunities, allowing small businesses to have better insight into the DoD programs and resources available to them.

Recommendation SB1.3: Update and execute the DoD Small Business Strategy to address defense marketplace entry barriers. DoD is finalizing strategic planning documents such as the DoD Equity Action Plan, as well as an updated DoD Small Business Strategy and Implementation Plan to address barriers to entry. The strategy will consider efforts to reduce those barriers, such as DoD supported reforms to category management by the Small Business Administration (SBA) to create more contracting opportunities for small businesses. These efforts will also include exploration of expanding capital access for small businesses.

Recommendation SB1.4: Measure and scale the impact of DoD small business industrial base programs. DoD has several small business and small business-focused programs that support DoD small business contracting and invest in small business research and development, manufacturing capabilities, and innovation in key technology sectors, all of which further E.O. 14017 objectives. These programs include the Small Business Innovation Research (SBIR) Program, the DoD Mentor-Protégé Program (MPP), the Manufacturing Technology (ManTech) Program, and the IBAS Program. The Department should also work to obtain permanent reauthorization and dedicated funding for small business focused programs to ensure that awards and investments are made to small business firms, including by establishing small business participation or assistance baselines. Finally, the Department should work to scale the reach of its small business programs. For example, the Department is using the results of the Defense Business Board's (DBB's) Congressionally-directed MPP program assessment to improve and expand the DoD MPP across the defense marketplace.

Interagency

Recommendation SB2.1: Increase small business participation. DoD should continue to work with the White House and interagency to advance opportunities for small businesses such as:

- Working with the SBA to implement reforms to category management that would give Tier-2 credit to awards with any small businesses, creating more opportunities for small businesses.
- Working with interagency partners, such as the SBA, to develop market intelligence tools that could be used by acquisition professionals to help identify capable suppliers, and to provide cyber education resources to small businesses.
- Leveraging the DoD OSBP's Memorandum of Understanding with the National Institute of Standards Manufacturing Extension Partnerships to help small businesses become ready to operate as part of the DIB.

International

Recommendations to collaborate with international allies and partners are captured in the Cross-Cutting Recommendations section.

Industry

Recommendation SB4.1: Improve small business awareness of foreign threats. A focus area for DoD should be to leverage the 96 PTAP Program and the Defense Acquisition University to create industry training and resources to help small businesses understand threats from foreign ownership, control, and influence.

DoD and the Small Business Association Administration (SBA) Collaborate to Support Small Business Manufacturing

In collaboration with the SBA, DoD has been working to support small manufacturers to diversify and strengthen U.S. supply chains. DoD proposes collaborating with SBA's Office of Government Contracting and Business Development (GCBD) and Office of Investment and Innovation (OII) to support small business manufacturing in critical supply chain sectors. For example, one of the most frequently cited challenges of new small-business government contractors is acquiring the capital to make the necessary upfront investments in talent, technology, and services to deliver on a new contract. In response, SBA (through OII and GCBD) is developing a public-private partnership that promises to provide the upfront financing from verified U.S. capital sources these businesses need. This partnership will enable business Government contractors to secure below market, low interest rate loans for working capital and fixed-asset purchases immediately following a Federal contract award, alleviating the burden imposed on their businesses before the Federal Government's initial payment.

Table 10 (next page) maps the recommendations against the two challenge areas for small business.

Table 10. **Challenges and Recommendations for Small Business.**

		Government Business Practices	Erosion of Domestic Industrial Capabilities
Internal	Rec SB1.1: Increase access to the defense marketplace	✓	
	Rec SB1.2: Implement a more unified management structure and resourcing for DoD small business programs	✓	
	Rec SB1.3: Update and execute DoD Small Business Strategy to address defense marketplace entry barriers	✓	
	Rec SB1.4: Measure and scale the impact of DoD small business industrial base programs	✓	✓
Interagency	Rec SB2.1: Increase small business participation	✓	✓
International	*See Cross-Cutting Recommendations section*		
Industry	Rec SB4.1: Improve small business awareness of foreign threats		✓

Manufacturing

National Security Significance

"America's manufacturing ecosystem has been a vital engine of economic growth and innovation for more than two centuries. It played a critical role in developing and driving the technologies that sustain our national security and economic competitiveness... Our declining manufacturing competitiveness leaves America's economic infrastructure and defense capabilities underprepared for geopolitical events, global competition, and even major armed conflict."

The Ronald Reagan Institute, *"A Manufacturing Renaissance: Bolstering U.S. Production for National Security and Economic Prosperity,"* Report of the Task Force on National Security and U.S. Manufacturing Competitiveness, November 2021.

If U.S. manufacturing supply chains cannot produce the types and amounts of high-quality products needed to meet DoD demands, the Department must either depend on foreign sources with their supply chain risks, or accept any resulting capability limitations. Previous sections of this report have discussed the implications of this choice in detail.

As an engine of economic growth, American manufacturers contribute more than $2.35 trillion to the U.S. economy, which taken alone, would represent the eighth largest economy in the world.[82] Every dollar spent in manufacturing results in an additional $2.79 added to the economy, making it the highest multiplier effect of any sector.[83]

American Manufacturing

- $2.35 Trillion Economic Contribution
- 12.5 Million Jobs
- Highest Economic Multiplier
- Enables NextGen Defense Systems

Manufacturing today employs over 12.5 million people and provides rewarding, living-wage jobs that pay an annual average of $88,406, including wages and benefits.[84] Advanced technology and automation are changing the nature of manufacturing work—creating new, more technically skilled and higher paying positions. As discussed in the Workforce section, many traditional and advanced manufacturing jobs will go unfilled without appropriate technical education and training to prepare new and current workers with the skills these jobs require.

Previous annual DoD Industrial Capabilities Reports have consistently warned that unless the U.S. defense manufacturing base modernizes and adjusts to the world's new geopolitical and economic realities, America will likely face a growing national security deficit. The health of defense supply chains is underpinned by the health, resiliency, and capacity of the national industrial base. For instance, DoD studies have shown 86 percent of 640 manufacturers surveyed earn less than 10 percent of their revenue from defense, yet they manufacture items key to fielding and maintaining weapon systems. SMMs in particular tend to cycle in and out of the DIB, and they must be able to modernize and remain competitive with domestic and foreign companies to do so. The DoD must take serious and decisive action to combat the challenges to the U.S. manufacturing sector, to both maintain the capabilities and capacity to sustain its legacy systems and expand and modernize manufacturing capabilities to build tomorrow's defense systems.

Challenges

In addition to the sector-specific manufacturing challenges and enablers discussed in the previous sections of this report, U.S. manufacturers face overarching and interrelated challenges related to diminished manufacturing capacity, uneven access to investment capital, and the modernization divide between small and large manufacturers. In general, declining investments in manufacturing create low-output growth, as reflected in manufacturing becoming a declining portion of the U.S. GDP.[85] There also exists a significant and growing gap in current technology and modernization investments between SMMs and large firms.[86]

82. U.S. Bureau of Economic Analysis, International Monetary Fund.
83. National Association of Manufacturers, retrieved 06/02/21.
84. U.S. Bureau of Labor Statistics, U.S. Bureau of Economic Analysis.
85. United States Department of Commerce, Bureau of Economic Analysis, *Gross Domestic Product (Third Estimate), Corporate Profits (Revised Estimate), and GDP by Industry, Third Quarter 2021*, Dec 2021.
86. Vijay Govindarajan, Baruch Lev, Anup Srivastava, and Luminita Enache, Harvard Business Review, *"The Gap Between Large and Small Companies is Growing. Why?"* 16 August 2019.

Diminished Domestic Manufacturing Capacity

Although absolute output has grown over the years, the share of U.S. manufacturing in global and domestic GDP has declined. In value-added terms, growth has slowed dramatically over the past 30 years—from 4.9 percent per year in the 1990s to 1.4 percent per year in each of the last two decades.[87] Most of this growth was driven by design services and software activities rather than actual production.

During the period of 2010 to 2019, the U.S. trade deficit in manufactured goods more than doubled, reaching $833 billion,[88] and productivity in the manufacturing sector fell by 4 percent over the same period.[89] Today there are 25 percent fewer U.S. manufacturing firms and plants than there were in 1997, reflecting not only closures but also fewer manufacturing startups.[90] Loss of domestic manufacturing capacity can have a deleterious effect on defense capabilities, resulting in the DoD securing more components from foreign sources. The increased dependence on imports has inflated the size and complexity of supply chains, and created more opportunities for supply chain disruptions and potential threats.

Over the past few decades, the United States has moved from a manufacturing economy to largely becoming a service economy. One reason is consumer's preference—including Government consumers—for lowest cost items, which has driven labor-intensive manufacturing to low-wage countries. This offshoring has reduced SMM's capacity by more than 50 percent since the 1990s.[91] Also, increasingly complex technology is often contingent upon advanced manufacturing and compelling specialization, which is often capital intensive and out of reach or difficult for new entrants. By the beginning of this decade—and driven home by the emergence of COVID-19 pandemic—it became abundantly clear that the United States is not able to support a wide spectrum of demand with our domestic manufacturing capacity.

As a high wage country, the United States needs to develop cost-competitive manufacturing capacity to capture more of the world market, which has 7.3 billion consumers versus 330 million consumers in U.S.

Uneven Access to Investment Capital

Annual manufacturing investment growth averages 1–2 percent.[92] This is lower than the overall GDP growth rate, indicating that society is underinvesting in manufacturing. Some of the contributing factors to this low investment growth are: limited venture capital interest, high cost of capital compared to Europe and Asia, and the outsourcing of manufacturing to other countries using the strategy "Invent here, and Manufacture there."[93] This strategy captures increased margins by manufacturing in low-wage countries, but lowers the incentive to invest in manufacturing domestically.

Low venture capital interest is attributed to the fact that venture capitalists seek large and quick returns on investment and the manufacturing sector requires longer than average times to yield returns. In addition, investments in manufacturing require larger amounts of investment capital for facilities, equipment, and materials. As such, the key metric of return on assets is not as favorable for the manufacturing sector as for software or services.

87. McKinsey Global Institute, *"Building a more competitive US manufacturing sector"*, April 2021.
88. McKinsey Global Institute, *"Building a more competitive US manufacturing sector"*, April 2021.
89. Atkinson, *"US Manufacturing Productivity Is Falling, and It's Cause for Alarm,"* IndustryWeek, July, 2021.
90. McKinsey Global Institute, *"Building a more competitive US manufacturing sector"*, April 2021.
91. Sridhar Kota and Tom Mahoney, *"Innovation Should Be Made in the U.S.A.,"* Wall Street Journal, Nov 15, 2019, *https://www.wsj.com/articles/innovation-should-be-made-in-the-u-s-a-11573833987*.
92. McKinsey Global Institute, "Building a more competitive US manufacturing sector", April 2021.
93. Sridhar Kota and Thomas C. Mahoney, "Insight into manufacturing policy", March 2020.

The consequence of low manufacturing investment is that our share of the world market in goods has continuously declined, and manufacturing output as a percentage of GDP has similarly declined, from more than 25 percent in 1947 to 10.9 percent at the end of 2020.[94] There has also been a decrease in the number of small and medium manufacturing enterprises due to business failures and multiple waves of consolidation.

As noted in other specific supply chain sectors, manufacturing and supply chain resiliency is greatly impacted by intrinsic aspects of the acquisition policy for DoD product procurement. The cyclical demand and the low-volume nature of DoD procurement, when compared to commercial products, creates volatility in the manufacturing supply chain. These factors limit the ability of companies to invest in new manufacturing technologies and capital equipment, and creates a disincentive for new entrants to the DoD supply chain, particularly from nontraditional companies.

In addition to the aforementioned factors, the sequential nature of the DoD product development lifecycle creates boundaries between stages of technology development. The DoD makes significant investments in early stage technologies through university research, small business innovation programs, and activities within Government R&D centers. However, there exists a gap between these investments, which can help build a more resilient supply chain, and the adoption of new technologies. This gap is often called the valley of death and it prevents existing supply chains that are driven by procurement of current systems from transforming into advanced, resilient supply chains of the future.

Modernization Divide between Small and Large Manufacturers

We are in the beginning of the fourth industrial revolution (Industry 4.0) where automation, Internet of Things, metaverse, cloud computing, and cognitive computing will become seamlessly connected to create smart factories. An end-to-end digital transformation through advanced digital technologies across engineering, manufacturing, and the U.S. supply chain could bring the domestic manufacturing sector to the forefront of Industry 4.0. Our large manufacturers are already leading this journey in the U.S.; however, for the United States to compete well in this global industrial revolution, it needs many more SMMs utilizing Industry 4.0 technologies as well. Today, the penetration of automation, digitization, and cybersecurity into the nation's 300,000 SMMs is uncertain—there is a lot of regional variation.

The DIB is not yet modern and its ability to modernize varies widely based on an individual organizations' available investment capital, knowledge of how and where to modernize, and its ability to make a business case for modernization. The OEMs, which are typically large companies, will modernize much more quickly. They have more access to, and can make a better business case for, the investment capital needed for automation and related workforce development. The SMMs face more challenges and delays in adopting Industry 4.0 technologies and processes, mostly because of the capital requirements.[95]

DoD organic base depots (DoD's maintenance facilities that are government owned and operated, and capable of repairs and overhaul of military systems) and manufacturing capabilities in the OIB face similar issues when trying to develop a business case for investment. DoD needs the benefits of automation to reduce total lifecycle costs and increase readiness. Modernized facilities and processes have the potential to improve product quality and reproducibility and lower unit costs. Digitization can ease sustainment processes by enabling predictive maintenance, diagnosis, and repair. However, long-term facility modernization projects are often required to support automation and other advanced manufacturing improvements, especially at depots, which can make these changes longer, harder, and more expensive to implement. DoD must also retain the capability to sustain its legacy assets while modernizing its OIB facilities and capabilities.

94. *https://www.statista.com/statistics/191972/value-added-by-us-manufacturing-as-a-percentage-of-gdp-since-2007/* accessed 1/13/2022.
95. OUSD Acquisition and Sustainment, "*Effects of Increased Automation of Defense Industrial Base on Manufacturing Workforce: Opportunities and Requirements for Change*," Briefing for the Congressional Defense Committees, January 2021.

Recommendations

Internal

Recommendation MG1.1: Invest in scale-up of advanced manufacturing. Use DoD authorities and investment programs to engage with both traditional and non-traditional industry to span the valley of death for adoption of advanced manufacturing technologies.

- Ensure that DoD recommendations for supply chain resilience align with its technology roadmaps for future technologies, and identify sufficient funding required for DoD and Military Service modernization priorities.
- Investigate assistance and incentives for defense-oriented SMMs to modernize capabilities with manufacturing technologies. Propose contract incentives as a conduit for lower-tier contractors to embrace digital engineering and manufacturing tools and technologies as a performance element.
- Ensure that DoD-backed manufacturing technologies get propagated across the industrial base to increase productivity of American manufacturing.

Interagency

Recommendation MG2.1: Align and coordinate DoD manufacturing assistance and investment programs with Federal response to the National Strategic Plan for Advanced Manufacturing and other DoD programs.

- Coordinate technical pursuit areas of DoD investment programs, (e.g. ManTech, Manufacturing Innovation Institutes, Industrial Base Analysis and Sustainment) with technology priority areas of the National Strategic plan.
- Expand assistance to meet Industry 4.0 needs, increase digital and advanced manufacturing skills for increasingly automated manufacturing factories.
- Explore or expand mentor-protégé programs in concert with MEP and Procurement Technical Assistance Program.

International

Recommendation MG3.1: Improve the U.S. manufacturing ecosystem and encourage ally-shoring. Study international programs, investments, and manufacturing capabilities to identify best-in-class practices and likely future trends. Leverage the results to guide manufacturing policy investments and ally-shoring activities.

Industry

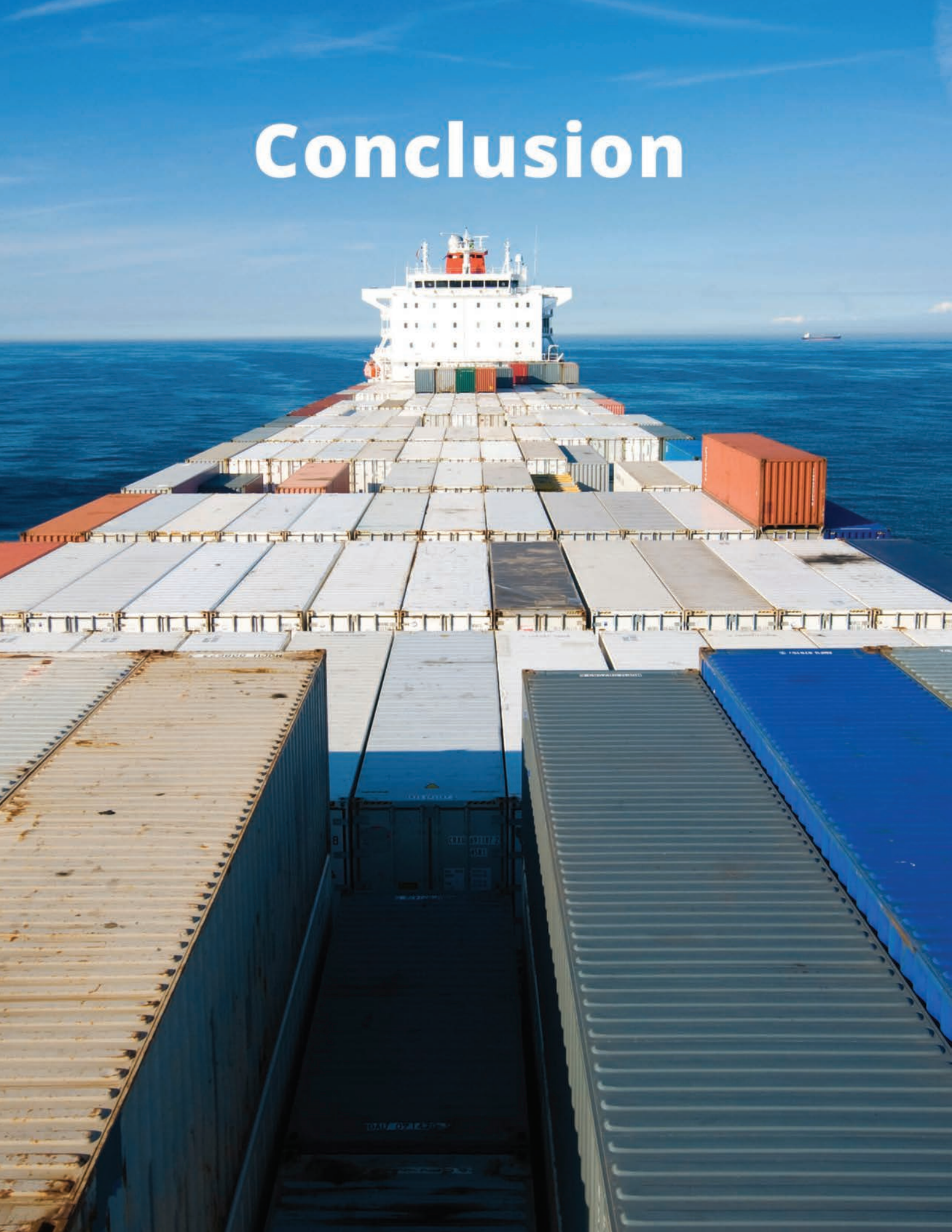
Recommendations to collaborate with industry are captured in the Cross-Cutting Recommendations section.

Table 11 (next page) maps the recommendations against the three challenge areas for manufacturing.

Table 11. **Challenges and Recommendations for Manufacturing.**

		Declining Domestic Capabilities	Declining Investments	Modernization Divide between Small/Large Manufacturers
Internal	**Rec MG1.1: Invest in scale-up of advanced manufacturing**	✓	✓	✓
Interagency	**Rec MG2.1: Align and coordinate manufacturing assistance and investment programs**			✓
International	**Rec MG3.1: Improve the U.S. manufacturing ecosystem and encourage ally-shoring**	✓	✓	✓
Industry	***See Cross-Cutting Recommendations section***			

Conclusion



Conclusion

As highlighted by the global COVID-19 pandemic, fragile supply chains can have far reaching and long-lasting implications to economic prosperity and national defense. The DoD will need to work closely both internally and with its partners—interagency, international, and industry—to build strong and responsive supply chains in the coming years. The 64 recommendations outlined in this report are initial steps on a longer-term effort to increase domestic manufacturing production and technology development capabilities, enhance efforts with partners and allies, and ensure economic and national security. DoD will use the recommendations to prioritize policy and investment decisions over the coming years as it works to strengthen the DIB and improve the resilience of its supply chains.

Appendix

Acronyms

BIL	Bipartisan Infrastructure Law
BLS	United States Bureau of Labor Statistics
C&F	Cast and Forged
CEMWG	Critical Energetic Materials Working Group
CMMC	Cybersecurity Maturity Model Certification
COTS	Commercial Off-the-Shelf
COVID-19	Coronavirus Disease 2019
C-SCRM	Cybersecurity-Supply Chain Risk Management
CTE	Career and Technical Education
DC3	United States Department of Defense Cyber Crime Center
DCISE	Defense Collaborative Information Sharing Environment
DHS	United States Department of Homeland Security
DIB	Defense Industrial Base
DLA	Defense Logistics Agency
DOD	United States Department of Defense
DOL	United States Department of Labor
DPA	Defense Production Act
E.O.	Executive Order
EDA	Electronic Design Automation
EPA	Environmental Protection Agency
EPEAT	Electronic Product Environmental Assessment Tool
EUV	Extreme Ultraviolet
EV	Electric Vehicle
FOCI	Foreign Ownership, Control, or Influence
FTC	Federal Trade Commission
FY	Fiscal Year
GCBD	Office of Government Contracting and Business Development
GDP	Gross Domestic Product

GM	General Motors
GOCO	Government-Owned Contractor-Operated
GOGO	Government-Owned Government-Operated
ICR	Industrial Capabilities Report
ICT	Information and Communication Technology
ISIS	Islamic State of Iraq and Syria
IT	Information Technology
ManTech	Manufacturing Technology Program
MEP	Manufacturing Extension Partnership
MPP	Mentor-Protégé Program
MQA	Measurably Quantifiable Assurance
MRO	Maintenance Repair and Operations
NASA	National Aeronautics and Space Administration
NDAA	National Defense Authorization Act
NIIS	National Imperative for Industrial Skills
NIST	National Institute of Standards and Technology
NM	Nanometer
NTIB	National Technology and Industrial Base
OEM	Original Equipment Manufacturer
OIB	Organic Industrial Base
OII	Office of Investment and Innovation
OSBP	Office of Small Business Programs
OT	Operational Technology
PEO	Program Executive Office
PTAC	Procurement Technical Assistance Center
R&D	Research and Development
RAPID	Rapid Assured Microelectronics Prototypes
SBA	Small Business Administration

SBA	Small Business Association Administration
SBIR	Small Business Innovation Research Program
SCALE	Scalable Asymmetric Lifecycle Engagement Microelectronic Workforce Development
SEE	Single Event Effects
SIA	Semiconductor Industry Association
SMM	Small and Medium Manufacturers
SOSA	Security of Supply Arrangements
SOTA	State-of-the-Art
SOTP	State-of-the-Practice
STEM	Science Technology Engineering and Math
TAP	Transition Assistance Program
VETS	Veterans' Employment and Training Services

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