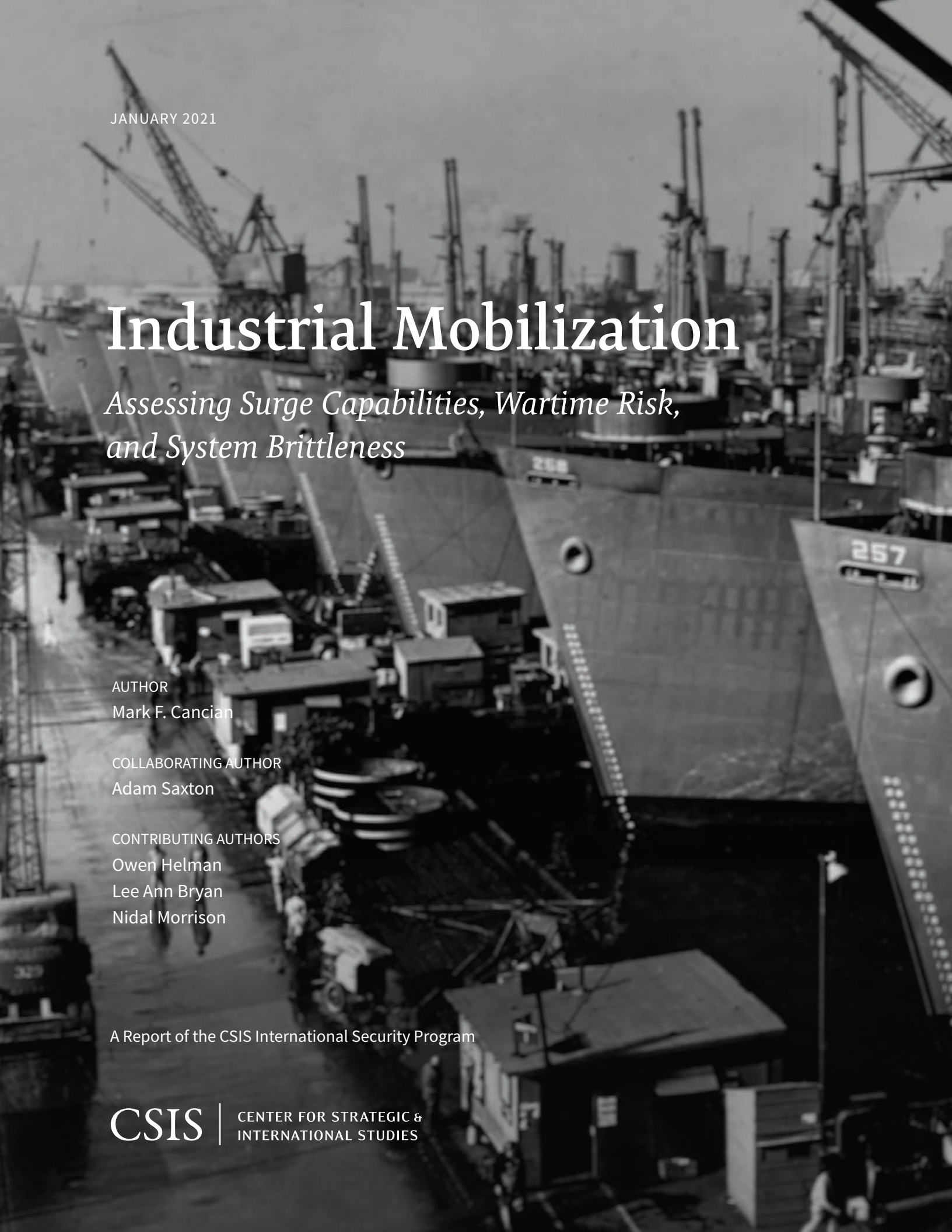

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Industrial Mobilization

Assessing Surge Capabilities, Wartime Risk, and System Brittleness

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A Report of the CSIS International Security Program

CSIS | CENTER FOR STRATEGIC & INTERNATIONAL STUDIES

DECEMBER 2020

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Executive Summary

With the shift of U.S. strategic focus to great power competition, interest in industrial mobilization for a long-term, high-intensity conflict has returned. However, the highly consolidated and fragile U.S. defense industrial base is not designed to meet this challenge. To gain insight into the ability of the defense industrial base to meet the demands of great power conflict, this project reviewed the history and literature on industrial mobilization and then analyzed the time needed to replace contemporary weapon systems' inventory at peacetime and surge production rates.

That history is not encouraging. In World War I, U.S. industrial mobilization began with the declaration of war. Although industry scrambled to respond, U.S. forces were mostly equipped by the French and British until late 1918. The interwar period saw much planning but lacked the resources for concrete action. Mobilization for World War II began before U.S. entry into the conflict, spurred by naval expansion in the late-1930s and then by French and British war orders. By the time of the attack on Pearl Harbor, the United States was mobilizing as fast as it could. Nevertheless, it was late 1943 to early 1944 before U.S. forces were large enough and sufficiently equipped to take on the main elements of the Axis armed forces. This history shows how long the industrial mobilization process takes, the importance of early action, and the value of prior planning.

During the Cold War, large defense budgets sustained a robust industrial base, but the end of the Cold War brought radical consolidation. Most recent studies of the industrial base focus on the sustainability and health of the peacetime industrial base with little attention to industrial mobilization.

To assess the capabilities of the current industrial base, the project calculated the time needed to replace weapon systems' inventory at peacetime and surge production rates. This analysis was based on an original database developed using production data found in the P-21 and P-40 exhibits in the Department of Defense (DOD) procurement justification books from 1999, 2008, and 2020.

The analysis produced several findings.

- First, the time needed to replace Major Defense Acquisition Program (MDAP) inventories at surge production rates would take an average of 8.4 years, about 5 years faster than the 13.8 years required at peacetime efficiency production rates.
- Second, some investment categories are at more risk than others, with space-based systems and missiles/munitions having significantly longer replacement times than others, and Navy shipbuilding facing the longest replacement times of all. Programs with analogs in the civilian economy, such as wheeled vehicles, mission support vehicles, and C4I (command, control, communications, computer, and intelligence) systems, appear to have faster replacement rates than uniquely military systems.
- Third, although the Army has by far the largest number of total systems, the Air Force has the longest replacement times (excluding Navy's ships).
- Finally, the project found that the industrial base has become more brittle over time, as it takes longer to replace inventories at FY 2020 production rates than at FY 1999 production rates.

Although these calculations give insight into the industrial mobilization challenge, they do not directly assess the wartime problem: replacing equipment losses in combat. These losses are likely to be quite large and the replacement times even more demanding than those shown in the results above. However, calculating wartime losses requires extensive historical research and goes beyond the scope of this project.

The project's findings indicate that existing surge capacities for MDAPs fall short of what would be needed for a long-duration great power conflict. More research is needed to provide decisionmakers with options to cope with this shortfall.

1

Introduction

Why Conduct Research on Industrial Mobilization Now?

Industrial mobilization was a concern during the Cold War but largely disappeared during the post-Cold War period of short, limited regional conflicts. After a generation of absence, it has now returned. The 2017 *National Security Strategy* criticized the notion that "all wars would be fought and won quickly, from stand-off distances and with minimal casualties." The 2018 *National Defense Strategy* highlighted the "reemergence of long-term strategic competition" against "revisionist powers," identified as Russia and China. In 2017, General Dunford, then chairman of the Joint Chiefs of Staff, expressed concern that an "increasingly brittle industrial base" might not sustain a protracted conflict.[1] Many observers—from the Commission on the Future of the Army, to academics and think tanks, to the Defense Science Board—have also warned about the renewed risk of long, high-intensity wars. Wars against great powers burn up weapons and munitions at a ferocious rate, far beyond what the United States has experienced in recent regional conflicts.

However, the highly consolidated and fragile U.S. defense industrial base is not designed to meet this challenge. After the Cold War, the demand for weapons declined, the need for surge capability disappeared, and the industrial base was under tremendous pressure to reduce cost. As a result, industry consolidated so that there were fewer producers in any weapons area. Programs were designed for peacetime efficiency, not mass wartime production, because maintaining unused capacity for mobilization is expensive. This focus on efficiency produces "brittleness" (to use General Dunford's

1 U.S. Congress, Senate, *General Joseph F. Dunford, Jr., USMC, Testimony for reappointment to the grade of general and reappointment to be Chairman of the Joint Chiefs of Staff,* Hearing before the Armed Services Committee, 115th Cong., 1st sess., September 26, 2017, 4, https://www.armed-services.senate.gov/hearings/17-09-26-nomination_--dunford.

term)—an acquisition system that is well designed for a particular set of circumstances but liable to failure in other circumstances.

When strategists and planners think of industrial mobilization, they think of World War II and all that came with it: conversion of civilian industry to military use, mass production, a long buildup of forces, and, finally, well-equipped, massive armies that overwhelm opponents. However, future wars are unlikely to have the long strategic warning that the United States had before World War II. Existing industrial mobilization capabilities are all that will likely be available.

This new strategic environment—of possible great power conflict, potentially long wars with high attrition, a consolidated defense industry, and the lack of strategic warning—drives a need to conduct research on the industrial base's ability to cope with attrition and the demands of high-intensity great power conflict.[2]

This project first begins by tracing the history of U.S. industrial mobilization, moving from World War I and World War II, through the Cold War, to the wars in Iraq and Afghanistan. The purpose is to put the current challenges into historical perspective. Second, the project reviews the current literature on industrial mobilization in light of the current *National Defense Strategy*. Third, the project assesses surge capacity using a new database on DOD production, focusing on the defense industry's ability to replace its service inventory objectives at efficient and surge rates. This assessment includes the extent to which the industrial base has become more brittle over time; which industries, weapon categories, and services are at greatest risk; and the comparative risk of weapon systems with civilian analogs. Finally, the project makes recommendations for developing better data so that decisionmakers can make fully informed decisions about industrial mobilization.

2 Andrew Krepinevich, *Long War* (Washington, DC: Office of Net Assessment Summer Study, 2017) [limited circulation]; and Antulio Echevarria and AWC research team, *Great Power War* (Carlisle, PA: United States Army War College, 2017) [limited circulation].

2

Background

The Modern History of U.S. Industrial Mobilization

Industrial mobilization has a long history in the United States, and that history can illuminate challenges currently facing the Department of Defense (DOD). The major insight that emerges from this history is that industrial mobilization takes a long time—years in many cases. This mobilization finds itself constantly behind where it needs to be because it occurs as demand increases many times over peacetime levels as a result of force expansion and equipment attrition in combat. Other insights arise from this long timeline and constant shortfall:

1. The need for centralized economic planning to cope with the massive dislocations that arise in an industrial mobilization situation;
2. The need to accept foreign designs when they are superior to U.S. designs;
3. The importance of balanced production that includes supporting capabilities as well as major end items;
4. The need to replace some prewar legacy systems that may be adequate for training and regional conflicts but are inadequate for great power conflicts;
5. The tension between efficient peacetime production and maintaining capacity for wartime surge;
6. The value of beginning industrial mobilization before conflict begins; and
7. The key role that senior officials play in pushing sluggish bureaucracies to move quickly.

World War I

When the United States entered World War I on April 6, 1917, it was ill-prepared to meet the challenges and demands of mass industrial mobilization. Prewar efforts to enhance coordination, equipment, and

doctrine were inadequate. The lack of relevant experience and modern designs, resource shortages, and deficiencies in organization, coupled with the immediate need to rapidly expand its production capability, left the United States heavily dependent on its allies to equip and train its forces. Output of most equipment and munitions did not begin to meet wartime requirements until just a few months before armistice on November 11, 1918. Some equipment, such as tanks, never did.

PREWAR PLANNING AND EARLY WAR YEARS

Just prior to entry into World War I, the United States attempted to address political, social, and economic shortcomings through the "preparedness movement" (1915–1916). A key element was the National Defense Act of 1916, signed in May and enacted in June. The act authorized an expansion of the Regular Army and the National Guard, created an Officers' Corps and an Enlisted Reserve Corps, and established a Reserve Officers' Training Corps program, which eventually led to the training of almost 89,500 officers during the war. The act authorized the president to place orders for defense materials and to force industry to fulfill those orders. One month after the enactment of the National Defense Act, the Council of National Defense was established to serve as a central point for the management of military and industrial needs.[3] The United States also moved to improve the defense of U.S. coasts and borders.

Prewar planning did not include plans for the equally important mobilization of industry and munitions production. It soon became apparent that the efforts of the preparedness movement, although useful, were insufficient to meet the high demands of mass mobilization.[4]

As orders for war production went out, shortages appeared, the price of inputs rose, and American factories became inundated with orders that surpassed their capacity. The unprecedented demand and expansion produced competition for resources and confusion about the duties and jurisdiction of government agencies. The Council of National Defense responded to these challenges by creating the War Industries Board in July 1917. The War Industries Board served as the principal agency for coordinating economic and industrial mobilization. With both civilian and military representatives, the board's function was to analyze the needs of the government, study the extent to which resources could meet the needs, assign priorities and encourage increased production, and disseminate rules and guidance for preventing waste and misuse.[5]

RELIANCE UPON THE ALLIES

World War I gave rise to the development of thousands of new items of ordnance, which were only generally understood by U.S. officers. The British and French furnished the United States with plans, specifications, working models, and complete manufacturing processes. Although this guidance greatly enhanced mobilization efforts, most U.S. industries were ill-equipped to take advantage of them, and

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3 Brian Neumann, ed., The U.S. Army in the World War I Era, part of the U.S. Army Campaigns of World War I Commemorative Series (Washington, DC: Center of Military History United States Army, 2017), https://history.army.mil/html/books/077/77-2/cmhPub_077-2.pdf.

4 Benedict Crowell, *America's Munitions 1917-1918* (Washington, DC: Government Printing Office, 1919), 18, https://history.army.mil/html/bookshelves/resmat/wwi/historical_resources/default/sec04/PDF/AmericasMunitions1917-18.pdf.

5 Bernard M. Baruch and Richard H. Hippelheuser, *American Industry in the War; a Report of the War Industries Board (March 1921)* (New York: Prentice-Hall Incorporated, 1941), 19–21.

production did not move fast enough to fulfill orders. For example, it typically took industry 12 to 18 months to go from the initial order to quantity production of artillery. Because of such shortfalls, much reliance was placed upon the Allies for support, with both the British and French furnishing equipment and munitions to U.S. troops deploying to Europe. The British and French had suffered their own equipment shortages early in the war, but by 1917 and 1918, they had greatly increased their production and could provide material to the Americans. In addition to the masses of tanks, airplanes, artillery, and machine guns provided to U.S. forces, allied assistance included even such mundane items as pyrotechnic supplies, wire cutters, and mortar shells as well as services such as training and transport of manpower.[6]

BUILDING PRODUCTION CAPACITY AND REDUCING ALLIED RELIANCE

Although the United States began to meet the demands of industrialized warfare only toward the final months of the war, the progress of U.S. manufacturing is notable. As outlined below, the United States gained production knowledge for new systems, altered designs to ensure efficiency, improved domestic transportation, modified inputs when necessary, and provided raw materials to allies in compensation for equipment and munitions.

Artillery: At the beginning of the war, the United States had only enough light artillery to equip an army of 500,000 and very little medium or heavy artillery. In June 1917, the Army decided to use U.S. guns for training and to equip troops abroad with French and British artillery. An arrangement between United States and the Allies was made so that the first U.S. divisions were equipped with purchased artillery from the British and French in exchange for equivalent amounts of steel, copper, and other raw materials.[7]

Rifles: At the outbreak of the war, the Army used its reserve stock of approximately 600,000 M1903 Springfield rifles to equip the first divisions of the Regular Army and National Guard that were organized. Roughly 200,000 older Krag-Jörgensen rifles that were in reserve were used for training. Production of Springfield rifles reached only 1,000 per day, far short of wartime requirements. This led to the decision to switch manufacturing to an entirely different rifle to meet the demand. Since several factories in the United States were completing British orders for Enfield rifles, the United States developed a new M1917 Enfield rifle to resemble the British Enfield, chambered so that it could use the same ammunition as the Springfield. By the end of the war, production of Springfield rifles totaled 900,000, but production of the new Enfield rifle reached nearly 2,300,000.[8]

Machine Guns: Before entry into World War I, the United States was vastly under-armed in automatic weapons compared to the Europeans. To address this, the Army conducted a series of tests comparing seven makes of automatic machine guns, with the Vickers machine gun (the British-designed Maxim gun, renamed) proving to be the choice model. However, production was slow, and it was not until mid-1918 that Colt Vickers guns started to be shipped abroad. Thus, the earliest demand for infantry

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6 Edward M. Coffman, *The War to End All Wars: the American Military Experience in World War I* (Madison, WI: University of Wisconsin Press, 1986), 40.

7 Neumann, ed., *The US Army in the World War I Era*, 28; Leonard Porter Ayres, *The War with Germany: A Statistical Summary* (Washington: Government Printing Office, 1919), 83.

8 Ayres, *The War with Germany*, 63-64; and Crowell, *America's Munitions 1917-1918*, 182.

weapons by U.S. forces abroad had to be met by French supplies, including 5,255 Hotchkiss machine guns and approximately 35,000 Chauchat automatic rifles.[9]

Later, Colt began production of the American designed Browning water-cooled machine gun Model 1917, as the production of the Browning was less complicated than the Vickers gun. Production reached high levels but only toward the end of the war.[10]

Tanks and Trucks: Despite the United States pioneering the mass production of cars, it was largely dependent on allies to equip its forces with vehicles. Most U.S. production was delivered after the armistice. For tanks, manufacturing in the United States focused on the improvement of design and mass production of small six-ton tanks for the 1919 campaign. Although only 64 had been completed by the time of the armistice, 799 were produced by March 31, 1919, when wartime contracts ended. U.S. tank units had to use French and British tanks. The French supplied 227 small tanks, and the British supplied 64 heavy tanks.

Of the 30,072 four-wheel-drive trucks that had been ordered, 12,498 had been completed, and 9,420 had been sent overseas by the end of the war. By January 1919, when war production stopped, 23,499 were completed. Thus, about half of production was completed after the armistice.[11]

Airpower: In the three years prior to U.S. involvement in World War I, the airplane had undergone a major mechanical evolution which left the U.S. aircraft industry unprepared for full-scale production. Up to this time, no American-made plane had ever mounted a machine gun or carried anything other than simple instruments. Airplanes on order in April 1917 (over 350 of them) were of such an obsolete design that the manufacturers, after increased understanding of war requirements a few months later, asked to be released from their contracts.

In July 1917, the Joint Army and Navy Technical Board recommended that 22,000 training and combat aircraft be produced within 12 months. It soon became clear that the United States could not redesign and expand its aircraft industry and deliver aircraft overseas before the summer of 1918. To cover this gap, the United States and France agreed to exchange 5,875 planes of French design and manufacture for U.S. raw materials. By the armistice, the United States had produced a total of 11,754 airplanes (though with spare parts for only about one-third of them), supported by 48 flying fields, 20,568 air service officers, and 174,456 enlisted men and personnel. However, most of the equipment used by U.S. flying units in theater came from the Allies.[12]

Naval Expansion: In the years leading up to World War I, the United States expanded its battlefleet, but with an emphasis on large ships such as battleships. By 1915, the U.S. Navy had 32 battleships and 30 cruisers but only 57 destroyers. The Naval Act of 1916, passed by Congress on August 29, 1916, authorized a large increase in funding for naval construction. However, because Mahanian

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9 Robert R. Hodges and Robert R. Hodges, Jr., *The Browning Automatic Rifle* (Oxford, UK: Osprey Publishing, April 17, 2012), 29.

10 Crowell, *America's Munitions 1917-1918*, 175–176; Ayres, *The War with Germany*, 65-72; and Robert G. Segel, "U.S. Colt Vickers Model of 1915," *Small Arms Defense Journal* 3, no. 1 (2012), http://www.sadefensejournal.com/wp/u-s-colt-vickers-model-of-1915/.

11 Crowell, *America's Munitions 1917-1918*, 148–149.

12 Ibid., 235–243.

views still prevailed, this three-year construction plan did not include measures to meet the strategic threat of submarines. The act called for the construction of 10 battleships, 6 battle cruisers, 10 scout cruisers, 50 destroyers, and 67 submarines. The act also established the Naval Flying Corps, provided improvements to shipyards, and expanded the Marine Corps.[13]

It was not until its entrance into World War I that the United States adjusted to the demands of the war in progress. Because German U-boats were sinking allied ships faster than they could be replaced, the focus shifted from seeking decisive battle to antisubmarine warfare and the protection of convoys. Antisubmarine patrol and escort required small vessels of light draft and high speed, so naval shipbuilding shifted to smaller craft, such as destroyers and patrol boats.[14]

Ten days after the United States declared war, the U.S. Shipping Board created the Emergency Fleet Corporation to build, own, and operate a wartime merchant fleet for the U.S. government. The Emergency Fleet Corporation oversaw the expansion of U.S. shipyards from 61 when the United States entered the war to 216 at the armistice, of which 111 were new yards.[15]

The U.S. shipbuilding program had yet to reach peak production by the end of the World War I. When the armistice was signed on November 11, 1918, the Emergency Fleet Corporation had delivered a total of 470 ships, with a monthly production record of 77 vessels (398,000 deadweight tonnage, or DWT) in October 1918. The U.S. Shipping Board continued its merchant shipbuilding program until 1922, when the Emergency Fleet Corporation finally completed 2,312 ships.[16]

Table 1: U.S. Shipbuilding Program During World War I

	First Keel Laid	First Ship Delivered
Requisitioned Steel	April 20, 1916	August 20, 1917
Contract Steel	July 29, 1917	January 5, 1918
Contract Wood	May 15, 1917	May 24, 1918
Contract Composite	September 27, 1917	August 28, 1918
Contract Concrete	April 20, 1918	October 23, 1919

Source: W. C. Mattox, Building the Emergency Fleet, (London, UK: The Penton Publishing Company, 1920), 98.

13 Joshua Keating, "What kind of Navy did we have before World War I?," *Foreign Policy*, 2012, https://foreignpolicy.com/2012/10/12/what-kind-of-navy-did-we-have-before-world-war-i/; and Frank A. Blazich Jr., *United States Navy and World War I: 1914–1922* (Washington, DC: Naval History and Heritage Command, n.d.), 16–17, https://www.history.navy.mil/research/library/online-reading-room/title-list-alphabetically/u/us-navy-world-war-i-redirect.html.

14 Dudley W. Knox, *American Naval Participation in the Great War (With Special Reference to the European Theater of Operations)* (Washington, DC: Naval History and Heritage Command, n.d.), https://www.history.navy.mil/research/library/online-reading-room/title-list-alphabetically/a/american-naval-participation-in-the-great-war-with-special-reference-to-the-european-theater-of-operations.html#.

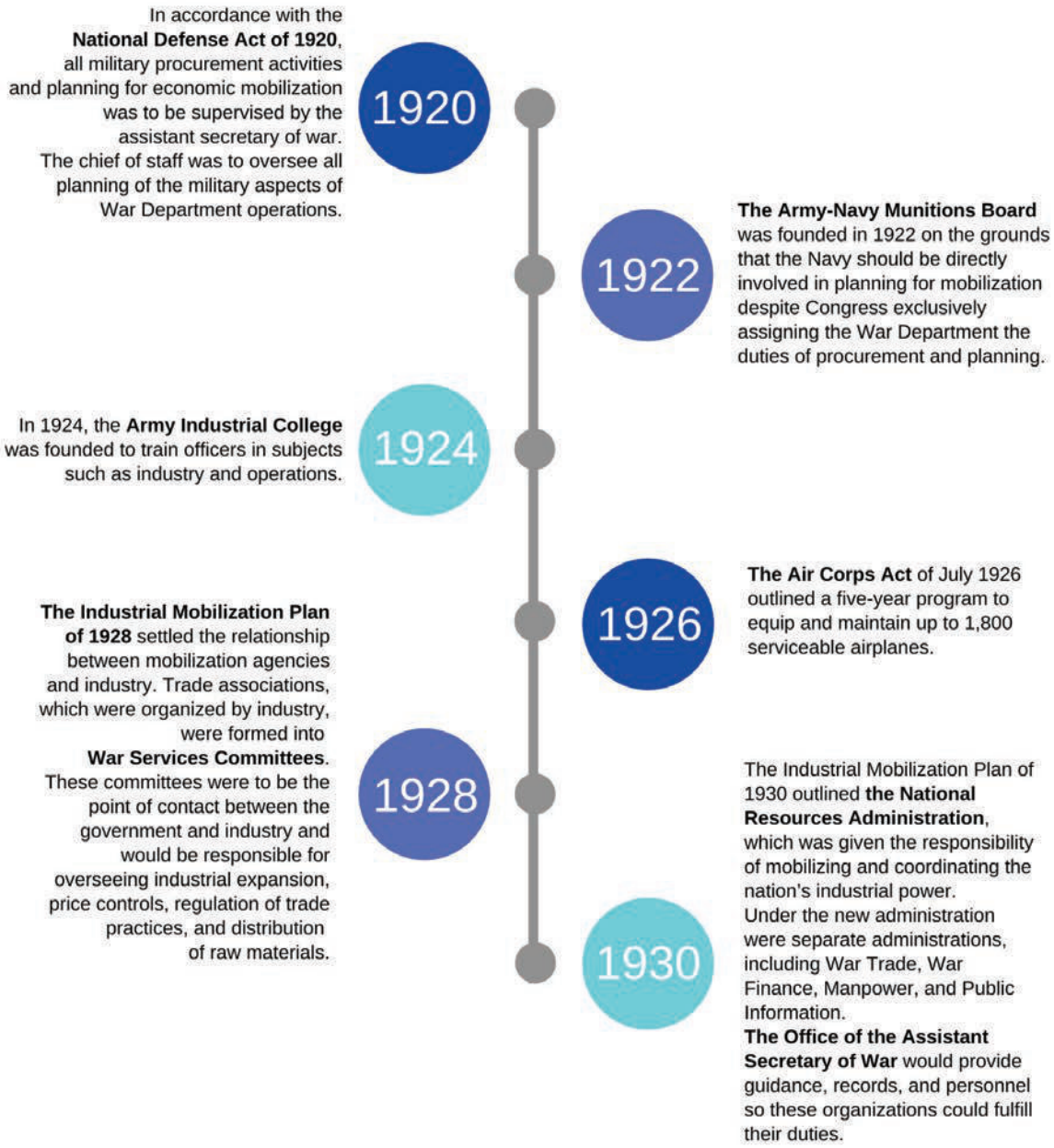
15 W. C. Mattox, *Building the Emergency Fleet* (London, UK: Penton Publishing Company, 1920), 206.

16 "The Maritime Administration's First 100 Years: 1916 – 2016," Department of Transportation Maritime Administration, https://www.maritime.dot.gov/history/historical-documents-and-resources/maritime-administration%E2%80%99s-first-100-years-1916-%E2%80%93-2016#_ftnref1.

The Interwar Years

The experience of industrial mobilization during 1917 and 1918 served as a model for wartime planning during the interwar years and World War II. In the decades that followed, attempts were made to address the lack of industrial preparedness experienced during World War I, as described in the timeline below. However, the excessive stock of materiel from production for World War I, isolationism, criticism of the defense industry ("merchants of death"), and revulsion against war in general (this was the age of the Kellogg-Briand Pact that outlawed war) meant that planning for a future war received little high-level attention.

Figure 1: The Interwar Years: Major Events in Industrial Mobilization



Source: Authors' own compilation.

During the interwar years, the main concern for the War Department was simply to maintain resources to fulfill peacetime missions. Over time, World War I weapons started to become obsolete, but arsenals and laboratories, struggling with small budgets, were hampered in developing new designs. The Army had to manage with arms left over from World War I since military policy at this time focused on bolstering the U.S. Navy, which was viewed as the nation's first line of defense. The Navy itself was limited by the Washington Naval Treaty of 1922 and the London Treaty of 1930.[17]

World War II

Industrial mobilization in the United States during World War II was vastly different from that of World War I. Mobilization began years prior to the United States' formal entry into the conflict. Thus, when the United States officially declared war on December 7, 1941, its process of industrial mobilization was far more advanced than had been the case at the declaration of war for World War I. This allowed the United States to eventually supply equipment not only for its own forces but also for those of its allies.

Industrial mobilization for World War II proceeded in three stages. The first stage ("rearmament") ran from the mid-1930s to the fall of France in May 1940. This stage was characterized by a naval buildup and by foreign orders for equipment that spurred U.S. weapons manufacturing. The second phase ("expansion") ran from May 1940 to the formal U.S. entry into the war in December 1941. This phase was marked by rapid expansion of the military sector. For example, the United States instituted a peacetime draft, mobilized its reserves, and built new production facilities. Production orders flooded industry. The third phase ("total mobilization") constituted total economic mobilization, with rationing and the conversion of civilian production to wartime use.

As had happened in World War I, organizational complications such as failure to adopt an industrial mobilization plan and disagreements over governing bodies slowed initial output. Shortages in materials, machine tools, or workforce plagued production throughout every stage of U.S. mobilization.

Nevertheless, despite the many challenges experienced during mobilization, the effort had many successes. Implementation of government-owned, contractor-operated (GOCO) plants as the main mechanism for the expansion of industrial capacity proved successful. Cooperation and innovation among firms allowed weapons to be efficiently produced on multiple production lines. In the end, the achievement of U.S. mobilization during World War II was monumental. The United States developed, produced, and delivered such vast quantities of weapons and supplies that it is still regarded as the classic case of full-scale economic mobilization.[18]

THE PATH TO MOBILIZATION

In the decade leading up to U.S. involvement in World War II, isolationism had swept the nation. By the mid-1930s, Congress passed two Neutrality Acts, which prohibited U.S. companies from selling equipment to any belligerent involved in an armed conflict.[19] Prewar expenditures on U.S. national

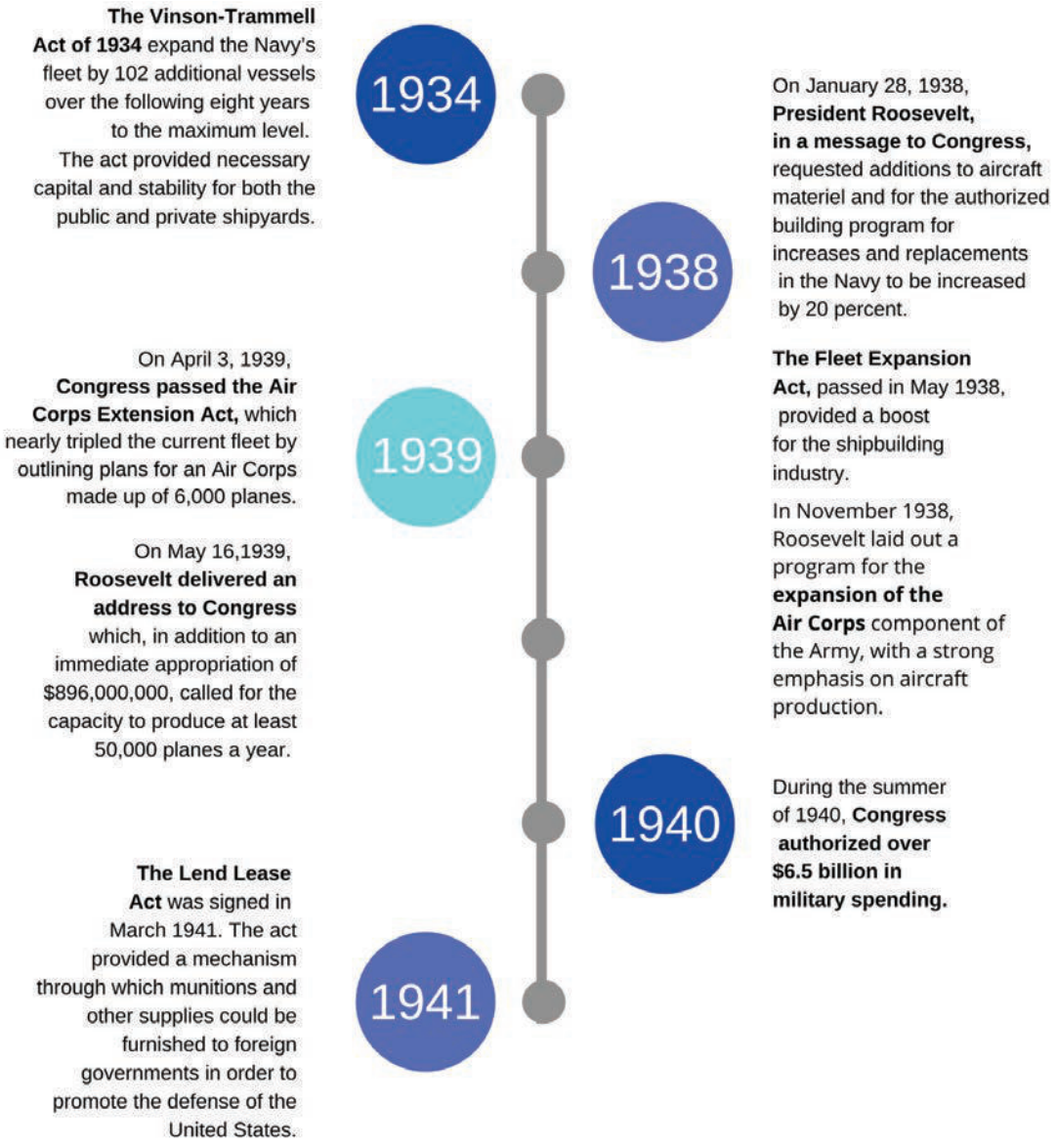
17 Center of Military History United States Army, *American Military History* (Washington, DC: 1989), 406–411, https://history.army.mil/books/AMH/amh-toc.htm.

18 Frank N. Schubert, *Mobilization: the U.S. Army in World War II—the 50th anniversary* (Washington, DC: U.S. Government Printing Office, 1994), 22.

19 Arthur Herman, *Freedom's Forge: How American Business Produced Victory in World War II* (New York: Random House, 2012), 5–7.

defense had been astonishingly low despite the worsening international situation. Total annual expenditures did not exceed $980 million from 1931 to 1938.[20] The position of non-involvement and lack of necessary procurement resulted in a level of unpreparedness for the United States. Fortunately, early steps taken to expand U.S. shipbuilding coupled with foreign aircraft exports in the years leading up to the first stage of mobilization helped facilitate a transition to mass production.[21]

Figure 2: Major Milestones on the Path to Mobilizing for World War II



Source: Authors' own compilation.

20 Roughly equivalent to $15.2 billion in 2020 dollars, about 1.0 to 1.5 percent of GDP.

21 Tom Lilley et al., *Problems of Accelerating Aircraft Production During World War II* (Boston, MA: Harvard University, 1947), 14.

Naval expansion began earliest because it was compatible with isolationist sentiment. The Vinson-Trammell Act of 1934 expand the Navy's fleet by 102 vessels over the following eight years to the maximum level allowed under the Washington and London naval treaties. The act provided necessary capital and stability for both the public and private shipyards. At that time, there had been only six companies in the private sector that were producing major combat vessels.[22]

Of the 1.3 million tons worth of warships available to the Navy in 1940, half had been added to the fleet since 1934. Because warships took years to complete and shipbuilding capacity had to be expanded, the Navy needed an early start to meet wartime demand. Orders placed in 1938 determined the scope of the U.S. Navy fleet that was available immediately after the attack on Pearl Harbor.[23] As evidence of the importance of prewar naval modernization, every Navy capital ship—every fleet carrier and battleship—that fought in World War II was authorized before Pearl Harbor.[24]

PHASE ONE: REARMAMENT

Because of the gradual involvement of the United States in World War II, there was no M-day scenario as had been envisioned by military planners during the interwar years. However, January 28, 1938 marked a significant step toward mobilization. On this day, President Roosevelt, in a message to Congress, requested additional aircraft and that the Navy's authorized building program be increased by 20 percent.[25]

"As Commander-in-Chief of the Army and Navy of the United States it is my constitutional duty to report to the Congress that our national defense is, in the light of the increasing armaments of other nations, inadequate for purposes of national security and requires increase for that reason."
–Roosevelt (Message to Congress, 1938)

The Fleet Expansion Act passed by Congress in May 1938 boosted the shipbuilding industry. The Navy was authorized $1.1 billion to begin increasing the U.S. fleet by 20 percent, as Roosevelt had requested. By the time war had erupted in Europe, two aircraft carriers, eight battleships, five cruisers, and three dozen destroyers were under construction.[26]

22 Mark R. Wilson, *Destructive Creation: American Business and the Winning of World War II* (Philadelphia, PA: University of Pennsylvania Press, 2016), 46.

23 Ibid., 46–48.

24 James C. Fahey, *Ships and Aircraft of the United States Fleet: Victory Edition* (Annapolis, MD: Naval Institute Press, 1945 (reprinted 1985)).

25 Franklin D. Roosevelt, "Message to Congress Recommending Increased Defense Appropriations," American Presidency Project, January 28, 1938, https://www.presidency.ucsb.edu/documents/message-congress-recommending-increased-defense-appropriations.

26 Wilson, *Destructive Creation*, 46–48.

After the Munich Agreement in September 1938 and a pessimistic assessment of French combat capacity, the mood in Washington began to shift even further. Roosevelt's foreign policy had relied on the British navy, the French army, and U.S. industry to check global aggression. France's limited air force and defensive orientation coupled with Britain's attitude of appeasement toward Germany led Roosevelt to believe that the prospects for collective security were fading.[27]

In November 1938, Roosevelt laid out a program for the expansion of the Air Corps component of the Army, with a strong emphasis on aircraft production.[28] He also asserted that the United States must prepare to defend the entire Western Hemisphere.[29]

In 1938, the French and British governments began placing large orders for combat aircraft. These foreign orders provided a needed stimulus for the industry. They also provided aircraft companies the incentive to expand and paved the way for the later acceleration of production.[30] However, even though planes and engines could be produced more quickly than large warships, it still took roughly two years to move from design to quantity production. Because of this lag, only a third of the $300 million of planes and engines ordered by France beginning in 1938 were delivered before the German offensive in the spring of 1940.

Roosevelt's State of the Union and budget request in January 1939 continued his campaign to build support for rearmament. However, rather than launch a large rearmament effort, which might not be supported politically, Roosevelt focused on specific elements of preparedness.[31]

"There comes a time in the affairs of men when they must prepare to defend, not their homes alone, but the tenets of faith and humanity on which their churches, their governments and their very civilization are founded. The defense of religion, of democracy and of good faith among nations is all the same fight. To save one we must now make up our minds to save all."

–Roosevelt (State of the Union, 1939)

27 Michael G. Carew, *Becoming the Arsenal: the American Industrial Mobilization for World War II, 1938-1942* (Lanham, MD: University Press of America, 2010), 10–11.

28 For a full background on aircraft production as it relates to surge rates, see David An and Christopher Bowie, "Aircraft Surge Production Capability: Full Brief," Northrop Grumman Analysis Center, September 29, 2017 [limited circulation].

29 Marvin A. Kreidberg and Merton G. Henry, *History of Military Mobilization in the United States Army 1775 - 1945* (Washington, DC: Department of the Army, 1955), 542.

30 Lilley, *Problems of Accelerating Aircraft Production*, 7.

31 Carew, *Becoming the Arsenal*, 12–13.

For example, concerns arose because the Army Air Corps had only 2,665 aircraft, a size thought to be much smaller than the Luftwaffe. Therefore, on April 3, 1939, Congress passed the Air Corps Extension Act, which proposed to triple the current fleet. By August, the aircraft industry received $100 million in new orders from the U.S. military. This act initiated the production of most of the bombers that would be flown during World War II.[32]

PHASE TWO: EXPANSION

The second phase of mobilization began on May 10, 1940, when the "phony war" ended and German forces advanced into Belgium, Holland, Luxembourg, and France. On May 16, 1940, Roosevelt delivered an address to Congress which, in addition to an immediate appropriation of $896,000,000, called for the capacity to produce at least 50,000 aircraft a year.

> ***"Our task is plain. The road we must take is clearly indicated. Our defenses must be invulnerable, our security absolute. But our defense as it was yesterday, or even as it is today, does not provide security against potential developments and dangers of the future."***
>
> ***–Roosevelt (Address to Congress, May 16, 1940)***

By July, Congress had appropriated funds for 24,000 more planes for the Air Corps and Navy. During the summer of 1940, Congress authorized over $6.5 billion in military spending. Even before the Selective Service Act of 1940, the War Department started to order supplies to equip an army of 2 million. Despite these increased orders, production was still modest compared to the total quantity needed. Mobilization takes time.[33]

As the U.S. economy rebounded in the expanded mobilization effort from 1940 to 1941, domestic orders and investment competed for resources with military production. Further, the large amount of equipment purchased by foreign nations began to interfere with the procurement objectives for U.S. forces. The War Department started to oppose additional sales of munitions and equipment abroad because it diverted weapons from U.S. training programs and force buildup. For example, the limited number of planes that were available resulted in reduced pilot training quotas by 50 percent at the end of 1940. To protect U.S. force expansion, the War Department sought to keep the planes already in Air Corps possession from being released to allies.[34]

For the United States to become the great arsenal for democracy, it was essential that production, allocation of natural resources, transportation management, and price controls be managed effectively.

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32 Wilson, *Destructive Creation*, 58.

33 Ibid., 53.

34 Kreidberg and Henry, *History of Military Mobilization in the United States Army*, 671–672.

Those duties fell upon the National Defense Advisory Commission, which was established in May 1940. Only a few months later, many of its duties were taken over by the Office of Production Management.[35]

This phase of mobilization was characterized by the establishment of the government-owned, contractor-operated (GOCO) facilities. Under this approach, the government paid for large plants that were built, leased, and managed by a contractor in the private sector. Thus, the government had the value of business expertise, but business did not take the risk of building a plant that might not have any postwar value. Because of the large scale of these industrial efforts, military procurement began to depend on "big" business rather than mid-sized contractors. This GOCO strategy had been used to a degree during World War I but became central during World War II.[36]

The first contract for a new GOCO plant was signed with DuPont Company in July 1940, followed by signing with the Chrysler Corporation in August. DuPont was responsible for the construction of a smokeless powder facility, and Chrysler Corporation undertook the construction of a tank arsenal.[37]

In addition to the GOCOs, the government invested roughly $2 billion in preexisting government-owned and operated plants, such as the arsenals and armories of the Ordnance Department.

In December 1940, Roosevelt introduced a new policy initiative in response to Britain's dwindling gold reserves. Rather than selling, the United States would "lend" military supplies to the British to ensure the security of the United States. Following two months of debate, the Lend-Lease Act was signed in March 1941. The act provided a mechanism through which munitions and other supplies could be furnished to foreign governments in order to promote the defense of the United States. Over the course of the war, approximately 792,000 trucks, 43,000 aircraft, and 37,000 tanks, along with an abundance of other items such as ammunition and prefabricated barracks, were shipped to foreign governments.[38]

PHASE THREE: FULL-SCALE MOBILIZATION

Following the attack on Pearl Harbor, the United States needed enough industrial capacity to fight a war in two theaters. On January 6, 1942, Roosevelt addressed Congress and asked for 60,000 planes and 45,000 tanks to be produced, with approximately $50 billion for war-related spending for the year. The GOCO arrangement was no longer sufficient. Conversion of manufacturing facilities from civilian to military production was now required to meet these production targets. Hundreds of firms and plants that had not participated in the first two stages of mobilization were folded into the war economy.[39]

Naval Vessels: Starting with the Vinson-Trammel Naval Act of 1934 and the Merchant Marine Act of 1936, the U.S. shipbuilding industry began groundwork for the battlefleet and merchant fleet that

35 Wilson, *Destructive Creation*, 53.

36 Ibid., 55–56.

37 Harry C. Thomson and Lida Mayo, *United States Army in World War II, The Technical Services, The Ordnance Department: Procurement and Supply* (Washington, DC: Center of Military History, 1960), 32.

38 Office of the Chief of Military History, *The United States Army in World War II, Statistics, Lend Lease* (Washington, DC: Department of the Army, 1952), 8–9, http://cgsc.contentdm.oclc.org/cdm/ref/collection/p4013coll8/id/2421.

39 Wilson, *Destructive Creation*, 67.

served during World War II. When the United States entered World War II, the U.S. fleet totaled 337 warships. The rearmament effort during the interwar years had produced over 40 percent of this fleet. Even though U.S. naval preparations were well under way prior to the attack on Pearl Harbor, significant increases in capacity and production coupled with major changes in naval doctrine were necessary to meet the demands of a global war.[40]

Table 2: Select U.S. Weapons Production in World War II

	1941	1943	Wartime Total
Artillery Pieces	10,918	98,387	173,675
Combat Aircraft	8,531	52,443	197,760
Merchant Tonnage (million tons)	794	7,191	20,903
Munitions–Artillery (million rounds)	2,748	111,180	266,000
Naval Ship Launched	53	414	1,202
Radar Sets	800	11,500	53,967
Tanks	4,052	29,497	88,410
Servicemembers	1,801,998	9,045,102	12,123,373

Source: Michael G. Carew, *Becoming the Arsenal: The American Industrial Mobilization for World War II, 1938-1942* (Lanham, MD: University Press of America, 2010), 264.

Prior to U.S. entry into World War II, large U.S. shipbuilding programs and British orders for new construction and repairs already had shipyards filled beyond their capacity. The creation of a "Two-Ocean Navy" outlined in the Vinson-Walsh Act signed on July 19, 1940 authorized vast new construction.[41]

At this time, more than 500,000 tons of naval vessels were already scheduled for construction in U.S. shipyards. Because of the high demand and insufficient capacity, more than half of all ships authorized under the program were not laid down for two years, and some were never started. While the Vinson-Walsh Act, and the acts that preceded it, laid the foundation for industrial mobilization and naval expansion, it took several years before the necessary volume of production for war was achieved. Meanwhile, the fleet often fought outnumbered and struggled to hold the line in the Pacific and protect convoys in the Atlantic.[42]

Navy shipbuilding faced a particular challenge: after the attack on Pearl Harbor, naval doctrine changed and, with it, so did the ships to be built. Before the war, as before World War I, the emphasis had been placed on capital ships as the main source of naval power. However, after the attack on Pearl Harbor,

40 Jamie McGrath, "Peacetime Naval Rearmament, 1933–39: Lessons for Today," *Naval War College Review* 72, no. 2 (2019): 83–103, https://digital-commons.usnwc.edu/nwc-review/vol72/iss2/7/.

41 *John A., Jr. Hutcheson, Encyclopedia of World War II: A Political, Social, and Military History (Santa Barbara, CA: ABC-CLIO, 2005), 1541.*

42 Carew, *Becoming the Arsenal,* 41–42.

the Navy recognized the need for escorts to deal with the U-boat menace in the Atlantic and masses of auxiliaries to support a global conflict.[43]

To meet the these demands, the U.S. shipbuilding industry greatly increased capacity and quickened the shipbuilding process. Through a massive expansion of shipyard capacity, government funding for new facilities, and standardization of ship design, U.S. shipyards were able to produce 1,500 naval vessels.[44] By 1945, the U.S. Navy eclipsed all other naval powers of the world combined.[45]

The United States also needed a vast merchant fleet both to support a global conflict and to replace merchant ships faster than they were being sunk. Over the course of the war, 733 merchant ships of over 1,000 tons were lost. It was not until 1943 that U.S. cargo ship production finally outpaced losses.

New shipyards arose to build the ships. Standardization of design—the Liberty Ship, followed by the improved Victory ship—also helped mass production. By the fall of 1943, the United States was producing 160 merchant ships per month, with a total of 208 merchant ships in the month of December. In July 1942, it took 105 days to construct a Liberty ship. By 1943, it took just over 50 days. By the end of the war, it only took 40 days from laying the keel to delivery.[46]

When the war began, the United States had approximately 1,340 cargo ships and tankers. By the end of the war, the merchant fleet reached 4,221.[47]

Aircraft: From 1939 to 1944, output by the aircraft industry expanded 70-fold in monetary terms—from approximately $225 million in 1939 to more than $16 billion. This scale of output is even more impressive when considering that production was delayed in the early stages due to lack of fully developed and tactically suitable models readily available for manufacture. For example, only 4 out of the 19 major airplane models used during World War II had been constructed by mid-1940. This left production during 1940 and 1941 limited to low-altitude fighters and light bombers.

Over the course of the war, the United States produced 303,713 military aircraft, compared to German output of 111,787 and Japanese output of 76,320.48 Air Force procurement deliveries totaled more than $43 billion, or 37 percent of all War Department procurement, in the period from July 1940 through August 1945.[49]

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43 Thomas Heinrich, "Fighting Ships That Require Knowledge and Experience: Industrial Mobilization in American Naval Shipbuilding, 1940-1945," *Business History Review* 88, no. 2 (2014): 273–301, doi:10.1017/S0007680514000038.

44 Maury Klein, *A Call to Arms: Mobilizing America for World War II* (New York: Bloomsbury Press, 2013), 516.

45 Carew, *Becoming the Arsenal*, 171.

46 "Naval Armed Guard Service in World War II," Naval Heritage and History Command, April 16, 2020, https://www.history.navy.mil/research/library/online-reading-room/title-list-alphabetically/n/naval-armed-guard-service-in-world-war-ii.html; Alan L. Gropman, *Mobilizing U.S. Industry in World War II: Myth and Reality* (Washington, DC: Institute for National Strategic Studies, National Defense University, 1996), 123.

47 "Naval Armed Guard Service in World War II," Naval Heritage and History Command.

48 Klein, *A Call to Arms*, 515.

49 Richard H. Crawford and Lindsley F. Cook, *The US Army in World War II: Statistics-Procurement* (Washington,

Tanks: With tanks, the Army was not plagued by an inventory of obsolete weapons as it was in other areas. However, the challenge was a lack of suitable designs. Early designs were too light for modern tank warfare, and it took several years to standardize production on the Sherman medium tank. In 1940, the U.S. Army had no first-rate medium or heavy tanks on hand. The production of heavy tanks in volume was not achieved until 1945, so they reached the front only at the end of the war.[50]

Changes in design were a major challenge. As with aircraft, tank design evolved rapidly during the war. It often took several months to transition to a new design due to the need for retooling. During this time, production suffered. Nevertheless, production increased from 331 in 1940 to 29,497 in 1944. From 1940 through 1945, U.S. industry delivered more than 88,000 tanks.[51]

Artillery: The lack of funds during the interwar period had slowed development and all but halted procurement of new artillery. Thus, in 1940, most field artillery consisted of antiquated pieces from World War I, with about 40 percent of the weapons being of vintage French manufacture. The light antitank weapons on hand were ineffective against the heavier tanks that were being fielded in Europe. The only relatively up-to-date weapons were the 105-mm Howitzer, the 155-mm "Long Tom" guns, and the 75-mm pack Howitzers.

Although stockpiles were small and obsolete, as had been the case during World War I, ordnance arsenals had recently been equipped with new tools and a skilled workforce, which prepared them for mobilization. Further, the Army had placed "education orders" to prepare companies new to the industry.

Nevertheless, the existence of a large legacy inventory slowed action. Only after the attack on Pearl Harbor, when President Roosevelt set a new and even more challenging objective for the production of artillery—200,000 pieces of artillery in 1942—did major production begin. Heavy investment in plant capacity during 1941 and 1942 made this possible. By August 1945, U.S. plants had produced 257,390 pieces of all types.[52]

Machine Guns and Rifles (Small Arms): Small-arms production before 1940 was low because the large inventory of World War I weapons had been adequate for U.S. forces.[53] The Army had developed enhanced models (such as the BAR) and access to new designs (such as the M1 Garand rifle), but the lack of funds and immediate need prevented quantity production. During the rearmament period, the Army placed "education orders" as it had in other areas. Foreign orders also helped, although the lack of facilities, machine tools, and workforce slowed response.

In the summer of 1940, as industrial mobilization entered its second phase, Roosevelt transferred to British forces all weapons and ammunition considered surplus. This transfer significantly reduced America's small arms stockpile while instilling a sense of urgency for increased production.

DC: 1952), 10, http://www.alternatewars.com/BBOW/Stats/USA_in_WW2_Stats-Procure_9-APR-52.PDF.

50 Crawford and Cook, *The US Army in World War II: Statistics-Procurement*, 9.

51 Thomson and Mayo, *The Ordnance Department: Procurement and Supply*, 242–264.

52 Ibid., 68–103; and Klein, *A Call to Arms*, 516.

53 "Small arms" are generally defined as weapons with bore diameter of .60-inch (.60-caliber) or less, whether pistols, revolvers, rifles, carbines, submachine guns, or machine guns.

Ultimately, investment in government depots, expansion of the civilian arms industry, and development of new entrants produced a massive increase in production. To give a sense of the scale of expansion, machine gun production increased by a factor of nearly 100, from 8,819 in 1942 to 799,000 in 1944.[54]

From the Cold War to Great Power Competition

Although the Cold War period saw the United States fight multiple limited conflicts, these never required industry to mobilize in the same manner as it had for the two world wars. However, U.S. industrial capacity always maintained a high level of readiness for mobilization in the event of a conflict with the Soviet Union. When the Cold War ended, the need for industrial mobilization faded, and the defense industrial base contracted. With the return of great power competition with Russia and China, interest in long-duration conflicts has revived. However, the literature on the industrial base has not adapted. It still focuses primarily on peacetime efficiency and sustainability.

THE WAR IN KOREA: COLD WAR INDUSTRIAL PREPARATION BEGINS

In contrast to the World War II, U.S. mobilization for the Korean War relied initially on existing stocks of weapons and munitions—the surplus left over from the war in the Pacific theater.[55] These seemed adequate for a limited "police action." When Communist China intervened, however, the U.S.-led coalition faced a sustained conflict that required more industrial and financial resources than expected.

The National Security Act of 1947 had created new organizations such as the National Security Resources Board, the National Security Council, and the Department of Defense itself, but these proved inadequate for meeting the industrial demands of the Korean War.[56]

To manage mobilization activity, Congress authorized the Office of Defense Mobilization in 1950. Truman stood the office up "to direct, control and coordinate all mobilization activities of the Executive Branch of the Government including but not limited to production, procurement, manpower stabilization and transport activities."[57]

The Korean War's major effect on industrial preparedness was enactment of the Defense Production Act (DPA) in September 1950. This act gave the president broad powers to manage the domestic economy in support of national security objectives.

While the DPA authorities were substantial, presidential authority did have limits. President Truman sought to seize control of steel factories in order to keep them operating during a strike by

54 Thomson and Mayo, *The Ordnance Department: Procurement and Supply*, 154–185.

55 Robert Coakley, *Highlights of Mobilization, Korean War* (Washington, DC: Office of the Chief of Military History: Department of the Army, March 10, 1959).

56 Conrad Crane et al., "Introduction," in *"Come As You Are" War: U.S. Readiness for the Korean Conflict* (Carlisle, PA: U.S. Army Heritage and Education Center, 2019), i–iv, https://ahec.armywarcollege.edu/documents/U.S._Readiness.pdf.

57 Rodolfo A. Correa, "The Organization for Defense Mobilization," *Federal Bar Journal* 13, no. 1 (September 1952): 2–3, quoted in Roderick L. Vawter, *Industrial Mobilization: The Relevant History* (Washington, DC: National Defense University Press, 1983), 16, https://apps.dtic.mil/dtic/tr/fulltext/u2/a135528.pdf.

steelworkers.[58] However, the Supreme Court struck down the action, finding in *Youngtown Sheet & Tube Co. v. Sawyer* that the president did not have the legal authority to claim private property, even in the interest of national security.[59]

Driven by these concerns about the DPA's intrusions into the private sector, Congress allowed four of the original seven titles to lapse. These titles were related to "requisitioning, rationing, wage and price fixing, labor disputes, and credit controls and regulation."[60] Nevertheless, the DPA continues to be a powerful tool available to the president for industrial mobilization. It has been continually reauthorized, with its most recent authorization coming in 2018.

Indeed, while some of its authorities were eliminated, the DPA's scope has been expanded since its creation in 1950 to include preparedness for domestic emergencies, such as natural disasters, terrorist attacks, and pandemics.[61]

The DPA currently contains three main authorities:[62]

- **Title I: Priorities and Allocations** allows the president to require persons and corporations to accept and prioritize contracts for materials and services to promote the national defense.
- **Title III: Expansion of Productive Capacity and Supply** allows the president to incentivize the domestic industrial base to expand the production and supply of critical materials and goods. Authorized incentives include loans, loan guarantees, direct purchases and purchase commitments, and the authority to procure and install equipment in private industrial facilities. Title III allows sustainment of critical production, commercialization of R&D investments, and the scaling of emerging technologies.
- **Title VII: General Provisions** includes a variety of authorities: to establish voluntary agreements with private industry; to block proposed or pending foreign corporate mergers, acquisitions, or takeovers that threaten national security; to employ persons of outstanding experience and ability; and to establish a volunteer pool of industry executives who could be called to government service in the interest of the national defense.

After the Korean conflict, these authorities became part of a broader effort to sustain a long-term competition against the Soviet Union.[63] The vision of long-term, strategic competition was laid out in *NSC 68: United States Objectives and Programs for National Security* (NSC 68), a classified national security

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58 "Executive Order 10340," Harry Truman Library and Museum, https://www.trumanlibrary.gov/library/executive-orders/10340/executive-order-10340.

59 *Youngstown Sheet & Tube Co.* v. *Sawyer,* 343 U. S. 579 (1952), https://law.justia.com/cases/federal/district-courts/FSupp/103/569/1469038/.

60 Jared T. Brown and Moshe Schwartz, *The Defense Production Act of 1950: History, Authorities, and Considerations for Congress*, CRS Report No. R43767 (Washington, DC: Congressional Research Service, November 20, 2018), https://fas.org/sgp/crs/natsec/R43767.pdf.

61 "DPA Title III Overview," Industrial Policy, Department of Defense (DOD), https://www.businessdefense.gov/DPA-Title-III/Overview/.

62 50 USC 4501 and 4502.

63 Roderick L. Vawter, *Industrial Mobilization: the Relevant History* (Washington, DC: National Defense University Press, 1983), 17.

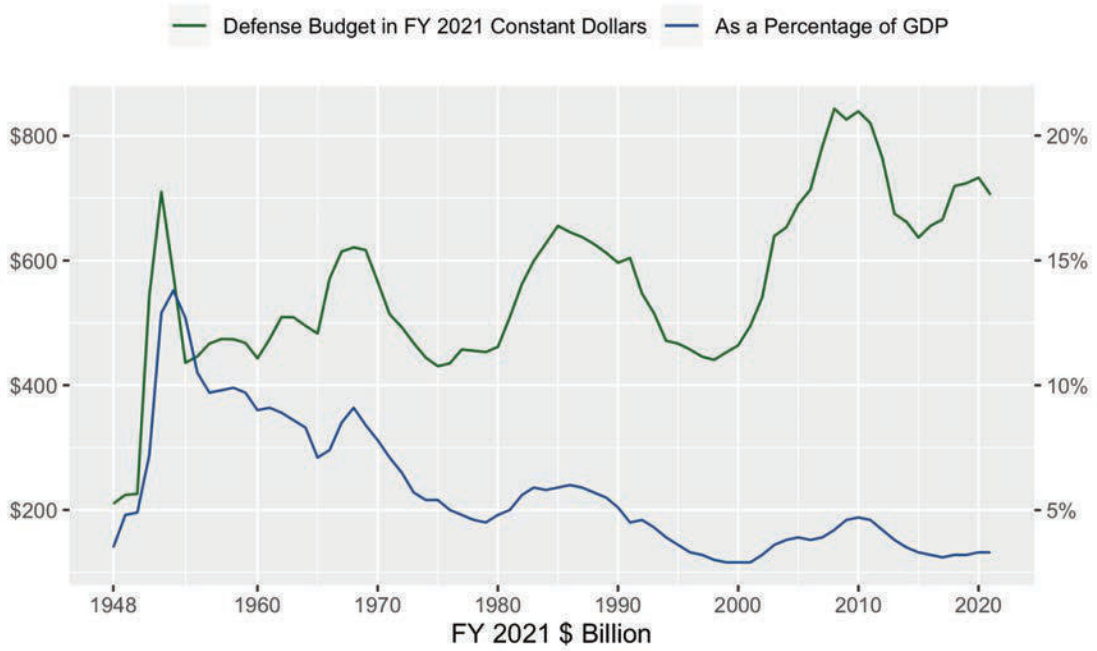
document whose primary objective was to recognize the threat the Soviet Union posed and design a U.S. response through containment. NSC 68 argued that the greatest threat to the prosperity of the United States in the post-World War II order was the conventional, nuclear, and ideological ambitions of the Soviet Union.[64] Recognizing the risk of war with the Soviet Union, the document recommended that the United States establish military readiness to contain the Soviet threat. Alongside George Kennan's "long telegram," NSC 68 was the intellectual foundation of the sustained government effort by which the United States eventually prevailed in the Cold War.

While the American economy was not engaged in total war production as in World War II, these authorities created a corpus of mobilization readiness authorities that would allow rapid expansion in the event of a national security crisis. Thus, the Korean War, while not requiring the level of mobilization of the early-1940s, induced the United States to develop an industrial mobilization strategy, first for the immediate needs of the war and then for a long-term competition with the Soviet Union.

INDUSTRIAL MOBILIZATION AFTER THE KOREAN WAR

Following the Korean War, defense budgets remained high and sustained much larger military forces at a far higher level of readiness and modernization than had been the case before the Korean War. Thus, the United States was able to fight the various regional wars of the Cold War period—in Vietnam, Panama, Kuwait (Desert Shield/Desert Storm), Bosnia/Kosovo, Afghanistan, and Iraq—without having to mobilize the defense industry. Peacetime budgeting and authorities were generally adequate, with limited and targeted interventions allowed by the DPA.

Figure 3: U.S. Historical Defense Spending



Source: U.S. Department of Defense, *National Budget Defense Estimate for 2021* (Washington, DC: April 2020), https://comptroller.defense.gov/Portals/45/Documents/defbudget/fy2021/FY21_Green_Book.pdf.

64 *NSC 68: United States Objectives and Programs for National Security* (Washington, DC: National Security Council, April 7, 1950), https://fas.org/irp/offdocs/nsc-hst/nsc-68.htm.

The Reagan administration took a more confrontational approach to the Soviet Union, boosting defense spending, especially for procurement, which doubled between 1980 and 1985. This expanded peacetime industrial capabilities and provided a stronger foundation for potential wartime expansion.

In theory, the Reagan national security strategy required preparation for a global war that would require sustained mobilization, but the administration took few actions to implement such a policy.[65] For example, there was no creation of standby industrial capacity. The administration's most visible policies, such as nuclear modernization, the Strategic Defense Initiative, and naval force expansion, had priority over an industrial mobilization.[66]

There was some modest intellectual focus on surge capacity and industrial mobilization. For example, the United States Military Academy at West Point held a conference on industrial planning with senior civilian, military, and industry leaders, concluding that in order to have the capacity to sustain production in conflict, the peacetime industrial base must overproduce and sustain the cost of this inefficiency.[67] That tension between procurement efficiency and surge capacity undermined peacetime industrial mobilization activities throughout the entire post-World War II era.

CONSOLIDATION OF THE DEFENSE INDUSTRY AFTER THE COLD WAR

The end of the Cold War brought deep cuts in the U.S. defense budget as the nation sought a "peace dividend" to invest in domestic needs. Between 1989 and 1998, the defense budget decreased by 40 percent in constant dollars, and military personnel declined by a third. Procurement spending fell 60 percent from its 1985 peak.[68] Thus, this period became a "procurement holiday" during which the services relied on systems inherited from the Reagan and Bush administrations rather than buying new systems.[69] In 1995, for example, the Air Force bought no new fighter aircraft, down from a peak of 250 per year during the height of the Reagan buildup.[70] Although many members of Congress feared the loss of jobs in their district, the academic and policy community saw this overcapacity as a problem, cutting into the efficiency of the defense industrial base and outstripping the strategic needs of the U.S. military.[71] The industrial base needed to eliminate overcapacity if it was going to survive in this post-Cold War world.

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65 Office of the President, "National Security Decision Directive Number 32," White House, May 20, 1982, https://fas.org/irp/offdocs/nsdd/nsdd-32.pdf.

66 Barry R. Posen and Stephen Van Evera, "Defense Policy and the Reagan Administration: Departure from Containment," *International Security* 8, no. 1 (1983): 35, doi:10.2307/2538484.

67 United States Military Academy, *Senior Conference on Industrial Capacity and Defense Planning: Final Report, 4-6 June 1981* (West Point, NY: U.S. Military Academy, 1981), https://books.google.com/books?id=2VffAAAAMAAJ&printsec=frontcover&source=gbs_ge_summary_r&cad=0#v=onepage&q&f=false.

68 Office of the Undersecretary of Defense (Comptroller), *National Defense Budget Estimates for FY 2021* (Washington, DC: DOD, April 2020), table 6-1, https://comptroller.defense.gov/Portals/45/Documents/defbudget/fy2021/FY21_Green_Book.pdf.

69 Ibid.

70 Congressional Budget Office, *A Look at Tomorrow's Tactical Forces* (Washington, DC: January 1997), https://www.cbo.gov/sites/default/files/105th-congress-1997-1998/reports/97doc29.pdf.

71 Eugene Gholz and Harvey M. Sapolsky, "Restructuring the U.S. Defense Industry," *International Security* 24, no. 3 (July 31, 2000): 5–51, http://muse.jhu.edu/journals/international_security/v024/24.3.gholz.html.

With defense cuts in full force, Deputy Defense Secretary William Perry sat down with heads of the leading defense firms for what is now colloquially known as the "last supper." Perry informed them that the defense budget would continue to shrink, hurting the bottom line of these firms.[72] Perry told the assembled CEOs that DOD would not step in to protect firms and that it was the market's duty to determine the outcome of the industry downsizing. Perry went so far as to say: "We expect defense companies to go out of business. We will stand by and watch it happen."

The Clinton administration eased enforcement of antitrust rules to allow mergers that would consolidate defense industry into a lean, efficient set of firms that could survive in the post-Cold War environment.[73] The U.S. defense industry responded with a wave of mergers. The Lockheed and Martin Marietta merger alone was valued at $10 billion dollars. The resulting firm, Lockheed Martin, became the largest defense corporation in the United States. Boeing bought McDonnell Douglas for $13.3 billion, making Lockheed Martin and Boeing prime competitors for shrinking defense dollars. Others, such as Raytheon and Northrop Grumman, followed suit, each buying several smaller defense companies. From 1992 to 1997, a total of $55 billion in mergers took place in the defense sector.[74]

By merging assets, the companies were able to cut excess production lines, lay off unneeded workers, lower overhead, and avoid large increases in per-unit costs.[75] This allowed them to operate efficiently in an era of low procurement funding and few contracts. However, the consolidated defense industrial base lost the capacity to surge production in times of crisis. Even amid the "merger mania" of the industry, some DOD officials were concerned the merger spree would go too far. Nevertheless, the defense industry moved decisively in the direction of peacetime efficiency.[76]

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72 John Mintz, "How a dinner led to a feeding frenzy," *Washington Post*, July 4, 1997, https://www.washingtonpost.com/archive/business/1997/07/04/how-a-dinner-led-to-a-feeding-frenzy/13961ba2-5908-4992-8335-c3c087cdebc6/.

73 James Sterngold, "Boeing's deal quickens pace for arms industry takeovers," *New York Times,* December 17, 1996, https://www.nytimes.com/1996/12/17/business/boeing-s-deal-quickens-pace-for-arms-industry-takeovers.html; Malcolm D. Knight, Delano Villanueva, and Norman Loayza, "The Peace Dividend: Military Spending Cuts and Economic Growth," *Policy Research Working Paper Series* 1577, February 1996, https://www.jstor.org/stable/3867351.

74 Jack Lynch, "Lockheed and martin Marietta set to merge in $10 billion deal," *New York Times,* August 30, 1994, https://www.nytimes.com/1994/08/30/business/lockheed-and-martin-marietta-set-to-merge-in-10-billion-deal.html; Jeff Cole, "Joining forces: Merger of Lockheed and Martin Marietta pushes industry trend --- combination would create A giant aerospace firm with $23 billion in sales --- further consolidation seen," *Wall Street Journal*, August 30, 1994, https://www.wsj.com/articles/SB980786648156606188; Greg Schneider, "Boeing Buys McDonnell Douglas $13.3 Billion Deal Will Create World's Largest Aerospace Company; Antitrust Approval Needed; Lockheed Martin Left as Firm's Lone Rival in Defense Industry," *Baltimore Sun*, December 16, 1996, https://www.baltimoresun.com/news/bs-xpm-1996-12-16-1996351017-story.html; and Leslie Wayne, "The shrinking military complex: After the cold war, the pentagon is just another customer military contractors now answer market forces," *New York Times*, February 27, 1998, https://www.nytimes.com/1998/02/27/business/shrinking-military-complex-after-cold-war-pentagon-just-another-customer.html.

75 Richard W. Stevenson, "Peace starts to take toll," *New York Times,* July 23, 1990, https://www.nytimes.com/1990/07/23/business/peace-starts-to-take-toll.html.

76 Leslie Wayne, "The shrinking military complex: After the cold war, the pentagon is just another customer military contractors now answer market forces," *New York Times*, February 27, 1998, https://www.nytimes.com/1998/02/27/business/shrinking-military-complex-after-cold-war-pentagon-just-another-customer.html.

MINI-SURGES FOR WARS IN IRAQ AND AFGHANISTAN

The shock of 9/11, the invasion of Afghanistan, and the later invasion of Iraq ended the post-Cold War environment of the 1990s. The need to fight two long insurgencies not only increased defense budgets but also required a mini-surge from the defense industry.

Production on existing production lines increased to replace equipment losses, modernize forces, and equip new units. Production of H-60 helicopters, for example, increased from 19 in FY 2000 to 78 in FY 2008. Production of medium trucks (Family of Medium Tactical Trucks, or FMTVs) increased from 2,115 in FY 2000 to a peak of 11,460 in FY 2007.

The defense industrial base also had to produce systems specifically for counterinsurgency. One ambitious DOD undertaking was the 2006 establishment of the Joint IED Defeat Organization (JIEDDO), created for the sole purpose of defeating IEDs, which were causing up to 60 percent of all U.S. casualties in Iraq.[77] JEIDDO enabled DOD to quickly turn to industry to come up with systems and equipment that could meet the changing tactics of insurgent groups. Pivotal to the rapid acquisition process was the establishment of the Joint IED Defeat Capability Approval and Acquisition Management Process (JCAAMP) to identify requirements and acquire

both materiel and non-materiel solutions rapidly.[78] By using the JCAAMP process, JIEDDO was able to articulate capability gaps to industry via Broad Area Announcements (BAAs) and then rapidly fund, test, and deploy new systems to theatre in a matter of months rather than years.[79]

Trucks were a prominent example of industrial surge during this period, combining existing production lines and traditional acquisition with new designs and rapid acquisition processes.

The initial troop transport in Iraq and Afghanistan was the High Mobility Multi-Purpose Wheeled Vehicles (commonly referred to as HMMWVs). HMMWVs lacked protective armor because that had not been needed in the past. However, these unarmored vehicles were vulnerable to IED attacks, which became increasingly common.

In response to the rising IED threat, the military added improvised armor to the existing HMMWVs. While this "Mad Max" style of armor upgrades helped survivability, it was not a sustainable solution. The additional armor made it difficult for troops to exit in the event of an IED attack and stressed the vehicle's suspension.[80] As casualties continued from IED blasts, pressure built to find a better solution.[81]

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77 Schmidt Lamb and Breit Fitzsimmons, *MRAPs, Irregular Warfare, and Pentagon Reform* (Washington, DC: National Defense University Press, June 2009), 16–17, https://apps.dtic.mil/dtic/tr/fulltext/u2/a502129.pdf.

78 Joint Improvised Explosive Device Defeat Capability Approval and Acquisition Management Process (JCAAMP), DOD JIEDDO Instruction 5000.01 (November 9, 2007).

79 Subcommittee on Oversight & Investigations, *The Joint Improvised Explosive Device Defeat Organization: DOD's Fight Against IEDs Today and Tomorrow* (Washington, DC: U.S. House of Representatives, Committee on Armed Services, 2008), 16, https://www.hsdl.org/?abstract&did=231992.

80 Norman Friedman and Scott C. Truver, *This Truck Saved My Life!: Lessons Learned from the MRAP Vehicle Program* (Washington, DC: Joint Program Office, Mine Resistant Ambush-Protected Vehicles, 2013), 25, 315.

81 Christopher J. Lamb, Matthew J. Schmidt, and Berit G. Fitzsimmons, *MRAPs, Irregular Warfare, and Pentagon Reform* (Washington, DC: National Defense University Press, 2009), 7.

Next, DOD vastly expanded production of the M1114 Up-Armored HMMWVs (UAHs), a version with integral armor and a stronger suspension to support the weight. These had been built in small numbers for the military police after experience with rioting crowds in Bosnia. During the first year of Operation Iraqi Freedom in 2003, the Army increased its orders of M1114s from 235 to 2,957 units.[82] By 2006, the main production center of the M114s—the Armor Holdings plant in West Chester Township, Ohio—was able to produce 650 M114s a month.[83]

Although the UAHs were an improvement, they were still heavy, vulnerable to IEDs, and susceptible to rollover.[84] Secretary of Defense Robert Gates turned to Mine-Resistant Ambush Protected (MRAP) vehicles, with a V shaped hull designed to deflect IED blasts and specifically designed for this environment. While DOD had a few MRAPs already in service, these were limited to mine clearing operations. Gates became personally involved, establishing an MRAP task force to move the MRAP acquisition to center stage.[85] To produce MRAPs as quickly as possible, DOD called on the entirety of the industrial base. A total of 12 firms began production of MRAPs, of which five produced the bulk of vehicles. This broad participation led to many variants being fielded, including the Navistar Defense Maxx Pro, General Dynamics RG 31, Force Protection Cougar, and Force Protection Buffalo.

A 2008 report by the Government Accountability Office described the MRAP acquisition as follows:

> DOD used a tailored acquisition approach to rapidly acquire and field MRAP vehicles. The program established minimal operational requirements and relied heavily on commercially available products. The program also undertook a concurrent approach to producing, testing, and fielding the vehicles. To expand limited existing production capacity, the department awarded indefinite delivery, indefinite quantity (IDIQ) contracts to nine commercial sources for the purchase of up to 4,100 vehicles per year from each vendor. To evaluate design, performance, producibility, and sustainability, DOD committed to buy at least 4 vehicles from all vendors. According to program officials, subsequent delivery orders were based on a phased testing approach with progressively more advanced vehicle test results and other assessments. To expedite the fielding of the vehicles, mission equipment packages including radios and other equipment were integrated into the vehicles after they were purchased. Finally, DOD designated the MRAP program as DOD's highest priority acquisition, which helped contractors and other industry partners to more rapidly respond to the urgent need and meet production requirements.[86]

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82 Fara Warner, "Army Stepping Up Its Humvee Orders For Troops in Iraq," *New York Times*, December 25, 2003, https://www.nytimes.com/2003/12/25/business/army-stepping-up-its-humvee-orders-for-troops-in-iraq.html.

83 "'Up-Armored' Humvees More Likely to Roll," *Baltimore Sun*, June 11, 2006, https://www.baltimoresun.com/news/bs-xpm-2006-06-11-0606110022-story.html.

84 Ibid.

85 Anthony Cordesman, *Success or Failure? Iraq's Insurgency and Civil Violence and US Strategy: Developments through June 2007* (Washington, DC: CSIS, 2007), https://csis-website-prod.s3.amazonaws.com/s3fs-public/legacy_files/files/media/csis/pubs/070709_iraqinsurgupdate.pdf.

86 Government Accountability Office (GAO), *Rapid Acquisition of Mine Resistant Ambush Protected Vehicles* (Washington, DC: 2008), https://www.gao.gov/products/GAO-08-884R.

The surge production of the MRAPs demonstrated that the industrial base could quickly respond to a theater-specific threat and that DOD could bypass normal acquisition procedures if the operational environment required it.[87] Several insights emerged from this experience:

1. **Involve the senior leadership.** Without Secretary Gates' personal involvement, the program would not have moved forward quickly or at all.
2. **Allow multiple producers.** Realizing that no single vendor had enough capacity to meet the demand, DOD engaged a total of 12 manufacturers, some of which used foreign designs. This approach accepted the logistics and maintenance complications arising from sustaining multiple types of vehicles.
3. **Minimize requirements.** The need for rapid fielding allowed only a few, minimal operational requirements. In effect, it relied on existing vehicles.[88]
4. **Ease regulations to allow faster deployment of the platform.** Instead of standard and lengthy testing procedures, the Pentagon took a concurrent approach to testing.[89] Doing so enabled a faster fielding of the vehicles, following up with more advanced ballistic tests after adoption of the MRAPs.[90]
5. **Standardize variations once widespread fielding has occurred.** The rapid fielding of systems from many different companies meant that there were many variants and subvariants, with estimates ranging from 50 to 300. While the massive amount of variation in the MRAP was driven by operational needs at the time, the platform needed standardization in the long term for interoperability and logistics sustainability. This occurred after fielding during periodic maintenance.[91]

87 Jen Judson, "30 Years: MRAP - Rapid Acquisition Success," Defense News, August 8, 2017, https://www.defensenews.com/30th-annivesary/2016/10/25/30-years-mrap-rapid-acquisition-success/.

88 GAO, *Rapid Acquisition of Mine Resistant Ambush Protected Vehicles*.

89 GAO, *Defense Acquisitions: Rapid Acquisition of MRAP Vehicles* (Washington, DC: Government Accountability Office, 2009), https://www.gao.gov/products/GAO-10-155T.

90 GAO, *Rapid Acquisition of Mine Resistant Ambush Protected Vehicles*.

91 Friedman and Truver, *This Truck Saved My Life*, 5.

3

Literature Review

Current Assessments of Industrial Base Mobilization

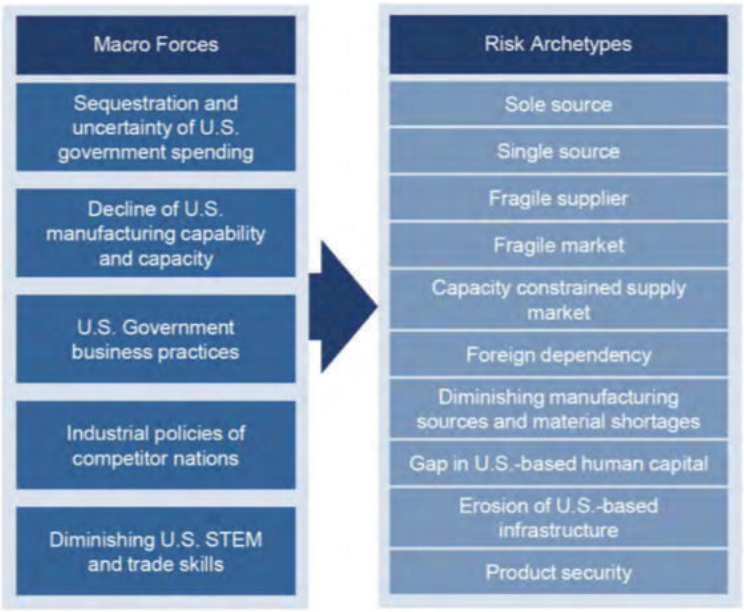
To support the new National Security Strategy, President Trump signed Executive Order (EO) 13806, which directed DOD to conduct a study evaluating the security and resiliency of the defense industrial base. The final report found that the defense industry is profitable overall, with the "Big Six"—BAE Systems Inc., Boeing, General Dynamics, Lockheed Martin, Northrop Grumman, and Raytheon—"healthy and expanding market share."[92] Their diversification to the civilian market and expansion in foreign military sales has helped.

The report identified five "Macro Forces" shaping the industrial base (Figure 2). From these macro forces, 10 risk archetypes arise, each of which contribute to insecurity in the defense industrial base.

The report stops short of describing if or how civilian industry could be converted to assist in boosting industrial capacity. Relevant to this project is the identification of two potential production constraints: Chinese control of the rare-earth metals trade, critical components for military equipment manufacturing, and the loss of STEM focused labor, which would hinder the ability for industry to hire sufficient skilled personnel for mobilization production.

92 DOD, *Industrial Capabilities Report to Congress* (Washington DC: May 13, 2018), 18, https://www.businessdefense.gov/Portals/51/Documents/Resources/2018%20AIC%20RTC%2005-23-2019%20-%20Public%20Release.pdf?ver=2019-06-07-111121-457.

Figure 4: Executive Order 13806 Report



Source: DOD, Assessing and Strengthening the Manufacturing and Defense Industrial Base and Supply Chain Resiliency of the United States (Washington, DC: DOD, September 2018), 3, https://media.defense.gov/2018/Oct/05/2002048904/-1/-1/1/ASSESSING-AND-STRENGTHENING-THE-MANUFACTURING-AND%20DEFENSE-INDUSTRIAL-BASE-AND-SUPPLY-CHAIN-RESILIENCY.PDF.

Surge Capacity in Doctrine and Directives

Military doctrine recognizes the importance of industrial mobilization. The relevant joint publication notes: "Industrial base expansion includes actions to accelerate production within the existing industrial infrastructure, add new production lines and factories, and implement provisions of the Defense Priorities and Allocation System."[93]

However, the publication does not go any further about how large the requirements might be, what kind of expansion might be necessary, or how long it would take. The document focuses almost exclusively on mobilization of existing resources, such as the reserves and production from existing defense industry.

DOD directives are vague, the main one giving responsibilities to an organization that no longer exists, the Office of the Under Secretary of Defense for Acquisition Technology and Logistics.[94]

Surge Capacity in the Literature on the Defense Industry

The literature on defense industrial surge follows what is seen in the 2018 report. It focuses on how the U.S. defense industry can operate efficiently, establish proper levels of oversight and

93 DOD, *Joint Publication 4-05: Joint Mobilization Planning* (Washington, DC: October 23, 2018), https://www.jcs.mil/Portals/36/Documents/Doctrine/pubs/jp4_05.pdf.

94 DOD, *"Acquisition and Management of Industrial Resources*, DOD Directive 4275.5 (Washington, DC: DOD, March 2005), with Change 1, August 31, 2018, https://www.esd.whs.mil/Portals/54/Documents/DD/issuances/dodd/427505p.pdf?ver=2018-11-08-122537-997.

accountability, and cope with variable and unpredictable defense budgets. However, this project's focus on rapid industrial mobilization in the event of a conflict is not touched on by the EO 13806 report or most of the recent literature on the industrial base.

This project examined 99 studies on the industrial base. The studies came from non-governmental reports, Government Accountability Office reporting, DOD internal reviews, and reviews from the industry itself.

The project assessed the degree to which the reports considered surge production.

- **Yes (22):** The literature focuses exclusively or substantially on the challenges that would arise if there were a sudden surge in demand. Key to being selected for this category was for the piece to explicitly state that the vulnerability would arise or be intensified under a surge.
- **Partial (40):** The literature devotes a small portion of its overall research to challenges relating to surge in industrial demand. Broadly speaking, literature that fell into this categorization tended to either mention industrial mobilization in passing (focusing more so on current, peacetime vulnerabilities) or otherwise allude to industrial base vulnerability but fail to explicitly put the conversation in the context of a rapid industrial mobilization.
- **No (35):** The literature focuses on the current sustainment and health of the industrial base but does not mention surge or production capabilities. Vulnerabilities or areas of improvement are either not linked to maximum production or not relevant to the conversation.

While the large swath of literature highlighted vulnerabilities in the industrial base, nearly all were focused on the current peacetime context. Of those 22 studies that considered wartime surge (the "Yes" category), only 2 were written in the past 10 years:

- An assessment, *Vital Signs 2020*, done by the National Defense Industrial Association, which rated the "Surge Readiness" as a slight improvement since 2017; and
- An internal document from Northrop Grumman, which assessed its own ability to surge aircraft production.

Despite the lack of focus on surge capability, five recurring themes relevant to surge production emerge from the many studies: (1) brittleness, (2) inability to convert civilian industry, (3) cyber vulnerabilities, (4) supply chain vulnerabilities, and (5) delays in obtaining security clearances.

1. **"Brittleness": Prioritizing Efficiency Over Surge Capacity**
   General Dunford, chairman of the Joint Chiefs of Staff, captured a key weakness of the industrial base by noting that it has become "increasingly brittle" over time, inhibiting the military's ability to "sustain a protracted or simultaneous conflict."[95] Surge capacity costs money, and the defense industry responds to the incentives that its customer—DOD—provides. As a consequence, the industrial base has eliminated excess production capabilities to cut costs. This decreases peacetime costs but leaves the United States unprepared for long wars. For example, the DOD's Annual Capabilities report to Congress for FY 2018 found that over 80 percent of USMC and U.S. Army vehicle production is done by a single manufacturer on a single assembly

95 U.S. Congress, Senate, *Testimony for reappointment to the grade of general and reappointment to be Chairman of the Joint Chiefs of Staff*.

line. The same report found shortfalls in domestic production of DOD explosives, where a sole producer fails to meet DOD demand, and foreign suppliers are unable to fill the gap.[96]

2. **Inability to Convert Civilian Industries: Specialization and Time**
   The manufacturing requirements needed to produce the most sophisticated platforms of the U.S. military require specialized manufacturing tools and processes. For example, stealth technology—a mixture of materials, coatings, and designs that reflect and absorb radio waves from enemy air defenses, used on most modern aircraft to some degree but especially the B-2, B-21, F-22, and F-35—is expensive, classified, and difficult to manufacture.[97]

   As a result of the sophisticated production methods used in producing advanced military equipment, building platforms simply takes longer.[98] During World War II, the United States produced 4,000 B-29 bombers in only three years. Compare that to the F-35, whose development took place in the 1990s, followed by its first flight in 2000 and its first delivery in 2014. As of 2019, a total of 440 F-35s have been delivered to the United States and partner nations.[99] Sophistication in design and the consequent slow production goes beyond aircraft. As one extreme example, modern Ford-class aircraft carriers are three times as large as World War II Essex-class carriers but take four times as long to build.[100]

   Limitations on production of military equipment are not as pronounced in equipment with civilian analogues.

3. **Cyber Vulnerabilities**
   Production lines in the defense industrial base must deal with advanced cyber threats every day. Thus, they generally have robust cyber defenses. This would be a significant challenge for civilian industries converting to wartime production, as their existing cybersecurity measures are often not as stringent as the defense industrial base.[101] The extensive cybersecurity

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96 DOD, *Annual Industrial Capabilities Report to Congress*, 39, 43.

97 Drew Middleton, "Stealth Technology: Progress in Concealing Planes," *New York Times*, May 31, 1983, https://www.nytimes.com/1983/05/31/us/stealth-technology-progress-in-concealing-planes-military-analysis.html#:~:text=As%20things%20stand%2now%2C%20Stealth,also%20developing%20a%20Stealth%20fighter.

98 Eliot A. Cohen, *The Big Stick: The Limits of Soft Power and the Necessity of Military Force* (New York: Basic Books, 2016), 210.

99 C. Todd Lopez, "DOD Finalizes Purchase Plan for F-35 Aircraft," DOD, October 29, 2019, https://www.defense.gov/Explore/News/Article/Article/2002585/dod-finalizes-purchase-plan-for-f-35-aircraft/.

100 Ford-class data from Ronald O'Rourke, *Navy Ford Class Aircraft Carrier (CVN-78) Program: Background and Issues for the Congress*, CRS Report No. RS20643 (Washington, DC: Congressional Research Service, August 2020), https://fas.org/sgp/crs/weapons/RS20643.pdf; and Essex-class data from Fahey, *The Ships and Aircraft of the US Fleet*, 9–10.

101 Samantha Ravich and Michael Hsieh, "Leveraging Blockchain Technology to Protect the National Security Industrial Base," Foundation for the Defense of Democracies, May 6, 2019, https://www.fdd.org/analysis/2017/07/10/leveraging-blockchain-technology-to-protect-the-national-security-industrial-base/.

requirements of the industrial base form a barrier to entry into the defense base, becoming a limiting factor for conversion in the event of demand surge.[102]

4. **Supply Chain Vulnerabilities**
   As highlighted in the EO 13806 report, further globalization leads to a new kind of vulnerability. Materials critical for military systems often come from foreign sources, including potential adversaries such as China. Rare-earth elements, used in nearly all electronics, domestic and military, are an extreme example.[103] The limited domestic supply and production capacity of rare-earth minerals forces the United States to rely on China for sourcing rare-earth resources.[104]

   In the event of a conflict with a near-peer competitor, the current supply chains would likely be disrupted, not only from Russian or Chinese sources but also from allied and neutral countries, including Australia, Vietnam, and India.[105]

   The F-35 alone requires 300,000 unique parts.[106] When Turkey acquired the Russia S-400 air defense system over repeated U.S. objections, the United States pushed Turkey out of the F-35 program. Just replacing the 1,000 Turkish produced parts has been a multi-year effort.

5. **Security Clearances**
   In the event of a surge in demand for labor for the defense industrial base, security clearances will form a bottleneck that will slow the rate that firms can hire new workers.

   The U.S. government requires that the designs, production processes, and operational capabilities of its most advanced weapon systems remain classified in order to preserve competitive advantage. U.S. companies that manufacture these advanced weapon systems are subject to obtaining varying levels of U.S. security clearances. These security classification standards ensure that intellectual property remains in the hands of the United States (and some allied partners) and is not accessible by adversaries. But these classification standards come with a cost.

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102 Corbin Evans and Christopher Smith, *Beyond Obfuscation: The Defense Industry's Position within Federal Cybersecurity Policy* (Arlington, VA: National Defense Industrial Association, October 2019), https://www.ndia.org/-/media/sites/ndia/policy/documents/cyber/beyond-obfuscation_final.ashx?la=en; and Robin, Lineberger, Alan Faver, Kevin Gallagher, and Jeffery Lucy, "Cybersecurity in Defense: New Approaches for Contractors," Deloitte United States, June 20, 2019, https://www2.deloitte.com/us/en/pages/manufacturing/articles/cybersecurity-in-defense.html.

103 Defense Industrial-Initiatives Group, "No. 22: Rare Earth Elements: A Wrench in the Supply Chain?," CSIS, October 5, 2010, https://csis-website-prod.s3.amazonaws.com/s3fs-public/legacy_files/files/publication/101005_DIIG_Current_Issues_no22_Rare_earth_elements.pdf.

104 Department of Commerce, *A Federal Strategy to Ensure Secure and Reliable Supplies of Critical Minerals* (Washington, DC: 2019), https://www.commerce.gov/news/reports/2019/06/federal-strategy-ensure-secure-and-reliable-supplies-critical-minerals.

105 "U.S. Dependence on China's Rare Earth: Trade War Vulnerability," Reuters, June 27, 2019, https://www.reuters.com/article/us-usa-trade-china-rareearth-explainer-idUSKCN1TS3AQ.

106 "Building the F-35: Combining Teamwork and Technology," Lockheed Martin, Accessed January 15, 2020, https://www.f35.com/about/life-cycle/production.

The process by which a person obtains and maintains a security clearance requires extensive government resources, background investigations, and time. In peacetime there have been long backlogs. The challenge in wartime would be far greater, as thousands of new workers would need clearances immediately.

4

Assessing Contemporary Industrial Mobilization

Surge Capacity

The history and literature review set the stage for the project's main work: assessing contemporary industrial mobilization capability. To gain insight into the industrial base's ability to cope with great power conflict, the project developed five research questions.

What is the ability of existing production capabilities to replace current inventories in peacetime?

This provides the basic analysis of the defense industrial base. Existing production rates need to be rapid enough to replace inventories on a peacetime schedule.

What is the ability of surge production capabilities to replace current inventories in the event of a prolonged great power conflict?

Surge production rates indicate how well the industrial base would support wartime operations. Slow replacement at surge rate indicates a potential wartime problem. The difference between the two rates shows how much the industrial base can surge.

Has the industrial base become more brittle—that is, less able to replace inventory—over time?

This question investigates the concern that General Dunford raised about whether the industrial base is becoming more brittle. As indicated in the historical analysis, the conventional wisdom is that this is true, as firms have consolidated and squeezed out excess costs. Nevertheless, it is an unproven assumption. If the industrial base has indeed become more brittle, then the challenge of sustaining U.S. forces in a prolonged great power conflict has become more difficult over time and may continue to get worse.

Are some industries or categories of weapons at greater risk than others?

DOD acquires weapon systems from many different industries, each with its own capabilities and dynamics. These differences may result in different surge rates, different lengths of time to replace inventory, and, hence, different levels of risk.

Are systems with civilian analogs at less risk?

Military systems with civilian analogs—where the civilian economy produces something similar—might have higher surge rates and lower time to replace because civilian capacity could be adapted to military use. The answer is important because DOD might need to rely more on such systems in a conflict where custom-designed military systems attrite faster than the industrial base can replace them.

Methodology and Data

To investigate these questions, this project developed a comprehensive database of DOD production data on individual systems for FY 1999, FY 2008, and FY 2020 drawing on DOD budget and acquisition documents.

DATA SOURCES

Service Budget Exhibits P-40s and P-21s: The P-40 exhibits contain summary data on procurement program cost and quantity for the budget year, two prior years, and the next four years. Occasionally, total, prior year, and future year data are also included. In that case, the P-40s can be useful in determining total inventory. The P-21 exhibits contain detailed system information on cost, quantity, surge production rates, production leadtimes, and deliveries.

Selected Acquisition Reports (SARs): SARs contain inventory data as well as information on acquisition strategy and program composition. Although not all SARs are publicly available in their full form, CSIS has access to an extensive portfolio for the budget year and prior years. Because SARs are statutorily required reports to Congress, the project used SAR data whenever inconsistencies arose.

Service inventory data: Each of the services publishes inventory data for major weapons systems. The Navy, for example, has data on current ship inventories, updated weekly, and historical data going back to the early-twentieth century. The Air Force annually publishes data on all aircraft inventories.

Production rates: The P-21 budget documents provide data for three kinds of production rates: minimum sustaining rate (MSR), "1-8-5," and "Max."[107]

> **Minimum sustaining rate:** The comptroller's guidance defines this as the "rate that is necessary to keep production lines open while maintaining a base of responsive vendors and suppliers; the quantity that will preclude start-up costs in the case of a production break; or the quantity that the contractor is willing to accept and produce at a reasonable cost." This rate is important in budget and acquisition analyses when the military services want to keep a production line going but lack the resources. Because the project was analyzing industrial mobilization—increases in production—it did not use this rate.

107 All definitions from Office of the Undersecretary of the Comptroller, *Financial Management Regulation Volume 2B: "Budget Formulation and Presentation (Chapters 4-19)"* (Washington, DC: Department of Defense, 2017), 4–48, https://comptroller.defense.gov/Portals/45/documents/fmr/Volume_02b.pdf.

"1-8-5," or economical production rate: The comptroller's guidance defines this as "the most efficient production rate for each budget year at which the item can be produced with existing or planned plant capacity and tooling, with 1 shift a day running for 8 hours a day and 5 days a week (1-8-5)."

"Max," the maximum or surge production rate: The comptroller's guidance defines this as "the maximum capacity rate that a contractor can produce with extant or PY planned tooling." This represents the surge production rate that is achievable with current facilities. Sometimes this represents moving from one shift a day to three shifts, but often there is a facility constraint that prevents such a tripling of output. The fiscal assumption is that sufficient funds would be available in any crisis that merited surge production. Given congressional and presidential support for DOD budgets in recent conflicts/crises, such as Desert Storm, the invasion of Iraq, and the Covid-19 pandemic, this assumption appears to be reasonable.

Navy shipbuilding, a special case: The Navy does not publish production rates for ships because of their unique circumstances: high cost and low rates of production. In its FY 2019 and FY 2020 long-range shipbuilding plans, however, the Navy produced a table that showed planned production for each ship type and potential increases in production. The project used this table as a statement of surge capability in the shipbuilding industrial base.

Data quality: A brief note is necessary regarding the data's quality. The service procurement justification books, particularly the P-21 budget exhibits, contained many errors and anomalies, and therefore the data needed to be examined carefully. An illustrative example was an Army trailer program that reported rates of MSR, 1-8-5, and Max of 20/20/80. It seems impossible that the maximum rate was four times the 1-8-5 rate since there are only 24 hours (3 shifts) in a day. Although the budget preparation guidance directs that the number of shifts be specified, few program offices did so, meaning it was hard to judge the validity of some surge data. Other program offices appear to triple the 1-8-5 rate to come up with a surge rate, without any indication of whether existing facilities would allow such an increase. Program offices sometimes input monthly data when the exhibit called for annual data, especially in the FY 1999 P-21s. There was also confusion about whether the quantities shown were actual or in thousands, although the budget preparation guidance directed that this be specified. Problems were also found in the 2020 data, though less commonly.

For example, one program that procured large satellites (GPS IIIF) reported a monthly production rate of one for MSR, two for 1-8-5, four for surge/Max. This implied a Max annual rate of 48, far beyond any likely capability. In this case, the project contacted the program office, which acknowledged that the data were, in fact, annual. The official in charge of inputting the data said that the exhibit preparation menus were confusing. Confusion is not surprising, given that the data are entered by dozens of individual program offices, each operating independently and with varying degrees of expertise.

The project identified anomalies—generally data that looked too high or too low in comparison with data in other exhibits or other documents, such as SARs—and corrected those that it could. Others that were anomalous—generally because their surge/Max rate seemed too high or their inventory objective was inconsistently reported—were tagged as such and excluded from the initial analysis.[108] Like the

108 This problem of inadequate data for industrial surge has been noticed elsewhere. See, for example, Julie C. Kelly, Daniel E. Lago, and James S. Thomason, "Strengthening Industrial Base Decision-Making for Precision

above program for large satellites, the project frequently reached out to programs to clarify these anomalous production rates. While not all programs returned with usable data, some provided helpful responses. For example, the Ground/Air Task Oriented Radar (G/ATOR) clarified that although four separate manufacturers were listed in the P-21 data, there was only one production line. This reduced the Max rate by nearly three-fourths and put it in a much more reasonable range.

THE INDUSTRIAL MOBILIZATION DATABASE

Using data from the budget justification books and the SARs, the project put together an industrial mobilization database. This consisted of current production rates, surge production rates, and total inventories for a wide variety of weapon systems—land, sea, air, C4I, space, and munitions—at three points in time: FY 1999, FY 2008, and FY 2020. Total inventory data was derived from the P-40 procurement quantities in past and future years or from the SARs when available. Production data for each weapon system manufacturer was recorded from the P-21s and aggregated to provide a single 1-8-5 and Max rate for each system. For each system, the database also contained information on industry category, production leadtime, military service, and budget line numbers.

FY 1999 was chosen for two reasons: first, it is the earliest year for which data are readily available in electronic form on the DOD comptroller's website. Second, that year gives a view of capabilities before the post-9/11 buildup and resulting wartime production surge.

FY 2008 represents the height of the wartime surge. FY 2020 was the most recent set of data available when the project began its work last fall. (FY 2021 data has since become available but is not materially different from the FY 2020 data.)

Calculations

For each system, the project calculated the time needed to replace the inventory.

Inventory replacement at peacetime production rate: As a baseline, the project used time to replace inventory at the current ("peacetime") production rate. The analysis used the "1-8-5" rate for the current ("peacetime") production rate. This was better than the production rate in any particular budget year, which jumped around year-to-year based on the vagaries of the political and budgeting process and thus did not provide a stable baseline.

$$\text{Inventory Replacement (Years) at 1-8-5 Rate} = \frac{Inventory\ Objective}{Agg.\ 1-8-5}$$

Inventory replacement at surge rate (in years): The key calculation was the ability of the industrial base to replace inventories under surge conditions. The calculation for surge evolved as the project refined its analysis. The first calculation divided the Inventory Objective by the Max production rate, measured in years.

$$\text{Inventory Replacement (Years) at Surge Rate} = \frac{Inventory\ Objective}{Agg.Max}$$

Guided Munitions," War on the Rocks, August 11, 2020, https://warontherocks.com/2020/08/strengthening-industrial-base-decision-making-for-precision-guided-munitions/.

Inventory replacement at surge rate with production leadtime: This initial calculation, however, did not allow for the time that production facilities needed to expand from the "peacetime" production rates to surge production rates, since no system operated at the surge rate. Available data do not specify a leadtime to reach surge rate. As a surrogate, the second calculation added the leadtime (called "Reorder Production LeadTime") cited in the budget justification books for any production increase. This time varied from two months to four years. Because this time interval covered any production increase, it was not the same as the leadtime to surge rate, which would likely be longer because surge rates are typically higher than amounts envisioned by the reorder rate. Nevertheless, this was a rough approximation, and including some leadtime was important because whatever the actual leadtime to surge rate was, it was not zero.

$$\text{Inventory Replacement (Years) at Surge Rate + Leadtime} = \frac{Inventory\ Objective}{Agg.Max} + Production\ Leadtime$$

Inventory replacement at adjusted surge rate: The final calculation, and the one used for calculations in the report, is the surge rate with production leadtime and inventory adjustments. This added another adjustment to account for the fact that during the time between peacetime production and surge production, systems would be produced and would, therefore, reduce the amount of inventory that needed to be produced at the surge rate. Thus, the final calculation was as follows: Reorder Production Leadtime multiplied by Aggregated 1-8-5 Years, subtracted from Inventory Objective and all divided by the Aggregated Max Years plus Reorder Product Leadtime.

$$\text{Inventory Replacement (Years) at Adjusted Surge Rate}$$

$$= \frac{Inventory\ Objective - (Production\ Leadtime \times Agg.\ 1-8-5)}{Agg.Max} + Production\ Leadtime$$

For example, the total Apache inventory objective is 639 (all models), the peacetime (1-8-5) production rate is 98 per year, the maximum production rate is 144 per year, and the reorder product leadtime is one year. Therefore, the time to replace the inventory is 6.5 years at the 1-8-5 production rate, 4.44 years at the surge rate, 5.44 years at the surge rate with leadtime, and 4.76 years at the surge rate with leadtime and inventory adjustment.

Major and non-major acquisition programs: This project pays particular attention to the production rates of Major Defense Acquisition Programs (MDAP) because these are the largest and most important programs. At any one time, they constitute about half of all procurement funding.[109] MDAPs are designated by statute as programs with a research, development, and test and evaluation requirement of more than $480 million in FY 2014 constant dollars, a procurement requirement of more than $2.79 billion in FY 2014 constant dollars, or have been designated a special interest program by the secretary of defense.[110] The project identified MDAPs using the SAR Summary Tables for the relevant budget year.

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109 Office of the Under Secretary of Defense (Comptroller)/Chief Financial Officer, *Program acquisition cost by weapon system* (Washington, DC: DOD, 2020), https://comptroller.defense.gov/Portals/45/Documents/defbudget/fy2021/fy2021_Weapons.pdf.

110 DOD, *Operation of the defense acquisition system* (Washington, DC: 2015), https://www.acq.osd.mil/fo/docs/500002p.pdf.

Not all MDAPs were suitable for surge analysis because of data limitations. For 2020, there are 87 total MDAPs reported in the updated SAR Summary Tables.[111] Of these, two MDAPS share the same production lines (Apache New Build and Remanufacture and the KC-130J and C-130s), leaving 85 separate MDAPs. Because the P-21 exhibits do not provide production data for Navy ships (the project did this analysis separately), this is further reduced by the 10 Navy ships to 75 total MDAPs. Of the remaining 75 programs, only 45 had production rates in the P-21 exhibits. To ensure programs were not missed because they did not have a P-21 in a particular year, the study team checked the budget years FY 2021, FY 2019, and 2018 for production data for the remaining MDAPs. This process showed P-21 production data for two additional MDAPs, particularly the UH-60 Blackhawk and the WIN-T Ground Forces Tactical Network, that were then included in the full database. Of the remaining 47, a further 9 were considered anomalous, generally because their Max rate seemed unrealistically high or their inventory objective was inconsistently reported.

Table 3: 2020 MDAP Breakdown

87	Total MDAPs 2020
-2	Apache New Build and Remanufacture and the KC-130J and C-130 share production lines
-38	10 MDAPS are Navy ships for which no generalized production data is included 28 other MDAP programs for which there were not P-21 production data
-9	MDAP programs that had anomalous data
38	**MDAPs Analyzed/Remaining**

Source: CSIS analysis.

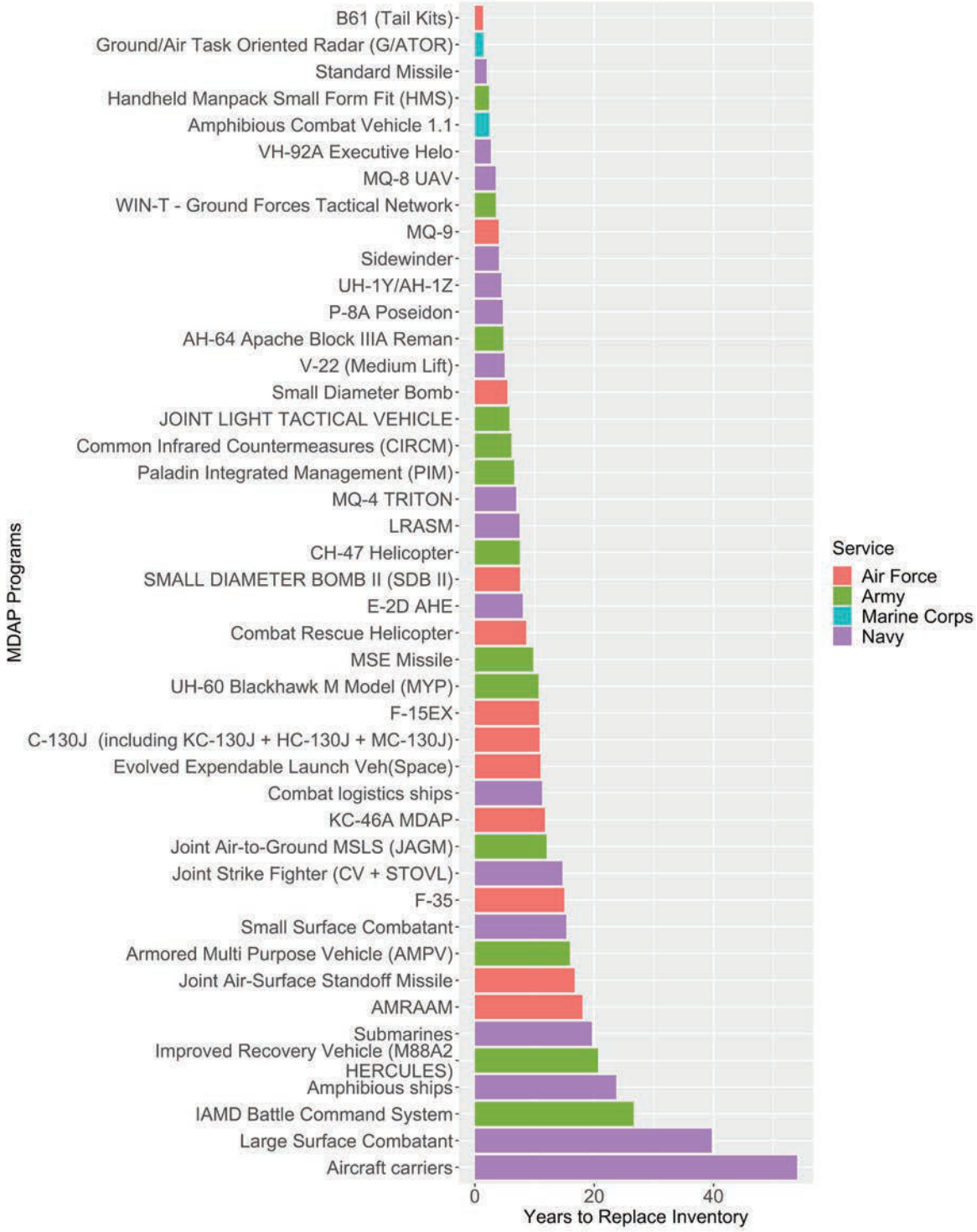
Non-major programs analyzed in this study are all those programs that do not meet the threshold for MDAPs but still have inventory and surge production data in the P-21 exhibits of the budget justification books. Programs with cost elements of more than $5 million in the budget year are required to submit a P-21.[112]

The respective replacement times for these MDAPs, including ships using a separate calculation explained later, are broken down by program in Figure 5 below.

111 DOD, *Comprehensive selected acquisitions reports for the annual 2018 reporting requirement as updated by the president's fiscal year 2020 budget* (Washington, DC: 2019), https://media.defense.gov/2019/Aug/01/2002165676/-1/-1/1/DEPARTMENT-OF-DEFENSE-SELECTED-ACQUISITION-REPORTS-(SARS)-DECEMBER-2018.PDF.

112 "Instructions – Exhibit P-21, Production Schedule" in Under Secretary of Defense (Comptroller), *Financial Management Regulation Volume 2B: "Budget Formulation and Presentation (Chapters 4-19),"* 4–48.

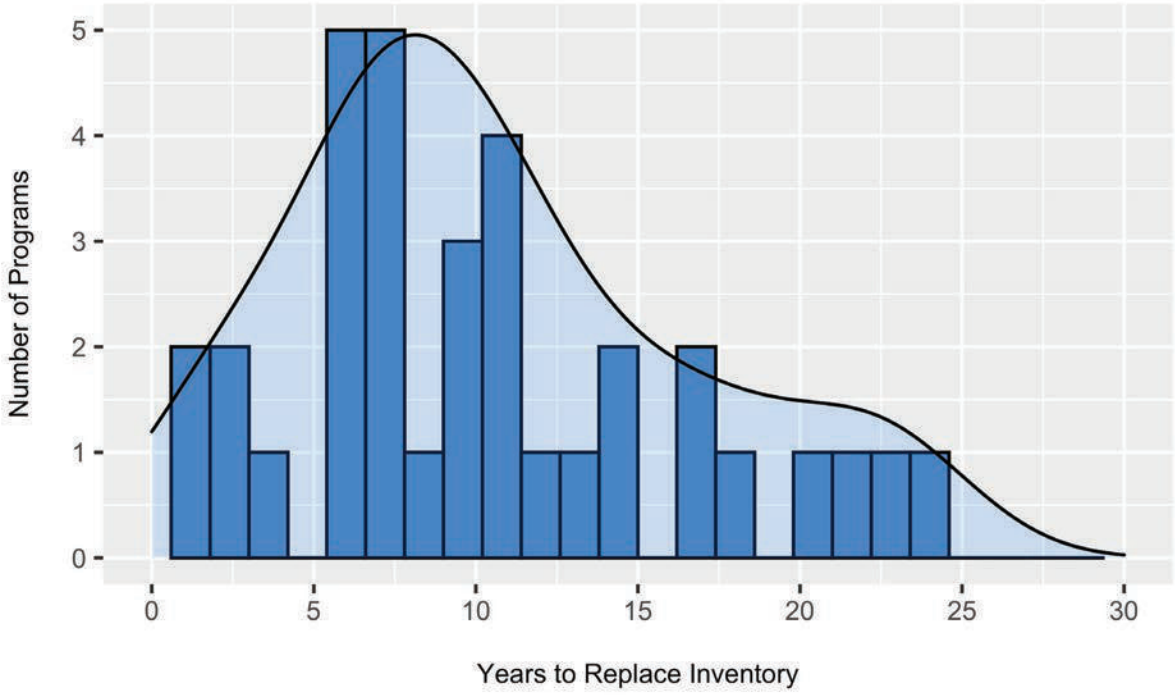
Figure 5: MDAP Replacement Times by Adjusted Surge Rate



Source: CSIS analysis.

Question 1: What is the ability of existing production capabilities to replace current inventories in the event of a prolonged great power conflict?

Figure 6: Time to Replace 2020 MDAP Inventories at 1-8-5 Rate



Source: CSIS analysis.

Table 4: Time to Replace MDAPs at 1-8-5 Rate, Mean and Median

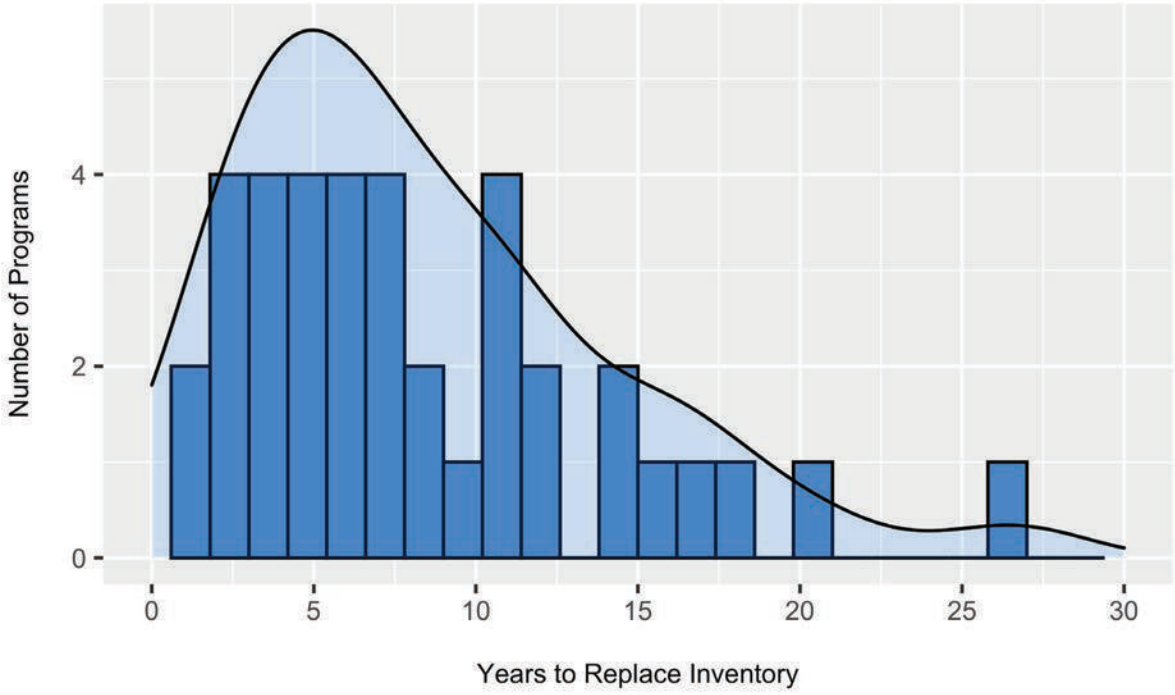
Mean	Median
13.8	10.2

Source: CSIS analysis.

The above histogram shows the time required to replace MDAP inventories at the "peacetime" production rate, defined as the 1-8-5 rate. This provides a baseline against which to compare surge production. The times appear to be reasonable for a peacetime, non-surge environment. Systems have useful lives of many years, decades in most cases. The replacement times allow the military services enough time to replace old systems with new systems. For example, the AH-64 Apache attack helicopter has a 20-year lifetime, according to the SAR. The inventory is 639 aircraft, and the 1-8-5 production rate is 98 per year. Thus, it would take 6.5 years to replace the inventory. This is enough time to get the new aircraft into the field and have an adequate service life before a new system replaces it.

Question 2: What is the ability of surge production capabilities to replace current inventories in the event of a prolonged great power conflict?

Figure 7: Time to Replace 2020 MDAP Inventories at Adjusted Surge Rate



Source: CSIS analysis.

Table 5: Time to Replace MDAPs at Adjusted Surge Rate, Mean and Median

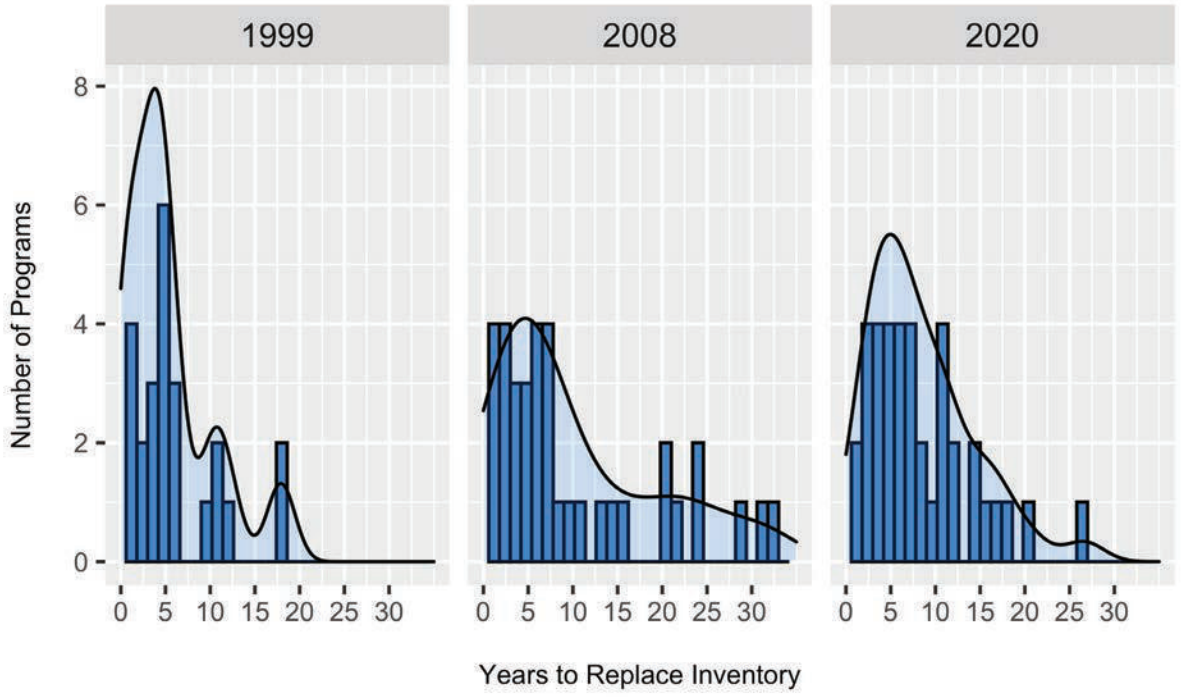
Mean	Median
8.4	7.2

Source: CSIS analysis.

Unsurprisingly, increasing production to the surge rate reduces the amount of time needed to replace inventories. However, the effect is not as large as might be expected. Even at surge production rates, replacement times still range out to 30 years. Mean replacement time declines from 13.8 years to 8.4 years, and the median declines from 10.2 years to 7.2 years. In theory, moving from 1-8-5 and one shift per day to Max/surge and potentially three shifts a day should triple production and, therefore, cut replacement time by two-thirds. This does not happen because constraints on facilities and tooling put limits on how much production can increase in many programs.

Question 3: Has the industrial base become more brittle over time?

Figure 8: 1999, 2008, 2020: Time to Replace MDAP Inventories at Adjusted Surge Rate



Source: CSIS analysis.

Table 6: 1999, 2008, 2020: Comparison, Mean and Median

	Mean	Median
1999	6.6	4.3
2008	10.2	7.5
2020	8.4	7.2

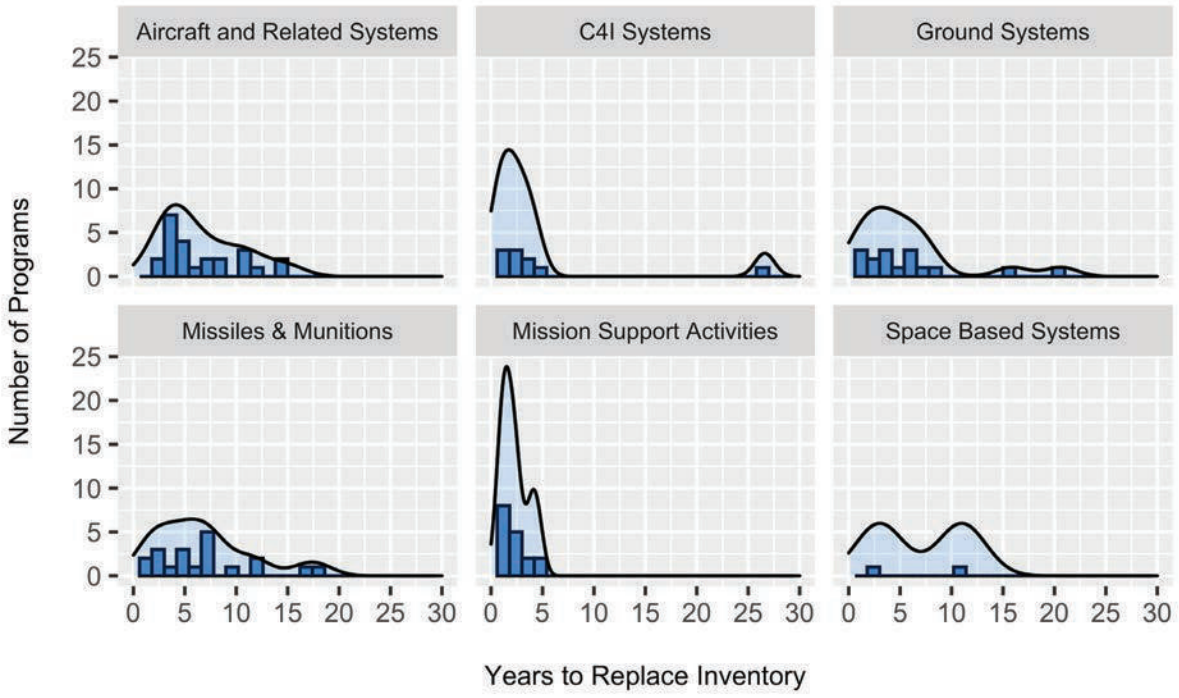
Source: CSIS analysis.

Table 6 sets the FY 1999 and 2008 times to replace MDAPs beside the FY 2020 curve. On average, inventories in FY 2020 take longer to replace. The mean increases from 6.6 years in FY 1999 to 8.4 years in FY 2020, and the median increases from 4.3 years to 7.2 years. This indicates that the defense industrial base is indeed getting more brittle, as General Dunford had noted. Although the data do not give insight into why this occurs, the literature review indicates that the consolidation of the industrial base over time has squeezed out slack in the system that might be used for surge.

The observation from 2008 is another important comparison as an intermediary between 1999 and 2020 and because it represents the height of production during the Iraq war. The median time to replace inventory is higher than in FY 1999 and slightly more than FY 2020, indicating an increase in brittleness despite the budget and production surge from the wars in Iraq and Afghanistan. The rise of the mean is the result of a few programs, such as the High Mobility Artillery Rocket System, with higher replacement times.

Question 4: Are some industries, categories of weapons, or services at greater risk than others?

Figure 9: Time to Replace Inventories by Investment Type at Adjusted Surge Rate (MDAP and non-MDAP programs)



Source: CSIS analysis.

Table 7: Investment Type Comparisons, Mean and Median (MDAP and non-MDAP programs)

	Mean	Median
Aircraft and Related Systems	6.7	4.9
C4I Systems	4.4	2.4
Ground Systems	5.7	3.9
Missiles & Munitions	6.9	6.2
Mission Support Activities	2.3	2.0
Space Based Systems	7.0	7.0

Source: CSIS analysis.

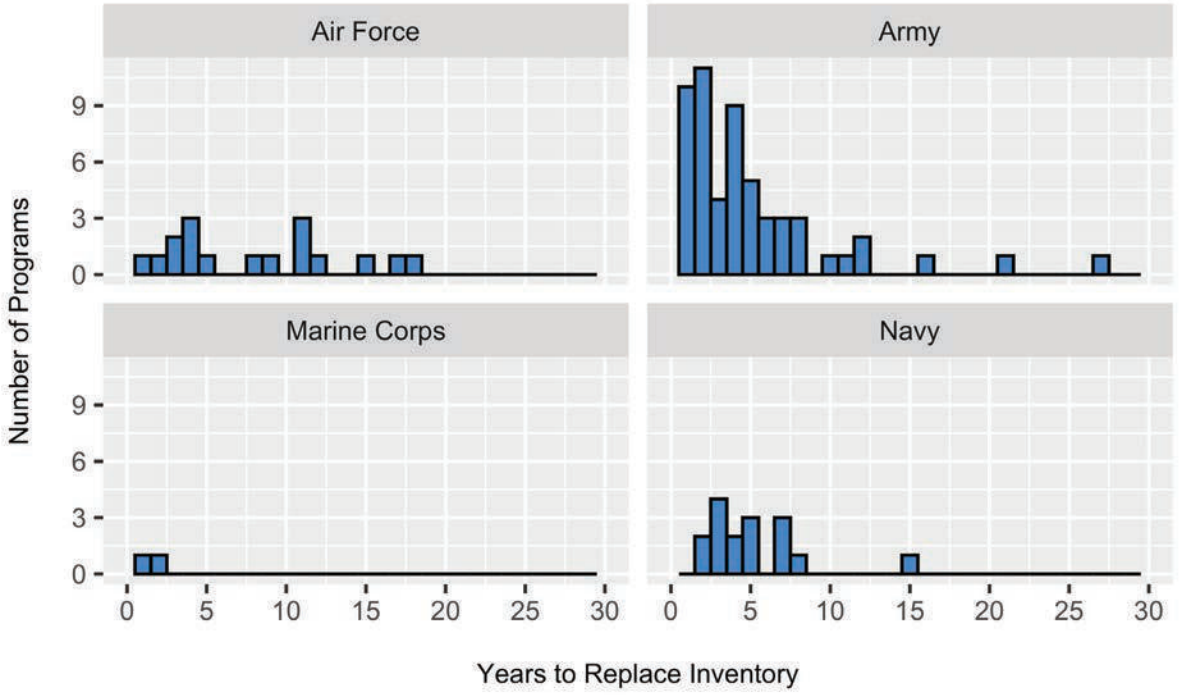
DOD acquires weapons of many different types, and each type has a different dynamic. This analysis allocates systems into the investment categories that DOD uses in its SARs and its annual *Program Acquisition Costs by Weapon System* reports.

The curves for the different investment categories show significant differences. Mission support activities and C4I systems have shorter replacement times, possibly because they have analogs in the civilian economy. Space systems have long replacement times because satellites are not built on

assembly lines but instead fabricated individually. That inhibits surge production. Also, production rates are low because satellites can last a long time once in orbit.

SURGE RATE BY SERVICES

Figure 10: Surge Rate Broken Down by Service Branches



Source: CSIS analysis.

Table 8: Military Service Comparisons, Mean and Median

	Mean	Median
Air Force	8.1	7.6
Army	4.8	3.6
Marine Corps	2.0	2.0
Navy	5.2	4.5

Source: CSIS analysis.

The military services also appear to be unequally affected by the different surge rates. The majority of programs are with the Army, which represents the largest service in terms of personnel, while the Marine Corps is the smallest. However, the data show that the Air Force would take the longest to replace its inventory objective, with an average of 8.1 years at the adjusted surge rate, followed by the Navy at 5.2 years, the Army at 4.7 years, and the Marine Corps at 2.0 years. The Air Force's particularly long replacement rate might be explained by the complex nature of its weapons and platforms. Significantly, this analysis leaves out Navy ships, which are addressed separately since it is a significant outlier with much longer replacement rates.

ANALYSIS OF SHIPS

Calculating how long it would take to replace the Navy's battle force ship inventory is difficult. The principal reason is that, unlike for other MDAPs, P-21 budget exhibits do not provide production rate data for ships. This is likely due to their unique procurement profiles. Ships are built one by one, not on assembly lines. Thus, estimating surge rates requires an assessment of the shipbuilders' production capacity across an entire yard, which entails more analysis than most program offices can do.

However, the project did develop a methodology to give an approximate answer to the question of how long it would take to replace the current ship inventory. That methodology is similar to the methodology used for other MDAPs but used the data that are available on shipbuilding—current inventory, current production rates, ship delivery times, and a Navy analysis of shipbuilding capacity. Data for current inventory and current production rate came from the Navy FY 2021 budget highlights book.[113] Table 9 below shows the result of this analysis.

Table 9: 2021 Ship Inventory Replacement Rates

	Current Inventory	Current Production Rate (ships/yr)	Surge Production Rate (ships/yr)	Time to Replace Inventory at Current Production Rate (yrs)	Time to Replace Inventory at Surge Production Rate (yrs)	Delivery Time (Contract to Delivery) (yrs)	Time to Replace Inventory at Surge Production Rate w/ Delivery Time (yrs)
Aircraft Carriers	11.0	0.2	0.25	55	44	10	54
Large Surface Combatant	96.0	1.6	3.0	60	32	7.7	39.7
Small Surface Combatant	31.0	1.8	3.0	17	10	5.3	15.3
Submarines	71.0	2.2	3.0	32	11	8.6	19.6
Amphibious Ships	33.0	0.8	2.0	41	17	6.7	23.7
Combat Logistics Ships	30.0	2.4	4.0	12.4	8.0	3.25	11.25

Source: CSIS analysis.

Current production rate was the total number of ships planned for procurement over the five-year period FY 2021–FY 2025 (FYDP) divided by five to smooth out the rate for any particular budget year. Because the five-year period is fiscally constrained, it provides a better peacetime rate than fiscally unconstrained long-term plans.

113 DOD, *Highlights of the Department of the Navy FY2021 Budget* (Washington, DC: 2021), 3-2, 4-3, https://www.secnav.navy.mil/fmc/fmb/Documents/20pres/Highlights_book.pdf.

Surge data came from the Navy's 2020 30-year shipbuilding plan, which showed not only planned shipbuilding but also additional capacity in the shipbuilding industrial base. This is a relatively new addition that arose in response to questions as to whether the industrial base could meet the 355-ship goal that the Navy had established. The Navy's analysis did not show any delay in achieving the surge shipbuilding rates, which seems overly optimistic. Nevertheless, the project accepted that assumption and did not include a leadtime to achieve surge production rate, unlike the project's assumption for other programs. Delivery times came from analysis of the P-27 exhibit and its production schedules for specific ships. Because delivery times for ships are so long, the analysis added that time as part of the total time to replace inventory.

This analysis is admittedly imperfect. Inventories represent a point in time and not a long-term average. Construction of particular classes of ships comes in waves so that even a five-year window does not smooth out all of the variation. Finally, over the long periods that would be involved in a surge situation, the Navy would have time to build new capacity in existing yards and bring in new yards that are not now building Navy ships.

Nevertheless, the analysis provides an important insight: the Navy ship inventory would take an extremely long time to replace even under surge conditions. When ships are included, the Navy's average time to replace its inventory more than doubles to 11.2 years, as indicated by Figure 9 and Table 10 below (median time increases by only 1.4 years because the number of ship types is small compared to the total number of Navy systems). Overall, compared with the other types of weapon systems, ships have by far the longest replacement period, and this presents the Navy with a unique challenge.

Figure 11: Navy Replacement Times Including and Excluding Ships

Source: CSIS analysis.

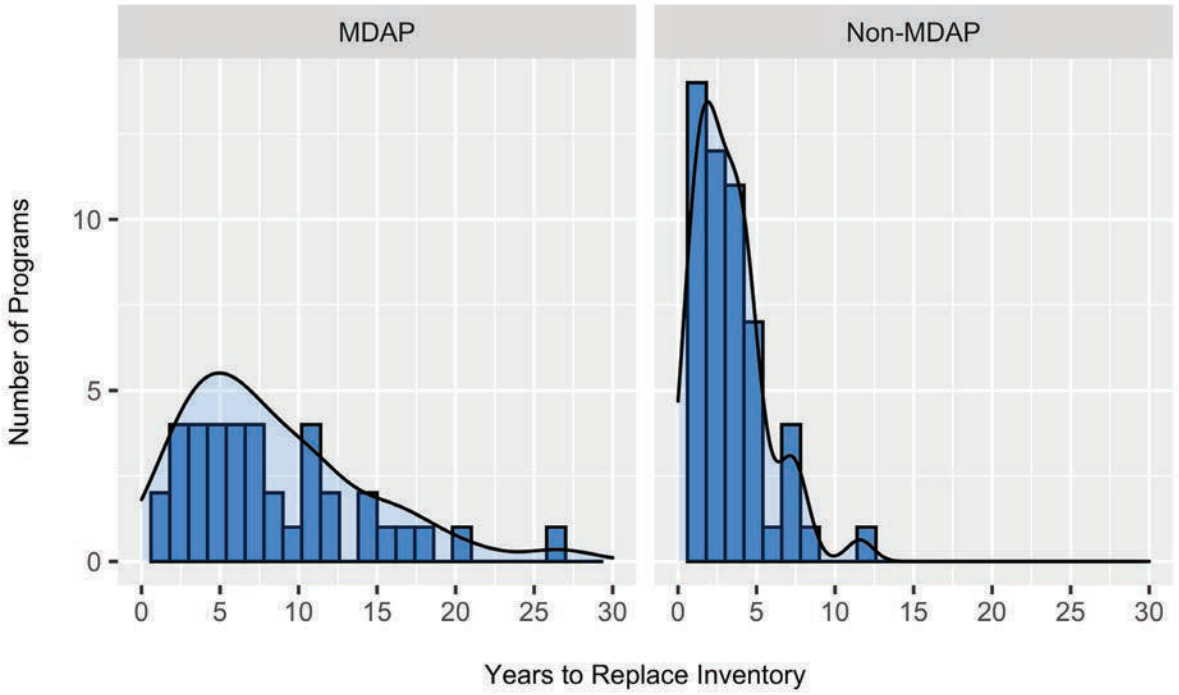
Table 10: Navy With and Without Ships Comparisons, Mean and Median

	Mean	Median
Navy with Ships	11.2	6.0
Navy without Ships	5.2	4.5

Source: CSIS analysis.

Question 5: Are systems with civilian analogs at less risk?

Figure 12: MDAP vs Non-MDAP Time to Replace Inventories at Adjusted Surge Rate



Source: CSIS analysis.

Table 11: 2020 MDAP vs. Non-MDAP Comparison, Mean and Median

	Mean	Median
MDAP	8.4	7.2
Non-MDAP	3.3	2.9

Source: CSIS analysis.

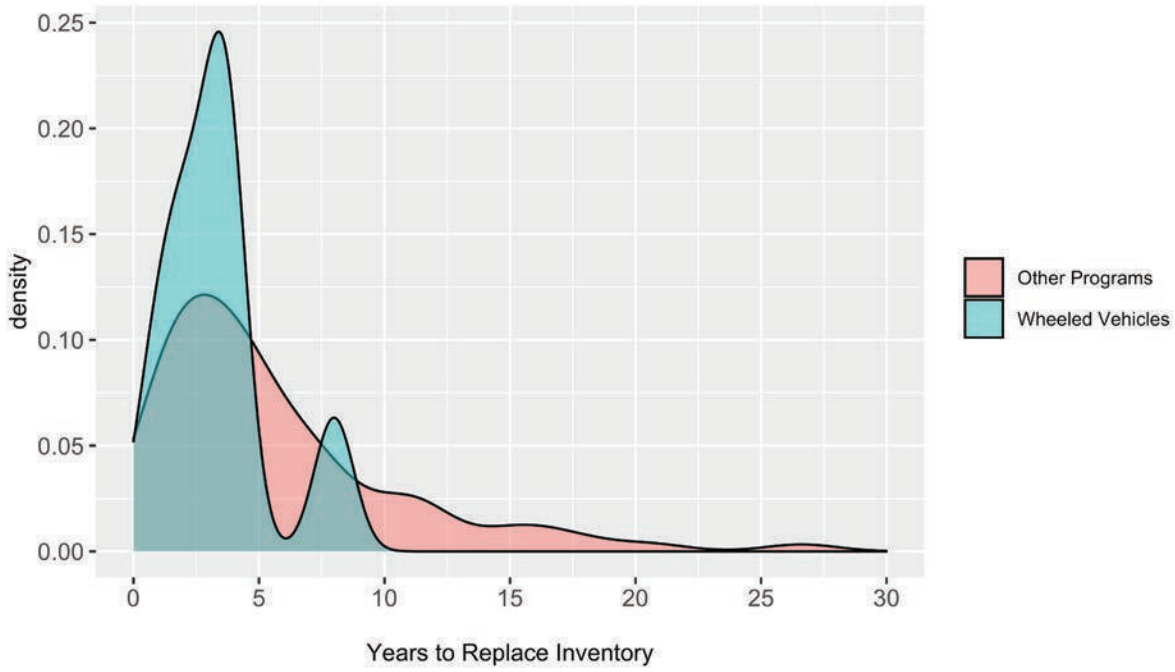
This chart compares the time to replace inventories for MDAPs vs. non-MDAPs. The MDAP curve is the same as shown previously. The non-MDAP curve shows data from 156 smaller programs that had inventory and production rate data in the budget justification books.

Smaller programs had much shorter times to replace inventory. This does not prove that programs with civilian analogs are at less risk. Many small programs do have civilian analogs, but others are uniquely

military, despite their small size. However, the data are suggestive since the lower cost of the non-MDAP programs would make them accessible to civilian firms.

WHEELED VEHICLES: A SURROGATE FOR SYSTEMS WITH CIVILIAN ANALOGS

Figure 13: Time to Replace Wheeled Vehicles at Adjusted Surge Rate



Source: CSIS analysis.

Table 12: Wheeled Vehicle vs. Other Programs Comparison, Mean and Median

	Mean	Median
Wheeled Vehicles	3.3	3.2
Other Programs	5.6	4.2

Source: CSIS analysis.

As a test case, the project looked at wheeled vehicles acquired by DOD to see whether systems with civilian analogs had shorter inventory replacement times. Wheeled vehicles were chosen because the civilian economy produces many such systems. The analysis showed that, indeed, these systems had shorter inventory replacement times than other systems and much shorter inventory replacement times than MDAPs.

Table 13: Select Wheeled Vehicles (2020)

Tactical Trailers/Dolly Sets
Semitrailers, Flatbed
Ambulance, 4 LITTER, 5/4 TON, 4x4
Ground Mobility Vehicles (GMV)
Family of Medium Tactical Vehicles (FMTV)
Firetrucks & Associated Firefighting Equipment
Tactical Wheeled Vehicle Protection Kits
Family Of Forklifts

Source: CSIS analysis.

THE REAL PROBLEM: WEAPON SYSTEM ATTRITION AND MUNITION EXPENDITURES

The project used this methodology because the data are available across the wide spectrum of systems that DOD uses. This allowed comparable analyses of many systems in different time periods. However, the wartime challenge is not to replace inventory. The wartime challenge is to replace losses. These losses manifest as the expenditure of munitions by friendly forces and the attrition of weapon systems due to enemy action. Unfortunately, forecasting attrition in peer conflicts is hard because such conflicts are—fortunately—rare. Attrition rates must, therefore, be deduced from historical analysis. One of the authors previously did an analysis of armored forces that gives a sense of what such dynamics might look like:

> In the Yom Kippur war of 1973, the Israelis lost 400 out of 1700 tanks, a rate of about 1.1 percent per day over the 20 days of increasingly lopsided combat. The Arab armies lost far more. The great 1943 tank battle of Kursk caused very high tank losses — the Germans lost 14 percent per day over two weeks of combat, or 110 percent of their initial force — but that was a short engagement of unusual intensity. In World War II, the average US infantry battalion on the front line lost 2.6 percent of its personnel per day, even without major fighting. It is, therefore, reasonable to assume that an intense peer conflict would destroy about 1 percent of the tank force every day. That includes losses from all sources — combat, abandonment during retreat, sunk en route to theater, and accidents.
>
> With all 15 armored brigades engaged, the US armored force would lose 13 tanks per day on average or 390 per month. The surge production rate for tanks is 29 per month. By pulling in replacements from the tanks in maintenance and the training base, the armored brigade combat teams could stay at full strength for about two months. After that, the force would decline steadily as losses exceeded replacements: to 74 percent in month four (960 tanks), 55 percent in month five (715 tanks), 41 percent in month six (533 tanks), and so on. By month 10, the force would be down to 158 tanks — two armored brigades' worth.[114]

114 Mark Cancian, "Long wars and industrial mobilization: It won't be World War II again," War on the Rocks, August 8, 2017, https://warontherocks.com/2017/08/long-wars-and-industrial-mobilization-it-wont-be-

Such loss rates imply that the industrial base, even surging production, would be inadequate. Munitions expenditures have a similar challenge but a different dynamic. Munitions are stockpiled in peacetime for wartime use, but peacetime inventories are often too small for actual wartime expenditures. Again, data are sparse, but it is possible to get glimpses. For example, during the Falklands War, the Royal Navy reportedly expended hundreds of antisubmarine munitions, depleting its Cold War stocks in a short war against a regional power (Argentina).115 For a great power conflict today, some analyses indicate that certain U.S. munitions would be quickly exhausted.116

Munitions expenditures and the capability of the industrial base to replace them may seem to be a technical military problem, but they have a political dimension as well. The "shell shortage" that Great Britain experienced in 1915 caused the fall of the Asquith government.

world-war-ii-again/.

115 Kenneth Privratsky, *Logistics in the Falklands War* (Barnsley, UK: Pen & Sword Military, 2016).

116 Jan van Tol, Mark Gunzinger, Andrew Krepinevich, and Jim Thomas, *AirSea Battle: A point-of-departure operational concept* (Washington, DC: Center for Strategic and Budgetary Assessments, 2010), https://csbaonline.org/research/publications/airsea-battle-concept.

Conclusions and Recommendations

The analysis produced by this project shows that the defense industrial base could not quickly replace most weapon system inventories. Even at surge production rates, replacement would take many years. In peacetime, this is not a problem because the military services have many years to build inventories. Structuring the defense industrial base for efficient production at expected peacetime rates makes sense in an environment where resources are always constrained and the cost of weapon systems is under continuous scrutiny. Wartime demands in the post-Cold War era were also not a problem because the regional conflicts that the United States conducted did not cause enough attrition or munitions expenditures to go beyond what the industrial base could produce. However, this analysis implies that in a great power conflict, as now envisioned in the *National Defense Strategy*, these production rates would be inadequate to sustain forces in the field for any length of time.

The fact that the industrial base has become more brittle in the last 20 years may indicate that it will continue to grow more brittle since the factors that have driven the change in the past—corporate consolidations and a quest for efficiency—will likely continue. This possibility is reinforced by the focus of industrial base reports on peacetime efficiency and sustainability.

The experiences of mobilization in World War I and World War II do not provide reasons for optimism. U.S. industrial mobilization in World War I generally began at the onset of the war and was unable to produce sufficient equipment until the very last months of the conflict. Instead, the United States relied on its allies, the British and the French, to equip its forces.

The mobilization in World War II succeeded because it began years before the United States formally entered the conflict. The United States was able to use this strategic interval to its advantage, mobilizing as fast as it could while its allies did the fighting.

Unfortunately, potential future conflicts are unlikely to allow the industrial base the many years needed to build capacity. Instead, the political will to build capacity would likely come with the onset of hostilities. The United States would eventually be able to build extensive weapons production capability. But what would military forces do in the two, three, or four years between the beginning of hostilities and the time when there was enough capacity to replace losses as they occur?

The following areas, therefore, deserve additional research to build a sufficient corpus of data and analysis that would allow DOD acquisition officials to make informed decisions about mitigating industrial base risk.

- **Identify low-cost ways to relieve bottlenecks.** Funding will always be limited for surge production, given the pressing demands of near-term acquisition and the pressure to remove "slack" in the system. Therefore, DOD should identify bottlenecks on key systems that small investments might mitigate with, for example, the addition of a critical machine tool or support for a supplier. This analysis should assume that when surge demand is required, the authorities of the Defense Production Act will be available, as will adequate funding. Congress and the president will likely provide both in a national emergency since they did both readily for Desert Storm in 1991, the Iraq/Afghanistan wars of the 2000s, and the Covid-19 pandemic.
- **Ascertain wartime attrition and expenditure rates.** As noted, the real demand on the defense industrial base in a great power conflict would be from combat attrition and munitions expenditures. DOD should conduct these analyses to get a sense of how severe these wartime demands would be. Because of the depth of historical research involved, such research would necessarily focus on a limited set of weapon systems and munitions.
- **Develop supplemental acquisition strategies ahead of time.** Even with some warning and the alleviation of key bottlenecks, the defense industrial base may not be able to produce the large amount of equipment that would be needed rapidly in a great power conflict. Therefore, the acquisition community should investigate supplemental approaches such as adaptation of civilian systems that might be appropriate for military use and acquisition of suitable foreign systems. Such an investigation could at least identify the parameters and key considerations for developing alternative acquisition strategies.
- **Scrub the production data in the budget justification books, particularly the P-21 exhibits**. Consistent and accurate data on production is essential for providing accurate assessments of the defense industrial base's capacity to respond to emergency conditions, but, as noted earlier, some data are inaccurate. Unlike the selected acquisition reports, for example, the budget exhibits relating to production data appear to receive little scrutiny. The relevant direction in DOD's Financial Management Regulations is clear. It directs, for example, that production rates should be "yearly rates," but many programs report monthly rates. The guidance also requires specification of the number of shifts under surge ("Max"), but few programs provide that information.

  DOD should therefore conduct a review of the production rate data to identify anomalies that appear to be out of line with the guidance and then resolve these with the relevant program offices. The review should require that programs provide any missing production rate data, which is a problem in about 11 percent of MDAPs. Since DOD produces these exhibits with little change from year to year, that review does not need to be repeated every year.

DOD should also direct a modest expansion of the required production rate data to include a short explanation of how program offices develop the surge rate since many rates seem to lack any analytic foundation except for being three times the 1-8-5 rate.

The goal of all this better data and resulting analysis is to allow decisionmakers to better position DOD to cope with a long great power conflict. In making those decisions, senior officials will need to keep in mind the insights that arose from the history of industrial mobilization:

1. The need for centralized economic planning to cope with the massive dislocations that arise in an industrial mobilization situation;
2. The need to accept foreign designs when they are superior to U.S. designs;
3. The importance of balanced production that includes supporting capabilities as well as major end items;
4. The need to replace some prewar legacy systems that may be adequate for training and regional conflicts but are inadequate for great power conflicts;
5. The tension between efficient peacetime production and maintaining capacity for wartime surge;
6. The value of beginning industrial mobilization before conflict begins; and
7. The key role that senior officials play in pushing sluggish bureaucracies to move quickly.

Appendix A

Surge Data Codebook

This codebook describes the guidelines used to code the respective variables of the industrial mobilizational database produced for this study. Unless otherwise noted, data was derived from the P-21 and P-40 exhibits in the procurement justification books of the respective services from the years 1999, 2008, and 2020.

Service: Army, Navy, Marine Corps, Air Force. Note: Marine Corps numbers are only separated when in clearly separate procurement justification books. Marine Corps aviation is included in Navy aircraft procurement books and therefore are counted under Navy.

Multi-Service: 1 or 0 depending on whether two or more services share the same production line. The lead service is kept, and the following service is dropped with its FY 2020 procurement numbers and inventory objectives added to the inventory objective of the lead service.

Other Service: Army, Navy, Marine Corps, Air Force. The other listed service indicates the service the system shares a production line with if it is multi-service.

Investment Type: Categorized by the following types:

- Aircraft and Related Systems (ARS)
- C4I Systems (C4I)
- Ground Systems (GS)
- Missile Defeat & Defense Programs (MDDP)
- Missiles & Munitions (MM)
- Mission Support Activities (MSA)

- S&T (ST)
- Shipbuilding & Maritime Systems (SMS)
- Space Based Systems (SBS)

These categories are derived from the *Program Acquisition Costs by Weapon System* book released every year as part of the DOD comptroller's budget materials.[117] The breakdown is based on Mission Area Categories as defined in the book, and each system was labeled accordingly by the authors as they fit the mission areas. The organization of the respective procurement books assisted with this categorization.

Type/Book: Categorized by the title of their procurement justification book, which roughly follows material categories such as aircraft, missiles, and vehicles.

P-1 Line Item Number: The number code at the top of each system as outlined in the P-40s and P-21s.

System Title: The relevant title for each system from the P-40s and P-21s.

Anomalous: 1 indicates the number can be dropped. This usually means there is some anomalous data, such as the production rates being unusually high or inconsistent to current procurement levels.

Anomalous Notes: General notes to explain why the data is considered anomalous.

General Notes: General notes about each system. This includes relevant data from the SARs and relevant remarks from the P-40s or P-21s.

MDAP: Major Defense Acquisition Program. A program listed as an MDAP, often meriting its own Service Acquisition Report (SAR). MDAPs were primarily identified using the SAR summary tables found in DOD's *Comprehensive Selected Acquisition Reports*.[118] For 2008 and 1999, the SAR summary data was exclusively used to find inventory objective quantities.

Unit Cost (2020 Gross Cost/Qty) Millions: The estimated unit costs of the relevant weapon system. Calculated from the P-40 by dividing the "Gross/Weapon System Cost ($ in Millions)" by "Procurement Quantity (Units in Each)." In cases where the procurement quantity was not listed and the program was an MDAP, the unit cost is calculated by dividing the relevant year's Quantity Summary from the Appropriation Summary in the most recent relevant SAR.

FY 2020 Procurement Level: From P-40, Procurement Quantity (Units in Each). If not reported, is left blank. If an MDAP program, the quantity is taken from the respective year in the most recent SAR. If no procurement quantity in the SAR, then entered as zero.

Inventory Objective: This number attempts to capture the current or projected inventory. From the P-40 it consists of all prior year numbers, current year, and upcoming years through the FYDP or until

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117 DOD, *Program Acquisition Costs by Weapon System: United States Department of Defense Fiscal Year 2020 Budget Request* (Washington, DC: March 2019), https://comptroller.defense.gov/Portals/45/Documents/defbudget/fy2020/fy2020_Weapons.pdf.

118 "Department of Defense Comprehensive Selected Acquisition Reports of the Annual 2018 Reporting Requirement as Updated by the President's Fiscal Year 2020 Budget," DOD, n.d., https://media.defense.gov/2019/Aug/01/2002165676/-1/-1/1/DEPARTMENT-OF-DEFENSE-SELECTED-ACQUISITION-REPORTS-(SARS)-DECEMBER-2018.PDF.

complete. Where possible from MDAP programs with SARs, the SAR numbers are substituted for the P-40 inventory number. The production totals are typically used from the SAR unless otherwise noted.

Peacetime Production: This number is derived by dividing the Inventory Objective by the FY 2020 Procurement Level.

Efficiency Production: This number is derived by dividing the Inventory Objective by the Aggregated 1-8-5 number.

Basic Surge Rate (Years): The Inventory Objective divided by the Aggregated Max years to calculate the rate by which the inventory objective will be replenished. Measured in years.

Surge Rate (Months): The previously calculated Surge Rate (Years) multiplied by twelve.

Basic Surge Rate Plus Leadtime (Years): Inventory Objective divided by Aggregated Max Years plus the Average Reorder Product Leadtime. Assumes that it will take time to reach the Aggregated Max rate, and therefore assumes Reorder Product Leadtime as a proxy for that time.

Adjusted Surge Rate (Years): Reorder Product Leadtime multiplied by Aggregated 1-8-5 Years, subtracted from Inventory Objective and all divided by the Aggregated Max Years plus Reorder Product Leadtime. Assumes that it will take time to reach the Aggregated Max rate, and therefore assumes Reorder Product Leadtime as a proxy for that time. In addition, the Adjusted Surge Rate takes into account ongoing 1-8-5 production, while the manufacturer moves to its Max rate.

Agg. MSR (Years): Aggregated MSR numbers as reported in the P-21s, converted into years.

Agg. 1-8-5 (Years): Aggregated 1-8-5 numbers as reported in the P-21s, converted into years.

Agg Max (Years): Aggregated Max numbers as reported in the P-21s, converted into years.

Item Number (DODIC): The DODIC number as recorded on the P-40 or P-21.

Avg. Production Leadtime (Years): Average Production Leadtime is the sum of all reorder manufacturing values divided by the number of manufacturers, converted into years.

Title (DODIC)/Aggregated Items: Listed title next to the DODIC number as recoded on the P-40 or P-21.

1st Manufacturer Name – Location: List the first manufacturing location as recorded in the first line of the P-21.

1st MSR: Converted as necessary to years, although not all 1999 numbers here converted into years. MSR defined Minimum Sustaining Rate: "This is the production rate that is necessary to keep production lines open while maintaining a base of responsive vendors and suppliers; the quantity that will preclude start-up costs in the case of a production break; or the quantity that the contractor is willing to accept and produce at a reasonable cost."[119]

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119 MSR, 1-8-5, Max, and Production Leadtime definitions from "Instructions – Exhibit P-21, Production Schedule," in Under Secretary of Defense (Comptroller), *Financial Management Regulation Volume 2B: "Budget Formulation and Presentation (Chapters 4-19)"*, 4–48.

1st 1-8-5: Converted as necessary to years. Economical Production Rate: "This is the most efficient production rate for each budget year at which the item can be produced with existing or planned plant capacity and tooling, with 1 shift a day running for 8 hours a day and 5 days a week (1-8-5)."

1st Max: Converted as necessary to years. Maximum Production Rate: "This is the maximum capacity rate that a contractor can produce with extant or PY planned tooling. Indicate the number of shifts."

Production Leadtime: "This is the amount of time required by a contractor to produce an item once a contract is awarded. Leadtimes should be based on a realistic projection of a contractor's capability."[120]

Each additional manufacturer after this follows the same structure as above.

120 Ibid.

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