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Industrial Mobilization: Assessing Surge Capabilities, Wartime Risk, and System Brittleness

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Abstract

With the shift of U.S. strategic focus to great power competition, interest in industrial mobilization for a long-duration, 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, the project analyzed the time needed to replace weapon systems' inventory at peacetime and surge production rates. The project found that to replace Major Defense Acquisition Program (MDAP) inventories at surge production rates would take an average of 8.7 years. Some investment categories are at more risk than others, with Navy shipbuilding being uniquely challenged. Programs with analogs in the civilian economy appear to have faster replacement rates than military unique systems. Finally, the industrial base has become more brittle over time in that that it would take longer to replace inventories at Fiscal Year (FY) 2020 production rates than at FY1999 production rates. These findings indicate that existing surge capacities for major defense acquisition programs fall short of what will be needed for a long-duration great power conflict. More research is needed to provide decision-makers with options to cope with this shortfall.

Introduction: Why Conduct Research on Industrial Mobilization Now?

Industrial mobilization was a concern during the Cold War but 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 (*Nomination,* 2017). 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 Gen Dunford's term), that is, 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 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.

Research Questions

To gain insight into the industrial base's ability to cope with great power conflict, the project developed four research questions.

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

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. 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 Gen Dunford raised about whether the industrial base is becoming more brittle. There are reasons to believe that might be true, but it is unproven. If the industrial base is indeed becoming more brittle, then the challenge of sustaining U.S. forces in a prolonged great power conflict is becoming more severe.

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

The 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, that is, 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 the 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.

Literature Review

Industrial mobilization has a long history in the United States, and the literature on that history and on the defense industrial base itself can illuminate challenges currently facing the DoD.

World War I. For 50 years after the Civil War, the United States fought frontier skirmishes and limited regional wars like the Spanish–American War. Thus, the United States was ill-equipped in 1917 for the massive undertaking of fighting a great power conflict. Recognizing the challenge, the president and Congress created the Council of National Defense and War Industries Board to coordinate the materiel and labor demands of industrialized warfare (Neumann, 2017). However, rapid military expansion, outdated equipment designs, and a lack of trained personnel forced the United States to rely heavily on its allies to equip its forces until the last few months of the war. For some armaments, like tanks, the United States never fielded its own equipment in time.

The Interwar Period. Because of the industrial challenges the United States faced during World War I, attempts at planning for a potential future war began in the early 1920s. Although considerable effort was made, few tangible steps were taken to address the challenges of mass mobilization (Koistinen, 1979). Instead, American isolationism, disillusionment about the cost of war, and economic depression prevented serious preparations for any future conflict.

World War II. It wasn’t until after the Munich Agreement in September 1938 and a grim assessment of French air combat capacity that the mood in Washington began to shift from neutrality and isolation to engagement. Overseas weapons orders and a naval buildup drove the first phase of industrial mobilization. The second phase of mobilization began in May 1940, when the “phony war” ended, and German forces advanced through Belgium, Holland, Luxembourg, and France. This phase entailed a peacetime draft, mobilization of reserves, and ordering of equipment to support a vastly expanded army. The Office of Production Management, its successor, the War Production Board, and a variety of subordinate agencies were established to coordinate industry, raw materials, and labor (Herman, 2012).

The third and final phase began after the attack on Pearl Harbor when it became clear that the United States needed enough military-industrial capacity to fight in two theaters. In addition to the earlier reliance on the government-owned, contractor-operated armament plants, conversion of manufacturing from civilian to military production was now required. Thus, hundreds of firms and plants that had not participated in the first two stages of the mobilization effort were folded into the war economy (Wilson, 2016). The results were nothing short of astonishing. Unlike in World War I, where the United States relied on its allies for equipment, in World War II, the United States supplied not only its own forces but also those of its allies. However, it took five years from the beginning of industrial expansion in 1938 before U.S. forces could face the Wehrmacht and Imperial Japanese forces on an equal footing.

The Cold War. Although the Cold War period saw the United States fight multiple limited conflicts, these never required industry to mobilize in the same manner it had for the two world wars. However, large defense budgets after 1950 allowed the U.S. defense industry to maintain a high level of readiness. The Defense Production Act, passed in 1950 in response to the Korean War mobilization, gave the president the means to prioritize national security production and allocate resources in an emergency and substituted for the government planning agencies of the world wars.

Post–Cold War. With the end of the Cold War, the need for industrial mobilization faded, and the defense budget declined by 40%. The defense industry was encouraged to merge and consolidate into a lean, efficient set of firms that could survive in the post–Cold War environment. Thus, 15 firms consolidated into four. With the return of great power competition with Russia and China, interest in high-intensity, long-duration conflicts revived. However, the literature on the industrial base still focuses primarily on peacetime efficiency and sustainability.

Methodology

To gain insight into the ability of the defense industrial base to meet the demands of great power conflict, the project analyzed how long it would take to replace the current inventory of weapon systems using a peacetime production rate and a wartime surge rate. To conduct this analysis, this project developed a comprehensive database of DoD production data for FY2020 and FY1999, 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 because they can be useful to determine total inventory. The P-21 exhibits contain detailed system information on cost, quantity, surge production rates, production lead times, and deliveries.

Selected Acquisition Reports (SARs). SARs contain inventory data as well as information on acquisition strategy and contract types. Although not all SARs are publicly available in their full form, CSIS has access to an extensive portfolio in 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 20th 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.”

The 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” (DoD, 2017, p. 4-48). This rate is important in budget and acquisition analyses when the military services want to keep the production line going but lack the resources. Because the project was analyzing industrial mobilization—increases in production—it did not use this rate.

“1-8-5,” Also Called the 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)” (DoD, 2017, p. 4-48).

“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” (DoD, 2017, p. 4-48). 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 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 FY2019 and FY2020 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 that, so 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 FY1999 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 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, like SARs—and corrected those that it could. Others that were anomalous—generally because their surge/MAX rate was too high or their inventory objective was off—were tagged as such and excluded from the initial analysis.

The Industrial Mobilization Database

Using data from the budget justification books and the SARs, the project put together an industrial mobilization database. This consists of current production rates, surge production rates, and total inventories for a wide variety of weapon systems—land, sea, air, C4I, space, munitions—at two points in time, FY2020 and FY1999. 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 lead time, military service, and budget line numbers.

FY1999 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.

FY2020 was chosen because it was the most recent set of data available when the project began its work last fall. (FY2021 data has since become available, but from an initial analysis, it is not materially different from the FY2020 data.)

Two additional years will also be analyzed in the future: FY2008, which represents the height of the wartime surge, and FY1989, the end of the Cold War, to see whether the industrial base of the Cold War was different. (Obtaining data from FY1989 will depend on the reopening of the federal archives, which are currently closed.)

Calculations

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

Inventory replacement at peacetime production rate is as follows:

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

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.

Inventory replacement at surge rate (in years) is as follows:

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

The calculation divided the inventory objective by the MAX production rate, measured in years.

Inventory replacement at surge rate with production lead time is as follows:

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

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 lead time to reach surge rate. As a surrogate, the second calculation added the lead time (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 lead time 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 lead time was important because whatever the actual lead time to surge rate was, it was not zero.

Inventory replacement at adjusted surge rate is as follows:

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

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

The final calculation, and the one used for calculations in the report, is the surge rate with production lead time 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:

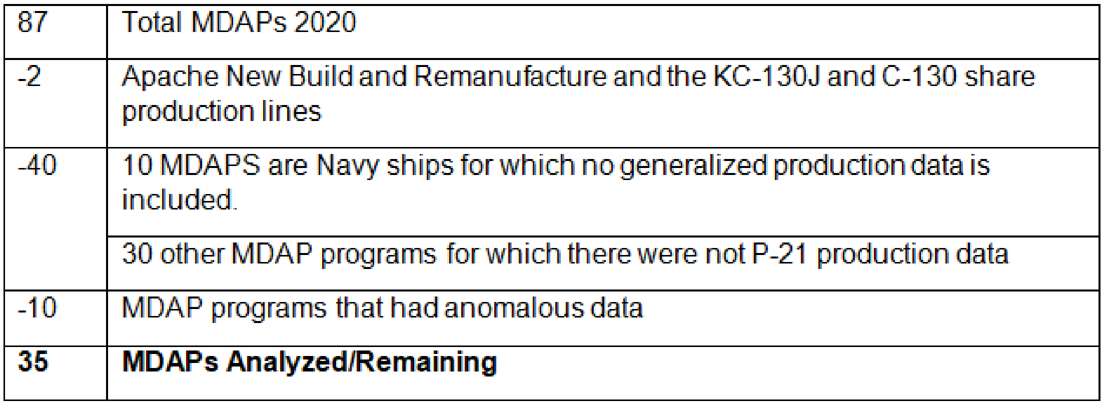
Reorder Production Leadtime multiplied by Aggregated 1-8-5 Years, subtracted from Inventory Objective and all divided by the Aggregated MAX Years plus Reorder Product Leadtime.

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

Major and Nonmajor Acquisition Programs. This project pays particular attention to the production rates of Major Defense Acquisition Programs (MDAPs), because these are the largest and most important programs. At any one time, they constitute about half of all procurement funding (Office of the Under Secretary of Defense [Comptroller], 2020). MDAPs are designated by statute as programs with a research, development, and test and evaluation requirement of more than $480 million in FY2014 constant dollars, a procurement requirement of more than $2.79 billion in FY2014 constant dollars, or having been designated a special interest program by the secretary of defense (DoD, 2015). The project identified MDAPs using the SAR summary tables for the relevant budget year.

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 (DoD, 2019). 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. Among these, a further 10 were considered anomalous, generally because their surge/MAX rate was unrealistically high, or their inventory objective was inaccurate when compared to other information. A breakdown can be seen in Table 1. The project is working to clarify the data on these systems.

Table 1. 2020 MDAP Breakdown



87	Total MDAPs 2020
-2	Apache New Build and Remanufacture and the KC-130J and C-130 share production lines
-40	10 MDAPS are Navy ships for which no generalized production data is included.
	30 other MDAP programs for which there were not P-21 production data
-10	MDAP programs that had anomalous data
35	**MDAPs Analyzed/Remaining**

Nonmajor 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 (DoD, 2017, p. 4-48).

Question 1: What Is the Ability of Existing Production Capabilities to Replace Current Inventories in the Event of a Prolonged Great Power Conflict?

Figure 1 shows the time required to replace MDAP inventories at the “peacetime” production rate, defined as the 1-8-5 rate.

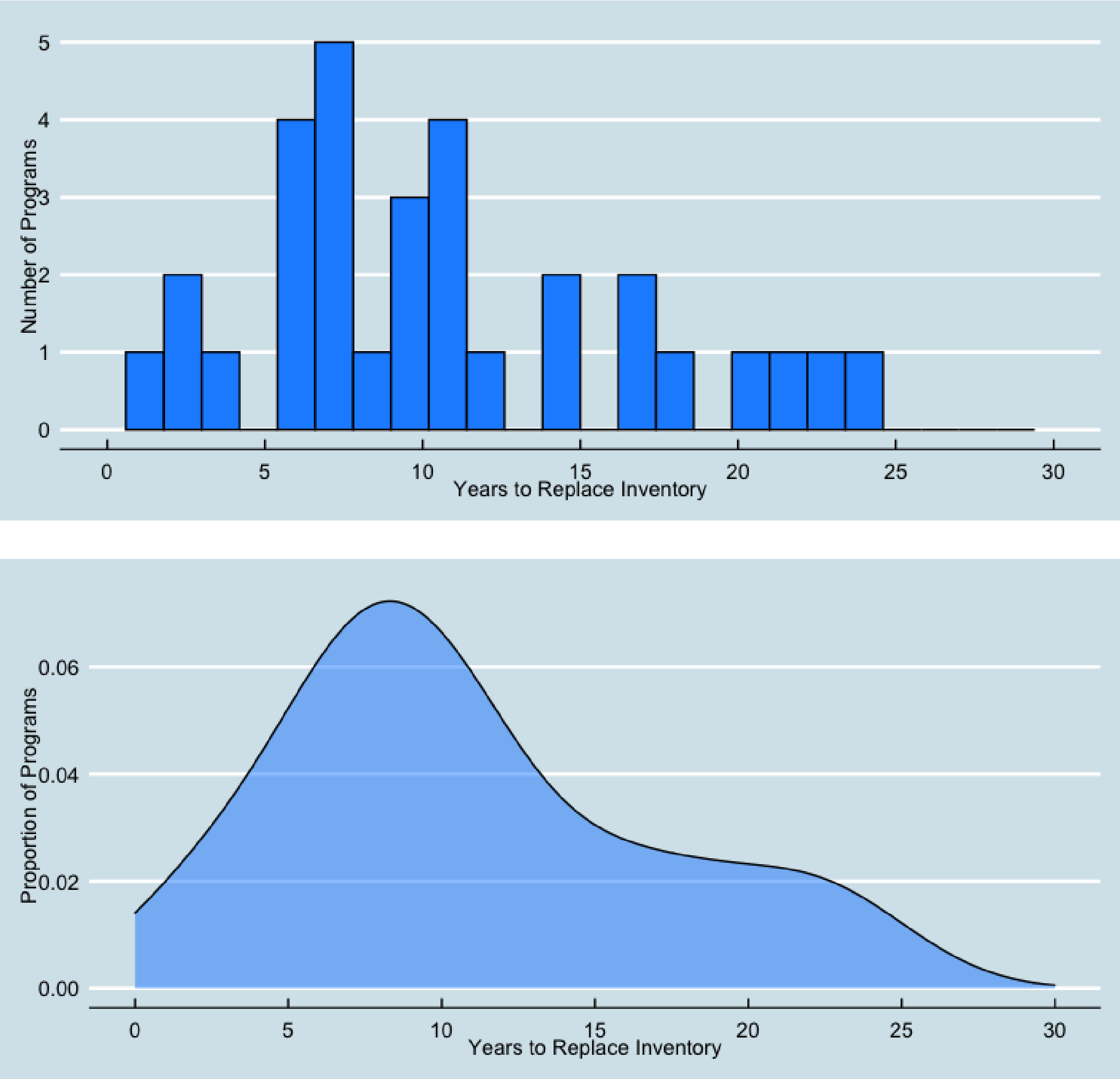


Figure 1. Time to Replace 2020 MDAP Inventories at 1-8-5 Rate

Table 2 shows the data from Figure 1 smoothed to a curve. These charts provide 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.

Table 2. Time to Replace MDAPs at 1-8-5 Rate, Mean and Median

Mean	Median
14.433	10.300

Question 2: What Is the Ability of Surge Production Capabilities to Replace Current Inventories in the Event of a Prolonged Great Power Conflict?

Not surprisingly, 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, as can be seen in Figure 2.

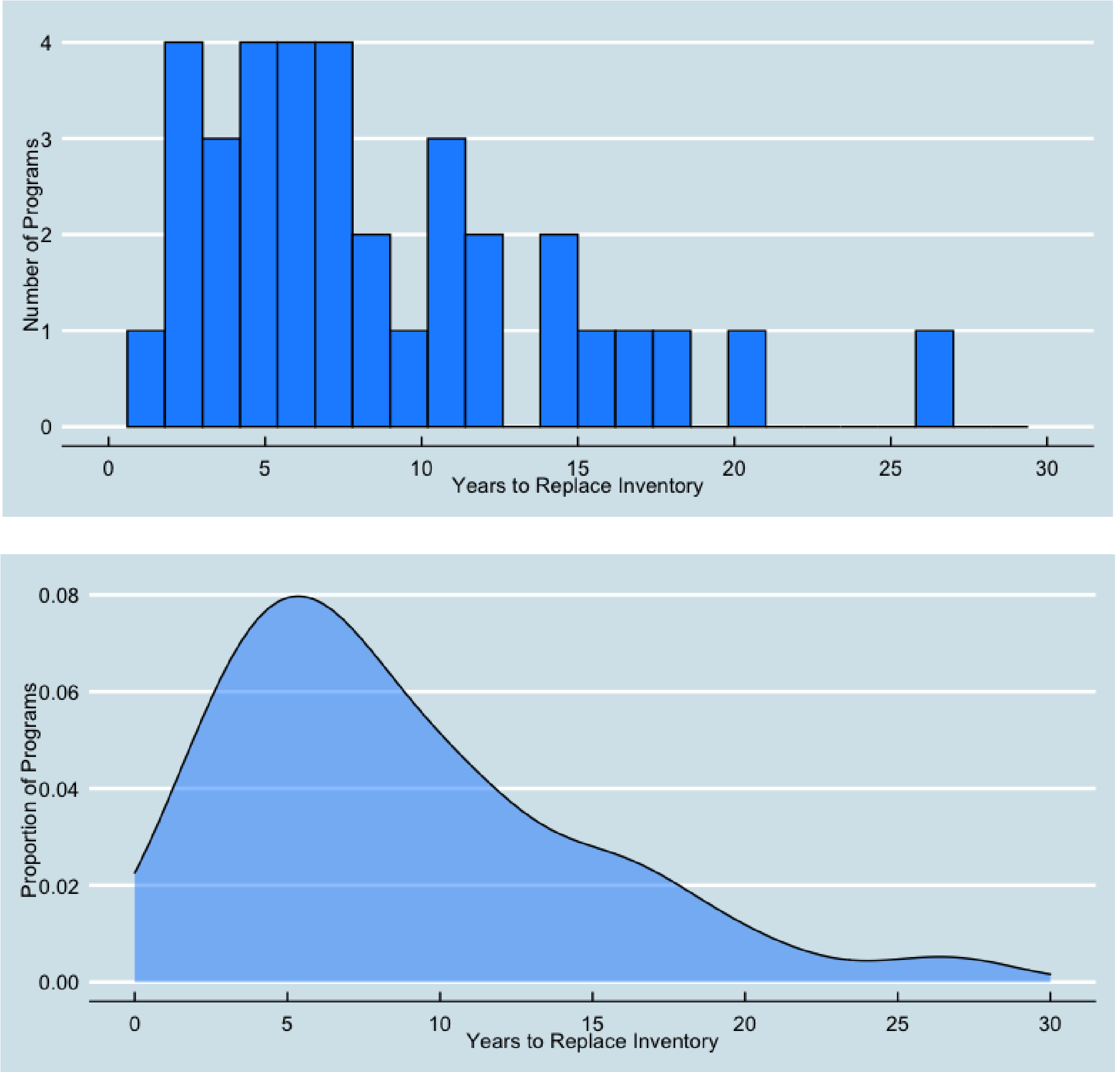


Figure 2. Time to Replace 2020 MDAP Inventories at Adjusted Surge Rate

Mean replacement time declines from 14.4 years to 8.7 years, with the median from 10.3 years to 7.5 years (see Table 3). 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 a third. This does not happen because constraints on facilities and tooling put limits on how much production can increase in many programs.

Table 3. Time to Replace MDAPs at Adjusted Surge Rate, Mean and Median

Mean	Median
8.711	7.480

Question 3: Has the Industrial Base Become More Brittle Over Time?

Figure 3 overlays the FY1999 time to replace MDAP curve onto the FY2020 curve. On average, inventories in FY2020 take longer to replace.

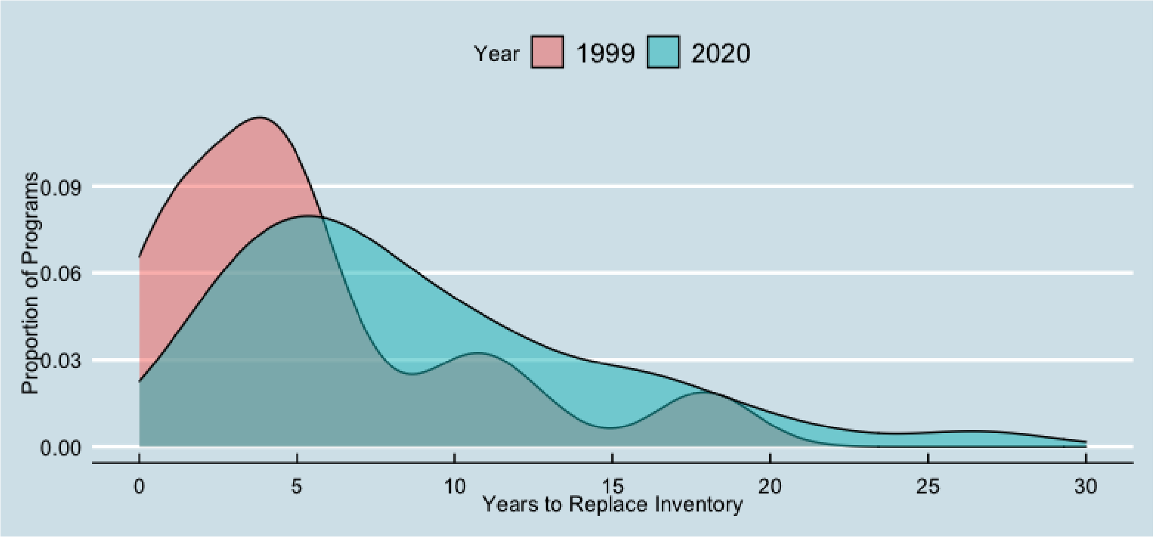


Figure 3. 2020 versus 1999: Time to Replace MDAP Inventories at Adjusted Surge Rate

As shown in Table 4, the mean increases from 6.6 years in FY1999 to 8.7 years in FY2020, and the median increases from 4.3 years to 7.5 years. This indicates that the defense industrial base is indeed getting more brittle, as Gen 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.

Table 4. 2020 versus 1919 Comparison, Mean and Median

2020	Mean	Median
	8.711	7.480
1999	**Mean**	**Median**
	6.580	4.270

Question 4: Are Some Industries or Categories of Weapons at Greater Risk than Others?

The DoD acquires weapons of many different types, and each type has a different dynamic. This analysis allocates systems into the investment categories that the DoD uses in its SARs and its annual report *Program Acquisition Costs by Weapon System* (Comptroller, 2020).

The curves for the different investment categories in Figure 4 show significant differences.

Legend: Aircraft and Related Systems (ARS), C4I Systems (C4I), Ground Systems (GS), Missiles & Munitions (MM), Mission Support Activities (MSA), Space Based Systems (SBS).

Figure 4. Time to Replace Inventories by Investment Type at Adjusted Surge Rate

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 individually fabricated. That inhibits surge production. Also, production rates are low because satellites can last a long time once in orbit. The data are summarized in Table 5.

Table 5. Investment Type Comparisons, Mean and Median

ARS	**Mean**	**Median**
	6.475	4.760
C4I	**Mean**	**Median**
	4.84	2.37
GS	**Mean**	**Median**
	5.683	3.930
MM	**Mean**	**Median**
	6.864	6.165
MSA	**Mean**	**Median**
	2.254	2.000
SBS	**Mean**	**Median**
	7	7

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 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 FY2021 Budget Highlights book (DoD, 2020, pp. 3-2, 4-3). Table 6 below shows the result of this analysis.

Table 6. 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 with delivery time (yrs)
Aircraft Carriers	11	.2	.25	55	44	10	54
Large Surface Combatant	96	1.6	3	60	32	7.7	39.7
Small Surface Combatant	31	1.8	3	17	10	5.3	15.3
Submarines	71	2.2	3	32	11	8.6	19.6
Amphibious Ships	33	.8	2	41	17	6.7	23.7
Combat Logistics Ships	30	2.4	4	12.4	8	3.25	11.25

Current production rate was the total number of ships planned for procurement over the five-year period FY2021 to FY2025 (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. 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 whether the industrial base could build 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 lead time 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. 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.

Question 5: Are Systems with Civilian Analogs at Less Risk?

Figure 5 compares the time to replace inventories for MDAPs versus 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.

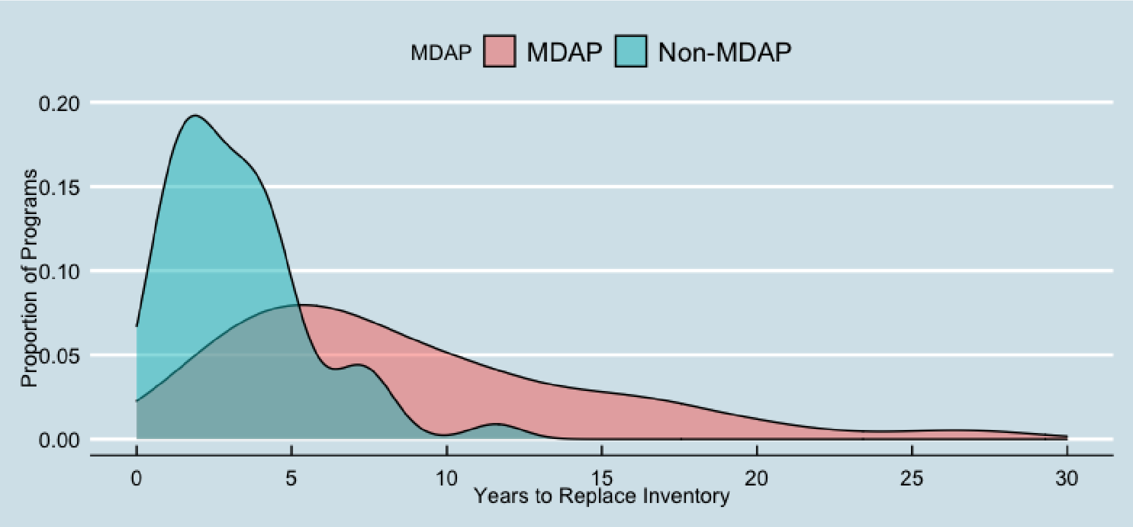


Figure 5. MDAP versus Non-MDAP Time to Replace Inventories at Adjusted Surge Rate

Smaller programs had dramatically shorter times to replace inventory, as can be seen in Table 7. This does not prove that programs with civilian analogs are at less risk. Many of the vehicle and communications programs do have civilian analogs, but others are uniquely military, despite their small size. However, it does open that possibility since the lower cost of the non-MDAP programs would make them accessible to civilian firms.

Table 7. 2020 MDAP versus Non-MDAP Comparison, Mean and Median

MDAP	**Mean**	**Median**
	8.711	7.480
Non-MDAP	**Mean**	**Median**
	3.28	2.92

Wheeled Vehicles: A Surrogate for Systems with Civilian Analogs

As a test case, the project looked at wheeled vehicles acquired by the 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, but there are potentially many other systems with civilian analogs. The analysis showed that, indeed, these systems had shorter inventory replacement times than other systems and much shorter inventory replacement times than MDAPs (see Figure 6 and Table 8).

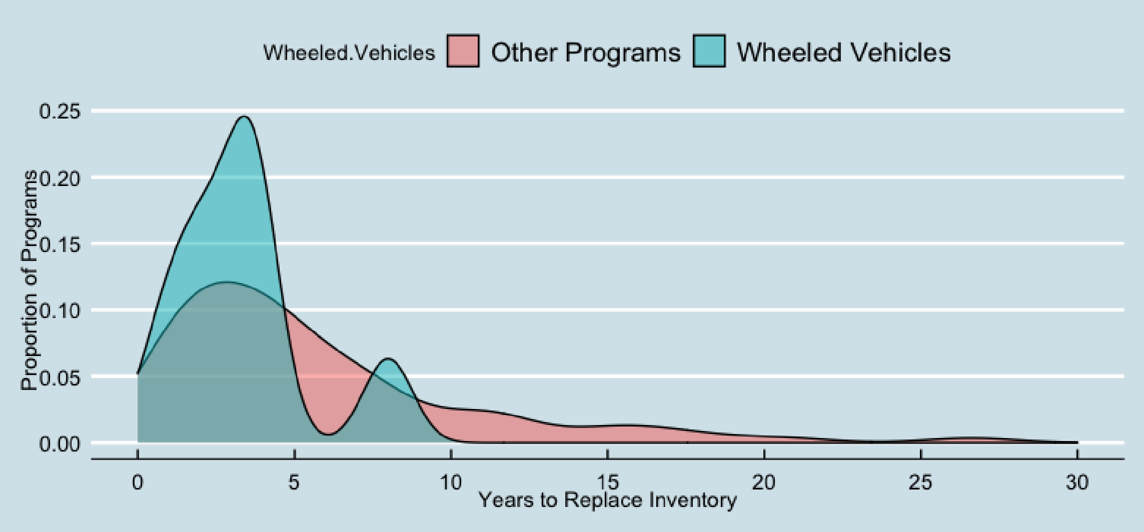


Figure 6. Time to Replace Wheeled Vehicles at Adjusted Surge Rate

Table 8. Wheeled Vehicle vs. Other Programs Comparison, Mean and Median

Wheeled Vehicles	**Mean**	**Median**
	3.60	3.54
Other Programs	**Mean**	**Median**
	5.649	4.200

Table 9. Wheeled Vehicles Selected (2020)

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

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 the 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 attrition of weapon systems mainly due to enemy action and the expenditure of munitions. 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 1,700 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 U.S. 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 U.S. armored force would lose 13 tanks per day on average or 390 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: 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. (Cancian, 2017)

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; Privratsky, 2016). For a great power conflict today, some analyses indicate that certain U.S. munitions would be quickly exhausted (Tol, Gunzinger, Krepinevich, & Thomas, 2010).

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.

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 make 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. Such conflicts do not allow the industrial base the many years needed to produce large numbers of replacement systems.

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.

1. 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, the DoD should identify bottlenecks on key systems that small investments might mitigate—for example, 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 well as 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 recent pandemic.
2. Ascertain wartime attrition and expenditure rates. As noted, the real demand on the defense industrial base in a great power conflict will be from combat attrition and munitions expenditures. The 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.
3. 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 might 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 appropriate foreign systems. Such an investigation could, at the least, identify the parameters and key considerations in developing alternative acquisition strategies.

The last recommendation is to scrub the production data in the budget justification books, particularly the P-21 exhibits. Consistent and accurate data on production are 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 the DoD’s (2017) 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.

The 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% of MDAPs. Since the DoD produces these exhibits with little change from year to year, that review does not need to be repeated for several years.

The 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.

References

Cancian, M. (2017, August 8). Long wars and industrial mobilization: It won't be World War II again. Retrieved from https://warontherocks.com/2017/08/long-wars-and-industrial-mobilization-it-wont-be-world-war-ii-again/

DoD. (2015, January 7). *Operation of the defense acquisition system* (DoD Instruction 5000.02). Washington, DC: Author.

DoD. (2017). *Financial management regulation, Volume 2B: Budget formulation and presentation (Chapters 4–19).* Retrieved from https://comptroller.defense.gov/FMR/vol2b_chapters.aspx

DoD. (2019). *Comprehensive selected acquisition reports for the annual 2018 reporting requirement as updated by the president's fiscal year 2020 budget.* Retrieved from https://www.hsdl.org/?abstract&did=828268

DoD. (2020). *Highlights of the Department of the Navy FY2021 budget.* Retrieved from https://www.secnav.navy.mil/fmc/fmb/Documents/20pres/Highlights_book.pdf

Herman, A. (2012). *Freedom's forge: How American business produced victory in World War II.* Random House.

Koistinen, P. A. (1979). *The hammer and the sword: Labor, the military, and industrial mobilization, 1920–1945.* Arno Press.

Neumann, B. (2017). *The U.S. Army in the World War I era.* Center of Military History.

Nomination: Dunford: General Joseph F. Dunford, Jr., USMC for reappointment to the grade of general and reappointment to be Chairman of the Joint Chiefs of Staff: Hearing before the Armed Services Committee, Senate, 115th Cong. 4 (2017) (testimony of Joseph F. Dunford, Jr.).

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

Privratsky, K. (2016). *Logistics in the Falklands War.* Pen & Sword Military.

Tol, J., Gunzinger, M., Krepinevich, A., & Thomas, J. (2010). *AirSea battle: A point-of-departure operational concept.* Center for Strategic and Budgetary Assessments.

Wilson, M. (2016). *Destructive creation: American business and the winning of World War II.* University of Pennsylvania Press.

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