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Competing in Time: Ensuring Capability Advantage and Mission Success through Adaptable Resource Allocation

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Cover: A view of the Pentagon Memorial honoring the 184 lives lost during the Sept. 11, 2001 terrorist attacks. (Brian Aho/DVIDS)

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KEY TAKEAWAYS AND RECOMMENDATIONS

- The keystone of the Department of Defense's institutional architecture is not acquisition, but rather the budgeting process. This governs its ability to allocate funding to achieve national security objectives, links together requirements and spending, sets the calendar of the department, controls changes to investment priority, and serves as the mechanism for Congress to exercise its constitutionally granted appropriations powers. While there have been dozens of acquisition reform efforts, the budgeting process has been nearly untouched since 1961.
- Bureaucratic resource allocation processes—especially planning, budgeting, and appropriations—are a critical engine for maintaining an edge in a long-term military competition. In the 1950s, this realization was mechanized by the US, when fast-paced military developments with shifting directions were used to drive cost into ponderous Soviet planning processes. Ultimately, Soviet strategists also recognized that agility in resource allocation would ultimately determine the outcome of competition given a sufficiently long horizon.
- The Department of Defense (DoD) allocates resources through the Planning, Programming, Budget, and Execution (PPBE) system. PPBE is the scheme by which DoD sets its own plans and priorities and also how it asks Congress to approve its spending and provide oversight (often by verifying actual execution against predicted schedule and performance). The history of the PPBE dates to 1961 and is based on period industrial planning concepts.
- The PPBE's inflexibility increases the difficulty of rapidly shifting funding to emergent innovations that appear promising, as new programs must typically wait more than two years to be included in the budget. Additionally, the PPBE encodes divisions between research, production, and operations activities that stymy iterative or feedback-based development.
- A common theme across core DoD processes including the PPBE is an emphasis on long-term prediction of future needs and an attempt to optimize high-performance weapons against projected requirements. When these conditions are not met (whether from shifting technology or shifting adversaries), these processes may not yield optimal, relevant, or militarily effective results.
- Historical analysis of innovation time cycles—the time measured from the origin of a new concept for military capability until its initial fielding—indicates the cycles were shorter prior to the implementation of the triad of McNamara-era processes, commonly with an average time around five years for both ships and aircraft, and have grown steadily since.
- Emerging technologies, especially information technologies, are central to future conflict and are largely commercial and globalized. The defense acquisition process and legacy defense industrial base approach struggle to accommodate timely adoption of these technologies, as evidenced by lengthy modern time cycles (more than ten years) for development and fielding of new-start weapon systems.
- China may have an edge in its resource allocation process, although this topic merits further investigation. Evidence includes their ability to develop and field twenty-five new unmanned aircraft systems from 2010 to 2020, including stealthy carrier-based unmanned systems.
- Efforts to improve adaptability that focus on acquisition milestones have been only partially successful. Analysis of the chained and linear components of the modern military capability development and fielding process suggests that it is difficult to create a competitive, adaptable resource allocation scheme without revisiting the PPBE and key decision processes that govern the ability to make rapid, early investments in new operational capability or concepts.
- Incoming administration leadership, military leaders, and Congressional leaders need to revisit institutional structure and the budgeting process recognizing the central role of time in driving innovation, adaptability, and resilience. It is

not yet too late to favorably shape the trajectory of long-term military competition with China, but the only hope of an upper hand rests on agility and initiative.

Recommendations

- Congress and the DoD should cooperate to promptly launch a limited-scope pilot project on an alternative resource allocation process, designed to foster adaptability in capability delivery and aligned around a high-priority national security operational challenge. Other pilots should also be considered.
- In parallel with one or more budget pilots, Congress or the DoD should sponsor a commission to study holistic changes to the Planning, Programming, Budget, and Execution (PPBE) and appropriations process structured to ensure that the US has a competitive advantage in long-term competition while maintaining Congress' constitutional role. This commission should include expert members with an understanding of current equities and limitations, and explore emerging concepts potentially including portfolio, organization, mission, and trusted-agent budgeting. This commission may extend its scope to cover critical capability timeline drivers including contracting and early investment decisions that also touch upon adaptability.
- The policy and research community should conduct comparative analyses of the bureaucratic research allocation processes between the US and China, especially focusing on the early decision-making processes associated with starting investments in new military capability and strategic priority setting.

CHAPTER 1: INTRODUCTION

Five years ago, Senator John McCain, then Chairman of the Senate Armed Services Committee, came to the conclusion that the US was not only losing its technological edge but was at risk of falling behind adversaries in bringing emerging technologies to bear on military problems. He recognized the need to go faster,[1] saw startups like SpaceX running laps around the military's legacy providers, and envisioned new acquisition processes that could enable a nimble, more startup-like approach driving future military innovation.[2]

The result was enactment into law of new authorities to bypass the linear planning, requirements, acquisition, and contracting processes that have been a hallmark of the Department of Defense since Robert McNamara's tenure as Secretary.[3] These authorities were designed with time in mind, to allow the military services and defense agencies an alternative pathway focusing on speed to deployment.

These McCain reforms, known colloquially as Section 804 after the portion of the National Defense Authorization Act that made

Photo Caption: Amphibious military vehicles are lined up on arrival at a military base in the United States, 1945. (Thomas D Mcavoy/The LIFE Picture Collection via Getty Images) them law, were motivated by historical data[4] and case studies of weapons system fielding and technology development in the Cold War. The vision was of the US returning to an era of military experimentation, rapid operational prototyping, investment in competing technological bets all structured to deliver new capability in the hands of the warfighter in less than five years.

Five years later, there is scant evidence to suggest that we can return to this pace at scale. Certainly, a few innovation cells, including the Defense Innovation Unit and portions of the Air Force, have used the middle-tier system[5] created by Section 804 combined with Other Transactions Authorities, a 1990-era scheme to prototype things mimicking commercial practices and bypassing the default inclusion of many Federal Acquisition Regulations.[6] More than 35 efforts have been launched and a few have even delivered capabilities into warfighters' hands, but, on the whole, the adoption has been limited and less than enthusiastic. Some have suggested that the sudden freedom of middle-tier acquisition will demonstrate learned helplessness in acquisition circles,[7] where persistent historic failures to succeed with rapid acquisitions could prevent experimentation or prevent effective adoption. In some instances, service and Congressional leadership have attempted to undermine these changes, including noting that "the growing trend toward acquisition-by-prototyping approach limits [management] of acquisition programs in the long-term by reducing full understanding of long-term program costs," and mandating additional tests and reporting.[8] This pushback is almost certainly not motivated by malice; a much more likely hypothesis is that it is very hard to shift from seeking predictability and efficiency to seeking speed and adaptability. In a stable technological and threat landscape and with an industrial model of established weapons designs and level production, an oversight approach focused on forecasts of production, operating, and support costs and the associated cost-based accounting would indeed be highly logical.

The current bureaucratic underpinnings of DoD favor centralized planning around a scientific predictive model of "systems analysis." This was popular in the automotive industry in the postwar years,[9] but ironically shares a great deal with the Soviet predilection for centralized planning and that, in the aftermath of Sputnik, some public policy elite feared might be superior to our own.[10] Since the delivery of new military capability is likely to include an acquisition of some sort, many of those concerned with this topic have chosen the acquisition process as a focus for reform, with dozens of efforts launched since the McNamara acquisition system was formalized in 1971. However, the keystone of the DoD's bureaucratic cathedral is not acquisition, but the budgeting process that predated it. This is the process that sets the operating calendar of the department, links requirements to purchases, and determines whether one can change directions in procurement. Rapid acquisition may be useful, but it does not create a competitive and adaptable resource allocation system by itself.

In the sixty years since the adoption of central control via the 1958 Defense Reorganization Act and the establishment of the Planning, Programming, and Budgeting System (PPBS) in 1961 that ushered in the systems analysis age, the US has continued to use and modify a system that favors low-risk development and lengthy fielding cycles: now ten to twenty years for new-start systems. Time is an afterthought for the PPBS and its modern derivative: the Planning, Programming, and Budgeting Execution (PPBE) system. By design, the PPBE favors compliance, predictability, and a false sense of detailed control over an uncertain future and is the very heart of bureaucratic decision-making in the Pentagon and the appropriations committees.[11]

With the fall of the Soviet Union almost thirty years behind us, it is the United States that finds itself shackled with what Donald Rumsfeld called "one of the last vestiges of central planning on Earth"[12] in a speech envisioning his plans to revisit the cumbersome planning and budgeting process that was waylaid by the events of the next day—September 11, 2001.

As a new administration takes over and China's military threat grows, the DoD must holistically revisit its institutional processes in light of the massive shift of technological power to the fast-moving commercial sector and information technologies. A strategy to thrive in a long-term competition with a great power competitor should turn on the asymmetry of core American strengths, such as our thriving commercial innovation sphere, and our light-touch regulatory approach to free-flowing information on the internet. We should be able to harness both innovation and the virtues of commercial industry in information technologies to drive military advantage. Critically, to innovate and compete with China, the US must be adaptive in its investments. To be adaptive, we must place greater attention on metrics of time.

The US institutional processes and defense industrial model are forged from the early industrial era and even with sixty years of reforms still have a Stalinist flair; they are unfit for an era where information technologies undergird all future weapons. Simply put, there aren't enough levers available in the budgeting and appropriations process (PPBE), acquisition system (as encoded in the DoD's 5000 series of instructions), and requirements process (Joint Capabilities Integration and Development System, or JCIDS) to create the rapidity and fluidity needed to deliver an asymmetric defense innovation advantage with respect to China. What the United States needs to compete isn't an update of our already best-in-class weapons systems: an F-35 with longer range and more payload, or a faster, lighter M2 Bradley. Just adding another pathway in the DoD's new Adaptive Acquisition Framework cannot by itself deliver agility. The US also needs a departmental resource allocation engine that can force China's hand through adaptability. Specifically, the US needs the ability to launch and terminate new development efforts more quickly, to pivot the direction of ongoing investments, and combine the outputs of multiple efforts at various levels of maturity in such a way as to force competitors to respond to US initiative. Rather than pining for a larger budget and more capacity, the US should consider an agile budget. The budgeting process can be used as a defensive weapon, reactively adding funds to patch holes in capability that our adversaries create. Alternatively, the budget can be an offensive weapon, permitting US initiative. While requirements and acquisition are also entrained in these concepts, the central metrics for adaptability are the friction and decision time required for investments in new defense capabilities.

Senator McCain chose to drive action through making change at the margins, trying to let pockets of innovation bloom. It may be time to consider a more radical overhaul of the defense management system. Certainly, one key to future military operations is jointness, and given the troubled history of joint acquisition efforts assigned to one military service for execution, it is understandable why some would argue for a return to more top-down oversight and central control of acquisition,[13] returning more power to the Office of the Secretary of Defense (OSD) including its Cost Assessment and Program Evaluation (CAPE) organization. However, an alternative is to seek jointness through more distributed, experimentation-focused thrusts, that link missions and operational challenges with technology and development,[14] but include multiple equities and services. This latter approach reflects how most cooperative (joint) complex adaptive systems, from biology to the internet, were developed—by building up from many distributed, small successes to increasingly complex capability.[15]

To foster discovery and innovation, the Department of Defense could extend its doctrine of local decision-making (known as mission command) not just in wartime military operations, but also in its bureaucratic activities like weapons development and acquisition. A push toward more initiative and autonomy fosters both adaptability and also imposes surprise on adversaries. To gain an advantage in a military competition with China, the US will likely need to revise its resource allocation processes to permit faster decisions and more adaptability in selecting how to best pursue its operational objectives; revisiting the budgeting and appropriations process is becoming a strategic imperative. To many officials with the responsibility of oversight, this argument for adaptability may seem irresponsible or wasteful. The historical perspective of defense institutional processes and analysis of defense capability development is intended to show that this is, in fact, the responsible course of action when the US is engaged in a military competition. In this history, we find remarkable men and women taking disciplined initiatives in order to realize top-level intent and acting with a sense of urgency.

Winning strategies emphasize favorable asymmetries with competitors; and the US advantage should lie in our system's capacity for delegation and autonomy and the speed of decision-making that results.[16] We cannot expect to prevail in military capability against the Chinese Communist Party by exercising stronger central control and oversight.

The results of a focus on adaptability and time coupled with distributed decision-making aren't only historic; they can be seen in the successful aspects of the fight against COVID-19. Exemplary time-focused efforts include DARPA's early push for rapid vaccine development technology,[17] to the Department of Defense's creative use of Other Transactions and Defense Production Act authorities[18] in vaccine procurement, flexible budgeting, and highly general description of need. Together, these efforts present a model for multiple competing entities to work towards a common goal structured around urgency and time-to-market.[19]

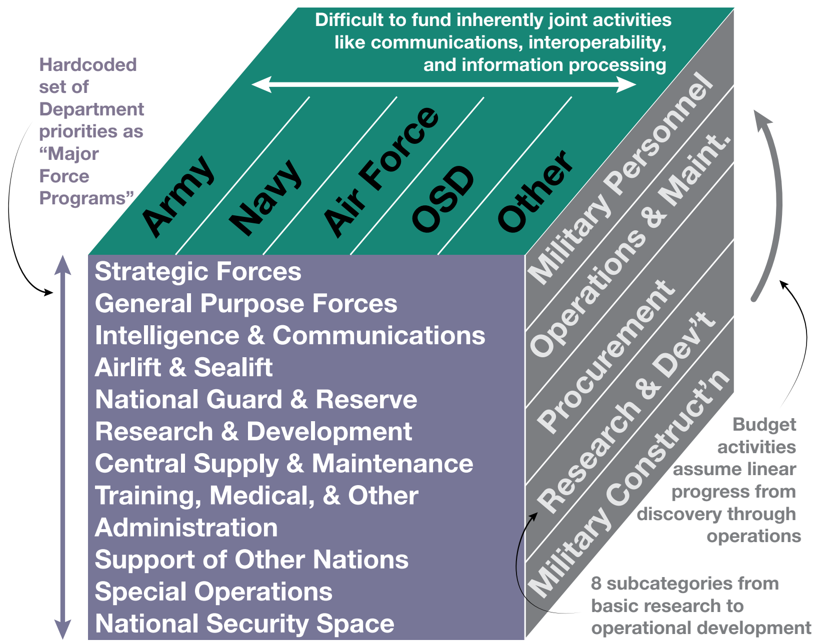
Returning to bedrock principles of the US innovation engine can restore our agility. But catalyzing change in processes that are older than the average age of the DoD's civilian workforce is not likely to be easy. To this end, it's important to understand the intentions, origins, and weaknesses of the current system. Metrics offer a simplistic lens through which to understand intentions. For example, 2009-era reforms focused on metrics of cost and schedule growth over baseline estimates. Programs with no growth from their original forecast were considered a success. Many of the metrics and criteria that the current innovation system holds to are reasonable; they strive to eliminate waste and ensure efficiency. However, once they are divorced from time or a sense of urgency, they undermine the ability to innovate and deliver value. In our current competitive environment, where adaptability is key, there is a need for a different metric—time—and an alternative set of decision processes prioritizing time. This paper will address time as it relates to defense management with an eye to competing with a power that does not act in ponderous five-year planning cycles[20] as did the Soviet Union.

Innovation, Adoption, and Time in Defense Capability Delivery

The word "innovation" has been used in every National Security Strategy published since 1987,[21] and is clearly seen as a cornerstone of defense policy. Innovation is difficult to define and even more problematic to measure; it spans both technology and operational concepts.[22] Innovation is crucially different from invention, because innovation requires turning inventions into things of practical and affordable use. In his research on the topic,[23] Matt Ridley argues that innovation is best framed as a bottom-up, fortuitous process that happens as a direct result of the exchange of perspectives and ideas between people, rather than an orderly, top-down process developing according to a plan. Innovation requires experimentation, learning, and failure; it cannot simply be mandated. Put simply, central planning is a poor fit for fostering innovation. If our National Security indeed depends on innovation, we must revisit our processes.

In the DoD, innovation is often conflated with research investment organized into technology bins. For example, the previous Under Secretary of Defense for Research and Engineering created various lists of between ten and thirteen technologies including hypersonics and artificial intelligence, calling these lists by turns strategies, innovation areas, focus areas, and priority domains, and assigning funding to them.[24] In a linear model, if current military programs fall short of forecasted need, then

Figure 1: Overview of Department of Defense budget



The Department of Defense budget structure slices funding into numerically coded cubes of activity along three directions. This structure sets department priorities that date from the 1960s and a model for linear progress from discovery to application.

Figure Source: Report Authors, Data Source: Brendan W. McGarry and Heidi M. Peters, *Defense Primer: Future Years Defense Program* (Washington; Congressional Research Service, 2020), https://crsreports.congress.gov/product/details?prodcode=IF10831.

research funding should be added to improve them. This is a convenient approach and one implicitly favored by the budgeting process, which slices up the bread loaf of funding into three-dimensional cubes across services, major force programs, and the nature of the budget activity (see figure 1). This latter class uses numerically coded budget activities known as *colors of money* that span basic and applied research, procurement, and operations and sustainment activities. This encourages a form of linear and symmetric thinking: if shortfalls in offensive missile effectiveness are forecast from adversary defensive developments, then basic research for faster missiles should be pursued. However, not only is discovery an inherently nonlinear process, but it also misses the fact that the most effective offset of missile defense might be entirely orthogonal, a cyber capability or offboard targeting, rather than an improvement upon known characteristics.

Not only is the structure of figure 1 ill-conceived for a dynamic environment or permitting bottom-up innovation, but it also doesn't suit Congressional oversight. In 2020, the Senate Armed Services Committee found that "Major Force Programs provide little analytical value. Program elements, the building blocks of the budget, are dispersed among several accounts and sub-activity groups, making the aggregation of relevant activities—from hypersonic strike weapons to artificial intelligence programs, for example—to understand mission capabilities and gaps extremely time-consuming and difficult."[25]

As the decades ahead plunge the world more deeply into an information age, we find underlying building blocks of both commercial and military technology increasingly incubated in the commercial sector. As a result, while military advantage still needs military-specific laboratory activity, the pace of adoption of technologies—both by governments and corporations—now becomes the primary driver of success in contests of power.[26] This was recognized in the 2018 National Defense Strategy, stating "success no longer goes to the country that develops a new technology first, but rather to the one that better integrates it and adapts its way of fighting," and was foreseen even in the 1990s by Paul Kaminski.[27] Innovation requires bringing new ideas into practice. However, for the DoD to meaningfully bring new concepts and new capabilities to bear, it must use the budgeting process—either creating new program elements or changing the schedule and milestones for existing program elements—and incurring an associated delay of two to three years (as explored later). This self-imposed speed limit does not deliver US advantage.

One metric relevant to national security innovation is time—tracking the years or days elapsed between an idea and its first utility as a military capability, however tentative. It is a variable that all innovations share; commercial entities often track the passage of time between the crystallization of an idea and its deployment in the marketplace, and even pursue it as a key source of competitive advantage.[28] Time is different than schedule, which is a projected, predictive, or perhaps hopeful measure of time. Time is actuality, reality, and certainty. It is the concrete measure of simply how long it took for an idea to work through unknown obstacles to eventual user impact. While other variables including performance and cost can be important, over a long-term competition an advantage in the time required to field capability and force an adversary interaction in a feedback loop is ultimately decisive. Thus, it is a critical variable to evaluate the effectiveness of the defense innovation system. It can also be a forcing function that, coupled with appropriate resources, spurs on greater effort, invention, and useful capability. Still, a focus on time in itself cannot overcome a lack of knowledge, scientific foundation, human incentive, or basic research. If innovation stems from exchange, then a vibrant ecosystem between the scientific and operational communities is needed. But innovation also requires that ideas reach utility, and thus that the DoD enable the quick traversal of this journey.

In this paper, the word *innovation* is used in the context of bringing new defense capability—paired technology and operational concept—into the reality of potential operational use. The time elapsed for historical systems to make this journey is conducive to analysis. As later sections will show, the time-to-market of new capabilities in defense has lengthened significantly since the end of World War II.

Many analyses from the DoD, research centers,[29] and think tanks[30] mask this lengthening by only focusing on more easily measurable interior milestones of the acquisition system—especially between the declaration of technical maturity and the end of engineering development (colloquially known as Milestones B and C[31]). This ends up undercounting significant amounts of the time-to-market of an idea, especially the time it takes to get from concept to technical maturity. Unfortunately, a fuller accounting of capability time cycles tells a more depressing story.

Critics of considering time as a pacing factor in capability development invariably cite the so-called iron triangle of program management:[32] conventional wisdom that posits the need for an early choice between cost, schedule, and performance. Not only does this mischaracterize the actual iron triangle (a flexible relationship between cost, schedule, and quality)[33] it ignores time as the principal driver of cost, the role of product value as separate from production cost, and the insights gained from iterative development.[34] A more pragmatic scheme to deal with the relationships between cost, schedule, and performance is to start as small as reasonably possible and build upon success. Thus, the more apt conventional wisdom is surely the Pareto principle, which provides that 20 percent of the invested input is responsible for 80 percent of the results obtained.[35]

When researchers do acknowledge increasing timelines for capability, the most frequently identified culprit is technological complexity.[36] This is a convenient explanation, because technological complexity increases with time, which implies that engineering and delivery cycles should also slow. If true, the century ahead would look dim for the United States, as the ever-increasing complexity of technology would surely eventually force acquisition to a grind. Fortunately, when analyzing time-to-market, it is possible to control for technological complexity by comparison with commercial sector developments, adversary developments, and careful historical study. These results—that suggest that it is still possible to bring a complex new system to life in under five years as the DoD used to—give some hope that, as technological complexity increases, so do the toolsets for managing and directing this complexity.

As will be shown later, historical analysis also suggests an intriguing inflection point in fielding timelines in the mid-1970s, which corresponds to the maturity of the processes and procedures of the oversight regimes that began to emerge in the 1960s. These processes, particularly when conducted in a serial or linear fashion, make it impossible to innovate at the same rapid rate of the early Cold War. Modern data show that simply taking the time to complete these processes requires more than it once took to deploy capability.

While the pace of defense innovation can be measured by the time it has taken to move from new concept to deployment of a military capability, the data on this time-to-market is surprisingly difficult to obtain. The DoD has long had a focus on cost control; Augustine's Laws[37] are well known, including their famous plot of tracking the increasing cost of military aircraft. A rich set of data on the cost and cost growth of military systems is available and studied.[38],[39] However, the more important factor in a long-running great power competition may well be speed and adaptability. It isn't that the proportion of the economy applied to defense isn't a critical factor; it is that the competitor able to allocate resources more quickly is in control of the competition. However, attention to timelines has only recently entered the policy conversation. The effort to standardize and track procurement administrative lead time (PALT)—essentially the solicitation-to-award time for a contract (not a weapon system)—was launched in just 2018, as an initiative from OSD's Defense Pricing and Contracting (DPC) directorate.[40]

As a result, when time metrics do exist, they differ widely in methodology and definitions. In this paper, we will explore defense responsiveness across several key time metrics including what we refer to as "time-to-market": assessing how long it takes from the first contracting action associated with a new capability to the deployment of that same initial operational capability, and also "innovation time," where we also include the early decision time that predates the first contracting action.

The Role of Information and Software

The discussion and analysis in this paper focuses on timely development and delivery of capability in the form of tangible weapons systems: cyber-physical systems that can be used for military purposes. It is undeniable that software and information systems have taken on an increasingly important role in weapon systems. The percentage of system functions performed by software has risen from 8 percent of the F-4 in 1960, to 45 percent of the F-16 in 1982, to 80 percent of the F-22 in 2000.[41] The very essence of modern software-defined systems is that all system functions involve software. The historical analysis presented herein captures the trends and effects of inserting information technology into advanced systems.

However, there are emerging scenarios in which the delivery of useful military capability involves software but does not involve the delivery of any new tangible physical system. Examples include the development and deployment of a cyber weapon, running an information campaign, creating a new kill chain linking existing systems, or deploying an algorithm to detect an adversary's precise location. These scenarios are likely to be of increasing importance in the future as the mechanisms of conflict evolve.[42] The historical analysis presented herein is not directly applicable to this class of innovation. However, the broader points on the criticality of adaptability and timelines remain pertinent. Indeed, if the planning and budgeting mechanisms of the DoD are challenged to achieve the five-year timelines envisioned by section 804, then the continuous adjustment made possible by the next generation of informatization will truly require an overhaul.

A software acquisition pathway[43] and software appropriations type (color of money or budget activity)[44] are good steps toward continuous development,[45] but remain hamstrung by a three-year predictive planning process.

Additionally, emerging concepts like Mosaic Warfare envision "shifting value from the performance characteristics of individual platforms to the resilience of a heterogeneous warfighting collective (a mosaic)," which "implies that the engineering burden moves from tight integration of a platform and key subsystems to the connectivity and command and control of a battle network."[46] This concept is designed around speedy capability delivery and combinatoric innovation, but requires flexible and mission-focused resource allocation processes to have a realistic path to implementation.

CHAPTER 2: HISTORICAL PERSPECTIVE ON TIME

Measuring times that culminate with the first delivery of a new defense capability into operations is a repeated focus because it is the first true opportunity to receive feedback on the combination of how a technology is used coupled with the performance of that technology. The sooner this feedback is received, the sooner a learning cycle can be started between developers and users—a concept commonly known as a minimally viable product. In other words, if the object to be pursued is adaptability, then the time to respond to an unanticipated input is the key metric to measure. While digital engineering and simulation can be useful tools to aid engineers and designers, their introduction into use has not accelerated fielding of defense capability compared to historical standards (shown subsequently). These tools and also risk management instruments are generally only useful to

Photo Caption: The nose sections of American B-29 Superfortress bombers under construction at the Boeing plant in Wichita, Kansas, October 1944. (FPG/Hulton Archive/Getty Images) help understand phenomena that were already anticipated in the design of the original analysis framework. For unanticipated risks, one should turn to the real world, which is a ready source of them. The narrative of history is filled with impressive insights, messy developments, and abject failures that give a rich set of examples of rapid, early fielding of new defense capability used in an iterative manner to shape operational concepts.

Time-Driven Innovation in World War II

World War II saw the US military deliver a remarkable string of time-driven innovations in weapon systems and adaptation of operational concepts. This was a unique period for disruptive defense technological developments, because time was clearly the pacing factor on innovation. While other inputs such as labor, capital, management, and knowledge were important, there was only so much one could do to use and incorporate them in a fixed amount of time driven by a two-theater war. Time focuses efforts and weeds out technologies and ideas that are not yet ready to operationalize. It can, if allowed to, constrain bureaucracy, calling for a responsive industrial base and engineering incentives and methods. During World War II, significant advances were made in the mass production of new military items using technologies such as radar, sonar, computing and electronic warfare, and of course nuclear weapons.

An example is found by looking at one of the slowest and most troubled development programs of the war—the B-29 Superfortress—which was almost canceled twice and suffered many prototyping mishaps.[47] This was not without reason. It had unprecedented technical complexity. It was the first pressurized aircraft built, the longest-range aircraft conceived, and the highest-flying aircraft, ultimately proving pivotal to victory in the Pacific. Boeing submitted a proposal in May and got a contract to build two XB-29 prototypes in August 1940. Based on progress and need, a production order for B-29s was awarded in May 1941, just a year after the initial proposal. The XB-29 had a troubled first flight in September 1942 and by December 1943 almost 100 aircraft had been delivered.[48] Due to poor reliability, a massive field upgrade effort was launched, which led to reliable forward deployments in India and China by April 1944. Despite pushing the forefront of aerospace scientific and technical understanding and overcoming tremendous technical and management problems that nearly tanked the program, it was delivered in under four years. At the faster end of technological development, the P-51 Mustang was ordered in April 1940 based on a short paper proposal, first flew 153 days later, entered production in May 1941, and began combat operations with the RAF in April 1942, a day under two years from concept to fielding.[49] Likewise, the development of the atom bomb was remarkably fast. The vast majority of US technological advancements occurred in the less than four-year window from Pearl Harbor to the surrender of Japan in August 1945 despite enormous technical risk.

Senior wartime leaders recognized the importance of time in achieving these incredible advancements and the need to move at deliberate speed. A 1945 letter sent by the Secretaries of War and Navy to the National Academy of Sciences emphasized the critical importance to national security of the "new weapons created by scientific and engineering research" underscoring that "the competitive time element in developing those weapons and tactics may be decisive."[50]

Early Cold War: Competition Drives Time

The early Cold War competition with the Soviet Union incentivized the US military to maintain World War II development emphases. Innovation efforts conducted during the war, in the 1950s, and then in the subsequent space race with the Soviet Union in the 1960s had several things in common: a focus on time, rapid experimentation, multiple technological pathways, and rapid operational prototyping. These efforts for the most part took less than five years to deploy something that was operationally capable and usable. It might have eventually taken a second, third, or more prototype iterations to resolve bugs and finalize the model to produce in quantity, but each of the earlier prototypes were useful operationally and drove technical and operational learning. In some cases, these prototypes may have been all that were needed and there was never a need to produce more. The first U-2 reconnaissance plane was flying nine months after signing a contract.[51] After Gary Powers' U-2 was shot down over Russia in 1960, work began on the U-2's successor. The A-12 prototype flew in 1962 and evolved into the SR-71, which flew in 1964.[52]

Experiment, test, prototype, and test again were hallmarks of technology development in this period. Most importantly, not every prototype or test was a success. Missile programs were equated with many experimental launches, tests, and failures. The first reconnaissance satellites had failed twelve times before success.[53] Still, the triumph of what can be called a time-based developmental model led to incredible advances. This model was initially developed based on urgency of need and limited by time. The US detonated a hydrogen bomb on November 1, 1952 less than three years after President Truman announced on January 31, 1950 the US plan to develop it. It wasn't just the Department of Defense; the National Aeronautics and Space Administration's Saturn V rocket, which enabled the US to achieve President Kennedy's goal of going to the moon in a decade, took just six years to get to first launch (1961–1967).

One of the first major programs to be developed after World War II was a new class of bombers. The development of the high-speed jet engine B-47 bomber was initiated by a letter contract in February 1945. Even with the postwar mobilization and uncertainty of the future of the program, prototypes (XB-47) were built and flown in 1947–1948 and the first production plane was delivered in 1950, or five years from program initiation. Further engineering issues would delay initial operational capability (IOC) until 1952, but nonetheless equating to a total of 6.5 years from first contract to design, prototyping of several versions of aircraft, and to operational use.[54] Remarkably, this represents one of the slower developments of the time, as subsequent analysis will show.

Missile programs, mostly unconstrained by flight safety issues because they did not have a pilot in the loop, went faster even as they had their share of mishaps and learnings. The history of the US Inter-Continental Ballistic Missile (ICBM) program illustrates the importance not only of time to development, but of prioritization and leadership. Once General Bernard Schriever was put in charge of the Air Force's ICBM efforts, four programs were completed within a five-year window of development to operations. First contracts were awarded for both the Atlas liquid-fueled missile and the Titan 1 liquid-fueled ICBM in 1955 with operational capability for both systems achieved in 1959. The Titan II ICBM initial award occurred in 1960 and the missile was operational by 1963. The solid-fueled Minuteman ICBM initiated development in 1957 and was operational in 1962. Initial follow-on ICBMs—the Minuteman II and Minuteman III—were delivered in comparable time frames from 1962 to 1967 and 1966 to 1970 respectively.[55] The Minuteman III is still in the US arsenal after fifty years. Chris Brose noted that at the start of the effort to develop an intercontinental ballistic missile that could deliver a nuclear weapon to the other side of the planet in a matter of minutes, the state of technology was such that it

> "was not even close to being feasible in 1954. Eventually, Schriever and his team did the impossible: they developed the Thor, Atlas, Titan, and Minuteman missiles that could deliver nuclear weapons to precise locations on the other side of the planet in minutes. They laid the technological foundation from which America first went to space and then the moon. And they did it all, from start to finish, in just five years."[56]

The history of submarine development in the 1950s was a similar story of rapid development, testing, and fielding of new defense technology. In just seven years (from 1952 to 1959), the Navy transitioned from World War II submarine designs to nuclear-powered ones. Ten different submarine designs were ongoing during this period with each in essence an operational prototype that succeeded in bringing the Navy into the nuclear age. The Navy nuclear reactor program that supported this effort under Admiral Rickover was approved to begin in December 1947[57] and supported the delivery of the first nuclear-powered submarine in less than seven years with the commissioning of USS Nautilus.[58]

The Navy's submarine development model of the 1950s was similar to the Air Force century-series approach that relied on rapid development and limited production runs of future aircraft. The Air Force's century series of fighter aircraft from the F-100 to the F-106 were all started in the early 1950s and achieved IOC in less than five years, resulting in 5,531 aircraft deployed to the Air Force.[59] Many of these had short service lives and low total lifecycle costs, as key operational concepts were refined and new weapons systems imagined and started.[60] The Navy was on the same pathway as the Air Force, fielding multiple front-line jets culminating in 1958 with the F-4 Phantom II. Navy shipbuilding was also on a fast pace as the first nuclear aircraft carrier, the Enterprise, contract award occurred in November 1957, was launched in September 1960, and commissioned in November 1961—a total of four years.[61]

The 1970s Onward: Timelines Increase

This string of rapid and risk-taking development initiatives did not continue; by 1976 things had sufficiently decayed that DoD leaders asked the Defense Science Board (DSB) to study the problem. In 1977, they released their analysis of capability development cycle time or innovation time (perhaps the first significant analytic effort of this topic) and broke the cycle down into three parts: (1) decision time—the time it takes to start development; (2) development time—the time to develop a system; and (3) production time, including the time to progress through acceptance and finalize the ability to produce in quantity.

The DSB found that from the 1950s to the 1970s, development time had been relatively constant; despite advancing technology, industry was still capable of executing a program quickly. Production time depended, for the most part, on budget and whether quantities were stretched out over longer time periods. Decision time, however, had grown dramatically. This time had grown from two years in the 1950s to over five years by the early 1970s. The DSB would blame the accumulation of layers of organization and management involved with decision-making for this increase.[62]

The analytic findings that follow generally support the DSB's conclusion here. Decision time analysis for ships shows an increase from less than six months in the 1950s to four years in 2020 when considering a decision start time as the approval of ship characteristics, or as many as eight years now when considering a start time as initial planning efforts. The weapon system time-to-market metric (from contract award to IOC) held constant from 1950 to 1975 at around five years, and has more than doubled since then, across multiple system types. Finally, the full acquisition cycle for new-start systems has increased by a factor of four from 1950 to 2020.

By 1986, the President's Commission on Defense Management (The Packard Commission) was at the cusp of an understanding that program development times were increasing dramatically:

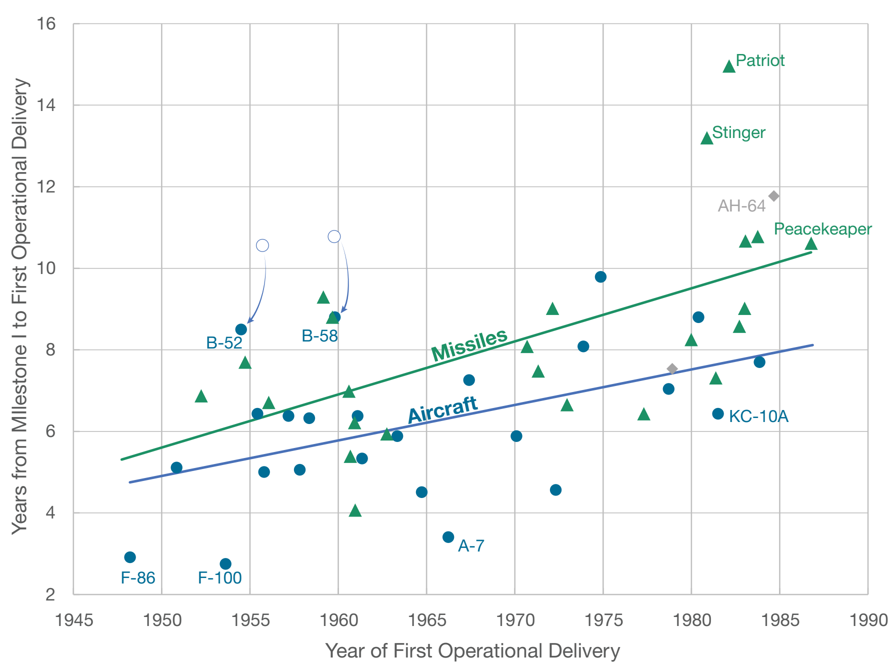
> "But a much more serious result of this management environment is an unreasonably long acquisition cycle—ten to fifteen years for our major weapon systems. This is a central problem from which most other acquisition problems stem:
>
> - It leads to unnecessarily high costs of development. Time is money, and experience argues that a ten-year acquisition cycle is clearly more expensive than a five-year cycle.

- It leads to obsolete technology in our fielded equipment. We forfeit our five-year technological lead by the time it takes us to get our technology from the laboratory into the field.
- And it aggravates the very gold-plating that is one of its causes. Users, knowing that the equipment to meet their requirements is fifteen years away, make extremely conservative threat estimates. Because long-term forecasts are uncertain at best, users tend to err on the side of overstating the threat."[63]

In 1990, RAND completed a study that reviewed development time for 107 aeronautical weapon systems (key results presented in figure 2, with adjustments to make the horizontal axis correspond to date of first operational delivery).[64] The methodology used was to measure the beginning of a program or initial program start at what was then known as Milestone 1, which was the beginning of the technology demonstration phase of a program and ending with the first delivery of a system. Since Milestone 1 was not established under the acquisition process until 1970, earlier programs had to be estimated as far as start dates. As the analysts admitted, this was a judgmental call and created some uncertainty over the older programs' data start times.

As a result, RAND threw out much of the pre-1970 data because the acquisition system had added a new phase, "the concept

Figure 2: Acquisition timeline trends, 1945 to 1990[130]



A 1990 study revealed upward trends in the timeline from Milestone I to operational delivery.

Figure Source: Report Authors, Data Source: Jeffrey A. Drezner and Giles K. Smith, *An Analysis of Weapon System Acquisition Schedules* (RAND Corporation, National Defense Research Institute, 1990).

definition phase" that did not exist prior to 1970. The time to complete this phase was not counted in post-1970 data, but those tasks would likely have not been required nor conducted in earlier programs. If they had been, it would have likely taken far less time than in later programs and would have been embedded in the time it took to complete these 1950s and 1960s programs.[65] For these reasons, the older, faster programs would have essentially skewed RAND's results and shown a larger increase in cycle time than was presented in their final analysis. Also, RAND did not address the DSB concept of decision time. This re-baselining of when a capability development starts has been one of the ways that the increase in time has been clouded in later studies. It has also made it difficult to make comparisons of time to market when looking across decades.

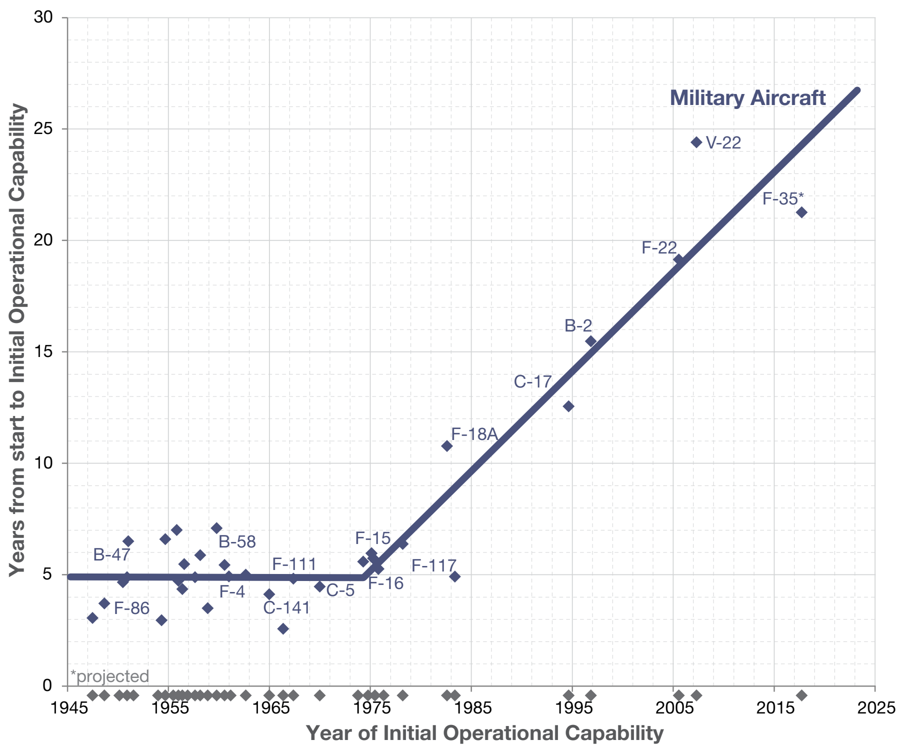
The estimates for programs that were kept in the analysis from the 1950s were also problematic, as some, like the B-52 and B-58, contained multiple pre-contract studies incorporated into one program definition. The dataset includes start dates for both programs before the Air Force had even formulated its internal requirement. It is possible to correct this using the detailed data of Rothman,[66] as indicated in figure 2. Still, the results of RAND's analyses showed that time to deployment was increasing and that programs were taking three to four years longer to progress from Milestone 1 to operational capability in the 1980s than in comparable programs from the 1950s and 1960s. While this is likely a significant underestimate because it neglects the DSB's notion of decision time, it still shows the beginning of a trend that should have generated more subsequent debate. The net effect of this study was instead to dull and counter the findings of the Packard Commission, suggesting that the state of affairs was not as bad as the commission had reported. A couple of years is not a big problem, particularly if systems are getting more advanced and complex.

A decade later, senior officials were still concerned about the effect of long cycle times. Secretary of Defense William S. Cohen stated, "When DoD fields a new weapon system today, many embedded subsystems are obsolete. DoD cannot continue to have ten-year weapon acquisition cycles when the underlying technology becomes obsolete in two to five years or less."[67] A 2001 DoD Inspector General (IG) audit report identified that in 1960, Major Defense Acquisition Programs (MDAPs) required seven years from program start to IOC. In 1996, this time had grown to eleven years.[68] While the DoD IG had many problems with the quality of data, it used the start of Milestone 1 as program initiation and, again, did not consider decision time. In the 2004 annual Secretary of Defense report to Congress, the DoD echoed these findings:

"Acquisition cycle time is the elapsed time, in months, from program initiation until a system attains initial operational capability—that is, when the product works as designed and is fielded to operational units. A number of years ago, we began measuring the average cycle time across all major defense acquisition programs, or MDAPs … We wanted to understand how quickly new technologies were moving from the drawing board to the field. This performance measure is a leading indicator of technology transfer—typically, the faster a program moves toward fielding, the quicker associated operational improvements can be introduced to the force, and the easier it is to control overall program costs. During the 1960s, a typical acquisition took seven years (84 months) from initiating program research and development activities to achieving initial operating capability. By 1996 a similar acquisition required eleven years (132 months) from program start to initial operating capability."[69]

Ten years later, in 2015, the Senate Armed Services Committee relied on a DARPA study that brought together data on time-to-market for new military aircraft development programs and other commercial programs.[70] As the committee reported: "A recent Defense Advanced Research Projects Agency study found that the current requirements process may be a significant hurdle to the DoD being able to conduct short, iterative development and fielding cycles and innovate like the more agile sectors of the commercial market."[71] This study effort

Figure 3: Post-Cold War increase in military fixed-wing aircraft time-to-market



The trend in military fixed-wing aircraft time-to-market (contract award to operational capability) shows a marked increase following the Cold War period.

Figure Source: Report Authors, Data Source: Dan Patt, *Time-to-Market: A DARPA study on Capability Fielding* (Washington, DC: DARPA, 2013 Internal Report).

unfortunately was never published in its entirety. The supporting data outlined the changes in the time it has taken to develop military and commercial systems since World War II. The data in this study was instrumental in driving the concept of middle-tier acquisition, which is a time-to-market concept that limited program times to a maximum of five years to deploy either an operational prototype or to rapidly field a system. This provision was included as section 804 of the 2016 National Defense Authorization Act. In a way, Congressional action that had roots in twenty-year-old findings is an example of lengthy decision-making cycles, especially as related to bureaucratic reforms.

Figure 3 is a reconstruction of this data based only on releasable sources and closely resembles that used by the Senate Armed Services Committee. To present a consistent comparison, the data in this chart are selected to only include one development type (manned fixed-wing aircraft), are comprehensive for that type in that they include every single new-start aircraft fielded in the study time period across all categories (tactical, fighter, transport) and all military services. For consistency, the starting date is set as the first contract award for an effort that eventually led to an operational capability. In this manner, purely exploratory studies or demonstrations are excluded (e.g., Have Blue), but early efforts associated with risk reduction for an operational class of systems are included (e.g., YF-16). The ending criteria is considered the date of initial operating capability. This dataset excludes systems that are derivative and not new-start, including for example the F-15E or KC-10, which were both major defense acquisition programs by dollar threshold, but derivative of the earlier F-15A and DC-10.

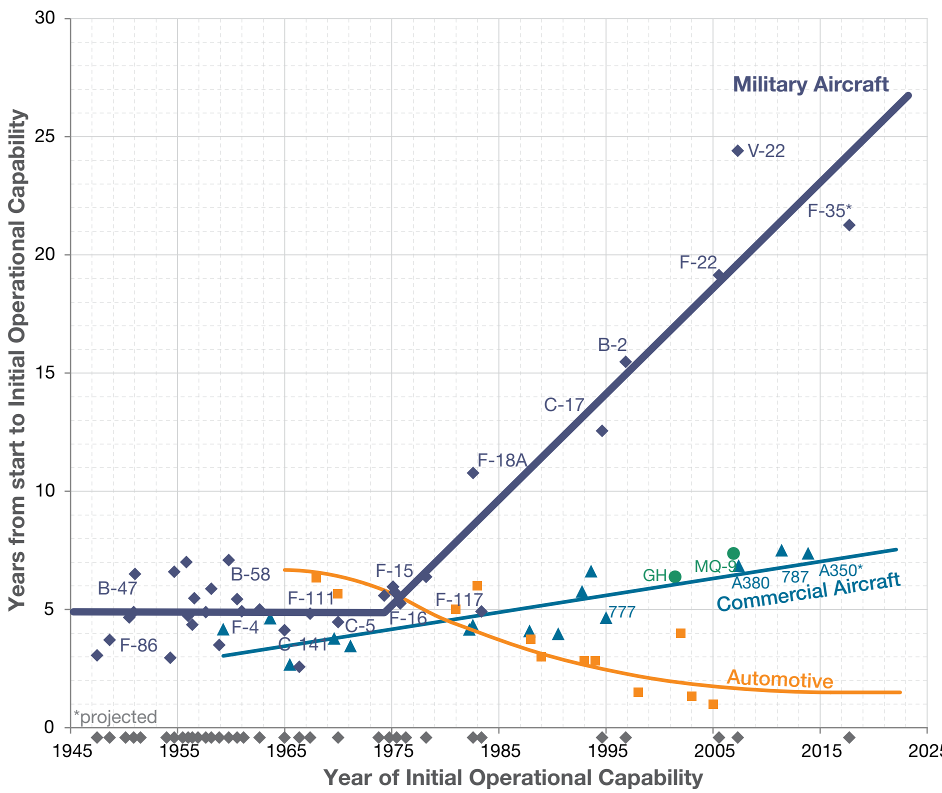
This analysis focuses on military capability development and delivery, rather than acquisition thresholds of dollar value or acquisition milestones that measure interior points along the way. This data does not address the time it takes to prepare, solicit, and award that contract, nor the requirements or budget process lag time to get to first contract award that correspond to the 1977 DSB's concept of decision time. As will be discussed in a later section, this time can be significant, so these data points are still an underestimate of the overall new capability delivery cycle time. Inasmuch as the purpose of weapons systems is as a deterrent, choosing the first viable date of operations (initial operational capability) is the critical ending point. Some studies choose achieving full rate production or Milestone C as the end points in development cycles. However, as the DSB found, for aircraft, production time is essentially meaningless for these types of comparisons. As a result of these factors, data for the B-52, B-47, and other systems differ in this time-to-market comparison slightly from the work cited earlier.

Figure 3 includes a line that is calculated from a bilinear least-squares regression analysis. As can be seen in the data, for the three decades that followed the end of World War II and including the Cold War periods, the average military aircraft time-to-market was just shy of five years. Since about the mid-1970s, that time to develop and deploy new capabilities has been increasing at an alarming pace with start to IOC or deployment dates quadrupling. The onset of the uptick has a notable correlation with the completion of the budgeting, requirements, and acquisition process triad with the issuance of DoD 5000 in 1971, that affected every subsequent aircraft development (those fielding in 1976 and beyond).

The second chart (figure 4) adds comparable data for every Airbus, Boeing, Douglas, and Lockheed new-start commercial aircraft and selected automotive industry new platform development programs for which data were available (excluding derivative designs). For commercial aircraft, the time-to-market was measured as board approval to proceed to design (which followed early market studies and concept studies) to first revenue flight (the closest equivalent to operations). For automotive applications, the time-to-market was measured from committee approval for new platform development to first dealer sale. This comparison across industries is critical to control for the role of technological complexity. Commercial aircraft experienced similar growth in complex software and avionics systems, a dwindling number of suppliers, and an intense testing regime before certification could be achieved. Remarkably, the much-criticized Boeing 787 development still managed to achieve a first revenue flight in about seven years.

Critically, despite all of these factors, while defense aerospace programs show significant growth in time-to-market, commercial aviation reveals a relatively modest growth during this period that is comparable to early DoD weapons programs in the 1950s, despite comparable software content. This strongly suggests that DoD processes have a role in the differences in time-to-market. Additionally, lengthy development cycles drive industrial base workforce costs and component obsolescence. In the highly competitive automotive industry, the trend in available data actually shows a decline in time-to-market, even as the complexity of more software and computing elements were introduced. This may have been a result of the competition with Japan that arose in the 1970s and forced the auto industry to focus more on time to deployment, continuous improvement, and more modular product architectures.

Figure 4: Commercial vs. military time-to-market trends



Commercial aircraft and the automotive industry show favorable historical trends in time-to-market as compared to military aircraft.

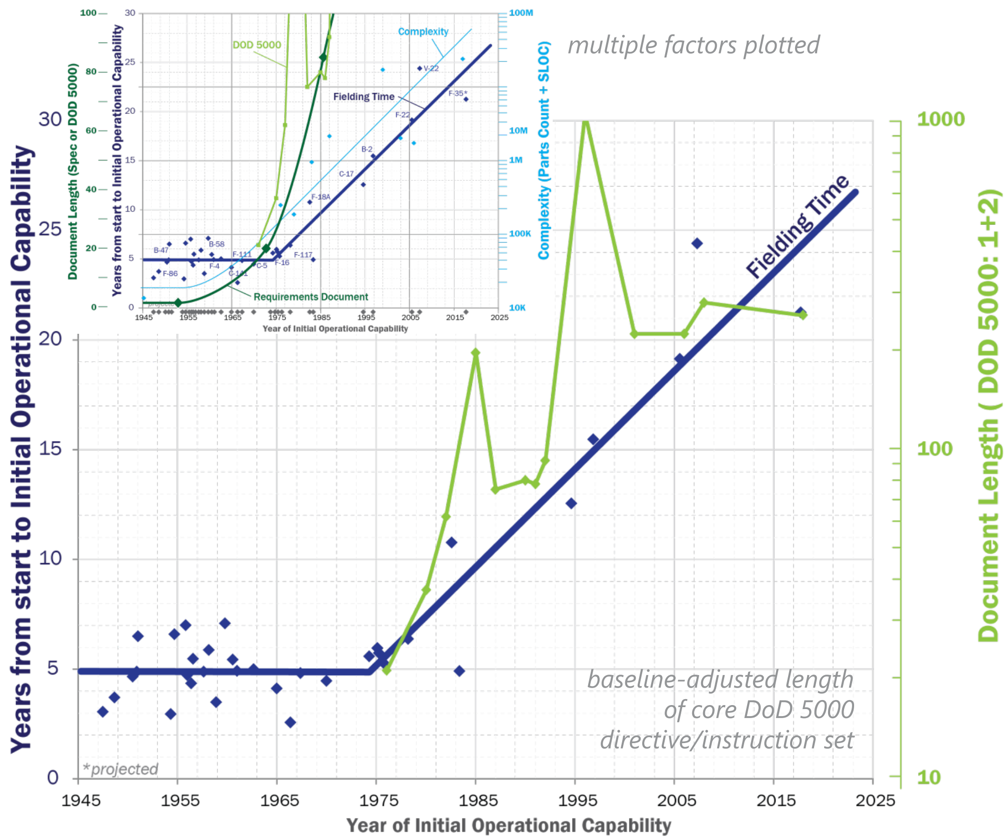
Figure Source: Report Authors, Data Source: Dan Patt, *Time-to-Market: A DARPA study on Capability Fielding* (Washington, DC: DARPA, 2013 Internal Report).

There are several anomalies in the chart. Notably, the F-117 managed to maintain a five-year time-to-market, likely attributed to the fact that it was a classified program and was excluded from the then-new DoD 5000.1 process, and was able to trade away key weapons systems requirements including maneuverability to deliver a system on time. More recently, the unmanned aircraft that have achieved an IOC—the Global Hawk (marked GH) and MQ-9 Reaper aircraft—were developed with novel mechanisms, the former involving DARPA and the latter private investment.

Seeking Explanations: A Penchant for Prediction

An approach to understanding the root causes of the increasing timelines, especially the 1975-era inflection point, is to compare candidate hypotheses and test for superior correlation. One hypothesis might be the increasing technical complexity or software content of weapons systems. The F-35 is exemplary of the extraordinary technical complexity possible to achieve in a weapon system. Satisfactory measures of technical complexity are difficult to come by, although system parts

Figure 5: Effect of DoD 5000 on time-to-market



The timing of the increase in time-to-market suggests that the introduction of DoD 5000 is the predominant factor, making it difficult to assure delivered performance against ever more complex requirements.

Figure Source: Report Authors, Data Source: Dan Patt, *Time-to-Market: A DARPA study on Capability Fielding* (Washington, DC: DARPA, 2013 Internal Report).

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count, new application-specific software lines of code (SLOC), or their sum is often used. Notably, tight coupling in hardware design parameters (e.g., radio frequency stealth considerations) is not well captured by this metric. Since software is used to accomplish every weapon system requirement on the F-35, some call it a computer with an airframe designed around it.[72] An early version of the core aircraft without mission or support systems on the F-35 had about 6.8 million lines of code,[73] which is roughly equivalent to a modern commercial aircraft, like the Boeing 787, at an avionics-only application-specific lines of code count of 6.7 million.[74] Both estimates exclude the full system software burden, including maintenance and support systems. These results illustrate that it is unlikely that the greater presence of software alone is driving timelines.

An alternative hypothesis would be that DoD processes and process complexity is the cause of the timeline increases. This is not a new hypothesis; the DSB implied as much in its 1977 report, and for contracting, Ronald Fox tried to illustrate process complexity by identifying that the original Armed Services Procurement Regulations (ASPR) measured 125 pages in 1947 as compared to the FAR and DFAR, the successors to the ASPR, which now total over 2,000 pages.[75]

To compare these hypotheses, in figure 5, the authors return to the earlier aircraft dataset and overlay a measure of technical complexity (light blue, log scale) as measured by the combined parts count and lines of code for each weapon system, and also the length of the contracted weapons system specification (dark green). While the technical complexity (light blue) line also tracks upwards, it reaches its inflection point as computing technology emerges, and precedes fielding timelines. Similarly, weapons system specifications increase greatly in length, but only roughly correlate with aircraft time-to-market. A final correlate might be the imposition of strongly predictive development process via the DoD 5000 series of regulations, which demand rigorous proof of performance against original requirements. This has the approach of magnifying the complexity of the classic systems engineering approaches, which attempt to link all lower-level engineering choices to top-level requirements. The length of the DoD 5000.1 and 2 instructions is shown in light green (log scale). Because DoD 5000 only affected programs that started after it took effect in 1971, a limit is shifted to the right by five years, the average time-to-market prior to its introduction. Figure 5 shows a remarkable correlation, suggesting that process complexity is a key driver, undoubtedly compounded with technological complexity and lengthy specifications.

To understand why DoD 5000.1 could have accidentally contributed to a remarkable increase in time-to-market, it is useful to examine the original text,[76] an austere seven-page document co-authored by David Packard.[77] Much of the original document includes Skunkworks-esque precepts like suggesting "management by a single individual with sufficient authority." But it also included a specific prioritization of the objectives for acquisition programs, explicitly ranking "performance requirements" before "cost" and "schedule," and stating the

"Achievements of [performance] objectives [shall be] the pacing function... Schedules shall be subject to tradeoff." Coupled with demands for testing against the original performance requirements, this inculcated the so-called systems engineering V model documented by MIL-STD-499 of 1969.[78]

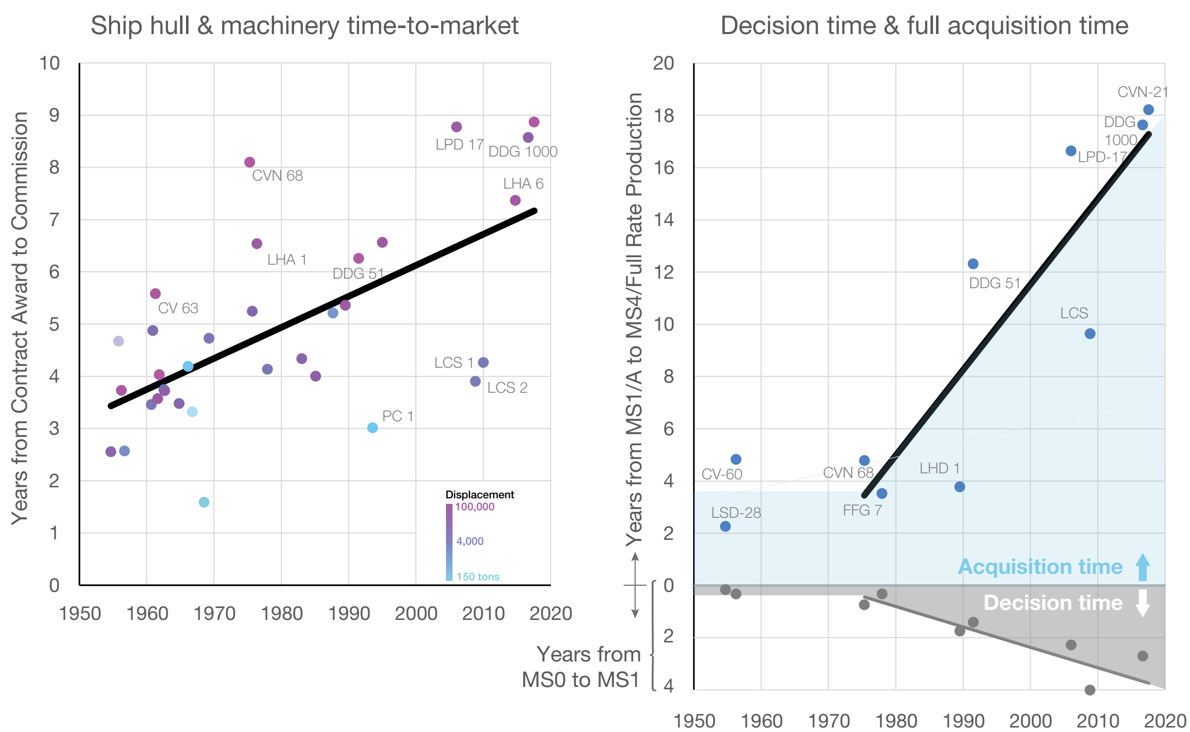
Thus, by 1971, the triad of budgeting, requirements, and acquisition processes was finally in place. All revolve around prediction of the future. With a ponderous Soviet ally entrenched in five-year planning cycles, this may have seemed logical. The fascination with prediction in program management was studied by Lenfle and Loch,[79] who concluded:

> "This implies a clear definition of mission and system are given at the outset (to reduce uncertainty), and subsequent execution in phases with decision gates. It contrasts with approach applied in the seminal projects that are credited with establishing the foundation of the [project management] discipline in the 1940s and '50s. Those projects started out with missions that were beyond the currently possible; any solutions had to emerge over time. They succeeded by a combination of parallel trials (from which the best would then be selected) and trial-and-error iteration (allowing for the modification of solutions pursued over a period of time). Although the success of these approaches was well documented and explained by scientific study in the 1950s, today they seem to fly in the face of accepted professional standards, making managers uncomfortable when they are encountered."

Creeping Decision Time

To explore if the timeline increases observed for aircraft are found for other system types, the study methodology was

Figure 6: Increasing time-to-market for first-in-class ships



Time-to-market for first-in-class ships also shows lengthening timelines, both when considering only the hull and machinery (industrial performance for design and ship construction) or when considering the full acquisition cycle. The decision time for moving from a Milestone 0 to 1 also increased.

Source: Report Authors

extended to first-in-class naval vessels. This dataset was selected to consider industry impacts, given the Navy's special focus on maintaining the health of its shipbuilding industrial base. The dataset from figure 6 is drawn from releasable records on every new first-in-class ship development, from patrol vessels to aircraft carriers, and from 1950 onward (data from before 1950 is incomplete). Focusing only on first-in-class developments is intended to capture the unique demands of first-time learning, testing, and integration associated with new military capabilities. Shipbuilders and naval architects typically assess that ten hulls are required to reach stable prices and build times.

The left side of the figure examines the time from a contract being awarded for ship design through the commission date of that same ship. This can be considered a time-to-market metric for only ship hull and machinery. This raw industrial performance shows that ship developments have slowed by a factor of two from the early Cold War period. Color coding indicates that there is also a measurable effect on time-to-market with ship size (displacement), with larger ships taking longer to launch. While building new ships in eight or nine years seems much better than the aircraft data, this isn't the full story.

The right-hand side of figure 6 measures the acquisition performance of ships, using a less-comprehensive dataset. The upper portion of the figure (in blue) measures the time elapsed from Milestone I or A, intended to mark the decision to enter technical maturation, through a decision to enter full rate production. Measuring initial operation capability data is challenging for ships, as delivered and commissioned ships may still have immature mission systems; for Navy systems, the production decision is usually made after the full weapon system capability has been matured, so the production decision is a reasonable proxy. Notably, the acquisition performance for ships has, like aircraft, also slowed by a factor of four. This implies that even as the industrial performance has slowed, the effect of working through the acquisition process of a fully integrated ship with mission systems combined with working through a lengthy test and evaluation period has increased by at least as much.

Finally, a proxy for decision time is included in gray, measured as the time from Milestone 0 to Milestone 1. Naval acquisition is unique in that it historically included a Milestone 0, corresponding to when the general characteristics of the ship were approved. Even though there is no longer a formal Milestone 0, and this name was not used during the 1950s, this approval date can still be recorded. The data show that decision time has increased substantially over the measured period.

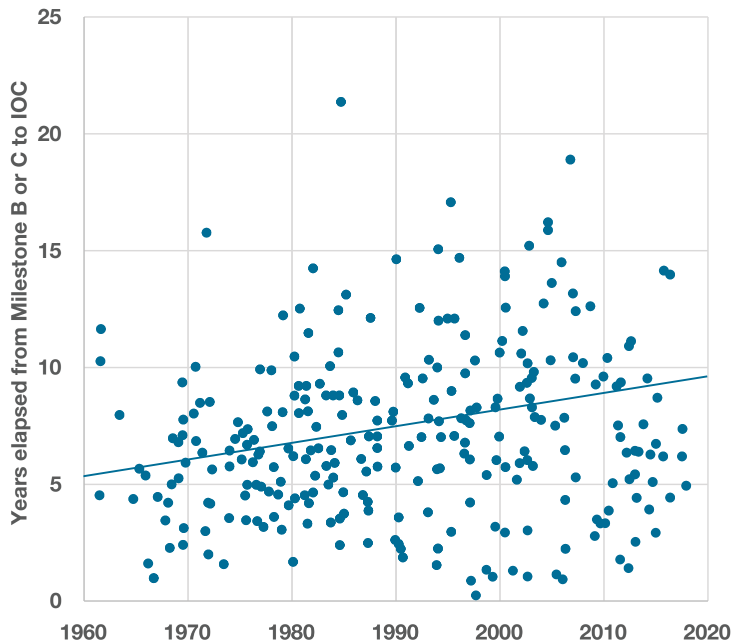
While the decision time data of figure 6 does not represent the entirety of the DSB's concept of decision time, it is a useful measure, because it can be extended across the timespan. For a more anecdotal example, consider that for the DDG-1000, that had its Milestone 0 approved in June of 1995, Navy planners began developing operational requirements for the next generation of surface combatants a full four years earlier in 1991.[80] This would suggest that modern decision times might be as long as eight years.

A Debate About the Metrics

Some analysts deny a lengthening in capability development cycles, focusing on alternate metrics Notably, a 2016 Institute for Defense Analyses study states, "Cycle times for typical programs are not increasing, going back to the late 1980s, the median cycle time has been roughly eight years over that entire span for all commodity types—aircraft, ground systems, space systems, ships."[81] A more recent 2020 Center for Strategic and International Studies analysis[82] constructed the most comprehensive known DoD acquisition database, including over 200 active and complete MDAP programs, and concluded that "from 1963 to the present it can be observed that acquisition speed has remained relatively constant throughout history." This dataset was digitized and is reproduced as figure 7. A least squares linear regression was run with all data included to generate the trendline. .

These differences come down to these analysts' choice of metrics and data for comparison. Analysis of these findings and their methodology is useful to understand the drivers of increasing innovation times. Notably, when their own datasets are subjected to statistical analysis across the entire study period, an increase of acquisition cycle time is observed (around three years across the study period), with this increase being highly significant in the statistical sense (pValue <0.01), but with R^2 of only 5 percent, meaning that program-to-program variation is more important than simply the passage of calendar time. This brings us to the second difference with these analyses, which is that they mix new-start efforts with block upgrades. The upgrade of the AIM-120 missile from block C to D is a fundamentally different development than a new hypersonic missile. Beyond this, all commodity types are mixed together, from computing systems to ground vehicles. Finally, these studies examine the time elapsed from Milestone B or C to IOC, just a portion of overall time to capability delivery as indicated in figure 14. Thus, they are useful analyses of the acquisition system, but not of the critical parameter in a great power technology competition—innovation time. Neither of

Figure 7: Acquisition cycle time trends



Trends in acquisition cycle time for major defense acquisition programs (both new-start and modifications).

Source: Morgan Dwyer, Brenen Tidwell, and Alec Blivas, *Cycle Times and Cycles of Acquisition Reform* (Washington, DC: Center for Strategic and International Studies, 2020)

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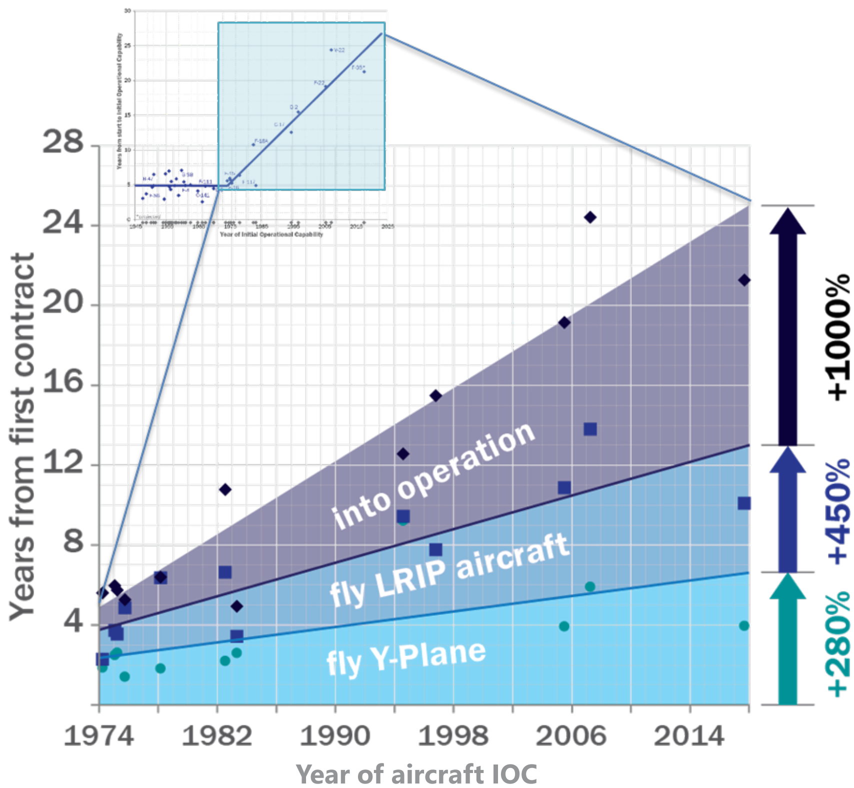
these studies consider what the DSB in 1977 had identified as the most rapidly increasing drivers of increasing time—decision time.

The results of these studies generally correspond to a statement made in October 2020 by Ellen Lord, the Under Secretary of Defense for Acquisition and Sustainment, who also used Milestone B as a start date to measure cycle time:

"For 100 of our largest programs at that time, the median duration from milestone B—the decision point to enter development of a product and generally considered the start of a program of record—to initial operational capability was nearly eight years."[83]

The aforementioned cycle time data are reduced by the inclusion of programs like the light utility helicopter (LUH) associated with the UH-72 Lakota, which was awarded to Airbus in June 2006, with a first delivery in December 2006, and IOC in 2007. This major defense acquisition program began at Milestone C and had an acquisition cycle time of just 0.9 years. The LUH program was launched after the LHX-U utility helicopter program that began in 1982 was canceled twenty-two years later in 2004. Airbus won the LUH program by proposing a mature variant of its commercial EC145 helicopter (called the UH-145), developed at private expense in 1999 that used the rear section of the older BK 117 helicopter that first flew in 1979. Off-the-shelf commercial upgrades of a ten- to thirty-year-old design was a smart, well-executed acquisition for the Army utility helicopter

Figure 8: Aircraft development phases



A more detailed analysis of the data from figure 2, dividing aircraft development up into segments: flying a Y-Plane, flying an LRIP aircraft, and finally bringing the aircraft into operations.

Figure Source: Report Authors, Data Source: Dan Patt, *Time-to-Market: A DARPA study on Capability Fielding* (Washington, DC: DARPA, 2013 Internal Report).

role. However, mixing data points like these with new nuclear submarine developments doesn't give a clear measurement of strategic innovation, certainly not the United States' ability to compete effectively with China.

Using Milestone B or C as the baseline to start a program tends to be a core analytical scoping issue due to the limitations of available comparable data, especially that sourced from Selected Acquisition Report data, but that decision skews the analysis and masks the overall innovation time problem. Each of these efforts, by collecting data to begin a program at what is now defined as Milestone B or C, has chosen a baseline that is, unfortunately, extremely late in the process.

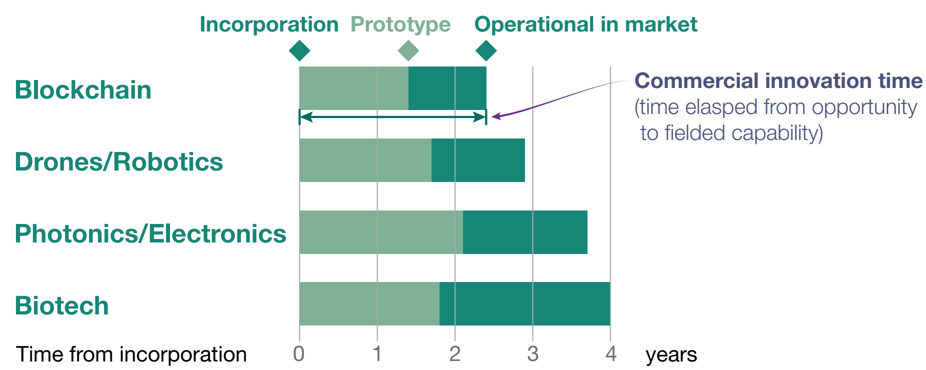
Apart from earlier discussion on pre-program decision time, figure 8 outlines how test and assessment is a driver of lengthening system development, by returning to the dataset of figure 3, and adding additional divisions. The first segment extends from first contract award to the first flight of a Y-Plane or production representative prototype. The flight and test of this vehicle typically corresponds to Milestone C, the completion of an Engineering and Manufacturing Development phase and the approval to proceed to low-rate initial production (LRIP). Over the analysis period (1974 to 2016), this phase increased somewhat, but is not responsible for the bulk of timeline increase. The next phase involves flying an LRIP aircraft and increased by around 450 percent during the analysis period. The final phase involves bringing the aircraft into initial operational capability and increased by an astounding 1,000 percent. This implies that the test and evaluation phases intended to vet production aircraft against initial requirements are the largest source of post-contract timeline growth. This is likely due both to changing standards for aircraft acceptance into service over the analysis period as well as changes to operational test and evaluation procedures, including a separate reporting chain.

Taken as a whole, this data suggests that DoD processes execute well on block upgrades and basic platform adaptations like the LUH. However, these processes seem to struggle with new-start capabilities. The source of the increased times comes from no single factor, but pre-contract award decision-making and test and evaluation are the clearest contributors to timeline increases. If the interest in measuring cycle times is to have relevance to military competition, it should be set not for convenience of data collection, but for alignment with the strategic context. We argue that innovation time is the best measure for this.

Commercial Innovation Time

Earlier discussion on commercial innovation time analogs focused largely on industrial systems like aircraft and cars. Certainly, many important future scientific discoveries and military innovations may not be targets for mass production. It is thus useful to explore innovation time cycles for emerging technology (sometimes called deep technology) startups, gathered from an analysis of 1,500 mostly venture-backed technology startups from 2016 to 2018.[84]

Figure 9. Emerging commercial technology cycle time



Modern innovation time cycles as measured for venture-backed startups across four emerging technology areas suggest that it is possible to deliver new operationalized technology in under four years.

Figure Source: Report Authors, Data Source: Massimo Portincaso, Arnaud de la Tour, and Philippe Soussan, *The Dawn of the Deep Tech Ecosystem* (Boston Consulting Group, 2019), https://www.bcg.com/publications/2019/dawn-deep-tech-ecosystem.

These commercial examples are useful to examine, because of the stark contrast in decision times and funding allocation times, which are included in this data. Incorporation typically takes one to seven months for an expedited process, depending on the state.[85] Raising venture funding typically takes three to nine months, much of which involves refining the business plan and identifying investors; closing the deal typically is closer to one month.[86] The vibrant startup business environment and ample access to capital is a strategic advantage of the United States.

It is likely not a realistic goal to imagine that the US government can achieve these same timelines, nor is it clear that venture-backed startups are the best tool for developing military capability. This data also includes a form of selection bias in that venture funding is usually applied toward companies able to commercialize technology rapidly. Indeed, a commonly acknowledged shortfall of the venture model is that it tends to exclude developments that require more patient funding.[87]

A DoD innovation strategy should pay close attention, though, to the singular attention of both these deep technology startups and their venture investors on time-to-market. These startups only get to market if they have something novel and they take many shortcuts to get early customer feedback to guide further development. The DoD is likely to need a diversity of partners, from academia, venture-backed startups, research-focused companies, and legacy players to achieve its future needs. However, it can only leverage this diversity if it improves its ability to allocate resources around its priorities.

CHAPTER 3: COMPETITION AND ADAPTABILITY

It is competition that makes the emphasis on speed and agility of resource allocation a pressing DoD policy issue. Decision speed and the delivery time metrics previously discussed do not have value in a vacuum. The value of speed is coupled both to the competitive environment (namely foreign actors and changes in available technologies) and the overall national security strategy. In simple turn-based competitions with fixed options, such as chess or poker, decision speed has little value and success is largely determined by decision quality, with players investing considerable time and energy on forecasting future outcomes and optimizing decisions.

However, in a fluid competition where each competitor has finite budgetary resources to invest in a fixed set of capabilities, and where some investment choices lead to higher military payoffs than others, decision speed can be decisive. If one of the two players has even a modest advantage in its ability to estimate payoff from investments, its best strategy is to press the tempo of the competition, making many decisions quickly, observing the payoffs, and adapting its future investments. When stability is removed by allowing the set of capabilities to constantly evolve, resource allocation decision speed becomes essential and prediction loses value. Faster resource allocation processes permit greater optionality, more fluid learning and re-allocation from less promising options to more promising options.

Competitive advantage in decision-centric operations (whether budgeting or on the battlefield) comes from the scale of available

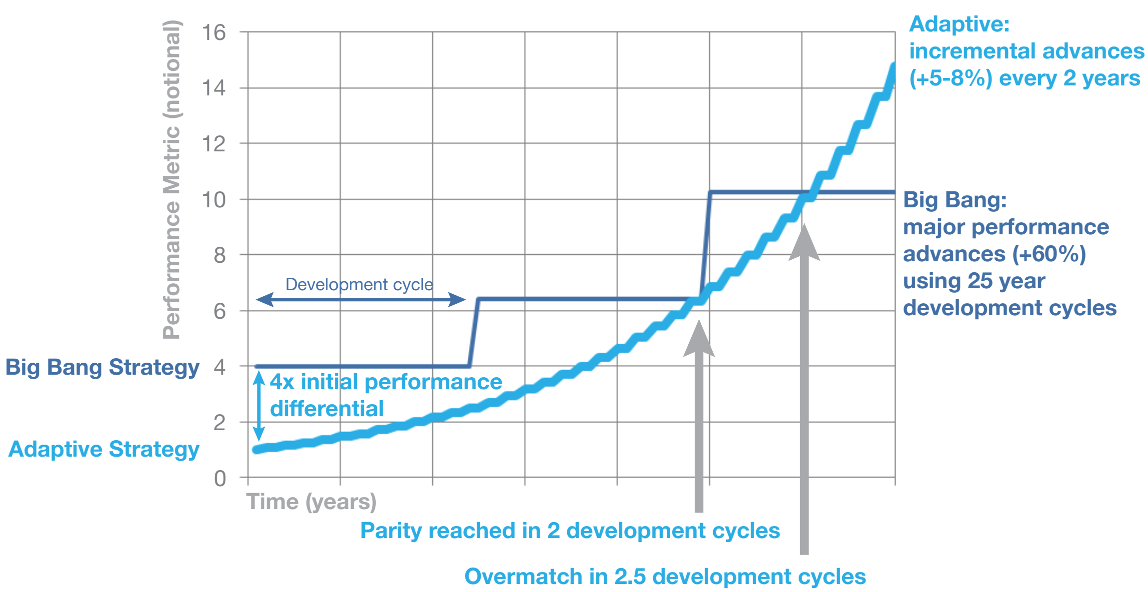
Photo Caption: The PLA hypersonic glide vehicle Dongfeng-17 is displayed during a military parade to celebrate the 70th Anniversary of the founding of the People's Republic of China in 1949, at Tiananmen Square on October 1, 2019 in Beijing, China. (The Asahi Shimbun via Getty Images) options, tempo of decision-making, and superior decision processes. More decisions come from a diverse array of options, better decisions come from a clear view of the competition, faster decisions come from operating at the highest possible speed. Together, these levers can paralyze an adversary and trap them into ineffective and inferior resource allocation.

Viewing competition and conflict as an evolutionary landscape is not new; recently, David Kilcullen painted a portrait of post-Gulf War national security developments as one of adaptation and convergent evolution,[88] with an insurgency in Iraq adapting to the strengths and capabilities of the US military, rapidly improvising tactics and weapons, and with inferior fighters being killed off. This Middle East conflict also permitted China to observe the strengths and weaknesses of the US warfighting model and develop a strategy that leveraged adaptability. The pressing question is how the US will, in turn, adapt itself.

A Tale of Two Investment Strategies

To illustrate the role of faster investment decisions and shorter development times in a competition, consider the hypothetical comparison sketched in figure 10. One player elects to use a "big bang" strategy, taking its time to make decisions, but only investing in major capability upgrades, achieving major performance advantages (of 60 percent in a notional metric) across each of twenty-five-year development and fielding cycles

Figure 10: Big bang vs. adaptive investment strategy



Two notional investment strategies are compared. A big bang strategy starts with a 4x advantage in a key weapon system performance metric and proceeds to field new systems with major advances (+60%) at a slower place, but is eventually overtaken by an adaptive strategy, fielding minor advances (+5-8%) on a faster pace.

Source: Report Authors

for a weapon system. The competition is handicapped by giving the "big bang" player a technological advantage, starting with a factor 4 overmatch in the performance parameter of interest. The second player starts at a marked disadvantage, but elects an adaptive development strategy, rolling out incremental performance improvements of only 5 to 8 percent, but on a fast, fixed cadence of every two years. As the figure shows, in two development cycles, the adaptive player catches up with the big bang player. In two and a half development cycles, the adaptive player overtakes the big bang player. There is no catching up beyond this point. Over a sufficiently long time horizon, the rate of delivering performance advantages becomes the determinative factor in the investment competition.

There are cost implications as well. The big bang approach would require significant spending on developing each increment, and the successive generations would likely be significantly different, creating the need for new training and logistics, and raising operations and support costs relative to the incremental approach, which would likely require less retraining or logistics changes for each increment.

This simplistic analysis focuses only on a symmetric performance competition where each player is only pursuing a single metric across many weapons system generations. Actual long-term military competitions are hardly symmetric; clever competitors shift directions, find new performance metrics of interest, exploit many pursuits simultaneously, and take advantage of a shifting technological landscape. Each of these factors, however, only increases the value of an adaptive strategy, which permits rapid pivots and hedging.

In the emerging model of decision-centric warfare,[89] a powerful approach to capability delivery is that of optionality strategies.[90] This model combines information-centric military capabilities, legacy multifunction military platforms, and an array of smaller, interoperable capabilities that can be quickly recomposed. Tactical adaptability is enabled by the ability to recompose forces in new combinations, which drives an adversary to suboptimal defense against multiple options. However, this strategy also benefits from optionality at the strategic and industrial timescales, with fast-paced investments driving new military equipment and rapidly increasing the available option set available for tactical recombination. Again, the key variables emerge as the scale of available options, the speed of decision-making, and decision processes.

Adaptability is a critical attribute for a long-term military competition. To foster superior adaptability, two things are needed: (1) decentralization to permit local initiative and novel developments, (2) a focus not only on quality of decisions, but on the speed of decision-making, which both increases the scale of available options and the ability of one side to impose surprise. The DoD's current processes for budgeting, requirements, and acquisition, the product of the industrial era, push in the opposite direction.

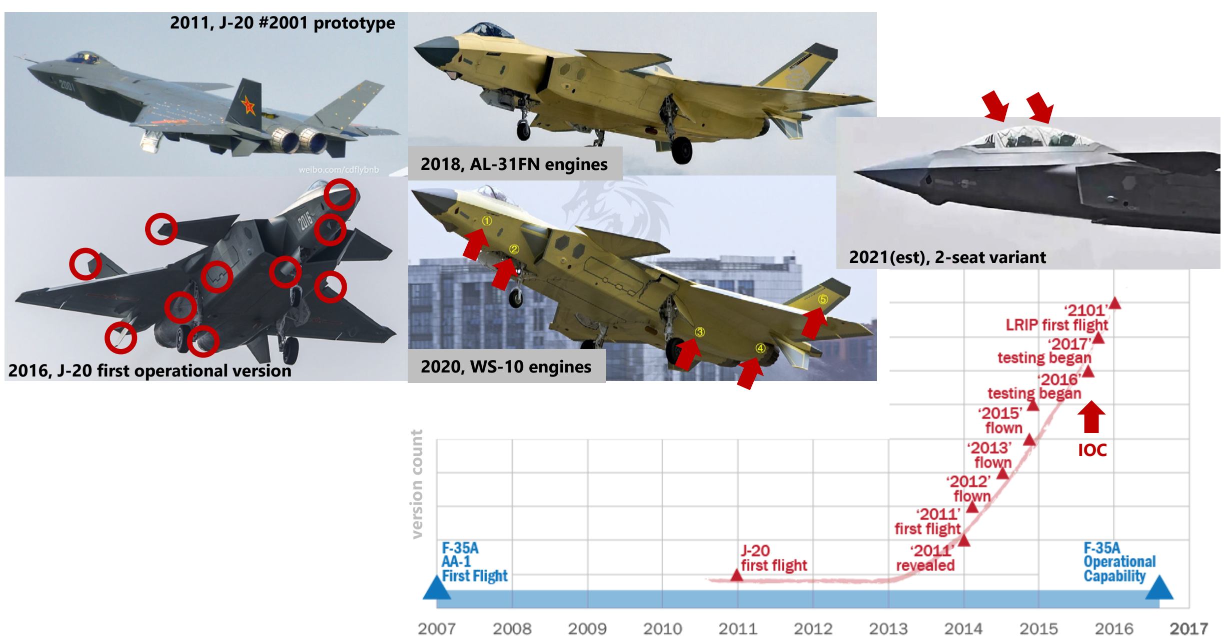
China's Remarkable Pace

The slowing US innovation time for new capability documented in chapter 2 does not compare favorably to our competitors. In 2018, Mike Griffin, the first Under Secretary for Research and Engineering, disclosed an innovation time comparison that it takes the US on average sixteen years to deliver an idea to operational capability, versus fewer than seven for China, and offering an example: "the Chinese have tested several dozen hypersonic attack vehicles over the last ten years, and most have been successful."[91] This sobering analysis implies that China accomplishes two and a quarter development and fielding cycles to every US turn. At this relative rate, any technological advantage that the US has would eventually be overcome; it is only a question of when.

This difference in development and investment strategies is hardly isolated to hypersonics. Figure 11 is compiled from open-source data on the state of the Chinese J-20 development as contrasted with the F-35. The US favored a model of trying long-term predictive requirements, and a lengthy waterfall development and testing model, whereas our competitors favored iterative models. China delivered nine visually distinct upgrades in five years to the J-20 following the type's first flight[92] before arriving at the "2101" model for production in late 2015. Six months later, they had rolled out three more copies of this production model, only after they had worked through the design issues associated with any new aircraft type. By March 2017, the first operational J-20 was deployed to a front-line unit, ahead of schedule, even as mission systems were being updated.[93] Some analysts may point out that the F-35 is superior to the J-20 in many performance metrics and mission systems. However, the intent here is not to draw a symmetric comparison—it is unlikely that these aircraft will soon face off in one-versus-one combat—but to contrast the differing development models used between China and the US. As we have seen previously, the pace of adaptation is ultimately a more important parameter than any current performance gap.

The other advantage afforded by rapid investment decisions is the opportunity to build out a diverse set of different capability options. Turning again to China's remarkable recent military buildup, we can see evidence of this in the diverse array of unmanned aircraft that China has fielded from 2010 to 2020, at least twenty-five, according to posts on the Chinese microblogging site Weibo. This is emblemized by the satellite photo from Malan airbase[94]

Figure 11: Iterative weapons development in China



China has adopted iterative development models in their advanced weapon systems, including the J-20. The J-20 has undergone nine rapid hardware and software iterations to converge on mature configuration in the same time period when F-35A has pursued concerted test, evaluation, and refinement to achieve IOC with Block 3F. The red markings highlight successive changes in the J-20 design.

Source: Report Authors

reproduced in figure 12. Fielded types include aircraft that bear resemblance to the US MQ-1C Grey Eagle, MQ-9 Reaper, RQ-4 Global Hawk, X-45 combat air vehicle, but also novel types including those with a box-wing configuration (the EA-9), long studied in academic settings for its theoretically high efficiency but never built by Western countries, massive twin boom models, and even supersonic drones, which the US has not had for many decades. Forums also suggest that work on at least another ten models during this time were started but did not reach fielding, indicative of a willingness to stop investment in developments.

This development and investment philosophy was characterized by an analyst in 2015: "China has repeatedly demonstrated an effective model in both the aerospace and defense industries that relies on incremental development and prototype launch of technologies over rapid full system development."[95] Again, it would be a poor strategy to seek a symmetric response and launch a dozen new US unmanned systems developments. Instead, the US should focus on its bureaucratic resource allocation and decision-making processes and understand how it can achieve a comparative advantage in innovation time to pursue adaptability.

Chinese Resource Allocation Processes

Despite the central importance of relative resource allocation speed and efficiency, there has been remarkably little study of the Chinese defense budgetary, requirements, and acquisition

Figure 12: China's unmanned systems fielded from 2010 to 2020.

Analysis of open-source intelligence suggests that China has fielded 25 varieties of unmanned systems from 2010 to 2020. Some of these include stealthy carrier-based unmanned systems inspired by US developments.

Figure Source: Report Authors. Data Source: Chinese Internet Forums found via Twitter processes by Western analysts. There has been more study on absolute levels of Chinese defense funding, including attempts to compare across both dollar-equivalent and purchasing power parity sources, and attempts to calculate the full sum of defense funding from all sources, including local governments and other non-reported subsidies.[96] Not only have China's military capabilities and fielded systems evolved since Desert Storm in 1991, so have their bureaucratic reforms.[97] This is an important but underserved research area. In an era where many technology building blocks are sourced from the commercial world, and are pursued by both China and the US, the pace of technological experimentation and adoption remains a driving determinant of military capability.

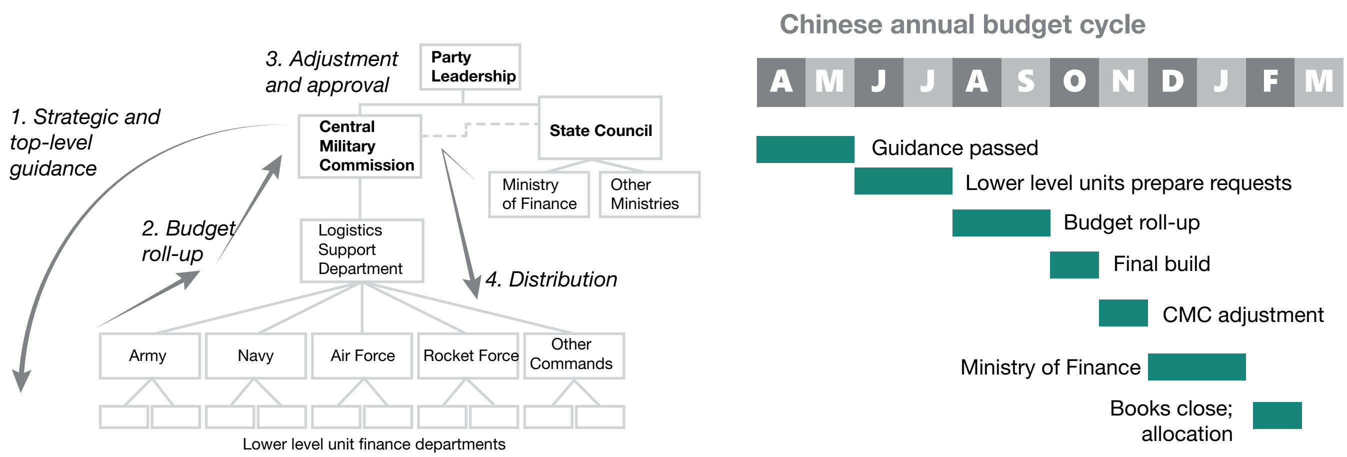
While not fully representative of the current system, a Chinese defense whitepaper from 2006 nonetheless offers a first-hand description of their budgeting process:

> "[Defense] budgeting is based on the defense development strategy, military building objectives and annual military tasks set by the state. Budgeting units at each level [of military hierarchy] carry out studies to decide on their budget items, make calculations of their requests for funds and then report to the next-higher authorities. The General Logistics Department (GLD), working with the relevant departments of other general headquarters/departments, analyzes, calculates and verifies the annual budget requests submitted by all the military area commands, [the Army], the Navy, Air Force and Second Artillery Force, and draws up the defense budget. After being reviewed and approved by the [Central Military Commission] CMC, the defense budget is submitted to the Ministry of Finance. The latter, on the basis of medium- and long-term fiscal plans and the estimated revenue of the year, puts forward a plan for military expenditure appropriations after consultation with the General Logistics Department, and then incorporates it into the annual financial budget draft of the central [Chinese] government. Upon approval by the State Council, the annual financial budget is submitted to the [National People's Congress] NPC for review. After the budget of the central government is approved by the NPC, the Ministry of Finance informs in writing the General Logistics Department of the approved defense budget. The defense budget is then [distributed to units] at different levels [in the hierarchy]."[98]

While the military proposes a defense budget, the civilian arms of the Ministry of Finance, State Council, and National People's Congress each have a role in approval. Notably, setting long-term priorities is kept separate from budget building. Branches of the Chinese military respond to long-term strategic priorities and establish their own objectives. The budgetary process is a largely annual affair, based on prior year budgets, shifting priorities, and available resources. The Chinese budget is structured organizationally and does not incorporate strict program definitions and schedules. Separate systems are employed for development progress accountability.

As China's budgeting process is currently undergoing a series of reforms,[99] authoritative sources for the current system are not available. The 2019 China Defense White Paper describes these changes as "adopting demand-oriented planning and planning-led resource allocation, China has established and improved the strategic management procedures of demand-planning-budgeting-execution-evaluation."[100] Demand planning uses analytic tools (often ranking methods) to determine the relative importance of demands. It shares some similarity to output-based methods in that it attempts to align budgetary requests with desirable outcomes, but are not likely based on the Western concept of a program with defined schedule and performance specifications. Budgets are accompanied by

Figure 13: Chinese defense budgeting process



Graphical representation of the Chinese defense budgeting process, synthesized from available sources. Planning, enactment, and execution are condensed into an annual cycle.

Source: Report Authors

justification documents including budget plan explanations. One notable facet of this structure is that an owning organization can shift directions, because there is not a programming process that locks in future years of funding.

Figure 13 presents a synthesis of the Chinese process based on the sources above as well as additional references from the 2005 timeframe.[101],[102],[103] Further research is needed in this area, especially in measuring decision times.

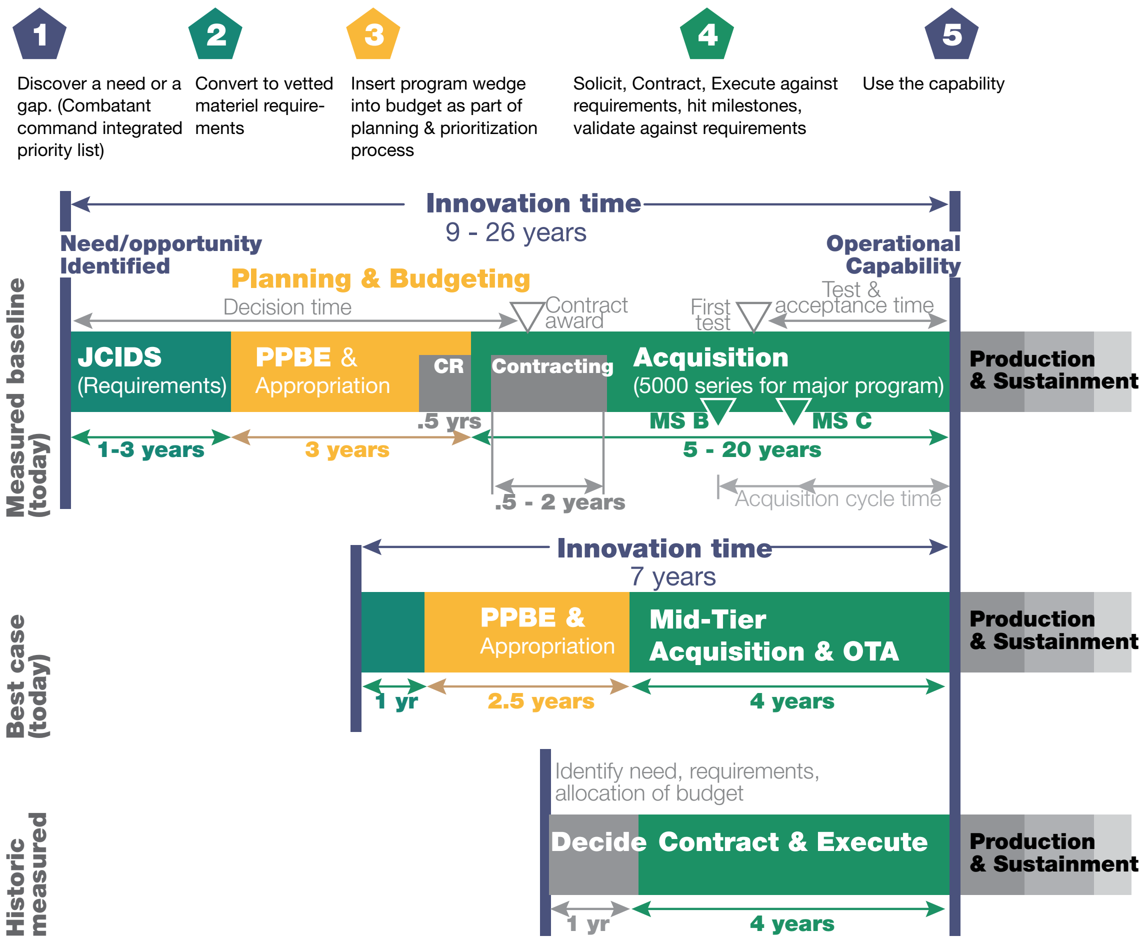
Linear US Processes Assume a Stable World

The prediction-centric process triad of the McNamara era results in the neatly aligned delivery cycle for new capability illustrated in figure 14: requirements flow into planning and budgeting, which flows into an acquisition and ultimately capability delivery. This section will explore data for the length of each of these major segments.

While there is some possible concurrency in each step of the process triad (budgeting may begin before a requirements document is approved by the joint requirements oversight council, for example), long staffing times reduce its occurrence in practice. A validated requirement initiates a program; the acquisition or contracting processes cannot begin until the Congress authorizes a new-start for a program and then budgets for it. Once money is available, the timing of the contracting process to actually begin work on a program becomes important. The issue of linearity is critical to the time cycle. As the requirements, budget, contracting, and acquisition processes are primarily conducted in a serial fashion, it is fairly straightforward to ascertain why time has been increasing. This also makes addressing requirements reform independent of budgetary reform intractable.

The upper portion of figure 14 represents segment lengths for new capability delivery for a new capability that is a major

Figure 14: DoD process changes over time



Processes governing DoD's model for delivering capability delivery process: contemporary baseline, best case, and historical.

Source: Report Authors

capability acquisition according to the adaptive acquisition framework. Notably, of a lengthy baseline timeline of nine to twenty-six years between identification of need and initial capability, only a portion of this is spent between Milestone C and IOC: a usual focus for acquisition cycle time study efforts. Before this period, five to eight or more years are spent on the DSB's concept of decision time—preparing to be able to develop a capability. This investment in preparation naturally raises the bar for the eventual acquisition.

The middle portion of figure 14 represents a current best case for acquisition of a new capability delivery using the middle-tier mechanisms of the McCain reforms, assuming highly accelerated award to an industry performer and solid technical execution. The PPBE can be seen as the pacing element.

The lower portion of figure 14 represents a 1950s-era historical norm case for acquisition of a new capability delivery based on the observations of the DSB in 1977. Notably, the PPBS/PPBE processes and the Joint Capabilities Integration and Development System (JCIDS) requirements processes did not exist and services had flexibility to move funds among program efforts and start programs when they wished, even if there had been a continuing resolution. There was no formal acquisition process as set forth in the 5000 instruction series. Contracting was simpler and faster, with many fewer mandated clauses. This did not mean there were no processes, but the time required for those processes was measured in months, not years. The DSB in 1977 stated it took two years of decision time in the 1950s to go from idea to validating the technology (now considered an interior acquisition Milestone). Already in 1962, General Schriever was testifying that the new, soon-to-be-called "concept definition phase" had delayed the start of new programs to comply with new systems analysis requirements mandated under the PPBS. He implied that without this process it would have taken much less than the year or more delay that he saw from complying with this analytical stage to start a new effort.[104]

The McNamara processes were intended to implement management best practices and were designed around industrial efficiency. A clean linear process flow with no concurrency is supposed to ensure that no mistakes are made, that all issues are resolved before the next step is taken, and that no wasteful spending occurs. But crucially this assumes that the cost of inaction is low—despite the fact that the industrial base must cover the costs of employing its workforce somehow, and assuming that there is no opportunity cost from inaction. In short, the McNamara processes depend on the ability to predict the future well.

In his 2011 work performed at the behest of DARPA, former Secretary of the Navy Richard Danzig makes a forceful argument that long-term national security prediction is futile,[105] and that the DoD must move toward a model focused on adaptability:

> "The US military relies on prediction to forecast needs and influence the design of major equipment. A future or futures are envisioned, requirements are deduced and acquisition and design decisions are made and justified accordingly. However, both the experience of the Department of Defense and social science literature demonstrate that long-term predictions are consistently mistaken. The acceleration, proliferation and diversification of technical and political changes make 21st-century security risks even more unpredictable than those of the past. Thus, whereas some efforts to predict the future are necessary and predictive techniques can be improved, acquisition programs should reflect the likelihood of predictive failure. The defense community should prepare to be unprepared."

Notably, the PPBE and accompanying appropriations process is the glue that holds the other elements of the process triad together and must be a priority for reevaluation. These elements require that the DoD document any planned new capabilities, forecast milestones, and system performance years in advance.

Processes That Govern Innovation Time

Although all measured time segments have increased, US innovation time is lengthening in large part because of delays before production starts: in conceptualization, requirements, planning, and acquisition processes, and are driven in large part by the structure of the US resource allocation process. Understanding these processes provides the motivation for reform.

As illustrated in figure 14, in today's conception, new military capabilities are birthed not by new technological possibilities, but by identification of a need. Weapon system requirements are generated for the most part by services based on their own analysis of projected scenarios, threats, and US capabilities. While Combatant Commanders are supposed to play a key role in the process, driving operational requirements for near and far term, this has been an area of persistent challenge.[106] Combatant Commanders are arguably the most directly impacted by future capability gaps, but they only have a small role in requirements development through their Integrated Priority Lists, which only comprise less than 5 percent of the budget total.[107] Combatant commands overwhelmingly stated that the 2009 Weapon Systems Acquisition Reform Act (WSARA) of 2009, intended to address this, had no effect on their ability to shape requirements documents.[108] The translation of need into formal requirements takes time.

Of course, military need is rarely birthed entirely from the imagination of services or combatant commanders. The opportunity space of what concepts, technologies, and systems could do plays an important part. For example, Will Roper described the role of the Strategic Capabilities Office (SCO) as driving opportunity-based developments, noting that SCO "created about 53 or so capabilities, and not a single one was requirements-driven. They were all opportunities that were either produced within industry or produced by some strategists and then we found industry that could make them."[109] Then SCO worked with combatant commands to generate requirements and begin an acquisition.

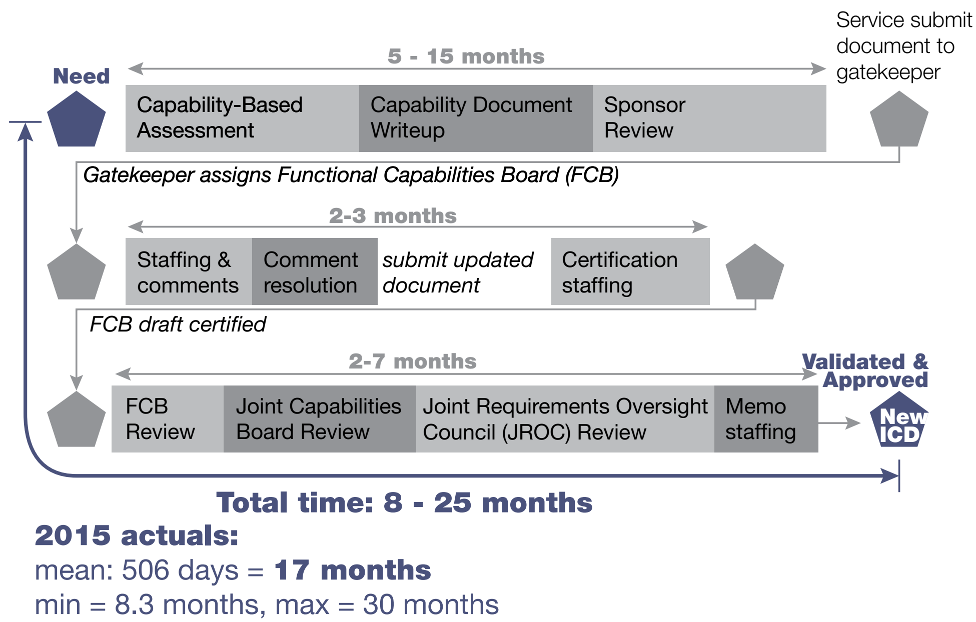
The requirements formulation process can also incidentally be destructive to innovation and competition. As Eric Lofgren notes, "In order to be justified as low risk, requirements usually gravitate towards defining the technical and performance characteristics of a system rather than a broadly stated mission outcome."[110] Citing Jacques Gansler:[111] "the budget process is driven by individual weapon line items. Thus, the requirements process considers individual weapons first and establishes requirements for next-generation weapons." The net effect is that requirements often embody a predetermined technical solution (often shaped by industry) prior to a formal industry competition.

Figure 15 lays out the timeline and key steps of the JCIDS process, including measured performance from two Army studies. In 2010, the Army estimated that it takes on average fifteen to twenty-two months to get a requirement approved.[112] More recent data from 2015 confirmed this, and found that JCIDS personnel approved zero needs in fewer than 250 days and one in 894 days with the median JCIDs approval time of 506 days (seventeen months).[113] Notably, these studies may both be somewhat optimistic, as they do not extend back to the original Combatant Commander need.

Once a capability requirement is validated via the Initial Capabilities Document (ICD), a military service can proceed to program and budget for it, shaping its Program Objective Memorandum (POM) and budget recommendation as part of the budgeting process. Ironically, while DoD's military capability development efforts are not driven by time, its internal planning process is. The Planning, Programming, Budgeting, and Execution (PPBE) is a yearlong calendar-driven process that, for any fiscal year cycle, begins more than two years before the expected year of budget execution.[114] This has the effect of forcing services and programs to begin planning three years in advance, forcing a significant lock-in of plans and requirements, and reducing the service's ability to pivot based on new developments from adversaries or technology. In practice, two years can be achieved if the requirement is completed at the most auspicious time in the cycle, had been concurrently moving through the planning process, and service topline authority funds happen to be available.

That budget containing the hypothetical new capability is sent to the Congress to wind its way through the authorization and appropriations processes and to receive a new-start designation from Congress. Without this critical new-start designation, the DoD cannot spend money on a new effort. History suggests

Figure 15. Baseline JCIDs process times



When following the baseline JCIDs process, it takes almost two years to validate a new requirement.

Source: Report Authors

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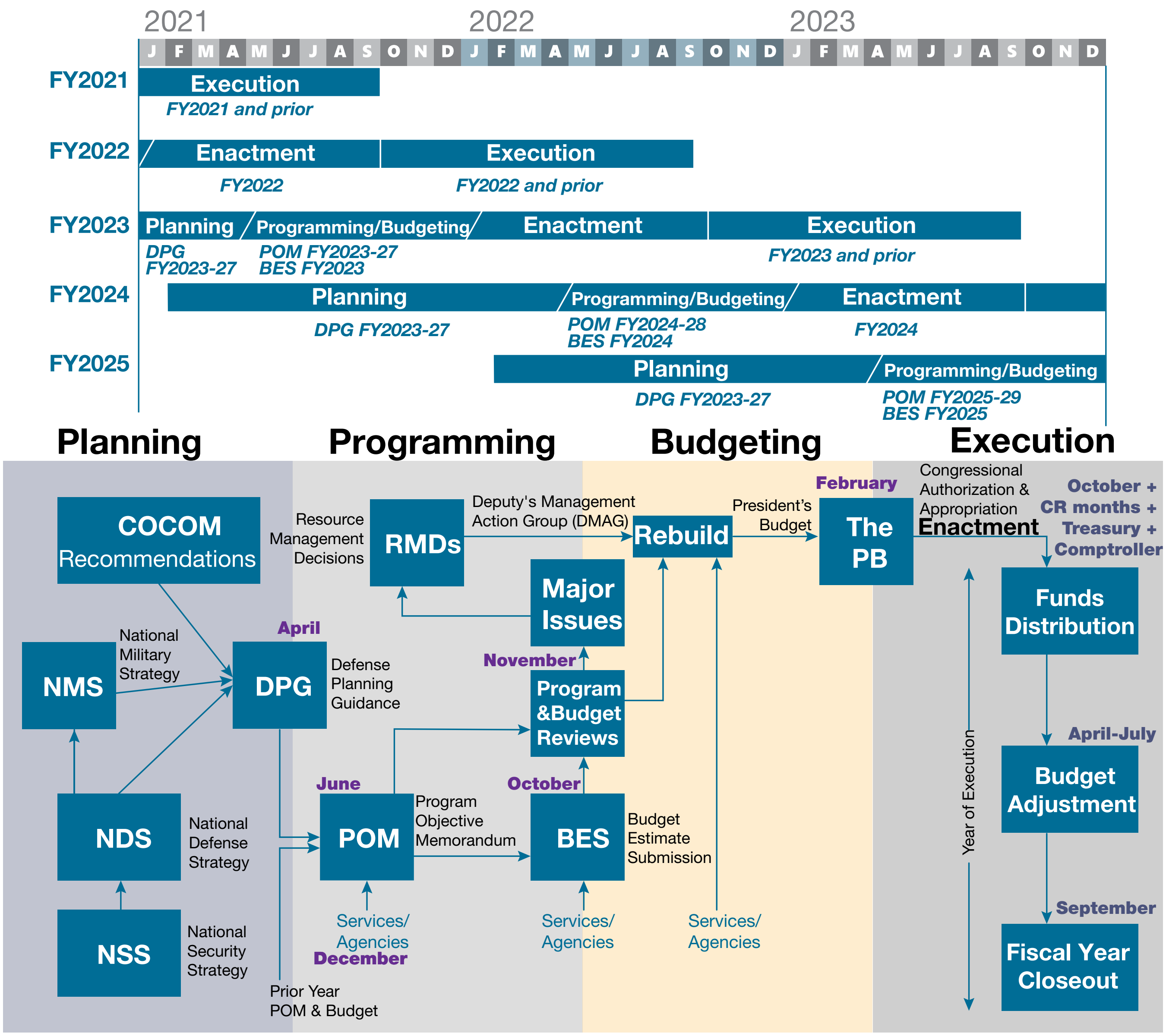
that it is difficult to count on Congress passing a budget on time; it is better to assume that the new year will start with one or more Continuing Resolutions (CR). Regular appropriations were enacted after October 1 in all but four fiscal years between FY1977 and FY2021. Consequently, CRs have been needed in almost all of these years to prevent one or more funding gaps from occurring.[115] Since continuing resolutions limit expenditures to acquisition programs that were funded in the prior year, no new effort can commence unless what is known as an "anomaly for the program" is included that authorizes the new-start and provides funding. Those anomalies are not easy to get and most programs need to wait until passage of the defense appropriations bill. As a result, the median PPBE-induced delay in decision-making is three years. It should be noted that non-acquisition research efforts can be started under a CR by modifying the schedule and scope of an overarching program element of a budget request.

Figure 16 lays out the intricate annual planning cycle of the PPBE. As this manuscript is written in late 2020, military staff are already working on the fiscal year 2023 through 2027 programs and budgeting. Decisions are made as far out as seven years in the future, even though a look back on the geopolitical climate and consumer technological landscape seven years ago makes this seem futile. A sudden emerging need or new technology maturation within the next two to three years would require intervention at the highest levels of the DoD, possibly through a reprogramming decision for the current budget or a resource management decision in the next year's budget. Watching the DoD work through this process every year is like watching

Figure 16: The calendar-driven PPBE process



The PPBE is in intricately orchestrated, cascading, calendar-driven process that plans future programs and expenditures many years into the future based on service and agency equities and military requirements.

Source: Report Authors

the intricate machinery of a clock working, with human labor working many late nights and weekends to accommodate the replanning required by every new top-level adjustment, as the DoD and services strive to submit a budget. The PPBE is anything but adaptive.

Some five years or more after a need was identified, funds are apportioned to the services and they can use that funding to obligate money for a program. These funds are obligated upon contract award. As the program enters its first (of many) future contracting actions, enough time has elapsed that many of the personnel that originally articulated the operational need, or technical people or industry engineers who contributed to the formulation of the capabilities-based assessment, have rotated on to another position or retired. Even in the DoD, computing equipment has been refreshed multiple times, and the state of commercial technology has certainly advanced.

Even if the original requirement was shaped on the basis of a particular instantiation of the material solution, a full and open competition needs to be conducted to determine if there are other ideas out there that are now better than this one. While in the commercial market or evolutionary sense, competition usually implies a contest to identify the fittest or best, in defense acquisition, specifications often need to be changed to allow multiple bidders to submit proposals. This tradition has extended long before McNamara; even though the Wright brothers were the only ones to have demonstrated a heavier-than-air flying machine, they were forced into a competitive solicitation with forty-one bids, a multi-party flyoff, and only one machine that could actually fly.[116]

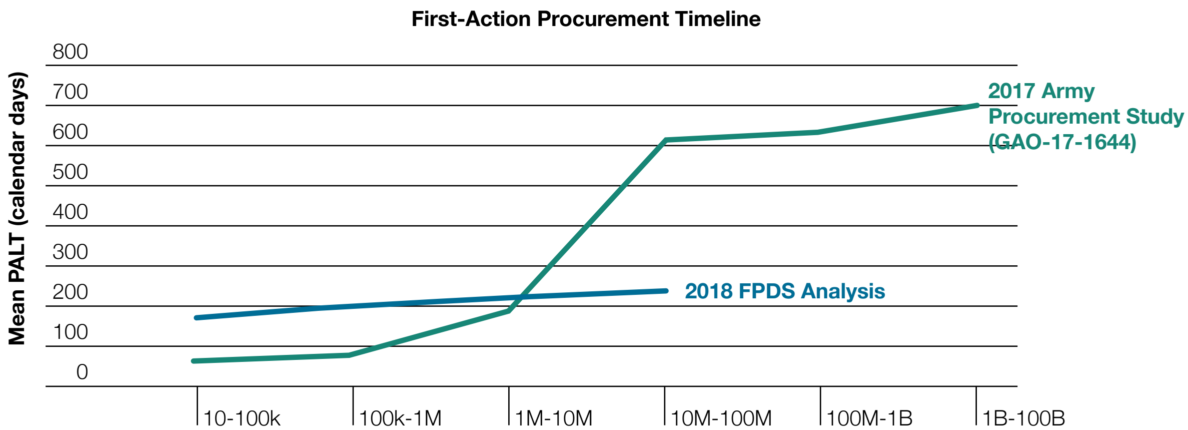
A high-stakes program contracting process executed in full accordance with the federal acquisition regulations could take almost two years, according to the GAO.[117] Contracting officers are forced to peruse thousands of pages of submitted documentation and draft lengthy justification documents. As illustrated in figure 17, a competitively awarded Army contract of $100 million would take a mean of 600 days.

Funds, however, will still need to be obligated within a two-year timeframe as these initial funds to begin a program will be for Research, Development, Test, and Evaluation (RDTE) funds, which expire in two years. If the contracting process is not completed in that period, the funds expire and eventually return to the Treasury. The length of the contracting process means that a contractor can start funded work a full seven years after the need was identified and a novel solution proposed.

Thus, in the current system for acquisition of a major capability, the effect of linearity is that perhaps seven years must pass from the identification of an idea, through the requirements, budgeting, and contracting processes to just start work on capability development. Referencing figure 14, this decision time is longer than the entire development cycle for many historical systems. It is consistent with the eight years documented for the DDG-1000 in chapter 2.

There are certainly notable examples of this baseline process being bypassed and capability being delivered faster, including the Mine Resistant Ambush Protected Vehicle (MRAP) delivered in under two years.[118] At the same time, this process can also take longer. Then-Army Chief of Staff Mark Milley was famously frustrated for Army acquisition taking thirteen years to award the first contract for replacing the Beretta M9/11 pistol, when he offered to buy pistols as an off-the-shelf product from Cabela's.[119] The Army began the program in 2004 and after being unable to agree on a requirement for nine years finally adopted the Air Force's requirement in 2013. It then took almost two years to release a Request for Proposal to initiate the contracting process in August 2015, and award a contract in January 2017. This was for something sufficiently small that it did not need to go through the systems acquisition process, yet still took thirteen years just to get to a contract and start the program.[120]

Figure 17: First-action contracting timelines



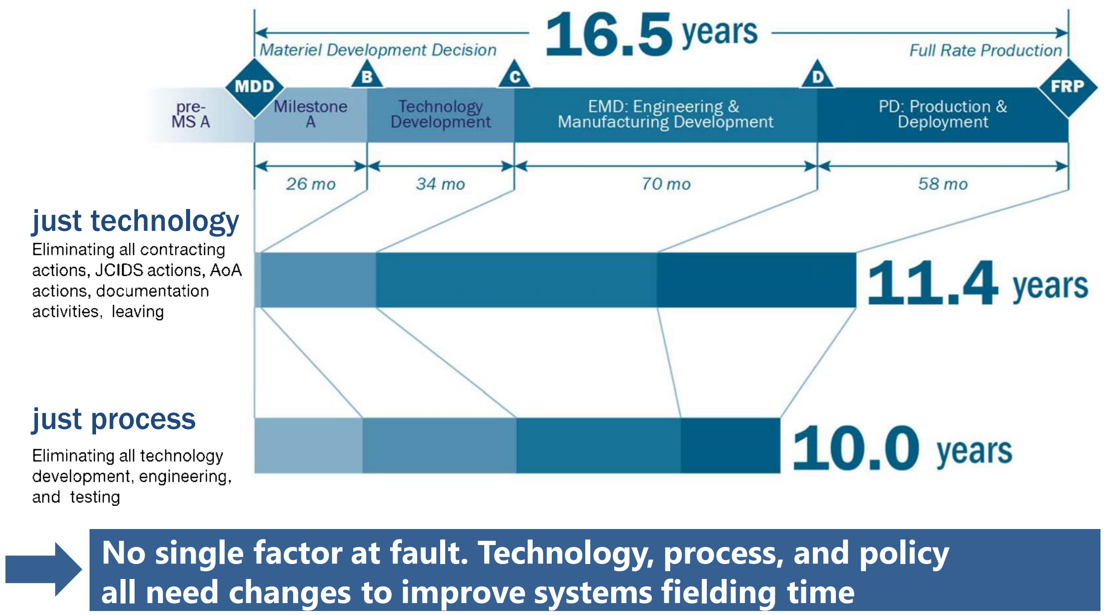
The results of two analyses of first-action contracting timelines (excludes exercising options), organized by contract size show that it can take two years to award a large contract. The PALT represents the time between the date on which an initial solicitation for a contract or order is issued by a federal department or agency, and the date of the award of the contract or order.

Figure Source: Report Authors, Data Source: U.S. Government Accountability Office, "DoD Should Develop a Strategy for Assessing Contract Award Time Frames," GAO-18-467 (July 2018).

Once a contract has been awarded, a new capability is in the hands of the acquiring program office and industry program management to execute in accordance with the DoD 5000 series acquisition process. The intertwined effects of process conformance and technology development were examined by the Army in a 2015 study, colloquially referred to as the null program brief.[121] This study was an extensive development and schedule analysis that began by creating a detailed execution plan model for a notional ground combat acquisition program. It was designed as a Major Defense Acquisition Program (MDAP Acquisition Category 1D) new-start, single variant ground vehicle system with limited, low to medium risk technology development, and activities with low concurrency. The program schedule was set up in full conformance to DoD instruction 5000.02 and the WSARA, with document staffing timelines populated based on prior measurements, and test and development timelines based on inputs from technical experts. The results are processed and presented below in figure 18.

This study suggested that progressing a ground vehicle development program from a materiel development decision and Milestone A to full rate production would take 16.5 years assuming no unexpected delays and solid execution, and with operational capability available at fifteen years. What was especially notable were two model excursions. In the first, the length of all technology development actions in the schedule were set to zero, which revealed that just staffing the requisite paperwork through the appropriate chains would take ten years. The second excursion made all staffing actions instantaneous and revealed that a technology-only development according to a rigorous top-down systems engineering process would take eleven years.

Figure 18: Ground vehicle acquisition program technology and process



Analysis of a ground vehicle acquisition program suggests that technology and process are intertwined in ways that neither is fully at fault for lengthy development timelines, including the 16.5-year baseline timeline for a ground vehicle.

Figure Source: Report Authors, Data Source: Leslie Polsen, "PEO GCS Baseline Program Timeline Analysis," October 2011, available through the Defense Technical Information Center.

Remarkably, the fifteen-year delivery estimate excludes the seven-year initial decision time described above, and this was for a low-risk development effort that hardly resembles the risk taking undertaken in the Cold War. This anecdotal example is useful in understanding the lengthy new-start time-to-market observed in figures 3 and 6, where a baseline of more than fifteen years is observed, again excluding decision times.

The lengthy decision cycle times and program execution times make the concept of long-term prediction that undergirds systems analysis ludicrous. As Danzig argues:

"In a world of unpredictability, there are heavy penalties for ponderous decision making and slow execution. This is primarily a result of the fact that although prolonged procedures may improve the likelihood of hitting a fixed or predictably moving target, they doom decisionmakers to fall behind an unpredictably moving target. Accordingly, private sector managers make and execute decisions in days, weeks or months. Only in a minority of cases do they develop products with schedules extending beyond two or three years because more extended development cycles are understood to be too vulnerable to unpredictable evolution (sometimes revolution) in the market. The aim is to reduce uncertainty by narrowing the time between the initiation of a concept and its realization."

Instead of long decision processes meaning slow, careful decision-making for delivering success without waste, delay increases the likelihood that an acquisition will fail because it increases dependence on impossible predictions. These long timeframes make it extremely problematic to establish a meaningful baseline and process to monitor and document cost overruns. The requirement to establish such a baseline in the Nunn-McCurdy process is complementary to and a result of the predictive approach to innovation, but it becomes increasingly out of touch with reality as a positive tool for management. It is extremely difficult to maintain baselines over a longer period of years, and in fact may be counterproductive to try and do so. Changing budgets, priorities, and technology—particularly if the military is not the only source of technological advance—will drive instability in programs. The original cost baselines become meaningless as time, threat, and technology changes, but nonetheless they serve as the basis for a false sense of accountability that, when subsequently measured by the criteria of long-ago estimated baselines, are often measured as failures.

The DoD has occasionally tried to adjust to these realities by setting new baselines when things change. Congress, on the other hand, has acted as if this was just a case of moving the goalpost and subsequently mandated in section 802 of the 2006 National Defense Authorization Act measures that force DoD to adopt measurement from the original cost baselines. This has the effect of setting DoD up to fail, because if DoD takes on risk in a program, accommodates changing conditions, or inserts new technology, it will likely be met with greater cost overruns for the program as these changes were not contemplated in the original baseline and will register as cost overruns. The effect of this policy is to force DoD to limit risk, adopt limited evolutionary innovative change over a longer period of time, and deploy technology that is likely inferior to that an adversary would deploy. Stick to the original plan at all costs, despite a changing world. With no great power competitor and a stable world, this might be a legitimate policy. In our current era, it appears foolish.

It makes little sense to punish the DoD for having failed to meet an obsolete prediction, when a good program manager and industrial partner should be smarter today than they were when the requirement was formulated. Instead, the DoD's processes should shift to reward rapid learning, adaptation, and continuous delivery of value.

CHAPTER 4: A PATH AHEAD

The preceding chapter set forth the constraints on delivering new military capability set by the DoD's three core processes. Pre-development decision processes, especially including the budgetary process, are a rate limiting factor on converting opportunities into a new development effort or shifting directions based on emerging need. Given the high barrier to entry for starting programs, once an acquisition is started, there is little incentive to change approaches. Adjustments in performance or system characteristics based on new technologies or shifting threats are implicitly discouraged by the oversight emphasis on managing performance to the original baseline estimate, including in budgetary reporting and selected acquisition reports.

However, inspiration for a more adaptable bureaucratic model for investment and development can be found in the DoD's history. This history points to time-focused developments and an iterative development process that enable shifting performance goals based on learning accrued during the development cycle. However, despite the introduction of rapid acquisition approaches designed to help, the PPBE remains a fundamental obstacle to this agility. Today, adaptation is essentially forbidden by the necessity of changing program baselines, schedules, program plans, and the associated reprogramming of funds.

Photo Caption: A computer engineer types on his keyboard in a server room. (Getty Images)

In a long-term competition with a capable and adaptive adversary, the critical element is not better planning or a larger force, but an ability to create surprise and uncertainty, to adapt to a changing environment, and insert complexity into their decision-making. The only way to achieve this upper hand is through a more flexible programming and budgeting model that aligns around our desired strategic outcomes.

Rapid Incrementalism to Foster Adaptability

Chapter 2 focused its analysis on new-start, tangible weapons system developments. This has the effect of excluding software-centric developments (e.g., cyber capabilities) and major system modifications (e.g., the KC-46 tanker program based on Boeing's commercial 767 airliner). However, both of these excluded categories have a role in the rapid delivery of future military capability. Indeed, if the strategic pivot in DoD institutional values must be from predictability to adaptability and surprise, then rapid development and adjustment will depend on operational learning. Making good decisions still matters, but adaptability depends on learning, which values decision speed.

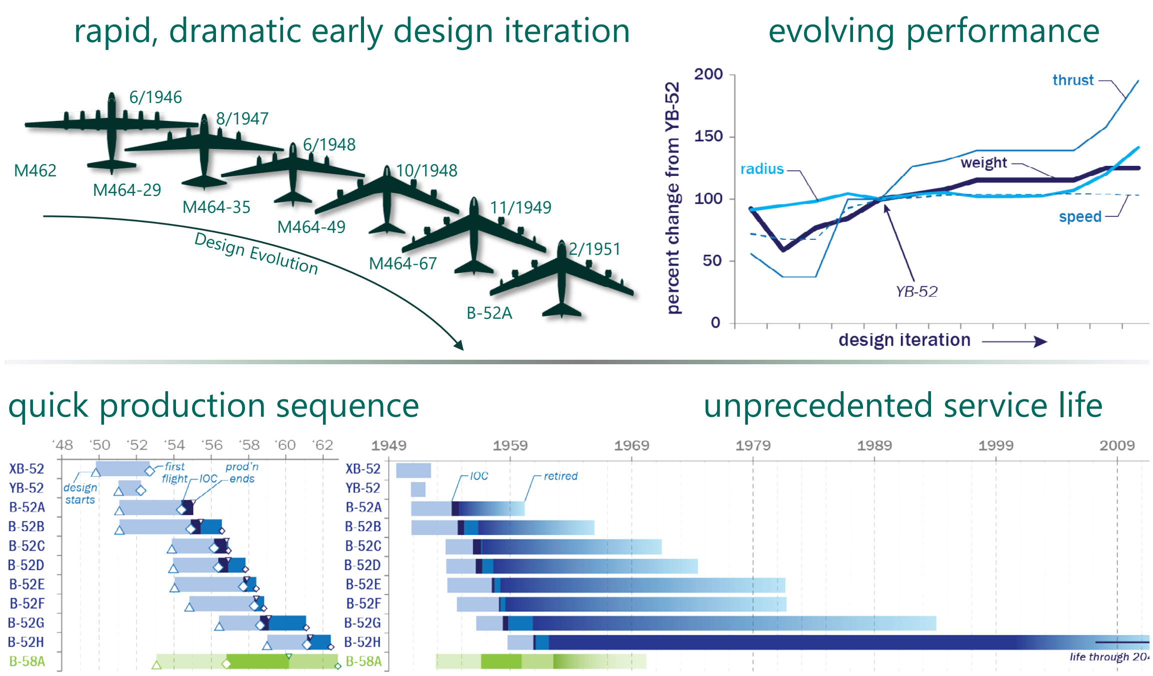
In many ways, this model focused on rapid learning echoes the development methodologies of the commercial software industry, which spawned both agile development and development operations or DevOps. These are flexible, bottom-up frameworks built to enable future change and that focus on delivering a capability as early as possible, and then using user feedback to prioritize future development, thereby focusing more on realized value.[122] While certain practices (for example, weekly sprints and nightly builds) may only be practical for software, there is a surprising degree of alignment with pre-McNamara systems development.

Cold War-era weapons systems developments had a strong resemblance to agile, time-fixed execution as depicted in figure 19 for the B-52, with data drawn from historical sources,[123],[124] which demonstrates that rapid serial incrementalism can conquer technical difficulties, improve the operational outcome, and enable adaptability on industrial (vice tactical) timescales.

The design of what became the B-52 evolved dramatically in the years immediately following World War II, as the Air Force's concept shifted from a bigger version of the B-29 to being heavily influenced by the success of the B-47, the rise of the jet age, and shifting threats in Asia. Boeing's need for a stable defense acquisition program accommodated these shifting sands, and the company repeatedly updated its design (upper left). The weapons systems performance parameters varied widely across thirteen design iterations, with thrust increasing by a factor of four over this period (upper right). Ten base versions were produced, with design for the next proceeding even while the prior version was still in production. The missions also varied—from low altitude to high attitude—with structural redesign to suit. Production was simultaneous across two factories in Washington and Kansas and, except for the B-52G, ran less than a year for each version. The short production runs reflected flaws in the early versions' designs. The XB-52 design was so troubled that it didn't get airborne until after the next version—the YB-52. The B-52A provided so little operational value that it was retired a mere four years after introduction. But, by the time the B-52H version arrived, the design had iterated and evolved into a robust vehicle with the longest planned service life of any military aircraft (through 2044).

None of that remarkable history was predicted when XB-52 design began in 1950, and there were no Congressional hearings on the Air Forces' failure to settle on the requirements for their bomber. The history of the B-52 can foreshadow a radically different future for US defense acquisition, where we focus less on performance against prediction, and more on the speed of capability delivery and learning. This approach presents a path to reverse the Chinese advantage in systems fielding timelines, and a scheme to continuously force their hand and expenses in responding to a breadth of fast-paced US developments.

Figure 19: Learning from the B-52's development methodology



The B-52's development methodology resembles agile development and iterative approaches.

Figure Source: Report Authors, Data Source: Marcelle Size Knaack, "Post-World War II Bombers," Office of Air Force History, 1988 and Peter Bowers, "Boeing B-52A/H Stratofortress, Aircraft in Profile," Volume 13, Profile Publications Ltd., 1973.

Acquisition processes, and recent toolsets like the middle tier of acquisition or software acquisition pathway can help improve the speed of development and enable more iterative models that don't hew to a fixed baseline. However, to address lengthy decision timelines that fundamentally limit adaptability, the PPBE must be revisited. The lynchpin in a competition with an adaptive adversary is not larger budgets or planning larger sustainment tails and more capacity, but returning to many iterative developments, and inserting uncertainty and complexity into adversary planning to drive the tempo of the competition with rapid decision-making. Put simply, we need a more flexible programming and budgeting model that prioritizes delivery of operational capability and permits hedging and learning.

Emerging Resource Allocation Concepts

The correlation of increasing innovation timelines and the implementation of the McNamara institutional era makes it clear that trying harder is not enough to create adaptability. Adjustments to processes are needed. Many efforts have been launched on acquisition reform, most recently those that led to the Adaptive Acquisition Framework. However, even the middle-tier system that permits bypassing the conventional requirements process does not address the high friction associated with starting new efforts. To address this, we must turn to the PPBE.

This paper is not the first to suggest that US resource allocation processes should be revisited, but the task of reforming the

PPBE, the foundational undergirding of the bureaucracy, is so daunting that it has never been seriously attempted. Eric Lofgren has compiled a list of more than forty political and DoD leaders who have called for some sort of reform.[125] There is an academic field associated with mechanisms of public budgeting,[126] as well as movements associated with more fluid systems for commercial budgeting.[127] Some concepts for DoD resource allocation are contrasted below, including several new alternatives.

Program Budgeting

This is the current budgeting model. The PPBE implements program budgeting, a form of output-based budgeting, where the atomic unit of budgeting for capabilities is a program element (PE). The concept for this model is that top-level leadership establishes desired weapon system programs and their associated outputs and performance characteristics. A lower-level organization (typically a program office) is assigned ownership of this program element and executes to try to meet the plan put forth in the budget document.

The motivations for and downsides of this model are well documented;[128] prominent downsides include its dependence on long-term predictions, lengthy time for starting a new program, and the difficulties of changing the resources allocated to a particular program. This model was also structured around program elements as major platforms, and has unfortunate seams for concepts like interoperability, which belongs to no single service and does not fit neatly into the model of a program element.

Portfolio Budgeting: Capabilities

The simplest modification to program budgeting that might improve adaptability is budgeting around capability buckets, where similar systems are agglomerated into a portfolio. For example, all fighter aircraft might be grouped together into a portfolio element (PE) in the budget, which essentially permits the portfolio owner (potentially Air Combat Command for the Air Force) to shift funds more fluidly between efforts without obtaining new-start authorization. Portfolios could be structured in any number of ways but are most likely aligned with a single owning organization. In certain instances, like the Missile Defense Agency, this might involve equities that were previously considered the purview of an individual service.

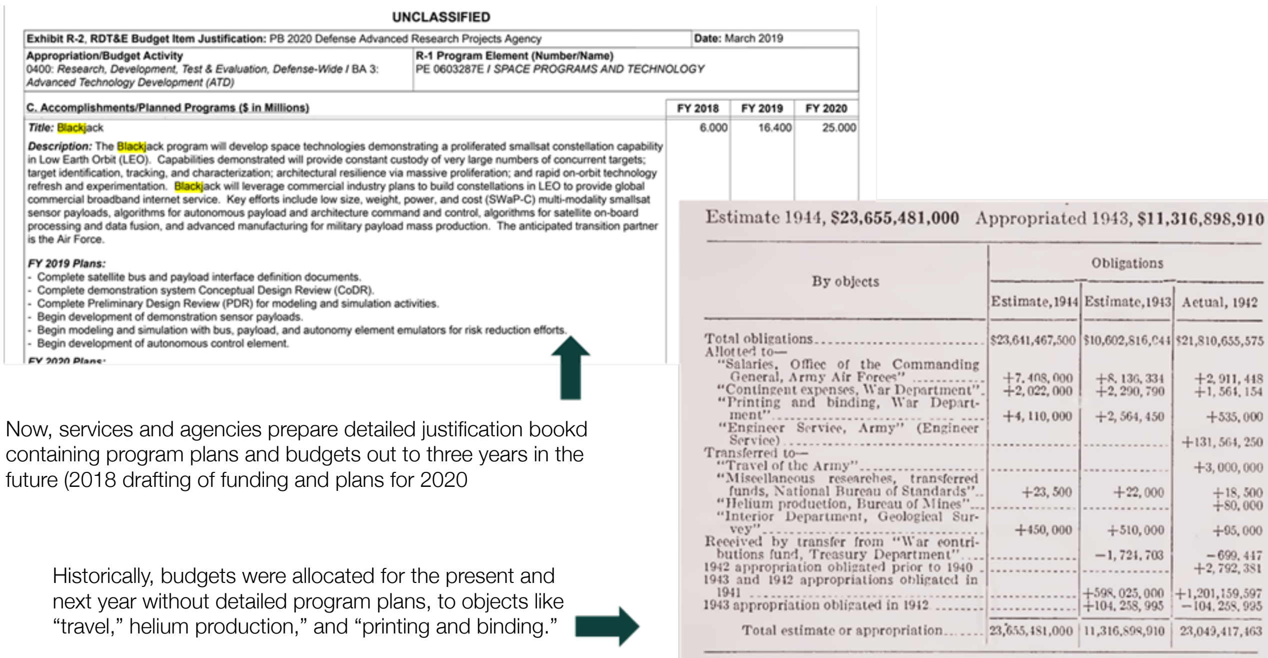
The downsides of this model include the fact that it may be more difficult for Congress to exercise detailed control over individual programs. In other words, only Congress successfully wields portfolio management tools today. For example, in the 116th Congress, appropriators eliminated 13 percent of funding from the Air Forces Next Generation Air Dominance research and development account and shifted funds to capacity buys for the legacy F-35A of twelve beyond what the Air Force requested, making the decision that capacity is more important to the strategic posture of the United States than capability.

Additionally, portfolio budgets tend to group like capabilities with like capabilities, and are unlikely to resolve the fact that concepts like cross-service, cross-portfolio command and control and interoperability, while judged by the Joint Chiefs of Staff as essential to future military operations, do not fit neatly into any single portfolio. Grouping like systems with like systems (e.g., missiles) together also groups together items that may have common strengths and weaknesses, and may not encourage a diversity of options to be developed to shape adversary behavior. The dimension of linearly conceived budget activities (codes 6.1, 6.2, etc.) is also anathema to modern iterative development that combines multiple activities into a continuous stream.

Portfolio Budgeting: Organizations

The atomic unit of the budget can, of course, be anything. It does not have to be a program. Indeed, this point is well illustrated by examining historical defense budgets, as illustrated in figure 20, which shows a 1944 budget with adjacent line items of travel, helium production, and printing and binding.

Figure 20: Budget request documents – 1944 and now



UNCLASSIFIED

Exhibit R-2, RDT&E Budget Item Justification: PB 2020 Defense Advanced Research Projects Agency	Date: March 2019
Appropriation/Budget Activity 0400: *Research, Development, Test & Evaluation, Defense-Wide* / BA 3: *Advanced Technology Development (ATD)*	R-1 Program Element (Number/Name) PE 0603287E / *SPACE PROGRAMS AND TECHNOLOGY*

C. Accomplishments/Planned Programs ($ in Millions)	FY 2018	FY 2019	FY 2020
Title: Blackjack	6.000	16.400	25.000

Description: The Blackjack program will develop space technologies demonstrating a proliferated smallsat constellation capability in Low Earth Orbit (LEO). Capabilities demonstrated will provide constant custody of very large numbers of concurrent targets; target identification, tracking, and characterization; architectural resilience via massive proliferation; and rapid on-orbit technology refresh and experimentation. Blackjack will leverage commercial industry plans to build constellations in LEO to provide global commercial broadband internet service. Key efforts include low size, weight, power, and cost (SWaP-C) multi-modality smallsat sensor payloads, algorithms for autonomous payload and architecture command and control, algorithms for satellite on-board processing and data fusion, and advanced manufacturing for military payload mass production. The anticipated transition partner is the Air Force.

FY 2019 Plans:
- Complete satellite bus and payload interface definition documents.
- Complete demonstration system Conceptual Design Review (CoDR).
- Complete Preliminary Design Review (PDR) for modeling and simulation activities.
- Begin development of demonstration sensor payloads.
- Begin modeling and simulation with bus, payload, and autonomy element emulators for risk reduction efforts.
- Begin development of autonomous control element.

FY 2020 Plans:

Estimate 1944, **$23,655,481,000** Appropriated 1943, **$11,316,898,910**

By objects	Obligations		
	Estimate, 1944	Estimate, 1943	Actual, 1942
Total obligations	$23,641,467,500	$10,602,816,044	$21,810,655,575
Allotted to—			
"Salaries, Office of the Commanding General, Army Air Forces"	+7,408,000	+8,136,334	+2,911,448
"Contingent expenses, War Department"	+2,022,000	+2,290,790	+1,561,154
"Printing and binding, War Department"	+4,110,000	+2,564,450	+535,000
"Engineer Service, Army" (Engineer Service)			+131,564,250
Transferred to—			
"Travel of the Army"			+3,000,000
"Miscellaneous researches, transferred funds, National Bureau of Standards"	+23,500	+22,000	+18,500
"Helium production, Bureau of Mines"			+80,000
"Interior Department, Geological Survey"	+450,000	+510,000	+95,000
Received by transfer from "War contributions fund, Treasury Department"		−1,721,703	−699,447
1942 appropriation obligated prior to 1940			+2,792,381
1943 and 1942 appropriations obligated in 1941		+598,025,000	+1,201,159,597
1943 appropriation obligated in 1942		+104,258,995	−104,258,995
Total estimate or appropriation	23,655,481,000	11,316,898,910	23,049,417,463

The contrast between a modern budget justification document and detailed program milestones and a 1944 budget request, with an eclectic mix of budget line items, is stark.

Figure Source: Report Authors, Data Source: Historic Defense Bills

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If a budget is to align the control and execution authority with an outcome, it may make sense to use an organization-focused budgeting model. In this element, the atomic unit of the budget is the organizational element (OE), which might be associated with a service capability specialty (the Bureau of Ships), a Combatant Command need (Southern Command Drug Interdiction), or even a particularly large joint program (like the F-35).

This shifts Congress' oversight role into holding the leadership of an organization accountable for their progress, plans, and delivered outcomes. This would also tend to align Congress' initiatives in addressing organizational reform with the resources to accomplish the associated objectives.

The downsides of this model would likely again relate to seams. The charter of existing organizations might not map to strategic or operational needs (e.g., no organization may align with countering China's Second Artillery Force), and rapidly reconfiguring organizations brings numerous problems.

Mission Budgeting: Attacking the Seams

An alternative concept designed to attack the seams of joint warfighting capability is mission-focused budgeting. Mission-focused budgeting can be thought of as an overlay on top of program- or portfolio-based budgeting. The program, portfolio, or organizational owner associated with their budget line item would be responsible for the continued control and execution of their budget line item. Simultaneously, a mission element (ME) would be associated with a critical operational problem that has a specific geopolitical context (e.g., ensuring freedom of navigation in the Taiwan straits) and would most typically be associated with a combatant command.

The mission element owner would use assigned funding to make modifications to existing programs, drive experimentation, create software and interoperability capabilities in order to advance progress against the operational challenge. The mission element owner would not be responsible for the performance of a constituent program (e.g., the F-35), but would be responsible for the immediate relevance of that system for the mission of interest (e.g., freedom of navigation), potentially investing in items like adaptive electronic warfare capabilities, satellite communications, and an airframe for theater experimentation. The mission element concept splits the concepts of program control and facilitating mission outcomes. It allows the DoD and Congress to invest in both, and benefit from the learnings of either.

The mission budgeting concept is likely the easiest idea to implement, as it is not a holistic architecture of the PPBE, and broad Congressional and DoD support for making progress against critical operational challenges should be possible to muster.

The downsides of this model are that it is only realistic with a small number of high-priority missions, and that it cannot map or scale across the entire DoD. Congressional oversight would also have to be adjusted to focus on desired strategic objectives and operational outcomes instead of only program performance.

Dynamic Budgeting: Thinking in Investments

Another concept would break apart elements of planning, programming, and execution using a concept derived from the commercial investment world. The venture capital investment model revolves around a broad set of limited partners (LPs), typically pension funds or corporations, choosing to invest funds with one or more venture capitalists (VCs). The VCs, in turn, invest LP funding into a portfolio of companies, typically organized around a thesis. The limited partners make longer timescale, slower, investments, while the venture capitalists are intimately involved with individual companies, offer guidance and redirection, and are quick to terminate or increase funding. In essence, LPs invest on the basis of trust of the VCs and the VC investment thesis, as part of a larger LP portfolio. VCs invest in companies to pursue their thesis, and make funding decisions with the VC's interest and trusted relationship in mind. Their future funds depend on their delivered results. This concept separates timescales and also responsibilities between LP and VC investors.

In a defense model, Congress would act as limited partners, investing taxpayer funds with trusted agents that are a part of the Department of Defense, and would likely be arranged around key theses. A number of trusted agent organizations (including, for example CAPE, but preferably including others from each service) would accept LP investment and act as VCs, creating investment portfolios in diverse operational concepts and technical capabilities, and dynamically assign funding according to their thesis.

Oversight would function in a distributed manner. The trusted agent would have primary responsibility to ensure that funds were being used responsibly. Congress would conduct its oversight with the trusted agent, and base future funding on the results and relationship. The dynamic budgeting model would probably best be implemented alongside a legacy program-centric model that permits lengthy developments like submarine hull and machinery.

The advantage of this model is that it is highly conducive to rapid decision-making and adaptability. The disadvantage of this model is that it is a dramatic departure from current processes, and would likely be a difficult organizational and cultural transition.

Hybrid Models

The authors plan future research around the concepts outlined above, among others, exploring the implications of each model. An initial hypothesis would be that the most appropriate budgeting model for the DoD would be a hybrid of these, choosing the right planning, programming, and oversight mechanism for the matter at hand. There is likely no one best way.

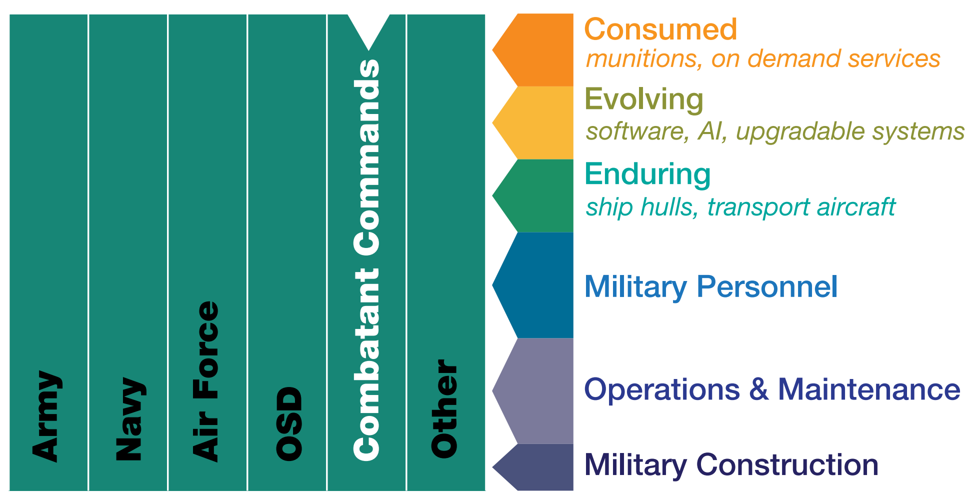
At the same time, they believe that Congress and the DoD should immediately begin work on a mission budgeting pilot around one or two pressing operational challenges as determined by the Joint Chiefs of Staff, or as derived from the National Defense Strategy. This concept has sufficient strategic imperative and is sufficiently undisruptive to implement to merit immediate consideration. At the same time, we recommend that Congress or the DoD form a commission of expert stakeholders to more fully study the range of potential options and formulate recommendations for holistic change to the DoD's resource allocation processes with an eye to adaptability in long-term strategic competition.

Revisiting the Cube

Another idea, complementary to those proposed above, is to reconsider the current three-dimensional cube-like division of the defense budget illustrated in figure 1. The dimensions were originally conceived of as an accounting system before the advent of modern information systems capable of producing real-time analysis.

In her analysis of DoD processes, Susanna Blume suggested revisiting the cube structure, noting that the PPBE process "drives results that are heavily biased toward the status quo and make it very difficult to adapt spending plans to changes in the threat environment or to changes within a given weapons system program."[129]

Figure 21: An alternative budget structure



Updated budget justification and real-time reporting could promote accountability and accompany a simplified and improved budget structure. Updated budget element descriptions presented for congressional approval could include real-time analytic insights into status, metrics, and learning.

Figure Source: Report Authors

There are incidental effects of the choice of structure on the DoD's flexibility. For example, the appropriations titles are categorized by the phase of a weapon system life cycle, which limits pace of development by forcing DoD and congressional approval of any advance. An alternative categorization would "realign appropriations titles to reflect the kind of life cycle a weapons system has, allowing a weapons system to remain in the same title throughout its life cycle, providing the department with additional flexibility" to field faster.

The major force programs could largely be eliminated and replaced by reporting and accounting insights. The effect would not be to eliminate funding for general purpose forces or strategic forces, but simply permit more flexible rollups and accounting that the static major force program categorization. The United States Special Operations Command's use of its special major force program to augment the equipment provided the Services could be generalized to other Combatant Commands through adding a Combatant Command, in recognition of the fact that Combatant Commands often have unique, joint needs not always directly met by general purpose equipment fielded by the Services.

Conclusion

Several conclusions can be drawn from the preceding review and analysis:

- Time of military capability development and fielding (new capability development cycle) is a significant factor in long-term strategic competition, enabling faster learning and faster shifts in more directions. It is critical both for adaptation of dynamic technology sets and also for implementing optionality strategies. Over a sufficiently long time horizon, innovation time is ultimately more important than set performance specifications for weapon systems.
- Time metrics of all types have increased for the development of tangible weapon systems from the post-World War II era. The metric of time-to-market (contract award through operational capability) for new-start systems has increased by a factor of four for aircraft and two for ship hull and machinery from 1970 to 2020. Measures of only interior acquisition milestones (B or C) have increased by less, especially when also considering weapon system modifications.
- The decision cycle time, which extends from the identification of need or possible capability until contract award, has increased substantially from 1950 from around one year to seven years. This is paced largely by the requirements and budgeting processes.
- The time from first test of a weapon systems to through its initial operational capability has increased substantially.
- Chinese weapons developments indicate more iterative development approaches as well as the ability to rapidly launch a series of fielded systems. Their processes may favor adaptive advantage, although this area needs further study.
- The linear prediction-centric processes of the McNamara era have a substantial lengthening effect on innovation time cycles. Alternative budgeting and development processes that emphasize adaptability over stability are feasible, as demonstrated in the historical record.

The public management framework used to guide and oversee US defense innovation since the 1960s has deemphasized the significance of time as an incentive to invention while emphasizing values such as cost, technology maturity, fairness, and perceived efficiency. As a result of an excessive focus on linear implementation of this management framework and compliance with processes to ensure these values, system development time increased and time-based constraints to innovation were lost, and the US ability to adapt has been damaged. Time was relegated in the predictive cost analysis worldview as a schedule issue that could be measured as an engineering and cost estimation problem, not as the ultimate driver of adaptable innovation. Time to development and deployment ultimately increased to adapt to the length of linear management processes that collectively make it impossible to innovate in the time spans of the 1940s and 1950s. These conclusions call for a reevaluation of the defense management regimes and the DoD's core institutional processes and a reconsideration of the criteria used in guiding and evaluating successful defense innovation.

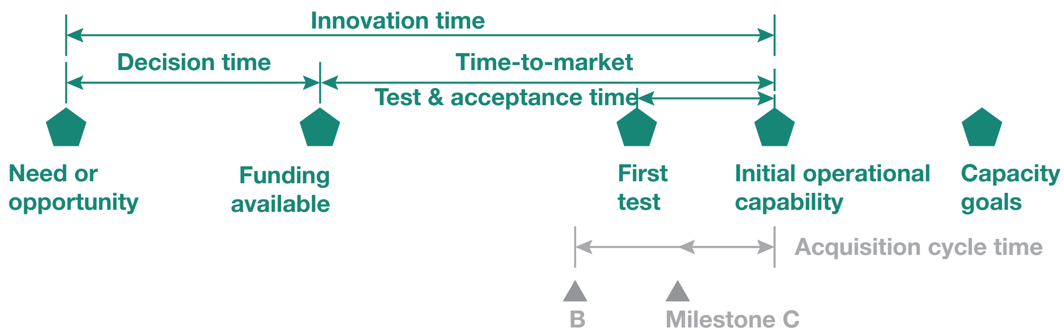
Recommendations

This paper makes three recommendations:

- Congress and the DoD should cooperate to promptly launch a limited-scope pilot project on an alternative resource allocation process, designed to foster adaptability in capability delivery and aligned around a high-priority national security operational challenge. Other pilots should also be considered.
- In parallel with one or more budget pilots, Congress or the DoD should sponsor a commission to study holistic changes to the Planning, Programming, Budget, and Execution (PPBE) and appropriations process structured to ensure that the US has a competitive advantage in long-term competition while maintaining Congress' constitutional role. This commission should include expert members with an understanding of current equities and limitations, and explore emerging concepts potentially including portfolio, organization, mission, and trusted-agent budgeting. This commission may extend its scope to cover critical capability timeline drivers including contracting and early investment decisions that also touch upon adaptability.
- The policy and research community should conduct comparative analyses of the bureaucratic research allocation processes between the US and China, especially focusing on the early decision-making processes associated with starting investments in new military capability and strategic priority setting.

APPENDIX A: DEFINITIONS

Figure 22: The cycle time to deliver innovations to operational usage encompasses more than just acquisition processes



The contract award associated with the effort is intented to lead to operational capability.

Source: Report Authors

Innovation time: The full time elapsed from the identification of an opportunity or need to the first introduction of an associated operational capability. This is the time cycle of principal interest for this paper, and also the most difficult to measure.

Time-to-market: The portion of innovation time associated with the producing partner or industrial base. This time cycle is measured from the first contract award or other approval to spend funds to the initial operational capability or first use by the end-user. This metric is easier to measure and an important parameter for defense innovation.

Decision time: The portion of innovation time that occurs before time-to-market (defined such that the sum of decision time and time-to-market is always innovation time). This period captures the time elapsed from the early identification of opportunity or need through the first contract or funding action to the industrial partner. Notably, this time period includes any planning, budgetary actions, and requirements documentation. Decision time has received much less study than acquisition cycle time.

Test and acceptance time: The portion of time that elapses between the first test of a system intended for operational use and its acceptance for operational use. This is typically associated with operational test and evaluation processes, and other procedures used to match measured system performance with desired specifications. This is called out as a separate sub-element of innovation time because of the availability of data and also notable increases in time.

Acquisition cycle time: A metric that measures the timing of an acquisition program through milestones (typically between a start of Milestone B or C and declared operational capability). This is frequently used by other studies of the performance of the acquisition system, but is of less interest to the current paper, which is focused on the strategic implications of the pace of capability delivery. Acquisition cycle time is usually the latter portion of innovation time, and does not reflect many elements of defense capability development, including early studies, conceptual design, concept refinement, industry prototyping, and identification of need.

APPENDIX B: ABBREVIATIONS

ASPR	Armed Services Procurement Regulations, in effect from 1948 to 1978
CAPE	Cost Assessment and Program Evaluation office, originally Systems Analysis
COVID-19	Coronavirus disease of 2019
CMC	Central Military Commission
CR	Continuing resolution
CSIS	The Center for Strategic and International Studies
DARPA	The Defense Advanced Research Projects Agency
DFAR	Defense Federal Acquisition Regulation
DoD	The Department of Defense
DPC	Defense Pricing & Contracting, formerly Defense Procurement & Acquisition Policy
DSB	The Defense Science Board
FAR	Federal Acquisition Regulations
FY	Fiscal Year, from October through September.
GAO	Government Accountability Office
GH	Global Hawk
GLD	General Logistics Department
ICBM	Intercontinental ballistic missile
ICD	Initial Capabilities Document
IG	Inspector General
IOC	Initial Operational Capability
JCIDS	Joint Capabilities Integration and Development System
LHX	Light Helicopter eXperimental; LHX-A: attack, LHX-U: utility
LRIP	Low Rate Initial Production
LUH	Light Utility Helicopter
MDAP	Major defense acquisition program
MIL-STD	Military Standard
MRAP	Mine Resistant Ambush Protected Vehicles
NPC	National People's Congress
OSD	Office of the Secretary of Defense
PALT	Procurement Administrative Lead Time
POM	Program Objective Memorandum
PPBE	The Planning, Programing, Budget, and Execution (PPBE) process
PPBS	The Planning, Programming, and Budgeting System (PPBS)
RAF	Royal Air Force
RAND	The RAND Corporation ("research and development")
RDTE	Research, Development, Test, and Evaluation
SAR	Selected Acquisition Reports
SCO	The Strategic Capabilities Office in OSD
SLOC	Software Lines of Code
WSARA	Weapon Systems Acquisition Reform Act of 2009
X-Plane	Traditional designator for experimental aircraft
Y-Plane	Traditional designator for prototype aircraft

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Notes

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