ABSTRACT

Title of Dissertation: THE IMPACT OF PUBLIC MANAGEMENT REGIMES ON TIME-BASED DEFENSE INNOVATION

William C. Greenwalt, Doctor of Philosophy, 2021

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Time was a significant factor in shaping disruptive defense innovation solutions in World War II and the early Cold War. During this period, significant advances were made in military aircraft, missiles, submarines, electronics, and other technologies that were achieved through a time-based development approach of rapid experimentation and operational prototyping. Since the 1960s, however, the time taken to develop and deploy U.S. military systems has significantly increased. This increase corresponded to a shift in emphasis within the public management regimes established to govern defense innovation to one of predominately controlling cost.

A systems analysis approach to defense management gained prominence during the Kennedy Administration and emphasized cost analysis, program budgeting, and centralized planning and control from within the Office of the

Secretary of Defense as a means to obtain greater efficiency in defense spending. This framework was implemented through a series of linear processes overseen by compartmented management regimes such as the requirements, budget, acquisition, and contracting functions in a structure institutionalized in law and regulation. These linear processes evolved in a way that increased the minimum time to conduct defense innovation that far exceeded previous developmental timelines.

Compounding the problem of linearity, government-unique processes and requirements within defense management regimes have created barriers to the civil-military integration of the industrial base. This has furthered the establishment of a narrow, specialized defense industrial base by excluding from the defense market those commercial companies that innovate quickly within time-based constraints.

While periodic end-rounds to management regimes were created when the Department needed to rapidly innovate in an emergency or to access innovation from the larger commercial market, these efforts have been at the margins of expenditures and were eventually constrained by the traditional management regimes. A broader ability to reduce innovation times or expand the defense industrial base will require systematic change to address process linearity and civil-military integration barriers.

THE IMPACT OF PUBLIC MANAGEMENT REGIMES ON TIME-BASED DEFENSE INNOVATION

by

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Dissertation submitted to the Faculty of the Graduate School of the University of Maryland, College Park, in partial fulfillment of the requirements for the degree of Doctor of Philosophy
2021

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Acknowledgements

I first want to acknowledge the inspiration and impact that the late Dr. Jacques Gansler had on this effort. I would not have embarked on this journey without his support and encouragement. This began one day at an acquisition conference over a decade ago where we were both speaking on a panel on acquisition reform – a perennial topic in Washington, DC defense policy circles. He was there in his role as a former Undersecretary of Defense and professor from the University of Maryland, and I was then a Deputy Undersecretary of Defense. After the panel discussion, I told him that I regretted never having earned a PhD. He brushed off my apprehensions about my "advanced" age approaching 50, and after his relentless persuasion, a few years later I found myself studying under him at the University. I am truly sorry that he was unable to see the completion of this product, but it reflects his guidance and suggestions. As for any mistakes, they are all my own.

Another individual who has cast his shadow over this research is the late Senator John McCain. In 2015, I had just completed my PhD coursework and drafted my initial dissertation ideas, which were published in a think tank report, when the Senator gave me the opportunity to return to the Senate Armed Services Committee and put these research ideas into practice. While that detour set me back several years in writing my dissertation, I am extremely grateful for the experience of working for such a visionary leader as Senator McCain. The initial conclusions and recommendations for my original research are now in law as a result. While I had to subsequently pivot in a different academic direction, the ability to analyze policy issues and then put them into practice is not always possible and I am grateful to have had that opportunity.

In addition, this effort would not have been completed without all the policy experts, military members, business leaders, entrepreneurs, politicians, and senior officials I was fortunate to work with and learn from over the course of my career. So many outstanding men and women serve our country in both the public and private sectors and have dedicated their lives to delivering the best equipment to our soldiers, sailors, airmen, and marines. My hope is that, in some small way, my research efforts will make it easier for them to do so.

I also want to thank Professor Philip Joyce for assuming the role of my advisor when Dr. Gansler became unable to continue. While Dr. Gansler inspired me to begin, completion of this project is due largely to Dr. Joyce's encouragement and guidance. I also greatly appreciate the support of the other members of my dissertation committee and particularly, Bill Lucyshyn who has been a part of this effort since the beginning.

My wife, Paula Mathews, is definitely due a shout-out for putting up with my many complaints about taking on this project later in life while I balanced it against an active professional life. I also appreciate her editorial help in reviewing and fine-tuning some of my prose. I must also thank the time-based academic constraints of an enforced deadline, which means my son, Geoffrey, and daughter, Jenna, will no longer be able to shame me by threatening to obtain their own PhDs before I completed mine. Finally, I must recognize my mother, Shirley Greenwalt, who

instilled in me a desire to never stop learning and always wanted to see me complete a PhD program.

Since the mid-1980s, I have been on the periphery and sometimes at the center of many of the events described in the following pages. This began with my first forays into government acquisition at the Government Accountability Office (GAO) while evaluating projects at Air Force Space Division in Los Angeles during the time of the Packard Commission. I then moved to Washington, D.C. to work for Senator Cohen to help him write and pass the Clinger-Cohen Act and the Federal Acquisition Streamlining Act. As an aide to Senator John Warner and in close partnership with my colleague Peter Levine from Senator Levin's staff, we worked on most of the management reform legislation that arose during the late 1990s and mid-2000s. I learned much about the workings of the legislative process from both Peter and Jon Etherton, my predecessor on the Senate Armed Services Committee. I then had the privilege to serve at the Pentagon under Secretary of Defense Gates where my most rewarding task was working with the industrial base to clear the way for the rapid production of Mine Resistant Ambush Protective (MRAP) vehicles that ultimately saved so many lives in Iraq and Afghanistan. Since then, I have focused on removing barriers to firms with new innovative technologies that are attempting to enter the defense market. Throughout my career, my arguments did not always carry the day, but no matter how heated the policy battle was I knew that those on the other side of a debate shared my ultimate goal of better serving and protecting the men and women of the U.S. armed services.

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AAF	Adaptative Acquisition Framework
ACTD	Advanced Concept Technology Demonstration
CAPE	Cost Analysis and Program Evaluation
CAS	Cost Accounting Standards
CMI	Civil Military Integration
COTS	Commercial Off the Shelf
CTIB	Commercial Technology and Industrial Base
DAPA	Defense Acquisition Performance Assessment
DARPA	Defense Advanced Research Projects Agency
DOD	Department of Defense
DPA	Defense Production Act
DSB	Defense Science Board
DSB	Defense Science Board
DTIB	Defense Technology and Industrial Base
FAR	Federal Acquisition Regulation
FFRDC	Federally Funded Research and Development Center
GAO	Government Accountability Office/General Accounting Office
GDP	Gross Domestic Product
IDA	Institute for Defense Analysis
IED	Improvised Explosive Device
IOC	Initial Operational Capability

JCIDS	Joint Capabilities Integration and Development System
JDAM	Joint Direct Attack Munition
JROC	Joint Requirements Oversight Council
MDA	Missile Defense Agency
MDAP	Major Defense Acquisition Program
MRAP	Mine-Resistant Ambush Protected Vehicle
NASA	National Aeronautics and Space Agency
NDAA	National Defense Authorization Act
NDS	National Defense Strategy
NTIB	National Technology and Industrial Base
OTA	Other Transaction Authority
PPBE	Planning, Programming, Budget, Execution
PPBS	Planning, Programming, Budget System
R&D	Research and Development
RDTE	Research, Development, Test, and Evaluation
RFP	Request for Proposal
SAR	Selected Acquisition Report
SBIR	Small Business Innovative Research
SDIO	Strategic Defense Initiative Organization
SLOC	Source Lines of Code
STEM	Science, Technology, Engineering, and Mathematics
UAV	Unmanned Aerial Vehicle
VC	Venture Capital

Chapter 1: Introduction

Sed fugit interea, fugit inreparabile tempus
"But time is lost, which never will renew" Virgil

The relationship between time, defense innovation, and the institutions responsible for such innovation is a misunderstood and unappreciated aspect of national security policy. For an individual, time is a non-renewable resource. There is only so much time in a day, week, month, year, or a life to complete the tasks we individually deem important. For an institution like the Pentagon or a corporation, there is no certainty of finality. If and when such an end may arrive, whether through reorganization, merger, defeat, or collapse, the life of an institution often exceeds that of any one individual. The institution is larger and seemingly more permanent than the sum of the individuals that support it with a portion of their life's energy. This has benefits as well as costs, as the importance of time or the urgency of a mission can sometimes be set aside to address other values that may arise, particularly if there is no near-term compelling existential threat to the institution that forces it to take other action. Management regimes within institutions are formed to implement and optimize processes to correspond to these values. Process may ultimately undermine time.

Time intersects with the institutions that are responsible for defense innovation in much the same way. The primary purpose of national defense institutions is to prepare for threats by training and equipping armed forces, which then can, if necessary, fight and win a nation's wars or conflicts. Yet there are periods when other competing factors and values deemed more important by Congress or an Administration come to prominence. In intervals when an existential threat is lacking, it is easier for these other matters to fill the vacuum of time and weaken the ability to respond once time becomes important again. This does not happen overnight and occurs through slow incremental changes in the way things are done. The discounting of the importance of time in these endeavors can slowly limit options. Decades of neglect make it even more difficult to respond differently or effectively.

This may be one of those periods. The future course of U.S. defense innovation appears to be at an inflection point. Concerns about an emerging great power competition is setting the stage to overturn what has been in essence a hiatus in large-scale defense innovation of over three decades. The end of the Cold War encouraged the U.S. and its allies to achieve a "peace dividend" through the taking of a "procurement holiday" that corresponded with a drawdown of forces in Europe. These last three decades could also be described as one in which the U.S. was able to take an innovation holiday, as there was little demand for new disruptive defense innovation.

As U.S. defense policy shifts its attention to China and, to a lesser extent Iran, North Korea, and a revanchist Russia, the ability to innovate and deliver new defense capabilities to U.S. forces similar to historical "Great Power" conflict periods such as World War II and the Cold War will become more important in discussions about maintaining future global security and stability. As in these past conflicts and other periods of rising security tension, the quality of defense equipment – and perhaps more importantly – the time to develop such innovative capabilities, will be critical factors in enabling national security success. In a global competition focused on deterrence and perceptions of technological superiority, time will be increasingly of the essence.

The Nature of the U.S. Defense Innovation Problem: Setting the Geopolitical and Technology Development Stage

The urgency to reconsider a nation's approach to innovation (both in its underlying economy and to support national defense priorities) typically comes in response to a threat, generally based on an assessment of changes in the global military and technological balance of power. These changes derive from the current innovation system not providing for technological or economic advantage and causing a country to lag behind other nations. From a national security perspective, how well a country develops and adapts scientific knowledge and technology into military capabilities is a component of deterrence, and, should deterrence fail, a significant basis for success or failure on the battlefield.

Recent trends appear to be moving in the wrong direction for the United States. As China continues to rise economically, there have been no shortage of concerns raised about U.S. economic decline and the competitiveness of the American economy, especially vis a vis China.[1] Closely linked to this belief has been a perception of U.S. military technological decline. The Department of Defense's

[1] U.S. Library of Congress, Congressional Research Service, *China's Economic Rise: History, Trends, Challenges, and Implications for the United States*, by Wayne M. Morrison, RL33534, 2019.

(DOD) concerns about the potential loss of technological superiority led to calls for a new "Third Offset Strategy" and the establishment of the Defense Innovation Initiative in 2014.[2] The offset strategy concept referred to two previous periods of intense U.S. defense technological innovation. The first occurred in the 1950s and saw the development of new long-range missile and space reconnaissance technologies. The second, in the 1970s, initiated advancements in stealth, precision guidance, and geolocation. A Third Offset was advocated that would take advantage of emerging, primarily commercially developed, technologies to counter China and Russia.

Former Secretary of Defense Chuck Hagel on the announcement of this strategy addressed trends in U.S. military technological superiority:

> "That superiority has never been guaranteed, and today it is being increasingly challenged. Technologies and weapons that were once the exclusive province of advanced nations have become available to a broad range of militaries and non-state actors, from dangerously provocative North Korea to terrorist organizations like Al Qaeda and Hezbollah – all clear threats to the United States and its allies.
>
> And while we spent over a decade focused on grinding stability operations, countries like Russia and China have been heavily investing in military modernization programs to blunt our military's technological edge, fielding advanced aircraft, submarines, and both longer range and more accurate missiles. They're also developing new anti-ship and air-to-air missiles, counter-space, cyber, electronic warfare, undersea, and air attack capabilities."[3]

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[2] "Defense Innovation Days" Opening Keynote (Southeastern New England Defense Industry Alliance), September 3, 2014, as Delivered by Secretary of Defense Secretary of Defense Chuck Hagel Newport, Rhode Island.

[3] Reagan National Defense Forum Keynote, November 15, 2014. as Delivered by Secretary of Defense Secretary of Defense Chuck Hagel, Ronald Reagan Presidential Library, Simi Valley, California.

The Senate report accompanying the National Defense Authorization Act (NDAA) for Fiscal Year 2016 summed up the challenge of how the Senate and Secretary Hagel's immediate successors were viewing the problem.

> "Still, the committee's primary concern with the acquisition system is that reform is now needed for national security reasons to maintain technological and military dominance. An inadequate acquisition system is leading to the erosion of America's defense technological advantage, which the United States will lose altogether if the Department continues with business as usual. The Undersecretary of Defense for Acquisition, Technology and Logistics stated recently: "We've been complacent. Our technological superiority is very much at risk, there are people designing systems [specifically] to defeat us in a very thoughtful and strategic way, and we've got to wake up, frankly."
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> Global R&D is now more than twice that of the United States. Chinese R&D levels are projected to surpass the United States in 2022. Even when the Department is innovating, it is moving too slowly. Innovation is measured in 18-month cycles in the commercial market while the Department acquisition cycles are measured in decades. At a recent speech at Stanford University, Secretary Carter stated: ``The same Internet that enables Wikipedia also allows terrorists to learn how to build a bomb. And the same technologies we use to target cruise missiles and jam enemy air defenses can be used against our own forces--and they're now available to the highest bidder. Whether it's the cloud, infrared cameras, or the GPS signals that provide navigation for ride-sharing apps, but also for aircraft carriers and our smart bombs--our reliance on technology has led to real vulnerabilities that our adversaries are eager to exploit."[4]

Ultimately, to address these concerns a new National Security Strategy was signed by the President in 2017[5] and a new National Defense Strategy (NDS) was produced in 2018 by then Secretary of Defense James Mattis. The NDS proclaimed: "Today, we are emerging from a period of strategic atrophy, aware that our

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[4] U.S. Congress, Senate, Committee on Armed Services, *National Defense Authorization Act for Fiscal Year 2016: Report (to Accompany S. 1376)*, 114th Cong., 1st sess., S.Rpt.114-49, p. 164.

[5] United States, President (2017-2020: Trump). *The National Security Strategy of the United States of America*. Washington: White House, 2017.

competitive military advantage has been eroding."[6] This document was significantly different from other strategies published since the end of the Cold War, in that it specifically recognized a distinct threat and outlined new challenges facing the United States in an emerging era of great-power competition. The 2018 National Defense Strategy Commission report mandated by Congress to review the NDS warned that "America's military superiority -- the hard-power backbone of its global influence and national security-- has eroded to a dangerous degree…It might struggle to win, or perhaps lose, a war against China or Russia."[7] In a September 2020 bipartisan report, the House Armed Services Committee continued to reinforce the fact that the gap in military capabilities between the U.S. and the rest of the world was narrowing:

> "The gravity and complexity of threats emerging to challenge the United States is proliferating as technological advancements in artificial intelligence, quantum information science, and biotechnology transform society and weaponry at an exponential rate. This is occurring as adversarial capability is increasing to the point where the United States may soon lose the competitive military advantage it has enjoyed for decades."[8]

The rise of these new threats has generated the need to create new military capabilities to address them. Unease about the quality of U.S. defense innovation has been growing for decades, but has become compelling as more evidence confirms the beginnings of a Chinese advantage. This shift in the technological balance of power

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[6] United States, Department of Defense. *Summary of the 2018 National Defense Strategy of the United States of America: Sharpening the American Military's Competitive Edge*. Washington, D.C.: Department of Defense, 2018. p.1.

[7] United States, National Defense Strategy Commission, and United States Institute of Peace. *Providing for the Common Defense: The Assessment and Recommendations of the National Defense Strategy Commission*. Washington, DC: United States Institute of Peace, 2018. p. iii-vi.

[8] United States Congress, House of Representatives, Committee on Armed Services, *Future of Defense Task Force Report of 2020*, 116th Cong., 2nd sess., p. 13.

is being demonstrated by the U.S. losing to China in numerous Pentagon war games.[9] While this shift has corresponded with China's growing economy, it has also been enhanced by trends in the commercialization, proliferation, and globalization of technology that have allowed the world to catch up to an unmatched U.S. military technology dominance at the end of the Cold War. These trends portend the beginnings of a shift in the perception of the global balance of power and could have serious ramifications for future deterrence strategies.

China is now a profoundly different potential adversary than the old Soviet Union was, and will likely require a different innovation approach than what was successful in the Cold War against a bureaucratic, statist, and non-market economy that was much smaller than the U.S. As Christian Brose observed:

> "The Soviet Union was powerful, but it was never America's peer. China is becoming America's peer, and it could become more than that. It is integrated into the global economy and developing its own domestic sources of technological development, not just copycat industries but increasingly innovative and world - leading companies. Made in China 2025, issued in 2015, seeks to establish China as a world leader by 2025 in ten high - technology industries, including robotics, aerospace manufacturing, biotechnology, and advanced communications and information technologies, such as 5G networks."[10]

A lesson relearned in the Cold War is that the overarching economy and the defense portion of that economy are closely linked and vitally important to national security. Ultimately, the U.S.-Soviet competition pivoted on which system could support a higher level of defense spending that could be directed to primarily

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[9] See "The Kill Chain" by Christian Brose which described that China has won every war game the U.S. has conducted in the last decade. Christian Brose, *The Kill Chain: Defending American in the Future of High-Tech Warfare,* (New York, Hachette Books, 2020), p. xi-xii.
[10] Ibid. p. 87.

government-sponsored and directed innovation. The Cold War arms race ended with a near Soviet economic collapse. The smaller and less efficient Soviet economy was broken trying to compete with a U.S. arms buildup in the 1980s that was underpinned by a larger, more market-driven economy that could withstand the shift of economic resources to defense.[11] This does not seem likely to happen anytime soon with China. In fact, at some point in the economic competition the U.S. may face the opposite truth and have difficulties budgeting and competing militarily with the types of capabilities an eventually larger Chinese economy could support.

China's military policy during its rise appears to have been shaped by the Soviet experience. Policies were designed to first nurture economic might. State-sponsored capitalism has focused on taking advantage of market incentives while relying on cheaper asymmetric defense technology disruption in the near term. Once economic parity with the U.S. had been achieved, a transition could be made (as what may be now happening) to increase more traditional defense outputs. It appears that Deng Xiaoping's strategy to "hide your strength, bide your time" may be coming to an end.[12]

The economic advantages the U.S. had vis a vis the Soviet Union are not comparable nor relevant with respect to China. China's larger population and

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[11] For a history of the Cold War see and the importance of economics see: John Lewis Gaddis, *The United States and the End of the Cold War: Implications, Reconsiderations, Provocations*. New York: Oxford University Press, 1992; John Lewis Gaddis, *The Cold War: A New History*. New York: Penguin Press, 2005; U.S. Department of State. Office of the Historian, "The Collapse of the Soviet Union" https://history.state.gov/milestones/1989-1992/collapse-soviet-union, accessed December 3, 2020; and Ofer, Gur, Soviet economic growth,1928-1985. Santa Monica, CA: RAND Corporation, 1988.

[12] Tobin Harshaw, "Emperor Xi's China Is Done Biding Its Time" Bloomberg Opinion, March 3, 2018. Deng's often quoted maxim is sometimes linked with Sun Tzu's "Appear weak when you are strong, and strong when you are weak."

economy (while still Leninist-controlled) has adopted market characteristics that have enabled enormous growth in the economy that the Soviet Union was never able to achieve. A future shift in China's state-sponsored capitalist model to a more Soviet-style planning process might offer the U.S. a respite from future competition, but despite some wavering in cultivating economic freedoms, the system still seems to be maintaining its economic output and growth advantages. The U.S. must adjust its innovation policies to try to compete with a potential adversary in the making that has four times the population, many more scientists and engineers, an equivalent sized economy that is growing at a faster rate, and equivalent access to globalized technology advances.[13]

Competing at a great power level today may have been easier if the U.S. had continued to robustly modernize and invest in new disruptive military technologies after the end of the Cold War. Instead, at least initially, defense investment budgets were significantly reduced and these resources shifted to consumer and domestic government spending priorities. While defense spending rose after the events of 9/11, the conflicts in Iraq, Syria, and Afghanistan required a technology development focus on counter insurgency that, while innovative in its own way, was narrower and more limited in scope than what would be required against a near-peer adversary. Rather than look to develop new advanced solutions against more potentially sophisticated adversaries, modernization efforts focused on incrementally upgrading traditional

[13] This daunting math changes when the U.S. combined with its allies in NATO/EU, Australia, Japan and Korea equals China in population and for at least the time being has economic output that is over three times as large, but this only matters if they can learn to work together.

capabilities and legacy platforms while addressing anti-terrorist operations against low-technology adversaries.

Thus, despite spending significant resources on defense over the last two decades, the U.S. allowed its technological dominance as measured against developed nation states to decline. The weapon systems dominance gained from technology developed in the 1970s, produced in the 1980s, and visibly displayed in the Gulf War, was allowed to atrophy as the knowledge of how to build these weapons proliferated. Meanwhile, the U.S. is now at risk of suffering a loss of competitive advantage through, for example, Chinese and Russian development of hypersonic missiles, asymmetric tactics, and the leveraging of new technologies. As the Defence Minister of the United Kingdom recently confirmed, “our enemies have studied our vulnerabilities and adapted far more quickly than us.”[14] Robert Work, the former Deputy Secretary of Defense and architect of the Third Offset strategy said that he regretted talking about the “Third Offset” because “in hindsight, it sounded like we (the U.S.) had an advantage.” On the contrary, as he stated with regard to growing Chinese military might that “this is what it’s like to be offset.”[15] Both adversaries and allies have begun to achieve parity in many defense capabilities, and in some cases may be moving beyond the U.S.[16] This potential reversal of fortunes has been helped

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[14] Helen Warrell, “Defence Secretary Admits UK is Behind Adversaries”, *Financial Times*, September 14, 2020.

[15] Robert Work, June 21 2018 speech at the Center of New America Security annual conference: Strategic Competition: Maintaining the Edge. Quoted in Byron Callan, Capital Alpha Partners “Sweating the Strategic Competition” June 21, 2020.

[16] William Greenwalt, *Leveraging the National Technology Industrial Base to Address Great-Power Competition: The Imperative to Integrate Industrial Capabilities of Close Allies*, Atlantic Council, April 2019. p.8-9.

by technological stagnation and risk aversion in the U.S. government, and by the passage of time.

Perhaps the most significant trend of recent history to call into question U.S. technological dominance is that defense innovation is no longer led by government direction and support as it was at the height of the Cold War. The commercial market has become the leading source of innovation in many areas of relevance to national security.[17] Advances made by Silicon Valley[18] in artificial intelligence, data analytics, robotics, autonomous systems, and quantum computing are at the forefront of recent DOD and other countries' interest in the future applications of these technologies in weapon systems. From an industrial base standpoint, the most innovative sources of these new "enabling technologies" are in the civilian sector, not the defense sector.

The 2018 NDS did not directly mention the concept of the Obama Administration's Third Offset strategy, but there was continuity in the same sustained focus on the need to develop the types of technologies dependent on commercial innovations to meet this new strategy.[19] The NDS identified the technologies of interest to DOD and six out of these eight technologies are being primarily advanced

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[17] National Defense Strategy, p.3; See also: National Security Commission on Artificial Intelligence, 2020 Interim Report; and Michael Horowitz, "Artificial Intelligence, International Competition, and the Balance of Power," *Texas National Security Review*, 1, No. 3, May 2018, p. 41.

[18] While the term "Silicon Valley" is a geographical description of the information-technology hub that grew up in the San Jose/San Francisco corridor in the United States, in this study it will be used to stand-in for the broader innovation culture of nontraditional firms and a venture capital ecosystem that have now planted innovation hubs in many other geographical areas in the United States, and within allied countries.

[19] It also should be recognized that the Obama Administration's strategy was greater than just the Third Offset and included as part of its Defense Innovation Initiative greater outreach to Silicon Valley through the creation of the Defense Innovation Unit Experimental, now called the Defense Innovation Unit.

in the commercial sector. The remaining two have important commercial technology components as well:

> "The security environment is also affected by *rapid technological advancements and the changing character of war.* The drive to develop new technologies is relentless, expanding to more actors with lower barriers of entry, and moving at accelerating speed. New technologies include advanced computing, "big data" analytics, artificial intelligence, autonomy, robotics, directed energy, hypersonics, and biotechnology – the very technologies that ensure we will be able to fight and win the wars of the future. The DOD recognizes that new commercial technologies will change society and, ultimately, the character of war. The fact that many technological developments will come from the commercial sector means that these state competitors and non-state actors will also have access to them, a fact that risks eroding the conventional overmatch to which our Nation has grown accustomed."[20]

A larger list of technologies was released by the U.S. government in 2020 that continued to reflect the importance of new advances in the commercial sector.[21] This list is in some ways similar to but not as comprehensive as the one in China's *Made in 2025* plan, which may be a more useful guide in identifying the commercial technologies that will be the source of future competition between the U.S. and China.[22]

The newfound interest in commercial advances by DOD is merely tracking trends of where the money has been flowing into research and development (R&D) over the last four decades. Recent data shows that three large commercial

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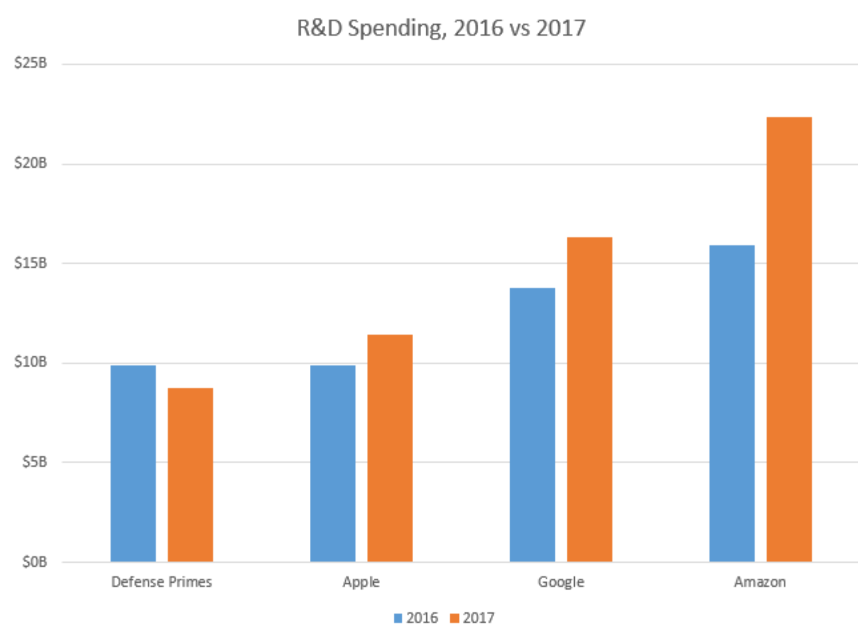
[20] National Defense Strategy, p. 3.

[21] The Critical and Emerging Technologies list reflects the 20 technology areas that United States Government Departments and Agencies identified to the National Security Council staff as priorities for their missions. See: "National Strategy for Critical and Emerging Technologies", The White House October 2020.

[22] See: Congressional Research Service, "Made in China 2025" Industrial Policies: Issues for Congress August 11, 2020; and U.S. Chamber of Commerce, Made in China 2025: Global Ambitions Built on Local Protections, 2017.

information companies – Apple, Google, and Amazon – each now spend more in R&D than the leading prime contractors of the U.S. defense industry combined. These companies were also increasing R&D while the defense industry was cutting back (see Figure 1.1).

Figure 1.1: Top Silicon Valley Firms R&D vs. Traditional Defense Prime Contractors (2016-2017)[23]

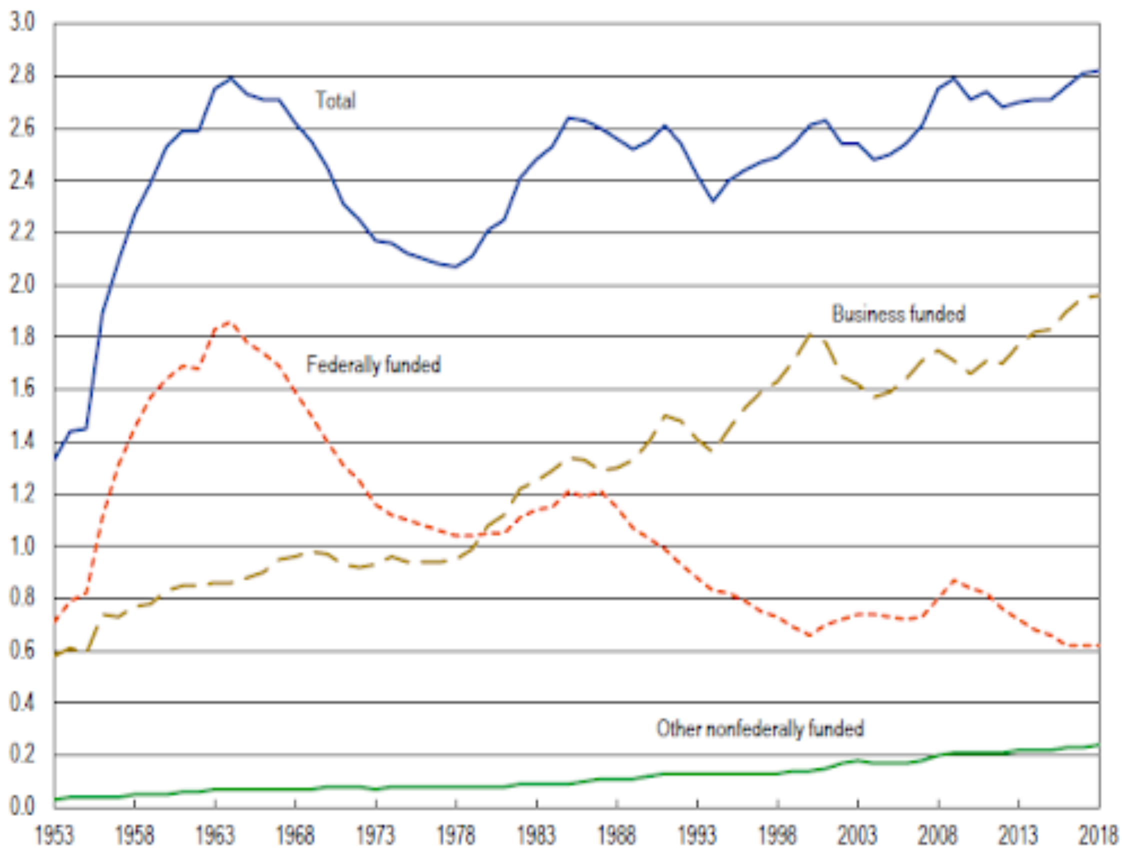


The trend that eventually led to the superiority of advanced commercial technologies over defense began in 1980, when U.S. private R&D first overtook U.S. government R&D. From parity in 1980, the U.S. government's share of U.S. R&D

[23] Silicon Valley Defense Working Group, "Department of Defense Emerging Technology Strategy: A Venture Capital Perspective" April 2019, p. 36. The defense companies included in Figure 1.1 are Lockheed Martin, Boeing, Raytheon, United Technologies (now part of Raytheon), General Dynamics, Northrop Grumman, and L3 Technologies (now L3Harris).

has been rapidly falling ever since (Figure 1.2). Unlike in the 1950s and 1960s, DOD is no longer the driver of innovation in the U.S.

Figure 1.2: Ratio of U.S. R&D to GDP By Source of Funding for R&D: 1953-2018[24]



NOTES: Data for 2017 are preliminary, and those for 2018 are estimates; some of these data may later be revised. The federally funded data represent the federal government as a funder of R&D by all performers; similarly the business-funded data represent businesses as funders of R&D by all performers. The other nonfederal category includes R&D funded by all other sources—mainly, higher education, nonfederal government, and other nonprofit organizations. The gross domestic product (GDP) data used reflect the Bureau of Economic Analysis's comprehensive revisions of the National Income and Product Accounts of August 2019.

SOURCE: National Center for Science and Engineering Statistics, National Patterns of R&D Resources (annual series).

[24] Byron Callan, Capital Alpha Partners "Some More Post-Pandemic Questions—Defense Sector Structure, Exports and R&D May 13, 2020.

This commercial R&D trend also subsequently led to a technological leveling of key dual-use technologies on a global scale as global R&D began to dwarf combined U.S. R&D. Just as the U.S. government no longer dominates U.S. R&D, its relative significance in global R&D has declined over many decades in both the public and private sectors. According to the most recent data from the National Science Foundation, global R&D equaled around $2.2 trillion in 2017, with the U.S. share comprising about 25 percent of that.[25] Based on the current government/industry split, U.S. government R&D equaled about 2.3 percent of global R&D. U.S. private-sector R&D would amount to about 18.1 percent of global R&D with the academia and the nonprofit sectors providing the remaining share, although some of the latter may be funded by the U.S. government.[26]

An understanding of the dynamic of how commercial innovation leapfrogged military progress will be critical in shaping future successful defense innovation approaches. China may have a better realization of these trends, as witnessed by its aggressive focus on the military-civil fusion[27] of its industrial base – a concept similar to what was once referred to in the U.S. in the 1990s as civil-military integration (CMI). While DOD began outreach to Silicon Valley, changes to underlying

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[25] National Science Foundation, Science and engineering indicators, 2020. https://ncses.nsf.gov/indicators

[26] Author calculations based on data from National Science Foundation, Science and engineering indicators, 2020. Another source of information on R&D trends is the annual Research and Development Magazine Global R&D Funding Forecast.

[27] Tai Ming Cheung, "From Big to Powerful: China's Quest for Security and Power in the Age of Innovation", East Asia Institute, p. 11.

innovation practices that would entice non-traditional companies into the defense marketplace and achieve greater CMI have not yet happened at scale.[28]

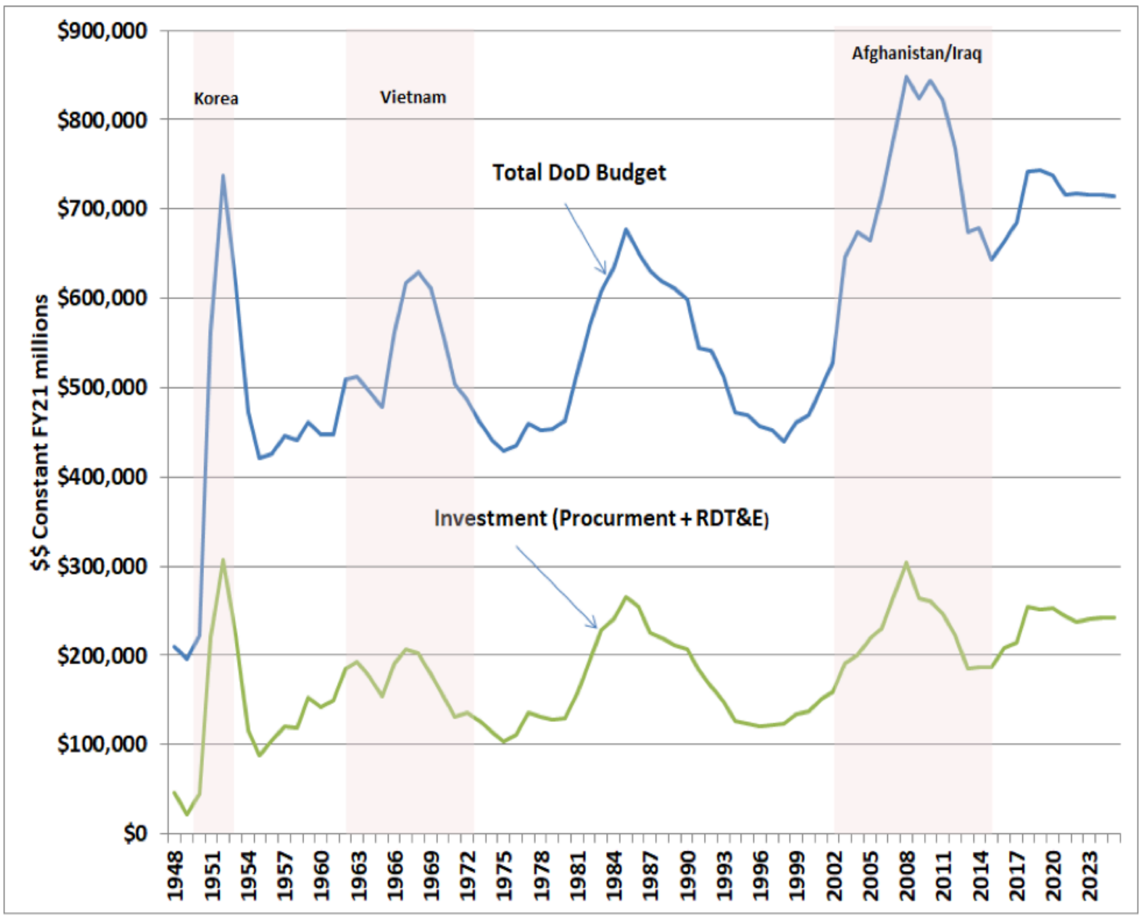
The debate on the impending decline of U.S. military technological superiority led to in the latter portions of the Obama Administration a defense budget rise after a 5-year decline from the heights of the Iraq war spending (that rise subsequently began leveling off in the Trump Administration – see Figure 1.3). These new resources were first used to shore up readiness and the maintenance of older systems, and then on spending more money on existing systems already in the acquisition pipeline. A recent focus has been placed on addressing a perceived hypersonic missile gap and developing a few other new defense systems and capabilities. While new U.S. defense programs have been initiated under a new great power competition strategy, it is far from certain that they will be successful – they may languish as many recent acquisition programs have over the past several decades.

A perhaps more productive and complementary exercise would be to first better understand how the innovation system and its underlying practices have been working, and then attempt to shape the necessary incentives to achieve more effective innovative approaches, rather than just increasing spending. As defense budgets have risen there has been a rather narrow and superficial debate fixated on how much money is needed for traditional weapons platform approaches, rather than questioning whether DOD is spending these resources effectively. More spending may not buy

[28] Future of Defense Task Force 2020, p. 68. For a history of the barriers to non-traditional participation in the defense market see: Jacques S. Gansler, William C Greenwalt, William Lucyshyn, *Non-Traditional Commercial Defense Contractors*. Naval Post Graduate School, Defense Technical Information Center: Fort Belvoir, VA, 2013.

greater security if the way those resources are used (i.e., how defense innovates) is constrained by diminishing returns or if circumstances have changed to such a degree that current technology development paths to innovation and acquisition practices are irrelevant or, at worse, counterproductive.

Figure 1.3: U.S. Defense Spending 1947-2020 (2021-2015 Projected) FY21 Constant Dollars[29]



Investment = DOD procurement + Research, Development, Test and Evaluation.

[29] Byron Callan, Capital Alpha Partners, Defense Primer: Version 2.1 June 2020. p.33.

It is thus necessary to look beyond the amount of resources being allocated to the question of how those resources are being spent. While overall budgets are important guides to priorities, many other factors, such as management processes, practices, and organization, and the nature of the industrial base are critical enablers as to whether these priorities can be met. Perhaps most importantly, incentives and the criteria used to measure success are key determiners as to what actually gets done.

Management reforms of how the U.S. equips its military have been ongoing for decades, but these attempts have been seen as only successful at the margins. A longtime observer of the defense innovation system remarked:

> Despite the many studies and the similarity of their findings, major defense programs still require more than fifteen years to deliver less capability than planned, often at two to three times the initial cost. Most attempts to implement improvements in the management of the defense acquisition process during the past fifty years have fallen short of their objectives.[30]

This trend may be an indication that greater underlying factors and barriers to implementation are at play and need to be identified and addressed with respect to defense innovation policies. It also could mean that perhaps the wrong questions have been asked over the last fifty years of management reforms or that inadequate criteria are being used to measure and guide success or failure. If this is the case, and the system is optimizing to meet the wrong criteria, then past reform solutions may have actually made the problem worse. At a minimum, the study of trends in the longstanding defense innovation system could provide needed insights into the

[30] J. Ronald Fox, *Defense Acquisition Reform 1960-2009: An Elusive Goal*, Military Bookshop, 2012, p. xii.

implications of any new technological competition that is emerging and perhaps provide a better understanding into the origins of technological progress and advancements that could inform future reform efforts.

Why Has Defense Technological Innovation Become Harder to Achieve?

The question guiding this research effort is based first on an attempt to understand the nature of the changes in how the U.S. develops and deploys military capability (i.e., how it innovates) today compared with previous historical periods, and then to determine what effect any of these changes may have had on current approaches to defense innovation. Defense innovation now appears to be a more difficult endeavor than it was in previous periods of U.S. history. If that is true, why is that the case? Why has defense technological innovation become harder to achieve than in earlier periods in U.S. history?

Exploring that initial research question leads to a number of sub-questions that will be considered:

- If the current defense innovation system used to develop U.S. defense capabilities is different than in earlier years, in what ways is it different – and does that really matter? Is DOD now less innovative (and by what measure) than it was in the early Cold War and does that make a difference?

- How does one measure innovation, and more importantly, how does one measure the quality of innovation? If defense technological innovation in the U.S. is found to have slowed over the decades, what are the specific factors behind this deceleration?

- Are technological trends causing the U.S. to have fallen or be at the risk of falling behind its potential adversaries, or are these adversaries merely catching up?

- Will future defense innovation challenges be equally as hard for all competitors?

- How have process rules, incentives, and disincentives that guide potential defense innovation changed?

- How are they the same or different and how have they impacted government program managers and the industrial base that supports defense, and has this impacted defense innovation?

The proposed path to answering these questions is to be found in reviewing the criteria and underlying incentives and practices the military has used in the past and now uses to develop and buy weapons capabilities. This can be explored through a combination of literature and historical review, process tracking, and data analysis of how the U.S. has attempted to achieve its defense technological innovation goals. The first step will be to define the concepts, terms, and variables of what comprises the defense innovation system. The dissertation will next review the historical record and determine the evolution of the changes that occurred within this defense innovation system to include the industrial base that supports innovation, and the rules and processes that guide innovative efforts in defense. The evolution of the rule sets that are created and implemented through various defense management regimes such as budget, acquisition, and contracting, are tracked and reviewed for their impact on the ability of the industrial base to deliver new innovative capabilities.

To evaluate this historical record, sufficient criteria are needed to determine the productivity of innovation. In this case two benchmarks are used – one that is more subjective and one that is more clearly measurable. The subjective criterion addresses when critical disruptive new military technologies emerged. While the date of first successful test or deployment of a technology may be measurable, the determination of what is a new, critical, or disruptive technology is more subjective and may be a source of some debate. Still, selecting technologies such as nuclear weapons, intercontinental ballistic missiles, the integrated circuit, stealth aircraft, nuclear submarine, precision targeting, satellites, and the jet engine should be revolutionary or disruptive enough to provide a minimum level of agreement for heuristic purposes.

The second criterion addresses time. How long did it take to create a new weapon system from the initiation of a program to a capability that is being used in the field by U.S. forces? Past studies and available data on the rate of defense innovation are assessed to compare time to development in different historical periods. Together these two measures, one of the quality of innovation and the other a factor or measure of the productivity of innovation, will be used in an assessment of the trends in U.S. defense innovation. The final methodological approach used is to review historical cases of when the defense innovation system is considered inadequate to achieve a near-term purpose and then determine what changes are made to enhance innovation and what criteria guides those changes. This provides insight into what criteria may be important and what needs to change to achieve that criteria.

Current Understanding of Defense Innovation Framework

Prior to World War II, there was not necessarily an academic focus on defense innovation. Major discussions on the topic were either the result of Presidential

Commissions or Congressional hearings in the furtherance of general oversight responsibilities. Many of these efforts began not from concerns with the state of defense innovation but because of perceptions of problems with wartime contracting such as profiteering, fraud, waste, and abuse when acquiring commodities such as food, clothing, and munitions. For example, the Nye Committee or the Special Committee on Investigation of the Munitions Industry was established in 1934 to investigate issues with U.S. defense procurement during World War I.[31] and during World War II, the Truman Committee – or the Senate Special Committee to Investigate the National Defense Program -- was formed to review ongoing allegations of fraud, waste, and abuse in defense programs. Its remit lasted until 1948 when the Senate Permanent Subcommittee on Investigations was created.[32]

After World War II, defense innovation became a significant topic of interest to the government. The U.S. government sponsored research at academic institutions and at government sponsored organizations. An early body of literature in the 1950s was conducted by the newly-formed Federally Funded Research and Development Corporations (FFRDCs) such as the RAND Corporation, that was established in 1948 and grew out of the World War II success with operations research. RAND was founded by Douglas Aircraft and senior Air Force officials and began to focus on (work that still continues to this day) the description of how DOD develops and acquires weapons systems to support reform of the defense acquisition and budgeting

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[31] When it comes to fraud, waste and abuse, time is usually not an issue to deter an investigation as the Nye Committee was established 16 years after the end of World War 1.
[32] The Senate Permanent Subcommittee on Investigations is now housed in the Senate Committee on Homeland Security and Governmental Affairs.

systems.[33] The two most significant focus areas of defense innovation policy in the post-war era were the recognition of the important role of the private sector and of government support for science. A large degree of the research, commentary, and analysis on defense innovation from this period is found in congressional testimony and reports, other primary government sources, or government-sponsored research that was primarily directed at incorporating in peacetime the significant shifts in the defense innovation system that occurred during the war.[34]

The first major public academic look at the acquisition process, undertaken within the Harvard Business School in 1958 and published in 1962, was *The Weapons Acquisition Process: An Economic Analysis* by Merton J. Peck and Frederic M. Scherer. This review has served as a classic in the field and explored the market structure and the performance of the weapons acquisition process.[35] Peck and Scherer relied on the work that the school did for the government during WWII and afterwards on the commercial aviation industry. Among more data descriptive exercises, they explored relationships between cost overruns and certain contractor incentives such as contract type and DOD oversight mechanisms. While some of Peck and Scherer's analysis was quantitative, most was not. It was based on a small set of case studies (12 weapon systems and 7 commercial developments) and surveys

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[33] See a brief history of RAND: https://www.rand.org/about/history/a-brief-history-of-rand.html ; and Virginia Campbell, "How RAND Invented the Postwar World" Invention and Technology, Summer 2004, p.50.
[34] The most comprehensive bibliography of these sources during the time period from 1945-1960 can be found in E.V. Converse, E. V and W.S. Poole, United States, Department of Defense, *History of Acquisition in the Department of Defense Volume 1: Rearming for the Cold War 1945-1960*; Historical Office, Office of the Secretary of Defense: Washington, D.C., 2012. p. 676-717.
[35] Merton J Peck and Frederic M Scherer. *The Weapons Acquisition Process: An Economic Analysis.* Division of Research, Harvard Business School, 1962.

covering the period of time between 1945-1960. Peck and Sherer's cautioned against treating weapons development like a commercial endeavor or a basic scientific research program. Weapon systems development to them was unique and uncertain:

> "it is characterized by unique elements of uncertainty resulting from the combination of, first, the extent to which weapons press the limits of existing engineering art and scientific knowledge and, second, the character of demand for weapons in a cold war environment. The better performance of commercial development in staying within budgets, meeting schedules, and achieving performance objectives is explained largely by the fact that most commercial products developments are not initiated until major state of the art and marking uncertainties have been resolved."[36]

These observations would subsequently be essentially ignored. In 1964, Scherer explored specific economic incentives such as competition and profits and their impact on acquisition in *The Weapons Acquisition Process: Economic Incentives*.[37]

Still. these two efforts by Peck and Scherer have served as the introductory basis for analysis conducted in the field of defense acquisition and innovation policy. The first book focused on macro issues of the outputs of acquisition and Scherer's second on micro incentives that guide actions in the industrial base. Peck and Scherer's more cautious and adaptable approach, to what at the time may not have been completely understood to be a revolutionary innovation system, was, however, in practice quickly overshadowed by the systems analysis approach at RAND. This understanding of how revolutionary that earlier system discovered at the height of World War II was, and could be argued is still today, lost on most practitioners.

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[36] Ibid. p. 8-9.

[37] Frederick M. Scherer, *The Weapons Acquisition Process: Economic Incentives*. 1964.

A significant watershed in defense management practices occurred in the 1960s when academic theory jumped from the think tanks to DOD practice. It was not only that significant work in academic theory and literature related to defense management occurred at RAND, but most importantly that this work served as the basis for major management reforms at DOD. The body of work by Hitch and McKean in, for example, *The Economics of Defense in the Nuclear Age,* and Novick's work on program budgeting[38] resulted in the underpinnings of the current defense management framework, which has served as the operating model for managing defense innovation since the Kennedy and Johnson Administrations. Hitch would later be credited as being the "father" of the Planning, Programming, Budgeting System (PPBS) although that title may legitimately belong to Novick.[39]

Novick outlined the need for program budgeting to essentially be used to oversee and manage individual weapons programs in a more scientific way. The analytical unit of the program and cost data related to such a program became the dominant variables to manage innovation efforts over the next six decades after the creation of the PPBS system in 1961. This process institutionalized program budgeting to managing weapon systems. Novick continued to refine the concept of

[38] David Novick, Efficiency and Economy in Government Through New Budgeting and Accounting Procedures. Santa Monica, CA: RAND Corporation, 1954.; David Novick, Weapon System Cost Analysis. Santa Monica, CA: RAND Corporation, 1956.; David Novick, Which Program Do We Mean in Program Budgeting? Santa Monica, CA: RAND Corporation, 1954.; David Novick, Program Budgeting: Long-Range Planning in the Department of Defense. Santa Monica, CA: RAND Corporation, 1962.; and David Novick (ed.), Program Budgeting: Program Analysis and the Federal Budget. Cambridge, MA: Harvard University Press. 1967.

[39] Alain C. Enthoven and K. Wayne Smith. *How Much Is Enough? Shaping the Defense Program, 1961-1969*, Dedication.

program budgeting to improve the link to defense acquisition.[40] There have been a few detractors to this concept, as Eric Lofgren recently noted:

> "Studying its implementation in the Pentagon and around the world, budget scholar Arron Wildavsky concluded in 1978 that "Program budgeting does not work anywhere in the world it has been tried." Revisiting the question in 2013, Allen Schick concurred. He found program budget efforts "were rarely successful."[41]

Line-item budgeting consisting of large pots of undifferentiated money that could be used on many purposes made it difficult to focus on performance of how well those funds were spent. Program budgeting at its basic level is simply a way to focus the budget on objectives. Implementation of what is a common sense "good government" management tool would be fraught with second order effects. This was particularly so as the program budgeting system moved to more detailed and specific objectives such as weapons system development that would at least in their initial and most innovative phases prove difficult or impossible to predict.

The problem of program budgeting's potential disconnect from practicality was pointed out as early as 1954 by Frederick Mosher, and its Achilles heel was time.[42] The process time it takes to conduct program budgeting as it has evolved

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[40] David Novick and Daniel J. Alesch, Program Budgeting: Its Underlying Systems Concepts and International Dissemination. Santa Monica, CA: RAND Corporation, 1970.; David Novick, Program Analysis Revisited. Santa Monica, CA: RAND Corporation, 1971.; H.G. Massey, David Novick, and R. E. Peterson, Cost Measurement: Tools and Methodology for Cost Effectiveness Analysis. Santa Monica, CA: RAND Corporation, 1972.; David Novick, The Meaning of Cost Analysis. Santa Monica, CA: RAND Corporation, 1983.; David Novick, The role of the military comptroller in defense management. Santa Monica, CA: RAND Corporation, 2004.

[41] Eric Lofgren, "The DOD Budget Process: The Next Frontier of Acquisition Reform" George Mason University School of Business, Center for Government Contracting, White Paper Series #5, June 29, 2020. p. 1.

[42] Frederick C. Mosher, *Program Budgeting: Theory and Practice with Particular Reference to the U.S. Department of the Army*. Public Administration Service, American Book-Stratford Press, Inc., New York, 1954, p. 2-3.

requires perfect foreknowledge of events many years prior to budget execution. Perfect knowledge may not often exist except in the minds of central planners, but it was this ability to precisely predict outcomes based on program cost estimates that Congress would eventually hold DOD accountable for while limiting flexibility to move funds to other alternatives when these estimates were wrong. A budget system disconnected from the importance of time and impervious to flexibility leads to waste, misallocation of resources, and missed opportunities for innovation that can never be recaptured.[43]

Any such criticism seems to not have had an effect on subsequent discussions surrounding defense budgeting and acquisition reforms. Alain Enthoven and K. Wayne Smith in *How Much is Enough: Shaping the Defense Program 1961-1969* primarily described the PPBS system that had been put in place during the Kennedy and Johnson Administrations as the ideal approach for defense management to enable proper oversight and structure to innovation efforts. They focused on the goal of cost efficiency in the outputs of defense and described the nature of the defense management problem as a matter for controlling cost overruns on these outputs and reducing duplication and waste. This goal was primarily directed at achieving better visibility over what had become a cost-based analytical system that depended on centralized management from the Office of the Secretary of Defense (OSD) over the services and defense agencies who needed to be tightly overseen by a higher

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[43] The other great disconnect in establishing program budgeting at the Pentagon in the early 1960s was the limited thought as to how Congress would use this tool. Perhaps not DOD's intention, but creating this process has allowed Congress to better plan for earmarks within states and congressional districts in a way that would require unattainable levels of prediction at DOD and limit future budgetary flexibility. Eventually, as will be explained later in this paper, the one way to come to terms with these congressional constraints is to limit innovation.

authority. James Q Wilson's advocacy of bureaucratic decentralization through distributed authority and distributed autonomy to the contrary[44] centralized control from OSD over military service run innovation programs has been a goal since the 1947 National Security Act.[45] The 1958 Defense Reorganization Act furthered centralization at DOD and allowed the adoption of the cost-based systems analysis approach of program budgeting advocated by Novick and Hitch. For management defense analysts like Enthoven and Smith they fully recognized that the 1958 Act was the defining moment that allowed PPBS to move forward.[46]

Subsequent Presidential Commissions from the Fitzhugh Commission (1970),[47] and the Commission on Government Procurement (1972)[48] continued to recommend greater centralized control over defense innovation programs, the use of program budgeting, systems acquisition, centralized joint requirements systems to initiate programs, and better cost estimating and planning to support program budgeting as programs were executed. The next major scholarly contribution was not until 1974, by Ronald Fox in *Arming America: How the US Buys Weapons* that addressed the macro-innovation outputs and described the management of the weapons acquisition process that had evolved since the 1960s reforms.[49] He would cover similar but updated material in 1988 in the *Defense Management Challenge:*

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[44] James Q. Wilson, *Bureaucracy: What Government Agencies Do and Why They Do It*. New York: Basic Books, 1989. p. 365.
[45] The 1947 Act established the Office of the Secretary of Defense that was in theory put in charge of defense acquisition. It was not until the 1958 Act that this theoretical power was strengthened.
[46] Enthovan p. 2.
[47] *Report to the President and the Secretary of Defense on the Department of Defense,* Blue Ribbon Defense Panel. Washington, D.C.: U.S. Government Printing Office, 1 July 1970.
[48] *Report of the Commission on Government Procurement,* vols. 1 and 2. Washington, D.C.: U.S. Government Printing Office, 31 December 1972.
[49] J. Ronald Fox, *Arming America*: *How the U.S. Buys Weapons.* Boston: Division of Research, Graduate School of Business Administration, Harvard University, 1974.

Weapons Acquisition.[50] Fox would return to what would become a familiar refrain for the next 40 years: that despite pervasive reform, issues previously identified by other analysts such as cost overruns, schedules slippages, and inadequate cost estimation still existed. In 1980, Jacques Gansler's *The Defense Industry* provided an update on the micro-innovation inputs and incentives in a detailed economic analysis of the defense industry of the time.[51] Fox and Gansler together can be viewed as a follow up to Peck and Sherer's macro and micro versions of acquisition analysis.

Scholarly research, congressional oversight, and government-sponsored research has continued to operate within the cost-based, program-centric, systems analysis paradigm of Hitch, Enthoven, and Novick. On the macro program level, there has been a focus on cost estimating and prediction and cost performance[52], while at the micro level issues related to competition, profits, and pricing issues related to the defense industry prevailed.[53] Most cost-based research has been conducted internally within DOD or by FFRDCs such as RAND and the Institute for Defense Analysis (IDA) specifically for DOD. Some, but not all, of these reports were made public.[54] While much of the qualitative literature has been primarily

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[50] J. Ronald Fox and James L Field, *The Defense Management Challenge: Weapons Acquisition*. Boston, Mass.: Harvard Business School Press, 1988.
[51] Jacques S. Gansler, *The Defense Industry.* Cambridge, Mass.: MIT Press, 1980.
[52] Robert L. Perry, Reforms in System Acquisition. Santa Monica, CA: RAND Corporation, 1975. Arena, Mark V., Obaid Younossi, Kevin Brancato, Irv Blickstein, and Clifford A. Grammich, Why Has the Cost of Fixed-Wing Aircraft Risen? A Macroscopic Examination of the Trends in U.S. Military Aircraft Costs over the Past Several Decades. Santa Monica, CA: RAND Corporation, 2008; Arena, Mark V., Irv Blickstein, Obaid Younossi, and Clifford A. Grammich, Why Has the Cost of Navy Ships Risen? A Macroscopic Examination of the Trends in U.S. Naval Ship Costs Over the Past Several Decades. Santa Monica, CA: RAND Corporation, 2006.; Gordan Adams, Paul Murphy, and William Grey Rosenau. *Controlling Weapons Costs*: *Can the Pentagon Reforms Work?* New York: Council on Economic Priorities, 1983.
[53] U.S. General Accounting Office, GAO Report, *Impediments to Reducing the Costs of Weapon Systems*, PSAD–80–6, 8 Washington, DC, 1979.; Fox p. 31-33;
[54] See: Younossi, Obaid, Mark V. Arena, Robert S. Leonard, Charles Robert Roll, Jr., Arvind Jain, Jerry M. Sollinger, *Is Weapon System Cost Growth Increasing? A Quantitative Assessment of*

government or industry sponsored, focused, and conducted, the academic literature addressing these issues has been more limited and, in many cases, also sponsored by the federal government.[55] While these efforts have focused on issues that were broader than cost (to include manufacturing incentives, maintenance and logistics, schedule, and the ultimate performance of systems), cost has been the most significant factor explored and the primary variable to be managed to address these other issues. Also, while acquisition reform research has focused some on commodity, services, and information technology acquisition, major weapon systems acquisition has dominated the literature.

In the last decade attempts were made to address the lack of public quantitative analysis, mostly on larger defense acquisition programs. Since Peck and Scherer there have been few subsequent academic quantitative studies published and those published focus on cost, and the differences in cost as compared to a beginning benchmark at the start of the program. Historical data is often based on congressionally-mandated reports called Selected Acquisition Reports (SAR) for larger weapon systems known as Major Acquisition Defense Programs (MDAP). These reports were mandated by Congress in the Nunn-McCurdy Act of 1982 but were being prepared internally at DOD since the 1960s.[56] The use of SAR data

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Completed and Ongoing Programs, Santa Monica, Calif.: RAND Corporation, MG-588-AF, 2007; Arena, Mark V., Robert S. Leonard, Sheila E. Murray, and Obaid Younossi, *Historical Cost Growth of Completed Weapon System Programs*, Santa Monica, CA: RAND Corporation, TR-343- AF, 2006; and Davis, Dan, *Pay Me Now and Pay Me Later: The Effect of R&D Cost Growth on Subsequent Procurement Costs*, Alexandria, VA: CNA, CRM D0024982.A1/Final, May 2011.

[55] The Naval Post Graduate School sponsors acquisition related research, as do the military service War Colleges and the National Defense University.

[56] Robert S. Leonard and Akilah Wallace "Selected Acquisition Report Data and Analytics," *Air Force Major Defense Acquisition Program Cost Growth Is Driven by Three Space Programs and the F-35A: Fiscal Year 2013 President's Budget Selected Acquisition Reports*, RAND Corporation, 2014, pp. 1–12.

analysis and weapon systems quantitative research analysis has been conducted internally by DOD to support decision-making. The last major departmental publicly released analytical study was performed by the IDA during the Obama Administration. Then Undersecretary of Defense for Acquisition, Technology and Logistics, Frank Kendall, initiated this effort to explore the reasons behind DOD's poor performance as reflected in cost overruns in developing weapon systems and to help guide policy in this area. The first report was published in June 2013 and the second was published in June of 2014.[57] In these quantitative based reports, DOD's level of analysis focused on individual weapon systems or types of weapon systems. The Government Accountability Office (GAO) has been another source of data on the performance of defense weapon systems. Since 2002, GAO has published an annual report on weapon systems development based on SAR cost reporting and while continuing to report on cost, schedule, and performance issues, has added a GAO-specific variable developed over the years regarding technical maturity and knowledge.[58]

The few quantitative approaches and the larger amount of qualitative analysis have been related to major weapons program and the perceived factors that have contributed to cost increases or focused on the effectiveness of contract incentives that have served as a source of many ideas and policy prescriptions proposed to try to

[57] U.S. Department of Defense, Performance of the Defense Acquisition System, 2014 and 2013 Annual Reports, June 2013, June 2014.

[58] U.S. Government Accountability Office. *Defense Acquisitions Annual Assessment: Drive to Deliver Capabilities Faster Increases Importance of Program Knowledge and Consistent Data for Oversight*, GAO-20-439: June 3, 2020. This criterion has been implemented by Congress through the use of technology readiness levels in subsequent legislation such as the Weapon System Acquisition Reform Act of 2008.

fix that problem. Performance issues have been addressed but primarily in the framework of not meeting predicted performance outcomes as promised at the beginning of a program. The underlying reasons for cost overruns on individual weapon systems have historically been blamed (among other things) on budgetary and requirements instability, technological immaturity, program management turnover or qualifications, bureaucratic oversight structures, poor cost estimating,[59] and political gamesmanship in selling weapon systems (i.e., no one would ever approve to buy a weapon system if they really knew what it was going to cost). This last item is known as "buying in" and can be attributed to both government and industry actors and can negatively impact not only defense programs but also public infrastructure projects.[60]

Because of these perceptions of past poor performance based on cost analysis benchmarks and the importance of these systems for national security, weapons systems acquisition has been one of the most studied processes within the federal government. During the last 60 years there has been no shortage of government-sponsored studies looking at the acquisition process. Beginning with Peck and Scherer there were close to 300 different studies on the acquisition process identified in 2012 by the Defense Business Board.[61] The 2006 Defense Acquisition Performance Assessment (an internal study mandated by DOD) identified 128 major

[59] Fox p. 50.
[60] Bent Flyvbjerg, Mette Skamris Holm, and Søren Buhl. "Underestimating Costs in Public Works Projects: Error or lie?" *Journal of the American Planning Association* (Chicago: American Planning Association) 68(3): 279–295, 2002.
[61] U.S. Department of Defense, Defense Business Board "Linking and Streamlining the Requirements, Acquisition and Budget Process" April 19, 2012. p.1.

studies on the subject of acquisition reform since the 1949 Hoover Commission.[62] According the Business Executives for National Security, there were over 262 relevant studies published between 1986 and 2009 advocating the reform of defense acquisition to address the efficiency of buying weapon systems.[63]

Since these tallies, in the last decade there have been no shortages of further reviews, studies and opinions on the process of defense acquisition and innovation, beginning with the Senate Permanent Select Committee on Investigations' October 2, 2014 report focused on weapon systems acquisition,[64] the section 809 panel reports,[65] and the most recent observations on "Defense Management Reform: How to Make the Pentagon Work Better and Cost Less" in 2020 by Peter Levine from IDA.[66]

The existing defense management literature that has grown up and evolved over the last 60 years continues to offer new recommendations on how to make the acquisition process better by improving cost estimating, management practices, and oversight. Observers of defense innovation practices and policy both inside and outside of government have rarely been able to break away from the basic assumptions that have underlined defense management systems and theory since the early 1960s. Marginal changes have been recommended to better implement the

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[62] U.S. Department of Defense, *Defense Acquisition Performance Assessment Report*. Washington, D.C.: Office of the Secretary of Defense, January 2006. p. 2.
[63] Business Executives for National Security Task Force on Defense Acquisition Law & Oversight. "Getting to Best: Reforming the Defense Acquisition Enterprise" July 2009, p. iii.
[64] U.S. Senate Permanent Subcommittee on Investigations, Committee on Homeland Security and Government Affairs. "Defense Acquisition Reform: Where Do We Go from Here?" October 2, 2014.
[65] U.S. Department of Defense. Section 809 Panel. *Advisory Panel on Streamlining and Codifying Acquisition Regulations: Section 809 Panel Interim Report* and Volumes 1, 2, and 3. Arlington, Va.: Section 809 Panel, 2016-2019.
[66] Peter Levine, *Defense Management Reform: How to Make the Pentagon Work Better and Cost Less*. Stanford, California: Stanford University Press, 2020.

existing structure to focus on process to manage programs and costs beginning with improving the processes for joint requirements, technology readiness, cost estimating and program budgeting to manage better outcomes. Ultimate success for a program is to be measured by a lack of cost overruns and delivering the requirements and specifications promised at the beginning of a program, and on a predicted schedule. A sub-genre of research has focused on contracting incentives, contract types, fairness, and competition with a goal of how these tools bring value to the taxpayer as measured by how well a program meets it predicted targets.

The results of the research cited here have not led to exemplary policy decisions or "fixed" the problem. Many of the same cost problems that Peck and Scherer first observed continue to plague the system.[67] There is no doubt that a concern about cost should be an important variable when dealing with taxpayer dollars on multi-billion and, in the case of the F-35, trillion-dollar programs. Still, as it has evolved, this cost-based approach is based on the premise that certainty and predictability in weapon system development and budgeting is achievable – often decades in advance. That level of precision simply may not exist in the real world, and to do so and be effective – as Peck and Sherer warned – would be to adopt a commercial model where all technical risk has been reduced. To continue to operate with the view that one can have it all and that this prediction is possible is to continue to refine processes based on assumptions that are counterproductive and even detrimental to U.S. national security if new innovation is needed. Other variables that

[67] See Government Accountability Office, GAO-20-439, Highlights section.

have previously been de-emphasized may be helpful to consider along with different criteria for measuring what it means to successfully innovate in defense.

The Criterion Problem

The primary thesis of this review is that a different criterion for assessing defense innovation success or failure should be considered: time. This focus on time or speed is distinct from the current idea of a planned schedule within a cost-based predictive framework. Time can act as an overarching constraining function to the process of innovation much as cost does today. The baseline assumptions originally made by Novick, Hitch and Enthoven, and others over the last six decades that have stressed cost as the basis for evaluation should be reviewed and assessed while a time criterion for measuring success in innovation should be explored and evaluated. Hitch and McKeon identified a criterion problem in 1960 that remains a valid issue: ". the selection of an appropriate criterion is frequently the central problem in the design of an economic analysis intended to improve military decisions."[68] If you start with the wrong criteria for evaluation, the answers one gets may be inappropriate to the problem, and perhaps worse, processes will become optimized for the wrong results.

The framework to deliver defense capabilities, or what will be described as the current defense innovation system, is very different than what existed in the great power conflicts of World War II and the early Cold War, and is not what is needed

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[68] Charles Johnston Hitch and Roland N McKean. *The Economics of Defense in the Nuclear Age*. Cambridge: Harvard University Press, 1967. p.158-181.

today. Three major variables have undergone significant change over the last 60 years. These include first, the structure of the industrial base and secondly, the applicable management regimes that together with the industrial base comprise the defense innovation system. The third variable is also one of the key outcomes of such an innovation system and that is the time it takes to deploy defense capabilities. These variables have likely changed because the criteria for success has also changed. A time-based focus to innovation has been lost due to an excessive focus on linear processes designed to manage cost that have continued to grow. Today's criterion problem is much different than the one that faced Hitch and McKeon. The criteria chosen to evaluate the success of defense innovation over the last 60 years is one of efficiency measured by cost. Effectiveness as measured by timeliness of the deployment of capability may be a more valid criteria in the current national security environment but it currently is not valued.

Contribution

This effort builds upon the defense management and acquisition process reform literature that provides the framework and foundation of analysis of past thinking on defense innovation primarily focused on predictive cost controls. From that foundation, an alternative management oversight criterion based on time will be proposed that could replace or, at a minimum, augment the measures of success to the current framework that is used to develop and deploy weapons capability. This approach is to a degree a return to asking some of the original questions and concerns about lead time that Peck and Scherer had first raised in 1962 and supporting their original observations of what it means to innovate in the defense environment.[69] Even at what in retrospect could be viewed as the height of successful U.S. defense innovation efforts, there was a concern that lead times were then too long and that defense should not be managed like a traditional commercial enterprise. According to Peck and Scherer:

> "In our view the weapons acquisition process is unique, without the salient characteristics of commercial activity on one hand or of scientific activity on the other. Ideas and concepts relevant to the weapons acquisition process are difficult to come by, for what is needed is not something borrowed, but something new." [70]

A subsequent focus on cost from commercial management practice – something that Peck and Sherer criticized and warned about – nonetheless became the dominant management tools to guide defense innovation.

While I do not intend to reject the values – cost, efficiency, fairness, or competition – that have led to the adoption of current management processes, this approach will attempt to relegate these values to a more subservient position with respect to a different criterion – that is, time to development and deployment.[71] These other values are important, and could still be factors of consideration in a time-constrained system. But in cases of national defense and certain other governmental

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[69] Peck and Scherer, p.4-6 and 53-54.

[70] Ibid. p. 586.

[71] There is likely a need for a future debate on the adequacies of the adoption of PPBS and the systems analysis framework at DOD and whether this system served more the interests of OSD and the appropriations committees rather than efficiency. Despite all of the potential good that can come form program and performance budgeting, the potential for these tools to be politically "weaponized" may do more to serve the allocation of the defense budget for political means on stated efficiency grounds when neither efficiency or effectiveness is being achieved. An interesting dissertation by a current analyst at RAND begins to dig into the debate on these questions when PPBS was initiated. See: Stephanie C. Young. "Power and the Purse: Defense Budgeting and American Politics, 1947–1972." Dissertation. University of California, Berkeley, 2009. This effort though will stick to the narrower issue of what has been lost over the years from pursuing current management approaches – a focus on time.

missions, an excessive or predominant focus on these other values may result in a continued crowding out of effective innovation without the constraints inherent in an overarching criterion of time. A system divorced from time that relies upon long linear processes will end up failing if the needs of the mission are time sensitive or one's adversary approaches innovation in a different, more agile way. Even if DOD were to suddenly meet its current measures of cost-based success under the existing system – something it has not been able to consistently do in the last five decades of weapon systems acquisition measurement – the outputs of the defense innovation system could be a failure if all innovation risk has been bled out of the system. The discussion must begin by exploring which criteria to use (and when) and how success should be measured.

This research will also build on academic work on civil-military integration of the industrial base to begin the questioning of many longstanding assumptions behind the basis for other current defense management processes and regimes.[72] While these regimes are not all strictly based on cost and process linearity, they have had the effect of creating barriers to those entities that specialize in time-based innovation.

As defense management regimes have been at the leading edge of the management practices in the government, this effort could also contribute to other government innovative and management efforts beyond strictly defense. Any technological or engineering-based projects established to address climate change or global warming will likely confront many of the innovation challenges that DOD has

[72] See Gansler, Greenwalt and Lucyshyn "Non-Traditional Commercial Contractors"; and William Greenwalt, "50 Legislative Ideas to Reform Defense Acquisition" American Enterprise Institute Working paper for the United States House of Representatives and Senate Committees on Armed Services. October 2014.

faced over the last 75 years. These civil missions are likely to face the same criteria that favors predictive cost systems and the predominance of values other than time that could negatively impact the ability of the government to guide successful innovation to address these vital challenges.

While further academic validation and study will likely be needed, this effort is an attempt to begin a dialogue on time-based innovation. It will also attempt to identify what should come next in further study, begin the discussion of the barriers to making policy changes that focus on time and working with agile industrial entities, and hopefully lead to future areas of research and collaboration. Still, the evidence will also lead to proposed alternative policy changes that could be immediately made to enhance defense innovation when speed and effectiveness as defined by time to market are required.

Organization of Dissertation

Initially, several concepts will be defined and put into historical context. First, in Chapter 2, the concept of innovation in general and then what it means to be innovative in a national security context will be explored. Next, a specific framework for what constitutes the defense innovation system will be established and its specific components identified and categorized. As will be described in more detail, the U.S. defense innovation system will be defined as comprising the industrial base (both public and private) and the managerial framework of regimes that provides the incentives of how this industrial base operates and is structured in order to deliver military capabilities.

In Chapter 3, the historical evolution of defense innovation outputs as categorized by deployable military capability, defense management regimes, and the industrial base in the United States will be reviewed. This review will specifically look at how defense management practices and processes have changed over time and how the industrial base has changed to meet the needs of these processes. Ultimately, in the 1960s the basis for the current management framework was established that subsequently evolved over the next six decades, but within a generally agreed upon set of values.

The key questions asked based on this history are: does the current management framework ultimately undermine defense innovation and should its underlying assumptions and basis (both academic and institutional) be re-appraised? Did a seemingly more scientific and cost-based approach founded on greater control over budgetary, capital and labor inputs actually achieve less innovation productivity than other approaches? By one significant criterion, time, the answer appears to be yes.

Chapter 4 reviews the data with respect to time to development as a variable and its relationship to defense innovation approaches. Time is an output but also an input and can be used as a constraining factor of the defense innovation system. The time it takes to deliver capability is a measurable variable that when linked to a tangible deliverable can also stand in for the degree or level of innovation. While innovativeness may be a value of a system or process it is only when something concrete emerges can one begin to measure its significance. Using time as a variable is useful in that it is measurable and can lead to many questions about process and values. Quality in innovation is obviously important and harder to measure, but rather counterintuitively the most significant disruptive advances in defense innovation history have occurred when time has been constrained. Past studies and data on the rate of defense innovation are assessed to explore whether time should be a basis to evaluate whether there is a current defense innovation problem. As will be demonstrated the time to market in defense programs has been lengthening significantly over the years.

However, the U.S. government has been able to deliver capability faster in certain circumstances when time is deemed important or access is needed to portions of the industrial base that value time-based innovation, but the key parameter that allows this is when programs have been given relief from the constraints of certain defense management regimes. This will be explored in a serious of case examples described in Chapter 5. These cases will focus on: commercial item acquisition approaches for information technology and the Joint Direct Attack Munition (JDAM) precision guided munition during what will be called the first wave of commercial technology dominance in the 1990s; the experimental prototyping that led to the Predator and Global Hawk unmanned aerial vehicles developed using Other Transactions Authority (OTA); the deployment of the National Missile Defense System in the mid-2000s; emergency rapid acquisition programs conducted after 9/11; SpaceX's rocket launcher development under a Space Act Agreement OTA; and in the latest example of this phenomenon new capabilities and prospects for addressing the second wave of commercial technology dominance through Mid-Tier acquisition and production OTA authorities granted by Congress in 2015 and 2016 to address competition with China.

The key factors identified in each of these examples was that time to market or the need to access a portion of the industrial base that valued time to market became important again. Most importantly, the methods used to achieve a quicker development and delivery focused on ways to go around key aspects of the existing management system and processes such as the linear budget, requirements, acquisition, or contract management regimes. For a select few programs the 1960s origin defense management regimes were temporarily waived and innovation success by measure of quicker time to deployment ensued.

The final chapter reviews this case experience, comparative time-based innovation rates, and the historical evolution of defense management systems and the industrial base and then critiques the results of the 1960s defense management framework. Four primary conclusions are made: 1) time is a significant factor in shaping defense innovation; 2) over the last five decades, time to deployment of new capability at DOD has increased significantly while innovation quality has become more incremental; 3) linear processes that implement defense management regimes have increased the minimum time to conduct defense innovation; and 4) government-unique processes within defense management regimes have created barriers to entry that have narrowed the defense industrial base and driven out companies that innovate on a time-based basis. Collectively, these conclusions call for a reshaping of defense management regimes and a reconsideration of the criteria used in guiding and evaluating successful defense innovation.

The U.S. defense innovation system was not only once faster and more effective than it is now but it will be argued that the current linear management oversight framework that implements predictive cost-based evaluation criteria is likely the greatest constraint on returning to past innovation successes. Without changes to the criteria and processes underlying defense management, U.S. defense capabilities will likely continue a relative decline that will lead to a further erosion of U.S. defense technological advantage against its potential adversaries, unless those adversaries adopt similar linear-implemented processes – unlikely given their study of our system. A number of recommended changes to conform these management practices to a more time-based system are proposed that could be made by law and regulation. In addition, the barriers to implementing any such changes are identified. Future research should be conducted to review the assumptions behind the creation and evolution of existing management regimes as potential causes that have restricted past management reform efforts and, if not addressed will make it difficult for future reforms to be implemented.

Chapter 2: Concepts and Variables: Defense Innovation, The Industrial Base, Civil-Military Integration, and Public Management Regimes

"Frankly, … in defense procurement, we have a real mess on our hands"
David Packard [73]

An understanding of the defense innovation system, including its various components and incentive structures, is foundational to confronting future defense and foreign policy challenges and threats. Defense acquisition has historically been the tool of choice when attempting to achieve technological innovation to meet new threats, but addressing the defense innovation problem is much broader than just fixing acquisition. To begin this inquiry, it is first necessary to define one's terms. In this chapter, an innovation nomenclature will be described and established to begin to identify which variables are important to examine. These will include the concepts of innovation, defense innovation, and the defense innovation system.

The focus of defense innovation in this review will be on measurable deployed technological capabilities. The elements of the defense innovation system will be defined as those entities, methods, and procedures that lead to the creation, development, management, and oversight of the deployment of defense technological capabilities. These include the defense industrial base and the rules and management regimes that influence the characteristics of that industrial base.

The components of the industrial base include a trained science, technology, engineering and math (STEM) workforce; and also, the knowledge, infrastructure,

[73] Quoted in Fox, Arming America, p.1.

and technologies generated from years of research and development, production, and maintenance of not only military equipment, but also dual-use technologies that support defense. The organization, nature, and characteristics of this industrial base depend on the resources, funding decisions, and priorities directed at defense; the processes that determine those decisions; the incentives put in place by the government; and the overarching economic market. This framework, or operating "rules of the game", provide the pathway a public or private sector entity to eventually innovate on behalf of the government, as they are the primary means that influence managers to organize labor and capital to meet defense needs.

These governmentally-generated rules establish the underlying process, procedures, and culture of a defense management system that is organized and divided into various budget, finance, requirements, personnel, acquisition, contracting, systems engineering, security policy, and oversight management regimes. To compete in the federal or defense marketplace, an entity must be cognizant of and compliant with these regimes. Depending on how regime incentives are orchestrated will have a direct impact on the quality of innovation, the rate or time it takes to innovation, and the level of participation that can be generated from the industrial base.

Innovation and Defense Innovation

The overall concept of innovation will first be explored and then adapted to the national security context to determine what is defense innovation and how does one measure it. Defense innovation is a critical concept for this review, but it is ill-defined as it rests upon the much more nebulous general concept of innovation. Nonetheless, many areas of inquiry provide insights into refining these concepts.

In the field of business management, innovation has received significant attention, highlighted by the works of Clayton Christianson, Peter Drucker, and many others.[74] Another relevant field of innovation inquiry has been in the area of economic history, particularly on the identification of technological turning points and their relationship to economic growth, often with a lag as new technologies require time to be adopted. Both of these paths of inquiry are useful for a discussion on defense innovation. This literature is helpful in framing questions that this study will raise, such as: What is defense innovation? Why focus on technological change? Is there a U.S. defense innovation problem? Are there limits to growth in innovation? Has it become more difficult to innovate?

Innovation is a difficult term to define. It becomes even more difficult when attempting to measure or quantify the impact of innovation – generally a subjective comparison of two different circumstances or states in time. It has, unfortunately, also entered the parlance of marketing as seekers of capital or sales want to be considered as innovative and working at the cutting edge of innovation. But what exactly is that? Innovation also must be distinguished from invention, which in a

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[74] Clayton M Christensen. *The Innovator's Dilemma: When New Technologies Cause Great Firms to Fail*. The Management of Innovation and Change Series. Boston, Mass.: Harvard Business School Press, 1997.; Peter F. Drucker. *Innovation and Entrepreneurship: Practice and Principles*. 1st ed. New York: Harper & Row, 1985.; James Collins. *Good to Great: Why Some Companies Make the Leap ... and Others Don't*. 1st ed. New York, NY: Harper Business, 2001.; W. Chan Kim, and Mauborgne Renée. *Blue Ocean Strategy: How to Create Uncontested Market Space and Make the Competition Irrelevant*. Boston, Mass.: Harvard Business School Press, 2005.; Peter Thiel. *Zero to One: Notes on Startups, or How to Build the Future*. Clitheroe. 2015.

defense context is quite important, as invention is the source of new discoveries and knowledge, funded as basic research, which then become the building blocks for future innovation.

Webster's Dictionary defines innovation as a new idea, method, or device, or the introduction of something new.[75] But newness for the sake of newness may not always define innovation. There appears to be no shortage of views on the concept. Scanning the business trade press, annual reports, and earnings calls, one may find hundreds of different definitions of innovation emanating within various companies each seemingly creating their own version of the term's meaning in their strategic planning processes. Much as a new start-up or a Fortune 500 company would, this review will attempt to develop its own applicable definition of innovation, to be used in a defense context.

In a practical sense, and at its most basic level, innovation can be looked at as some given output to a series of inputs (budget, personnel, equipment or capital, research or invention) that come together to deliver some new thing or process that is markedly different from (and provides some advantage over) the previous output. This idea becomes much more complicated when attempting to come to terms with the *quality* of innovation. Quality is another subjective term that is dependent on the varied levels of inputs, incentives, and the effect of the innovation. There can be a standardized aspect of quality related to factory production when a unique part needs to be repetitively made and one is measuring tolerances or error rates. Trying to

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[75] Merriam-Webster, Inc. *Merriam-Webster's Collegiate Dictionary*. Eleventh ed. Springfield, Massachusetts, U.S.A.: Merriam-Webster, Incorporated, 2003.

measure a qualitative difference can run into issues related to different standards influenced by whether inputs support outcome and performance-based objectives rather than output and process-based ones. In other words, is quality generated by the recognition of a greater value or by improving process? Something may be new or different but is it better, and if so, who should be the judge of that and by what criteria?

Although he didn't expressly explore the concept of defense innovation, Clayton Christianson is helpful in not only trying to address the issue of the quality of innovation, but also the effect of innovation. His classification of innovation types in business, while addressing the relationship between business firms, can provide a useful nomenclature for describing certain types of defense innovation that arise in the competition between states. Certain definitions may need to be adapted and take on different connotations when looking at a national security environment rather than a business environment.

Still, modifying Christianson's "Innovator's Dilemma" framework to military technology can provide a useful analytical tool in helping to define certain aspects of defense innovation.[76] The incentives and objectives that Christianson focused on to address why companies fail will be different within a business market than in the national security enterprise, where competition among states is not tested in the same way or as quite as often as in the market. In fact, success in deterrence strategies involves never having to test that competitive balance between powers. Still, there are

[76] Christianson, p. xv.

enough similarities that the model of sustaining and disruptive technologies can become a useful explanatory tool in defense.

Christianson's first innovation type is sustaining or continuing to make only those improvements necessary to maintain market competitiveness. This is primarily focused on continuous process improvement within one's business model. It requires no change to culture or operations and is the way a firm maximizes profits over the long term. In a national security context, this can be thought of as the minimum effort necessary to maintain the balance of power.

The incremental improvement of weapons systems initially designed in the 1970s has been the predominant focus of U.S. acquisition approaches toward the modernization of weapon systems for the last fifty years. In fact, many of those same systems started during the Cold War are still the foundation of U.S. military forces – the Bradley Fighting Vehicle, M-1 Tank, Apache helicopter, F-15, F-16, and FA-18. Ships, of course, have planned lifetimes and receive incremental upgrades whenever they are in port for maintenance. For the last several decades, incremental upgrades – either through new contracted programs with the original contractor or conducted during depot maintenance of these items – have been the major source of defense innovation. This is a minimalist strategy that corresponded to the lack of threats after the end of the Cold War and thus could be compared to sustaining or maintaining one's position in the market. As will be seen, it also corresponds with a constraining oversight process focused on delivering capability to meet pre-ordained estimated cost and technical goals. It is easier to meet those goals if one limits risk – either technical or managerial. Sustaining innovation can continue in a national security context until these forces are tested on the battlefield.

In Christianson's concept, one could have radical or revolutionary change within the sustaining innovation category. This is a step change in technological innovation that provides further market advantage, but is designed to maintain one's place in the marketplace. As in more incremental sustaining efforts, there is no need to change culture or operations. This distinction in the national security context seems to be worth its own category of revolutionary or sustaining revolutionary. A step change in military innovation occurred in intelligence, surveillance, data analytics, and sensor fusion to address post 9/11 national security threats designed to track down small independent combatant units in Afghanistan, Iraq, and Syria. These new innovative efforts were examples of how to enable near-term technological advantage on the battlefield, but they would not have been made except for urgent operational shortcomings. Other rapid innovation efforts conducted during this time, such as adapting the V-frame hull on Mine-Resistant Ambush Protected vehicles (MRAPs), counter-improvised explosive device (IED) programs, and advances in battlefield medicine to address the proliferation of road side bombs and armor-penetrating weapons, could also be thought of as revolutionary in the sense that they while technologically significant did not require a significant change in culture or operations to incorporate and provided further battlefield advantage.

Finally, disruptive innovation upends markets. It not only requires a major technological or market offering change but a change in culture and operations or business model. In Christianson's analysis this is an easier to use, cheaper alternative that is more accessible and available to a larger population. This is likely not to come from the incumbent, who is more focused on sustaining innovation. In business, disruptive innovation comes from finding a cheaper way of doing things -- which has not always been the case in the defense market. The one area in defense that might qualify is the proliferation of cheap, unmanned drones to smaller militaries as a more accessible way to achieve several military missions. The increase in the use of drones by less capable militaries and insurgent groups may adhere more to Christianson's idea of finding a cheaper way to do something. The recent use of drones in Nagorno-Karabakh for tactical advantage by Azerbaijan and the drone strike on Saudi Arabian oilfields in 2019 are recent examples of that type of potential disruptive defense innovation. The asymmetric strategies pursued by Russia and China, such as cyber warfare and disinformation, and anti-access/area denial (A2AD) strategies may be cases of revolutionary innovation, but could also meet Christianson's disruptive criteria of cheaper, more accessible innovation likely to be initiated from outside the dominant culture.

While disruptive innovation can change the market and culture or operations, the Christianson framework would need to be modified in defense to address a truly radical new revolutionary technology or capability to emerge, which is likely to be less accessible and perhaps more expensive than other alternatives, at least initially. The submarine, tank, aircraft carrier, nuclear weapons, and satellites were disruptive innovation candidates as defined by the need to change culture, but they do not meet the rest of the Innovator's Dilemma definition. Disruptive innovation may be closer to the technological component that supports the concept of the Revolution in

Military Affairs doctrine from the 1970s that originated in the Soviet Union and was the source of much interest in the U.S. after the Gulf War by Andrew Marshall in the Office of Net Assessment.[77] Future disruptive innovation in this context could potentially cover the potential use of artificial intelligence linked to autonomous systems or directed energy weapons. Recent advances in hypersonic missiles may be disruptive, but as they seem to fit within the culture of current missile systems and delivery, they might also be thought of as a revolutionary step change from ballistic or cruise missiles.

Under these definitions, defense innovation in the U.S. has focused in peacetime on evolutionary or sustaining, and (in a pinch) in minor conflicts since the end of the Cold War, on revolutionary sustaining innovation. To compete in a new Great Power competition, defense innovation will likely need to be disruptive, and that will likely require a change in culture. The ingrained cultural resistance to disruptive new technologies and ways of doing business is a useful concept when addressing opposition to any potential changes to the industrial base and management regimes necessary for further future defense innovation.

The arms race or action-reaction arms control literature that arose during the arms control debate of the 1960s may also be relevant in assessing the logic behind advances in defense sustaining and revolutionary innovation.[78] If the logical next step

[77] Peter Dombrowski and Andrew L. Ross. "The Revolution in Military Affairs, Transformation and the Defence Industry." *Security Challenges* 4, no. 4 (2008): 13-38.

[78] This concept was introduced in a speech by Secretary of Defense McNamara on September 18, 1967. Also see Morton Halperin, "The Decision to Deploy the ABM: Bureaucratic and Domestic Politics in the Johnson Administration," *World Politics, 25*(1) (1972), 62-95; Albert Wohlstetter. "Is There a Strategic Arms Race?," Survival, 16:6 (1974), 277-292,; and Paul Warnke. "Apes on a Treadmill," *Foreign Policy,* (18) (1975), 12-29.

in weapons technology development would just elicit a new expensive countermeasure, would it not be better to call a halt to all of that wasteful expenditure through an arms control agreement? Perhaps, but only if your opponent decides to pursue domestic spending alternatives as well, rather than use the savings in forgone countermeasures to invest in another, more troublesome threat like cyber warfare or hypersonic missiles.

The policy debates conducted since the 1990s on achieving a Revolution in Military Affairs or a Third Offset Strategy in the mid 2010s may well fit within a disruptive innovative framework, but these analyses may better correspond to another approach to assess innovation by focusing on historical turning points (or what can be viewed as past disruptive innovations).[79] The history of technology, and particularly the industrial revolution, has focused on identifying broad sweeps or turning points in innovation – such as steam power, railroads, electricity, the internal combustion engine, airplanes, or computers. For example, Robert Gordan classified these periods and technologies in the following way:

> 'The interpretation of past economic growth is anchored by the three industrial revolutions. The first (IR #1) centered in 1750-1830 from the inventions of the steam engine and cotton gin through the early railroads and steamships, but much of the impact of railroads on the American economy came later between 1850 and 1900. At a minimum it took 150 years for IR #1 to have its full range of effects.
>
> The second industrial revolution (IR #2) within the years 1870-1900 created within just a few years the inventions that made the biggest difference to date in the standard of living. Electric light and a workable internal combustion engine were invented in a three-month period in late 1879. The number of municipal waterworks providing fresh running water to urban homes

[79] Barry Watts, "The Maturing Revolution in Military Affairs," Center for Strategic and Budgetary Assessments, 2011. p. 1.

> multiplied tenfold between 1870 and 1900. The telephone, phonograph, and motion pictures were all invented in the 1880s. The benefits of IR #2 included subsidiary and complementary inventions, from elevators, electric machinery and consumer appliances; to the motorcar, truck, and airplane; to highways, suburbs, and supermarkets; to sewers to carry the wastewater away. All this had been accomplished by 1929, at least in urban America, although it took longer to bring the modern household conveniences to small towns and farms.
>
> The third revolution (IR #3) is often associated with the invention of the web and Internet around 1995. But in fact electronic mainframe computers began to replace routine and repetitive clerical work as early as 1960." [80]

Defense technologies could be categorized using a similar classification of turning points in defense technologies, grouping into historical periods various disruptive technologies such as gunpowder, the longbow, firearms, the machinegun, iron-hulled ships, submarines, tanks, aircraft, radar, the jet engine, missiles, reconnaissance satellites, nuclear weapons, stealth, and precision guided weapons and navigation. In defense, however, identifying what is most innovative in the last 40 years is difficult, if not daunting, as innovation moved to more incremental sustaining types of innovation while the commercial sector has been more disruptive.[81]

The idea of a lack of major disruptive defense technologies in the recent past leads to another useful source of ideas from debates and ideas between those who tend to be technological pessimists, such as Robert Gordan and Tyler Cowen, versus the techno-optimists such as Matt Ridley or the culture of Silicon Valley.[82] Has there

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[80] Robert J. Gordon, "Is U.S. Economic Growth Over? Faltering Innovation Confronts the Six Headwinds" Working Paper 18315; National Bureau of Economic Research, Cambridge, MA. August 2012.

[81] Unmanned defense systems may eventually prove to be the exception, but as will be seen in Chapter 5 these systems were developed outside the prevailing defense innovation system.

[82] Tyler Cowen. *The Great Stagnation: How America Ate All the Low-Hanging Fruit of Modern History, Got Sick, and Will (Eventually) Feel Better*. New York: Dutton, 2011.; Ridley, Matt. *The Evolution of Everything: How New Ideas Emerge*. First U.S. ed. New York, NY: Harper, an imprint of Harper Collins Publishers, 2015.

been a decline in innovation and if so, how does one measure that? The pessimists argue that we have reached the end of the easy discoveries and that the computer revolution has not had the productively increases that we imagined. The optimists argue that the world is getting better and innovation will continue as long as it is based on the freedom of thought and application of venture capital flowing to new innovative ideas in the Silicon Valley eco-sphere.

This debate is relevant to national security as some of the more significant approaches that the military is pursuing are the next steps in the computer revolution. DOD can still benefit from those advances taking place in the economy as a whole. Whether it can take the next innovation step or it has just gotten harder to elicit breakthroughs in defense science and technology development remains to be seen. Unlike in the rest of the economy, DOD has not taken advantage of and adapted to the commercial computer revolution and innovation as well as the commercial market. DOD's innovation approach currently supports the techno-pessimists, but is a limit to knowledge or the innovation model that might be holding DOD back? The technological optimists may argue for adopting a different model that could lead to disruptive innovation that would reject the pessimist's thesis.

Defense Innovation as a Capabilities Based Variable

While the preceding literature may be useful in a defense policy sense and can provide potential analytical insights, what is missing is *data*. What are the most important aspects to assess when looking at defense innovation, and can they be measured? Many of the described concepts focus on shifts in technology or the use of technology, although process innovation can also be argued as being disruptive. In looking beyond defense technology, defense innovation can be found in a number of personnel, process, and operational areas. First, innovation can occur through different strategy and tactics, such as the application of forces and technology in new combinations, for example, the Blitzkrieg of the 1940s, the Airland Battle of the 1980s, or potentially today's concept of All Domain Operations. The French had more tanks than the Germans at the start of WWII, but they also had a different and ultimately unsuccessful concept of operating them. James Q. Wilson thought the secret to the German success against France was better organization: "the key difference between the German army in 1940 and its French opponents was not in grand strategy, but in tactics and organizational arrangements well-suited to implement those tactics. Both sides drew lessons from the disastrous trench warfare of World War I. The Germans drew the right ones."[83]

Technology alone may not lead to victory, but new ways of using equivalent technology can make a difference. A matchup between two forces with identical technologies can lead to entirely different outcomes. Better and more innovative tactics and training leading to greater force readiness are critical to implementing strategy. Leadership innovations such as those that would allow individual soldiers to make decisions in the "fog of war" rather than rely on centralized headquarters decisions beyond the battlefield may also be a force differentiator.

[83] Wilson, p. 14.

Still, science and technology development is a critical factor usually considered first when discussing future defense innovation. Better tactics, leadership, and training will find it difficult to overcome severe technological or industrial overmatch. While the lessons of Vietnam and Afghanistan prove that overmatch can be overcome, in these cases success came only through decades of unconventional warfare and political strategy aimed at maintaining a stalemate. Technology can and should be a focus area for analysis and policy, but technological superiority should not be thought of as a guarantee to achieving one's political objectives through warfare.

What technology does have going for it as a variable to use when analyzing defense innovation are the decades-long sources of data underpinning it. There are usually official public discussions about military programs starting with earlier technology research efforts. Research funding levels and priorities provide insights into where future disruptive ideas may be coming from. While many of these ideas don't succeed, are abandoned, need further discovery, or meet the so called "valley of death" awaiting non-existent funding in the future, those programs that do survive can serve as a basis of further analysis.

The level of science and technology spending is measurable and can provide insights into priorities and possible future capabilities. Still, even proving an idea in research doesn't mean it will be adopted or that adoption won't have a significant lead time. These efforts do not imply that it will actually lead to a useful new item that military personnel may be willing or able to use.   Once usage happens though, a threshold has been crossed that provides for a real basis for analysis. It is for that reason that science and technology development leading to deployment as a capability is an appropriate measure of defense innovation. The focus of the measurement of defense innovative efforts in this study will be on the physical weapons system capabilities that are tested, deployed, and used by U.S. forces, while recognizing that defense innovation also occurs in many other non-technology areas.

Thus, as a basis for measurement, defense innovation will be defined as the changes that are made with technology as demonstrated in the tangible and measurable output of a deployable defense capability. These deployed or operational programs are not only material and calculable, but often used as a basis for measuring the balance of power between states, for example in the International Institute for Strategic Studies' annual *Military Balance* that lists by nation the number and types of ships, combat aircraft, armored vehicles, and other military equipment and capabilities.[84] When trying to measure or define defense innovation, it becomes practical and logical to focus on weapon systems. This is not only where most data are, but also where there has been the greatest focus of governmental and academic literature on defense management.

Advances in basic science and invention are important, but if not coalesced around a usable system or capability, are just an unused building block until incorporated into an operational prototype or system. The key data point for analysis is likely to be found in the later stages of technology development, particularly regarding operational prototyping and the fielding of a defense capability or weapon

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[84] Institute for Strategic Studies, (London, England), The Military Balance, Journal, 1963-present.

system where operators can use and test the system. A similar point in commerce would be at the stage of the marketing of a new product where consumers for the first time decide whether to buy such a product.

Weapons systems are the tangible outputs of defense innovation policies and over the years significant data has been collected on the underlying costs, schedules, plans, and performance of these systems. Identifying lessons learned from this data and experience that can be used to inform future policy decisions and debates is one goal of this research. The use of these systems for evaluation is not only important for analysis because there is data, but also because of their outsized importance in military affairs.

The Defense Innovation System

If the concept of successful defense innovation is equated to deployed defense capabilities, then the next step is defining the system that produces those capabilities, followed by identifying and categorizing specific system components. The defense innovation system is critical to the success, failure, quality, and performance of any new defense innovation that manifests itself as a deployed capability. The defense innovation system can be divided into two components. The first is the industrial base that develops and produces the results of defense innovation – i.e., designs, produces, and maintains a deployed weapon system. The second is the management framework that provides the rules and management oversight regimes that govern and incentivize the behavior of that industrial base.

Industrial Base Component of the Defense Innovation System

The industrial base component of the defense innovation system includes the stock of people, knowledge, infrastructure, and capabilities generated from prior research and development, production, and maintenance of not only military equipment, but also dual-use technologies that support defense. How these different factors are organized to support defense and national security needs determines the nature, structure, and characteristics of the industrial base (such as whether it is competitive, monopolistic, privately or government run). The defense industrial base is a subset of the larger domestic economic and global industrial base and varies in its makeup based on ownership of the means of production.

The determination of how defense capability is provided, and by whom, is the subject of a nation's defense industrial policy. Defense industrial policy is, in the broadest sense, how a nation harnesses its economic resources to meet its military needs. It is a subset of (and also dependant on) a nation's overall industrial and national economic policy. This industrial policy can be de facto, de jure, laissez-faire, or explicitly identified and codified. Those who oppose the concept of a national industrial policy need to come to terms with the fact that a laissez-faire approach to let the markets decide the course of investment and innovation is in actuality an industrial policy in itself.[85]

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[85] The implications of a laissez-faire industrial capacity were illustrated during the COVID-19 pandemic. The personal protective equipment industry had moved offshore to China absent any incentive to stay in the U.S. as there appeared to have been no countervailing awareness or policy to maintain that capability domestically.

A nation's industrial base or industrial capacity places limits on the kinds of defense innovation that can be pursued. For example, if certain industrial capacities are lacking, a nation may have to either develop that capability within the government, provide incentives for domestic industry to enter the government market,[86] or contract with entities abroad to obtain that capability. Once a capacity has been created, maintaining or monitoring that capacity becomes important, otherwise due to neglect it may atrophy or disappear.

A nation's defense industrial policy can function at the national economy level, the industrial sector level, the industrial unit level, and at the workforce level. Economic incentives and other variables operate at each of these levels and contribute to industrial policy outcomes. Industrial policy is dependent on a series of management regimes, such as contracting, whose practitioners would likely not consider themselves conducting defense industrial policy but are critical in shaping how the defense industrial base is organized and incentivized.

At the national level, the ability to provide security to its citizens from external and internal threats is a primary function of government and a key test of competence. To defend against threats to its sovereignty, the military and civilian sectors of the economy of a nation are linked at a basic level. Military capability has to be paid for and the underlying economic capacity to create a surplus is a necessary requirement to supporting a professional military and dedicated defense industry. This was as true with a Bronze Age agricultural surplus that allowed for the creation

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[86] Possible incentivizes include creating domestic source restrictions that require all government agencies to source from a domestic company, tariffs, taxes, sanctions, and advanced purchase agreements to establish future market demand upon which to justify investing in production capacity.

of a specialized warrior class as it is for the role of the Federal Reserve, sufficient tax revenue, and Treasury financing in the nuclear age. A surplus in the underlying economy is a necessary prerequisite of any military capability.

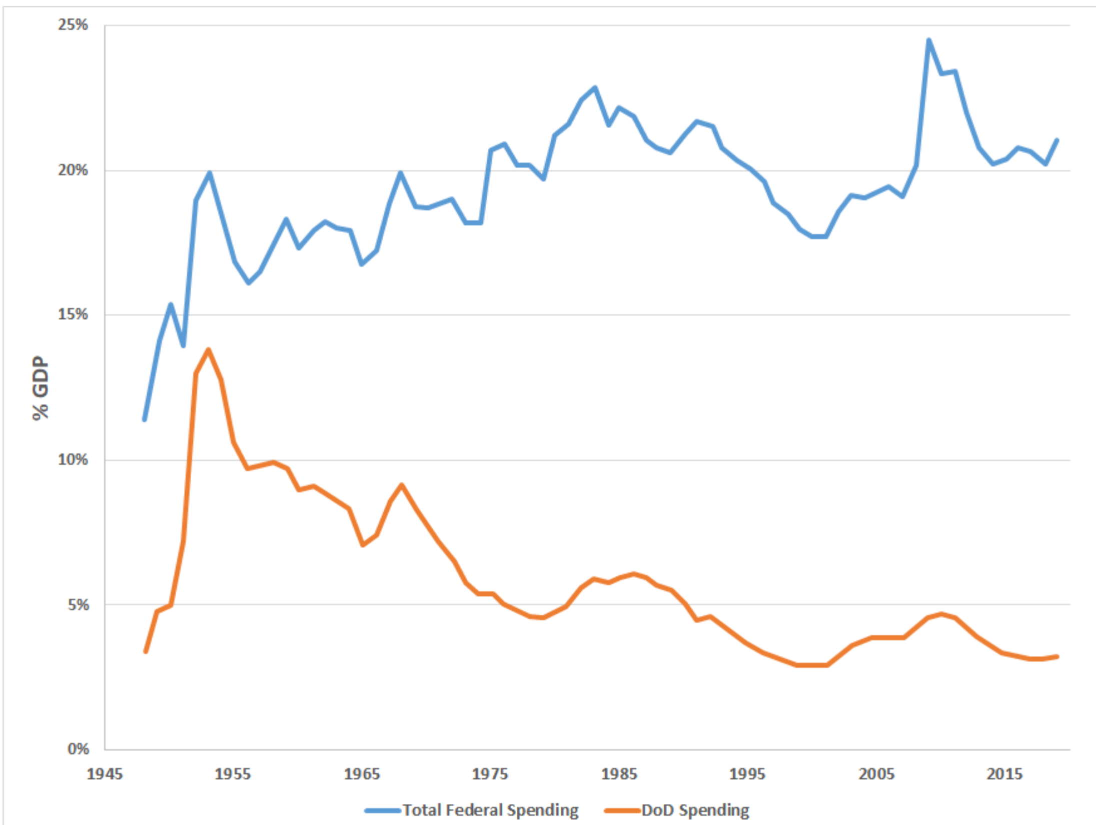
At the national level of industrial base strategy and policy, wealth in the underlying economy is a key variable with Gross Domestic Product (GDP), level of debt, and the ability to borrow money in peacetime or wartime critical to the military potential of a nation. Defense capability relies on the civilian sector to create the wealth or surplus that can be taxed, expropriated, used as collateral to incur debt, or otherwise shifted to meet military needs.[87] Thus, the ability of the civilian/commercial side of the economy to ultimately create overarching wealth and a growing GDP is key to the ability of a nation to remain militarily strong. While overall economic health is not always thought of as traditional defense policy goal, it actually stands as the first principle of any supporting defense industrial policy.[88] Once a decision is made to transfer funds to the government, a decision must be made about how much of a government's revenue should be applied to military needs ("guns") or domestic needs ("butter"). Figure 2.1 identifies the public policy choices that the U.S. has made since World War II. While top-line defense expenditures have risen during this time, the allocation between guns and butter has changed with a

[87] Decisions made about how to allocate the resources of a nation to meet defense needs have significant national security and economic implications. The inability of the underlying economy to create enough wealth to pay the debts incurred to support the military activities of 16th and 17th century Hapsburg Spain and France in the 18th century weakened these nations and contributed to their decline from Great Power status. It did not take long after the destruction of Europe's wealth in World War II to see that these nations could no longer maintain large colonial possessions overseas nor prevent the passing of global power to the United States and the Soviet Union.

[88] Former Chairman of the Joint Chief of Staff Admiral Mullen's concern about the national debt in 2012 may have taken by some as a surprise coming from a senior military official, but looking through history it should come as no surprise that the military is concerned about the ability of a nation to finance its wars. See: "Mullen Focus on Debt as Security Threat", Politico December 6, 2012 p. 14.

growing percentage of GDP moving to nondefense government spending and a declining percentage for defense.

Figure 2.1: Defense and Non-Defense Federal Expenditures as a Share of GDP[89]



Once resources are shifted to military control and executed through a defense budget, defense industrial policy focuses on the industrial sector level and how the

[89] Byron Callan, p. 31.

defense industrial base should be structured. Throughout history, as the need for advanced weaponry evolved, the defense sector of an economy primarily become a specialized unique government-run industrial base focusing on products that typically do not have a civilian use. This often required maintaining a dedicated industrial base in peacetime that could be ramped up in times of conflict. Gradually, in many nations there began an evolution from an arsenal model, where the government controls the means of defense production, to a greater role of the private sector – particularly in times of crisis, where there is a need to mobilize to meet a near-term threat. This private sector participation has been justified for efficiency, but also for innovation reasons.

The next policy level of analysis is at the industrial unit level and the microeconomic and behavioral incentives that operate within a firm or a governmentally owned industrial enterprise. If the entity is privately owned, concerns such as the maximization of profit, market share, risk, and the control of intellectual property become important values. The various distinctions in private ownership also become important, as contractors can be publicly-traded firms or privately held, and the views of these investors on profits, cash flow, and revenue can impact the firm's behavior. What is significant, at least in the U.S. and other democracies, is that private sector firms usually have the option of participating or not in the defense industrial base. Therefore, the nature of regulatory management regimes are key determinants in that participation decision.

If an industrial base entity is government-owned, political factors are more relevant than market incentives in determining how resources are allocated. The state will likely be responsible for directly appropriating funds for the operation of these entities. Sometimes, market-like mechanisms are created to try to mirror the private sector or incentive private sector behavior in a public sector entity, such as the use of working capital funds or competition between public entities, but these are not necessarily needed or the norm.[90] The U.S. experience with its government-run arsenals and depots illustrates that it is extremely difficult politically to close a government run facility, while the private sector can do this much easier. This resistance to political factors is one source of near-term comparative advantage for the private sector. On the other hand, having a "just-in-case" governmental capability provides greater resiliency in a crisis and an alternative to a monopoly private sector provider. Once closed, however, sufficient demand, lead time, and resources are necessary to reconstitute an industrial capability – whether private or public. U.S. allies have found it easier to close or privatize government facilities, but it has often only been severe defense budget constraints that forced these countries to do so.

Finally, a fourth level of defense industrial policy is concerned with the personnel capabilities of industrial units and the associated government organizations' ability to effectively oversee the industrial base that can meet defense needs. As technological and managerial complexity rises in defense systems, the workforce must have the necessary skills and experience to address that complexity. The workforce level unit of analysis is important not only at the industrial unit level but also in the managerial workforce of the government that must oversee a vast

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[90] Working capital funds are revolving funds established by Congress to finance commercial like operations at DOD such as maintenance depots. See: U.S. Congressional Research Service, "Defense Primer: Defense Working Capital Funds" March 23, 2018.

technical enterprise. The core question at this level is: does a nation have the scientists, engineers, managers, technical knowledge, and necessary resources to design, develop, test, and produce advanced weapon systems?

The defense industrial sector can take on many different structures, as outlined in Table 2.1. One of the key distinctions that can be made when analyzing the structure of the defense industrial base is highlighting the degree of private sector or public sector participation and the ownership of facilities, equipment, and intellectual property. On one end of the spectrum, the government can own and operate the means of production and the private sector's role is limited. In the middle of the spectrum, is a military-unique, privately-run industrial base that only supports the government, and on the other end of the spectrum, is an integrated commercial and military base that supports both defense and commercial applications. The industrial base can be privately held and run or be some mixture of the two-sector model, such as a hybrid where the government owns the assets but the private sector runs operations. In each of these structures the private sector can execute a government-created specification or mandated solution, have discretion in developing and determining a military unique solution, or bring in a commercial solution developed at its own expense to meet a military need.

TABLE 2.1: Defense Industrial Sector Structures Based on Degree of Reliance on Private Sector

Structure	Role of Private Sector
Government Owned-Government Operated Arsenal	• Private Sector May or May Not Provide Raw Materials or Services to Government Arsenal
Government-Owned Contractor Run Arsenal	• Private Sector Management of Government Arsenal
Private Sector Arsenal	• Private Sector Management and Ownership of Means of Production • Build to Print from Government Designs and Military Specifications
Military Unique Industrial Base	• Develops Military Solutions within Specialized Industrial Base
Military-Unique + Commercial-Off-the Shelf (Limited Civil-Military Integration)	• Augments Defense-Unique Solutions with Non-Modified Commercially Available Off-the Shelf Products
Military-Unique + Commercial Items (Partial Civil-Military Integration)	• Augments Defense-Unique Solutions with Modified Commercial Products
Full Civil Military Integration	• Integrates Commercial and Military Unique Bases • Adopts Commercial Best Practices • Produces Military Products on Commercial Production Lines

Within the privately-held defense industrial base a further level of distinction can be made. Are these private firms conducting only military business or combining their military with commercial business in development and production? Do firms have unique separate defense divisions or do they support both markets with limited internal separation? This is important in assessing whether the government market is so unique that a firm has to essentially set up the equivalent of a stand-alone private sector arsenal, which is differentiated from the public one in that the profit motive provides some market discipline – which the public arsenal lacks. Each of these issues must be considered at not only the prime contractor level, but at the lower tiers, since the latter frequently represent the major risk and cost issues on a defense program.

This discussion of the internal structure or incentives of the private sector leads to the introduction of the concept civil-military integration (CMI). Defense technological innovation in the U.S. and elsewhere has been greatly influenced by the periodic cooperation and integration of the commercial and military unique industrial bases. The level of this technological cooperation has been referred to as the degree of CMI in the national industrial base. CMI became a widely-used defense term of art and policy objective in U.S. in the early 1990s and refers to a policy that was starting to be pursued in the 1980s, but whose roots go back farther.

In the 1990s, a congressional agency, the Office of Technology Assessment, defined CMI "as the process of uniting the Defense Technology and Industrial Base (DTIB) and the larger Commercial Technology and Industrial Base (CTIB) into a unified National Technology and Industrial Base (NTIB). Under CMI, common technologies, processes, labor, equipment, material, and/or facilities would be used to meet both defense and commercial needs."[91]

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[91] U.S. Office of Technology Assessment, "Assessing the Potential for Civil Military Integration," September 1994, p. 15. The DTIB is comprised of both privately run and government run entities that are distinct from the rest of the CTIB.

The level of CMI is differentiated by the degree of segregation of various aspects of the industrial base into a stand-alone DTIB and CTIB.   This segregation can occur at the technology, process, workforce, industry, individual firm, or facility level. The goal of CMI at each of these levels is to encourage desegregation and establish greater integration of the two industrial bases to enable improved cooperation and the sharing of ideas, workforce, and capital to maximize productivity and innovation in both the defense and commercial sectors. Thus, if a firm like Boeing was producing a defense and commercial product on the same production line (as it now does with the P-8 and the 737), that implies a higher degree of CMI than having separate production facilities or separate business units focused on different markets.

The nature of the private portion of the industrial base can be changed through mergers and acquisitions leading to the consolidation of the defense industry, foreign investment, or through new entrants into the market such as emerging small business and from the venture capital market. The health of adjacent commercial markets and perhaps the most importantly – revenues, cash flow and profit margins in relation to those available in the commercial market are other key factors. Revenues, cash flow and profits and cash flow determine whether a company will enter or continue to remain in the defense market. Ultimately, it will be profits that determine whether a company stays in business. Wall Street and private finance police how well a firm manages its profitability over the long run and will provide incentives such as punishing the stock price or withholding capital or debt financing if it believes management is not maximizing its profits.

The financial markets are vitally important in shaping incentives for whether a company chooses to stay in the federal market or not, yet are often not considered or are an afterthought in government actions. The industrial base is a collective of individual units. If private, these units as individual firms respond as a dependent variable to either a constraining or liberating set of rules and incentives that are made in the capital markets or, as will be explored in the next section, by its monopsonist buyer, the DOD.

A final factor that is useful in analyzing the defense industrial base is the degree to which the domestic industrial base is open to buying or cooperating with industrial units in foreign countries. This could range from public sector R&D cooperation, to purchasing from foreign governments and foreign companies, to private-sector to private-sector cooperation. Domestic source restrictions and security requirements may prevent such cooperation, but it also may prevent commercial firms from accesses technology and internal industrial units that reside overseas to participate in defense programs.

The Public Management Regime Component of the Defense Innovation System

The organization, nature, and characteristics of the industrial base that supports defense is dependent on the budgetary resources, funding decisions, and priorities directed at defense; the processes that determine those decisions; and the incentives put in place by the government. This framework of rules provides the pathway for how a public or private sector entity (domestic or foreign) will eventually innovate successfully for the government, as they are the primary means that influence managers to organize labor and capital to meet defense needs. These rules influence whether to enter or exit the market and the degree of CMI within a firm and collectively in the larger industrial base, based on multiple company decisions.

These incentives, or rules on the government side, are implemented by public management regimes that may set the rules in addition to overseeing them. Some of these rules are enacted into law, often at the request of the executive branch management regime, or from companies attempting to gain a market advantage. This rule set is influenced by a series of values that the government – either the Administration or Congress – is trying to achieve. For example, to achieve a certain level of efficiency, effectiveness, fairness, competition, innovation, socio-economic goal, or other purpose. The availability of resources and the level of threat are two other variables that may influence these rule sets.

These governmental rules comprise the underlying process, procedures, and culture of defense management regimes that address budget, finance, requirements, personnel, acquisition, contracting, systems engineering, security policy, and oversight. To compete in the federal or defense marketplace, a governmental actor or firm must be cognizant of and compliant with these regimes. How the regimes' incentives are orchestrated has a direct impact on the degree of innovation and level of participation that can be generated from the industrial base. For private sector firms and participation, this is particularly exacerbated when the governmental regimes are at odds with market norms and practices – which is the other side of the coin that constrains private sector behavior. How government rules impact capital markets is equally important as these rules factor into whether firms will even enter the government market. For those that stay, it can impact their access to talent and financing.

Each management regime can impact defense innovation in two major ways. The first is on the nature of the industrial base and how it is able to propose solutions to defense problems. The second has to do with the constraining factor of regime process on the time to conduct innovation. Governmental rules set a timetable for how long it takes to innovate – i.e., how long it takes to deliver a weapons capability to the troops in the field or sailors at sea. Compliance with the rules of the regimes takes time, and that time becomes the lower limit of how fast the government can innovate, as defined by the ability to deliver defense capability. Obviously, if the government is trying to do the impossible, time goals become meaningless, so there is always a necessary balance between the art of the possible and desired schedule.

The amalgamation of defense management regimes that impact defense innovation are part of a larger government management framework that exists in the federal government. All of the regimes have a congressional component or interest, and many have either active participation or oversight from other federal agencies that restrain and check DOD behavior. Many other management functions at DOD address more than just the development of technological capability. On the DOD organizational chart, policy, intelligence, strategy, and operations are important and each of these functions has its own management regime, which could be assessed and analyzed for its impact of innovation. While these regimes will be discussed where appropriate, the portions of management regimes that relate to the development of technological capabilities and thus are critical to defense innovation will be of primary focus. This set and subset of management regimes that support the function of developing weapons systems capability are the components of the Defense Innovation System.

The collective management regimes that constitute the Defense Innovation System could also be described as the overarching acquisition system (Appendix A provides a more detailed description of each regime's focus, rule set, and potential impact on innovation in general). This would be a much broader framework than what one currently thinks of as the acquisition system, but may have a better explanatory function. For years, much of the theoretical focus on the acquisition system has seen an undue focus first on the contracting system and then the program management function. The Defense Acquisition Performance Assessment (DAPA) panel report in 2006 attempted to broaden this to include other several management regimes into a concept of "Big A" acquisition that included – requirements, budget and acquisition vs. "Little A" – contracting.[92] This has been a useful but not inclusive description as other regimes such as personnel, security, and oversight can also impact and are an integral part of most acquisitions of defense innovation programs. It is also significant that larger issues related to innovation and the industrial base are often not considered a holistic system with the industrial base often assumed as a given or a constant. While this framework is more complex than the DAPA "Big A" construct, it is more realistic. Each of the management regimes that influence

[92] *Defense Acquisition Performance Assessment Report,* p. 4.

weapons acquisition can be better described as the management regime component of the Defense Innovation System.

Each management regime – whether structured to do so or not – impacts the nature of the industrial base and often the time it takes to innovate. These impacts are determined through policy choices by the government in how it formulates the problem of what it wants innovation for, how it wants to engage the industrial base (both public and private), and how it uses its market power to set the rules that govern relations with the private sector. These rules are not only public procurement or contracting rules, but include, for example, addressing technology transfer and the ability of the private sector to use its technology and sell a product or service once it does so to the government.

The government can set these rules because the defense market is not a normal market that exists in a capitalist economy. It is a monopsony market comprised of one sovereign buyer and many sellers. Within the defense monopsony market, the government can structure the rules to fit the type of industrial base it prefers, with each structure requiring an optimal rule set to achieve.[93] Thus, by the virtue of being a monopsony, the government determines the rules through acquisition policy and guided by industrial policy objectives, which ultimately determines the makeup of the defense industrial base. The reality is that the

[93] There are several advantages and disadvantages to the current U.S. government run monopsony market. The government can focus on leading edge technologies that the commercial market is not focusing on that can lead to various technological spin-offs to the commercial sector. The size of the U.S. defense market at over $400 billion in domestic contracts and foreign sales allows for a degree of concentration of effort, but still, it pales in comparison to the $2.7 trillion information technology market. While the defense market lacks competition at the prime contractor level, the majority of costs are to be found at lower tiers where competition can be more plentiful. On the other hand, unique regulations, accounting requirements, and low profit margins deter market entry participation.

government may not be guided by the overarching impact when it makes up its rules separately in each specific management regime, but creating rules does not mean that there is not an impact. The optimization of rules for each management regime may actually suboptimize the outcome of the system as a whole.

If regime rules are too limiting or the market too small, there may be no firms willing to participate or only one sole-source provider that the government then has to monitor and potentially, be forced to manage the health of that provider. On the other hand, in some markets the government can choose to leverage the commercial marketplace and take advantage of whatever level of competition exists in that market, but may be limited to buying whatever the current commercial solution is that may not completely meet the military's need. In other cases, the government may need to manage competition, creating an artificial market that attempts to maintain competition for a unique government need – for example in the cases of submarines or warships that have limited commercial equivalents.[94]

However, the government may not always obtain significant benefits from maintaining competition in the defense market, such as greater innovation and cost reduction because of how the market is structured. The market can be centrally managed through a more command and control approach or can be more passively managed, taking advantage of the incentives of the marketplace and only intervening when competition or some other priority is under threat. Still, even with what may be

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[94] Although, even in these predominantly defense-unique markets there is a civilian submersible market and similar shipbuilding technologies are used on container ships and cruise liners (not to mention commercial electronics and business practices) that could be tapped to the military's benefit through CMI efforts.

defined in government programs as robust competition – 2-3 defense unique firms bidding on a major defense system – this approach might be leaving out the innovational opportunity from firms that have little incentive to do business with the government.

Therefore, in a monopsony, the criteria used in any top-down command and control management approach is an important factor to explore in what type of industrial base coalesces around the government market. Because the defense market is controlled by the buyer, a seemingly laissez-faire approach to competition could end up with only a few providers that specialize in compliance with centrally-determined unique government rules. This could be at odds with an outwardly centralized approach that would divide up the market in ways that could encourage new entrants by making government rules more open and commercial-like. Whether using a centralized or laissez-faire approach to implement government-unique or commercial-type rules are some of the alternative government market structures that a private sector firm may face as it determines the costs to comply with the government rule set.

Chapter 3: The Evolution of U.S. Defense Management Regimes and the Industrial Base

"[PPBE is] really a relic of the Cold War — a holdover from the days when it was possible to forecast threats for the next several years because we knew who would be threatening us for the next several decades … [It is] one of the last vestiges of central planning left on Earth." Donald Rumsfeld[95]

Prior to any potential reallocation or increase in resources to address a rise in national security threats, it is vitally important to understand the reasons behind past innovation successes before determining what approach the U.S. should adopt in developing and delivering new military capability. This chapter assesses the historical record of the factors that influenced U.S. defense innovation to include specific defense capability advancements, the industrial base, and defense management regimes. Three periods will be reviewed. The first, from the founding of the Republic until the beginning of World War II, saw the rise of a narrow and limited price-based peacetime defense innovation framework that was found unworkable in periods of conflict. The second period emerged during World War II and lasted until the early 1960s. This system relied on a time-based innovation approach and was ultimately replaced in the third period by a cost-based system that continues to dominate today.[96]

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[95] Donald H. Rumsfeld, remarks delivered to the DOD Acquisition and Logistics Excellence Week Kickoff—Bureaucracy to Battlefield, Pentagon, Washington, D.C., September 10, 2001; quoted in Institute for Defense Analyses (IDA), *Exploring a New Defense Resource Management System*, IDA Paper P-3756, Alexandria, VA: IDA, April 2003.

[96] Several sources of documentation have been extremely useful in providing a foundation in the history of how the U.S. has managed defense innovation efforts. The U.S. government has done a remarkable job through its network of history offices at OSD and the services to document acquisition, logistics and maintenance issues that have faced the military since the revolutionary war. One such project to describe the history of defense acquisition since World War II was commissioned in the late 1990s and culminated in an assessment by Fox in 2011 ("Defense Acquisition Reform: An Elusive Goal") referenced above that describes the history of acquisition reform efforts and outlines the

Overarching Cycles in the Pre-World War II Defense Innovation System (1792–1938)

The roots of the defense innovation system (both in the industrial base and federal management regime incentive framework) date back to the pre-World War II era. The U.S. Constitution gave Congress the power "to provide and maintain a Navy" and "to raise and support Armies." This was offset, however, by an aversion to actually creating a strong standing military by limiting army funding in the Constitution with the caveat "but no appropriation of money to that use shall be for a longer term than two years."[97] This anti-militaristic approach was also linked to the experience of the Revolution when the British quartered troops in American homes -- the subject of the Third Amendment to the Constitution to prohibit such a practice.

Upon independence, a cyclical history of conflicts influenced U.S. defense innovation policies and the development of a defense industrial base up until the beginning of World War II. These cycles manifested themselves through defense budgets increasing in response to conflicts but – most critically – followed by a desire to return to minimal defense spending after each conflict. As Jacques Gansler observed: "Beginning with the revolution, the United States has built up its defense production as required for a war, and as soon as the conflict was over, producers essentially disbanded and returned to normal commercial operations. Each time, the

difficulties in reforming the defense acquisition system over a 50-year period. The first two volumes in the series by Eliot Converse and Poole provided significant insight into the evolution of defense management regimes from World War II to 1968. Another significant source of historical context is James Nagle's history of government contracting. Nagle, James F. "A History of Government Contracting" Washington DC: George Washington University Press, 1999.

[97] Article 8, United States Constitution.

approach taken was that this would be "the last war, and no future military would be required."[98]

Defense technological innovation and the nature of the industrial base has been shaped by a demand signal usually triggered by a threat or perceived threat and then followed by the application of resources. In the U.S. prior to World War II there was little demand except during periods of conflict. Thus, a historical cyclicality centering on peacetime vs. wartime needs can be measured and delineated by the rise and fall of the defense budget. Budgets were limited during peacetime and then grew rapidly during periods of conflict. These cycles were measured in decades (as seen in Figure 3.1) with the Civil War and World War II accounting for the largest spikes in spending interspersed with smaller spikes for the War of 1812, the Mexican Wars and the Spanish American War.

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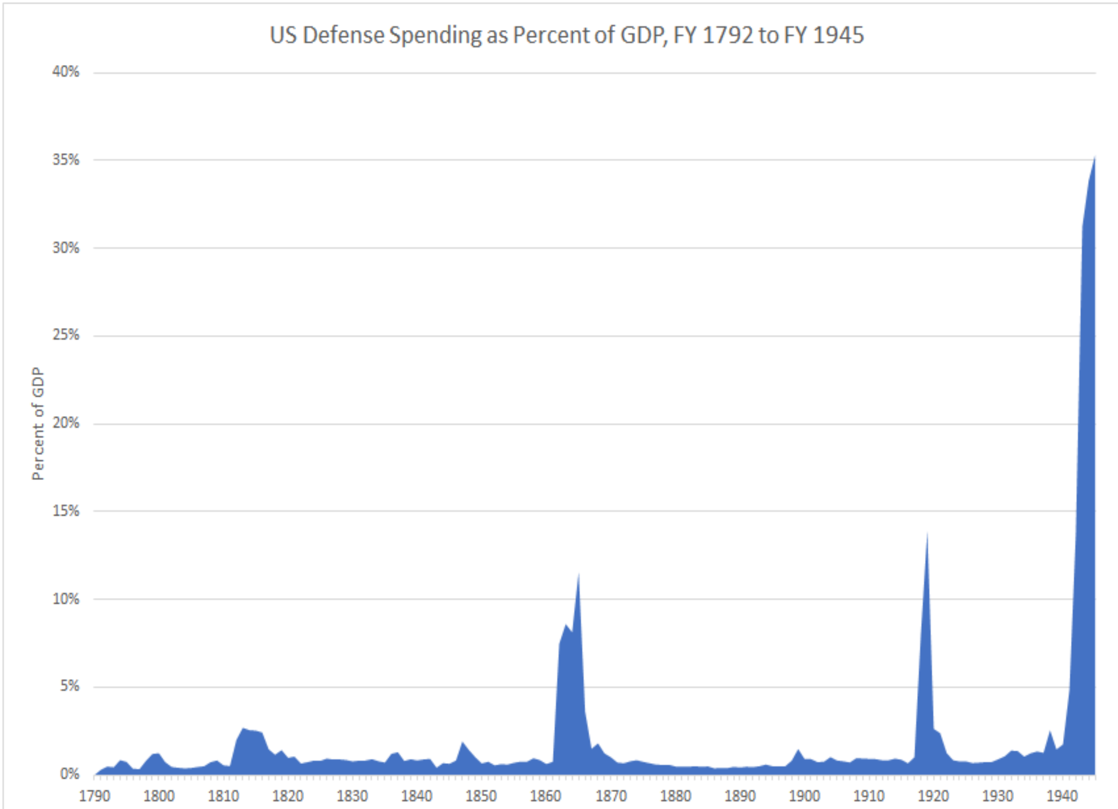
[98] Jacques S Ganlser, *Democracy's Arsenal: Creating a Twenty-First Century Defense Industry*, MIT Press, 2013, p. 9-10.

Figure 3.1 Defense Spending From 1792 to 1945[99]



Industrial Base Prior to World War II

The pre-World War II experience of long cycles between conflicts had a significant impact on the U.S. industrial base. From the initial large-scale defense program initiated by President Washington (the building of 6 frigates that came to prominence in the War of 1812)[100], to the need to build a self-sufficient armaments

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[99] United States. Bureau of the Census, and Social Science Research Council (U.S.). *Historical Statistics of the United States, 1789-1945*. Washington, D.C.: U.S. Dept. of Commerce, Bureau of the Census, 1949.

[100] Ian W. Toll, *Six Frigates: The Epic History of the Founding of the U.S. Navy*. 1st ed. New York: W.W. Norton, 2006.

industry, and to supply troops during the Civil War and World War I, defense needs have shaped how the federal government approached the private sector and what type of industrial base was created to support the U.S. government's national security needs.

Essentially, two different industrial bases formed depending on whether the nation was in the middle of a conflict or not. The first was a self-sufficient, peacetime industrial base that was primarily composed of government-run and operated facilities. These facilities were supported by the private sector for primarily raw materials and supplies, and incentivized through a price-based contracting system. During these peacetime interludes, the U.S. Congress and presidential administrations were satisfied with a limited military budget that was insufficient to conduct major operations. This peacetime budget could support a few publicly-run arsenals and shipyards, a limited navy, and a few army units based in frontier forts far away from the population.

The second system rose up during war or periods of conflict and focused on rapidly incorporating overseas and domestic private sector innovations and production to augment the limited capacities of the public arsenals and shipyards. To address mobilization needs, the U.S. government would begin to quickly look to commercial companies, but without investment over the years it took time for these firms to stand up and produce military items. There was limited to no anticipatory planning or recognition of a threat prior to a conflict, and thus no signalling of an advance expenditure of funds to begin the long lead times required to conduct research, build facilities and production capacity, and mobilize an industrial base.

U.S. defense spending rose rapidly at the beginning of a conflict that then initiated an inevitable mad dash to lock down supplies and equipment. [101]

Because mobilization was not planned in advance, the shift to the private sector for military production took longer than most would realize. Oftentimes, the conflict was over before equipment could be delivered. For example, during World War I, a new private defense industry (including a nascent aircraft industry) began to develop, but did not ramp up production in time to make a major difference in the war. With the armistice, contracts were canceled and the private defense industry all but evaporated. In between these various cycles, that portion of the private sector industrial base that geared up to support the government's war effort went back to supporting the commercial sector and the public sector arsenals regained their predominance in supporting a peacetime U.S. military. Private shipyards resumed a focus on commercial shipbuilding. Early U.S. defense manufacturers such as Dupont or Colt would shift from the U.S. military market to supplying gunpower and armaments to the overseas market or the mining sector and to other commercial uses.[102]

Defense Management Regimes Prior to World War II

Implementation of the cyclical rise and fall of defense budgets that impacted the composition of any temporary private defense industry was carried out primarily

[101] Nagle, Volume 1, p. 131. While the South in the run up to the Civil War attempted to lock down supplies to a degree before the conflict started, this process has historically revolved (as it did in the North) around the demand signal coming after a conflict had already begun.
[102] Ibid. p. 138-159.

through the contracting process, which developed in peacetime into a price-based regime. Until World War II, management regimes were fairly basic. The most important were the budgeting, finance, and contracting regimes. The budget account structure was not complicated and was based on organization or mission. The finance system designed to report to Congress on expenditures was tallied by clerks who kept detailed receipts according to Congressional direction.[103] Contracting was the most fluid and changing over the various budget cycles. A cyclical contracting experience arose that first had to address the enormity of mobilization and then inevitable wartime fraud and abuse became embedded in government management culture. A similar pattern would reoccur in response to each subsequent increase in defense expenditures driven by war or conflict.

In peacetime, management regimes focused on spending a limited budget to support arsenals, military installations, and forts. The government was highly distrustful of the private sector. This was likely for good reason, given past examples of fraud and profiteering. The private sector was not always entirely to blame, however. There was also a history of government procurement agents in charge of contracting who, when given greater discretion in contracting, often were incentivized to look after their own interests rather than the government's. Procurement agents were often paid a percentage of the contracts they negotiated, which unfortunately did nothing to incentivize low prices being paid, and in fact did the opposite.[104] As a

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[103] Act of March 3, 1809, Act of the Tenth Congress of the United States.

[104] Modern contracting can suffer from a similar dynamic when a contractor receives a cost-plus contract. There is little incentive for a contractor to reduce plant, equipment, overhead or other costs as profit is paid as a percentage of sales.

result of abuses from paying inflated prices, a system of sealed bidding and awarding contracts based on low price became the peacetime contracting default, rather than negotiating contracts based on a subjective concept of value to the government. The concern over officials enriching themselves through taxpayer dollars has a long legacy, reaching back to at least 1808, when Congress passed statutes to prevent government officials from benefiting from contracting.[105]

The peacetime contracting regime became a price-based model designed to limit fraud and price gouging. Any private sector contracting, usually for supplies to support government installations, was conducted on a low-price basis after a sealed bid competition. These two criteria – sealed competitive bids and low price -- formed the basis of the contracting management regime of the pre-World War II era and would be re-emphasized in later historical periods. The reality, though, is that very little defense contracting was taking place during these long periods of peace and low military budgets. Contracting in peacetime was higher at civilian agencies such as the postal service or for infrastructure projects. Further, these civilian contracts also tended to go to low bidders under a competitive sealed bidding process. As Nagle observed: “the country, especially, Congress, has idealized competition and fixed-price contracts. Since the early days of the Republic, Congress has clearly preferred a competitive bidding system in which contracts are advertised, all bidders given a fair opportunity to compete, and the lowest bidder receives a fixed price contract.”[106]

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[105] Ibid. p. 52-3.

[106] Ibid. p. 5

Sealed bidding is extremely competitive and incentivizes private industry to bid as low as possible – locking in gains for the government. On the negative side, companies could bid too low and run into problems of performance – i.e., they lose so much money that they default on their contract and the government is left with few options when faced with an unexecuted contract except to start over. While designed to prevent profiteering and fraud, there was always the chance that a contractor would bid low and then walk away or deliver poor quality goods. This is known as product substitution in order to skim off a higher profit. Still, these low-price sealed bid competitions did eliminate the procurement agent's incentive to pay higher prices.

The other problem with competitive sealed bidding was the time involved to conduct a procurement. Nagle noted that: "Competitive bidding is often the least efficient way to contract and has often obstructed America's ability to prepare for war. A major part of America's preparation for its wars, both in the nineteenth and especially in the twentieth centuries, has been the need to suspend or modify the competitive bidding rules as the country rushed to overcome decades of neglect."[107] As will be seen in Chapter 5, the approach of suspending the rules was continually used to address more than just contracting issues as management processes became more complex in the latter half of the 20th century.

The sealed bid contracting process, while adequate in peacetime, came under immense pressure early in a conflict. The process was too slow to respond to high demand. Thus, when the traditional procurement system could not handle the new demand and as the role of the private sector and time became critical, the peacetime

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[107] Ibid. p.5.

procurement system collapsed and emergency contracting authorities were used. These wartime authorities relied on negotiated procurement methods with often multiple contractors, but awarded without competition to sole-source providers.

In the meantime, in the rush to get anything out to the troops as quickly as possible, procurement scandals and fraud flourished. Inevitable ethics and conflicts of interest issues arose during rapid negotiations that led to even greater fraud and abuse. A protectionist preference was also inherent in peacetime contracting, when money become available and the government did not want to buy from abroad. The inability of U.S. companies to produce immediately led to emergency negotiated overseas procurements. Many of these contracts also suffered from fraud, waste, and abuse and the purchase of old, outdated, sometimes unusable European equipment.

This emergency wartime system – susceptible as it was to cases of wartime profiteering, price gouging, and fraudulent product substitution (delivering sawdust rather than gunpowder as an example) – would eventually be wound down after hostilities ended. If the conflict lasted long enough, countervailing pressures would arise during hostilities to begin to immediately address cases of fraud, waste, and abuse, such as when Congress passed the False Claims Act of 1863 known as the "Lincoln Law".[108] This Act incentivized whistleblowers to come forward by paying them a percentage of funds of identified fraud. Since most conflicts were of shorter duration, it was usually after demobilization that congressional hearings would address wartime excesses and inevitably laws were passed designed to prevent such occurrences from happening again. Ultimately, a reset to the peacetime acquisition

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[108] Title 31, United States Code, §§ 3729-3733.

system would commence, reverting to the sealed bid, low price, government run, protectionist arsenal system. The procurement system tightened up, budgets were slashed, profits limited, and the cycle resumed.

This cyclical history of the U.S. innovation system prior to World War II was relatively stable and predictable. Paying a low price was most valued in peacetime while rapid access to supplies mattered in wartime. What might be most significant was the length of the peacetime cycles. The time between wars was measured in decades, which gave the acquisition system time to reset to a "peacetime acquisition equilibrium." For over 150 years, the U.S. defense innovation system responded to this pattern. Moving from a peacetime to a wartime system and back again -- responding to wartime needs that then triggered contracting oversight scandals and then adjusting to a decline in the budget.

Defense Innovation Prior to World War II

How did this early U.S. defense innovation system actually perform in delivering innovation? The reality is: not very well. Developing new defense capability was not a driving factor in peacetime and in wartime equipping troops was the first priority. Most new innovation came from Europe as technologically, the U.S. arsenals lagged developments in Europe with a few exceptions. When conflicts arose the first place to look was to the state of art in Europe. The foreign transfer of technology made sense as the European powers were in a constant state of war or preparation and R&D was more robust in Europe than in the U.S. Given the short timeframes of conflicts, the wartime U.S. focus was on production of arms, supplies, and explosives with a limited role, at least initially, of bringing in new indigenous innovations based on wartime R&D.

Peacetime indigenous defense innovation was measured in decades and primarily conducted in-house in the publicly-run arsenal system. While several peacetime initiatives periodically built up the navy and led to a few sporadic out-of-conflict cycle increases in the shipbuilding budget, once built the U.S. often lost interest and allowed these ships to age. In wartime an opposite trend occurred. As Mowery observed:

> "…. mobilization for war since at least the mid-nineteenth century has involved a surge in military demand for existing weapons and systems that is available in a crisis situation and are compatible with established tactics and strategies. Wartime mobilization therefore relies on the increased production of weapons that were largely designed and developed prior to the outbreak of hostilities. The pressures of wartime mobilization focus R&D and related investments in weapons development on improving reliability and performance of existing systems, rather than developing radically new technologies."[109]

Several exceptions to these innovation trends hold relevant lessons for future U.S. defense innovation. First were periodic pockets of U.S. innovation that arose in wartime – particularly during the Civil War and World War I – that served as the inklings of an eventual need for a corollary to Mowery's argument. The length of a conflict had an impact on the introduction of new innovations with the Civil War and World War I. The Civil War saw the introduction of new time-base innovations such as the repeating breach loaded rifle, the machine gun, naval mines and torpedoes, and the iron-clads, along with the adoption of new innovations from the commercial

[109] David C. Mowery, Chapter 29 - Military R&D and Innovation, Editor(s): Bronwyn H. Hall, Nathan Rosenberg, Handbook of the Economics of Innovation, North-Holland, Volume 2, 2010, p. 1225.

market to military uses (railroads, telegraph, and balloons for aerial reconnaissance). World War I continued to build on some of these advances but added tanks, submarine warfare, airplanes, flamethrowers, poison gas, and radios to the mix. The first lesson is that each of these wartime innovations came about or were significantly advanced due to time constraints of meeting the threat. Still, like most U.S. defense innovation in this period, these were largely forgotten and unfunded after the war and, if applicable, an advancement moved out into the commercial market and drove new commercial advances such as for continuous wave technology in radios after World War I.[110]

Two other lessons came from this experience. The first was the CMI benefit from working with the military. In both the Civil War and World War I came major shifts in the creation of commercial industry. The Civil War propelled the clothing industry into the industrial age through the standardization of clothing sizes and the same types of demand kickstarted the radio industry after World War I. These industries became stronger and benefited greatly from supporting the war effort. At times in U.S. defense economic history the commercial sector has been the lead change agent for technological advancement and at other times military needs drove innovation.[111] From the late 1800s to the present day, the materials, telecommunications, and transportation industries each grew and expanded, through a push-pull mechanism of national security and commercially competitive needs. As a

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[110] See Nagle, Volume II, p. 23 and Jon Gertner, *The Idea Factory: Bell Labs and the Great Age of American Innovation*. New York: Penguin Press, 2012. p. 25-40.

[111] Mowery outlined several cases studies of military to civilian spin offs: machine tools, commercial aircraft, semiconductors, electronic computers, the internet, and nuclear power. Mowery, p. 1237.

result, both the military and consumers benefited from the cross-pollination of ideas, research, and breakthroughs in technology, manufacturing, and business practices.

The other issue was the concept of industrial mobilization lead time. In World War I, the U.S. performed poorly in ramping up to support the troops. It wasn't until the end of the war that industry was at full capacity. As a result, General Pershing did not receive a single American tank on the battlefield in time to make a difference.[112] It took 18 months of war to finally get industry mobilized. This is still a pretty good standard of the time it takes to create a new industrial capacity to meet a wartime need. Even increasing spending has limited effect on reducing that time. This time needs to be factored in before the process begins. Mobilization must begin 18 months to 2 years ahead of time or one risks suffering the reality of what former Secretary of Defense Donald Rumsfeld once said: "You go to war with the army you have, not the army you might want or wish to have at a later time."[113]

There were also a few significant peacetime innovation exceptions during the pre-World War II era. These include: 1) the development of interchangeable parts in the1820s; 2) technological changes in the steel industry in the late 1800s driven by naval shipbuilding requirements; 3) the rise of private R&D facilities in the late 1800s; and 4) the history of early aircraft development and post WWI aircraft experimentation funding by the Army. Each of these examples shine some light on the issues related to and the nature of defense innovation that will be important to

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[112] Leo P. Hirrel. "Supporting the Doughboys: US Army Logistics and Personnel During World War I. Combat Studies Institute Press US Army Combined Arms Center Fort Leavenworth, Kansas. p. 25.
[113] *Quoted in Eric Schmitt, "Iraq-Bound Troops Confront Rumsfeld Over Lack of Armor" New York Times, December 8, 2004.*

later analysis. While wartime efforts in this period illustrate the importance of time to development, these peacetime innovative examples illustrate the importance of CMI in the industrial base, and the role of rules in the innovation system.

Case Example: CMI Innovation Transfer from Military Unique Defense Technology to Commercial Market Development (Springfield Arsenal)

Despite efforts to control military technology and practices, if there is a commercial use, this technology and knowledge ultimately moves into the commercial market. For example, the shipbuilding demands of the Royal Navy in the 16th and 17th centuries furthered the development of new technologies and manufacturing techniques that were applied to commercial shipbuilding. The evolving military need for interchangeable parts that would eventual revolutionize commercial manufacturing received its first significant boost through the evolution of cannon production in France in the 1700s.[114] European improvements in military manufacturing brought forth knowledge that eventually spread to European commercial enterprises and then across the Atlantic Ocean, just as in the last several decades manufacturing knowledge proliferated to China and other parts of the developing world. This diffusion of intellectual property and manufacturing knowhow from Britain and Europe would ultimately lead to the creation of the "American System" of manufacturing or mass production.

[114] Shipbuilding required complex industrial processes to produce pulleys, rope, sails and other fittings in quantity to support the Royal Navy's demands for warships. The legacy of Jean-Baptiste Vaquette de Gribeauval's improvements in French cannon production were the source of an illuminating vignette in Guru Madhavan, *Applied Minds: How Engineers Think*, New York: W.W. Norton & Company, 2015.

This first started to germinate in the Springfield arsenal in Massachusetts in the early 1800s. Mass production's development in the U.S. was advanced by military research and development generated by the U.S. Army's specific and quite rigorous military requirement to achieve interchangeable parts in gun manufacturing in the early 1800s. "Believing that interchangeable weapons would mean easier field repairs and cheaper manufacture, the officers of the Ordnance Department urged development of uniform small arms, with detailed written specifications and gages for inspection purposes." [115] This did not happen overnight as it took "thirty-five years of sustained effort at making essentially uniform muskets, succeeding to the satisfaction of Armory mechanics in 1849."[116]

The manufacturing solutions for this requirement once developed at the Springfield U.S. Army arsenal eventually spread throughout the U.S. economy.[117] These techniques were further refined in the commercial marketplace over many decades as workers left the arsenal and built their own enterprises. This knowledge applied to clocks, furniture, bicycles, and eventually automobiles ultimately created the industrial capacity and ability to mass produce at scale.

The development of interchangeable parts at the Springfield Arsenal became the first of many examples of the need to solve hard military problems or requirements that exceeded what was available in the commercial marketplace. This

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[115] Michael Scott Raber, Patrick M. Malone, Robert B. Gordon, Carolyn C. Cooper "Forge of Innovation: An Industrial History of the Springfield Armory: 1994-1968. p-16

[116] Ibid. p. 16.

[117] Brooke Hindle and Steven D Lubar. *Engines of Change: The American Industrial Revolution, 1790-1860*. Washington, D.C.: Smithsonian Institution Press, 1986.p. 233; R.A. Howard, "Interchangeable Parts Reexamined: The Private Sector of the American Arms Industry on the Eve of the Civil War," Technology and Culture, 19 (1978), pp. 633-649.

triggered research into new technologies and once these hard problems were solved that knowledge was eventually transferred back to the commercial sector where it took on a different life of its own. In our own era, this dynamic is one that could incentivize many artificial intelligence, robotics, and data analytics firms to enter the defense market to try to solve some of these difficult military problems and then use the knowledge that comes from that research on more profitable commercial uses.

Case Example: CMI Innovation Transfer from the Imposition of Military Unique Requirements on the Commercial Market (Specialty Steel)

While the Springfield Arsenal example is one where the government led an innovation that moved into the private sector, the military's need for a more costly solution not available in the commercial market can oftentimes set the stage for competitiveness for those private sector firms that produce to a more demanding military specification. These requirements can sometimes be imposed on industry through a product specification. The steel industry in the 1880-1890s was shaped by one such a product specification for naval ships.

The U.S. Navy asked the steel industry for higher quality steel. Despite intensive resistance from a steel industry that did not want to make the required investments, the U.S. Navy continued to insist on a more stringent requirement. Many companies decided to forgo U.S. contracts because the cost of compliance and the capital costs in building a new mill to produce such steel would be too high. Two companies, Bethlehem Steel and Carnegie Steel, eventually would specialize in meeting this harder requirement, which would give these companies a comparative advantage as this new specialty steel eventually became the commercial standard. Other steel manufacturers could not compete and went out of business, leaving these two companies to dominate the market. The Navy's requirements and enforcing those requirements through rigorous testing "were the real means of producing the quality of material now so universally used in the industry."[118]

Unique military specifications do not always lead to adoption by the overarching commercial market but neither does this dynamic always lead to an isolated industrial capacity that only supports the military. It is possible that the current requirement for higher information security requirements in the DOD's Cybersecurity Maturity Model Certification and the National Institute for Standards and Technology SP800-171 cybersecurity standard could bring change to the commercial market. Both of these standards now required on current defense contracts are more stringent than what the commercial marketplace requires of vendors. This could create a situation where U.S. firms achieve a comparative advantage similar to the late 1800s Navy specialty steel example.

Case Example: CMI Innovation Transfer from Commercial R&D (Edison/Bell labs)

At other times, advancements in the commercial market led to huge innovations that can be leveraged in wartime. In the U.S. prior to World War II, CMI manifested itself primarily in the civilian side supporting national defense in times of crisis but also serving as a source of innovation and new products and ideas when

[118] Nagle, volume I. p. 174.

called upon.   CMI in one form or another has been a key aspect of developing military capability in the U.S. since the Revolutionary War. The U.S. Navy's first six frigates authorized in 1794 (the first large-scale weapons platform purchase by the U.S. government) were built in those shipbuilding communities that were producing commercial merchant ships. The Civil War necessitated the mobilization and integration of industrial and commercial capacity on both sides of the conflict. The importance of the non-defense commercial industrial sector and CMI should not have come as a surprise, as from the beginnings of the industrial age to the dawn of the information age, technological change has been sparked and maintained by a combination of military and civilian demand signals and investment. As the industrial revolution advanced, military applications and improvements closely followed commercial breakthroughs.

In the late 1800s, an important development arose that would influence the rise of the time-based processes of experimentation and prototyping that would be adopted by the U.S. government in WWII. This was the transition from sole inventor to inventor-run research and development centers. As Whitehead sums up the century: "the greatest invention of the 19th century was the invention of the method of invention."[119] The industrialization of R&D that occurred in Edison's labs and then in company laboratories like Bell Labs provided a framework to invention through experimentation and prototyping, but also more importantly, the scientific and engineering basis that could be built upon by the military. While technologies such as radio were heavily used and both Edison and the predecessor to Bell Labs

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[119] Elting E. Morrison, *Men, Machines, and Modern Times*, MIT Press 1966. p.12.

were active in supporting research efforts in World War 1, the reality is that it would take something like WWII to take full advantage of this development method.

These commercial research and development centers were the foundation for significant innovation in the U.S. For decades new technologies and ideas germinated in these invention workshops and many of these technologies made it into military solutions. But they also became the example of how to innovate on an industrial scale. When it came time to develop radar and nuclear weapons in World War II there was already a model in place.

Audrey Cronin recently pointed out the importance of the "tinkerers" of the late 1800s-early 1900s who were at the forefront of innovation that resulted in capabilities with profound military uses. She argued that in today's decentralized information technology centric innovation environment "Rather than try to wrest control of the chaotic process of open technological innovation, the U.S. government should better inspire and incentivize today's whizz kids—the Nobels, Marconis, and Wright Brothers of the twenty-first century…"[120] There are still lessons in the invention of the method of invention that may be relevant almost 150 years after Edison started his first laboratory in Menlo Park, New Jersey.

Case Example: Experimentation Authority – the First OTA

The final example illustrates that even in the peacetime culture prior to World War II it was sometimes necessary to go around management regime rules to

[120] Audrey K. Cronin, "Technology and Strategic Surprise: Adapting to an Era of Open Innovation," *Parameters* 50, no. 3 (2020), p. 84.

innovate. While this consistently happened in wartime, it was during the interregnum between WWI and WII that the U.S. military attempted to break the mold of limited peacetime innovation by pursuing a partnership with the private sector. Advances in aircraft that were made in WWI continued around the globe and in the commercial sector but the U.S. military quickly fell behind. After the war, the fledgling airline and aircraft industries were kept alive mostly due to U.S. government airmail contracts and not because of military demand. The expectation was that the U.S. would need to wait for the next conflict to advance this technology as procurement rules were preventing successful experimentation.

This delay did not happen and for just a short period of time the military would be able to advance aircraft technologies that would prove insightful and important to future U.S. success in WWII. Both the Navy and the Army Air Corps in the mid-1920s took some of the biggest steps taken toward future CMI efforts through a reinvigoration of U.S. aircraft development programs. In 1924 Congress created a committee to review progress in aircraft development and this committee concluded that "the destructive system of competitive bidding" was leading to disastrous results as the lowest bidders were not making progress. As a result, Congress acted and passed the Navy Air Act of 1926 and the Army Air Corps Act of 1926. Rather than dictate a military specification and solution which would have been required under the sealed-bid competitive process, the new approach allowed the services to, engage the private sector to come up with their own solutions, leaving "most management decisions to private aircraft and engine firms, where research, development, and production could be merged and managed with flexibility unavailable to federal managers."[121] Thus, to get around the existing bureaucratic and inflexible contracting and acquisition process, Congress authorized experimental authority that was the precursor of what is now known as Other Transactions Authority (OTA). This authority allowed for a more commercial contracting process and enabled greater innovation and flexibility in accessing the private sector.[122]

The experiment only lasted about 8 years but it was enough to jump-start the industry and experiment with new concepts, and it allowed the military to continue developing aircraft that evolved from those experimental aircraft. The reason this new experimental contracting authority lost favor is that in the early 1930s the U.S. entered a rather late countercyclical reaction to the excesses of that last war. The narrative of the "Merchants of Death" who drug the U.S. into WWI for profit was the topic of a book bestseller in the early 1930s. It was not long before these arguments were amplified in 1934 by the Republican isolationists in the Munitions Investigating Committee in Congress or the Nye Committee as a means to keeping the U.S. neutral in the growing potential for conflict in Europe. In this environment the Vincent Trammel Act of 1934 was passed. While allowing the Navy to finally rebuild, it contained provisions that limited contractor profits, required ships to be built in government shipyards, and introduced more stringent government audit rights on

[121] Thomas L. McNaugher, *New Weapons Old Politics: America's Procurement Muddle*, Washington: The Brookings Institute, 1989, p. 27.
[122] This authority currently exists in section 2373 of title 10 United States Code with its origins in the Air Corps Act of 1926 that originally provided an exemption from standard contracting statutes for the purchase of experimental aircraft and supplies. The Army still had issues with buying subsequent production models of these experimental aircraft similar to follow on production issues related to OTA authorities reviewed in Chapter 5. See: Holley, I. B. *Buying Aircraft: Matériel Procurement for the Army Air Forces*. United States Army in World War II. Special Studies, 7. Washington, D.C.: Office of the Chief of Military History, Dept. of the Army, 1964. p. 114.

contractors. This would not be the last time that acquisition reforms and the narrative of fraud, waste, and abuse were surreptitiously linked to seemingly non-related issues of disarmament, isolationism, and an anti-war effort. Still, that was the price to pay to allow the U.S. to begin to reconstitute a naval force that would be sorely needed in 7 years' time.

World War II to Early Cold War Defense Innovation System

World War II was a watershed moment for U.S. defense innovation. It didn't have to be and could have very easily conformed to the pre-World War II pattern. Whether through serendipity, planning, luck, or foresight, the past cycle was broken both immediately prior to the conflict and afterwards. This period did not last long – at most 25 years from the late 1930s to the early 1960s – but it became the most innovative period from a defense perspective in U.S. history and the source of some of the most significant military technologies still in use today.

Many lessons had already been validated from the pre-World War II experience.   Time constraints (primarily in wartime) could focus innovation efforts. Civil military integration of the industrial base cut both ways. It was an enabler as research conducted in private sector labs could have significant military potential and these labs validated the importance of experimentation and prototyping. On the other side of the ledger, for commercial firms solving hard government problems there were benefits to be had from applying this knowledge to the commercial market such as was seen in the advances made in communications after WWI or the steel industry addressing naval requirements. Management regimes, particularly in contracting, became barriers to innovation and participation by the types of firms the government may need, but could be sidestepped with special authorities such as was seen in aircraft experimentation during the 1920s. And finally, as witnessed in all previous conflicts, the industrial base needed time to transition to war-time production and innovation so the sooner to begin that effort, the better.

As in previous conflicts, the peacetime management and industrial base framework was set aside during World War II. What was a bit different was that this shift began prior to the conflict and continued into the early Cold War period to meet the immediate needs for rapid innovation to first address heretofore unprecedented war-time needs and then an unexpected competition with the Soviet Union. The World War II system began as a wartime system similar to those enacted in past conflicts that were established to bypass the older management framework. The exigencies and length of the war led to some different innovation approaches being successful with time to deploy capability emerging as even more of a critical variable. After the war, the onset of the Cold War, the maintenance of larger peacetime defense budgets, and a new robust approach to government's role in peacetime science and technology policy saw a continuation and evolution of the distinctive WWII innovation model. This model was different than any peacetime model in previous U.S history and was similar to the World War II model that it closely mirrored. This system was defined by a focus on experimentation, prototyping, and time-based development and brought together both the government and the private sector in a high degree of civil military integration of the industrial base, although somewhat less than what occurred in World War II.

Still, in the 1930s there was no defense industry to speak of. In what has been a similar historical pattern, demobilization after World War I resulted in a smaller military footprint and a specialized industrial base that resided in a few government-owned arsenals and facilities. The first difference was the degree of advanced industrial base mobilization that allowed for the gearing up of the private sector in the years preceding the U.S. entering the conflict. After the failure of the Washington Naval Treaty, the beginning of a naval build-up occurred in the 1930s. The typical need for a rapid rush to mobilize industry was somewhat tempered due to the ability of President Roosevelt to offer support and equipment to the UK and France in the run up to World War II through the lend lease military aid program. This allowed the U.S. industrial base to begin production in the late 1930s to support these arms transfers, which then paved the way for a more rational mobilizational in 1942 after the U.S. entered the war and needed to increase its own equipment needs.

The other important factor was the large transfer of technology knowledge from the UK that occurred in the Tizard mission in 1940 and the subsequent industrial cooperation that occurred between the UK, Canada, and the U.S. The sharing of the UK's technology for (among other things) the cavity magnetron miniaturized microwave radar levelled the playing field and saved the U.S. decades of research, development, and experimentation time. This allowed the U.S. during the war to focus on the next incremental developments in radar and other technologies that could build off of a higher level of knowledge. Next, the overall emergency and the limited time frames to get technology into the hands of the soldiers, sailors, airman and marines focused the industrial base on what was achievable and usable. Time-based innovation became the order of the day, but it had the advantage of gaining access to the UK's technology. It also had the benefits of the knowledge brought in from decades of experimentation in the private sector and the adoption by the government of that experimentation and prototyping process. Finally, the U.S. effort was furthered by the large immigration of scientists and engineers from Europe who came to the U.S. to escape the Nazis in the run up to the war.

This period became the height of CMI. The existential threat of World War II resulted in an almost complete integration of the U.S. military and civilian industrial bases as the country converted commercial production to military uses. Thus, as World War II began for the U.S., the U.S. aircraft industry expanded from its role of carrying the mail and a few passengers in a developing airline industry. These passenger plane designs were converted into bombers and British fighter and engine designs were produced en masse in the U.S.[123] The rest of commercial industry converted to military applications and served as the "Arsenal of Democracy" and a foundation for eventual victory. The commercial manufacturing base and its mass production expertise was able to reduce the excess capacity that had built up from the legacies of the Depression.

This was no mere government takeover of the commercial industrial means of production to conduct the war effort, but a partnership where industry was allowed to bring its manufacturing technology and knowhow to bear on military problems of increasing production of military items on a vast scale. In a nod to the interwar

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[123] Jeffrey A. Engel, *Cold War at 30,000 Feet: The Anglo-American Fight for Aviation Supremacy*. Cambridge, Mass.: Harvard University Press, 2007. pp. 17-52.

experimentation and development of military aircraft, the greatest success of World War II industrial innovation occurred not when the U.S. government dictated a solution but when it engaged the commercial industry. Individual scientists and engineers with problems or requirements allowed the private sector to apply commercial development and manufacturing methods to come up with solutions.[124] The results were staggering: two million trucks and thousands of aircraft, tanks, ships, and artillery pieces were built in just a few years.

It was also not a one-way street as the commercial industry benefited from the vast expenditures the U.S. government spent on such things as machine tools. These same machine tools would eventually serve as the basis for U.S. manufacturing dominance into the 1960s and 1970s. Industrialists such as William Knudson from Ford and then General Motors, who was brought in by Roosevelt to run U.S. war production, understood that the war would not last forever and that it offered the potential to re-tool American industry that could not afford to so during the Great Depression. This type of foresight allowed for the new machine tools and infrastructure purchased by the U.S. government to support the war effort and provided the means by which the U.S. maintained economic dominance and competitiveness for decades.[125]

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[124] See: Allen R. Millett, "Patterns of Military Innovation in the Interwar Period," ed. Williamson Murray et al., New York: Cambridge University Press, 1996.; and Arthur Herman, *Freedom's Forge: How American Business Produced Victory in World War II*, Random House, 2013.

[125] One of the more interesting findings in Arthur Herman's book Freedom's Forge was the realization by William Knudson (former President of General Motors) and those managing the industrial base conversion to defense work that re-tooling U.S. industry "was more than just rearmament" but "a way to revitalize American business and industry" in anticipation of the post-war environment (Herman p. 112).

Still another innovation model emerged that was different from the "Arsenal of Democracy" mass production model. This was the bringing together, under government leadership and planning, scientists and engineers to work on emerging breakthrough technologies. The research labs of Edison and Bell were replicated writ large under government watch and ownership. Whether it was in radar, communications, the breaking of encrypted codes, or what became the greatest example of the model – the Manhattan Project – centralized government planning and execution of technology development led to huge technological advances.

The other significant approach taken by the Manhattan project was it was planned with significant duplication in mind. Failure was expected, and thus planned in, so there was never one path to development. In one sense, the Manhattan Project managers were replicating the competition that would occur in private research labs. As Peck and Sherer observed, "five completely different full-scale methods of producing fissionable material were carried forward simultaneously" on the Manhattan project.[126] This is an important lesson that has been forgotten in the singular linear acquisition and predictive developmental management approaches pursued since the 1970s. A final point should be made that any time-based constraints were limited by the stock of scientific knowledge that had existed at the start of World War II. Research could obviously be advanced, and was, but in the short period of time that the war lasted (less than 4 years for the U.S.) the current baseline of knowledge was what everyone had to work off of to start. The importance of this past academic and private sector research and experimentation was critical.

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[126] Peck and Scherer, p. 261.

The differences between the centrally-planned model and the CMI model has sometimes led to debate on the source the source of WWII innovation and its role in ultimate victory. Does innovation come primarily from the private sector and then is incorporated into military products, or is it the public sector with its demand and command and control planning process that leads to revolutionary or disruptive new technological innovations? There are probably no one size fits all answers to that question, as it turns out both models were used effectively and were likely critical for success in World War II. There was both a high degree of CMI and government direction where appropriate. Basic scientific research before the war was critical. Technology leadership depends on where one is on the innovation cycle. In the midst of war there was no one right answer or pathway chosen but there was a portfolio of innovation approaches that allowed the government to pick and choose from the best models. Both models benefited greatly from time constraints. The exigencies of the war made *time* the most important factor in driving innovation in both of these two models and that was more important than whether they were contractor or government run. Time and the need for speed drove out the bureaucracy and the second-guessing. Things either worked or they didn't. They could be abandoned and something else tried. Mission oriented success is what mattered most.

Not that excess bureaucracy didn't exist at the time, but if process, bureaucracy, and poor management had been allowed to dominate and prevail, a focus on time would not have succeeded. A price-based focus on competition and controlling prices and profits did not go away. The Vincent Trammel Act had been passed a few years before and it was evident that WWII was not immune from the oversight cycle seen in past conflicts over concerns about war time profiteering and potential fraud, waste, and abuse. Mark R. Wilson devotes a chapter in his book "Destructive Creation: American Business and the Winning of World War II" to "One Tough Customer" that describes issues with red tape, the arbitrariness of contract demand, profit and price control to include an excess profit tax of 90 percent. Government-owned production facilities and arsenals were used to gain insight and benchmark private contractor costs to guard against profiteering and to provide more competition.[127]

Popular sentiment and congressional oversight bodies such as the Truman Committee continued to be highly suspicious of the rise the private sector. Due to these wartime sentiments and oversight uncovering a host of fraudulent examples, after the War many factors were in place that were aligned to return the defense innovation system to the traditional peacetime cycle. At war's end, demobilization began its usual course. Americans were eager to engage in consumption after the hardships of total war and the commercial industrial base began to reconfigure production back from meeting military to consumer needs. President Truman could not have been unaffected by his experience just a few years earlier in Congress focusing on the excesses of the war and concerns over war profiteering. It was understandable that there was a Presidential desire to follow up on some of the issues outlined. The late 1940s saw the establishment of the Armed Services Procurement Regulations and the beginning of the bureaucratization of the acquisition statutes.

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[127] Mark Wilson, *Destructive Creation: American Business and the Winning of World War II*. American Business, Politics, and Society, Philadelphia: University of Pennsylvania Press, 2016.

The National Security Act of 1947 began the process of centralization with the creation of OSD and the new Secretary of Defense nominally in charge of acquisition, although the military services remained effectively in charge until the late 1950s.

During this beginning to a return to normalcy, if past post-war era experiences in the U.S. were maintained, it would have been expected to see a return to a publicly-run arsenal system to meet defense needs, such as existed at the army arsenals and the public navy shipyards in the lead up to the Civil War and World War I and II. Instead, after World War II, a new dominant model emerged where the private sector would become the predominant player in both defense R&D and the production of defense systems, creating a more powerful augmentation layer over the government-run military research and production facilities. Arsenals would be maintained but focused on munitions and maintenance, and were not significant sources of new innovation. A new government-run laboratory structure did arise focused on building on the advances of the Manhattan project. These nuclear laboratories established during the war continued to focus on the building and development of nuclear weapons, but also relied on private contractors for many inputs and systems.

Several factors eventually countered the usual historical cyclical trend of demobilization and budget cuts and a return to the arsenal system and a more rigid procurement process. Driving these changes were two significant figures who played key roles in two countervailing trends. The first was General Eisenhower, who recognized the importance the private sector played in the war effort and the second was Vannevar Bush, who argued for the need to maintain scientific R&D.

Still, neither of these visions would have likely played out if the Soviets hadn't seized Eastern Europe and the Cold War broke out.

The experience of World War II influenced Eisenhower immensely. The great advances made in the automotive manufacturing industry as it supported the army during the war continued to influence policy once Eisenhower became president. But before that, as the chief of staff of the army, Eisenhower outlined his view on the role of the private sector and achieving defense innovation. In a 1946 memo to the army Eisenhower stated:

> "The recent conflict has demonstrated more convincingly than ever before the strength or our nation can best derive from the integration of all of our national resources in time of war. It is of the utmost importance that the lessons of this experience be not forgotten…. The future security of the nation demands that all those civilian resources which by conversion or redirection constate our main support in time of emergency be associated closely with the activities of the Army in time of peace. The armed forces could not have won the war alone. Scientists and business men contributed techniques and weapons which enabled us to outwit and overwhelm the enemy."[128]

Ike went on to call for the need for civilian assistance in planning to understand development in science and technology but also for the private sector to be used in the production of weapons. The arsenal system was under siege. This recognition of the role of the private sector was widely shared and as defense contracts continued in the beginning the cold war there was a greater reliance on the private sector than ever before. This policy to rely on the civilian industrial base for its needs was put in a

[128] Memorandum from Army Chief of Staff Dwight D Eisenhower on Scientific and Technological Resources as Military Assets, April 30, 1946.

policy document in the Eisenhower administration in which the government explicitly stated that it would rely on the civilian industrial base for its needs.[129]

The second lesson from World War II was a realization that science and technology were key enablers and something that the government needed to not only nurture but lead by sponsoring research and development. Vannevar Bush was instrumental from his position as Director of the Office of Scientific Research and Development. In his report to the President "Science the Endless Frontier" Bush wrote to the President on the need to continue to link scientific research to the military's needs:

> "The bitter and dangerous battle against the U-boat was a battle of scientific techniques - and our margin of success was dangerously small. The new eyes which radar has supplied can sometimes be blinded by new scientific developments. V-2 was countered only by capture of the launching sites.
>
> We cannot again rely on our allies to hold off the enemy while we struggle to catch up. There must be more - and more adequate - military research in peacetime. It is essential that the civilian scientists continue in peacetime some portion of those contributions to national security which they have made so effectively during the war. This can best be done through a civilian-controlled organization with close liaison with the Army and Navy, but with funds direct from Congress, and the clear power to initiate military research which will supplement and strengthen that carried on directly under the control of the Army and Navy."[130]

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[129] In 1955, the Bureau of the Budget's Bulletin 55-4 stated that the federal government would "not start or carry on any commercial activity" that the private sector could perform.

[130] Vannevar Bush, Science: The Endless Frontier -- A Report to the President by Vannevar Bush, Director of the Office of Scientific Research and Development, July 1945, United States Government Printing Office, Washington: 1945; The argument for public funding of R&D would be furthered by: R.R. Nelson The simple economics of basic research Journal of Political Economy (1959) and K.J. Arrow in Economic welfare and the allocation of resources for R&D R.R. Nelson (Ed.), The Rate & Direction of Inventive Activity, Princeton University Press, Princeton, NJ (1962).

This report was instrumental in convincing Congress and the Truman administration to undertake significant funding for scientific research. This R&D was not only directed at the government laboratories but also the private sector. Federal R&D expenditure would serve as the basis of U.S. technological dominance for decades. It was not until 1980 that the U.S. private sector caught up to the government in research and development spending.

Still, it was the advent of the Cold War that prevented the return to a peacetime system. Despite a commitment to a return to normalcy and a new faith in the power of the United Nations, the wartime alliance between the U.S. and the Soviet Union began to break down. The stirrings of the Cold War began with the unfinished business of the war, but it still took two years to recognize what was happening and the Truman Doctrine declared. The eventual fall out between the wartime allies and the split between the West and the Soviet Union created a far different budget situation than had existed after previous conflicts. The budget fell, but to a higher sustainable level as the Cold War began to be realized. The budget then went up sharply again with the onset of the Korean War in 1950.

Thus, the immediate post-World War II era saw a different industrial model evolve whose origins were established at the height of war. The establishment of both a large privately-run defense industrial base and a government-owned laboratory structure to conduct scientific and developmental research (as distinct from a government-run system of munitions arsenals and shipyards to build and maintain defense equipment).

Something also different happened to the defense industry and the rules of the acquisition system after World War II because of the onset the Cold War. The budget cycles played out in much the same way as they did in earlier U.S. history but they did so in an intensified manner as the budget cycles became shorter and amplified the effects (see Figure 1.3). Perhaps most importantly, the cyclical downturns never quite went back down to pre-World War II levels or even to the levels immediately after WWII. This provided a minimum sustaining base of defense expenditures that could support a private defense industrial base during these periods of traditional spending reductions.

Thus, the post WWII experience was different and the initial phases of the Cold War served as the partial continuation of conflict. This led to a slowdown in demobilization and budget declines but also in the continuance of the wartime management regimes. What all of this allowed was the maintenance of faster acquisition and innovation cycles through the end of the Eisenhower Administration. The post Korean War reduction in funds still left DOD with a budget twice as large as that at the end of World War II. While constrained, DOD implemented the New Look (First Offset Strategy) within a period of flat to moderate growth and with a focus on strategic and tactical nuclear weapons and guided missile systems.

President Eisenhower's "New Look" defense policy set the stage for both the blossoming of a unique defense industrial base, and also the creation of new civilian commercial sectors in electronics, space, and computing. Defense research of the period led to many of the technological advancements that still serve as the basis for U.S. military power – Intercontinental Ballistic Missiles (ICBMs), nuclear powered submarines, advanced bombers, reconnaissance satellites, and the electronics and communications technology that support these major platforms.[131]

Still, the most important factor for innovation during this period may not necessarily have been who worked on projects, or how, or even the budget. The Eisenhower era management construct continued to be guided by time constraints imposed on projects that encouraged scientists and engineers to freely experiment, prototype, and question. There was a tolerance for failure, but most importantly a focus on adaptability as that was the only way to bring a project in on time. This experimentation and adaptable mindset were relevant to both innovation in the private sector and in the government-run labs during World War II and would carry on for at least another 15-20 years after the war.

Rise of the 1960s Defense Management Framework

This Golden Age of defense innovation lasted less than two decades, with the 1960s becoming a transition decade. First, the longstanding public management framework's focus on price focus and control never really went away, and underwent a resurgence with the passage of the Truth in Negotiations Act of 1962. More importantly, management practices were significantly modified in the 1960s and 1970s to reflect a greater cost-based emphasis. This rested on a belief that a more centrally-managed focus on planned predictive outcomes could be achieved that

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[131] This period was subsequently referred to as the "First Offset Strategy. "For a discussion of the various "offset strategies" see Ben Fitzgerald, "Can America Maintain its Technological Edge: Why it is Time for a Third Offset Strategy". The National Interest, August 13, 2014.

culminated in a new centralized-management framework based on systems analysis, program budgeting, and cost analysis. Cost analysis supported price analytics and the priced-based system was subsumed into the new system. This management system emerged in a series of controlling institutions and regimes designed to oversee defense innovation. It eventually became engrained in culture and administered within the military structure and bureaucracy that was stood up after World War II to give greater centralized control in the Office of the Secretary of Defense.

The further incremental evolution of the institutions and regimes associated with the original changes made in the 1960s to defense management continued to develop in the subsequent six decades. While the overall basic premises and objectives of the 1960s framework did not change, the management regimes matured and became even more prescriptive and compliance oriented over time. This process was incremental like the accretion of barnacles on a wooden ship. The process began with ideas that generated policy frameworks, which grew into institutions, which were then further modified by implementation regimes and protected by interests in the new status quo. The new model was not created overnight and despite the default to a centralized approach, most of this change was incremental and haphazardly applied to different management stovepipes, which made it difficult or even impossible for a centralized approach to work effectively.

1960's Antecedents and the Rise of New Values

Many precursors of the 1960s system began to show themselves in the 1950s in reaction to the peacetime use of the rapid innovation model and reliance on the private sector. Much of this was built on an intellectual legacy that was nurtured in the 1950s and shaped by events. The following factors all came together to shape the management system that was eventually adopted in the Kennedy Administration. These include a data-focused scientific management outlook, a belief in the effectiveness of central planning emanating from the newly created OSD; systems and program cost analysis, systems engineering, a preference for linearity over concurrency, enhanced security, an anti-private sector bias, and the rise of socio-economic factors. Perhaps most importantly, the 1950s system began to be seen as something that needed to be fixed. It was perceived as undisciplined and chaotic: multiple paths were duplicative and experiments that didn't always work were wasteful. Estimates of costs were fictitious and unreliable. The system was ripe for efficiency and better management, but by what criteria?

Scientific management has a long history in business management theory, beginning with the experiments of Frederick Taylor and the rise of Taylorism. The application of the idea of making a process more efficient has been a leading driver of business and also in the government. The two Hoover commissions, in 1949 and 1953, focused on this ideal but interestingly enough had the foresight to decide to exempt DOD from this ideal. As Moe observed, "As a statement of administrative philosophy, the goals of the first Hoover Commission were definitely in the tradition of the Scientific Management movement and of earlier reform efforts. Hoover wanted to achieve "economy and efficiency" in the Federal Government."[132]

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[132] Ronald Moe, "The Two Hoover Commissions in Retrospect", Congressional Research Service, March 12, 1982.

In reality, it did not take long for the concept of greater efficiency and the ability to manage the government scientifically to take hold. This greater level of efficiency would be implemented through centralized planning, which at DOD would be the Office of Secretary of Defense, newly created in 1947. The idea gained ground that the government should be run like a business that in the immediate post war era were also centrally-run organizations that were benefiting from the legacies of the war that left the U.S. as the only functioning manufacturing economy on the planet as other economies were still left in ruins.

Command and control tendencies were furthered by the experience of the government directing the economy in WWII. The need to mobilize the commercial economy again at the beginning of the Korean War sparked Congress and the Truman Administration to re-establish wartime authorities used in World War II through the enactment of the Defense Production Act (DPA) of 1950. The resulting establishment of the Defense Priorities and Allocation System, or DPAS, ensured that the U.S. government had priority access to civilian production to support the Korean War effort and future defense needs, but it was based on the concept of compulsion and was more attuned to a central planning approach than an effort grounded in market incentives and cooperation.

Finally, the Soviets' success in developing their own nuclear weapon in 1949 and hydrogen bomb in 1955, and most significantly, the launch of Sputnik, led to deep questioning of the U.S. capitalist system. The "Sputnik Moment" shattered U.S. confidence and for a certain period of time led to a belief by some in the inevitability of the management practices of the Soviet Union. The centralized planning ideals of the Soviets corresponded to a worldview of the U.S. government planners leading the effort in World War II against the Nazis. The subsequent perceived “missile gap” in the runup to the 1960 election only fed the paranoia. Just as in the Soviet Union, to maintain competitiveness and regain the innovation edge, some looked to more central government planning based on scientific management as a panacea.

But how to implement this scientific management approach? The tool for efficiency and effectiveness and managing the government in a more scientific matter was systems analysis. Systems analysis grew out of the great benefits derived from the field of operations research during World War II, which applied statistical analysis to the operations of war. It was a highly successful way of creating efficiencies and greater effectiveness in the previous haphazard way of conducting bombing and in anti-submarine warfare. Systems analysis went the next step above operations research. It continued with the idea of studying how to be more efficient by creating step-by-step processes through breaking down each individual component of activity and optimizing its functionality. The acquisition, budget, requirements, and engineering processes would subsequently be analyzed and shaped by these systems analysis approaches.

In practice, what systems analysis and the subsequent demand for a more data driven approach that followed the success of operations research in the war seemingly missed was a disconnect from time. Operations research problems were always time-based and had a sense of urgency. The problem of the most efficient way to take out a bombing target or how to minimize shipping losses in the Atlantic had a short shelf life and would change as the Germans changed tactics. Operations research divorced from time and applied to non-urgent problems could go on forever -- lost in a debate over data and quality of data. The systems analysis approach as applied to specific processes also seemingly lost the significance of the time it takes to coordinate between various other processes, each individually optimized for excellence. These two factors would plague the management regimes that through systems analysis thinking evolved step-by-step into a linearity of process implementation.

In a systems analytical process, cost became the variable that it was necessary to manipulate in order to move to a more centralized approach rooted in scientific management. Cost was a variable that was relatively easy to measure at first and by easy to measure this allowed the acquisition and budgeting process to evolve around various cost measures. Novick and Hitch were instrumental in the 1950s in outlining the theory, and eventually the framework, for a concept of program budgeting to enter DOD through the PPBE process.

The 2nd Hoover Commission (1953-1955) moved beyond reorganization issues and continued its focus on managing the government in a more scientific way and using the budget as a means for reform to measure performance. While the value of managing efficiency through greater cost control had been a main part of the Hoover Commissions criteria for government improvement, however, for DOD the Commission was hesitant to use that criteria: "Because national survival is at stake, cost cannot be the primary factor. In words of a prominent flag officer, "our military people are not hired primarily to see how little they can get along with; they are hired primarily to seek to get enough material to meet their responsibilities."[133] This philosophy did not last for long and the idea of managing budgets through cost analysis was already being debated at the RAND Corporation in the 1950s. Cost based program budgeting would be advocated by RAND and then brought to DOD and within a very short time, no general officer would ever make such a likely career-killing statement before Congress again.

It was, however, much more than just the concepts of cost, program, or performance-based budgeting that eventually would morph into DOD's budget process. The planning process was critical to absorbing the concepts of evaluating performance, sorting needs by programs, measuring through cost data, and requiring long-term estimating tools of those costs. Collectively these would serve as the basis for the PPBS process and would eventually influence the development of other management regimes such as acquisition and requirements. It was the bringing together of these concepts and regimes that was critical to create the management system as used in DOD today. As Allen Schick summarized:

> "Budgetary reform in the United States has evolved through three distinct stages, the last of which is associated with the contemporary Planning-Programming- Budgeting System. In the initial stage, the primary emphasis was on central control of spending and the budget was utilized to guard against administrative abuses. The detailed classification of objects of expenditure was the main control mechanism. The second stage was management-oriented. It was concerned with the efficient performance of work and prescribed activities. The performance budget, officially introduced by the Hoover Commission, was the major contribution of the management orientation. The third stage is reflected in the planning orientation of the new

[133] United States. Commission on Organization of the Executive Branch of the Government (1953-1955): Business Organization of the Department of Defense; A Report to the Congress. Washington, DC: United States Government Printing Office, 1955. p. 4.

> PPB system. It had roots in Keynesian economics and the new technology of systems analysis."[134]

Systems analysis thinking then permeated beyond just thinking about the budget and impacted both the engineering and scientific processes. There began the identification of a linear process of advancement. Eventually, the budget process for science and engineering would be categorized based on a RAND recommendation into a linear process from basic research to advanced development.[135] Thirty-year scientific plans would become the norm with predictive pathways for science, engineering, and technology to meet. Somewhere along the way, concurrency of development and multiple pathways became seen as duplicative, wasteful, and inefficient. The concept of linear pathways and checklists would eventually creep into the acquisition, budget, and requirements processes.

As cost data was collected and applied to weapon systems performance, the initial analysis would show that cost estimates at the time were wildly underestimated. Peck and Sherer, in their review of 12 weapon systems, showed significant cost increases from initial estimates but surprisingly relatively mild schedule time increases. Unfortunately, conclusions made from such data gathered on the cost and schedule performance of weapon systems acquisition that, while appropriate to certain acquisitions, was not appropriate in all circumstances. The data were accurate but divorced from the reality of how innovation worked during that

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[134] Allen Schick, "The Road to PPB: The Stages of Budget Reform." *Public Administration Review* 26, no. 4 (1966). p.243.
[135] David Novick, What Do We Mean by "Research and Development?" Santa Monica, CA: RAND Corporation, 1959.

period. 1950s innovation was about doing things that no one had ever done before, such as building a rocket to fly into space. Of course, no one had any idea about how much that would cost beforehand. Because of that reality, applying rigorous cost estimation parameters to these new experimental developments would have led to this type of analysis being misused -- leading the government down the wrong path when disruptive innovation is needed.

The inability to predict cost and the adoption of more scientific systems engineering techniques led to an argument that innovation and experimentation was wasteful. On the extremes, on one side of the spectrum was a desire to slow down military advancement, and on the other side a view that all government spending was merely a means to inevitable fraud, waste, and abuse. The amount of money DOD was spending was another growing factor in the 1950s pressure on defense. There was a greater scrutiny of these expenditures and the desire to not only use this spending for military purposes, but also to gain a social socio-economic advantage. The passage of Small Business Act of 1953 was the first of many socio-economic statutes that aligned with a protectionist desire, much like the passage of the Buy American Act of 1933 and the Berry Amendment in 1941 to ensure that public money went to certain states and congressional districts. What Congress really needed was a mechanism to earmark more efficiently. Program budgeting would eventually provide the information to support the types of directed spending the appropriators would embrace.

Another factor driving change in the 1950s was the legacy of Soviet espionage that had infiltrated U.S. government programs. That Soviet spies were embedded from the start in the Manhattan project and the subsequent, fallout from the Hiss, Fuchs, and Rosenberg spy scandals triggered not only McCarthyism but new security requirements. These security fears would lead to enhanced secrecy that would favor a return to the arsenal system, but this time with specially cleared private sector firms.

Eisenhower, for the most part, kept many of these trends to negatively impact defense innovation in the 1950s in a box. But as he left office, he stoked the fire of what had already been burning as defense expenditures grew and the private sector dominated. Eisenhower's farewell address on the military industrial complex confirmed many in their distrust of profits and the private sector. Thus arose a resurrection of the historic contracting values from the pre-war era and new legal and regulatory measures which would have serious unintended consequences. Despite Eisenhower's support in moving DOD to rely on contractors, he saw profiteering coupled with parochialism (he debated whether to mention a Congressional complex as well) as a problem that needed to be addressed. This would kick off another round of distrust of the private sector behavior and a return to managing profits and incentivizing low price solutions. Congressional patronage was never addressed and the result was the return of more oversight and constraints on the private sector. This, ironically, turned the defense sector into the privatized arsenal system ever more dependent on Congressional support that Eisenhower had warned against.

1960s Institutions: Rise of 1960s Defense Management Systems Framework

None of these pressures for change would have mattered unless leadership embraced them and new management regimes were created to implemented them. So, as Eisenhower left the stage, the time-based innovation approach of WWII early Cold War ad hoc was coming under pressure. It was seen as wasteful. Rockets blowing up and satellites not making it into orbit seemed excessive. Cost overruns on large development programs would drain the Treasury. The Soviets looked like they were winning the Cold War innovation competition. But waiting in the wings was a solution in predictive management and systems analysis – if only a new leadership would grasp it.

That leadership duly arrived in 1961. The current defense innovation system (both the industrial base and federal management incentive framework) then began to rapidly change with the arrival of the Kennedy Administration and its choice as Secretary of Defense Robert McNamara. His so-called "whiz-kids" documented in David Halberstam's book on the origins of Vietnam, brought a new scientific approach to national security policy that in Halberstam's telling brought disaster on the battlefield that has taken decades to exorcize.[136] But a more long-lasting impact was the introduction of these approaches to the overall management of the Department. This significant watershed in defense management practice was based in academic theory and literature related to defense management that occurred at RAND. Hitch, Enthoven, Novick, and others from RAND joined the Administration

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[136] David Halberstam, *The Best and the Brightest*, New York: Random House, 1992.

to implement this new framework that resulted in what can be described as the underpinnings of the current defense management systems framework. This framework has served as the operating model for managing defense innovation since the Johnson and Nixon Administrations. Whether this framework rises to the level of a "Kuhnian" paradigm could be the source of a debate, but it has permeated the culture of the government and industry.[137]

The period from 1962-1984 is important as the foundational management oversight constructs still in use today were established during this time. For example, the PPBS budgetary system was inaugurated in 1961; the Truth in Negotiations Act passed in 1962; the Cost Accounting Standards were created in 1970; the DOD 5000 series acquisition process was established in 1971 based on the then developing discipline of systems engineering; and the Arms Export Control Act of 1976 established the current basis for technology transfer and control. Each of these constructs contributed to the operational frameworks for defense management and oversight and influenced the constructs of the defense industrial base.

Up until the Kennedy administration, the value of the defense innovation system had been speed and effectiveness. Rapid prototyping experimentation, rapid deployment, and quick iterations of capabilities were the norm. When the Kennedy administration came to power this all changed to a focus on efficiency, as defined through a systems analysis cost and price-based analytical approach.

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[137] Thomas S Kuhn, and Ian Hacking. *The Structure of Scientific Revolutions*. Fourth ed. Chicago: University of Chicago Press, 2012.

This framework was based on a centralized government planning process, a predictive focus on technology development, enhanced secrecy and technology control of the outputs of this research, improved cost control and the pricing of inputs from the private sector, and finally a scientific management outlook that encouraged the government to adopt incremental budgeting and five-year plans that mirrored Soviet practice. Systems analysis guided a demand for program cost data and estimation based on pricing of inputs from the private sector, eventual constraints on the discretion of governmental program managers, and finally a scientific management outlook in defense budgeting and planning. These new concepts were overlain upon and adapted to longstanding cyclical management and acquisition trends harkening back to founding of the Republic that favored government led arsenals supported by limited and highly regulated private sector participation as sources of supply to the arsenals, procurement processes and practices overly designed to limit any appearance of corruption and favoritism, a skepticism of private sector profits, and a preference for sealed-bid competitions to support the goal of achieving the lowest possible price. While public arsenals would become private ones, and low-price fixed price contracts would evolve into cost-based ones overseen by auditors armed with tools to verify cost and price, the original values of distrust of contractors would prevail.

Budgeting, finance, acquisition, engineering, and requirements development were all caught up in the Vietnam era of intellectual fervent that favored systems analysis, cost analysis and estimation, program budgeting and the faith in the ability of government leaders to centrally plan, manage and predict the working of the innovation enterprise. Through the right processes and data, decision makers could annually turn the knobs in a scientific fact-based way to predict and achieve desired outcomes. Perhaps even more damaging was a creeping linearity that was based on a view that advancements in science, technology, and economics were predictable and inevitable and that one just had to follow a known path in a step-by-step fashion. Experimentation, concurrency or the attempt at multiple paths as in the Manhattan Project were thought as duplicative and doomed to failure as processes were created to prevent such excess expenditures.

The RAND corporation economists subsequently turned their academic research into one of the largest experiments to be conducted in American government by bringing systems analysis, enhanced centralized planning, and program budgeting into the Pentagon. This way of thinking eventually impacted the acquisition, requirements, engineering, contracting, and finally the scientific development process as each regime had to adjust to the new power of the changing budget process when it was adopted in 1961. The RAND analysts' legacy of the search for ever improving cost estimating techniques and the adoption of the criteria of managing to estimated cost, schedule, and performance baselines for weapon system development has been maintained over the decades.

Non-linear (or what might in today's world view might even be classified as quantum thinking) approaches were relegated to the dustbins of pseudo-science while experimentation and prototyping thought of as useful only as part of a program development process not as a possible end in itself that might lead to something unexpected. Innovation was not something fortuitous or based on serendipity and often ended in failure but something that could and must be planned. Time became not a constraining factor but one that was incorporated in predictive schedules that ultimately were driven more by adhering to processes rather than building something that could be used operationally. Time as a constraining, limited in duration, variable faded from memory.

In aggregate, these factors led to a new innovation system that replaced the post-Cold War system of rapid innovation, time-based development, and what would today be known as a "fail fast" culture. This new system was much more than the pre-WWII public management framework that focused on competition, price and minimizing profits although this became a pillar. It was altogether a new thing established based on a flourishing of academic and business management focus on systems, cost, program management, and budget analysis that began in the 1950s. This body of work resulted in a set of oversight criteria, institutions, and processes reflect a set of values that once adapted in the early 1960s in the Pentagon have become deeply engrained in today's defense and oversight culture.

Beginning in 1961, there was established and institutionalized new public management regimes to translate these new values into action. These management regimes (budget, acquisition, security, personnel, and information management) were designed to provide a framework for the oversight of defense spending and the programs that matured out of the disruptive innovations and technology developments of the 1940s and 50s, but also to protect those technologies from unauthorized release and use. These new institutions can be categorized by effect on time-based on linearity – a process of a multitude of if/then statements and processes – and impact on CMI. Another set of management oversight entities (contract auditors, inspectors general, operational testers, and contract law judges and protest lawyers at GAO) were eventually created to enforce compliance with the new institutions' complexity.

Chapter 4: Time-Based Defense Innovation Data Comparisons

"Make use of time, let not advantage slip".
Shakespeare [138]

Innovation is a challenging concept and even more problematic to measure. It is difficult to evaluate the characteristics and attributes of innovation without using subjective criteria, particularly when trying to assess the impact or quality of such innovation. One variable that all innovations share, however, is time. There is a certain passage of time between a good idea and its deployment in the marketplace; between the start of a project and its eventual completion. Time is different than schedule, which is a projected, predictive, or perhaps hopeful measure of time.[139] Time is actuality, reality, and certainty. It is the concrete measure of simply how long it took to perform a given task. As such, time can be a variable used to differentiate and classify innovative efforts based on the length of time to completion and therefore serve as a basis 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 alone cannot overcome a lack of a knowledge, scientific foundation, or basic research. One

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[138] William Shakespeare. *Shakespeare's Venus and Adonis*. Folger Shakespeare Library edition of *Shakespeare's Sonnets & Poems*, edited by Barbara A. Mowat and Paul Werstine. Folger Shakespeare Library, 2004. Line 129.

[139] This is a significant distinction. Many concerns about cycle time are actually about how to improve schedule, not in the use of a set amount of time to constrain other variables. Unsurprisingly, when time does not drive programs schedules slip due to influences of these other variables such as using unrealistic requirements, immature technology or too few resources. See: Jessie Riposo, Megan McKernan, and Chelsea Kaihoi Duran. *Prolonged Cycle Times and Schedule Growth in Defense Acquisition: A Literature Review*, RAND Corporation, 2014.

can only go so fast and achieve so much in a limited amount of time, but when other factors are not working against time, it is surprising how much progress can be made.

In this analysis time will be used as a variable to assess the rate of innovation. This rate will be measured by how long it has taken to deploy a military or commercial capability. As will be demonstrated in a number of studies and by reviewing past data on weapon systems development, time to market in defense has been lengthening significantly over the years.[140] While this could be due to technological complexity, other factors seem to be more relevant as comparable actors (primarily in the commercial sector, but increasingly, our adversaries) seem to deliver programs equally complex in less time or at the same rate that DOD did in the 1940s, 1950s, and early 1960s.

The inflection point for the rise in time among U.S. defense market innovation rates appears to be 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 time-based rate and approach of the early Cold War. Simply taking the time to complete these processes requires more than it once took to deploy capability. Management regimes untethered to time have also had an additional secondary impact by erecting barriers to those commercial companies that have adopted a time to market philosophy and approach. The decline in CMI has disincentivized the participation in the defense market by commercial companies –

[140] As will be seen there have been several analytical studies that have effectively masked this lengthening time by moving the effective start of a program through changing the definition of when to measure that start date. This ends up undercounting significant amounts of program time.

particularly those that are backed by venture capital or have a Silicon Valley provenance focusing on rapid or agile innovation within a strict time period.

While the rate of defense innovation can be measured by the time it has taken to deploy a military capability, the data on this time to market is surprisingly difficult to obtain. When it does exist, it differs wildly in methodology and definitions. Time to market for the commercial sector can be identified by measuring how long it takes from the start of a program to its introduction in the marketplace. For defense programs, development time or time to market can be explored by assessing how long it takes from the start of a program to the deployment of an initial operational capability. Specifically, the time it takes to deploy a major weapon system from program start to first operational deployment or what is known as Initial Operational Capability (IOC). Determining the specifics of either the start or end date can have a significant impact on the measurement of time to market. Data must be reviewed critically and adjusted based on some standard starting and ending point for measurement, or the conclusions drawn from such data will have wildly different meanings. Most data available for weapon systems are for larger MDAP systems.[141]

[141] The MDAP definition is currently in law in Title 10, United States Code, section 2430 and covers those programs "estimated by the Secretary of Defense to require an eventual total expenditure for research, development, test, and evaluation of more than $300,000,000 (based on fiscal year 1990 constant dollars) or an eventual total expenditure for procurement, including all planned increments or spirals, of more than $1,800,000,000 (based on fiscal year 1990 constant dollars)."

Time-Based Innovation Up to World War II

Prior to the end of World War II, two types of defense innovation programs existed, depending on whether they were conducted during long peacetime budget cycles or in wartime. Naval shipbuilding and improvements to conventional munitions such as cannons and rifles were the results of long-cycle peacetime efforts and usually based on technology transfer from Europe. The second type was conducted during conflict periods. Before World War II, most wartime innovation in defense was directed at increasing production of existing types of technologies, with some limited new time-based technological innovation occurring depending on the length of the conflict. While the Civil War and years following until World War I did see some advances in U.S. defense innovation that occurred within these time constrained environments, most conflicts were too short to drive much innovation.

World War II was a different story. There was a greater impact from more disruptive defense technological developments achieved as time became a dominant limiting 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 within a fixed amount of time. 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 different type of industrial base and engineering incentives and methods. As a result, significant advances were quickly made during World War II in the development and mass production of new military items using technologies such as radar, sonar, computing and code breaking, and of course nuclear weapons.

The B-29 bomber illustrates how quickly new technology could be developed, prototyped, produced, and deployed during the war. It eventually became the workhorse of the U.S. military in the Pacific during World War II. The first contract was let in May 1941. The first XB-29 prototypes flew in June 1943 and B-29 planes began to be deployed to India and China in April 1944. This was a little over 3 years from first contract to initial deployment.[142] The Manhattan project took three and a half years from President Roosevelt authorizing the nuclear weapons program in January of 1942 to the first test detonation on July 16, 1945 at the Trinity Test Site in New Mexico. The vast majority of U.S. technological advancements occurred in the less than four-year window from Pearl Harbor to the surrender of Japan in August 1945.

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"[143]

[142] For a history of the B-29 see: https://www.b29-superfortress.com/b29-superfortress-design-development-models.htm and Leonard Bridgeman. Janes Fighting Aircraft of World War II. Bracken Books. 1989.

[143] Bush, Science the Endless Frontier, p. 15.

Time-Based Innovation Data: The Early Cold War

The early Cold War competition with the Soviet Union incentivized the U.S. military to maintain the World War II emphasis on time. Innovation efforts conducted during the war, in the 1950s and then in the subsequent NASA space race with the Soviet Union in the 1960s, had several things in common: a focus on time, rapid experimentation, and rapid operational prototyping. These efforts generally took less than 5 years to deploy something that was operationally capable and usable. It might have eventually taken a second, third, or more prototype iterations to finalize the model to produce in quantity, but each of the earlier prototypes were useful operationally. 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.[144] After Gary Powers' U-2 was shot down over Russia in 1960, work began on the U-2's successor. The A-12 protype flew in 1962 and evolved into the SR-71, which flew in 1964.[145]

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 failed 12 times before success.[146] Still,

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[144] Lockheed Martin History: https://www.lockheedmartin.com/en-us/news/features/history/u2.html; For a description of this and other advanced aircraft development program of the era see: Ben Rich, "Skunk Works: My Personal Memoir of My Years at Lockheed," Back Bay Books-Little Brown and Company.

[145] Lockheed History: https://www.lockheedmartin.com/en-us/news/features/history/blackbird.html.

[146] National Reconnaissance Office, Corona Fact Sheet: https://www.nro.gov/History-and-Studies/Center-for-the-Study-of-National-Reconnaissance/The-CORONA-Program/Fact-Sheet/.

the success 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 U.S. detonated a hydrogen bomb on November 1, 1952, less than three years after President Truman announced on January 31, 1950 the U.S. plan to develop it. NASA's Saturn 5 rocket, which enabled the U.S. to achieve President Kennedy's goal of going to the moon in a decade, took just six years 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 post-war 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 5 years from program initiation. Further production issues would delay IOC until 1952, but nonetheless equate to a total of 7 years from first contract to design, prototyping of several aircraft, and operational use.[147] Another way to view the B-47 program is as two distinct programs. The XB-47 prototyping program delivered an operationally capable plane in 3 years while the next program to produce a B-47 in quantity took 4 years. This sub-dividing of programs is a critical distinction that needs to be made when comparing later programs that abandoned the idea of creating interim operationally capabilities through prototyping. Data on the B-52 (to be discussed later) and the B-58 supersonic bomber each suffered from this data analysis problem of determining program start and finish. Each program over a 10-year timeframe from concept to deploying operational squadrons had several interim initial aircraft

[147] Elliott V. Converse and Poole, p. 280.

with operational capability that were built, flown, and tested. Despite issues in agreeing on a design, a B-58 a prototype was delivered within 4 years from initial contract.[148]

Missile programs unconstrained by flight safety issues because they did not have a pilot in the loop went much faster. The history of the U.S. 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, 4 programs were completed within a 5-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 Minutemen 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 1962-1967 and 1966-1970 respectively.[149] The Minutemen III is still in the U.S. arsenal after 50 years. 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. This 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

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[148] Ibid. p. 487-8.

[149] Ibid. p. 490-506. Also see: Jacob Neufeld, *The Development of Ballistic Missiles in the United States Air Force 1945-1960*, Office of the Air Force History, United States Air Force, Washington, DC 1990.

> went to space and then the moon. And they did it all, from start to finish, in just five years."[150]

The history of submarine development in the 1950s was a similar story of rapid development, testing, and fielding of new defense technology. In just 7 years (from 1952-1959), the Navy transitioned from World War II submarine designs to nuclear powered ones. As shown in Figure 4.1, 10 different submarine designs were ongoing during this time 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[151] and supported the delivery of the first nuclear powered submarine in less than seven years with the commissioning of the Nautilus.[152]

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 5 years, resulting in 5,531 aircraft deployed to the Air Force.[153] As one commentator mentions, the Navy was on the same pathway as compared to the Air Force:

> "In the 1950s, the Navy fielded front-line jets just as quickly: Grumman's F-9 Cougar and F-11 Tiger, the Douglas F-4D Skyray and A-4 Skyhawk, the McDonnell F-3H Demon, the Vought F-8 Crusader, the North American A-5

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[150] Brose. P.43.

[151] Allen, Thomas B, and Norman Polmar. *Rickover: Father of the Nuclear Navy* (version 1st ed.). 1st ed. Military Profiles. Washington, D.C.: Potomac Books, 2007. P. 25.

[152] Converse and Poole. p. 114, 499.

[153] Ted Spitzmiller, *The Century Series: The USAF Quest for Air Supremacy 1950-1960*, Schiffer Publishing, Ltd. 2012.

> Vigilante, and three way-late-to-need variants of the F-86 Sabre, the North American FJ-2/FJ-3/ FJ-4 Fury series. Buried in the later years (1958) was the cream of the crop, the McDonnell F-4 Phantom II, arguably the best jet fighter built in the western world."[154]

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.[155]

Figure 4.1: US Navy Submarine Development and Prototyping [156]

Class	Commissioned	No.	Advancements
Tang class	1951-1952	6	Improved conventional WWII design
Albacore	1953	1	Tear drop hull
Nautilus	1954	1	First operational nuclear submarine
Darter	1956	1	Improved Tang; new acoustic sensors; new fire control; new maneuvering control
Seawolf	1957	1	Tested liquid metal cooled reactor
Skate class	1957-1959	4	First production run of nuclear submarines; based on the conventional Tang class
Barbel class	1959	3	Tear drop hull; combined control room, conning tower, attack center in one space, bow torpedo tubes; diesel engines; hydraulic ballast controls
Skipjack class	1959 – 1961	6	Nuclear power; single shaft; tear drop hull
Triton	1959	1	Nuclear powered fast surface radar picket submarine
Halibut	1960	1	First guided missile submarine, carrying Regulus missiles

[154] Mike Pietrucha, "Finding the Way Again: Building the Air Force's New Century Series," War on the Rocks, June 11, 2019.
[155] Converse and Poole. p. 530; Naval Vessel Register, https://www.nvr.navy.mil/SHIPDETAILS/SHIPSDETAIL_CVN_65.HTML
[156] Table adapted from: https://navy-matters.blogspot.com/2020/08/uss-albacore-and-submarine-development.html.

Time-Based Innovation Data Comparisons

In the early 1960s, Peck and Sherer were concerned about lead time comparisons between the U.S. and the Soviet Union for systems that made it appear the U.S. was behind the Soviet Union. These differences were actually quite minor. They were also incredibly short compared to what was to eventually become the norm for U.S. systems just a few decades later. The differences between U.S. and Soviet lead times or time to market were likely based on comparing two different baselines. This will be an important and recurring point in later comparisons. Peck and Scherer attributed the differences in comparing time to development to the fact that the U.S. program start date was often the "gleam in the eye" date, while Soviet start dates (as determined by U.S. intelligence) were based on tangible evidence of production or development: "Indeed, one reason why development time comparisons appear so consistently unfavorable to the United States is the tendency to assume that American weapons programs began when a feasibility study was requested or when a far-sighted military requirement was written, rather than when it was first recognized (often as a result of technical breakthroughs) that development of a desired weapon was technically feasible."[157] The reality is the U.S. at this time did not have a cycle time to development problem. That would come later.

The Defense Science Board (DSB) in 1977 studied acquisition cycle time and broke an acquisition into three parts:

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[157] Peck and Scherer, p. 5.

- Decision time – the time it takes to start development;
- Development time – the time to develop a system; and
- Production time.

The DSB found that from the 1950s to the 1970s, development time had been relatively constant. 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 2 years in the 1950s to over 5 years by the early 1970s. The DSB would blame the accumulation of layers of organization and management involved with decision-making for this increase.[158] This claim was opposed by OSD, which to no surprise was the source of all of these new layers and requirements.

By 1986, the President's Commission on Defense Management (Packard Commission) was on the cusp of 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-

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[158] U.S. Department of Defense, Defense Science Board. *Report of the Acquisition Cycle Task Force, 1977 Summer Study*, Defense Science Board, March 1978. p.vii.

> term forecasts are uncertain at best, users tend to err on the side of overstating the threat."[159]

In 1990, RAND completed a study that reviewed time to market data for 107 aeronautical weapon systems (Figure 4.2).[160] The methodology used was to measure the beginning of a program or initial program start at what was then known as Milestone 1, defined as 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, start dates for earlier programs had to be estimated. 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 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 equivalent concept definition processes were in place, it would have taken far less time to complete these processes than in later programs and would have been embedded in the time it took to complete these 1950s and 1960s program.[161] For these reasons, the older, faster programs would have essentially skewed RAND's results and shown a much greater increase in cycle time than was presented in their

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[159] President's Blue Ribbon Commission on Defense Management. *A Quest for Excellence: Final Report to the President.* Washington, D.C.: U.S. Government Printing Office, June 1986. p.47.

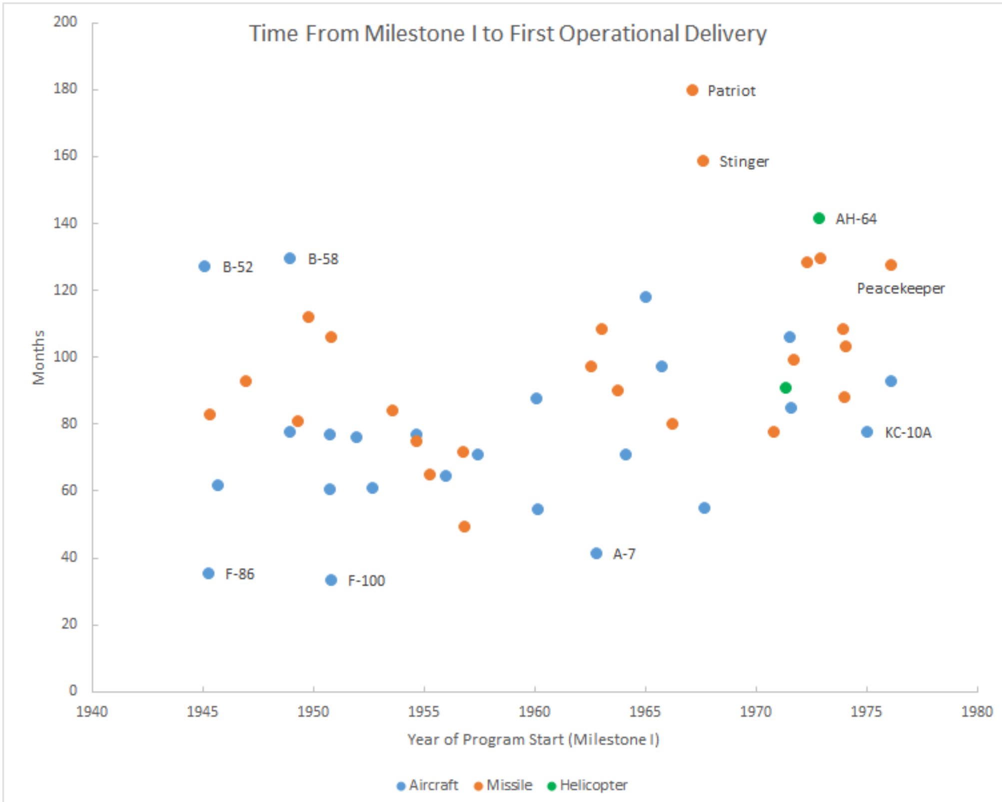
[160] Jeffrey A. Drezner, Giles K. Smith "An Analysis of Weapon System Acquisition Schedules" RAND Corporation, National Defense Research Institute, December 1990.

[161] The precursor of the concept definition phase was created in 1961 to conform to the PPBS process and began to slow down the process according to testimony by General Schriever (see below).

final analysis with what was actually happening in the 1950s. Also, RAND did not address the DSB concept of "Decision Time" which DSB found to be the source of cycle time increase. This re-baselining of when a "program" starts or what counts as the length of a program has been one of the ways that the increase in time has been masked in later studies. It has also made it difficult to make comparisons of time to market when looking across decades.

Many of these 1950s programs were really the equivalents of what, in the 1970s, would be covered somewhere between the duration of milestone 1 (demonstration and validation) through the end of milestone 2 (full scale development). The difference was that in the 1950s, these programs would then have deployed something operationally useful and a decision would have been made as to whether to produce more, develop the next generation of capability, or decide that the deployed operational prototype capability was sufficient to meet the mission. It was not until the formal acquisition process under the 5000 series was created in 1970 that the demonstration and validation and full-scale development phases would become something more rigid and thus merely linear transitions to a later phase in a program.

Figure 4.2: Cycle Time Program Data: 1950-1990 RAND Corporation[162]



The estimations for programs that remained in the analysis from the 1950s were also problematic, as some, like the B-52 and B-58, contained multiple operational prototyping efforts incorporated into one program definition. Still, the results of RAND's analyses showed that time to deployment was increasing and that programs were taking two years longer to progress from Milestone 1 in the 1970s and 1980s than in comparable programs from the 1950s and 1960s. While this is likely a significant underestimate because it neglects decision time, it still shows the

[162] Dreszner and Smith, p. 10. Programs identified by RAND in original data and figure labeled.

beginning of a trend that should have generated significant debate – but did not. The reality is the RAND study may have been commissioned and then used to counter the findings of the Packard Commission in attempt to show that things were not as bad as the Commission had reported. A couple of years is not a big problem, particularly if things 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 10-year weapon acquisition cycles when the underlying technology becomes obsolete in two to five years or less."[163] A 2001 DOD Inspector General audit report identified that in 1960, MDAPs required seven years for completion from program start to IOC. In 1996, this time had grown to 11 years.[164] While the DOD IG had many problems with the quality of data, like RAND it used the start of Milestone 1 as program initiation and did not consider "decision time." In the 2004 annual SECDEF report to Congress, the Department provided data that corresponded to the IG's report:

> "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

[163] William S. Cohen, Secretary of Defense, Annual Report to the President and Congress Fiscal Year 2000. p. 152.

[164] Department of Defense Office of the Inspector General, "Audit of Major Defense Acquisition Programs Cycle Time" Report Number D-2002-032, Dec. 28, 2001. p.2.

> control overall program costs. During the 1960s, a typical acquisition took **7** years (84 months) from initiating program research and development activities to achieving initial operating capability. By 1996 a similar acquisition required 11 years (132 months) from program start to initial operating capability."[165]

Neither the IG nor OSD tried to make comparisons with programs that started in the 1950s, when the Department had been moving even faster, presumably because SAR data was not collected until the 1960s.

Over a decade later in 2015, the Senate Armed Services Committee relied on a Defense Advanced Research Projects Agency (DARPA) study brief that brought together data on time to market for U.S. Air Force programs and other commercial programs. 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 Department being able to conduct short, iterative development and fielding cycles and innovate like the more agile sectors of the commercial market."[166] This study, unfortunately, was unpublished and is no longer available. The supporting data outlined the changes in the time it has taken to develop military and commercial systems since World War II. The data that originated in this study was instrumental in supporting the concept of Mid-Tier acquisition, which is essentially 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

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[165] Donald H. Rumsfeld, Secretary of Defense, Annual Report to the President and Congress 2004. p.61.

[166] U.S. Senate. Committee on Armed Services, Senate Report to accompany S. 1376, National Defense Authorization Act for Fiscal Year 2016 (S.Rpt.114-49) 2015. p. 173.

provision was included as section 804 of the 2016 National Defense Authorization Act.

The following data in Figure 4.3 is an attempt to replicate from public sources some of the original data that was used by the Senate Armed Services Committee.[167] These systems are for new aircraft and do not include subsequent upgrades to these aircraft that may have triggered a second MDAP program reporting requirement. Also, this data's starting point is from first contract award and thus 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 corresponds 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 time to innovation.

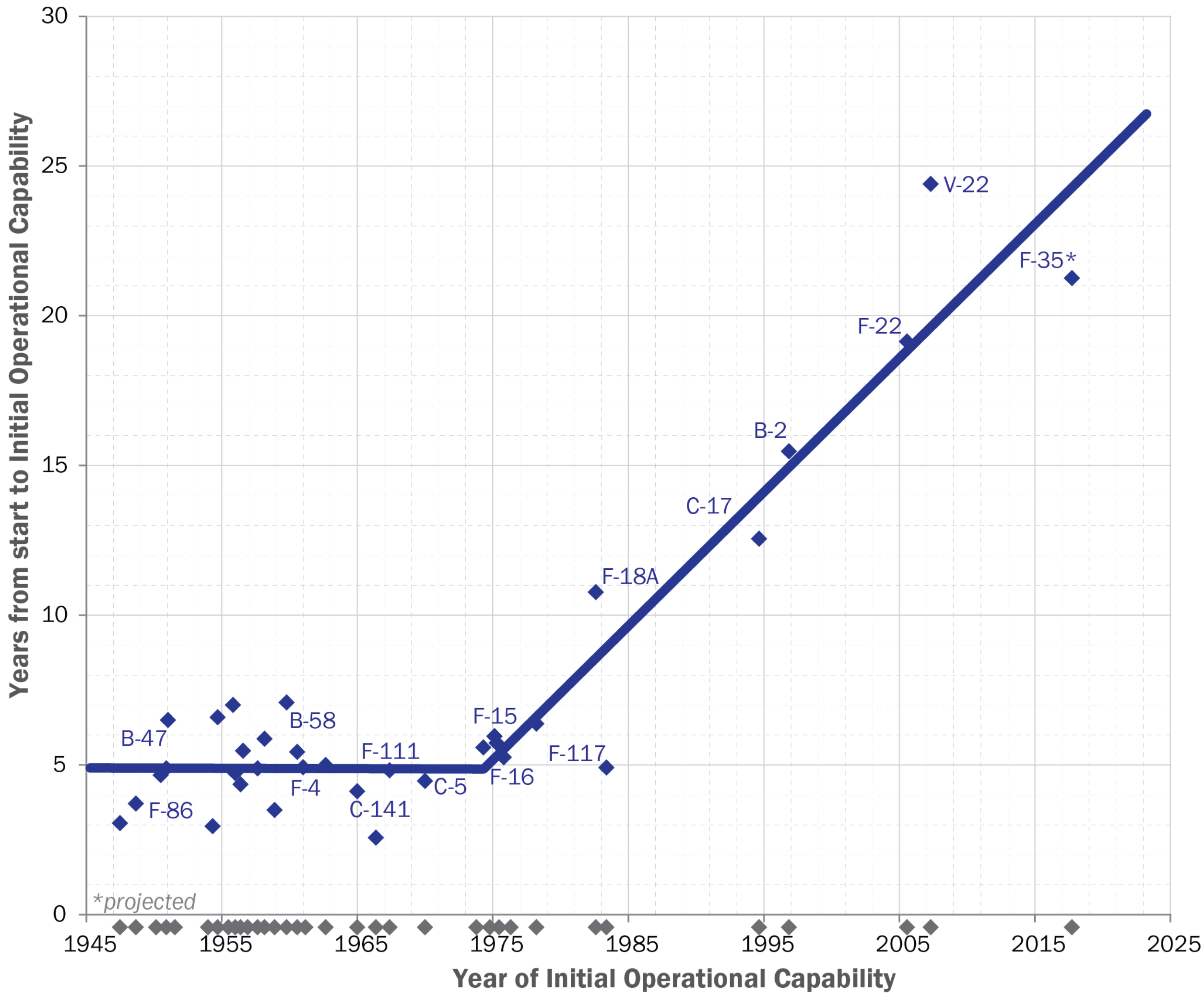
The data in Figure 4.3 presents time to market for military aircraft programs developed and deployed since World War II. Specifically, that is defined for a military capability as the time it takes to deploy a major weapon system from program start measured by the first contract award to first operational deployment or IOC. IOC is set at when there is the basis for an operational capability that is deployed and occurs before most program production begins. As the DSB found, production time is essentially meaningless for these types of comparisons because it is a function of how many units one wants spread out over time depending on the

[167] This data is from a study I am a co-author on with Dan Patt that will be published by the Hudson Institute in February 2021 entitled: "Competing in Time: Adaptable Resource Allocation is Crucial to Delivering Capability Advantage and Winning Future Wars." The source data for this effort comes from reference library research. Key sources are historical archives of the annual periodical Jane's All the World's Aircraft and the weekly periodical Aviation Week. Some additional public data including monographs on a single program were also used.

budget and time it takes to produce a unit. The important thing to focus on from an innovation perspective is the time to get to first deployment or in DOD parlance, IOC.

As can be seen in the data, the time to market data for U.S. military aircraft programs during the early Cold War periods was about five years for a typical program. Since about the mid-1970s, that time to develop and deploy significant new capabilities has been increasing at a rapid pace with start to IOC or deployment dates quadrupling. From 1945 to 1974, the average time to develop a new aircraft from program start was about five years. In 1971, the DOD 5000-series acquisition policy was published. Since then, time-to-IOC for military aircraft has increased at rate of approximately five years per decade: the F-18 achieved IOC in 11 years (1985), the B-2 in 16 years (1996), and F-22 in 19 years (2005). The F-35, after over two decades of development, achieved IOC in 2016.

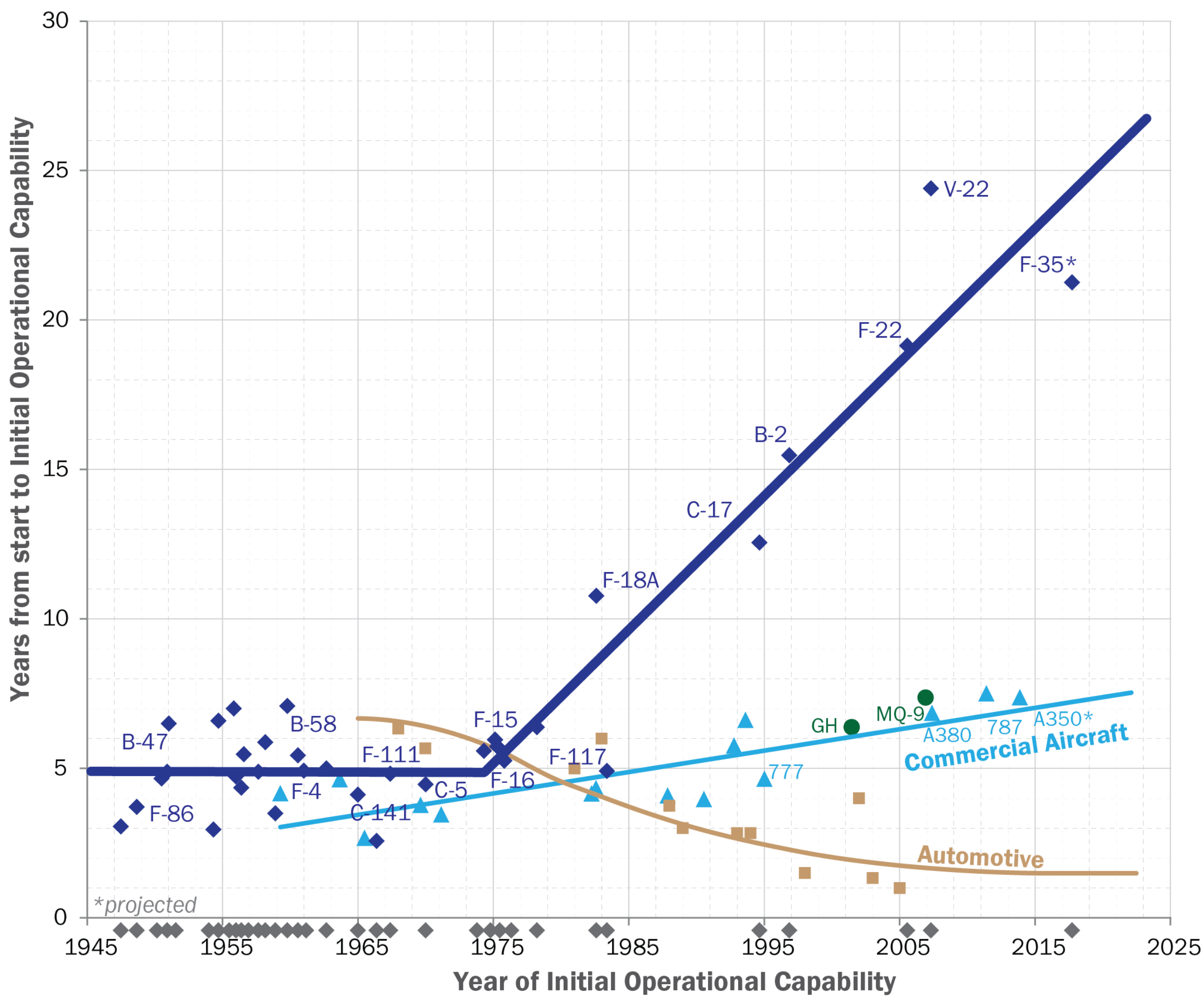
Figure 4.3: Defense Aeronautical Program Time to Market (Contract Award to IOC)



The second chart (Figure 4.4) adds comparable data for commercial aircraft and automotive industry programs. This is measured from the initiation of a commercial program effort until initial market appearance. This comparison can serve as a proxy to measure the innovation rate or time to market both in the defense and commercial markets. While defense aerospace programs show significant time to market growth, comparable commercial aviation reveals a more relatively modest growth during this period that are comparable to early DOD weapons programs in the 1950s. Trends in the automotive industry that actually show a decline 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.

Based on this data, it appears that early Cold War innovation cycles were comparable to current commercial cycles (around five years) and much different from late Cold War and present defense innovation cycles. From what is known about other commercial development, such as the evolution of the product cycle in the integrated circuit/microelectronics industry operating at the speed of Moore's Law for over 50 years, commercial innovation trends appear to be anywhere from 1-7 years depending on the class of product. Commercial aircraft are currently at the higher end. There are two anomalies in the data chart: GH stands for Global Hawk and MQ-9 for the Predator unmanned aircraft system. These are military aircraft and serve as a case example in the next chapter as they were developed under special authorities in a manner similar to the how the military developed systems in the 1950s. When comparing other weapons system data with comparable data for the development and deployment and initial market appearance of commercial technologies such as aircraft, time to market in defense can be seen to be lengthening significantly over the last several decades.

Figure 4.4: Time-Based Innovation Data: DOD Programs and Commercial[168]



While this data is only for U.S. military aircraft programs, it does conform to recent statements by DOD officials. For example, in 2018, DOD's Chief Technology Officer stated that it now takes "the US on average 16 years to deliver an idea to

168 Ibid. This data also comes from the ongoing study to be published in February 2021.

operational capability, versus fewer than 7 for the Chinese."[169] This DOD validation for the rest of DOD programs is significant, but even more so is the comparison with the Chinese, who have adopted a military-civil-fusion innovation model similar to earlier U.S. approaches, but also implying adoption of military time-based innovation models and processes. Time focus alone at this rate would allow the Chinese to get two and a quarter turns on the technology cycle to every U.S. turn.

Issues of Technical Complexity

If time to market weapons system data for U.S. systems has been increasing, does that matter? Was a shorter period of time to deployment appropriate in earlier history but now other factors require a longer time frame to achieve similar milestones or breakthroughs in defense innovation? If U.S. adversaries and the commercial market are now faster than DOD, does that make a national security difference? Are the Chinese merely catching up with their version of the F-22 (the J-20) and is that pace merely the result of stolen technology from the U.S.? Will future new "greenfield" project approaches undoubtedly take longer? If the rate of innovation as measured by "time to market" has slowed over the years, the next step is to attempt to explain why and whether that variable is significant.

If weapons system cycle time has been increasing since the 1960s, technical complexity could be driving this and thus increased time to market would simply be considered the new norm. It is possible that it is more difficult now to do the

[169] Katrina Manson,"Robot-soldiers, stealth jets and drone armies: the future of war," Financial Times, November 16, 2018.

necessary systems integration and software development for these complex systems. Perhaps the U.S has reached the limits of knowledge and capacity, making it impossible to go any faster to bring new sophisticated defense systems into operational use. On the other hand, there may simply be an issue with the way systems are developed.

In an attempt to address these valid questions, a measure of complexity is needed for comparison. As an example of systems integration complexity, the F-35 stealth fighter has represented a bellwether of that complexity. It is often called a computer with an airframe designed around it.[170] The level of software or source lines of code (SLOC) for the operational system on the F-35 when it was first delivered after 21 years was 6.8 million lines of code.[171] It also has thousands of complicated parts and systems to integrate. And yet, when looking at commercial aircraft equivalents, which also have a high parts count, and using SLOC as a measure of complexity, that may not be the case. The Boeing 787 Dreamliner had an equivalent 6.5 million SLOC and delivered in 7 years. While the F-35's SLOC has risen to 22 million SLOC as maintenance support software has been added, Google manages billions of SLOC to conduct its operations.

Still, while defense systems may be more of an engineering challenge and therefore bound to take longer, it will be hard to prove that this complexity in itself requires three to four times the time. Another metric besides SLOC may be needed as

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[170] Kris Osborn, "The F-35 Is More 'Flying Computer' Than Fighter Jet, And That's Changing How America Fights," National Interest 2-19-2020; Dan Grazer, "The F-35: Still No Finish Line in Sight", Project on Government Oversight, 3-19-18.
[171] Christian Hagan and Jeff Sorenson, "Delivering Military Software Affordably", Defense AT&L. March/April 2013, Defense Acquisition University. p. 32.

the comparison of SLOC or software lines of codes imply that commercial technological efforts such as the development of commercial aircraft can be equally as complex as defense programs. The Defense Innovation Board's SWAP study didn't think SLOC was an adequate measure of complexity for DOD systems: "Source lines of code (SLOC) is not a measure of value and should not be used to evaluate projects in any case, as its use creates perverse incentives."[172] This is because not all software is created equal. Determining the impact of complexity on IOC is therefore challenging.

Issues of Process Complexity

If the data on general technical complexity is inconclusive, could process complexity have impacted DOD's ability to innovate, as the 1977 DSB study implied? DOD's inability to innovate in a time-based manner likely came after the 1960s, which marked the post-Sputnik period of innovation. This period included the development of the first reconnaissance satellites launched in 1960 through the period of NASA's Apollo program. The barriers to time also likely occurred before the late 1970s. This would correspond to beginning of the second offset programs such as the stealth fighter that were classified and exempted from the traditional development management process. The biggest process changes occurring in the period from 1962-1978 were related to contracting, acquisition, budgeting, and requirements. The issue is how to measure that complexity.

[172] U.S. Department of Defense, Defense Innovation Board, Software Acquisition and Practices (SWAP) Study Final Report, May 2019, p.14.

In contracting, 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.[173] A similar argument used by Jacques Gansler to illustrate regulatory complexity over the years was to show the increase in the page count of the Code of Federal Regulations. It is possible a similar data gathering exercise could be conducted for other variables. The easiest may be to count the pages of the DOD 5000 series as it has grown since 1971. This would likely show a correlation to the time increase in Figure 4.1. Another area to examine for process complexity is the budget process. Budget process complexity could possibly be measured by a page count of the authorization and appropriations bills and reports and by the page numbers of budget justification documents that went to Congress over the years. For example, the first NDAA in 1962 was just 1 page and the 2020 NDAA was 1,120 pages long. Finally, an even more daunting data collection effort would be to review original requirements documents for each weapons system program and look for a correlation with time to market data. Length of contracts for each program might also be a possible measure, if the data were available.

While these proxies are all likely to have increased over time, the effort to collect them and perform the analysis still may not offer conclusive proof of process complexity. Each of these potential data sets may illustrate the idea that process complexity entered the innovation process during this time. But while there may be a visible link between a rise in management complexity variables from the number of

[173] Fox. Defense Acquisition Reform. p. 14.

specifications and requirements or the regulatory impact of the acquisition and contracting process, there is, however, no conclusive proof that there would be an effect. These linkages would, at best, show that these systems likely added process complexity to the system that did not exist earlier.

While statistical analysis will likely on its own to be inconclusive, the underlying complexity of process data as measured by an increase in pages of the outputs of these processes also may or may not be the best measure for complexity. Many of those regulations may just be guidance that can be ignored or provide options in specific situations that may not be applicable in each case. This extra guidance could actually reduce complexity and make it easier for practitioners to execute on a program. Thus, this measure of complexity alone may not explain the increase in time but does provide an indication of where to look further for factors. Intuitively, the bend in the curve in Figure 4.3 begins in 1975 just a few years after the establishment of the 5000 process.

While it is probable that there is a link between these types of data, I did not choose to collect a proxy for contract, acquisition, requirements, or budgetary complexity and explore a statistical analysis between each of these processes and time. Instead, I chose to employ a much simpler and I believe, better analytical proof designed to explore the possible link between process complexity and time using other evidence related to process linearity described below. A future quantitative study might be beneficial to explore further the relationships between these variables and attempt to test at what point process complexity may have specifically impacted time or not.

Issues of Process Linearity

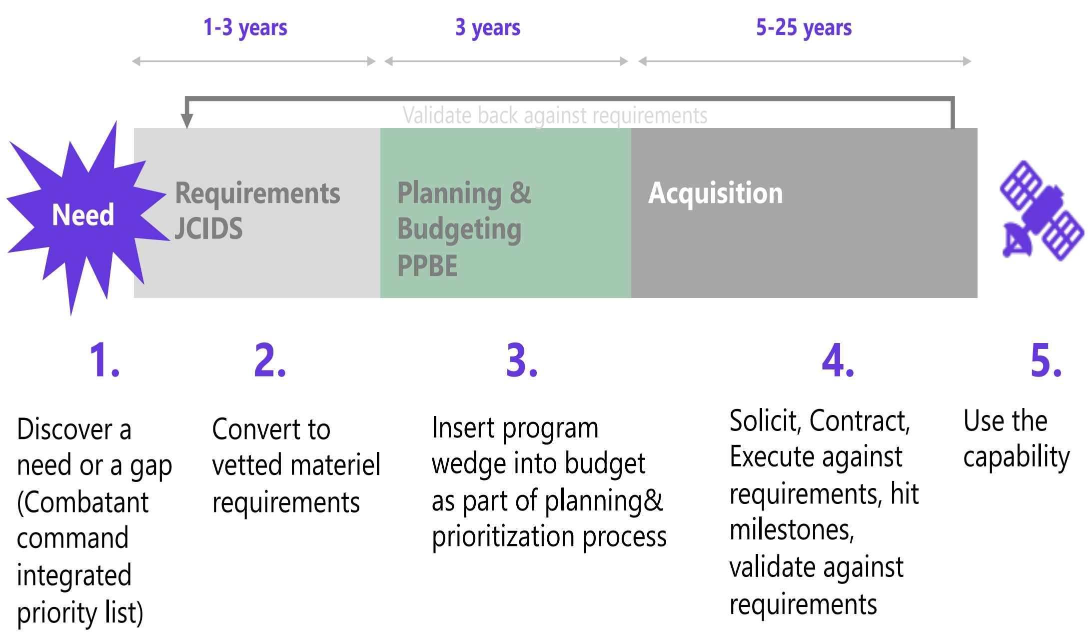
In the absence of statistical evidence and analysis, the means I chose to address the impact of time was not to look for process complexity, but to look for process linearity by identifying measurements of the time each process takes to complete. Measuring or estimating in a general sense the time it takes for management regime processes to be implemented provides a greater sense of how management regimes may have impacted the time it takes to develop a military capability. As these processes did not exist in their present form in the 1950s, they are unique in their application to programs.

The most significant drivers of process time in weapons system development are the requirements, budget, acquisition, and contracting regimes. These regimes do adhere to a concept of linearity as they are conducted in a serial fashion with some limited concurrency. The first step in this analysis is to collectively line up these processes, factor out where they overlap, and then compare the time taken, in general, to adhere to these processes versus the time taken to deliver capability when these processes did not exist. This is a useful and demonstrable exercise. Doing so illustrates that it is nearly impossible to innovate at the same rate as the U.S. used to prior to the establishment of these processes, as they collectively take much longer than the five years it took to deliver many of the capabilities from the 1950s.

While there is some concurrency in each of the processes, it is not as significant as one would first imagine. 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 becomes 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. But first it is necessary to baseline the start of a program in the 1950s. The PPBS/PPBE budget process and the Joint Capabilities Integration and Development System (JCIDS) requirements process did not exist and services had flexibility to move funds among program efforts and start programs when they wished. There was no formal acquisition process as mandated in the 5000 series. Contracting was simpler and faster. 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 in decision time in the 1950s to go from idea to validating technology, which actually included awarding a contract and bending some metal.

Today is a different story (see Figure 4.5). To demonstrate linearity, I will propose two examples to illustrate that the time it takes to conduct these processes in a linear fashion makes it impossible to innovate in the 5-year typical average that occurred in the 1950s and 1960s. These examples will actually underestimate the time it takes to conduct the defense innovation cycle but are illustrative of how these processes impact time. The first example examines three of the processes conducted in a linear fashion to follow the realization of a good idea to implementation in a program start that ends with the award of the first defense contract to actually initiate work on the program. This corresponds to the segment of the DSB's decision time that follows the requirements, budget, and contracting processes, but does not account for technology validation. This example will ignore acquisition process time as some of the acquisition process could be done concurrently with the contracting process.

Figure 4.5: DOD Linear Innovation Processes



This first linear model would correspond to an estimated time spent before award of an initial contract and thus, is an estimate of time it takes to initiate a program prior to the time a program was started in Figure 4.4.   As the JCIDS and PPBE processes did not exist in the 1950s, the equivalent process to get to first contract were measured in months, so we can assume for purposes of comparison that collectively, these processes to start a program in the 1950s took one year – which is likely an overestimate.[174] 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 required under PPBS. He implied that without this process it would have taken much less than the year or more delay that was then being seen from complying with this analytical new phase to start a new effort.[175]

The second comparison baseline is to look at the time it takes to travel only through the acquisition management process. This would roughly correspond to the equivalent of moving from the award of the first contract to deployment or IOC as was measured in Figure 4.3. Except for the award of the first contract, contracting time is assumed to be embedded in acquisition time, as it would be conducted concurrently with the process to conduct program management activities. Putting the two timelines together and subtracting the initial contract preparation time would correspond to a more comparable average time to market time with a program from the 1950s covering the period from initial first interest or identification of a need to deployment.

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[174] For analytical purposes we can assume that it might have taken 1 year in pre-program approvals and 1 year to perform technology validation in the 1950s that would correspond to the DSB estimate.
[175] "Systems Development and Management (Part 3)." Hearings before a Subcommittee of the Committee on Government operations House of Representatives Eighty-Seventh Congress, Second Session, July 1962, pp. 814-819.

Time to Conduct JCIDS, PPBE and Contracting Process

In the first example, merely going from the identification of a need or good idea (or the need to generate a good idea) to first contract has a 7-year time window. During this time, nothing is being done except for process and analysis to get to a final decision of award a first contract to a vendor to initiate development of a capability. If, in the 1950s this was being done in a year's time, one can see that DOD is already six years behind in its ability to move at the same acquisition speed. It is possible to reduce this time through concurrency of the processes but that would require significant top-down advocacy and a substantial bypassing of current rules. Even then, as will be illustrated in the second timeline, that would not guarantee a successful time-based outcome.

Establish a Need: In this example to be set at the beginning of 2020, the first step in the process is developing market or technical awareness. This is the initial identification of a "need." Let us assume that a leading aerospace engineer who now heads their own company and has a terrific track record of deploying innovation in both the military and the commercial sector designs a new vertical lift engine technology that would provide multiple performance improvements over existing systems. The engine is already being tested in the California desert and these tests have validated the technology concepts, but the engine has not flown on an aircraft. Most good ideas die at this stage because there is no military sponsor that wants to commit to such an idea and actually build something at scale. Defense entrepreneurs spend years in what is called this proverbial "valley of death" trying to convince senior officials to begin the long path to a program. Most never succeed, but in this case, let us assume that General X has several meetings with this company and thinks the technology is mature and should be prototyped as a potential to serve several missions in an unmanned version of a new vertical takeoff and landing tilt rotor aircraft capability. This market or technological awareness and gaining of a sponsor could take many years to achieve, but for sake of argument, let's assume this was accomplished in a one-year process of briefings, site visits, and Pentagon meetings.

JCIDS Process: To start a program, however, one needs funding. To be eligible to receive funds, one needs a validated requirement. The JCIDS is a multiyear process, but we can assign a two-year period to accomplish this goal. In 2010, the Army estimated that it takes on average 15-22 months to get a requirement approved.[176] More recent data for 2015 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.[177] Both of these data sets may be looking at different baselines of when the requirements process actually started. A 2-year estimate will likely be an underestimate, as in order to enter the joint requirement process and get JCIDS personnel to start looking at something, this effort will need to start with one of the services preparing the paperwork to justify the requirement. That will also add additional time, perhaps years in coordination unless General X can move it faster, but we can safely assume that 2021 and 2022 will be spent getting JCIDS approval.

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[176] "Army Strong: Equipped, Trained and Ready" Final Report of the 2010 Army Acquisition Review Chartered by the Honorable John M. McHugh Secretary of the Army. P. 94.
[177] Dan Patt, Don Schlomer & Doug Campbell, "Strategies to Streamline the U.S. Army's Acquisition Approval Process", 2015.

PPBS Process: Once the performance requirements are validated and it is determined that it makes sense to have something that is perhaps twice as good as what the Department currently has, now comes the hard part – trying to find enough money to allocate to the program over the course of the program. This budget process takes 2-3 years, 2 years if the requirement is completed at the most auspicious time in the cycle and money happens to be available. We will assume this is the case so another year is not lost waiting to enter the following years' service Program Objectives Memorandum (POM) cycle, which is a key segment of the PBBE process. That extra year is probably more likely than not. Still, under this analysis the assumption is that 2023 will be spent in the Service POM cycle for insertion into the 2025 President's budget. That budget is sent to the Congress in 2024 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 Department cannot spend any money on it.

The likely outcome is that the appropriations bill will not be completed and a new start designation not be made until after the fiscal year starts in October, which would most likely be at the start of calendar year 2025. Past history reflects the inability of Congress to pass a budget on time and then be forced into a series of Continuing Resolutions (CR) to start the fiscal year. CRS has noted that "regular appropriations were enacted after October 1 in all but four fiscal years between FY1977 and FY2019. Consequently, CRs have been needed in almost all of these years to prevent one or more funding gaps from occurring." [178] Since CRs limit expenditures to 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 passed in the CRs. Those anomalies are not easy to get and most programs need to wait until passage of the defense appropriations bill.

Contracting Process: Finally, and optimistically, after five years, 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, so much time has lapsed since this illustrative engineer had the initial great idea that the initial sponsor has long moved to another position or retired. Nonetheless, 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. That contracting process, following the FAR, could take almost two years, according to the GAO.[179] In the Army, for example, a competitively awarded contract between $50 million and $250 million was estimated to take 600 days.[180] A program such as the one in this hypothetical example would have a high risk of a bid protest as it could threaten existing programs in production, which might take it to the higher end of GAO averages.

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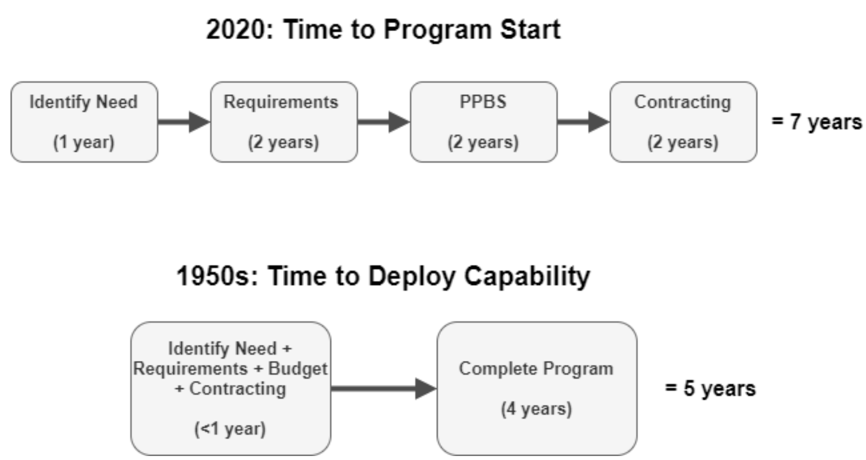
[178] U.S. Congressional Research Service, "Continuing Resolutions: Overview of Components and Practices", R42647, Updated April 19, 2019 p. 9-11. For further information on the funding gaps that occurred during this period, see CRS Report RS20348, *Federal Funding Gaps: A Brief Overview*.

[179] U.S. Government Accountability Office, DOD Should Develop a Strategy for Assessing Contract Award Time Frames, GAO-18-467: Jul 16, 2018.

[180] Ibid p. 9.

Funds, however, will still need to be obligated within a 2-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 go back to the Treasury. The length of the contracting process will lead to likely program start by the end at the end of 2026. And if everything goes right, the contractor starts can start work in the beginning of 2027 – a full 7 years since a good idea was proposed.

Figure 4.6: DOD Process Comparison: 1950s Time to Complete Program to 2020s Decision Time to Start Program



Thus, the linear time it takes to go from identification of an idea, through the requirements, budgeting, and contracting processes to simply begin work on a program is seven years, or two years longer than to deliver an entire capability under the old regime – pre-PPBE, 5000 and JCIDS. (See Figure 4.6). This assumes a five-year cycle which from previous examples such as the U-2, SR-71 or ICBMs is a probably a high estimate. This time is only for the front-end linear processes that is rarely factored in to any assessment on acquisition cycle times. None of the examples in Figure 4.2, 4.3 and 4.8, or in other studies factor in this time (with the exception of the 1977 DSB study) but it is extremely important to DOD's ability to compete in the future against more advanced adversaries than Al Qaeda, ISIS, or the Taliban.

This process can take much longer. For example, something as seemingly simple as a sidearm for the Army that could theoretically be bought as a commercial off the shelf product from Cabela's[181], took the Army 13 years to award the first contract for when replacing the Beretta M9/11 pistol. 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 (RFP) to initiate the contracting process in August 2015, and then award a contract in January 2017. This was for something that was sufficiently small that it did not need to go through the systems acquisition process, yet it still took 13 years just to get to a contract and start the program.[182]

Time to Conduct Acquisition Process

If the time to go from zero to a contract is longer than the time DOD used to deliver capability prior to the Kennedy Administration reforms, what happens when

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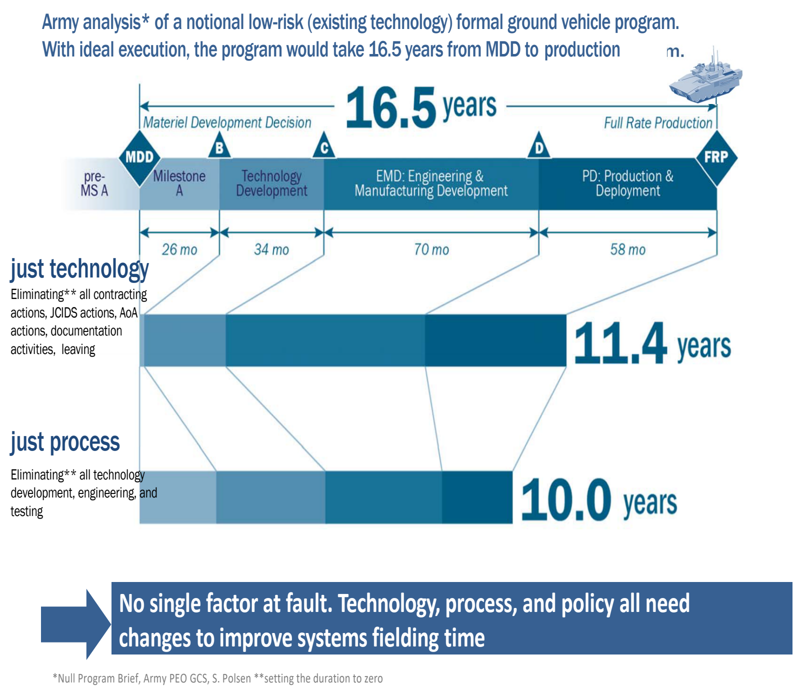
[181] Chairman of the Joint Chiefs of Staff Mark A. Milley when he was the Army Chief of Staff once threated to do just that. See: Kyle Jahner, Army chief: You want a new pistol? Send me to Cabela's with $17 million. Army Times, March 27, 2016.

[182] Moshe Schwartz and Jason Purdy, "Army Modular Handgun Procurement", Congressional Research Service, June 19, 2018.

the systems acquisition process is added? The U.S. Army conducted a very helpful study in 2015 to estimate how long it would take to just do the paperwork required by the 5000 series acquisition process at the time (Figure 4.7). This was called the Army "null" study and it looked at how long the process would take without ever buying anything and then compared that with a typical development time for a low-risk incremental program.

The Army found that it took 10 years just to comply with the acquisition process. This 10-year process is, of course, longer than the time it took to deliver capability in the 1950s and it is above and beyond the requirements, contracting, budget, and new start processes previously outlined. Contracting could be conducted concurrently once funds are appropriated by Congress, so perhaps the time added to the previous process is "just" eight years, but since this is only the time to perform the paperwork and get through the process, the actual time it takes to deliver capability is in fact much longer. Either way, the acquisition process time alone is longer than earlier time to deployment.

Figure 4.7: Army Null Study Results[183]



Another noteworthy data point from this analysis is that the time it took to develop the technology was very similar to process time – 11.4 years vs. 10 years. What that likely means is that knowing how long it takes to conform to the process, the services had the opportunity to continue to concurrently develop technology while waiting on the process requirements to be completed. Otherwise, they would have been forced to use 10-year-old technology for all of their future systems. The other interesting comment that can be made from this chart is that the real development

183 This program brief was first delivered on October 27, 2011 for public release and distribution. It was later briefed to the Senate Armed Services Committee and used by the late Senator McCain in many subsequent speeches, referred to in public hearings of the Committee, and was the source of several of his reform proposals to reduce cycle time.

time once technology is mature is 5.1 years, which conforms to earlier time-based data (16.5 years in total development – 11.4 years in technology development). This implies that the military still can innovate like it did in the 1950s, but it cannot do so unless the 10-year paperwork process is abandoned or significantly reduced.

Ultimately, what we see from the Army null study is that the data they analyzed estimates a 16.5-year time frame to get to a decision to enter full-scale production for a relatively risk-free solution. This would correspond to getting to IOC with limited production. There is no room or time for a risky disruptive solution like the targets of 1950s innovation efforts. This study's output does conform with an MDAP acquisition timeline of about 15-25 Years. The extra 10 years comport to the time to continue producing the system at scale. Adding the Army's estimate of the 10 years it takes for the acquisition process to the 7 years it takes to get to first contract and then subtracting for a concurrent 2-year contracting cycle equals 15 years – again fitting within the parameters of a 15-25-year acquisition program. Still, both the Army's null program (10 years) and actual estimate (16.5 years) ignore pre-program decision time, so it is quite possible it would take 23.5 years to get to IOC in this example if the 7 years in decision time were added to the program.

When a program takes that long, the whole idea of predictability is called into question. Can one really set a cost, schedule, or performance baseline that is tied to the budget over such an excessively lengthy period? 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.

DOD over time has tried to adjust to these realities by setting new baselines when things changed. Congress, on the other hand, believed this was just a case of moving the goalpost and subsequently mandated in section 802 of the 2006 NDAA to force DOD to adopt measurement from the original cost baselines. This makes one wonder if Congress was politically just setting DOD up to fail, because if DOD takes on any risk in a program, 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 actual 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. Without a significant "Great Power" adversary as occurred at the end of the

Cold War and lasted for almost 25 years,[184] this could be a legitimate policy. In a different era, it appears foolish.

Issue with Baselines

Baselines are critical as the foundational criteria of measurement. Pick the wrong baseline and you get a different answer. The difficulty in choosing which cost baseline criteria for Nunn-McCurdy measurement to use leads to a logical question about the correct baselines for measuring when to start and end the calculation of cycle time or time to market. This is extremely important and will lead to a different view of reality depending on the baseline chosen. As was seen in the two earlier measurements of time for aeronautical programs, RAND choose to start with the beginnings of technology demonstration and the data in Figure 4.4 begins with the initiation of a contract. Each of these ignores the likely now 7-year upfront time it takes to move through the budget, requirements, and initial contracting processes.

A 2016 IDA study and a 2020 study by CSIS on time to development unfortunately muddy the water a bit further and drive home the importance of baselines and methodologies.[185] Still, upon closer examination these two studies cannot reject the thesis that time to development is increasing unless one buys into their initial assumptions. The results generated by these studies are helpful in

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[184] This corresponds to the recognition by the Obama Administration of the threat from China and Russia after the invasion of Ukraine by Russia in 2014 and the subsequent militarization of disputed islands in the South China Sea by China.
[185] Morgan Dwyer, Brenen Tidwell, and Alec Blivas, Cycle Times and Cycles of Acquisition Reform. Center for Strategic and International Studies, August 2020; David M. Tate, Acquisition Cycle Time: Defining the Problem (Revised), Institute for Defense Analysis, October 2016.

supporting the cycle time debate and would be even more helpful if they would publish their data and not just their results.

The first issue to address with these two studies is their timeframes. The IDA study covers the period between 1990-2015, well after the main problem of increased cycle time had been identified. The best takeaway from this study was that the problem hasn't gotten worse in this timeframe nor has it gotten better. The reality is the problem has worsened, but to determine that relates to the studies choice of baselines. On the positive side, both studies collected data that includes all MDAPs not just those in aircraft programs. The CSIS data goes back to 1960, which is much better than 1990 but still does not include 1950s data or comparisons when the U.S. did cycle time execution well. CSIS then subdivided the data to correspond to various sub periods that relate to acquisition reform cycles (See Figure 4.8 and Table 4.1).

The next issues relate to baselines. Both studies primarily compared these programs from Milestone B to IOC. Milestone B refers to what is called engineering and manufacturing development. The results of these studies generally correspond to a statement made in October 2020 by Ellen Lord, the Undersecretary 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."[186]

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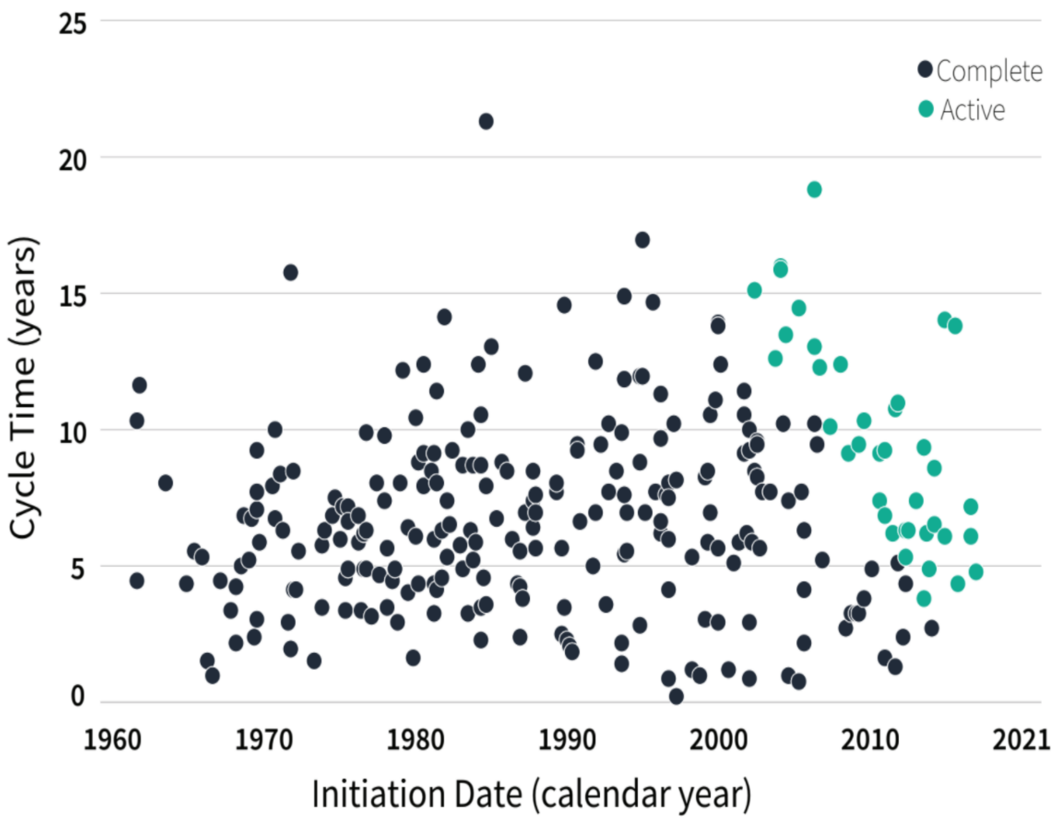
[186] Press conference, Ellen Lord, Undersecretary of Defense, Acquisition and Sustainment, October 7, 2020.

Figure 4.8: Cycle Time Program Data: CSIS 1960-2020 MDAP MS B to IOC



Using Milestone B as the baseline to start a program may be an analytical scoping issue due to the limitations of available comparable data, but that decision skews the analysis and mask the overall time to market problem. Each of these efforts, by choosing to collect data to begin a program at what is now defined as Milestone B, has chosen a baseline that is, unfortunately, extremely late in the process. It effectively discounts the tremendous amount of time necessary to get to Milestone B. Milestone B would correspond to Milestone 2 in the earlier RAND study that measured the start of a program much earlier in the process at Milestone 1.

Milestone 2 and Milestone B, which, while called different things – full scale development vs engineering and manufacturing development – is roughly the same data point.

This implies most significantly that the cycle time situation is much worse once pre-Milestone B time is added to these programs. Not wanting to add in or emphasis this time is what advocates for those portions of the process – in the early requirements, budget, and contracting that are slowing things down in the pre-MS B phases -- would want to emphasize. But, even in these studies they are not counting the technology development time to go from Milestone A to Milestone B. When competing with the U.S., the Chinese are not looking at the time it takes to go from Milestone B to IOC, but how long it takes the U.S. to deliver capability – which is much greater than that. That is why is it important to include and consider all phases of the process. Policymakers need to be cognizant of study baselines and what is covered and what is not.

I will propose adding pre-Milestone B linear time estimates to CSIS's data to reflect a truer picture of today's reality when innovating to compete against a near peer such as China. The first adjustment to be made to programs since the mid-1990s will be to add in the seven years of decision time for market awareness, requirements and budgeting process and then add the two years (26 months) that the Army estimated was the time for a program to progress from Milestone A to Milestone B for just the paperwork. The second adjustment will be made for those programs in the 1960s where there is data for additional decision time according to the 1977 DSB report at 2 years and for programs in the 1970s was 5 years. This will result in a slight time underestimate as there is no readily available comparable estimate for the time it took to go from equivalent measures of Milestone A to B during these time periods. For 1980s and early 1990s programs, I will propose to split the difference between pre-Milestone B time at 5 years in the 1970s and 9 today, and mark that adjustment at 7 years. Adding those adjusted time frames to the CSIS data table corresponds to a minimum of 15 years to complete a program.

Table 4.1: CSIS Time to Market Numbers Adjusted for Pre-Milestone B Activities and Decision Time

Time Period	MS-B-IOC CSIS Data in years to complete			Pre MS-B-IOC Adjusted in years to complete		
	Mean	Max	N	Mean	Max	Adj
FY 1963-1969	5.0	11.5	13	7	13.5	2
FY 1970-1976	6.1	15.7	30	11.1	20.7	5
FY 1977-1982	6.3	12.3	38	11.3	17.3	5
FY 1983-1989	7.1	21.2	48	14.1	28.2	7
FY 1990-1993	6.4	14.5	15	13.4	21.5	7
FY 1994-2009	8.0	18.7	90	17	25.7	9
FY 2010-2018	6.0	12.3	26	15	21.3	9

MS-B: Milestone B (Engineering and Manufacturing Development Start)
IOC: Initial Operational Capability
N: Number of cases
Max: Length of longest program in time period
Adj: Decision time and pre-Milestone B adjustment

The most critical step to attacking time to market addresses the time it takes to get to Milestone B. While there may be ways to streamline the 6-8-year timeframe from Milestone B to IOC, the likely longer period to get to that point is even more important to assess. If it takes 9 years to just get to Milestone B and experimentation and prototyping are not a part of that equation, there are two potentially negative outcomes: technology will not be as mature at Milestone B as it should be, or perhaps worse from a national security perspective, operators will be denied an operational step change that could be created during that transition to a traditional MDAP program.

While both of these studies and Undersecretary Lord's statement serve as a positive contribution to generating public data for evaluation, they ignore a large segment of time to development and in doing so any conclusions could lead to the adoption of poor management practices that leave the U.S. military further behind technologically. Nonetheless, these studies are important steps in getting more data into the public space even if they require more refinement and analysis. What is most striking is that there may be an ideal time that could serve as a goal for future Milestone B to IOC programs. This could be set at five years or less as is the current requirement in the Rapid Fielding pathway of the Section 804 Middle Tier authority. This authority closely corresponds to a Milestone B to production program and is much shorter than the current time frame that is the source of Undersecretary Lord's concerns with an 8-year process to move from Milestone B to IOC.

Issues with Innovation Quality

Reviewing the defense budget each year for new programs and technologies can lull one into a false sense of security, as it would appear that DOD is always innovating and focused on new technology. That would be a true statement and one could legitimately ask whether there is a problem. The key questions are, what types and quality of innovation is DOD pursuing? Is it disruptive, sustaining, revolutionary, incremental, or evolutionary? How does time impact the quality of these innovative approaches?

The next set of issues relate to many of the studies that have to rely on MDAP SAR data, which is a data analysis problem. Having more data is better, but the first problem with the data is it needs to be differentiated. Mixing first of class and new types of technology endeavors with incremental limited upgrades to existing equipment makes it difficult to draw the right conclusions from the data. It should be expected that incremental programs with limited new technology will take a shorter period of time to complete and there will likely be more of these kinds of programs, particularly if that is what oversight frameworks are incentivizing. For that reason, the aircraft data in 4.3 is differentiated by new aircraft and does not include subsequent upgrades to these aircraft that would be included in a consolidated MDAP data set.

The problem with using aggregated MDAP data to measure time is that no matter which baseline is chosen, it is ignoring this discussion of quality. The quality of the innovation being pursued is an important clarifying concept that should be considered with regards to time-based approaches and measurements. This becomes problematic when data is aggregated as there was, for example, no differentiation in size or complexity in the IDA or CSIS analysis. Unfortunately, each MDAP is unique and despite statutory classifications addressing dollars spent, there is no one-size fits all description of an MDAP program. Many of these MDAPs have a size and quality of innovation problem. They are not something disruptive or even new. Many are upgrades of existing equipment and because they trigger the statutory dollar threshold, even a minor upgrade of electronics in a combat vehicle program that could take a year to complete would be classified as an MDAP. Thus, a distinction in the data should be made between first in a class of innovation (lead ship, new aircraft) and those that are incremental improvements to an original innovation. Then, within those first in their class new developments a further, more subjective distinction could be made of how many of these are truly disruptive or not.

The quality of innovation should matter and intuitively one would think that an increase in time to development would increase quality. Similarly, a time-based strategy would seemingly incentivize incremental innovation that truly couldn't be disruptive. But what is counter-intuitive is that the greatest disruptive sources of defense innovation – ICBMs, reconnaissance satellites, nuclear submarines, and stealth aircraft – occurred during a time-based approach. And while in the post-McNamara data that CSIS collected there is a need to differentiate between small incremental efforts and more challenging new programs, little has been developed since the late 1970s (with the exception of stealth and a few other Second Offset technologies) that can accurately be classified as disruptive when compared to 1950s and early 1960s deployed technologies. A greater focus on planning, cost estimation, and taking one's time to "get things right" led to less disruptive technologies rather than more.

While process protections against failure may have stretched out time, even more importantly, they may have created a risk-averse culture and incentives in the budget and acquisition systems that encourage incrementalism in innovation. Weapons developed under this system over a long space of time counterintuitively are not the most disruptive if past history is a guide. The reason for this is that in trying to adhere to the checklist mentality of the 2008 Weapon Systems Acquisition Reform Act (WSARA) and other NDAA legislation that has embedded very specific Milestone A/B/C criteria into law and then to be able to meet the stringent original estimated cost baselines of the Nunn-McCurdy Act, a program to be successful would need to focus on very limited incremental innovation. Anything else would trigger the inability to move beyond milestones or a likely a Nunn-McCurdy breach.

The current acquisition process discounts experimentation, prototyping, and disruption as reform criteria to oversee the acquisition process have incentivized incrementalism in MDAPs. Thus, under the current defense innovation system, disruptive innovation may be procedurally being driven out of the system through these reforms and DOD has been pursuing limited incremental innovation such as seen in the army's continual upgrades of its large systems developed in the 1970s – the so called Big 5 – M1tank, Bradley Fighting Vehicle, Apache Attack Helicopter, Patriot air defense system, and Blackhawk helicopter once they were first deployed in the 1980s.

Rapid Incrementalism as an Alternative Developmental Strategy

What did earlier major disruptive technologies have in common? Rapid experimentation and prototyping that were based on a bedrock of scientific progress. The ability to fail and learn from these failures. This leads to a very interesting issue regarding the types and definition of incrementalism. Incrementalism need not stifle innovation if it is limited by short bursts of time and classified by innovation goals. Serial incrementalism can be highly disruptive as will be argued by earlier cases of successful time-based serial incrementalism. One could classify incremental MDAP programs pre- and post-McNamara into categories of either rapid serial incrementalism or planned incrementalism. The post-McNamara planned incremental systems conform to the linear requirements, acquisition and budget processes. Technology is mature at Milestone B and thus fewer technical problems can delay the fielding of the program while this new technology insertion can be completed in a one-time innovation turn according to CSIS data in 6-8 years after earlier decision time is completed. The quantity of innovation as measured by serial iterative prototyping and what is now known as agile development in the commercial world was a foundation of earlier innovation practices. This could be described as rapid serial incrementalism and several innovation turns can occur in a limited time period.

Multiple prototyping turns conducted in a rapid fashion can have a level of quality all its own and can be seen by the experience of the development of the B-52. This is an example of rapid incrementalism or the success of a developmental effort going through multiple rounds of rapid prototyping and experimentation. The B-52 may not have been the first, but is one of the most significant examples of agile development, as we can still see the results today. How to classify this program is a methodological challenge in itself. As can be seen in Figure 4.2, RAND believed that time to deployment for the B-52 was around 11years. In Figure 4.3, this number is seven years. The difference again has to do with how a program is defined. Incremental turns of innovation that occurred in the B-52 program were counted as one program by RAND and multiple efforts in Figure 4.3.

Development of the B-52 may well have been the 1950s equivalent of the iPhone that turns out a new version every year, as it was conducted in a very similar agile manner. First, the B-52 underwent multiple rapid design iterations beginning in 1946 and ending in 1951 with a new designed being produced roughly each year. Then, two prototypes were built with the first being flown in 1952. Starting with the B52A, eight different models went into production with a new model coming off the production line and achieving IOC roughly every year until the Air Force stopped production on the B-52H. Each model was designed to have an increase in performance and all models were delivered by 1963.[187] The plane is still in active service with the Air Force today with plans to continue flying for many decades to come.

While initial efforts correspond to a rapid design and developmental prototyping and testing, the eight production models correspond to a concept of rapid

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[187] See Converse and Poole, Volume 1 and 2; and Preston, L. E., Contract Negotiations and Results in Aircraft Procurement: Case Studies of the B-52 and B-58. Santa Monica, CA: RAND Corporation, 1962.

operational prototyping with each model evolving into better capabilities and service life. Such a concept of rapid time-based incremental development prototyping and operational prototyping that puts out a new product each year can be highly disruptive over the course of multiple innovation turns. A turn would be defined as whenever a new product is introduced. Even if the innovation turn rate was greater than 1-2 years, a focus on achieving a 3-5-year innovation turn cycle DOD could vastly impact the quality of innovation by getting 3-4 turns of innovation in a time-based manner rather than in one longer 15-20 year centrally managed program.

Planned predictive innovation could be an improvement as long as it is conducted in a time-based basis. While this incremental approach could be criticized as being not revolutionary, a time series of this type of innovations may provide greater and more innovative capability than one 20-year planned program. As was described above, both 1950s submarine development and the Air Force's Century Series subscribed to a time series model similar to the B-52 experience.

The Bifurcation of Industrial Base

The next issue with time relates to the difficulty in attracting to the defense industrial base those firms that still innovate on a time-based basis. In the immediate period World War II, there was some decline in CMI that began with the creation of a dedicated defense industrial base, but this bifurcation picked up in the 1960s and 1970s with the development of unique government processes and requirements than that in the commercial industrial base. The privately-run defense industrial base eventually split off and differentiated itself from the underlying civilian commercial base from whence it came. As this base became more defense unique and integrated with the government run defense industrial base, barriers developed that would eventually limit the cooperative ties with the rest of the civilian commercial industrial base.

The origins of the current CMI structure can be traced to decisions made during and immediately after World War II. The existential threat of World War II resulted in an almost complete integration of the U.S. military and civilian industrial bases as the country converted commercial production capability to military uses. The evolution of this industrial model in the 1950s created what Eisenhower described in his January 17, 1961 farewell speech as the military-industrial complex.[188] This complex was a hybrid – not quite completely commercial in practice, but not quite a government enterprise, as was the case with the publicly-run arsenals.   Even though the industrial part of the military-industrial complex was predominantly privately run it ultimately became more and more government unique in its outlook and orientation, drifting away from its commercial roots – in due course looking more like a privatized version of the public arsenal system.

At the time of Eisenhower's speech, dual-use commercial entities were still a part of the industrial base. As time progressed, a greater, and depending on the criteria used for evaluation, almost complete, separation between the private sector portion of the military-industrial base and the rest of commercial technology industrial base eventually prevailed in the post war experience. Ultimately, this

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[188] President Dwight D. Eisenhower's Farewell Address, January 17, 1961.

“privatized arsenal” approach looked similar to the old public arsenal model with defense-unique private companies relying only when needed on the rest of commercial industry for raw materials like steel, titanium, and some “off the shelf” commercial products.

But how and when did the defense-unique industrial base and commercial industry go their separate ways? As management systems evolved, other values embedded in these management processes such as compliance with a rules-based system, enhanced accountability and oversight, security, competition, fairness and geographical dispersion in place of performance replaced disruptive innovation and speed as the dominant criteria to be achieved. These processes and values ultimately significantly altered the types of companies that bid on and won defense contracts.

As the 1960s cost-based processes grew more linear they would eventually serve as barriers to new entrants in the defense market. Still, it was likely that the cost-based accounting and government-unique contracting process related to price began the bifurcation of the industrial base in the 1970s. The passage of the Truth in Negotiations Act of 1962 (TINA) was the first defining moment. The embrace of TINA and its establishment of the government’s rights to internal contractor pricing and cost data forced companies to decide whether to specialize in defense contracting or not. Not surprisingly, some firms and parts of firms began to specialize in these military products while others pursued commercial markets. This process took about a decade to take hold.

TINA traces its origin to the Vincent Trammel Act and to late 1800s audit rights provisions targeted at the steel companies supplying U.S. naval ships. In 1962 when TINA was first passed into law, this requirement was a rather reasonable one that companies should certify that the prices and costs that they gave to the government were correct. At this point that certification was based to a great degree on trust and policing by internal company employees who could file a Qui Tam suit as the TINA certification requirement triggered a legal requirement covered by the False Claims Act. In 1968, Congress didn't trust that certifications were enough to deter fraud and added enhanced government audit rights for TINA. But then auditors were confused by the proliferation of different cost accounting systems at companies that made it difficult to audit.

The creation of CAS in 1970 completed the government-unique CAS/TINA process. It was argued that CAS was needed to effectively implement TINA as the government could not make sense of all of the data it now had a right to have. Each company's accounting system was different and it was difficult, if not impossible, to make comparisons. The driver behind this system, ironically, was the individual who did the most to ensure the Navy's earlier time-based success on nuclear submarine development. Admiral Rickover is credited with spearheading the creation of the CAS system based on his congressional testimony.[189] Once his focus moved to how to build submarines at scale after submarine class designs stabilized, the Admiral focused on production and price. And while Rickover had a problem with maintaining competition and incentives to perform, what really seemed to rankle him was not knowing how much money a contractor was making. Ultimately, this came

[189] U.S. Congress. Senate Committee on Banking and Currency, A Bill to Amend the Defense Production Act of 1950, and for other purposes, Hearing on S. 3097, 90th Congress, 2nd session, June 18, 1968.

down to a lack of trust of the private sector and the desire to drive down profits. In testimony before Congress Rickover stated:

> It should be clearly understood that under existing procurement rules it is not possible to tell just how much it costs to manufacture equipment or just how much profit a company actually makes without spending months reconstructing the supplier's books. Large additional profits can easily be hidden just by the way overhead is charged, how component parts are priced, or how intercompany profits are handled… Thus, profit statistics are meaningless unless measured in accordance with a uniform standard."[190]

This was all perfectly true under a cost-type contract where the government reimbursed a company for all of its costs. Rather than focus on negotiating a fixed price, the dislike of profits made this option even more distasteful. Rickover, again: "Under fixed price contracts, a contractor has virtually unlimited flexibility in deciding how he will keep his books and how he will assign costs among a number of individual contracts."[191] As a result of Rickover's testimony, Congress created the Cost Accounting Standards Board in 1970. The obsession with managing costs and profits on government-unique contractors was adopted not just at DOD, but government wide. The harmonization of a company's accounting system to support government auditor and pricing requirements from then on necessitated the creation of an entirely government-unique accounting system that was not useful in the commercial marketplace.

Companies were forced to choose. Cost contracts under CAS became a specialized way of business with firms that chose to do business with the government.

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[190] Ibid. p. 26.
[191] Ibid. p. 26.

These firms essentially became privatized versions of the old arsenal system. The procedures requiring firms to manage on a cost basis was instrumental in not only the bifurcating of the industrial base but the maintenance of this separation until the present time. They also had an impact on future innovation that would come out of the defense industrial base. Profit margins were managed to the levels comparable to a publicly regulated utility, which in essence these firms are, and that are lower than the more dynamic portions of the economy. The management of costs and the limitations on what the government would eventually reimburse for engineering talent put the defense industry in a comparative disadvantage with other high technology companies. Low profits and cost reimbursement rules have disincentivized R&D investments beyond what can be reimbursed through allowable overhead rates on a contract. There is little to no incentive for a defense company to invest in any R&D, above that it is reimbursed, as that comes right out of already lower profits margins than obtained in the rest of the commercial market.

The Vietnam War era thus became a turning point in the path to the bifurcation of the civilian and military industry bases and the development of greater barriers to commercial firms' participation in the DOD market. The cost-based focus of the government had several other unintended consequences. As companies were forced to specialize in either defense or commercial sectors, there eventually became limited discussion or understanding of trends in the commercial marketplace. In the 1960s and 1970s when DOD was driving R&D innovation, this did not have an effect, but it did impact the culture at DOD, which was to always assume that everything DOD did was unique. The result was a proliferation of unique military specifications on producing goods for the military. Even once DOD fell behind the commercial marketplace it was never able to change its attitude that defense solutions were superior to commercial ones.

Several other requirements to include security and the treatment of intellectual property also underwent significant changes since the 1960s that served as barriers to commercial participation in the defense market. Security brought unique process that contractors had to create compliance programs. The government's treatment of intellectual property in a way that favoured the government raised the stakes for a company as whether to participate in a government contract or not. From a commercial perspective, the worst provision was the authority to allow the government to transfer a company's intellectual property and technical data to competitors to further competition. This drove those companies that paid for their own R&D and wanted to capitalized on that investment out of the government market. Still, the most significant barriers to commercial company participation in the defense market have been CAS and TINA. These factors embedded within the contracting regime have created a very complex set of often contradictory propositions that serve as barriers to those commercial industries such as those in Silicon Valley and within the commercial aircraft industry that have adopted a time to market philosophy and approach. Thus, the decline in CMI of the defense industrial base that these regimes have encouraged has kept out of the traditional defense industrial base precisely those firms that are incentivized to focus on rapid or agile innovation within a strict time period.

The defense industrial base appears to have merely adapted to government-imposed process change rather than being a driver of it. There was no widespread lobbying to impose greater regulatory checks and balances on the defense industrial base. There was no industry support for TINA and CAS or limitations on industry data rights, and in fact there was resistance over the years. Still, those companies that wished to do business with the government adapted these constraints into business practices. Ironically, the industrial portion of the military industrial complex that was the source of worry when President Eisenhower first warned against the rise of such an entity, actually benefited tremendously when processes were created to regulate it. The defense industry actually did quite well out of new management regimes while those commercial firms who chose not to comply left the market or never entered in the first place.

Management changes in budgeting, personnel, technology security, and acquisition since the 1960s furthered specialization in the defense industry. This first led to the creation of stand-alone defense units within corporations designed to deal with unique rules of the government defense market and then to the eventual sale and consolidation of these units as specialized defense-only companies. The end of the Cold War and the collapse of defense expenditures furthered this consolidation. By the end of the Cold War, it was recognized that the two industrial bases (defense and commercial) had indeed bifurcated and were completely separated, which led to a debate over the cost of severing those ties.

The Commercial Industrial Base Time-Based Legacy

The true time frames to complete a new defense innovation program in today's environment is probably now around 15-20 years. This would include seven years of pre-program efforts, technology development and demonstration, full scale development, initial low-rate production and then a follow-on effort that leads to production at scale. This is not an ideal system if one's adversary is able to make faster innovative turns and adopts a serial prototyping strategy similar to DOD practices of the 1950s. Since this old approach is similar to today's commercial approach displayed in the development of the iPhone, it should not be surprising if China were trying to develop weapon systems the same way. Although what might be lost now is that today's best practices look surprisingly similar to the B-52 strategy.

The current DOD weapons system process is also not an optimal market for a fledgling new commercial AI or robotics startup if it takes 7 years to just get into the door and to start earning revenue. Still, why is the commercial marketplace fixated on time and DOD is not? In the Post-Cold War era, the time-based experimentation, prototyping and development model that the Defense Department once used was maintained in the commercial sector. Why has the commercial market done such a consistent job in deploying capability though history as time to market for the commercial sector has corresponded to what DOD used to achieve in the 1950s and early 1960s? One possible explanation for this is that in at least two segments of the economy, the commercial aircraft industry and Silicon Valley, the culture of faster innovation might be found in the legacy of the origins of these industries.

The history of the origins of the commercial aircraft and IT industries may suggest that they are the direct decedents of the time-based defense innovation model that, while no longer being used effectively in the government, has been adopted by these leading enterprises of commercial innovation. One has to only look at Silicon Valley's philosophy of "fail fast" to see the significance of time. These industries actually owe much of their rise to 1950s and 1960s investments by DOD. Commercial sector adoption of the model was encouraged by significant government-sponsored industrial policy actions that helped incubate the commercial jet aircraft and information technology industries. DOD demand, its dominance of research and development in the 1950s and 1960s, and an activist industrial policy of being the first buyer for new technologies was instrumental in helping these industries grow.

Advance purchase agreements for technologies still being developed allowed companies to build up necessary capital and successfully demonstrate technology to expand in the commercial marketplace. These purchases of such items as the Boeing 707 jet[192] that served as the basis for the KC-135 tanker still in service today, and advances in integrated circuits and microelectronics led to commercial dominance or greater competitiveness for those companies and industries that kept to a time-based innovation model.[193] During the 1950s and early 1960s, the Defense Department

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[192] The U.S. military provided significant R&D for commercial aircraft in the post war period, particularly for jet engines: Mowery, David C, and Nathan Rosenberg. *Paths of Innovation: Technological Change in 20th-Century America*. Cambridge, UK: Cambridge University Press, 1998.

[193] R. Miller, D. Sawers The Technical Development of Modern Aviation Routledge and Kegan Paul, London (1968) p.193-94. Importance of production contracts the electronics industry cited by Mowery "Military R&D" p. 1247 in H. Kleinman The integrated circuit industry: A case study of

provided a "path to commercialization" for a number of potential dual-use technologies.[194] This was in common with an industrial policy of the time to nurture new companies and ideas and then transfer to the commercial sector advances created by the nuclear and space programs. The NASA manned moon program in the 1960s served as another mechanism to transfer technology to the commercial sector. This type of industrial policy would be extremely difficult, if not impossible, to conduct under existing constraints as current export control thresholds would now likely be triggered by an item being classified as a military product through military first use or by receiving research and development money from the Department of Defense.[195] But in the early 1960s theses type of export constraints were not written into law and the government was not yet empowered to serve as a brake on dual use defense innovation.

The commercial information technology industry arose from its military roots in the late 1950s and early 1960s, driven by a need to miniaturize electronics to fit within advanced missile, aircraft, and radar systems.[196] This industry, once freed

product innovation in the electronics industry (1966) Unpublished D.B.A. dissertation, George Washington University.

194 For another example of the past use of a military lead customer that provided the capital for a commercial provider to dominate an industry see the use of military contracts for the use of containers for shipping in Vietnam cited as a huge catalyst for the revolution in shipping: Levinson, Marc. *The Box: How the Shipping Container Made the World Smaller and the World Economy Bigger*. Princeton, N.J.: Princeton University Press, 2008.

195 For this reason, U.S. commercial firms now go out of their way to ensure the commerciality of the application of new technologies before applying that technology to a national security need. There are also other constraints such as intellectual property contracting requirements and WTO trade subsidy rules that have made it more difficult for DOD to play the role of first buyer of commercially developed technology or to create partnerships to create that technology.

196 For an excellent history of Silicon Valley and a list of source documentation on the subject see: Margaret O'Mara, The Code: Silicon Valley and the Remaking of America, 2019. Steve Blank's (entrepreneur and adjunct professor at Stanford) website (steveblank.com) is also a good source on information on this early military relationship with Silicon Valley.

from its largely forgotten military roots, is now a multi-trillion-dollar market generations ahead of the military in technological development. It should not be surprising that before it was called Silicon Valley, the area south of San Francisco was the epicenter of the military transistor and radar technology industrial base of the 1950s and 1960s. What has happened since in Silicon Valley is just the most recent example of the phenomenon of military technology moving to the commercial market and being refined and improved upon in ways that military planners did not anticipate.

It appears that these commercial companies and individuals behind the miniaturization of electronics and the development of the air defense and command-and-control systems of the 1950s escaped from the path to pseudo-nationalization and control by first working with NASA, which was more reminiscent of the early Pentagon programs. These companies formed the basis of Silicon Valley and the Massachusetts Route 128 commercial computer and electronics industries, chasing and eventually capturing the higher returns to be found in those sectors. But Silicon Valley was eventually to dominate Route 128 as innovation moved to Silicon Valley away from the military. Not only was it the defense contracts and defense electronics infrastructure that was in place in Silicon Valley in the 1950s and early 1960s, but Silicon Valley adopted a number ways to out-innovate not only the military in the intervening years, but also other potential innovation clusters.

These traits that enabled Silicon Valley to dominate innovation in the world can be argued may have been passed on from the 1950s defense innovation model that looked from a later systems analysis viewpoint perspective to be chaotic, duplicative, and wasteful. The first is that the history and culture of experimentation/prototyping conforms very well to the "fail fast" Silicon Valley culture. This process of agile development and serial operational prototyping was adopted to keep moving new products to the marketplace on an annual basis, similar to DOD's 1950s weapons systems program. The second was the role of an incubator of technology by making many bets of different multiple pathways to a solution. In the place of DOD programs of the 1950s, Stanford University and the growth of the venture-capital community took over in making these initial bets.

The third trait was the ability to pick winners. The 1950s government model allowed the government to be the first customer after using research funding to compete many solutions. This was essentially emulated and replaced by the venture capital (VC) industry. Success in an A round leads to subsequent B, C, and D rounds. But picking winners was not about technologies and companies, but people. At least in the early days of the Cold War, the government was able to encourage senior engineers from one company to start their own company and award them a sole source contract. This process may have reached its height when Eisenhower appeared to be personally picking winners, such as when Simon Ramo was encouraged to leave Hughes aircraft due to security concerns with the parent company and create TRW to manage the ICBM program. [197] This is an example of something that would likely never happen today in government due to procurement

[197] Peter Pae and W.J. Hennigan, "Simon Ramo, leading figure in Cold War defense technology, dies at 103", Washington Post, June 29, 2016; Converse and Poole, p. 494.

integrity concerns, but in Silicon Valley many an engineer can be tempted by VC capital.

Finally, what is probably the fourth most important driver of innovation that made Silicon Valley what it is today it is the focus on time to operational deployment. VC funding only lasts so long. It is either succeed or see the money run out. A 1950s defense program was something similar. There were always other alternatives to spend the government's money. The 1950s defense innovation model moved on from time-based, flexible funding, multiple pathways, entrepreneurial risk taking, and picking winners to one based on order, one predictive long-term path, processes designed to limit risk and ensure fairness for all. Is it any wonder where innovation would eventually come from?

The commercial aircraft would take a less risky route but would detach itself from defense by creating separate business units that were culturally and economically distinct. One would be defense-facing and adapted to the new defense management culture of compliance and the other commercial-facing and operating under a separate set of rules. Most importantly in the development of commercial aircraft, engines, and subsystems, there remained a culture of time-based development that was lost in the defense context.

The evolving role of what are now referred to as non-traditional sources of innovation is a key piece of evidence in the impact of the post 1960s management regimes as applied to defense. Both commercial aerospace and Silicon Valley were once a part of that greater defense industrial base in the Early Cold War and post-integration were left to go off on their own as the defense industry was required to focus on compliance. Collectively, this framework impacted the ability to innovate in many perhaps unintentional ways. The attempt to manage the innovation system through greater centralized planning, pricing and cost management controls, and linear processes did not achieve the results that were originally intended. They did not achieve the advertised efficiency goals and negatively impacted innovation by driven out a time and civil-military integration of the industrial base.

During the acquisition reform efforts of the early 1990s, the industries Congress was most concerned about were the commercial aircraft and computer industries that either were not working with DOD or had created separate methods for doing so. The inability to effectively access these firms though the management process barriers in a failed CMI approach serve as a validation of how far the current defense innovation model has evolved from its origins. Neither Silicon Valley nor the commercial aerospace industry wanted to innovate on behalf DOD because their time-based business models are not rewarded.

Chapter 5: Defense Innovation Case Examples: When Time-Based Innovation Becomes Important Again

"You are remembered for the rules you break."
— Douglas MacArthur

This chapter explores cases when the U.S. government decided to resurrect time as a key variable and place it higher in priority to other values previously more important than speed in the defense innovation system. There is a history of temporary or alternative workarounds of management regimes that support the defense innovation system. These were created when it was determined that DOD or the military services needed to either develop capability faster on a time to market basis or to access new sources of innovation that had been or could be developed from a faster commercial system that values shorter development times. This same dynamic transpired at NASA once the Space Shuttle was retired and the U.S. lost its own access to space and was forced to rely on Russia.

In response to these political demand signals, the most reliable solution to a time-based challenge is to construct or take advantage of laws, regulations, policies, and practices that bypass time-intensive public management regimes. Alternative pathways for time-based development are established, but inevitably these pathways become limited exceptions (usually for an emergency or when funding is limited) and are subsequently pared back either entirely or to a degree. These pathways do not replace, but merely augment, the more traditional longer development and oversight processes based on cost that remain in place for the vast majority of defense innovation efforts.

The Case for Remaking the Rules

As demonstrated in the evidence from the last chapter, time to market or time to deployment has been increasing for defense systems since the mid-1970s. This time appears to have been impacted by the new management regimes that were put in place beginning in the early 1960s, which stressed process linearity. These processes, when lined up end-to-end, added time to a development effort for a weapon system that far exceeded the development times from the early Cold War period. Linearity impacted most significantly the requirements, budget, acquisition, and contracting regimes. There is also evidence that segments in commercial industry maintained a more time-based product development focus that was similar to earlier defense development times. Commercial sources of innovation that took advantage of expanded private sector R&D expenditures have created industries and technologies that are far more advanced than those in current defense capabilities. Barriers to CMI emanating from DOD management regimes have continued to limit access to this time-based commercial innovation.

Still, these longer innovation time trends in defense would not be considered a problem if Congress and DOD valued other benefits that derived from these management regimes and processes despite adding time or causing defense to fall behind the more time-focused commercial market. These other benefits include economic support to state and local jurisdictions, the ability to exercise control over resources, and the political value of being perceived as a defender against fraud, waste, and abuse – whether real or imagined. For senior DOD leadership, political control over resources and the security that arises from solutions produced in a secure, autarkical U.S.-controlled industrial base are other potentially more beneficial value factors.

High levels of defense spending can also mask or offset any increased cost from implementing unique oversight regimes as long as more weapons platforms can be deployed, especially in comparison to the rest of the world. The U.S. has consistently outspent the world in defense.[198] As long as threats remain relatively low and spending high, an inefficient and non-innovative system can continue to operate with limited concern. This situation only becomes undermined when a gap appears, as for example when another country achieves a quantitative or qualitative advantage. In the absence of a gap, whether real or imagined as with the missile gap of the late 1950s, longer management process times can become the norm as innovation time is not valued. This results in a greater focus on security, economic welfare, and oversight compliance benefits. The resulting defense innovation system serves in this scenario as an expensive insurance policy that may not necessarily work in an emergency without major changes, or as history shows, significant lead time to ramp up the industrial base. This is similar to the situation the U.S. has faced

[198] Data from the Stockholm International Peace Research Institute shows the U.S. outspending the next 10 countries combined. and while there is likely much undercounting and issues with purchasing power comparisons in the rest of these countries it is still a useful number

throughout its peacetime history, although DOD is now spending over $700 billion annually on this baseline peacetime system.

The April 1986 Packard Commission report was the last major defense study commission to focus on defense management issues during the height of the great power competition with the Soviet Union. In retrospect, the Commission was a missed opportunity to address time to innovation. Unfortunately, the recommendations made by that commission and eventually put into legislation were aligned with the cost-based, centrally planned, management framework that had grown up in the 1960s, but had the effect of increasing process linearity. This may have been the result of missing the significance of successful classified programs DOD had initiated beginning in the late 1970s that had minimized and blurred the problem of a general movement away from time-based development. These classified programs either never adhered to the emerging management regimes or were able to pay these regimes negligible attention because they were still nascent and evolving and did not yet threaten programs that were managed at a highest level in the Department.

Regardless, from that point forward in the mid-1980s, management and acquisition reform efforts focused on two paths. The first, and primary, path was to build on the cost-based linear management regimes established in the 1960s and reinforced and reinvigorated by post-Packard Commission legislation to address criteria other than time to market. The second path, explored in the case examples in this chapter, was to focus on time and provide exemptions to "break the rules" of these management regimes to allow incentives for timely development and delivery of military capability. Thus, in an emergency or when it feared it was falling behind technologically, DOD (with Congressional support) circumvented established management regimes just as it did in earlier in its history, such as in the aircraft experimentation programs of the 1920s, in World War II, the early Cold War, and in the Second Offset Strategy of the 1970s. While there is a general historical cycle of creating alternative management regimes during an emergency dating back to the War of 1812,[199] the last 30 years' experience have had to address a much more complicated management system. To be successful in a time-based manner, DOD had to be more explicit in ignoring its own cost-based linear based management systems rather than only relying on emergency contracting authorities. What has not been successful or seriously considered was to call into question the underlying system that was being circumvented.

The Missed Opportunities for the Packard Commission to Address Time

There have only been a few opportunities to address the reform of defense management regimes in a comprehensive way rather than in a piecemeal fashion. The 1960s offered that opportunity when the application of a presumed more superior data driven, predictive, fact-based scientific management approach to innovation was created with the goal of not only being more efficient but improving results and further innovative outputs. Program budgeting, systems, and cost analysis and a step-

[199] In its first test since the revolution, the U.S. supply system was totally inadequate in the War of 1812 and Congress had to establish an alternative that did not always work as intended. See Nagle 65-75.

by-step criterion for managing systems through the life cycle of innovation was seen as the pillar of effective and competent defense management that would prevent cost increases and schedule slippages and lead to greater performance of weapon system outcomes.

When these results were not achieved after a quarter century of implementation and institutionalization in the Pentagon and Congress, a second opportunity for comprehensive reform arose in the mid-1980s. At the height of increased defense spending in the Reagan Administration, similar complaints arose about the management of U.S. defense weapons systems acquisition and the inability to control costs. This debate led to the creation by Executive Order 12526 of July 15,1985 of the President's Commission on Defense Management headed by David Packard, Chairman of the Board of Hewlett Packard and a former Deputy Secretary of Defense.

Obviously, the creation of such a significant commission indicated that something had not quite gone right and DOD's acquisition process was seriously flawed. Program managers from the 1950s testified before the Commission that they could no longer innovate as they had 25 years earlier. The most prominent of these were General Bernard Schriever, the so-called father of the U.S. ICBM program in the 1950s, whose time-based development approach was instrumental in leading U.S. efforts during the missile race with the Soviet Union. In his letter to the Packard Commission in 1986, he argued that the system at the time would have made it impossible to innovate as he had in the 1950s. Included are some excerpts that are just as appropriate today as they were then:

- “I strongly believe that the timely application of technology to provide qualitatively superior weapons, second only to people, is the most important ingredient to our National Security.”

- “However, during the last several decades we have lost the way. As a result, the timely fielding of qualitatively superior weapons is not being achieved.”

- “We have let the acquisition time from laboratory to Initial Operational Capability (IOC) more than double and costs inflate enormously.”

- “We are inhibiting technological innovation, the cornerstone for maintaining qualitatively superior military systems.”

- “We are not moving rapidly enough in putting new technologies into systems and we are no longer taking the prudent risks or using “concurrency” as we did in the 50’s.”

- “We have more rules, requirements, documents, people, reviewers and checkers than ever before involved non-productively in the decision-making process.”

- “We have reached a point in history where we should create a new set of policies and procedures along with a management environment whereby technology can be brough into the weapon systems process earlier and the IOC affected on a more timely basis.”[200]

The Packard Commission seemingly agreed that the nature of the problem was that long acquisition cycles were the “central problem from which most other acquisition problems stem”[201] and that past management regimes were more successful:

> “This technique -- establishment of strong centralized policies implemented through highly decentralized management structures -- has its legacies at DOD. On this model, for example, Navy-industry teams working together as

[200] Letter from Bernard Schriever to Packard Commission, February 11, 1986.

[201] President’s Blue Ribbon Commission on Defense Management: *A Formula for Action*. Washington, D.C.: U.S. Government Printing Office, April 1986, p. 8.

> one brought the Polaris submarine-launched missile system from initiation to successful operational test in one-third the time it would take now." [202]

The establishment of the Commission was an opportunity to address time and re-evaluate what had been institutionalized in the preceded decades.

In the end, however, the Commission would choose to operate within and reinforce the same top-down management approach from the 1960s. On the issue of long acquisition cycles, it did nothing to actually remedy the problem, and while identifying the need for a strong program manager such as Schriever or Rickover to be given broad authorities to manage programs and be held accountable for them, the Commission never fully addressed the increasing constraints on program manager discretion and authority. Despite the continuing failure in results, the underlying basis for the collective defense management approach was never brought into question by the Commission.

The Packard Commission instead opted for a stronger centralized military joint requirements system and supported other organizational recommendations to create a new centralized authority in OSD (the Undersecretary of Acquisition, Technology and Logistics) to manage defense innovation. These recommendations cemented the 1960s management framework. The Commission's recommendations were put into law by the Goldwater Nichols Act of 1986, subsequent National Defense Authorization Acts, and the Military Retirement Reform Act of 1986.

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[202] President's Blue Ribbon Commission on Defense Management. *An Interim Report to the President. A Quest for Excellence: Final Report to the President.* Washington, D.C.: U.S. Government Printing Office, June 1986. p. xii.

Despite calls by Packard to empower program managers, the trend of putting further limits and controls on program managers' authority and autonomy continued with the rise of an independent test organization (established in 1983) and the empowerment of independent contracting officers. The creation of new checks and balances in the acquisition and contracting system served as additional brakes that further slowed the innovation process and ensured conformance to linear, step-by-step management processes. These processes were intensively audited by the GAO, a newly empowered Inspector General established in 1978, the services audit agencies, and the Defense Contract Audit Agency established in 1965 – each of which spent a significant amount of time reviewing weapons acquisition. The rise of a new bid protest process and criteria after the passage of the Competition in Contracting Act (CICA) of 1984 furthered the linear oversight framework. CICA had the effect of empowering contracting officers to ensure that contracting process compliance was more highly valued than programmatic output, as a means to avoid protests. The protests themselves delayed contracting time, but the process created to avoid protests stretched contracting time out even longer. Legislative requirements such as the 1981 Nunn-McCurdy regime to oversee cost overruns and the requirement for live-fire testing in 1985 established additional new compliance regimes. Each of these processes led to increasing constraints, the diminishment of the program manager, and a crowding out of time as an important factor in development.

Packard missed an opportunity to swim against the tide, but the reality is that the data was not completely visible to the Commission to support a different path. The data that was available was anecdotal and stood squarely against the management culture and values that had permeated both government and the private sector of the time. The Commission, supported by the leading acquisition thinkers of the day, looked to the problem as one of implementation and emphasis and did not try to recreate or understand what had made Schriever and others successful in the 1950s. In hindsight, that would have included flexible funding, a culture of experimentation and prototyping, a tolerance for failure, the funding of multiple competitive paths to a solution, and the empowerment of a single point of accountability in a governmental program manager who had a long enough tenure to be responsible for the delivery of a capability.

What had changed in that intervening period was that the foundational management oversight constructs still in use today were established and would ultimately undermine each of these successful attributes. Program managers' authority was diminished by a vast array of new bureaucratic entities that could all say no and were effective in slowing down the process. The budget process became inflexible and focused on predictive programing years ahead. Experimentation, prototyping, and multiple pathways were seen as wasteful and duplicative and so were not funded in a program budgeting concept because they were too immature, didn't meet the criteria to be a program, and thus couldn't compete for limited funds. Program budgeting became mismatched and incompatible to acquisition needs.[203]

The Packard Commission did not address these problems or even try to put a constraint on their manifestation in impacting cycle time. It did not recognize the

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[203] This is not to say that program budgeting is not appropriate in some cases. Where acquisition needs are predictable and stable and disruptive innovation is not needed it makes sense. When rapid innovation is needed, program budgeting becomes more than just a hinderance it becomes a threat to that innovation.

problem of process linearity and in fact, compounded it by centralizing the requirements and acquisition oversight processes. It did recognize the problem of budget instability that was inherent in an annual review of program budgets in the PPBS and the appropriations process, but except for a recommendation for a two-year budget, it did not question the underlying appropriateness of program budgeting. Thus, program budgeting continued and each year the flexibility to move money around to experiment and prototype diminished. Meanwhile, the reinvigorated centralized requirements, acquisition, and contracting processes continued to lengthen.

In the late 1970s, it was much easier for William Perry, then Undersecretary of Defense for Research and Engineering, when he laid the groundwork for Second Offset programs to bypass linear processes that were still being established and gaining acceptance. The Packard Commission missed the significance of this as the successful rapid developments of stealth aircraft (F-117A), GPS, and precision targeting technologies and munitions had already been or were just being deployed while the Commission was reviewing defense management issues. These systems may have masked the impact of emerging management processes created in the 1960s as they were able to, through senior leadership direction and classification of the programs, essentially sidestep these evolving processes. This would prove to observers with high levels of security clearances at the time that there was nothing wrong with the system. To reformers, organizational changes and more rigor in the process was needed to address the failures of programs not adhering to cost, schedule, and performance metrics.

The lessons that could have been learned from these on-going classified weapon system acquisition efforts were not assessed. Stealth aircraft such as the F-117A and GPS were operationally prototyped within a short period of time in less than five years.[204] What was not appreciated at the time was that these systems time-based success may have owed more to their ability to be classified and managed in a way that separated them from the more ridged budget, acquisition, and requirements regimes. As Brose observed:

> "By the late 1970s, innovators in the DOD found themselves compelled to work around the acquisition system, rather than through it, to get good technology fast. Indeed, many of the weapons that debuted in the Gulf War, such as stealth aircraft and precision - guided munitions, were developed this way: William Perry, the Pentagon's leading technologist until 1981 and later secretary of defense, gave these programs such a high level of classification that most of the bureaucracy did not even know they existed."[205]

This allowed these so called "black" programs to operate similarly to a developmental program from the 1950s. Thus, Commission members and staff who may not have been privy to information on how these classified programs were managed could argue that time was not yet an issue and that the early problems of lengthening acquisition cycle time, such had just occurred on the F-18A program,

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[204] The GPS demonstration and validation phase of the program was conducted pretty much in the same manner as a 1950s defense program. The program was initiated in December of 1973. The first phase of the program was completed in June 1979 and deployed a fully operational satellite constellation to support increased accuracy of the Navy's submarine ballistic missiles comprised of 6 satellite to do that. See Jeffrey A. Drezner, Giles K. Smith. "An Analysis of Weapon System Acquisition Schedules" R3937, RAND Corporation, National Defense Research Institute, December 1990.p. 181. It took five years for GPS to move from a concept to an operational capability. The program then entered the more formal acquisition process at Milestone 2 in 1979 where it continued to evolve in various incremental iterations and new programs.

[205] Brose p.46.

could be fixed by greater centralized oversight through a joint requirements system and a strong and empowered acquisition head in DOD.

Finally, the Packard Commission had the first insight that something new was happening in the commercial market. This makes sense because Packard was one of the last senior defense officials (along with Perry) to straddle both DOD and the historical nexus between Silicon Valley in its developmental days as a segment of the defense industrial base. He was still working in an industry that valued time to market, but he unfortunately missed the counter-trend that was happening at DOD. Nonetheless, the advice of the Packard Commission on moving the Department away from unique requirements when there is a commercial alternative was sound:

> "No matter how DOD improves its organization or procedures, the defense acquisition system is unlikely to manufacture products as cheaply as the commercial marketplace. DOD cannot duplicate the economies of scale possible in products serving a mass market, nor the power of the free market system to select and perpetuate the most innovative and efficient producers. Products developed uniquely for military use and to military specifications generally cost substantially more than their commercial counterparts. DOD program managers accordingly should make maximum use of commercial products and devices in their programs."[206]

While recognizing the advances being made in these new commercial companies, the idea took hold that these firms did not want to do business with DOD because of the low volumes of DOD purchases. Other barriers to participation were not identified until another Congressional Committee, the section 800 panel, looked closer at that issue.

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[206] President's Blue Ribbon Commission on Defense Management (Packard Commission), June 30, 1986, p. 95.

The Packard Commission almost got it right by focusing on program manager authority and accountability, but unfortunately also empowered new actors to enforce time-intensive hoops for program managers to jump through. Inevitably, the cost, schedule, and performance problems continued to worsen subsequent to Packard. Yet in later years, the vast critiques of defense innovation and the programs that were created to bring that innovation to market never placed time to market as an important criterion for success. For 35 years since Packard, the criteria for evaluating the success of major defense acquisition programs has been a predetermined cost, schedule, and performance metric initiated at the start of a program after receiving a validated joint requirement and a positive long-term budget allocation in the PPBS budget process. Management regimes became more complicated to support optimization for these goals while time to endure these processes lengthened.

The importance of accessing the commercial innovation that David Packard saw was not addressed sufficiently in the report and the mechanisms used exacerbated the problem of time while doing nothing to recognize or address the barriers to commercial innovation. The calls for reform that Schriever made were essentially dismissed as anecdotal. Efforts to empower the program manager were never put in place and new power centers arose to limit the program managers' authority and flexibility. In this systems-based data focused world it is no surprise that the changes made in response to Packard only exacerbated the problem by increasing the time it took to develop weapon systems.

Bypassing the System: Case Examples

With no relief generated from the Packard Commission or Congress, one of the consistent truths of the last 30 years of acquisition practice is that, if the conditions are right and the military needs something important, a mechanism would be created to bypass the traditional acquisition process and use a more streamlined approach. These end rounds of management regimes can be classified into two categories based on the effects of management regimes within the traditional innovation pathway. The first set addressed those management regimes that were driven by linearity and created a serial development process that directly impacted time. The second set of workarounds addressed those regimes that, while in part or not necessarily linear, created barriers to entry to those commercial firms that pursued time to development as a practice. These barriers to CMI, or barriers to the participation in the defense market by non-traditional contractors, required circumvention of management regimes to enable superior technology and practices to be incorporated faster into military systems.

The first large-scale case example from the last 30 years of bypassing management regimes occurred not in an emergency but in an era of declining budgetary resources in the period immediately after the end of the Cold War. This occurred in the 1990s during what can be classified as the first wave of commercial IT dominance. New acquisition pathways were created by Congress through commercial item procurement reforms that focused on taking advantage of the rapid innovation skills of the commercial sector. Three types of pathways were created by Congress at this time – one to access off the shelf, slightly modified, or similar commercial products; the second to encourage the use of commercial practices to the development of weapon systems such as resulted in the Joint Direct Attack Munition (JDAM) missile; and the third to establish in defense prototyping, authorities previously given to the National Aeronautics and Space Agency (NASA) that led to the development of unmanned systems such as the Predator and Global Hawk.

In the early 2000s, as a counter to address concerns over an accidental launch of a nuclear ICBM and the growing missile capabilities of North Korea and Iran, Congress and DOD gave the Missile Defense Agency the ability to bypass traditional budget and acquisition regimes in a manner that addressed process linearity. Similarly, in the period after 9/11, linear processes were subverted by the establishment of rapid acquisition authorities and programs that relied on standing up alternative requirements, acquisition, and budgetary processes granted through new legislative flexibilities. After the retirement of the Space Shuttle, NASA used longstanding, but little used production OTA authority under the Space Act of 1958 to create new space launch capabilities, most notably by SpaceX, that were eventually transitioned to DOD. The SpaceX example addressed both linearity and CMI and served as the basis for later legislative action advocated by the late Senator John McCain that carved out new alterative pathways for DOD around the traditional management regimes and tried to reinvigorate many of these older authorities.

The behavioral evidence from these case examples suggests that the way for DOD to effectively innovate when time becomes critical is to sidestep current management processes and regimes. This supports the case that management processes have crowded out the ability to innovate as measured by a time to market criteria. These case examples not only validate the theory that management processes serve as a barrier to innovation, but also provide clues into which processes are most problematic, as those are the ones that are consistently evaded. In each of these cases, the innovation model was deemed to be insufficient and actions were taken for at least a subset of DOD's budget to create an alternative path to access innovation.

Table 5.1. Case Examples

Case	Objective	Effect	Example
FASA FAR Part 12	Access Commercial Products	CMI	Computers
FASA Acquisition Pilots	Access Commercial Business Practices	CMI/Linearity	JDAM
DARPA Other Transactions	Replicate Cold War Development Practices	Linearity	Predator Global Hawk
Missile Defense Agency	Replicate Cold War Development Practices	Linearity	National Missile Defense System
9/11 Rapid Acquisition	Replicate WWII Rapid Acquisition Practices	Linearity	MRAP
NASA Space Act	Replicate Cold War Development Practices	Linearity	SpaceX Falcon
McCain Reforms	All of the Above	CMI/Linearity	Mid-Tier/OTA Programs

FASA: Federal Acquisition Streamlining Act of 1994
FAR: Federal Acquisition Regulation
CMI: Civil Military Integration of the defense and commercial industrial base
DARPA: Defense Advanced Research Projects Agency
JDAM: Joint Direct Attack Munition
MRAP: Mine-Resistant Ambush Protected vehicles
OTA: Other Transaction Authority

CASE 1: The Section 800 Panel, FASA, Clinger-Cohen and FAR Part 12 Commercial Items

This first case illustrates what happened when DOD needed to access a part of the industrial base that no longer could or would do business with it. In the mid-1980s, the realization began to dawn on defense policy makers that commercial items were important to DOD and that commercial market technology (particularly in the computing industry) was being developed faster and cheaper than in the DOD innovation model. This fact was helpfully pointed out by the Packard Commission. Increased commercial R&D and a time-based innovation model incentivized by the rise of venture capital in Silicon Valley resulted in cheaper and more advanced technology emanating from the commercial market.

Many of the barriers to the commercial sector participating in the defense market were already established by the late 1970s. As Jacques Gansler stated: "… that the Department of Defense is no longer the predominant user of high technology now that the civilian sector has gone into high-technology products makes it clear that, for those firms that have a choice, defense is considered an undesirable business area."[207] The commercial market was already seen at this time as more attractive from a profitability and ease of doing business standpoint than the government market. It was not until more than ten years later that attempts were made to address these issues.

By this time Silicon Valley and other commercial companies were refusing to sell items to the Pentagon because of the burdens of the acquisition system. The

[207] Gansler, Defense Industry, p. 145.

procurement process was sclerotic, overburdened with regulations and government unique requirements. It permeated the entire system, from advanced technology to the mundane, as DOD had even developed unique 700-page specifications for things like chocolate chip cookies that precluded buying an item that was sold in a grocery store.[208] In his report "Computer Chaos" Senator Cohen outlined the nearly 4-year process for the government to buy a computer one could buy at Radio Shack, which, by the time the government was able to obtain that computer was then several generations out of date.[209] Selling such items opened commercial firms to oversight requirements and compliance regimes that were not worth the cost from the benefits of government sales. When the government might be less than one percent of your sales the burdens of CAS, TINA, government unique intellectual property regimes, and other compliance burdens did not make a lot of busines sense.

The only way around this conundrum was to remove barriers to participation by these commercial companies in the system. That process began with the establishment of the Section 800 panel. Congress established this panel in 1990 to review and assess the efficacy of existing laws impacting the government's procurement system.[210] The Section 800 report, published in January 1993, recommended a different acquisition approach to commercial-items acquisitions by explicitly stating a preference for acquiring commercial items and waiving acquisition

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[208] Gore, Al, and National Performance Review (U.S.). *Common Sense Government: Works Better and Costs Less*. New York: Random House, 1995 p. 1. Thinking that this specification was long ago abolished through the work of Vice President Gore and Secretary of Defense Perry, research for this paper found this specification to be still alive and well, but at a more streamlined 26 pages.
[209] William S. Cohen, *Computer Chaos: Billions Wasted Buying Federal Computer Systems:* Investigative Report of Senator William S. Cohen; U.S. Government Printing Office, 1994. P. 13.
[210] The Section 800 Panel, the DOD Acquisition Law Advisory Panel, was required by section 800, Public Law 101-510, the National Defense Authorization Act for FY 1991.

laws, regulations, and rules for the purchase of these items. In the 1994 Federal Acquisition Streamlining Act (FASA) the Congress implemented these recommendations by creating significant exemptions to a class of items defined as commercial. The FASA recommendations addressed several significant barriers addressing unique accounting rules, contract pricing, intellectual property and socio-economic requirements – requirements that had been created since the 1960s, although a few of the socio-economic provisions traced their origins to the 1930s. In the Clinger-Cohen Act of 1996, Congress would expand the definition of commercial items and decentralize the oversight of information technology to overcome the slowness of the centrally managed governmentwide process led by the General Services Administration by repealing the requirement for that process established in the Brooks Act of 1964. [211]

During this reform period, statutes were eliminated and those that remained provided commercial items with broad-based exemptions. While the most significant exemptions of importance to commercial companies were the exemptions to TINA and CAS, it was the creation of a new process for small purchases of items that may have had the most immediate effect. This process was significantly streamlined and the vast majority of these purchases would eventually be for commercial items bought with a government credit card. A preference was established to buy such commercial items whenever available and any new law passed had to explicitly state that it

[211] This requirement for centralized oversight was put in place by Congress to break the IBM model of leasing time on their mainframes that Congressman Jack Brooks thought was wasteful. In his mind it was cheaper and more efficient for the government to own these computers and managed centrally by the GSA. For decades the government owned and operated its own data centers and agencies waited for GSA approval to buy computers. Cloud computing in one sense is really a return to the old 1960s IBM decentralized sales model of leasing computing time in private sector run data centers.

applied to the acquisition of a commercial item rather than automatically apply. This was done to try and protect against future backsliding, as the expectation was that Congress could not help itself in using the procurement process as it had been used for decades to impose unique processes and socio-economic requirements. In the course of 2-3 years and for a certain class of items this all came tumbling down.

The Defense Department then addressed military unique specifications. Secretary of Defense Perry began his own acquisition reform efforts by attempting to move DOD away from its dependence on unique military specifications and by adopting commercial specifications wherever possible. The so-called Perry memo repudiated the use of inflexible military specifications that limited competition, stifled innovation, increased costs, and delayed the fielding of new systems.[212] Secretary of Defense Perry outlined further Departmental goals in a 1994 paper "Acquisition Reform *A Mandate for Change*." This criticized DOD's inability to acquire state-of-the-art commercial technology and overpayment of what it did acquire.[213]

The application of commercial item reforms under FASA and Clinger Cohen has been one of the government's true success stories, with over $47.6 billion in commercial items being purchased by DOD in 2016 despite a decline from $82.7 billion in 2007.[214] FASA and Clinger-Cohen were successful by allowing DOD and the rest of government to quickly buy the exact same commercial goods (even with a

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[212] Perry, William. J. Department of Defense Memorandum. *Specifications & Standards – A New Way of Doing Business.* June 29, 1994.
[213] Perry, William. J. Department of Defense Memorandum. *Acquisition Reform - A Mandate for Change.* February 9, 1994.
[214] Government Accountability Office. *Defense Contracts: Recent Legislation and DOD Actions Related to Commercial Item Acquisitions Annual Assessment*, GAO-17-645: July 2017, p.5.

credit card) just like an American consumer could at Walmart and Best Buy. Still, even for these commercial off the shelf items, DOD has been backsliding on these reforms in the last 25 years. Unfortunately, even these successful commercial acquisitions have suffered from an accretion of new restrictions that have been applied to commercial contracting in the last two decades.

The first class of new restrictions that have impacted commercial items is the creep of government unique contract clauses. As the section 809 panel observed:

> "Since FASA was implemented, the number of DOD-related commercial buying provisions and clauses has increased by 188 percent, and the number of commercial clauses that may be flowed down has increased five-fold. In 1995, the FAR and DFARS contained a combined total of 57 government clauses applicable to commercial items. Today there are 165 clauses, with 122 originating in statute, 20 originating in executive orders, and 23 originating in agency-level policies." [215]

This "clause creep" occurred despite legislation that prohibits the application of a new law to the procurement of commercial items unless explicitly stating in the statute that it applies to commercial items. The problem is, each political party enamored by the government's purchasing power wants to use government contracting as a means to achieve other policy ends. The reality is the government no longer moves markets, and these new requirements, if not adopted elsewhere in the commercial market, merely keep the government from purchasing the best solution.[216]

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[215] United States. Department of Defense. Section 809 Panel. *Advisory Panel on Streamlining and Codifying Acquisition Regulations: Section 809 Panel* Volumes 1 Report, Arlington, Va.: Section 809 Panel, 2018, p. 17.

[216] To see how this process works see: Steve Kelman, "Here we go again: 'diversity training' and government contractors." Federal Computer Week, October 2, 2020.

These new restrictions and regulations have incentivized a new generation of commercial companies to stay out of DOD contracting and those commercial companies that currently sell to the military increasingly face the choice of opting out of the government marketplace or radically changing their structure to conform to these new requirements. In recent years it has become harder to comply with new commercial items clause mandates. There has been a rise of resellers who stand between the government and commercial companies to provide a layer of protection after the incessant whittling away of the commercial item exemptions. DOD has also begun to increase the number of unique military specifications that precluded the use of commercial items to and overturn the intent of the Perry Memo to such a degree that Congress put the Perry Memo into law two decades later in section 875 of the 2017 NDAA.

CASE 2: Acquisition Pilots (JDAM) and Commercial of a Type

FASA and Clinger Cohen were immediately successful when buying what are now known as Commercial off the Shelf (COTS) items – products already sold in substantial quantities in the commercial marketplace. What the Department also needed was to buy things commercially that were not identical to COTS but were modified or developed in a similar fashion. The importance of commercial items to U.S. military strategy was much greater than being able to buy the latest computer from Best Buy. This was outlined when then Undersecretary of Defense Paul Kaminski stated in a testimony before the Senate Committee on Armed Services Subcommittee on Defense Technology, Acquisition and Industrial Base: “The military advantage goes to the nation who has the best cycle time to capture technologies that are commercially available; incorporate them in weapon systems; and get them fielded first."[217]

A strategy beyond COTS was needed to get modified commercial products incorporated into weapon systems rather than just buying stand-alone commercial products that had already been sold on the global commercial market. In 1994, the Congressional U.S. Office of Technology Assessment (OTA) described the factors driving the need for a beyond COTS CMI strategy in the following manner:

> "Confronted with declining budgets, many government officials and private-sector executives advocate the increased use of the commercial technology industrial base (CTIB) as one strategy for preserving adequate technological and industrial capability to help meet future national security needs. This increased use of the CTIB, dubbed civil-military integration (CMI), can take many forms, including purchasing commercially available goods and services, conducting both defense and commercial research and development in the same facility, manufacturing defense and commercial items on the same production line, and maintaining such items in shared facilities."[218]

CMI would not be achievable unless barriers to its use were eliminated and incentives were created to encourage participation by the commercial sector in working on defense needs. The bifurcation of the industrial base driven by the need to comply with unique government requirements had caused those commercial companies that also did business with DOD to be forced into establishing separate

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[217] Statement of The Under Secretary of Defense for Acquisition and Technology," Paul G. Kaminski before the Subcommittee on Defense Technology, Acquisition and Industrial Base of the Senate Committee on Armed Services on Dual Use Technology. May 17, 1995.

[218] United States Office of Technology Assessment, p. 2.

business production lines – one for commercial and one for the military.[219] This was done to comply with the requirement for detailed cost data on weapon systems demanded by the cost contracts typical of defense procurement that then triggered the requirements of TINA and CAS. Government auditors would not accept companies' commercial accounting practices that did not exactly break out the cost for a military part of a commercial part in a specifically mandated government way. This was particularly a problem in those companies such as Boeing, Honeywell, and Collins Aerospace, which built and supplied similar parts to commercial airlines.

Thus, companies in the 1970s set up separate defense and commercial production lines and, in the case of Boeing, to actually sell the U.S. government a so called "green" aircraft from its commercial division in Seattle and then fly it to its military division in Wichita, Kansas to be disassembled and reinstalled with military unique features.[220] This was incredibly expensive and wasteful, but auditors were more concerned about precision in costs and not estimates of costs where a commercial company might be hiding profits.

Budget cuts at the end of the Cold War finally tipped the scales. DOD could no longer afford to prop up these secondary production lines and the issue was how to allow commercial companies to consolidate their production lines without triggering unique government auditing requirements. Congress, in FASA and Clinger-Cohen, tried to address this larger problem rather than just getting the government to buy

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[219] For a listing of the major drivers of regulatory cost for these companies in their government unique plants see – Coopers and Lybrand that identified at least an 18% cost premium to implement government oversight. Coopers and Lybrand. *The DoD Regulatory Cost Premium: A Quantitative Assessment.* 1994. Others thought this premium was over 40%. The later experience of SpaceX ability to compete in the national security launch business implies the premium may even be higher.
[220] Gansler, Greenwalt, Lucyshn, p. 26.

exactly what was out in the commercial market. It needed an alternative to a commercial item definition beyond what was sold in substantial quantities in the commercial market that was the easiest for government auditors and contract specialists to price.

The solution Congress found to this problem was to create several different classes of commercial items beyond COTS. The first was for making minor modifications to COTS items and the second for those commercial-like items that were produced in a dual commercial and military production line called commercial "of a type."

The minor modifications definition was just that. If DOD wanted to have commercial companies make minor modifications to their COTS products, these items could be treated as commercial items with all of the exemptions to law. Even this definition provoked some challenges as the government had to figure out how to price these items, but since they were by definition, minor, in theory this could be easily overcome in contract negotiations. The second type of product the government wanted to buy was much harder to address. This entailed encouraging commercial companies to design and build items that were similar to items that they were being produced in the commercial marketplace but customized for DOD purposes. FASA addressed this by creating the commercial of a type definition that allowed for "modifications of a type customarily available in the commercial marketplace." Precisely what this meant has been the source of much angst and cost ever since.

Commercial contractors customize their products all the time, creating new but similar products for specific customers. Congress wanted companies to do that for DOD, but implementing the "commercial of a type" definition is still a hot topic of debate and resisted by the DOD IG and many contracting officers because of the difficulties to price these solutions. In 1994, Congress disagreed with the oversight community and tried to establish true CMI to allow the building of military and commercial units on the same production line and allow commercial companies to modify their products or build products using their same commercial process for the military.

Some in Congress at the time wanted to go even farther than authorizing and treating commercial of a type like products as commercial items. These advocates wanted to reform the way traditional defense contractors had been doing business and allow them to develop entire weapon systems as commercial entities and operate on commercial basis. This did not happen, but in section 5604 of the Federal Acquisition Streamlining Act of 1994, Congress authorized the establishment of five pilot programs to waive acquisition laws to test streamlined acquisition approaches with traditional defense contractors. The result was an adoption of commercial practices by these traditional contractors on a number of programs, which led to significant advances in technological innovation and reduced costs. For example, commercial practices such as those used on the JDAM program (which was the most successful FASA pilot) enabled DOD to radically lower costs and improve capabilities.

Then Under Secretary of Defense Paul Kaminski described this success: "We made JDAM a pilot acquisition reform program and we did that procurement again. We put in place all the acquisition reform initiatives and the commercial specification initiatives. We went from an RFP that had a 100-page work statement to an RFP with a two-page performance specification—not how to build this, but what we wanted it to do with no mil-specs required. The winning bid on that round was $18,000 a kit: less than one-half the original cost."[221]

Greater efficiencies generated by the effective use of commercial private sector practices was proven successful in defense programs such as the JDAM. Not only did unit costs decrease from improved commercial production techniques, but the increased number of units that could be bought by using commercial production techniques would provide greater security through greater survivability in conflicts. In other words, the increase in the numbers of systems deployed have a quality in and of themselves and focusing on cost efficiencies is as important as focusing on quality efficiencies.[222]

Reforms made in the Federal Acquisition Streamlining Act of 1994 and the Clinger Cohen Act of 1996 made it easier to sell to the federal government, and for a while, commercial firms tiptoed into the federal market. Firms like Honeywell and Rockwell Collins made the investments to combine their commercial and military production lines. The KC-45 Tanker, the P-8 Maritime Patrol aircraft, avionics subsystems, and other aerospace components all began production on commercial lines. These reforms led to radical changes at the Pentagon that continued for about a decade in the traditional procurement system. Commercial companies began to wade

[221] Remarks at the Second Klein Symposium on the Management of Technology, Pennsylvania State University, 17 Sept.1997. quoted in: James Hasik. *Arms and Innovation: Entrepreneurship and Alliances in the Twenty-First Century Defense Industry*. University of Chicago Press, 2008.
[222] Lisa Brem and Cynthia Ingols, *Implementing Acquisition Reform: A Case Study on Joint Direct Attack Munitions (JDAMs*), Defense Systems Management College, May 1998.

into the defense market, and barriers between the defense and commercial portions of firms began to evaporate. While the reforms did not go far enough for some commercial firms, they did open the door for enough firms to make a difference.

The benefits to the DOD included access to the latest technology, faster delivery, lower prices, integration of the defense and commercial industrial bases, access to commercial support services, and elimination of the need to fund the development and support of unique items. The use of commercial contracting practices allowed commercial companies to enter the government marketplace and provide products to both commercial and military customers using common product lines and workforces. Internal investments to develop commercial products benefitted both commercial and military customers and created a larger production base with lower prices because of economies of scale. The R&D for these products was paid for by these commercial companies, which freed up funding for DOD to pursue other priorities.

However, during the mid 2000s, the contract pricing community and the auditors fought back in what can be called the revenge of the cost and pricing framework. No new FASA pilots were forthcoming and the idea of buying commercially derivative aircraft as a commercial item came under intense scrutiny, particularly after a procurement ethics scandal was uncovered during a Congressional investigation into the proposed sole-source Boeing tanker lease in 2003 that was to be leased under a commercial arrangement. This undermined support in Congress for some commercial item procurements. Some pricing specialists and audits continued to try to undermine commercial item procurement by demanding TINA-like data on exact costs in the belief that the government received a better deal in a non-commercial cost contract basis and that knowing these costs was the only way to hold down profit margins. Many in government could not separate the concepts of corporate profit from corruption. As a longtime observer of the system testified before the House Armed Services Committee: "Culturally we have evolved to a point where the system would rather pay $1 billion and 5% profit for a defense good, than $500 million and 20% profit." [223]

The problem of determining a fair and reasonable price and profit margin dominated this decade. The bureaucracy wanted to return to collected cost-based information through the use of TINA and CAS on all commercial contracts. Congress acquiesced to allow the government the option to ask for non-certified cost and pricing data under TINA. Many commercial contractors refused, rightly saying that their accounting systems did not break out the difference in costs between their commercial and military products. This left these firms at risk of being accused of hiding profits and overcharging the government. Commercial protection of data rights continued to be an issue as well. The FASA concept of the presumption of the rights of commercial company's intellectual property rights on commercial items was challenged by some in the contracting community who wanted to return to pre-FASA days and believed that government contracts should trigger automatic rights to technical data and company IP rather than have this data be negotiated.

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[223] Twenty-five Years of Acquisition Reform: Where Do We Go From Here? Statement of Pierre A. Chao Before the Committee on Armed Services, House of Representatives October 29, 2013.

Thus, in recent years, the process by which the government acquires goods and services from the commercial market has been destabilized and suboptimized. Much of this rollback can be attributed to the lack of budget pressures and the reemergence of a preference for a return to a centralized command-and-control approach in the Pentagon and Congress. A steady stream of legislative and regulatory changes, some initiated in the annual defense authorization process and others driven by internal Pentagon audit findings and policy changes, have undermined commercial buying reforms by imposing new defense-unique acquisition oversight requirements that are inconsistent with commercial practices and threaten the commercial procurement model.[224] This steady erosion of the government's use of the streamlined approach to commercial acquisition incurs both monetary and innovation costs.

Ironically, after almost two decades of delivering improved JDAMs at lower cost to the military, DOD ultimately forced the prime contractor to convert this program from a FAR Part 12 to a FAR Part 15 contract in order to extract exact cost data through CAS and TINA. This action on the JDAM program symbolically illustrates how far the Pentagon has fallen from its acquisition reforming tendencies and marks the end of an era.

The reality is that while the Pentagon was tightening up, for many commercial firms the FASA-Clinger Cohen reforms did not go far enough, as they were too easily undermined by the bureaucracy. For example, the changes failed to completely

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[224] U.S. Government Accountability Office. *Military Acquisitions: DOD Is Taking Steps to Address Challenges Faced by Certain Companies*, GAO-17-644: July 2017.

remove the requirements to comply with expensive to implement unique government accounting standards that are vastly different from commercial practice; they failed to completely protect commercial intellectual property rights; and they failed to limit government audits designed to elicit data such as cost and pricing information that the government is not legally entitled to. With the passage of time and absent senior leadership support, bureaucratic inertia set in and resulted in the re-imposition of old requirements, in the creation of new barriers to doing business with the government, and in a *de facto* preference for government-unique rather than commercial solutions.

So, Silicon Valley did what it does best: ignore the U.S. government and make a lot of money elsewhere to include working with China and other potential adversaries. The effect was profound, as Brose pointed out: "[DOD] missed the commercial space revolution. It missed the move to cloud computing. It missed the advent of modern software development. It missed the centrality of data. And it missed the rise of artificial intelligence and machine learning. "[225]

By 2015, the easy pathways for commercial companies that innovate on a time-based basis had been closed off. COTS could still be bought by the government but a new pathway was likely needed or reform of the old commercial item pathway was needed for the DOD to keep up with the commercial market. The easier buying of COTS was vitally important as it allowed DOD to catch up to decades of commercial innovation, but the time for DOD to commit to COTS items imposed a significant adoption lag time behind what was currently in the marketplace.

[225] Brose p. 71.

CASE 3: DARPA's use of Other Transaction Authority for Unmanned Systems (Predator and Global Hawk)

At the end of the Cold War, Congress had additional concerns about DOD innovation beyond accessing the commercial market that it addressed with the commercial item exemption or the FASA acquisition pilots. It wanted to provide a pathway for DOD with new entrants or entities like Lockheed's Skunkworks division (the source of the U-2 and SR-71) to innovate as they once did earlier. This meant allowing for the waiver of rules beyond those in FASA for special situations. It did this by giving DOD Other Transactions (OTA) authority. OTAs allow for the non-applicability of most acquisition rules by starting off with a clean sheet of paper in determining the business relationship between the government and industry. Most importantly, OTAs are designed to return to the rapid prototyping that resulted in residual operational capabilities. The NASA Space Act of 1958 is the original source of OTA authority, passed in response to Sputnik to give NASA the ability to better compete in the space race with the Soviet Union.

In 1958, DOD was not included in the Space Act because it already had similar authority and was using it. Experimental authorities with providence going back to the Army Air Corps Act of 1926 were already authorized in law and DOD did not need a new authority. By the late 1980s, however, the disuse of experimental authority (now codified in 10 USC 2373) led Congress to look again at the National Aeronautics and Space Act to spur DOD innovation. Congress, concerned about the lack of experimentation and prototyping at DOD, first gave a limited research version of this authority to DARPA in 1989 in 10 USC 2371. This was later expanded to prototyping authority and eventually expanded to allow other DOD entities beyond DARPA to use OTAs.

The issue that Congress was trying to address was how to experiment, prototype, and innovate as with the U-2 and SR-71, but also how to avoid a formal acquisition development process or highly classified environment. These earlier efforts, much like the National Reconnaissance Office's Corona satellite program, were prototyping efforts that left the government with a useful operational capability that would meet some, but not all, requirements. DARPA's unique development approach led to such advances over its history as the Internet, and its later use of authorities such as OTAs was instrumental in the development of unmanned systems. The Global Hawk and Predator programs were launched using a similar approach to major operational prototyping programs of the past. DARPA was the ideal place to use OTAs for the development of these unmanned aerial vehicles (UAV). This was particularly the case when the Air Force had no interest in the movement to autonomy as it was seen as potentially threatening manned aircraft programs.

DARPA was already heavily involved in trying to bring UAVs into the mainstream. Prior to receiving OTA authority: "In 1984, DARPA initiated the Amber program. The Amber concept traced back to 1978, when a small firm, Leading Systems Incorporated, headed by innovative UAV developer Abraham Karem, approached DARPA with ideas for developing a long- endurance UAV." [226] The

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[226] Richard H. Van Atta, Project Leader, and Michael J. Lippitz with Jasper C. Lupo, Rob Mahoney Jack H. Nunn , *Transformation and Transition: DARPA's Role in Fostering an Emerging Revolution in Military Affairs Volume 1 – Overall Assessment*, Institute for Defense Analysis, Washington, D.C., p. 43. For a more detailed history of the Predator program see: Whittle, Richard. *Predator: The Secret Origins of the Drone Revolution*. First ed. New York: Henry Holt and Company, 2014.

success of Amber led Congress to push the Department to develop UAVs and to eventually give DARPA OTA authority. Amber would eventually become Predator, but not in time to initiate funding for Karem, who had to sell his design and concept to a larger defense contractor.

DARPA then seized the initiative with the new OTA authority. Subsequently, a small business unit under a larger non-defense conglomerate company, Teledyne Ryan Aeronautic, innovated like it was 1959 and developed the Global Hawk.[227] The Amber-Predator concept by this time was also being funded under a new concept called an Advanced Concept Technology Demonstration (ACTD) project, which essentially was a throwback to how DOD used to develop systems.

> "On the Global Hawk program, DARPA pioneered several new acquisition methods to speed technology transition. Like Predator, the program was designated an ACTD. It also used Section 845 Other Transaction Authority (OTA), which allowed DARPA to waive almost all traditional acquisition rules and regulations in favor of a tailored program structure with increased contractor design responsibility and management authority."[228]

Each of these developmental efforts went from contract to design to flight and a useful operational capability in the same time frame as comparable commercial aircraft development (see Figure 4.4 GH and MQ-9 data points). Thus, using OTA and ACTD authorities led to what could be called disruptive operational capabilities in half or a third of the time it would take to deliver something under the traditional system.

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[227] Robert S. Leonard and Jeffrey A. Drezner, Innovative Development: Global Hawk and DarkStar - HAE UAV ACTD Program Description and Comparative Analysis. Santa Monica, CA: RAND Corporation, 2002.
[228] Van Atta p.46.

One lesson learned from the DARPA efforts in comparison to a traditional program was that traditional programs at Milestone B had evolved to the point that they rarely built a prototype built for that milestone. There may have been some piece parts and component demonstration that in some earlier plane was hoped to be integrated into a working prototype. But, typically due to funding limitations, they had never flown, shot, drove, sailed, or been tested or used by operators before proceeding toward low-rate production. Despite historic support for "fly before you buy" and competitive prototyping strategies,[229] there has rarely been money available to build such prototypes on MDAP program of records – another casualty of the incentives of the PPBE process where there is a desire to fund too many programs at one time without enough funds to adequately do that. To continue to fund these programs over the course of decades, certain tasks are jettisoned early in a program to include the option to prototype. This is perhaps one of the singular problems with defense acquisition. If the Global Hawk and Predator were not taken outside of the system it is highly doubtful they would have been developed at all. These resulting operational prototypes could, and eventually did, form the basis of a "program" as

[229] While even just developing one operational prototype would be a sound strategy, Congress has waxed and waned about going even farther by trying to ensure at least two prototypes would be completed, but rarely funding this strategy. The 1987 NDAA required a competitive prototyping strategy for MDAPs. This requirement was repealed by FASA with the expectation that DoD would continue considering prototyping as an option in the acquisition planning process and to use competitive prototype strategies where appropriate. However, DOD policy did not reflect this until a September 2007 USD(AT&L) policy memorandum required competitive prototyping through Milestone B. WSARA strengthened this requirement and then the 2016 NDAA provided greater flexibility in implementing this requirement. Current statutory requirements are found in 10 U.S.C. section 2431.

both Global Hawk's and Predator's successful performance created demand for additional units.

The one glaring problem with the OTA authority of the 1990s was that innovative companies had nowhere to go after developing their successful operational prototypes. To start additional production, one had to enter the traditional contracting, acquisition, requirements, and budgeting processes. There was no production OTA authority at DOD, unlike what NASA had in the Space Act. To comply with all of the complexities of the acquisition process and work the budget process, these companies (Landing Systems and Ryan) were forced to sell to and be incorporated into a larger, more traditional defense contractor to keep their programs moving to the next stage of the process. This was not a model that was sustainable, as innovators and companies learned from this lesson and were not incentivized to spend money and effort on OTA prototypes in the future.

Eventually, OTAs gravitated in their use to traditional contractors. Congress wanted to spur innovation from new entrants and subsequently, in section 803 of NDAA FY01, provided an incentive to their participation by limiting DOD's authority to use OTAs with traditional defense contractors by requiring a cost share for defense companies that receive OTAs unless they partnered with non-traditional contractors. This cost share requirement, though limiting, actually had a positive impact on DOD innovation by forcing traditional firms to work with these non-traditional firms without spending their own money. Still, Congress never could agree on fixing the production disincentive that was a barrier to non-traditional participation. It tried in section 822 of NDAA FY02 to create a production authority, but this merely allowed production items to be bought under commercial item authorities under FAR Part 12 and such product be considered as a commercial item for acquisition purposes. As was seen in the discussion about commercial of a type and the JDAM example, those kinds of contracts were coming under fire in the late 2000s and early 2010s for a lack of transparency into contractor costs.

Eventually, the use of OTAs would decline for about decade after some in Congress objected to the Army using a broad-based OTA with a large traditional contractor to develop the failed Future Combat System (FCS). Given the scope and size of the FCS effort, some considered the use of non-traditional robotics contractors on this OTA unsatisfactory. Still, the robotics company iRobot, that was the leading non-traditional company in this OTA, gained significant experience and was highly successful in spurring on the use of ground based robotic solutions in Iraq and Afghanistan. Eventually though, the barriers to working with DOD became too great for iRobot and they left the defense market in 2016 and focused on the more profitable Roomba.

Case 4: The Deployment of a National Missile Defense System

The role of missile defense in American defense policy has been highly politically contentious since the missile defense debates of the 1960s. The dispute, leading up to the signing of the ABM Treaty in 1972, centered on concerns that any attempt to defend against nuclear weapons would be seen as destabilizing the

Mutually Assured Destruction concept.[230] Twelve years later, Ronald Reagan attempted to resurrect that debate by creating the Strategic Defense Initiative Organization (SDIO) and the so-called "Star Wars" missile defense approach. Post-Reagan, research would continue into missile defense, particularly as tactical missiles were proliferating beyond Russia and the U.S. SDIO was renamed in 1994 as the Ballistic Missile Defense Organization to reflect that change. In 2002, it became the Missile Defense Agency (MDA).[231]

A transition to a new administration in 2001 changed the view of what types of missile defense programs should be considered a priority. While the Clinton Administration endorsed a National Missile Defense system (NMD) "when feasible" that caveat would keep any expenditures on such a system from growing too large. Rather than focus on medium range and tactical missile defenses, the Bush Administration wanted an NMD to defend against a rogue missile from North Korea or an accidental nuclear launch from either Russia or China. The issue became how to rapidly deploy such a missile defense system and the answer was to essentially experiment, prototype, and innovate on a defense program similar to the early ICBM programs.

Ultimately, a Republican controlled Congress agreed with this policy and provided MDA with streamlined budget and acquisition authorities that were used to not only deploy an NMD, but were helpful in the development of shorter-range

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[230] Robin Ranger. *Arms and Politics, 1958-1978: Arms Control in a Changing Political Context*. Toronto: Macmillan of Canada, 1979. p. 152-155.

[231] Rumbaugh, Russell "The Fragmentation of DOD: Changing Role of the Services and What it Means for Space Force, Aerospace Corporation Center for Space Policy and Strategy, October 2020. p. 32.

missile defense programs as well. This was a politically acrimonious development effort that culminated in the passage of section 222 of the 2004 NDAA. In this provision MDA was authorized to use funds available for RDTE and use those funds for "the development and fielding of an initial set of ballistic missile defense capabilities." This authorization allowed DOD to quickly be able to deploy an operational prototyped system. CSIS best described this initial deployment as:

> "In 2004, Lt. Gen. Henry "Trey" Obering, III, USAF, the Director of MDA, declared limited defensive operations including five GBIs in silos at Fort Greely, Alaska; an upgraded Cobra Dane Radar at Eareckson Air Station in Shemya, Alaska; and an upgraded radar at Fylingdales in the United Kingdom."[232]

This was significant in that the authorization eliminated the "color of money" issue in which research money cannot be used for procurement or procurement money for operations or construction. Having this ability to flexibly move money around for different purposes allowed for the rapid deployment of the NMD system. Since this system was essentially a prototype system, that funding flexibility was needed to enable the building of launch sites, and to develop, test, and produce a limited number of missiles something under existing budget and financial laws and regulations MDA would have been prohibited from doing.

Up until then, the Bush Administration had used all of the acquisition flexibilities it had in law and provided these to MDA for this program. Previous authorization authority allowed greater budgetary flexibility to move money between

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[232] Center for Strategic and International Studies, Missile Defense Project website, "Ground-Based Midcourse Defense (GMD) System" accessed December 3, 2020, https://missilethreat.csis.org/system/gmd/

various missile defense programs within larger RDTE accounts and to allow programs to be stopped and started. Thus, MDA was able to go around the requirements, acquisition, and budgeting processes and in doing so deployed an initial NMD system in less than 3 years based on previously conducted research and testing of similar systems. Going around the system not only allowed for the rapid deployment of country wide missile defense system, but it copied the concept used in the Manhattan project and other 1950s development programs of being able to fund multiple pathways for technologies and programs. This ability to start and stop efforts if they were not working eventually would lead to the development and deployment of the Aegis and THAAD ballistic missile defense systems.

The deployment of an NMD system was in essence one large operational prototype system and came into being because of the budgetary and acquisition flexibilities granted to MDA by Congress at a critical moment. These flexible authorities were eventually rolled back by Congress. This kind of funding flexibility has not been authorized for any other mission since then, although there was a Senate proposal by Senator Kirk(R-Il) on the 2017 NDAA to do something similar for electronic warfare programs, but it was not agreed to by the House of Representatives.[233] Many of these undifferentiated or mission pots of money are referred to derogatorily as slush funds and the appropriations committees have been loath to create these types of accounts over the years. What was significant about the NMD example is that DOD can deploy capability and innovate in a time-based

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[233] Section 897 of S 2943, 114th Congress, 2nd session. This provision was partially incorporated into section 234 of the NDAA for 2017 but only after dropping the original flexible funding authority.

manner, but only if give a fast-track development authority to do so that bypasses the linear management regimes that form the basis of the requirement, budget, and acquisition processes of the Department. As the system currently stands that would likely require Congressional authorization and the appropriations of flexible mission-based funds to do so.

CASE 5: Post 9/11 Rapid Acquisition Pathway

After 9/11 and the beginnings of the conflict in Afghanistan, the need arose to rapidly get new technology in the hands of the warfighters in the ongoing conflict. As a result, rapid acquisition authorities were enacted by Congress in Section 806 of the Bob Stump National Defense Authorization Act for Fiscal Year 2003 (10 USC 2302 note). A key provision subsequently enacted on the 2004 NDAA as an amendment to section 806 of the previous year allows the Secretary of Defense to waive procurement law to meet combat requirements that have resulted in, or could result in combat casualties. These authorities helped support the creation of a number of rapid acquisition entities and processes that did not have to conform to the statutory linear acquisition process enshrined in the DOD 5000 series or in the FAR. Many of these new organizations emulated the acquisition buying practices of the Special Operations Command, which has had its own long-standing special acquisition authority contained is section 167, Title 10, United States Code that was authorized in the FY 1987 NDAA.

Next, DOD created a special requirements process to bypass the JCIDS process. This rapid requirement process rested on acting quickly on theater commanders' requirements. These requirements called Joint Urgent Operational Need (JUON) and Joint Emergent Operational Need (JEON) statements were established and allowed for a quicker process. The final piece in this puzzle was the establishment of flexible funding through the creation of large flexibly mission funds that Congress provided such as for counter- improvised explosive device (IED) purposes and the much larger Overseas Contingency Operations (OCO) funding. Existing emergency contracting procedures such as the use of un-definitized contracting actions (UCAs), directed sole source contracting, and higher emergency thresholds for the use of simplified acquisition procedures supplemented the section 806 rapid acquisition authorities and completed the alternative system to the traditional management regimes for rapid acquisition. Collectively, these end-rounds of the acquisition, requirements, budgeting, and contracting processes allowed DOD to focus on deploying new equipment and technology solutions to the field in 1-2-year timeframes and many times in just a few months.

These authorities allowed former Defense Secretary Robert Gates significant latitude to create programs to support combat personnel. For example, when Gates decided troops needed better protection from IEDs, acquisition rules were waived under new rapid acquisition laws to get new vehicles, counter-IED equipment, advanced battlefield medical solutions, and surveillance assets into Iraq and Afghanistan. As Gates points out in his memoir, he often had to be the catalyst to provide the political cover and will to circumvent the entrenched liner management regimes.

In a well-named chapter called "Waging War on the Pentagon," Gates outlined how he had to overturn the requirements and budget process and "At the end of May I approved putting the MRAP program in a special, very small category of Defense procurement, effectively setting aside many bureaucratic hurdles typical of military programs."[234] The result was that Mine-Resistant Ambush Protected vehicles (MRAP) were being shipped to troops and saving lives in less than a year's time.

MRAPs are a special case in many ways.[235] This was likely the largest rapid large-scale production program since World War II. It was comparable to the aircraft, vehicle, and Liberty ship programs of the 1940s. In addition to using rapid acquisition authority, an alternative requirements process, and large flexible funding accounts, Gates focused on multiple pathways of MRAP solutions (nine companies were awarded contracts to develop prototypes) and providers to ensure success. If a company could meet the requirement and build an MRAP, the government would buy it. Ultimately, some 27,000 vehicles would be supplied to the military.

Initially, as U.S. forces in Iraq and Afghanistan began to decline, the ad- hoc organizations and processes created to address these rapid needs began to wind down as well. Since hostilities never completely ended though, and troops remain deployed

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[234] Robert Michael Gates. *Duty: Memoirs of a Secretary at War*. New York: Alfred A. Knopf, 2014.p. 123

[235] See Hasik, J. M. *Arms and Innovation: Entrepreneurship and Alliances in the Twenty-First-Century Defense Industry*; University of Chicago Press: Chicago, 2008.

in harm's way in Afghanistan, Iraq, Syria, and the Sahel, the Department has maintained a network of innovative buying commands that has evolved into reaching out to non-traditional buyers such as SOFWERX, AFWERX, and the Strategic Capabilities Office (SCO) that was established to focus on near term rapid acquisition deployments of capabilities. Still, the army has decided to wind down its rapid acquisition organization, SCO was downgraded from its position reporting to Secretary of Defense's office, and flexible funding has been under pressure or abolished.

CASE 6: Space Act and SpaceX: NASA OTA Production Authority

The retirement of the Space Shuttle and budget limitations at NASA that limited the government's new launch capability led to a conundrum at NASA. To maintain access to space it needed to experiment, prototype, and innovate as before but the government did not have the money to do so in the typical cost-plus reimbursement contracting environment. What NASA did have was its legacy 1958 Space Act OTA authority to create new business relationships with the private sector and most importantly, unlike at DOD, NASA had the ability to use this OTA to not only prototype a new solution but also to move into production.

The idea was to create new, cheaper launch capabilities and providers starting first with launch satellites but eventually creating human-rated capabilities to perform the Space Shuttle mission of transporting astronauts to the Space Station. The first Space Act agreement called the Commercial Orbital Transportation Services (COTS) agreement between NASA and SpaceX was 26 pages long.[236] It was essentially a cost-share R&D agreement in which NASA made a series of milestone payments to SpaceX for meeting performance goals and required SpaceX to continue to self-fund its development efforts. NASA OTA authority did a number of important things. First, NASA could commit to buying launch services from companies (i.e., there was a guarantee of production if these companies could deliver) if they were successful. This was similar to the industrial base incentives that DOD used of being the first buyer for semiconductor companies and Boeing in the 1950s and 1960s and is also similar to an authority rarely used in the DPA for advanced purchase agreements.[237] This prospect of a market created a positive business case for companies like SpaceX and Orbital to invest the capital to build a new rocket. So, in this sense, the budget process was subverted. Then, most importantly to a company like SPACEX, an OTA allowed them to disregard the government-unique acquisition constraints that would have added cost and time to the development effort. By not-applying socio-economic laws and regulations, SPACEX was allowed to concentrate its efforts at its California plant and vertically integrate its operations without spreading subcontracts all over the country to meet small business participation requirements. It did not have to comply with CAS or TINA and its IP was negotiated with the government under the OTA. The results were that the SPACEX rockets were completed in similar

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[236] Space Act Agreement between NASA and SpaceX for Commercial Orbital Transportation Services Demonstration, August 18, 2006, NASA website accessed December 3, 2020: https://www.nasa.gov/centers/johnson/pdf/189228main_setc_nnj06ta26a.pdf

[237] This type of advanced procurement arrangement was used by the U.S. government to assure a market for the Pfizer-BioNTech Covid-19 vaccine prior to its development.

timeframe as innovations of the 1950s. Orbital's Antares development experience was much the same --- getting to first launch in five years' time from the signing of their Space Act agreement.

In 2006, NASA when it signed its COTS agreement with SpaceX it did not have to contend with the growing backlash at DOD and in Congress to the loosening of management regimes that were described in the previous case examples. The efforts to circumvent the traditional innovation system were all under threat by the mid 2000s – with the exception of NASA's commercial launch program.[238] Defense budget increases after 9/11 took the pressure off of the need to save money in the commercial marketplace and the oversight focus shifted to addressing fraud, waste, and abuse in overseas contingency contracting.

The rapid acquisition, commercial item, and other transactions pathways began to run into head winds even as the need for rapid acquisition developments in theater was gearing up. MDA's budget authorities were limited and the ability to transfer the benefits of the JDAM experience to commercial derivative aircraft such as the tanker were closed off. Thus, the political dynamic of trying to break down barriers to greater CMI and experimenting with time-based development lasted for about 10 years after the passage of the Clinger-Cohen Act. The roll back of these reforms led to a resumption of the bifurcation of technological advancement and a lack of focus on time to development.

[238] The SpaceX example succeeded perhaps because as it was a domestic and not a military program it was not caught up in the debate over the Iraq war.

While perhaps not its original intent, the congressionally-sponsored Services Acquisition Reform Act (SARA) Panel served to further undermined commercial procurement. The SARA panel (officially the Acquisition Advisory Panel) was authorized by Section 1423 of the Services Acquisition Reform Act of 2003, that was enacted as part of the National Defense Authorization Act for Fiscal Year 2004 to further contracting reform government-wide and address commercial contracting. The panel made several positive recommendations related to building up the acquisition workforce and increasing performance based or value-based contracting. Since both of those issues were difficult to implement, they were mostly ignored and the other areas that the panel focused on such as improving pricing, transparency, and accountability led to new legislative and executive branch measures that made it more difficult to access the commercial market.

The 2006 DAPA panel was established in response to continued concerns with the cost, schedule, and performance of major weapons systems. While it recognized the importance of integrating and reforming as a whole the budget, requirements, acquisition, and contracting regimes it continued to be focused on the problem as one of prediction: "This creates a cycle of government-induced instability that results in a situation in which senior leaders in the Department of Defense and Congress are unable to anticipate or predict the outcome of programs as measured by cost, schedule and performance."[239] Next, concerns about rapid acquisitions in Iraq and Afghanistan led to the establishment of the Wartime Contracting Commission in 2008, which issued a series of reports up until 2011. These reports outlined examples

[239] Defense Acquisition Performance Assessment Report, p. 6.

of waste and fraud and led to a slowing down of rapid innovation authorities. In a series of NDAAs, Congress reacted to these reports with legislation that began to roll back the reforms of the previous 15 years. In the area of major systems acquisition, this included the adoption of specific Milestone A B and C criteria and requirements for certifications that slowed down the acquisition process. Finally, the 2008 WSARA adopted a methodology for MDAPs that encouraged incrementalism rather than disruption.

This trend continued in the executive branch. Senior leadership set the tone with President Obama's so called "culture of corruption" speech on federal procurement in March 2009.[240] While it is not clear that the President was targeting more than a small subset of acquisition issues related to wartime contracting abuses, the application of his concern was much wider than the limited number of overseas contracts that have been winding down as the U.S. extricates itself from Iraq and Afghanistan. For better or for worse, this speech and the policy memos issued as a result established an atmosphere of distrust for the procurement community, resulting in adversarial relations with industry, a return to government-unique oversight

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[240] The White House. *Remarks by the president on procurement. March 4, 2009.* Retrieved from http://pogoarchives.org/m/co/obama-remarks-20090304.pdf . Specifically, what the president said was, "The days of giving defense contractors a blank check are over," as well as, "But I reject the false choice between securing this nation and wasting billions of taxpayer dollars. And in this time of great challenges, I recognize the real choice between investments that are designed to keep the American people safe and those that are designed to make a defense contractor rich." His comments about waste, fraud, and abuse in defense contracting were interpreted by Danielle Brian, executive director of the Project on Government Oversight, who was quoted in the Washington Post the day after the speech as saying that "by giving this speech, President Obama has highlighted the culture of corruption (emphasis added) in contracting in Washington and is embracing the necessary changes to fix it." Wilson, Scott and Robert O'Harrow Jr. President Orders Review of Federal Contracting. Washington Post, March 5, 2009.

mechanisms not applicable to commercial contractors, a reinstatement of government-unique requirements, and a prevalent culture of risk aversion.

This congressional and Presidential pressure empowered the oversight community. Commercial item procurement was rolled back and socio-economic contracting clauses proliferated. The use of OTAs declined and WSARA limited innovation to incremental step changes that could easily meet the confines of the predictive system. CMI was moving backward and slow linear processes advancing. The commercial item experimentation of the 1990s had ended and a counter-revolution to restore the traditional management regimes and ways of innovating had gained traction in the early 2010s and had seemingly won by 2015.

At the height of this tightening of defense management regimes, in 2014 SpaceX filed a lawsuit protesting that DOD was limiting it from competing to provide launch services. SpaceX's commercial time-based innovation business model based on selling a service and not being linked to the traditional budget, acquisition, requirements, and contracting processes for research and development, production and operations and maintenance was in jeopardy when SpaceX tried to expand its market beyond NASA and enter the DOD market for launch. DOD wanted to impose CAS and TINA and treat SpaceX like a traditional contractor and ensure that all of the requirements imposed on the Lockheed-Boeing origin merged launch provider (the United Launch Alliance) were imposed on SpaceX. This would have essentially required SpaceX to change its business model and become a traditional defense contractor. SpaceX refused and sued to be treated as a commercial provider.[241]

As SpaceX's case was making its way through the courts, collectively, the process for innovating in a time-based manner and acquiring goods and services from the commercial marketplace that innovated based on time was limited and sub-optimized by these many legislative and regulatory changes. The pathways to time-based innovation were either closed or were closing fast.

And then Congress changed its mind again.

CASE 7: The McCain Management Reforms (2015-2016)

Under the leadership of the late Senator John McCain (R-AZ), a new set of authorities designed to avoid each of the linear management regimes and enhance CMI was initiated in 2015. These efforts are the primary source of the experimentation with time-based innovation currently taking place at DOD and they also provided the tools for DOD to better access Silicon Valley, which was a goal of Secretaries Hagel and Carter through the Third Offset and Defense Innovation initiative.

Senator McCain, who had previously been part of the attempt to roll back many of the earlier authorities to bypass entrenched management regimes, became a convert of the need for these flexibilities and put into law authorities that far exceeded

[241] SpaceX would eventually prevail and the path of suing your customer to continue to operate as a commercial provider was followed first by Palantir (a data analytics company) and then by AGI (a space situational awareness software solutions company).

many of the original exceptions. His change of mind came as China began to militarize the islands in the South China Sea after President Xi assured President Obama that he would not, and Russia annexed Crimea in 2014. The Senator understood that the acquisition system was not capable of moving fast enough to address a growing threat and he was impressed by how quickly SpaceX was able to develop its launch system when the traditional rules were not applied. The issue for him became how to quickly create many more companies like SpaceX. The Senator thus moved to significantly reform defense management policy and practices through actions in the 2016 and 2017 NDAAs. These changes created new acquisition pathways around the traditional requirements, acquisition, and budgeting systems that were specifically designed to spur innovation at the Department and were influenced by the debates over the Third Offset Strategy.

McCain's time-based reforms tried to address process linearity and CMI and were in the tradition of each of the above case examples while building on them. On the linearity path, section 804 established a pathway around the statutory process for MDAPs that were strengthened in WSARA. It did this through a legal fiction. Just as an OTA is a legal fiction in that it is legally defined as not a contract and thus no laws that apply to contracts apply to an OTA, section 804 was designed in a similar fashion. Section 804 Mid-Tier authority as amended in the 2017 NDAA defined any program that can be deployed as an operational prototype or rapidly fielded in 2-5 years as not being classified as an MDAP even if it met the legal criteria for an MDAP. By doing this, all of the acquisition process and laws that applied to MDAPs in law and regulation no longer applied. Then the legislation went further by exempting these programs from the JCIDS requirements process. To address budget linearity, a Rapid Prototyping Fund was created to serve as the mechanism for bridge funding to initiate new prototyping efforts.

The other major reform that occurred in the 2016 NDAA was the granting to DOD of production OTA authority. This was a nod to the ability of NASA to effectively use the Space Act to create new space launch capabilities. Experimental authority – another OTA authority with its root going back to the 1926 Army Air Corps Act was expanded as well. As a result of this authority, OTA contracting has increased significantly. This is because these OTAs are now seen as a pathway to a program of record and because of that more and more companies are interested in working for the federal government. This path to production OTA authority immediately opened up interest in Silicon Valley as now there was a path to a program and revenue. Defense was no longer a customer that you were sure to lose money on while you gave away all of your intellectual property

Production OTAs than can address CMI and the problem of approaching Silicon Valley. The problem with the government's regulatory approach to acquisition is that top engineers, innovators, and firms do not want to focus their time on rules-based compliance and have other places to work beyond the defense market. Even if they could have been convinced to use an OTA prototype they would have, like the Predator and Global Hawk, been forced back into the traditional system. Most firms previously decided to stay away. Production OTAs now provided a pathway for these firms to provide a total solution to DOD's needs.

The Operation Warp Speed COVID-19 vaccine development contracts managed by DOD on behalf of the rest of government are using these new OTA authorities, most likely because of the production authority that would allow the government to immediately buy a vaccine that works. There is perhaps is another case study on COVID that may provide future insight into the process of going around existing rules in an emergency, but it is far too soon to see the effectiveness of the current use of OTAs to speed vaccine development and distribution.

The McCain reforms also tried to reverse the issues related to commercial item "of a type" acquisitions. It strengthened that law and bolstered the commercial item preference. Finally, Congress tried to address culture by doing two things that attempted to reverse the legacy of the Packard Commission. First it tried to bring the operators back into the acquisition process by empowering the military service chiefs and giving them a role again in the acquisition process rather than just in the requirements process. Secondly, the position of Undersecretary of Defense for Acquisition, Technology, and Logistics was abolished and its duties split and authorities delegated to the services. These were both designed to decentralize decision making and break up the power of the center but also to focus OSD on innovation that the services with their inevitable parochialism might not fund.

All of these authorities are currently being implemented and in a sense are the experimental phase of either an alternative management system or just another end-round of the system that will be abandoned as the threat decreases or a counter-narrative of risk averseness, process compliance, and potential waste, fraud and abuse begins to dominate. It may have more resilience in the sense that the perceived growing Chinese threat and the need to address a second wave of commercial IT dominance is currently subject to a bipartisan agreement. Still, that same bipartisan agreement existed during the passage of FASA and Clinger Cohen and after a decade or so that went away, much as the bipartisan agreement over loosening the rules on aircraft experimentation in the 1920s only last for a few short years. It remains to be seen how successful these reforms will be and what the next steps will be.

Will Agile Software Be the Next Case?

Unlike in the first wave of commercial IT technology dominance in the 1990s, which was primarily a hardware phenomenon, the second wave of commercial IT dominance that crested in the 2010s was software dominated. The phrase "software eats the world" generated by Marc Andreessen, venture capitalist and co-founder of Netscape had not made it to DOD.[242] While commercial item reforms could be adapted to DOD buying and incentivizing commercial software producers to build DOD the next generation of software, the business models now being used by commercial companies are completely different than what was used in the 1990s. The experience of non-traditional commercial software companies such as Palantir and AGI (both of which had to sue the U.S. government like SpaceX to try and enter the DOD market) to sell their self-financed software as a service solution has not been a promising advertisement for DOD's ability to adopt to this new world. The Palantir

[242] This phrase entered popular culture in a 2011 Wall Street Journal Op-ed: Marc Andreessen, "Why Software is Eating the World," Wall Street Journal, August 20, 2011.

and AGI problem returned to the issue of pricing as government contracting officers want to price software as they price hardware, which is not even close to current commercial practice and provides commercial companies no opportunity to generate commercial profits off their R&D.

As with many things within the government, the budget, acquisition, and contracting process rules complicate the ability to incentive innovation. Silicon Valley companies with their own investment can build superior software solutions at a fraction of the cost to anything DOD currently uses. Still, these companies are running into difficulties bringing them to market as DOD does not know how to price these solutions or how to pay for them. This led to Congress on the 2018 NDAA to come up with a new idea that is built on the concept of the section 804 Mid-Tier pathway. This was to authorize a new software acquisition pathway and require a study on how that pathway should look. This study by the Defense Innovation Board called the Software Acquisition Practices or SWAP report recommended a time-based approach and a way around the budgetary process by proposing a new software color of money. This, as in the MDA example, would allow software programs to mix and match software dollars for RDTE, procurement, operations and maintenance, and perhaps even construction dollars to build data centers. The Congress and OMB are now considering whether to grant the DIB's recommendation for such a software "color of money" – which would also be a way to evade the linear budget process as these funds would be fungible and able to move from project to project. The success or failure of that kind of budget reform is still to be determined.

Chapter 6: Conclusion and Recommendations

"Innovation cannot be an auxiliary office at the Department of Defense. It must be the central mission of its acquisition system."
John McCain[243]

U.S. defense innovation approaches prior to World War II were cyclical and heavily influenced by limited spending during long periods between conflicts. A peacetime approach dependent on government-run defense arsenals and tempered by a wide-ranging suspicion of the private sector and profits has predominated throughout most of U.S. history. The model of innovation in this peacetime process was price-based with little incentive for new advancement in defense technology. This changed with the onset of World War II and the Cold War, as a new U.S. defense innovation system was created to counter the existential threats posed in the 1940s and 1950s. In retrospect, that system was based on time exhibited by speed. While government-run enterprises did not go away and in fact increased in both number and size, the private sector's role in weapons development and production would eventually dominate.

This time-based innovation system developed and built ad hoc solutions using rapid procedures, experimentation, prototyping, and flexibility in budgeting to support swift technology development and deployment. Time to development and deployment was perhaps not explicitly expressed as a goal in this system but it was understood as the constraining factor that permeated the work of all who supported

[243] Remarks on Defense Reform at the Brookings Institution, May 19, 2016.

the war effort. This mission focus on time to capability was subsequently adopted in the early Cold War weapons competition with the Soviet Union. While in the midst of a global conflict, time was a key constraint, but it also became a measure of success that resulted in new advanced and disruptive defense technologies to include radars, jet engines, computers, microelectronics, missile systems, satellites, nuclear submarines, and nuclear weapons that were the source of decades of U.S. military advantage. Each of these new technologies were initially developed and deployed on rapid timelines.

This time-based approach to delivering military capability fundamentally changed, beginning in the early 1960s. The current innovation system is much more structured and process-oriented than that of the post-Cold War period. The attempts to institutionalize and bring order to the 1940s and 1950s system of innovation that some saw as wasteful and duplicative undermined the time-based model during the 1960s and 1970s when policy makers wrestled with the goals of overseeing, protecting, and replicating in standard processes, but also improving upon, the successful disruptive technological advances the U.S. had achieved in the previous decades. New approaches to both public and private sector management were gaining prominence in academia and business practice at the time, which resulted in a step-by-step linear approach to weapons system development and budgeting. These concepts were heirs to the scientific management tradition and included systems analysis, program budgeting, and systems engineering approaches and thinking that, when applied to defense scientific and technology research, engineering, and program management, were not neutral in their effects. The defense industrial base adapted to these processes and barriers arose to companies that innovated in a time-based manner.

Conclusions

Four primary conclusions can be made from this review and analysis of the defense management literature, historical record, case examples, and available developmental time data and studies for both defense and commercial programs. These are: 1) time is a significant factor in shaping defense innovation; 2) over the last five decades, time to deployment of new capability at DOD has increased significantly while innovation quality has been incremental; 3) linear processes that implement defense management regimes have lengthened the time to conduct defense innovation; 4) government-unique processes mandated by defense management regimes have narrowed the defense industrial base by creating barriers to entry to those companies that innovate on the basis of time.

In general, the public management framework used to guide and oversee U.S. defense innovation since the 1960s has deemphasized and crowded out the significance of time as an incentive to invention while emphasizing values such as cost, price, technology maturity, fairness, socio-economic factors, 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. Time was relegated in the 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 made it impossible to innovate in the time spans of the 1940s and 1950s. Management regime impacts on civil military integration caused commercial companies that value time-based innovation to face significant disincentives to deploying that innovation in a more agile and rapid manner in the defense marketplace. These conclusions call for a reevaluation of defense management regimes and a reconsideration of the criteria used in guiding and evaluating successful defense innovation.

Time Can be a Significant Factor in Shaping Defense Innovation

The prioritization of time has been a significant factor in shaping past defense innovation and could be used again as a means to influence and guide future innovation efforts. Defense innovation, like all innovation and invention, is neither linear nor predictive. It is first based on a bedrock of scientific research and then furthered by iterative risk-based experimentation and prototyping. Time-based development from an orderly planning perspective can look chaotic as scientists, engineers, and managers focus on meeting constrained deadlines that incentivize innovation and are the source of potential progress. In its earliest incarnation, when focused on hard "never been solved before" problems, this approach may look duplicative when pursuing multiple paths to a solution that often lead to failure and dead ends. However, it is these multiple paths that provide a greater chance of ultimate success, as many of these time-based experiments and efforts should be expected not to work, but help lead to one that does.

Perhaps most importantly, with regards to early time-based experimentation there is a need to develop a tolerance for potentially repeated failures. In Silicon Valley parlance, this is to accept the need to "fail fast" and then quickly move on to another alternative. Unsuccessful experiments or prototyping efforts can be viewed as inefficient and even wasteful by those who subscribe to a more predictive management approach. Missiles blowing up during testing – something that occurred with some frequency in the 1950s – or failed satellite deployments in the 1960s were not wasteful exercises of governmental excess that were the result of poor management, but were a result of time constraints based on an urgent need acting on the experimentation and innovation process.

For the most significant milestones in defense innovation, time constraints either in an emergency or due to perceptions of high threat levels have furthered what is thought possible with regards the delivery of new capabilities. These solutions may have only achieved 80 percent of what may have been aimed for, but they were better than anything before. This dynamic occurred in World War II, during the height of the Cold War and in the series of case examples described in Chapter 5. The key lessons from these efforts were to fail early, learn from these failures, and have flexibility to quickly move in another direction. In addition, something should not be branded as a failure if it didn't meet 100 percent of an initial, and perhaps, unobtainable goal. The criterion for success is utility. Is it useful and better than what came before?

Time constraints can become an even greater factor and shaper of innovation beyond the initial discovery, experimentation, or first prototype phase of a new defense innovation. Serial, time-based incremental improvements conducted after an initial successful operational prototype can lead to disruptive innovation after multiple rapid iterations. Multiple serial operational prototyping was demonstrated in the military in the 1950s in the bomber, nuclear submarine, fighter aircraft, and missile programs. In the commercial sector, the similar iPhone development model is being pursued not only in the digital world but in the automotive and other sectors. The 1940s and 1950s process of focusing first on limiting time to experiment, prototype, and test different versions of a product and then incrementally operationally deploying new versions of that product on a rapid time-based serial schedule is perhaps one of the greatest innovation practices that was created and adopted by the federal government, but for the last half a century has no longer been used by DOD.

Time to Development at DOD Has Increased Significantly as Innovation Became More Incremental

The significance of this time-based innovation model was never fully recognized by DOD in the 1950s and subsequently DOD embraced a predictive incrementalism that was most successful in delivering new modifications to older platforms in time-frames exceeding a decade or more. DOD now faces innovation cycles for anything more than a minor incremental upgrade to an existing system that are 15-20 years in duration versus 2-5 years in World War II and the early Cold War. It has lost the systemic ability to carry out rapid experimentation, operational prototyping, rapid incremental prototyping, or to develop greenfield disruptive new technologies in the time frames of the early Cold War without providing significant exemptions from current rules. Long acquisition cycles are currently a fact of life and the data implies that development times even for incremental modifications to existing technology have continued to increase.

It appears that in the 1960s, once the lesson of the importance of time could have been learned, it was forgotten, or as is more likely, the exigencies of the day never allowed this experience to coalesce as other values such as the promise of efficiency through predictive management came to dominate. While Peck and Sherer in their 1962 analysis understood the importance of time, it was not then a particular problem and they and others focused on other issues. Academia and the Pentagon were moving in other directions to address greater efficiencies in the innovation process that focused on measuring and predicting cost. The analysis that emerged from RAND and was adopted by DOD focused on premature prediction and cost estimating efforts that were inapplicable to the types of prototyping and experimentation that was occurring in the 1950s. These efforts were highly unpredictable by definition as they were pursuing disruptive knowledge or capabilities.

Longer term predication can be made to work and programs managed under stringent cost baselines only if technical risk is reduced. Planned predictive cost estimates and schedules can be realistic and achievable if technology risk is reduced to near zero, but by that time the objective is not very innovative. Yet, in fact, the goal of GAO's knowledge-based criteria and technology readiness levels that are embedded in statutory requirements for Milestone B and C decisions are designed to do just that with regards to technical risk. The WSARA acquisition reform law by attempting to remove technical risk out of programs results in these programs focusing on low-risk incremental innovation. The results of this legislated oversight framework are long procedural time frames married to low-risk technical incremental programs.

This outcome of favoring incremental low risk innovation may not have been the intent of the original cost-based analysts and program budgeters. However, over the years the effect of the management regimes that implemented the cost-based innovation model was to continue to emphasize planned schedules and predictable goals and annually modify five years of future budgets through the PPBE process. Each subsequent improvement to the overarching management regimes was designed based on delivering these programs within their predictions and improving cost estimation, which required more data – usually from program managers and defense contractors, which slowed down the process even more. There was no room for any time-constrained goals in this system that could lead to a failed test that would likely lead to a funding cut and potential cost overrun. Failure was to be avoided, but in doing so, learning and discovery were limited as well. The possibilities for disruptive innovation were seen as far too politically risky.

The lesson to be learned from this experience is that the criteria used for the evaluation of the measurement of success of a program or effort is extremely important. What is measured will likely be emphasized, and often with unintentional consequences. Today's cost-based criteria or focus on technology readiness levels if applied to the development of the first ICBMs, reconnaissance satellites, and nuclear submarines would have led to these efforts being classified as failures due to their inability to predict costs and specific technological progress. This would have likely led to their early cancellation after a failed test even though these efforts were some of the most successful innovations in defense history. That kind of innovation would not be tolerated under the current management system at DOD and in Congress.

Management Regimes Are Constraining the Ability to Reduce Time to Development

While changes in threat, budget and requirements instability, and technological challenges can all lead to increases in time to development, the initial baseline process time to initiate and manage a current defense program would make it impossible under today's traditional management regimes to reduce innovation cycle time to the levels of the 1950s. Collectively, several defense management regimes account for a longer period of time than needed to ideally develop defense capability, if using the 1950s as a benchmark. The same can be said about other benchmarks of the time it takes to develop comparable items in the commercial market and by some indications, what our potential adversaries are able to achieve.

While legitimate debate can be had over the reasons behind these longer timeframes, focusing on the linear process of the requirements, budget, acquisition and contracting regimes alone illustrates that these processes do not comport with a focus on delivering capability within a less than 5-year framework unless they are ignored. The time to comply with these processes now takes a minimum of 15 years, with 5 years allocated for the requirements and budget processes and 10 years for the acquisition process that includes multiple 2-year contracting cycles embedded within that 10-year acquisition process.

Many processes, particularly in the acquisition regime, have been created to adjust to the realities of a longer 15-20-year developmental cycle. Given the length of time to deploy new capability, it makes sense to conduct certain processes to ensure quality, as subsequent changes will further drive cost and schedule. The desire for a certain predictive outcome in several decades actually drives the need for even more time to be added into the process to allow for additional testing and to address, for example, future maintenance and operational issues.

With more discipline, it is possible that the traditional system may be able to accommodate a 5-year development cycle as is demonstrated by the current time it takes to progress from Milestone B to deployment or IOC at between 6-8 years. The time-based problem that currently exists with these programs is the amount of time it takes to get to Milestone B. A 7-year front-end "decision time" that accounts for requirements, budget, and initial contracting process time add such significant time as to question the efficacy of DOD ever meeting a five-year time-based cycle for development. At its best, achieving a 5-year Milestone B to IOC would still leave such an effort at 12 years in time to development. This is perhaps better than current timeframes but probably not sufficient for a future competition with a near-peer adversary.

Management Regime are Narrowing the Industrial Base

The extraordinary complexity of the linear management processes has made the defense market less attractive to those companies that innovate on a time to market basis. Waiting for the time it takes to get someone in the government interested in a technology, validate a requirement, obtain budgetary resources, start an acquisition program, and then compete a contract is largely beyond the time horizons of most commercial firms and the private capital backing them. Beyond the linear process regimes are other management regimes that serve as barriers to civil-military integration of the industrial base, making it difficult or even impossible to break into the market for those commercial firms that may have an interest in working with DOD.

Despite work arounds described in Chapter 5, such as FAR Part 12 commercial item exemptions and OTAs, there are increasing process barriers to using these authorities to attract those companies that innovate quickly rather than specialize in government process. There are also many other incentives and barriers dealing with security, export controls, intellectual property, finance, and oversight that continue to make the defense and the government market as a whole unattractive for the most innovative companies in the U.S., particularly those backed by private venture capital that are currently the source of advancements in AI, robotics, big data analysis, and quantum computing. Until these barriers are addressed, commercial firms' participation will lag and defense innovation will suffer.

Recommendations

Collectively, these conclusions call for a reevaluation of current defense management regimes and a reconsideration of the criteria used in guiding and evaluating successful defense innovation. DOD currently has a cost and price-based driven innovation system. The cost-based system originates from the 1960s, while the price-based system originates prior to World War II. The time-based system that developed during World War II and the early Cold War has found little use since the 1970s.

The case examples in Chapter 5 illustrate that, on an exception basis and for a very few programs, there is the possibility that the U.S. government can innovate in a time-based fashion as it once did. These examples illustrate that bypassing or streamlining the requirements process, having access to flexible sources of funding, using more flexible contracting procedures, streamlining competitive procedures, and not using the traditional acquisition management processes allows decision makers to start and end programs more quickly. The innovation model needs to change to be able to attract new entrants and technology and deliver capability faster on a grander scale rather than can occur through one-off workarounds and on an exception basis. This becomes critical if other nations learn from the U.S. experience and focus on time-based innovation – as they appear to be doing. [244]

To counter rising threats and maintain the competitiveness of its military, the U.S. should reestablish an alternative time-based innovation system at a larger scale. This new system should build upon the past examples of successful time-based development and civil-military integration models. Future DOD weapons

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[244] It can be argued that China, Russia and even North Korea have already come to this conclusion and their military development programs show significant evidence of time-based iterative prototyping. The Chinese development of the J-20 fighter and Russian air defense systems show signs of rapid iteration and deployment in time periods much faster than comparable U.S. systems. North Korean missile test failures are the mark of progress being validated by the successful deployment of new more advanced capabilities as they make incremental improvements to technology -- a lesson the US learned in the 1950s under its own missile program but has somehow seemingly forgotten. The U.S. keeps being surprised by these advances, but they all look unsurprisingly similar to the U.S. model from the 1950s.

development should focus on delivering operational capability in a maximum of 5-year increments – from concept to actual hardware that can be tested and used in the field. In an attempt to change the innovation model back to one that adopts a more time-based development approach, a series of recommendations are made. These recommendations suggest modifying management regimes to: 1) focus on time by addressing process linearity; and 2) incentivize the civil-military integration of the industrial base.

Based on past data, it appears that large hardware projects ideally take 4-7 years to start a program and bring it to market. It does not seem to matter if a product is a new disruptive operational prototype or an incremental modification to existing technology. It may be quite possible to shorten that cycle to the 2-4-year timeframe demonstrated in the 1950s, but focusing on a five-year cycle for innovation would provide a vast improvement over current outcomes. Software is an entirely different developmental effort. New software changes, unlike in the past, can be accomplished within months rather than years, and management processes must change to accommodate this new world of agile software development. This change could be enabled through an iterative open-source software development process based on time.

To maximize the most advantageous system and time-based goals, the modernization or replacement of existing platforms or systems with a lifetime of greater than 10 years would ideally be faced with two types of incremental developments working simultaneously. The first would be a continuous five-year effort to incrementally upgrade any needed hardware changes and the second would envision a one-year or even faster rate of continuous software upgrades on the platform. New disruptive solutions would form a different pathway that relied on time-based rapid experimentation, multiple solution options, the flexibility to move from one option to the next, and serial operational prototyping that leads to either stand-alone capability or a decision to produce at scale.

Several new tools are used in the commercial sector that further enable time-based development and could be adopted by DOD to help in implementation of such an approach. In addition to iterative prototyping and agile development, digital engineering and modelling, modularity, component reuse, common architectures and open systems design are all emerging approaches that can be used enable time-based development.[245] Advances in 3-D printing and additive manufacturing will likely make it easier to prototype and bring to market an initial operational system faster than current techniques.

This first set of recommendations addresses the issue of linearity. In one sense, DOD could continue its past management practices with a new system of ad-hoc end-arounds of the current management regimes, but that would be insufficient. Progress has been made in the last five years through the beginnings of the implementation of the 2015-16 NDAA Mid-Tier acquisition reforms that provide for an alternative pathway around some of the management regimes. Section 804 Mid-tier authority is a time-based authority that allows a path around the requirements and acquisition process if capability can be delivered in 2-5 years. While the success of

[245] For a primer on some of these new tools see: Will Roper, Assistant Secretary of the Air Force, Acquisition, Technology, and Logistics, *Take the Red Pill: The New Digital Acquisition Reality,* (Department of Air Force, September 15, 2020).

this authority still remains to be seen (as of March 2019 35 Mid-Tier programs existed),[246] it should only be a few more years before data can be collected to identify best practices and determine any changes that need to be made to this authority. The measures used to gauge that success or criteria for evaluation will be critical in that evaluation. There are now ongoing program efforts and potential capabilities that wouldn't have existed such as the new fighter prototypes, command and control, missile and hypersonic programs, if not for this authority. The head of the Army's Futures Command "observed that the Army had been on 10-15-year timelines to introduce new equipment but these are being shortened to four years in some recent programs."[247] The U.S. military is one step closer to being able to compete against China because of the use of section 804. Still, even now these programs only cover a very small amount of the military's development budget and are subject to an increase in initial decision time to gain funding, a growing call for new restrictions, and a return to the traditional developmental process.[248] While rising in significance, these programs have not achieved a critical mass and without further reforms will continue to lag behind what a nimbler adversary can do in less time.

Mid-Tier authority is a first start in moving to a time-based framework and is now part of the new Adaptative Acquisition Framework (AAF) that, as of October

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[246] U.S. Government Accountability Office, *DOD Acquisition Reform: Leadership Attention Needed to Effectively Implement Changes to Acquisition Oversight*, GAO-19-439, (Washington, DC, 2019), 26.

[247] Center for New American Security, Fireside Chat with General John M. Murray, September 10, 2020, https://www.cnas.org/events/virtual-fireside-chat-with-general-john-m-murray.

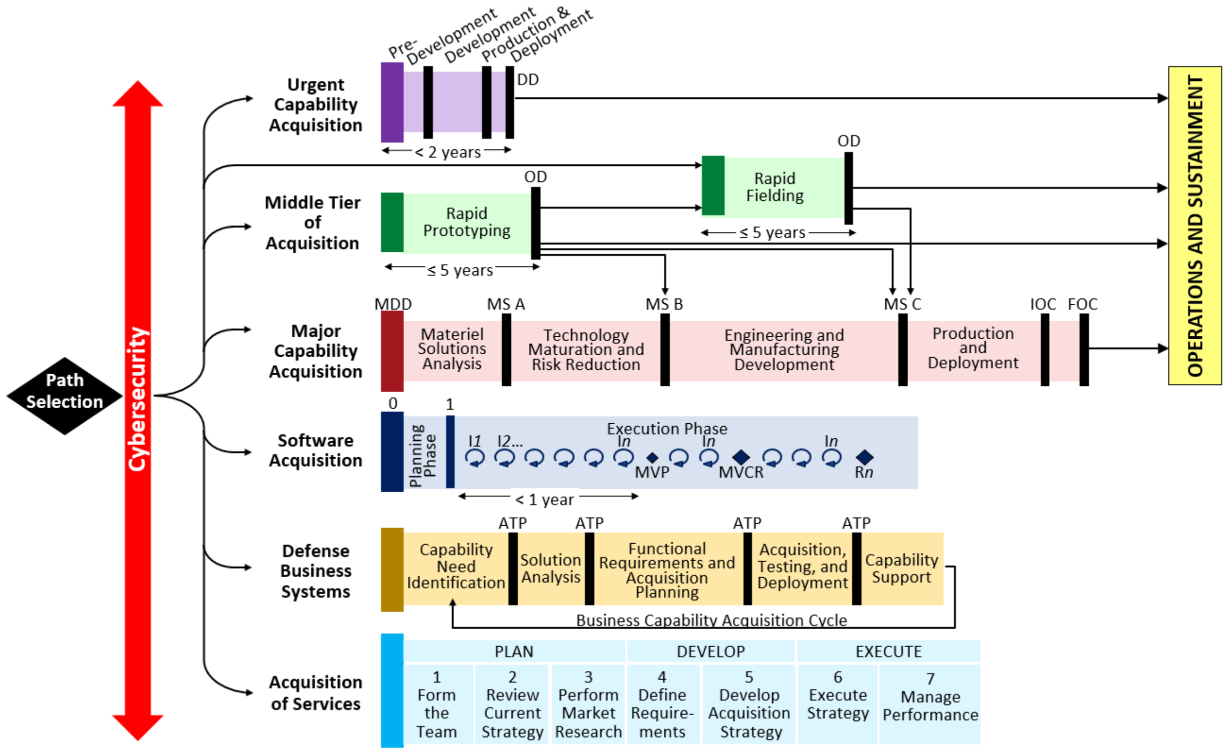
[248] For example, In the Senate Report to accompany the FY 2021 Defense Appropriations Act (p. 161) there are several new reporting requirements and restrictions proposed to be applied to Mid-Tier acquisitions conducted the Department of Defense. GAO has provided several recommendations for enhanced oversight of Middle-Tier programs in recent reports (GAO-20-439, Highlights).

2020 is embedded in the latest DOD 5000 series rewrite. The new AAF (see Figure 6.1) has the potential to move DOD to a more time-based development approach as it has put time schedules into several of its acquisition pathways. Three of the pathways, Mid-Tier (2-5-year), software (1-year), and urgent capability acquisition (this conforms to the legacy authorities and practices outlined in case example 5 from chapter 5 that have a 1-2-year acquisition cycle) are now constrained by time. However, these pathways are the exceptions to the traditional pathway, which will likely continue to dominate. While under the AAF, the Department has begun to put in place a framework for a time-based acquisition system it must go much farther in the other pathways.

Recommendation 1: Modify the acquisition system to focus on time by addressing linearity and establishing separate innovation pathways that can be completed in five years or less to address low-volume disruption or high-volume incremental improvement

This first recommendation is designed to better use time in the acquisition system as a mechanism to control its cost-based system. To do this, the next step is to put time constraints on the rest of the acquisition pathways described in the AAF and further subdivide acquisitions within these pathways depending on whether they should focus on low-volume disruption or high-volume incremental improvement. Low-volume disruptive capabilities would be developed under the Mid-Tier authority while high-volume incremental improvement programs would be conducted under the traditional pathway, but whose initial capability deployment would likely have been proven in a previous Mid-Tier program.

Figure 6.1 Adaptive Acquisition Framework[249]



DOD must apply time-based constraints on major capability acquisition, which is the new name for the older traditional acquisition model. There is no reason that any major capability acquisition should take longer than 5 years or that DOD continue with its overly lengthy 15-20 systems acquisition time cycle. Even as larger volumes of capability are bought under the major capability's pathway, these purchases should continue to be limited by time. Five years to produce a block of new capability should be sufficient based on past production histories. New technology

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[249] U.S. Department of Defense, DOD Instruction 5000.02: Operation of the Defense Acquisition System, (Washington, DC Updated 1/23/2020)

can continue to be planned for the next production version block buy just as new iPhone versions are planned for release today.

To further encourage the development of evolutionary platform developments, Congress may want to consider that DOD only approve programs at Milestone B that will be initially deployed in less than three to five years. These types of platforms may still be purchased over a 20-year span but a shorter deployment requirement will have the benefit of breaking programs into smaller production increments and spreading out riskier technology insertions over several iterations. DOD should be thinking of separating future programs into a number of programs along the lines of the block upgrade concept used on the F-16 and some missile systems. DOD can be held accountable for Nunn-McCurdy cost and schedule baselines established for each block or increment rather than a decades-long life of program effort where the first production article may have little in common with the last.

If this process for major capabilities works as intended it will force evolutionary, less risky alternatives to meet the shorter time for deployment and the ability to meet stringent milestone B and C requirements. Milestone B – IOC programs will likely focus on incrementalism and cost, schedule, and performance objectives can be easier to manage if riskier programs are moved to the Mid-Tier or the urgent pathway. This process should be adequate for most of DOD's incremental system development buys. While no one size fits all, the major systems acquisition framework can work for these large buys of non-innovative platforms that one keeps for decades. It is probably best to limit those given the inevitable rapid advances in technology that will likely continue into the future. For this baseline set of forces

DOD will need to design-in flexible and adaptable new technology insertion options either on a hardware or software side based on open systems interfaces.

For less mature programs, it is necessary to distinguish whether the acquisition need is for a low-volume disruptive solution or an eventual high-volume incremental solution. Each of these solutions should be first tested and prototyped using the Mid-Tier pathway. Mid-Tier acquisition should be a preference for most developmental programs and the initial roll out of operational capability. If the Department is only looking for a low-volume disruptive solution, then a second or multiple follow-on Mid-Tier programs could be established using the rapid fielding authority or a follow-on serial prototyping authority within the section 804 authority. If a capability is planned to be widely produced in large quantities, then the major capability acquisition pathway should be used, but even under this pathway for the initial prototyping phase and perhaps the initial block of capability produced at a lower volume, the Mid-Tier authority should be exercised first.

Thus, in the place of most traditional 15-year major development programs, DOD should focus on building operational prototype systems that can be deployed within one- to two-year (urgent capability pathway) and three- to five-year (middle tier) timeframes. These operational prototype systems should provide U.S. forces with real capabilities and not be technology demonstrators designed to sit on a shelf. This “fly before you buy” approach is different in the sense that these systems not only demonstrate capability but can be used in a conflict. They also have the added benefit that if only a few are needed (and if they work) the acquisition program could stop there. These categories of acquisition pathways not only can provide needed capabilities but can also serve as the basis for future programs that can enter the traditional evolutionary process at the milestone B or C point or continue with a follow-on Mid-Tier program.

For urgent capability acquisition and middle tier acquisition, an alternative requirements system has been created that should limit the linear time it takes to move through the requirements process. Although even here it will be necessary to reduce or monitor the time those new alternative processes take to initiate these efforts. The traditional requirements JCIDS process should either be streamlined or scrapped for major capability acquisition and an alternative process created. The requirements management regime should be reformed to emphasize time to development and initial deployment leading up to a transition to a system that a decision has been made to buy in large quantities or in the cases of ships – identical follow on to new ships in a class. Thus, only for these technology transition programs should what is legislatively defined as an MDAP programs be established and the current JCIDs process, program budgeting, and the major capabilities pathway procedures apply.

The AAF has set up the policy framework for this to happen. The problem is that there existed under the old 5000-acquisition series the possibilities for this flexibility and none was forthcoming. The same could be said about this new rewrite of the 5000-acquisition series and the key will be found in implementation. As with previous rewrites that allowed for incremental and evolutionary acquisition, the failure of the stated process to conform with the actual process has led to a mismatch in time to development.

There is also no reason that what used to be called MAIS – Major Automated Information Systems, now classified as the Defense Business Systems pathway – should take longer than 2-5 years as well. Within the acquisition of services pathway there may be room for longer contracting timeframes for public private partnerships under, for example, Energy Savings Performance Contracts, but most of these contracts should not last more than 5 years and the time it takes to acquire that service should be relatively short and measured in months, not years.

The other benefit from a time-based approach that is focused on 2-5-year increments for each of these pathways is that the cost-based system can be focused on near-term actuals that the budget can accommodate. Not only will programs be time constrained but they will be cost constrained as there will only be so much money that one can spend in such a 2-5-year period. One will very quickly determine the feasibility of execution in this timeframe and as long as there are incentives to move money around, these shorter programs can be more readily cancelled and new alternatives pursued. Still, the greatest budgeting problem at the moment is the waiting for funds to initiate new experimentation and prototyping projects.

Recommendation 2: Establish flexible budget pathways to accelerate new innovations through experimentation and prototyping new systems in the software, Mid-Tier and urgent operations pathways.

The most significant change that remains to enable time-based acquisition is to address the upfront linear problem of the budget process. The current use of OTA and Mid-Tier authority has suffered from the same inability of the budget process to initiate flexible new program effort starts and risks aversion to their use. An authority to create a bridge fund for prototyping and experimentation is still needed to prevent urgent capability, Mid-Tier programs and software programs languishing first for three-years in the PPBE process.

Even with the ability in Mid-Tier authority to go around the MDAP acquisition process and the JCIDS requirements process, the Department suffers from the inability to rapidly start one of these programs due to the constraints of the budget process. The military services have had to wait the 2-3 years for the PPBE process to work before getting section 804 programs into their budget. This gap in funding was proposed to be addressed by the creation of a Rapid Prototyping Fund authorized as a part of section 804 in 2016 but DOD and the appropriators did not operationalize the fund. Thus, the three-year wait to begin these efforts.

DOD budget processes have become the structural impediment to change and are the last remaining item to address in acquisition reform.[250] Change will require a multi-faceted solution that includes agreement and buy-in from the congressional appropriation and authorization committees, DOD, and the Office of Management and Budget. Current DOD funding is inflexible particularly for research and development activities, where prototyping and experimentation is most needed. The innovation budget (RDTE and Procurement) is still focused exclusively on programs, does not encourage experimentation, and does not allow for the rapid movement of funds when experimentation provides answers that an alternative path is needed. The infamous “valley of death” can only be bridged by a 2-3 year wait for funds. This is

[250] George Mason University’s Center for Government Contracting held an August 20, 2020 event on “The DoD Budget Process: The Next Frontier of Acquisition Reform” which touched on this theme. https://business.gmu.edu/govcon/webinars-podcasts-and-virtual-networking-events/

too long for a design and prototyping team to stay together at any commercial company with no revenue except for a dedicated defense firm that receives IR&D subsidies from the government due to its other DOD cost contracts. The Air Force's recent attempt to use more flexible Small Business Innovative Research (SBIR) funds (which are not subject to appropriations control)[251] to immediately initiate tech efforts is an example of how to provide some interim funding. Still, this is insufficient as the SBIR contracts are too small to make a significant difference. Pooling SBIR funds into large amounts is one workaround to this but may invite political backlash in Congress based on the original intent of this small business program.

In order for the acquisition system to focus on time, more flexible budget processes need to be created to address linearity at the beginning of an innovative effort. A 6.4 RDTE budget classification is probably the correct classification of money, but what is needed is to fund these prototypes in mission areas rather than on a program or project basis, which is the source of the budget wait time. Thus, Congress and DOD should work together to establish a series of flexible mission area funds to initiate new innovative efforts in the software, Mid-Tier and, urgent operations pathways. These efforts could first leverage the section 804 rapid prototyping fund that is already authorized or create a new fund or budget line items. These funds may need the authority to also support the immediate funding of urgent

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[251] The SBIR program is funded in a unique way through what is essentially a "tax" on federal government research and development programs. This structure allows these funds to be off budget and outside of the control of the appropriations committees. The SBIR program funds small-scale R&D efforts from small businesses that would normally not be funded through the appropriations process. The historical issue for SBIR like many DOD R&D programs is the problem of follow-on funding after initial research has been completed. Most of these efforts languish in the "valley of death" and never receive funding at scale through the appropriations and budget processes.

operational needs, or new software and artificial intelligence efforts or an additional fund could be established for these pathways. It is likely that each service would need its own rapid funds to limit the time it would take to get approval from centralized authorities who would likely control one overarching DOD fund.[252]

Other potential budgetary reforms that could be considered that would enable time-based innovation include the establishment of mission and capabilities budgeting beyond RDTE for certain categories of effort similar to the authority that was given to MDA in case example 4 that also allows for movement of funds between RDTE categories, Procurement, O&M and MILCON. Another option is to merely establish mission funds with "No Color of Money" that negates these distinctions. This would be similar to the DIB's proposal for a software color of money but to apply that concept to multiple mission or capabilities areas. Yet another option that was once given to the now expired JFCOM is to give operational commanders limited acquisition and budget authorities to address urgent operational needs in their area of responsibility. This would streamline the time it takes for urgent needs to be addressed that currently rarely get acted upon and leave gaping holes in U.S. operational ability to address rising threats. Each of these budgetary authorities would require agreement from Congress and OMB to implement, but the first step is for DOD to want to make any of these reforms a priority and then argue for them based on a compelling case for change.

[252] Service specific funds are already authorized for the Rapid Innovation Fund established under section 897 of the 2017 NDAA that amended section 804 of the 2016 NDAA.

For any new budget flexibility there will be a need to ensure that the congressional appropriations committees have insight and transparency into the execution and use of these funds. It is also possible that these funds would be needed only as a bridge for two to three years and then the traditional funding process could continue under the PPBE process and be supported by current budget justification documents that are sent to Congress. These bridge funds could be executed by budgeting wedges of money each year for these purposes, but not putting forth the detailed program budget justifications currently required for other funding lines since those programs and technology efforts would not yet exist. Periodic reports to Congress could be made after the obligation of funds from these flexible accounts.

Because of the inflexibilities inherent in the current program budgeting construct, these new flexible funds could quickly fund rapid prototyping initiatives. As such they would be the primary means of funding the Pentagon's efforts to compete in a Great Power Competition level or conduct a "Third Offset Strategy" as these funds could take three years off the linear time-based cycle. During the Cold War in both the first and second offset strategies when America really needed an important strategic or intelligence capability, the Pentagon emulated a more streamlined version of acquisition and budgeting that empowered entities like Lockheed Martin's Skunk Works to build operational capabilities faster than the traditional acquisition process. These revolutionary operational prototypes should again be developed.

The next set of recommendations would address changing management regimes to incentivize the civil-military integration of the industrial base. Reducing the upfront time it takes to initiate capability development efforts would enhance the ability of non-traditional contractors to focus on providing defense solutions. Still, the requirements for government-unique cost and pricing data under TINA, the requirements of CAS, intellectual property risk, and government unique contracting clauses are still huge barriers to CMI. Reforms to FAR Part 12 commercial item exemptions in the last 5 years have not been successfully implemented and as a result, commercial firms that want to innovate on behalf of the government are advised not to contract with the government on that basis.

As a result of the bureaucratization of FAR 12, there has been a large increase in non-traditional firms trying to enter the defense market on an OTA basis. U.S. government-wide OTA spending has risen from about $1 billion in FY15 to $7.8 billion in FY19 with DOD accounting for more than 90 percent of that.[253] This shift from FAR 12 to OTAs was not the intention when new commercial item reforms were passed by Congress in 2015. The inability of the contracting community to determine and measure value in a commercial contract has led DOD back to a price-based system and an overreliance on TINA and CAS. In addition, new socio-economic requirements that should have been exempted in FAR 12 have slowly crept back into the system. Because of the inability to reform commercial item procurement the following recommendation is made.

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[253] This number will be inevitably be higher in FY2020 given the OTA awards by DoD for COVID-19 related medical work is alone valued at approximately $6 billion. Data comprised from: Benjamin Schwartz and William Greenwalt, "Other Transaction Authority & the Consortia-based Acquisition Model: A Valuable Tool for Rapid Defense Innovation," Draft Paper to be published in December 2020.

Recommendation 3: Implement the preference for OTAs to address both contract linearity and CMI in DOD time-based innovative efforts.

As a means to more quickly start new innovations to experiment and prototype, Congress in the 2018 NDAA created a preference for the use of OTAs. This should now be the default position to create a value-based commercial contracting process that removes barriers to CMI and the use of non-traditional contractors. This preference can also be helpful in addressing time-based issues with contract negotiations.

OTAs have the potential to be the best way for non-traditional and venture capital backed companies to participate in the DOD market. It enables but does not guarantee commercial cost accounting and price-based negotiations based on commercial best practices and pricing. It allows for the ability to negotiate intellectual property rights and has the opportunity to be the most commercial like terms and conditions that nontraditional contractors are used to.

However, both price and cost-based FAR clauses and socioeconomic requirements are creeping into OTAs. This is now occurring on OTAs as the contracting community is slowly inserting more government unique FAR clauses in OTAs to make these contract vehicles look more and more like a traditional FAR contract. To achieve CMI these clauses need to be limited on future OTAs. To effectively do this, DOD should create OTA templates for non-traditional participation in government contracting.

Another successful effect of the use of OTA authority is the ability to reduce the time it takes to compete and negotiate a traditional contract. Contract lead times for OTAs are measured in months, as opposed to years with traditional contracts. The Defense Innovation Unit and other entities executing Commercial Solutions Opening OTAs are getting on contract within 60-90 days.[254] Consortium based OTAs are another way to execute contracts faster.[255] For urgent, Mid-Tier and software time-based acquisition pathways with both commercial and defense unique providers DOD should use OTAs to take almost 2 years out of the linear innovation cycle.

Recommendation 4: DOD should create an adaptive CMI arrangement for nontraditional firms.

Many other barriers beyond contracting exist that prevent nontraditional and venture capital backed companies in Silicon Valley working for DOD. For example, different security requirements are a challenge. Obviously, these requirements are needed in a number of the classified applications that DOD is working on. Still, there is a need to streamline and adapt the security requirements to the ability to attract the types of firms and engineering talent to work on defense problems.

DOD could consider an arrangement that would address the ability to rapidly clear personnel in nontraditional companies to allow them to bid on contracts. It would create a commercial pathway through the export control process to ensure that

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[254] From the Defense Innovation Unit website: "Through our Commercial Solutions Opening (CSO) process, we competitively solicit proposals for innovative solutions that meet the needs of our DoD partners. DIU leverages Other Transaction authority (10 U.S.C. § 2371b(f)) to award prototype agreements in as few as 60-90 days. More importantly, after a successful prototype, the company involved and any DoD entity can enter into a follow-on production contract or agreement just as easily." https://diu.mil/work-with-us

[255] A consortium is an association formed by multiple parties for the purpose of participating in a common activity or pooling resources to achieve a common goal. Consortium-based OTAs allow multiple companies and academia to collaborate with government customers and to partner with each other to accelerate innovation.

these firms have a path to commerciality to be able to sell modified products and use their intellectual property in the global marketplace to eliminate the disincentives to working with the federal government. In addition, special security requirements such as information security standards should be adopted to commercial standards to the maximum extent for non-traditional firms.

Just as DOD needs an OTA contracting template that is tailored to these non-traditional firms, it should tailor a number of other business practices in a way that makes defense more attractive to these firms. These templates would also undermine the comparative advantage traditional firms have from merely being able to comply with non-technical management regimes requirements. These new business arrangements could cover security, investment, auditing, testing, finance, and other regimes that have unique requirements not found in the commercial marketplace.

Concluding Thoughts: Barriers to Adopting a Time-Based Innovation Approach

This research has attempted to demonstrate that time to development and deployment of military capability has been increasing over the past 60 years and that this is linked to the increasing time it takes to perform management processes designed to oversee defense innovation programs. Based on the data presented, there should be little debate that existing management processes no longer allow for developments to proceed at the speeds that occurred in the early Cold War. However, understanding that there is a link though between time and process will not automatically lead to the ability to actually reform those processes and effectively implement recommendations to reduce time. Despite long standing complaints about bureaucratic procedures and the establishment of periodic workarounds to achieve limited time-based innovation objectives, the DOD innovation model has not been able to effectively attract new entrants, incorporate leading commercial technology and deliver capability faster on a larger scale.

Many reforms have been tried before. While the case examples identified in this study show that process changes can succeed in bringing back on a limited basis time as an innovation focus, they also demonstrate how easily they can be rolled back by advocates that continue to adhere to the existing management paradigm. Each new workaround to the existing management system has also had the unfortunate effect of adding further complexity by requiring approvals to implement any process exception or off ramp for innovation. The ability to implement any alternative time-based system and adapt new management regimes will continue to face significant barriers to change

To successfully reduce process time, it will be important to not only continue to better understand why those times have been increasing, but to address the difficulties in modifying these processes. While it is important as a first step to establish that managerial process and development times are linked, there is a need to proceed to the next level of analysis focused on the reasons for the staying power of existing management processes. Time to development can be thought of as a dependent variable to a collection of managerial process variables but there are several other variables and values that have impacted managerial process time and now serve as barriers to change. As future analysis proceeds to further levels of specificity, the identification and underlying reasons for management process rigidity may ultimately serve as enhanced explanatory variables as to why time to development will be difficult to reduce. Future areas of inquiry should focus on understanding why management processes are the way they are and what factors underpin the length of management process time. Many of the following observations are designed to not only identify areas for future research but also to highlight where policy makers will likely need to focus if reform implementation slows when meeting these barriers.

Within this study framework it has been proposed that a focus on other criteria such as cost, price, and systems analysis, particularly in the acquisition and budget regimes, have increased management process time implementation. Increasingly segregated, stand-alone management regimes have focused on these other than time criteria and values in a step-by-step manner over decades. A lack of an overarching criteria or centralized focus on time has allowed for the optimization of other values in each of the regimes that has resulted in the suboptimization of the overarching innovation process. This structure as it has evolved over the last 60 years offers the clearest explanation of the forces driving the managerial complexity that has overtaken the importance of time in development.

Still, there are likely other factors and barriers beyond the stove piping of processes, a systems analysis approach, and a value emphasis on cost and price that should be considered. Each may eventually offer additional explanatory benefits but will also create a more complicated theoretical model when trying to address change. It is likely there are a number of other causal effects that have either increased managerial process time, or perhaps now more importantly, serve as justification for maintaining the status quo. Ultimately, while time to development is now dependent on managerial process time, this process time is a likely a dependent variable to a collection of other factors and values. In the course of this review, several other theoretical explanations and additional variables were identified. These could be further explored and may underpin and explain some of the rise in time to development and managerial process time, but also to why it might be difficult to change these processes once they have been established.

The first of these factors addresses the perception of the threat. This variable should be a compelling force for change, but until there is an agreement of the nature of the threat it may be difficult to move away from the status quo. In the past, the realization of an impending threat has come later than was ideal (usually upon enactment of hostilities) and before changes could be made to the innovation system. This realization of the threat has been often too late given the lead time it takes to develop and deploy new weapons capabilities.

In the post-Cold War era, the threat has not been considered as existential as it was in the 1950s. Since that time, it has never been thought as compelling enough to argue for comprehensive process change, but as demonstrated in the case examples military innovation objectives could be achieved through ad-hoc measures. As the perception of the threat changed after 9/11, management changes to meet that threat were addressed at the margin by going around the management system. A similar framework of waivers and exemptions from management process has begun to be established in an attempt to address great power competition with China.

The increase in management process time over the last thirty years could be linked to a lesser concern about the threat in the post-Cold War period. Without a compelling threat-based need management processes could be allowed to focus on other values besides time leading to a longer time to development. While process time and time to market were already increasing in the 30 years prior to the end of the Cold War, this could potentially correspond to a perception in the relaxation of the threat through détente and arms control measures that began in the 1960s. This and the policy and political ramifications from the Vietnam War could have undermined the importance of time and allowed for the beginning of the rise of other oversight criteria to take its place. A minimalist industrial strategy would then have called for a shift in focus on sustaining innovation to keep the industrial base more as a hedge against a future increase in threat.

The second factor is the rise of complexity. As it has evolved, the management system has arguably become too complex to change. The accretion of complexity over decades has been furthered by oversight and budget reform cycles that are too compressed to allow for a complete reset to a previous baseline as occurred in U.S. history prior to World War II. The result has seen reform and counter reform cycles often linked to the rise and fall of the defense budget leading to a layering of new requirements and process complexity. Periodic efforts to streamline processes have been limited to a segment of one or two management regimes and have never comprehensively addressed the entire management system. Technological and engineering complexity addressing systems integration, new advances, and the protection of data and technology may also be factors in the stretching out of managerial process time.

Another issue are the many institutions that derive their current power and raison d'etre from the current cost based predictive management system. These institutions, including the Director of Cost Assessment and Program Evaluation (CAPE) in OSD and the appropriations committees, will find it hard to change as they either truly believe that the current system is correct or will not wish to give up their power to an untested system. The insights from academic work in bureaucratic politics could be insightful in addressing barriers to empowered actors not willing to cede power or pursue reforms.

The PPBS process gave the appropriations committees a ready-made tool to enhance Congress's constitutional power of the purse to better earmark expenditures, but it also empowered a centralized management approach emanating from the OSD comptroller and CAPE. Congress emulated this centralized controlling system in the budget regime by creating several independent organizations in other management regimes. These include the Director for Operational Test and Evaluation, the Undersecretary for Acquisition and Sustainment and Research and Engineering, the Inspector General, the Defense Contract Audit Agency, and Defense Contract Management Agency each of which exercises authority over the waning power of program managers that manage defense innovation programs.

Interest group politics is another area to study and address as not only do entrenched bureaucracies benefit from the current management system. Traditional defense contractors that gain advantage from CMI barriers that have been put in place will also resist change as will federal employee unions that oppose acquisition reforms that might jeopardize workload on old defense systems that by law need to be maintained by federal employees. There has been a degree of regulatory capture by special interests that will be difficult to dislodge. System and process complexity provides a cover for some of those benefits to accrue. Socioeconomic factors designed to enforce competition, fairness to bidders, and small business participation actually limit participation to those firms that can specialize in government contracting rules and be rewarded for compliance with process. As a result, Silicon Valley start-ups are not a significant part of the defense industrial base. Buy American legislation, security requirements and immigration controls all favored by various interest groups limit the participation in defense innovation from our allies. This rejects the immense history of the technological inflows that occurred during World War II and the early Cold War that helped drive U.S. defense innovation.

Another important factor that may underly the rise in new management process is the declining public trust in government that the Pew Research Center has been documenting since 1965.[256] The public perception of defense innovation efforts has been impacted by a view in Congress that the defense budget is plagued by fraud, waste and abuse, industry profiteering, and programs that fail to meet cost, schedule and performance measures. While many of these arguments have been used to support past cuts to the defense budget, there is a complementary narrative that arose since the 1980s about the wastefulness of non-defense programs. The result has been

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[256] Pew Research Center "Declining Trust in Government: 1958-2019" Retrieved from: https://www.pewresearch.org/politics/2019/04/11/public-trust-in-government-1958-2019

a decades long competition to discredit the effectiveness of any expenditure of public money on innovation and to ratchet up managerial oversight measures. It is perhaps not surprising that the public has come to believe that the government is broken and inadequate. Somehow the cycle of adding complexity to the system upon the latest case of fraud, waste or abuse, real or imagined, needs to be broken. Rather than creating new processes that disincentivize risk, innovation and results-based solutions, the effectiveness of the legal system to prosecute real fraud and abuse in the small number of cases that occur using already sufficient existing authorities should be enhanced. A much harder discussion will need to be had on research and experimentation when the results do not lead to immediate success.

Finally, a further factor discussed in this paper are embedded historical values that have not always rewarded innovation. These values include: a desire for centralization, control and security; an aversion to private sector profits, initiative, ideas, and investment; the need for aaccountability enforced by government unique standards; full and open competition; and a preference for the lowest price. Predictability and the prevention of cost overruns is a value adopted by Congress but ironically the fixes put in place to address cost overruns oftentimes ensure their creation. Many of these values and the processes to address them grew up in the Cold War and in another irony the success of "winning" the Cold War may have led to an unwarranted belief in the success of these legacy values and management processes. If they worked then, in the sense that they were in place when we outlasted the Soviet Union, there may be little incentive to change the system. While this system might have not impaired competing against an adversary held back by the weaknesses of its economic and political system, it may be unlikely to be of much use in different circumstances.

While difficulties in change management have been often attributed to culture, there are multiple countervailing currents working against a cultural adoption of prioritizing time to innovation over other values and providing incentives to change management processes. Still, as a practical manner, any change to a time-based innovation system will require a realization and a consensus by leadership and those who execute innovation programs on a need to change culture and values.

First, senior leadership and those who implement the management system need to understand why adopting a time-based innovation system is so important. There is a need for not only leadership buy-in and support, but also for bottom-up execution and to be the source of continuous new ideas. This awareness and understanding needs to occur particularly at the Congressional, DOD, and executive branch/OMB leadership level, as this is where most of the potential barriers to adopting a time-based innovation system will initially reside. Once that leadership backing has been achieved the next step will be to focus on training of the oversight, budget, and acquisition workforce on time-based defense innovation practices and alternative value measurement beyond cost and price comparisons.

These communities will be key because even when buy-in occurred, as it did with FASA in 1994 with both congressional and DOD looking for new innovation approaches, the biggest barrier to achieving a time-based innovation process continued to reside in the contracting and oversight workforce. Values, personnel training, and political incentives will need to change before any move to time-based approaches can be successful on anything beyond a minor scale. The cost-based and price-based culture that is embedded in the workforce will be very difficult to overcome, as witnessed by the continuous pushback by the contracting community on FAR part 12 commercial item reforms of the past. In addition, the oversight communities have been trained and wedded to evaluating current acquisition programs based on cost and price criteria that is not readily conducive to a time-based approach.

However, it is vital for these communities to understand the inherent need for speed to compete against China. This will be all about culture change and the acceptance of new values and a prioritization of those values. This will be extremely difficult and there will be a large need for training and leadership direction to address any such culture change.

There is a longstanding fear in not only these communities but the budgeting and acquisition communities that experimentation and testing that is not successful will be seen as wasteful by Congress and an excuse to slash budgets. Training the next generation of the workforce away from process to agility and in new definitions of what is wasteful or not will be important, but equally important is what the appropriations committees, CAPE, comptrollers and OMB do and think. Criteria will be important. There will likely be a need for greater oversight of the overseers in the future. Congress and the executive branch need to understand and agree on what criteria is being used for evaluation and the measures of success. While there may be a need for organizational changes, it is more important to get overarching agreement by the many interested actors on evaluative criteria before the system could effectively move from a more predictive cost-based model to a more time-based risk and value-based model.

But it is not just about the oversight and contracting community. The military itself will need to adopt a new way of thinking and debate where the use of time in innovation fits in to what is termed its DOTMILPF (Doctrine, Organization, Training, Materiel, Leadership and Education, Personnel, Facilities and Policy) and reinforce this in its officer training programs such as the Joint Professional Military Education program. To be successful, the military may need to look at its promotion process to ensure it does not unnecessarily weed out officers who may be future General Schrievers and Admiral Rickovers that can lead time-based innovation efforts.

Perhaps more importantly, military officers will need to become less isolated from business and commercial technology. Eventually, the demand signal and constant feedback from the military operators will be crucial and the hoped-for engagement by the Service Chiefs now back in the acquisition chain will encourage not only an operator embedding in the innovation process but a restoration of a longer tenured military program manager authority over many of the current management stovepipes.

It will first be necessary for these communities to want to change – the military, Congress, and the implementation and oversight bureaucracy. Then there will need to be an agreement on the nature of why it has been so hard to make management change. This will need to be critically thought through and addressed.

These are not easy hurdles to overcome and a time-based system will likely have to come to an accommodation with all of these potential barriers that will lead to less effectiveness of the time-base system. The first step is to identify that there is an alternative that once worked in a different and better way. The next step is to build the compelling case of why changing to this alternative is needed. In many ways, this is similar to the challenge that Roosevelt faced prior to WWII, or that Eisenhower and Vannevar Bush faced in maintaining the WWII innovation system in the early Cold War. The system can change when confronted with a specific threat and can implement the correct policies. The key question will be how much lead time is still needed and available to implement those policies. There is an urgency given shifts in power, capabilities, and threats to begin to address some of these issues. Will DOD be successful? Only time will tell.

Appendix A

MANAGEMENT REGIME DESCRIPTIONS

In Table A-1 several management regimes that are critical to defense innovation are identified. Of these regimes, four have the most significant direct impact on the time it takes to deliver military capability: requirements, budget, acquisition, and contracting regimes. In addition to contracting, the finance and accounting, security, information management, and oversight regimes, while also having a time impact, have been most responsible for barriers to CMI and the participation in the industrial base by those firms that specialize in agile development. Science and engineering, personnel, and maintenance and logistics regimes while supporting regimes can also directly impact time and CMI. A greater connection between the regimes of the defense innovation system and the operators or operations regime could positively impact on the effectiveness of solutions. How all of these regimes are organized to interact with one another can be classified as a regime in itself. Much reform over time has been organizational in nature as a way to try and address conflicts and encourage better working relationships between management regimes.

Table A-1: Description of Management Regimes Important to Defense Innovation and Industrial Base

	CMI Impact	Innovation Time
Requirements (strategy, policy, intelligence)	X	X
Budgeting	X	X
Acquisition Program Management	X	X
Contracting	X	X
Finance and Accounting	X	
Security	X	X
Oversight	X	X
Science and Engineering	X	X
Personnel		
Maintenance and Logistics	X	X
Information Management	X	
Operations		
Organizational		

Requirements: The requirements regime addresses how the government determines what it needs to develop or buy. The process for this can be formal or informal, but several steps are required. The first is awareness. This requires both intelligence to understand the threat and technological or market research to understand what alternatives can be developed to meet the threat. This awareness, combined with a strategic and policy focus, provides insight into how a new technological solution or capability might shape the balance of power or an adversary's reaction, which helps inform the determination of a need.

After the government determines a general need, it must make a more refined determination of how to meet that need. Should, for example, the solution be a missile, manned aircraft, or unmanned underwater vehicle? More clearly defined requirements may be needed to determine what a potential solution needs to do to meet that need, for example, travel 800 nautical miles, perform its mission, and then return to base. A separate requirements process can be referred to as the technical requirements process and, in this case, there will be a focus on standards and specifications that any solution should meet. For instance, these types of requirements might cover the quality of steel, tolerances, or the security of a contractor's information management systems. Technical requirements, standards, and specifications are placed in the contract and are linked to the contracting regime for implementation.

Factors impacting the industrial base's willingness or ability to compete for any solution identified by the requirements process include:

- Is the requirements process long and cumbersome?
- Do the requirements take into account what the commercial market has already done or what been produced elsewhere?
- Does the process rely on unique technical requirements and specifications that are geared to past military specific solutions?

In principle, the threat should drive the requirements process, but this process could develop bureaucratic rules and outcomes not related to the threat, such as in cases of so-called logrolling of services requirements designed to justify current force structure. Requirements instability and requirements changes can be key contributors to failed acquisition programs. Finally, the time it takes to enter and exit the requirements process is a factor to consider in delaying innovation outcomes.

Each of the U.S. military services has its own separate requirements process and the current joint requirement process is called the Joint Capabilities Integration and Development System (JCIDS), overseen by the Joint Requirements Oversight Council (JROC). Key events in the development of the requirements process include the establishment of the predecessor of the JROC the Joint Requirements Management Board in 1984 and in 1992 the creation of the Requirements Generation System that would be replaced in 2003 by the JCIDS process. Legislative modifications occurred to the JROC on the FY 2017 National Defense Authorization Act to decentralize some requirements back to the services.

Budget: The budget regime is the policymaking process that determines what the government wants to spend its resources on. The budget process impacts innovation by the choices that are made, the level of instability driven by changing planned levels of funding over the course of a project, and by the time that it takes to implement the process. Expansive needs identified in the requirements process will add up to nothing if resources are not allocated to meeting that need, but if these processes are conducted in a serial fashion, the time it takes to initiate the start of a program to deliver innovation will be constrained by the combined length of these two processes.

The process for the allocation of resources to develop defense capabilities can be complex and detailed or simplistic and allocated in lump sums by mission, function, capability, organization, or program. As in all resource allocations processes, resources are scarce and alternative choices need to be made. Of a nation's economic resources, only part will go to the government and within that, a decision needs to be made as to what is allotted to defense. Within the overall defense budget number, distribution decisions need to be made to allocate funding by organization, mission or program, and possibly further subdivided into defense production, research and development, supplies, services, maintenance and personnel, with additional classifications within these functions. More specific apportionment designed to manage cash flow between various lines of effort within larger categories needs to be made and then a process developed to address unspent or unobligated funds to move these to potential higher priorities – or not. The rules for how this is done has a significant bearing on what can be developed and the time that may take.

The relative size of the defense market as determined by the budget process relative to other markets is an important factor in commercial company participation. Another factor impacting industry participation is consistency in budgeting. A history of budget instability or unkept funding promises may impact any assessment of a firm as to whether to enter the market. Did the agency or program receive its requested budget from Congress and if not, what was the difference each year? Were funds late to arrive, such as when budget agreements are not made on time and the government operations under a continuing resolution and, if so, how did that impact the revenues and profitability of firms that had already entered the market?

The current DOD budget process is called Planning, Programming, Budgeting, and Execution (PPBE) that was established in 1961 and was then called the Planning, Programming, Budgeting System (PPBS). It is DOD's contribution to the Presidential budget process that is ultimately approved or adjusted by the congressional appropriations process. The ability to move funds within or among budget categories is called the reprogramming process and, depending on the threshold or whether a new program is being initiated, may trigger congressional notification or approval, which further impacts time to development.

Acquisition and Program Management: The processes that governs and oversees how capabilities are developed and managed is the acquisition and program management regime. This is the regime that attempts to bring together representatives from several of the other regimes and coordinate them all to a common purpose of developing a weapons system. The processes to do this can be highly regulated and compliance-oriented, government-unique, or based on widely accepted commercial practices. Compliance costs are important factors that influence the industrial base while time to implement these processes impacts the rate of innovation.

The formal acquisition process, as evolved in the U.S. and mirrored in many other nations, is a very time-centric enterprise breaking down the steps of innovation into components often linked to budget categories and different "colors of money" embedded in research and development spending or that is distinctive from procurement or operations dollars. Thus, one allocates budgeting resources based on whether they are to be used for basic and applied research, early prototyping and technology development, advanced development, advanced prototyping, low-rate initial production, production, operations, and maintenance, and finally the disposal of an asset. There can be a large degree of linearity by implementing each of these components in a serial fashion on a defense program or one could conduct several functions in a concurrent fashion in an attempt to move faster. This process is built around the systems engineering process described below, which has also developed in a linear fashion. Whether the linear engineering and acquisition process grew up around the budget process or the budget process conformed to the engineering and acquisition process of the 1960s is an open question, but having these categories locked in the budget process makes it difficult to change other processes.

The current defense acquisition and program management process is outlined in a series of DOD Instructions known as the 5000 series. The first is DOD instruction 5000.01: The Defense Acquisition System and the second is DOD Instruction 5000.02: Operation of the Defense Acquisition System. Established in 1970, the 5000 series have been rewritten many times with the latest revision occurring in October 2020. Responsibility for acquisition programs has followed a path of centralization of responsibility up until 2016 when it began to be decentralised to a degree back to the military services.

Contracting or Public Procurement: Once a government entity decides through a "make or buy" decision that, rather than federal governmental personnel providing a solution, it should be contracted out to the private sector, an innovation effort has entered the contracting or public procurement regime. Public procurement or contracting is the process of buying goods and services from the private sector.

Contracting regimes provide the overarching framework underpinned by legal and regulatory rules of how the government buys goods and services. These laws, regulations, and policies ultimately determine the nature of the industrial base that will support our country's national defense.

The contracting regime level is the starting point for the essential rules that a private sector firm must master to compete for and win a defense contract. As such, these rules are the determining factors of who will bid on these contracts and how the industrial base will evolve to meet the government's needs. The terms of a contract can determine the level of profits, cash flow, and other incentives that private firms must consider before deciding to invest in the defense sector. If the acquisition rules create too high of a barrier to entry, firms will make a rational business judgement to steer clear of government contracting, leaving the market to those companies choosing to specialize in the arcane rules of the government. The rules of the contracting system have, for the most part, set the framework for whether a private sector entity will bid on a defense contract or successfully obtain one.

Several values can guide the contracting regime, such as competition and fairness to ensure that there is an equal opportunity to bid for a contract. Another important factor is ensuring the government is paying a fair and reasonable price, as is validating that the government is receiving quality goods and services and value for its money. Factors to implement efficiency, effectiveness, transparency, and socioeconomic values and goals can be directed in a contract. Other values important to other management regimes, such as mitigating conflict of interest of personnel or enforcing security concerns, have often used the contracting regime to enforce compliance with policies emanating from those regimes. To achieve the desired benefits from each of these values is an imposition of an implementation cost in either time, an increase in price, or forgone opportunity or innovation, by constraining the number of vendors who can comply with the regime requirements that to implement those values.

U.S. contracting rules are contained in the Federal Acquisition Regulations (FAR), the DOD supplement to the FAR known as the DFAR, and various policies, executive orders, and agency memoranda. Congressional direction for defense contracting usually occurs in Title VIII of the annual National Defense Authorization Act (NDAA), but also in various appropriations bill and general government management laws.

Finance and Accounting: The finance regime comprises the accounting processes required whenever the government spends taxpayer dollars. On the government's side of the contract, the government itself needs to have a financial system to track expenditures and revenue. In addition, the contractor that receives government money will also need to have a finance and accounting system to ensure that any government payments have been properly spent and accounted for. The finance system in the government could be focused on how outlays and expenditures from appropriations bills are managed, or it can be focused on a listing of assets and liabilities such as required under the Chief Financial Officers Act of 1990. A governmental finance system could also be focused on the actual costs that the government is expending under some type of managerial accounting scheme.

On the contractor's side, this accounting can be done in accordance with how securities laws or the private market imposes requirements on companies to allocate revenues and costs, or the government can require the development of a unique financial accounting system enforced by the contracting regime. The current U.S. governmental requirements to conform to the Cost Accounting Standards (CAS) is an example of a system created to measure the actual cost used to implement a cost-based reimbursable government contract. Firms need to look at the incentive structure of the governmental finance system to determine if they are capable of complying with these requirements before receiving a contract and also the costs of such compliance. Many commercial firms have made a business decision to not bid on a government contract that would trigger CAS compliance or, if they do, to create a separate business unit with a different accounting system. Thus, the finance system can impact the industrial base but it can also impact time, while waiting for a contractor to develop an accounting system that is CAS-compliant before beginning work on a contract.

Oversight: To ensure that management regimes are implemented properly, a system of overseers who audit, test, or check on the implementation of these regimes has been created over time. Oversight can be a cooperative exercise conducted with a light touch to gain insight and to provide alternative suggestions from experienced "old hands." It can also be an adversarial and risk-averse process deteriorating into a "checking the box" compliance activity that is conducted by individuals with little experience in the area being audited or reviewed. At its worse, it can be a source of detailed, duplicative micromanagement that diffuses accountability and responsibility. At its best, oversight can be the source of valuable management information and ideas that can save the government time, money, or enhance mission effectiveness. The quality of oversight agency personnel as well as the criteria that they base their evaluations on are extremely important factors in the impact oversight has on innovation efforts. The criteria used to evaluate compliance (which usually exists in other regimes rules) can either enhance or negatively impact time or the nature of the industrial base to continue to work on government contracts. Congress, in its responsibility for the oversight of the use of federal funds, relies to a great degree on the work of audit entities to support legislation and oversight.

The GAO, DOD Office of the Inspector General, service audit agencies, Defense Contract Audit Agency, Defense Contract Management Agency and Director, Office of Test and Evaluation are examples of oversight agencies that help regulate the U.S. defense innovation system.

Security: This regime is the result of being in a national security defense environment, but all commercial and other governmental entities will need some sort of security component to conduct operations. The need to secure and ensure that adversaries are not stealing or sabotaging one's defense technology or equipment is something that has long been an issue of concern to defense managers. Several types of security systems become important. Data or information is the first level of security and a determination needs to be made on what data is needed to be protected and at what level of security differentiation. This has led to a system of security classifications such as unclassified but sensitive, confidential, secret, top-secret and above. It also gives rise to the need for a process to control how such data is stored and where discussions or manufacturing using such information can take place. In the physical world, this relates to building security and safes to lock up and store paper-based information. In the cyber world, information systems security standards and practices will be needed and required.

The next system relates to personnel. Can you trust people and firms to access such data? What is the process to grant and maintain some type of access to information or security clearance to show that level of trust? A third type of security system relates to relations between one country and another and whether countries can share data and technology, either at a government-to-government level or at the industrial level. This is usually administered through an export control process that governs military goods and services and also dual-use technologies and knowledge. Finally, security processes regulate investments of foreign entities or individuals who could potentially gain access to security data and technology through those investments in another country. Each of these security processes can influence the kind of private entity that can bid on defense contracts – but also can add time for compliance.

The U.S. has a security classification and review process administered by the Defense Counterintelligence and Security Agency. Export controls for military items are regulated by the State Department under the Arms Export Control Act and administered through the International Trafficking in Arms Regulations, for dual-use items by the Commerce Department under the rules of the expired Export

Administration Act now administered under the authority of International Emergency Economic Powers Act and the Commerce Control List. Foreign investment is regulated by Committee on Foreign Investment in the United States under the Defense Production Act (DPA).

Science and Engineering: This regime relates to the type of engineering process that would be used in creating new capabilities, the process of determining technology maturity or technology readiness levels, and how scientific and basic research supports developing innovative capabilities. If the government mandates the use of certain engineering processes, or in the requirements process requires certain standards, technology, or specifications, then engineering regimes are very important to the success or serve as barriers to innovation.

Systems engineering process and the adoption of the linear waterfall engineering process can impact acquisition and program management regimes time parameters. Agile engineering methods can reduce time, but ultimately time to innovation is a science and engineering process. Mandating a certain engineering process will set not only time constraints, but also limit the industrial base. For example, a software developer who specializes in agile development may not be interested in or prepared to implement the compliance documentation necessary to comply with a waterfall software process. Most of these impacts will be subsumed in this analysis under the acquisition and program management regimes but it should be recognized that this is an important regime to overall outcomes.

Personnel: The personnel regime is the framework for obtaining the quality and quantity of the workforce that supports the governmental regimes that enable innovation. Issues related to the incentive structure of maintaining engineering talent both in the government and private sector are critical in personnel policies. How to acquire the right level of qualified and non-conflicted personnel to meet a government need has been a historical challenge. Governmental personnel rules impact the quality of government workers, while how the government chooses to reimburse contractors can impact the quality of contracting personnel by, for example, imposing a salary limitation on reimbursement for private sector engineers.

Conflicts of interest from the government or industry in decision-making has been a longstanding personnel issue to mitigate. These conflict-of-interest issues reach into aspects of civil service reform, the unionization of the federal or private workforce, the backgrounds of political appointees, and the oversight of defense contractors that can be enforced through the contracting regime. Organizational conflict of interest rules have been developed to address potential conflicts from those individuals and entities that advise the government. Ethics rules have also been created in statute, such as the Procurement Integrity Act, and in regulations to address conflicts of interests or appearances of conflicts of interest when managing or executing a contract.

Maintenance and Logistics: Whenever a government develops or buys a capital asset it will be expected to maintain that asset. How it chooses to do so and what processes are put in place can be barriers or enhancements to innovation. The government may choose to conduct maintenance itself in a centralized government-owned facility or it may rely on contractors. Policies vary for certain types of maintenance, such as the difference between major overhauls or depot maintenance and preventative or operational maintenance.

When the government wishes to maintain a system, it may need a process or system of technical data rights from a contractor, enforceable by the contracting regime, to ensure it has the knowledge to maintain the system. If it relies on contractors for maintenance, the government needs to determine whether it wants to have only the original contractor that built the item also maintain the system or – if the government owns the data rights – give that data to other contractors to compete for the right to maintain that system. The maintenance regime primarily places limitations on private sector calculations on downstream profits and revenues that impact decisions on whether to enter the market or not. How long the government plans to keep an asset will impact the time and innovation cycle of future upgrades or new technologies. There is little incentive to create a new disruptive system if plans call to keep an asset and maintain it for 50 years. The industrial base, both private and governmental, adjusts to that eventuality and even an increase in threat level may not be enough to generate new innovation to replace legacy systems. The maintenance of U.S. systems by law is evenly split between public sector and private sector performance and there is a requirement for the public sector to have a “core” maintenance capability to be able to maintain all weapon systems.

Information Management: This regime regulates how information and data is used, shared, and stored. Information management systems support other management regimes and operational systems. How information will be used and secured is important in determining underlying requirements. Unique information technology standards will increase compliance costs that could impact company participation in the industrial base and time. Many of the information standards that will influence whether companies participate in defense innovation are implemented and enforced through the contracting regime, but established through the security regime. Complexity and any information standards differences from the commercial market will require unique governmental processes and create time and compliance issues. Late adoption of commercial standards and products could negatively impact innovation. Information management was once centralized at the Office of Management and Budget and the General Services Administration. This was decentralized at least for procurement purposes back to DOD in the Clinger-Cohen Act of 1996.

Operations: There is often a disconnect between those that actually use whatever capability is created out of the defense innovation system. Operators are often the last to know about what is happening in an acquisition program after the setting of the initial requirement. The operations regime, other management regimes responsible for overseeing innovation, and the industrial base should be working together if innovation is going to effectively support defense operators. Without a feedback loop between users and producers that documents how capabilities are working can be a major issue in the success or failure of defense innovation system. A problem in regime management is the concept of "stove-piping", in which each regime operates to maximize its own benefits to the exclusion of all other regimes. In the absence of a feedback loop from the operators and users of a system, there is a risk that management regimes will self-optimize and deliver something of marginal or very little use to the operators – in a time period that is irrelevant to effective use. Time to deployment and the quality of innovation are important to the operators, but if the end-product is not useful or inadequate, the benefits of whatever value the other management regimes are achieving becomes questionable.

Organizational: Finally, as issues with the role of operators illustrate, how all of the management regime pieces fit together organizationally to execute and oversee defense innovation is a critical component. The various authorities, power, and degrees of autonomy of actors within each of the regimes can determine which regime dominates, or whether the system degenerates into an inefficient balance of power structure that is created between the various regimes. Stove-piping of authorities and whether processes are concurrent or linear can be influential as well as the process for solving conflicts between management regimes. Coordination between regimes impacts innovation time, but the process of coordination can lead to sub-optimal decision making.

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