Managing US Defense Acquisition

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Management in government differs fundamentally from private sector management, the more so in defense, which differs from other US government missions in that very large sums are spent on high-technology systems and equipment to meet the unknowable contingencies of an uncertain future. Because of technological complexity, the difficulties of program selection, contracting, and oversight exceed those in other parts of government. An underappreciated set of problems aggravates these difficulties, notably a lack of metrics for assessing the performance of military systems. In the absence of such metrics, and given the elastic meanings attached to national security, civilian officials have been unable to exercise effective oversight of defense acquisition, leaving discretionary choices by military leaders largely unchecked. For such reasons, common prescriptions for acquisition reform, such as adoption of "proven business practices," are unrealistic. Meaningful reform would begin by increasing the influence of civilian officials over acquisition decisions and reducing that of the armed forces.

Year after year and decade after decade, critiques of the programs through which the US Department of Defense (DoD) develops weapons and related systems (e.g., for communications, surveillance, and intelligence) identify the same set of problems: cost escalation; schedule slippage; unstable and unrealistic design objectives; overly optimistic forecasts of future technological capabilities. The consequences include systems and equipment that may fail to perform as advertised even after extensive postproduction design modifications.

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The issues are systemic.They have never been addressed effectively because the root causes have not been fully apprehended.

The analysis in this paper finds two fundamental causes for the pathologies of acquisition. (In DoD terminology, acquisition includes both R&D and procurement, or production.) The first cause, rivalry within and among the armed services, has received much attention over the years. The second, lack of practically useful methods for judging the military effectiveness of existing and proposed weapons systems, has gone largely unrecognized. In the absence of such methods, the Army, Navy, Marine Corps, and Air Force put forward proposals for new weapons with the claim that they reflect military necessity. Many of these proposals emerge through opaque processes within the particular service, reflecting intraorganizational politics, adding to difficulty of assessing claims. The first step in reform should therefore be to reduce the influence of the services over major acquisition decisions.

Given the technological complexity of modern military systems, the paper approaches acquisition from the standpoint of innovation. Following a brief introduction, it opens by comparing technological innovation in military and commercial spheres. The third section highlights the very demanding technical goals of major acquisition programs, an imperative traced in the fourth section to the experience of the Korean War. Two following sections compare major investment decisions in private firms with those in DoD, focusing on the limitations of the systems management ideas adopted by the Pentagon in the 1960s. The paper ends by considering acquisition reform.

Introduction

Over the first decade of this century (2001–2010), the Department of Defense (DoD) spent $1.55 trillion on acquisition, $637 billion of that for R&D (or RDT&E, i.e., research, development, test, and evaluation) and $914 billion for procurement.[1] (These totals exclude spending by non-DoD intelligence agencies, the Department of Homeland Security, and the defense programs of the Department of Energy.) Projected fiscal 2013 outlays, down somewhat over the recent past with the end of US fighting in Iraq, total $72 billion for RDT&E and $125 billion for procurement.

What the Pentagon terms major programs account for the bulk of technology-related spending. Major programs are those expected to cost at least $2.19 billion in fiscal 2000 dollars (originally $1 billion

1. Office of the Under Secretary of Defense (Comptroller), *Budget Estimates for FY 2013*, table 6–11.

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in 1980 dollars) or, for programs consisting only of RDT&E, $365 million (originally $200 million in 1980 dollars). In recent years, DoD has typically had seventy-five to one hundred major programs underway. Military officers detailed by the responsible service manage nearly all of them. Major programs often incorporate highly demanding new technologies. The F-35 Joint Strike Fighter, for example, flies with aid of 25 million lines of software code; the Marine Corps version must be able to hover and to land vertically. This $400 billion program began in 1996 with a unit cost target of $28 million; by 2012, cost estimates had reached $160 million per plane. DoD plans to buy nearly 2,500 F-35s.

Four decades ago, RAND, a nonprofit analytical organization advising DoD, reported that

> High system cost and cost growth appear to arise primarily from efforts to subdue difficult technology on highly compressed schedules and an apparent willingness to pay what is required to insure satisfaction of original (or even expanded) system performance goals. Another obvious and important contribution is the customer acceptance of optimistic assumptions about the long-term predictability of technology and the cost of coping with it.[2]

In 2010, the head of the Government Accountability Office (GAO, formerly the General Accounting Office) told an audience at the National Defense University that

> programs continue to take longer, cost more, and deliver fewer quantities and capabilities than originally planned. Why does this happen? It is because at the program level, programs are begun and continued without enough knowledge about system requirements, technology, and design maturity. Lacking such knowledge, managers rely on assumptions that are consistently too optimistic, exposing programs to significant and unnecessary risk, and ultimately cost growth and delays.[3]

Critiques such as these from RAND and GAO, along with findings by numerous ad hoc groups, repeat in seemingly endless refrain. Their basis lies in studies of public administration and managerial economics. Leaving aside a few reports by the Defense Science Board (DSB), technology receives mostly superficial treatment, as illustrated in the quotations above. Because sensible application of managerial tools depends

2. Perry et al., *System Acquisition Strategies*, 39.

3. Dodaro, *Maximizing DoD's Potential to Face New Fiscal Challenges and Strengthen Interagency Partnerships: Presentation to National Defense University*, 7.

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on understanding the particulars of complex military systems, this essay begins instead from the perspective of technological innovation.

Innovation, Military and Commercial

Social scientists, policy analysts, and media commentators explore commercial innovation because of its significance for business outcomes and, through these, for economic growth and competitiveness. The literature on military innovation is thin by comparison. Much work on civilian industries, such as microelectronics and pharmaceuticals, examines interactions between business strategy and technology development. By contrast, few studies of military innovation pay even superficial attention to technological specifics. Case studies of weapons programs have commonly emphasized bureaucratic politics.[4] While Stephen Rosen's *Winning the Next War*[5] provides a wide-ranging account of innovation and adoption, it addresses institutional and organizational issues almost exclusively. The edited volume entitled *Military Innovation in the Interwar Period*[6] includes a set of excellent case studies, broad, deep, and comparative across nations, again with little to say about technology. Donald MacKenzie's *Inventing Accuracy*[7] remains unique in giving fine-grained attention to both technical and political-organizational issues. The authors of *American and British Aircraft Carrier Development*[8] provide a broader, and exemplary, analysis of the interplay of national strategy, technological alternatives, and organizational politics over several decades. Substantial literatures also discuss the defense industry and the "military-industrial complex"; much of this work was undertaken in the 1970s and reflects the preoccupations of the time.

Recent accounts of innovation in the civilian economy—the creation, commercialization (i.e., marketplace introduction), and diffusion of new goods, services, and organizational practices—commonly embody perspectives associated with Joseph Schumpeter and the phenomenon he described of "creative destruction," in which newly produced goods and services sweep away their predecessors.[9]

4. In addition to work cited subsequently, early examples include Davis, *The Politics of Innovation: Patterns in Navy Cases*, and Armacost, *The Politics of Weapons Innovation: The Thor-Jupiter Controversy*.

5. Rosen, *Winning the Next War: Innovation and the Modern Military*.

6. Murray and Millett, eds., *Military Innovation in the Interwar Period*.

7. MacKenzie, *Inventing Accuracy: A Historical Sociology of Nuclear Missile Guidance*.

8. Hone, Friedman, and Mandeles, *American and British Aircraft Carrier Development, 1919–1941*.

9. Schumpeter, *Capitalism, Socialism and Democracy*.

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Schumpeter emphasized the uncertainty that accompanies technological change, resulting in frequent business failures among would-be innovators. Aware of such possibilities, established firms may hesitate to pursue innovation-centered strategies for fear of harming established product lines. Military organizations, similarly, may resist innovations that could endanger existing missions, capabilities, and self-images. The US Air Force was famously reluctant to embrace ballistic missiles, which threatened its core mission of long-range bombing. Air Force leaders moved just fast enough to keep the Army and Navy from encroaching on the budgetary favor enjoyed by the Strategic Air Command (SAC). "Manned aircraft were continually promoted over the missile competitors on grounds of cost, trustworthiness, efficiency, and capability. On the other hand, missiles were generally admitted to be a potentially useful weapon for the future—but a future placed far enough ahead to be meaningless."[10]

The contrast between DoD spending on RDT&E and private business spending underscores, as no disquisition on the technical details of particular systems could, how strongly the military services push on technological frontiers. At the time of the Korean War, DoD began budgeting larger sums for RDT&E, and the ratio of RDT&E to production rose toward 50 percent and sometimes above—well above in later years—as figure 1 shows. (Lower RDT&E-to-procurement ratios since 2005 do not reflect significant decreases in RDT&E; rather,

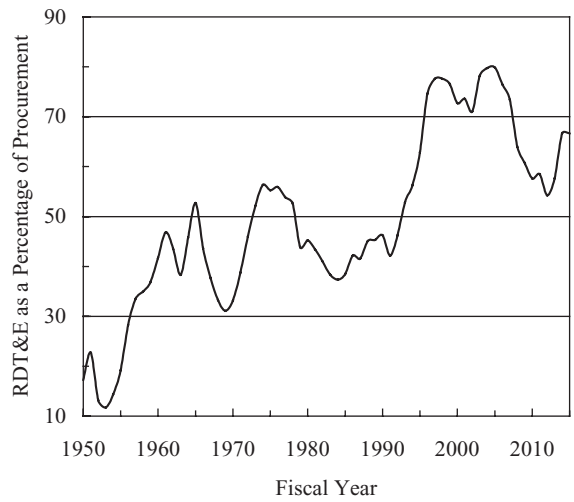


Figure 1 RDT&E Relative to Procurement. Note: Outlays. 2011–2015 estimated. Source: Office of the Under Secretary of Defense (Comptroller), *National Defense Budget Estimates for FY 2013*, table 6–11.

10. Beard, *Developing the ICBM: A Study in Bureaucratic Politics*, 167.

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procurement has grown to replace equipment lost or damaged in Iraq and Afghanistan.) By contrast, US firms across all industries allocate an average of 3.5 percent of revenues to R&D.[11] To be sure, the DoD ratio is not directly comparable, for reasons beginning with different accounting conventions. Yet even in high technology sectors, such as biotechnology, companies rarely spend more than 15 percent of sales on R&D. DoD technology development is sui generis.[12]

Business firms centralize major investment decisions in managerial hierarchies, including the decisions most like those on DoD RDT&E and procurement—spending on product development and production capacity. In the US government, not excluding the Pentagon, centralized decision making and clear-cut hierarchies are hard to find. DoD's military and civilian hierarchies are joined only at the top. While at the highest levels civilian control of the military remains unthreatened, it exists alongside the well-honed ability of the armed forces to frustrate policies regarded by the officer corps as inimical to the interests of their service or service branch. Within the armed forces, at the same time, "there will *always* be the potential for tense intracommand and interservice relations at the most senior leadership levels simply by virtue of the fact that the top echelons ... are populated by smart, strongwilled, and opinionated people."[13] Private firms too "are populated by smart, strongwilled, and opinionated people." But senior managers in the private sector have organizational power to command, coerce, or manipulate those in lower-ranking positions, within and across divisions, greatly exceeding that available to civilian officials in the US government.

Early in the nineteenth century, the Army and Navy (to which the Marine Corps is administratively attached) won the right to control their own procurements. Within the services, messy struggles between supply bureaus and command authorities became the rule.[14]While post–World War II policies weakened the power of the supply bureaus, internal conflict hardly disappeared, as a number of detailed case histories illustrate.[15] The big change, nonetheless,

11. National Science Foundation, *Research and Development in Industry*. About four-fifths of DoD RDT&E dollars flow to private firms; including federal funds with self-financed R&D raises the average to 3.8 percent of revenues.

12. Alic, *Trillions for Military Technology: How the Pentagon Innovates and Why It Costs So Much*, especially 150–88.

13. Lambeth, *Air Power Against Terror: America's Conduct of Operation Enduring Freedom*, 311.

14. Koistinen, *Beating Plowshares into Swords: The Political Economy of American Warfare, 1606–1865*.

15. Haworth, *The Bradley and How It Got That Way: Technology, Institutions, and the Problem of Mechanized Infantry in the United States Army*; McNaugher, *The M16 Controversies: Military Organizations and Weapons Acquisition*.

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was the rise of interservice competition for budget dollars after 1947, as the newly independent Air Force joined the Army and Navy within a single department. Also in 1947, Congress provided a statutory basis for the Joint Chiefs of Staff (JCS), although declining to give it meaningful authority. Further legislation in 1949 created the position of Comptroller within the Office of the Secretary of Defense (OSD), in emulation of managerial structures in private corporations but without giving OSD and the Comptroller significant new authority over service spending. Then in the wake of national embarrassment caused by the first Soviet Sputnik flights, for which duplication of effort among competing rocket, missile, and space programs managed by the Army, Navy, and Air Force took much blame, Congress added another high-level civilian position within OSD, the Director of Defense Research and Engineering (DDR&E), tasked with coordinating technology development by the services.

When Robert S. McNamara became Secretary of Defense in 1961, a few weeks after completing his rise to the presidency of Ford Motor Company, he sought, far more aggressively than his predecessors, to utilize the powers available in principle to DoD civilians. McNamara instituted a series of administrative procedures, such as the well-known Planning, Programming, and Budgeting System (PPBS), that drew on practices widespread in private industry. Many of these practices had already been introduced and adapted to defense under the guidance of civilian analysts, notably those employed by RAND, a nonprofit that had been advising the military since the late 1940s. McNamara gave these practices new visibility and with a strong and consistent push from the top insisted that they be treated as integral rather than incidental to defense planning and budgeting. The armed forces resisted, just as they had resisted efforts going back to the time of the Civil War to increase civilian control over acquisition. The basis of their argument has been consistent: choice of weapons must rest with the professionals who may have to fight with them; while civilian officials might set the "top line" of service budgets, they should have little say over the allocation of acquisition funds. Despite this opposition, the methods introduced during McNamara's tenure, including PPBS (now the Planning, Programming, Budgeting, and Execution system), remain in place as the foundation of what is now a baroquely complicated set of administrative procedures.[16]

16. On the formal structure and mechanics, see Defense Acquisition University, *Introduction to Defense Acquisition Management*, a "living document" that runs to nearly nine hundred pages in print form.

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Big Systems, Big Spending

With exceptions for a few high-visibility strategic programs, such as missile defense, impetus for new weapons normally comes from the military. When, for example, John S. Foster, long-time DDR&E (1965–1973), was asked whether he saw his office "as an evaluator of service suggestions or as an initiator back the other direction to the services?" he replied "mostly the former."[17] In essence, then, postwar reorganization added another decision layer above the service chiefs. The armed forces were now expected to justify their preferences to civilian managers inside the Pentagon, such as Foster, as well as to non-DoD officials, such as those in the Office of Management and Budget (OMB) and Congress.

These justifications tend to be couched in arcane, opaque language. This is to some extent standard bureaucratic procedure, yet it is also strategic behavior, on the part of both the services and their contractors, aimed at confusing and obfuscating so as to create room for maneuver and to foreclose more-or-less rational debate and possible objections. The Army's recently abandoned Future Combat System (FCS) illustrates. Originally described as a system of systems based on "network centric concepts for a multi-mission combat system," the FCS was to be "overwhelmingly lethal, strategically deployable, self-sustaining and highly survivable in combat through the use of an ensemble of manned and unmanned ground and air platforms."[18] As such, it would become "the materiel centerpiece of the Army's future modular force."[19] Plans called for "18 systems, the network, and the Soldier (18+1+1)."[20] There were to be six types of robotic ground vehicles, nine crewed vehicles (e.g., "mounted combat system" [tank], "infantry carrier vehicle"[21]), and three robotic aerial vehicles. Anything this complicated would be very costly, but Army leaders expected the funds to be available. In 2002, Secretary of Defense, Donald Rumsfeld, had compelled the Army to cancel its Crusader artillery program, seen as a Cold War relic. This freed billions of dollars that could be redirected. Two years later, the Army itself ended work on the Comanche helicopter, at the time finally approaching production after 20 years of development; service leaders decided that the money needed to bring the Comanche program to conclusion would be better spent on the recently approved FCS.

17. Foster, *Oral History Interview I*, 3.

18. US Department of Defense, *Program Acquisition Costs by Weapon System: Department of Defense Budget for Fiscal Year 2005*, 49.

19. Ibid.

20. US Department of Defense, *Program Acquisition Costs by Weapon System: Department of Defense Budget for Fiscal Year 2007*, 50.

21. Ibid.

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As RDT&E on the new program proceeded, projected costs rose and, in a typical response to such overruns, the Army reduced the number of FCS components. Even so, the system as whole remained highly complex, as suggested by indicators including an estimated 65 million lines of software code, a total that continued to rise even as the number of subsystems declined. In 2009, OSD began to unwind the program. While the Army initially hoped to retain some elements "to continue previous Future Combat Systems efforts to stage and spin out emerging technologies to current forces," the service's own tests revealed this would yield "little or no military utility."[22] By 2012, the program had disappeared from DoD budget documents.

Technical performance is only one ingredient in evaluating a weapon system. What a system can accomplish in actual warfighting, against a capable and committed opponent, depends on the doctrine, skills, and equipment of the opposing forces, the competence of their commanders, and a host of other variables. Yet technical evaluation of programs such as FCS will always be the starting point and will always be problematic at least until RDT&E has progressed to the point that design choices can be assessed on the basis of more-or-less standard engineering methods (e.g., empirically validated mathematical models and simulations). For systems that press the state of the art, this may take years (or decades, as for ballistic missile defense). For FCS, the RDT&E necessary to, in essence, disprove the concept cost about $20 billion (figure 2). Then the program, which had been "initiated by fiat from the Chief of Staff of the Army [General Eric Shinseki] .... [w]ithout evidence of in-depth supporting analysis ....,"[23] collapsed.

After President Barack Obama took office, hold-over Secretary of Defense, Robert M. Gates, made plain his intent to bring acquisition under better control by curbing service appetites for costly systems of uncertain utility. Gates won a series of victories, cancellation of FCS prominent among them. Whether these mark any sort of turning point remains to be seen. Similar episodes in the past, such as termination of the Navy's A-12 fighter in 1991 by then Secretary of Defense, Richard Cheney, left only the lightest of traces. Experience going back more than five decades shows how difficult it is to alter permanently the political-bureaucratic dynamics of acquisition.

22. US Government Accountability Office, *Defense Acquisitions: Key Questions Confront the Army's Ground Force Modernization Initiatives*, cover sheet.

23. Porter et al., *The Major Causes of Cost Growth in Defense Acquisition, vol. 2: Main Body*, 30–31.

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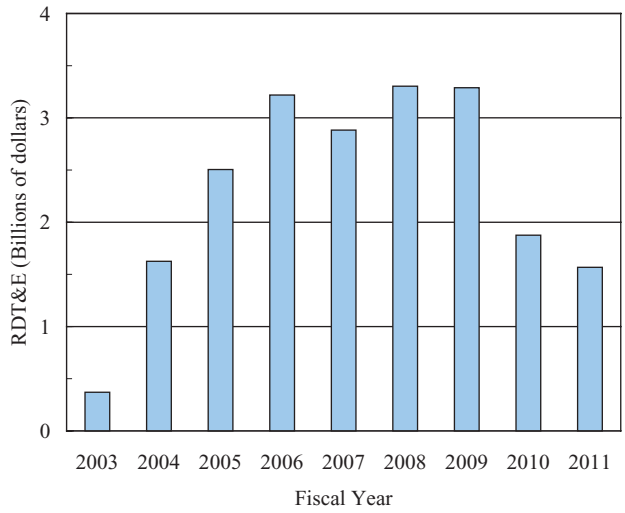


Figure 2 RDT&E Expenditures for Army Future Combat System. Note: 2010 and 2011 spending for the Army's Brigade Combat Team Modernization program, which absorbed elements of the terminated Future Combat System program. Source: Office of the Under Secretary of Defense (Comptroller), *Program Acquisition Costs by Weapon System*, various years; *RDT&E Programs (R-1): Fiscal Year 2007*.

The 1950s: War in Korea Triggers Growth in RDT&E

Programs like FCS and Comanche, which continue for years before moving from RDT&E into production, if they ever do, appeared first in the 1950s. In the immediate aftermath of World War II, the services had reverted to prewar practices in weapons development and acquisition. When in 1946 the Air Force sought a new heavy bomber, the plane that became the B-52, Boeing's contracts contained no explicit provisions for R&D. The company simply agreed to deliver two prototypes that met Air Force requirements. These prototypes eventually cost the government about $100 million, considered at the time "a shocking sum."[24] Yet the Air Force went on to spend $6.7 billion to buy nearly 750 B-52s, meaning that the initial phase of design, development, and prototype fabrication amounted to only 1.5 percent of total program expenditures. This was the old model. Three decades later when the government paid some $45 billion for 21 stealthy B-2s, more than half of the total, some $25 billion, went for separately budgeted RDT&E.

24. Knaack, *Encyclopedia of U.S. Air Force Aircraft and Missile Systems: Post-World War II Bombers, 1945–1973*, vol. 2, 226.

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The onset of the Korean War found US forces ill-prepared and poorly equipped. The fiercely fought yet inconclusive conflict became the proximate cause of the US shift to high-technology weapons based on extensive preprocurement R&D. As Chinese troops flooded down the Korean peninsula in December 1950, driving the outnumbered US Eighth Army before them in near-panicked retreat, Washington policymakers drew the obvious conclusion: to fight and win against the massive land armies of the Soviet Union and its proxies, then presumed to include China, US forces needed superior weapons based on superior technologies. The Soviet Union's 1949 atomic bomb test had ended America's nuclear monopoly. While the United States could expect to increase its nuclear arsenal at a faster pace than the Soviet Union, the outcome at best would be strategic standoff. Should deterrence fail in Europe, as it appeared to have failed in Korea, the forces of the North Atlantic Treaty Organization (NATO) might be unable to stop the Red Army before the Channel coast. Today it appears plain that US leaders misjudged the geopolitical ambitions of Stalin and his successors, who, while alert for opportunities to provoke small wars, appear in hindsight to have had no more desire than NATO for a big war in Europe. And it is plainer still that US intelligence consistently overestimated the size and capabilities of the Soviet military at a time, before the availability of remote surveillance systems, when little could be known with accuracy about those capabilities. Both factors, overestimation of the Kremlin's expansionary aims and overestimation of Soviet military power, spurred the shift in US national security policy and the rise in RDT&E that followed. As figure 3 shows, RDT&E spending continued to increase even as overall defense spending declined following the 1953 Korean armistice. Much of the growth—which amounted to a six-fold increase over the years 1951–1960—came in the latter part of the decade. It is this growth that accounts for the sharply upward trend in RDT&E-to-procurement ratio plotted in figure 1.

High levels of RDT&E complemented the Eisenhower administration's announced policy of "massive retaliation," intended to signal the possibility of nuclear response to almost any sort of Soviet military action. As it was, the US threat was widely disbelieved. The credibility of Eisenhower's policy would have been still lower without robust spending on nuclear-capable delivery systems, as well as surveillance and early warning.

The spending was forthcoming, for "strategic" systems intended to deliver nuclear warheads to targets in the Soviet Union and its satellites and also for tactical weapons to be deployed on the territory of European members of NATO or elsewhere. Nuclear warheads, not that costly, came from the Atomic Energy Commission (AEC). The

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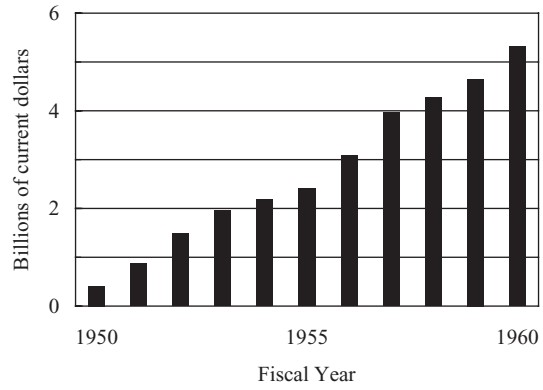


Figure 3 Defense Department RDT&E Spending. Note: Outlays. Department of Defense only; does not include R&D spending by the AEC for nuclear warheads and naval reactors (a total of $5.7 billion over these years). Source: Office of the Under Secretary of Defense (Comptroller), *National Defense Budget Estimates for FY 2012*, table 6–11.

Pentagon's budget provided bombers for SAC, including the B-36, B-47, and the B-52, and shorter-range fighters and fighter-bombers, many designed to carry nuclear payloads. The Navy too wanted nuclear-capable aircraft, along with large-deck carriers to convey them near Soviet borders, thereby allowing the Navy to share the strategic mission with SAC. By 1960 the Navy had, in addition, an independent deterrent in the form of Polaris-class ballistic missile submarines. The Army, for its part, got atomic artillery, nuclear land mines, and battlefield rockets and missiles fitted with nuclear warheads. DoD and the intelligence agencies also paid for early-warning radar networks, spy planes such as the U-2, and spy satellites.

The cost and complication of the new weapons and systems, including the powerful and expensive digital computers at the heart of far-flung radar nets and warfighting command-and-control, pushed RDT&E spending steadily upward. Some 10,000–15,000 engineering hours had gone into the design and development of North American's F-86 Saber Jet, which began its flight tests in 1944; a decade later, the Republic F-105, another Air Force workhorse produced in large numbers, absorbed something like 100,000 engineering hours.[25] In 1955, RDT&E accounted for 4.4 percent of DoD's budget. By 1960,

25. These estimates are based on parametric relationships in Hess and Romanoff, *Aircraft Airframe Cost Estimating Relationships: Study Approach and Conclusions*, which defines engineering inputs, 67, as "the hours expended in the study, analysis, design, development, evaluation, and redesign of the basic airframe as well as the system engineering and project management efforts undertaken by the prime contractor," thus leaving out testing, which is also a heavy consumer of engineering time.

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the RDT&E share reached 12.8 percent; RDT&E has remained above 10 percent of DoD spending in every year since, excepting only 1970 when the Vietnam War drained funds away to support military operations.

Building a Generic Technology Base

During the 1950s, technological complexity forced DoD away from the older practices illustrated by procurement of the B-52. Before World War II, research, though not unknown to the Army and Navy, had been a minor strand in military affairs. With exceptions for radar and the atomic bomb, the United States fought that war chiefly with systems and equipment developed before Pearl Harbor. In fact, the armed forces, preoccupied with mobilization, production, logistics, and operational planning for two wars in two widely separated parts of the world, were sometimes reluctant to adopt innovations flowing from the civilian-managed Office of Scientific Research and Development (OSRD). The services, then, entered World War II with little technological capability and exited positioned little better. They were, however, far more aware of the significance of military technological innovation.

As the improvized structures assembled by OSRD melted away, the services found themselves struggling to oversee fast-paced developments such as those in jet engines and supersonic flights. Defense contractors too, having spent the war years focused on high-volume production of standardized designs, lacked the technical skills needed for innovation. Jet engine developments during the 1950s illustrate both the difficulties encountered at the time and the responses that emerged.

The Air Force and Navy began many new engine programs during these years. Their contractors, including technological leaders such as General Electric, experienced many unanticipated problems. Some early engine designs would not even run; inefficient turbines failed to produce enough power to drive comparably inefficient compressors.[26] Slide-rule analytical methods incorporated gross simplifying assumptions just to make calculations possible and actual behavior sometimes deviated greatly from predictions. With enough time and money, most of the difficulties could be overcome; but all too often engineering groups, in the absence of analytical insight, had little choice but to proceed by trial and error. None of the engine firms commanded the knowledge and skills needed to move from design through development into testing and production along a relatively smooth and predictable path. The old approaches to procurement

26. St. Peter, *The History of Aircraft Gas Turbine Engine Development in the United States . . . A Tradition of Excellence.*

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might still work for planes such as the B-52, but they manifestly did not work for their powerplants, including the Pratt & Whitney J-57 installed on early B-52s, an engine that became highly successful but only after a long and troubled gestation period.

DoD's fundamental response to these difficulties was to uncouple support for the underlying gas turbine technology base from design and development of particular powerplants. "Before the 1960s, research into engine phenomena in the United States was generally carried out in the context of engine procurement programs. Requirements for the engine were established, and technology development was part of the process of designing a new engine."[27] With the relaxation of assumptions formerly necessary for analytical tractability, predictive accuracy improved and trial and error diminished. With the advent of computer-aided engineering, DoD supported applications of computational fluid dynamics (CFD) to the flow fields around internal engine airfoils (more difficult than calculations for wings, because the vanes in engines spun at high speed and were short, which meant end-effects were too large to neglect).

In other technical fields too, defense agencies built broad portfolios of technical knowledge. Most such work falls under what DoD calls its Science & Technology (S&T) program, corresponding to budget categories 6.1, 6.2, and 6.3 (basic research, applied research, and advanced technology development). Although the S&T program claims a relatively small slice of DoD's RDT&E budget, the sums are large in absolute terms, a projected $11.9 billion in fiscal 2013 (for what DoD calls Total Obligational Authority), corresponding to 17 percent of RDT&E.[28] The remainder of RDT&E spending, expected to total nearly $60 billion in 2013, pays chiefly for design, development, and testing associated with particular weapons programs. This is the RDT&E that matters most for acquisition management, and for acquisition reform.

Conceptual Design Decisions

For military systems, whether complex or simple, and likewise for commercial products, early design choices largely determine ultimate performance and costs.[29] During preliminary design, engineers work though alternatives, which come in literally uncountable profusion.

27. Hong and Collopy, "Technology for Jet Engines: Case Study in Science and Technology Development," 769.

28. Office of the Under Secretary of Defense (Comptroller), *RDT&E Programs (R-1): Department of Defense Budget, Fiscal Year 2013*, 3A.

29. Alic, "Computer-Assisted Everything? Tools and Techniques for Design and Production"; National Research Council, *Pre-milestone A and Early-Phase Systems Engineering: A Retrospective Review and Benefits for Future Air Force Acquisition.*

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Some are kept, others discarded. Analytical tools offer limited support at this stage, which is open-ended and fluid. Because there are too many permutations to be explored with even the most powerful computer-based methods, designers rely, as they always have, on tacit know-how and experience-based judgment. As the design takes on more concrete form, it becomes increasingly difficult to revisit the overall concept for reasons including the risk that even the appearance of difficulty or delay could invite political attack. Yet once the overall "architecture" has been defined, no amount of analysis, modification, and refinement can salvage a deficient concept.

To be sure, analytical tools have improved. In the late 1960s, McDonnell-Douglas evaluated 750 wing configurations for the F-15, conducting wind tunnel tests on fully 120 of them.[30] With current CFD methods, more alternatives can be examined at less cost, the set narrowed more quickly, and testing reduced. Even so, alternatives must be compared one against another, and eventually in the wind tunnel; only in the simplest of cases do computer methods lead directly to something approaching an optimal design. At the system level, engineers get still less help from predictive methods, the application of which presumes a well-defined design with features that can be modeled mathematically—and it is at the system level that DoD tends to over-reach, as illustrated by the Army's FCS and, much earlier, the nuclear-powered bomber and Dyna-Soar space plane. These two 1950s-era programs suggest how little has changed in DoD acquisition over the past half-century.

Before intercontinental ballistic missiles (ICBMs) had demonstrated their accuracy and dependability, SAC's bombers formed the basis of the US deterrent. If caught on the ground during a surprise attack, they would be easy targets. Nor could bombers such as the B-52 hide aloft for long, since inflight refueling was in its infancy and the Air Force had only a few tankers. Aircraft powered by nuclear reactors held out the promise of cruising aloft for days at a time, nearly impossible for the enemy to locate, track, and target. Following more than a decade of R&D and more than $1 billion in expenditures by the Air Force and AEC, the White House in 1961 canceled the nuclear aircraft program.[31] Polaris submarines had joined land-based ICBMs in the strategic triad, and the vulnerability of manned bombers was no longer so central a concern.

Dyna-Soar, a nearly contemporaneous program, targeted a different sort of vulnerability. Air Force planners feared that SAC's bombers

30. Werrell, *Chasing the Silver Bullet: U.S. Air Force Weapons Development from Vietnam to Desert Storm*, 66.

31. Comptroller General of the United States, *Review of Manned Aircraft Nuclear Propulsion Program*.

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would be knocked from the sky in droves as they approached Soviet-controlled territory, just as the waves of B-17s and B-24s sent to bomb Germany during World War II had been decimated by interceptors and antiaircraft fire. Search radars were improving rapidly and the Soviets were adding new generations of surface-to-air missiles to their defenses. Bombers might hope to fly higher than these missiles could reach, yet the latest jet fighters excelled at climbing quickly to such altitudes. Dyna-Soar would demonstrate technology for a future bomber able to fly outside earth's lower atmosphere, beyond the reach of both ground-to-air missiles and conventional jet-propelled interceptors. Approaching the target, the pilot would swoop down to release his nuclear payload, then zoom back into space for the ride home. (To some, Dyna-Soar was also or alternatively intended to demonstrate technologies for manned military space missions.) Yet ICBMs put no aircrews at risk and cost far less; OSD cancelled Dyna-Soar in 1963 after expenditures of nearly $1 billion.[32]

Both these programs would have consumed many more billions just to reach the prototype stage. Even as a notional design, nuclear propulsion for aircraft has vanished and seems unlikely to reappear, if only because radiation dangers have become more acutely appreciated since the 1950s. Dyna-Soar, on the other hand, had descendents including the Space Shuttle and the stillborn National Aerospace Plane (NASP). After the Reagan White House took on faith promises that NASP would demonstrate the ability to fly payloads for the Strategic Defense Initiative directly into orbit, DoD and the National Aeronautics and Space Administration spent $1.7 billion before the Clinton administration canceled the program in 1993.[33] Projected costs had by then reached $17 billion, five times the figure put forward initially.

Managing Uncertainty

Technological Risk and Business Risk

In making spending decisions, both private firms and government must try to anticipate an unknowable future. Because time horizons for weapons development and production greatly exceed those for threat assessment based on actual intelligence rather than speculation, new weapons cannot be chosen on the basis of what seem the most probable threats: decision-makers must select weapons for

32. Geiger, *History of the X-20A Dyna-Soar*.

33. Schweikart, *The Hypersonic Revolution: Case Studies in the History of Hypersonic Technology, vol. 3, The Quest for the Orbital Jet: The National Aero-Space Plane Program (1983–1995)*.

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an indeterminate future. Business time horizons, with exceptions for such long-lived capital investments as petroleum refineries and electrical power plants, will normally be much shorter. Three other contrasts stand out. Market mechanisms quickly resolve many of the uncertainties surrounding commercial innovation, whereas the realized effectiveness of military systems and equipment remains indefinite absent the tests of war. Second, while responsibility for major business decisions can be fixed at executive levels in the firm, responsibilities within government are diffuse and contestable. And perhaps of greatest significance, projected financial flows provide a crude but useful basis for comparing proposed business investments, whereas in defense there is no way to put quantifiable value on national security or military power; hence quantitative comparisons among alternative investments are impossible.

R&D reduces technological uncertainty, generating data, information, and knowledge previously unknown (else there would be no need for the work). Engineering design and development reifies what was initially just a concept, typically through an iterative process of analysis and refinement that culminates in a set of specifications from which a product or system can be built. At that point the main residual uncertainties for commercial products, in addition to the degree of correspondence between realized performance and analytical predictions, concern marketplace response. For many or most such products, the technological tasks are fairly straightforward. Managers generally expect that capable technical employees can be identified, based on credentials and experience, and that these employees will be able to carry well-conceived projects through to some more-or-less satisfactory conclusion. Technical risks, in other words, are widely assumed in the civilian economy to be manageable. Business risks, on the other hand, may not become fully apparent until commercialization, when large sums have already been spent (on final design and testing, production startup, marketing, and so on). In defense, on the other hand, it is business risks that, from the perspective of the firm, will seem controllable, once contracts have been won, while the risks of technological failure are likely to be much higher than in the civilian economy because of DoD's propensity to over-reach or simply to insist on incompatible requirements.

From its introduction in the late 1980s, sales of Beech Aircraft's Starship, an innovative design intended to appeal to corporate customers, lagged far behind those of conventional turboprops, including the firm's own King Air line. Even as King Air sales mounted—some 7,000 have now been built—Beech ended production of the Starship after 53 units. The company coped effectively with the technical uncertainties of designing and fabricating an airframe entirely from fiber-reinforced

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composite materials, a radical approach at the time in a conservative segment of the aerospace industry; customer response caught Beech out. Within DoD, likewise, organizations such as the Defense Advanced Research Projects Agency (DARPA), known for innovation, have sometimes found customers indifferent. The Air Force resisted DARPA's initial push into stealth, and the Navy, after an initial show of support, killed off the arsenal ship.[34] Yet stealth did find eventual acceptance, so that Lockheed had orders in hand when it began work on the F-117, the first plane designed from the beginning with minimal radar signature as a primary objective; unlike Beech and the Starship, Lockheed faced minimal business uncertainties. On the other hand, considerable technological uncertainty remained, notably concerning how the F-117 would fare against sophisticated air defenses in actual combat. Even though R&D aimed at reducing aircraft radar signatures had been underway since the 1950s, demonstration of the F-117's ability to hide from enemy radar, not just in tests, did not come until the 1991 Gulf War, a decade after the plane first flew.

While the Starship was an exception in incorporating radical technological advances, in commercial industries technical uncertainties more often combine with market-related imponderables to induce generally conservative design choices. DoD and the services, by contrast, often take big risks deliberately. Risky programs do not always fail: the F-117 program was aggressive technologically, yet came to be regarded as a model acquisition undertaking. Nevertheless, and unsurprisingly, programs deemed successful more commonly embody conservative design choices. Recent examples include the Patriot/Medium Extended Air Defense System Combined Aggregate Program Fire Unit (Army), Standard Missile-6 (Navy), and Minuteman III Propulsion Replacement Program (Air Force), to cite one from each of three services.[35] Major acquisition programs based on relatively mature technologies, however, account for only a small share of acquisition spending: "21 percent of programs in DoD's 2008 major defense acquisition portfolio appeared to be stable and on track with original cost and schedule goals. These programs tended to represent relatively smaller investments, with just under 9 percent of total dollars …."[36]

Feedback into Design and Development

As illustrated by the F-15 wing example, much R&D entails analysis of tradeoffs. In a different sort of example, one closer to preliminary

34. Van Atta et al., *Transformation and Transition: DARPA's Role in Fostering an Emergent Revolution in Military Affairs, vol. 1–Overall Assessment*.

35. US Government Accountability Office, *Defense Acquisitions: Strong Leadership Is Key to Planning and Executing Stable Weapons Programs*.

36. Ibid., cover sheet and 6.

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design, the Army chose a gas turbine engine for its M1 Abrams tank, opting for power-to-weight ratio greater than the traditional, more fuel-efficient diesel engines installed in earlier generations of main battle tanks. During the 1991 Gulf War, US armored columns sometimes had to slow or even stop to avoid outrunning their fuel convoys. Although the Abrams had been in service for years, the delays, which risked loss of military advantage, came as a surprise (Pentagon planners overestimated Iraqi capabilities and anticipated a slower pace of advance).

There are no formulas for managing design tradeoffs. Even so, commercial firms, unlike the Army with its Abrams, get more-or-less continuous feedback from customers and the marketplace. For consumer goods (and service products), high volumes of information flow to the firm in near real time. Based on this feedback, companies can modify designs, marketing strategies, and pricing, reorient next-generation R&D, perhaps choose to exit some lines of business and enter others. Firms that make intermediate and capital goods, with fewer customers, maintain direct linkages with the more important (as Boeing does with commercial airlines). While managers with reputations to protect and careers to advance try to spin interpretations of market-determined outcomes, they cannot evade the verdicts of sales and profits indefinitely, at least in publicly owned firms obligated to release financial information. Market analysts, business journalists, and stockholders pore over these reports and argue their meanings. Some sort of consensus eventually emerges. Apple's Steve Jobs becomes a folk hero, Microsoft's Steve Ballmer does not.

DoD decision-makers, by contrast, must typically do without immediate feedback, especially as concerns battlefield performance. Wars are intermittent and unique; one purpose of military innovation is to deter them. If war does come, it can be difficult to disentangle the capabilities of systems and equipment from those of the forces employing them. Data and information on battlefield performance may be closely held if not classified. And while many military organizations take pride in seeking "lessons learned" from combat experience, self-interest also leads to after-action reports that "read more like public relations documents than like serious and thoughtful analyses of what happened and why."[37]

Even if available, feedback from military operations is almost invariably hard to interpret. During the 1999 NATO bombing campaign intended to compel Slobodan Milošević to pull his forces out of Kosovo, Serb resourcefulness—fooling NATO pilots with decoys

37. Winnefeld and Johnson, *Joint Air Operations: Pursuit of Unity in Command and Control, 1942–1991*, 169.

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intended to look like tanks, trucks, and artillery pieces while hiding the real thing—rendered damage assessment from the air almost impossible. After seventy-eight days of bombing, Serb forces finally withdrew, permitting on-the-ground inspections. Even then, estimates of the damage actually inflicted did not converge, and the effects of the aerial campaign on Milošević's decision remain contested.[38]

While uncertainties attach to all innovation, for three main reasons those surrounding military innovation cannot be resolved as quickly or confidently as those surrounding commercial innovation. First, costs and performance for military systems cannot be reliably predicted until concepts have been transformed into engineering designs and prototypes. This may take a decade or more following initial program approvals. By contrast, product cycles in the civilian economy rarely exceed half a dozen years and often are much shorter. Second, only wars fully reveal the strengths and weaknesses of military systems and equipment, and only wars fought against skilled and determined adversaries. Because each conflict is different and feedback from warfighting is noisy and error-prone, finally, even the tests of combat do not necessarily resolve all ambiguities.

Decision Tools

Critics sometimes assert that American businesses rely too heavily on financial metrics, said to bias decisions in favor of short-term profit-taking and discourage long-term innovation. Regardless of the validity of such claims, financial analysis gives upper-level managers a means to constrain the exploitation of power and position within the organization by internal advocates of particular investments. In DoD, by contrast, high-ranking military officers, contractors and lobbyists, and elected and unelected officials can put forward extravagant claims with little fear of decisive rebuttal.

Business firms commonly weigh major spending decisions within a framework of projected financial flows. In setting expected revenues against costs for R&D and expenditures on new plant and equipment, decision-makers do not fool themselves that projections can be accurate. The intent is to place competing proposals on a common basis. Technological optimism is an ever-present and oftentimes necessary ingredient in innovation: belief in one's ideas breeds persistence and resourcefulness on which success often depends. By insisting that proponents present estimates in transparent fashion, with explicitly stated assumptions, executive-level decision-makers aim to

38. Nardulli, *Disjointed War: Military Operations in Kosovo, 1999*, 49–56.

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curb overenthusiasm, self-delusion, and outright rigging of proposals by those at lower levels in the organization. Profitability serves as common denominator and only sometimes as a gate. (The extent to which earnings motivate firms and their managers, as opposed to alternative organizational goals, such as growth or survival, can be questioned, but is immaterial here.) Final decisions—at division or corporate level, perhaps by the executive committee—are based in part on financial comparisons and in part on nonquantitative considerations such as fit with the firm's larger strategy. Joseph Bower notes this often-overlooked counterpoint to "managing by the numbers," quoting from an interview with a divisional vice president who states that "There will always be a segment of business you'll still want to be in regardless of financial criteria."[39]

Within the firm, preparation, presentation, and critique of spending proposals serve as "an instrument of internal two-way communication and top-down control."[40] Within DoD, PPBS and related tools, the most general of which have come to be known as systems analysis, fill similar functions. Much as the controller's office in a corporation deploys accounting measures, OSD employs quantitative tools and metrics in an effort to control, however imperfectly, a large organization, really an organization of organizations, rife with competing interests.

Despite endless elaboration in mathematical models and statistical estimation, all such methods have their basis simply in counting, in the systematic collection and analysis of data and information that seem to bear on organizational performance—direct labor inputs to production, inventory turns, mean time between failures of an avionics module, circular error probability for guided missiles. In this, they trace their origins to cost accounting, as pioneered in early factory-centered business firms, and engineering economics, as developed for assessing infrastructure investments such as canals and railroads.[41] Firms in many industries adopted accounting-based methods for setting prices, planning production (scheduling, inventory management), and evaluating investments.[42] DoD's procedures, whether used for evaluating proposed weapons systems that may not see production for two decades or for predicting prices of jet fuel during the next fiscal year, have the same origins.[43]

39. Bower, *Managing the Resource Allocation Process: A Study of Corporate Planning and Investment*, 9.

40. Eliasson, *Business Economic Planning: Theory, Practice and Comparison*, 219.

41. Pollard, *The Genesis of Modern Management*; Porter, *Trust in Numbers: The Pursuit of Objectivity in Science and Public Life*, 55–65.

42. Lamoreaux, Raff, and Temin, "Beyond Markets and Hierarchies: Toward a New Synthesis of American Business History."

43. Novick, *Efficiency and Economy in Government through New Budgeting and Accounting Procedures*; Novick, *Beginning of Military Cost Analysis 1950–1961*.

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With some exceptions, such as systems engineering for locating substations in AT&T's rapidly expanding telephone network, quantitative decision methods penetrated little farther than traditional accounting tasks until World War II. Then came an explosion of activity for military logistics and also for operational planning, including strategic bombing and antisubmarine warfare. Herbert Simon remarked in his Nobel Prize lecture.

> For reasons not clear to me, this territory was very sparsely settled prior to World War II. Such inhabitants as it had were mainly industrial engineers, students of public administration, and specialists in business functions. . . . During World War II, this territory, almost abandoned, was rediscovered by scientists, mathematicians, and statisticians concerned with military management and logistics, and was renamed "operations research" or "operations analysis."[44]

After the war, applications continued to expand. DoD and its contractors examined, among other examples, basing of bombers for attacking the Soviet Union and the best ways to safeguard surface ships from nuclear-powered submarines, much faster when submerged than the diesel-electric submarines that all but slow cargo vessels could outrun. In the 1960s, powerful digital computers made it easier to conduct large-scale studies requiring simulations with wide-ranging assumptions.

Quantitative methods do not substitute for discretion. They support it. That is why Aaron Wildavsky wrote, "The good systems analysis is a 'chochem,' a Yiddish word meaning wise man, with overtones of 'wise guy.' His forte is creativity."[45] Even cost accounting, more nearly mechanical than operations research or systems analysis, begins with discretionary choices in the definition and delineation of rules to be followed; if unambiguous, these rules can be applied thereafter with minimal recourse to judgment. Systems analysis offers, or demands, much greater scope for discretion in setting up and applying models (determining system boundaries, initial conditions, selecting empirical data for calibration). None of the available methods offer much guidance in the early design of either weapon systems or commercial products, when an essentially uncountable number of possible configurations can in principle be considered, the more so if there is little or no applicable experience base from which to draw data.

Elsewhere in government, benefit-cost methods can at least in principle help curb the discretionary exercise of power by elected or

44. Simon, "Rational Decision Making in Business Organizations," 498.

45. Wildavsky, "The Political Economy of Efficiency: Cost-Benefit Analysis, Systems Analysis, and Program Budgeting," 298.

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appointed officials. Whether delving into the economics of a new airport or highway or more stringent air quality standards, analysts express both benefits and costs in dollar terms. Given "[t]he inherently speculative character of the analysis,"[46] results can easily be skewed. As in defense, proponents of a particular program tend to understate costs and inflate benefits, sometimes vastly.[47] Enthusiasts and entrepreneurs (and scam artists) underestimate front-end investment and overstate projected revenues; almost by definition, innovators are susceptible to optimism bias. Still, honest estimates are at least theoretically possible. That is not the case in defense—not because honesty is impossible, but because only costs can be estimated quantitatively. National security is a highly elastic construct; there is no way to put a number on benefits.

Organizational Behavior

The limitations of systems analysis were well and widely understood in the 1960s when McNamara institutionalized PPBS. Many of the methods, after all, stemmed directly from military experience. Nor were quantitative methods presented, by those who understood them, as anything other than means to "sharpen the intuition and judgment of decision makers."[48] Yet the resistance of the services was immediate and strong, and has lasted, even though some of McNamara's initiatives were hard to oppose. With the costs of maintaining F-100 fighters exceeding $800 per flight hour, for example, compared with 1950s-era F-86s at about $135 per hour, the armed forces had little choice but to accept the need for life-cycle perspectives.[49] At the same time that they opposed OSD's overall policy, then, the services began to hire many more systems analysts of their own. They also sent promising officers to civilian graduate schools in larger numbers to prepare them for arguing the military's case to civilians in OSD, OMB, and on congressional staffs.[50] Through such actions, military leaders acknowledged the usefulness of quantitative methods for at least some kinds of questions.[51]

46. Hammond, "Convention and Limitation in Benefit-Cost Analysis," 196.

47. Flyvbjerg, Garbuio, and Lovallo, "Delusion and Deception in Large Infrastructure Projects: Two Models for Explaining and Preventing Executive Disaster."

48. Fisher, "Cost Functions and Budgets (Cost Considerations in Systems Analysis)," 235.

49. Knaack, *Encyclopedia of U.S. Air Force Aircraft and Missile Systems*, vol. 1, 63, 200, and 203.

50. Gibson and Snider, "Civil-Military Relations and the Potential to Influence: A Look at the National Security Decision-Making Process."

51. For contrasts between the approach of analysts working for civilian officials in the McNamara tradition and those employed by one of the military services, see Hughes, "Navy Operations Research."

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The most serious conflicts, still widely recalled, stemmed from efforts by civilian officials to reshape and harmonize the spending plans of the four services in order to enhance "the defense effort as a whole."[52] McNamara aimed to strengthen national security while saving money. That promised to diminish the autonomy of the services and served as the primary source of military opposition. McNamara's policies reignited and then fanned a longrunning source of conflict. Until World War II, the roles and missions of the Army and Navy had been largely self-assigned, and within their appropriated budgets both services were largely free to choose their own weapons—the composition of the Navy's fleet, the Army's preferred mix of tanks and artillery, bombers and fighters. This comfortable arrangement ended with postwar reorganization, especially the establishment of the Air Force as an independent and coequal service, and the budget cuts imposed by the Truman administration. Stable duopoly gave way to three-way budgetary competition. Nuclear strategy brought out the conflicts most starkly, as illustrated by the "Revolt of the Admirals" over roles and missions in the delivery of atomic warheads and the Navy's plan to build very large-deck aircraft carriers to embark long-range nuclear bombers.[53] James Webb, Director of the Bureau of the Budget (OMB's predecessor), gave voice to the atmosphere of the time in remarking on the "terrible prospect," apropos of military efforts to wrest control of nuclear weapons from the AEC, "of turning over custody of atomic bombs to these competing, jealous, and insubordinate Services, fighting for position with each other."[54] The Korean War muted some of these hostilities, and Eisenhower knew how to keep peace with and among the services. McNamara and others in the Kennedy and Johnson administrations did not.

Again and again over the nation's history, the services have portrayed questioning of their choices by civilians as an assault on professional competence. This has been part of the standard response to unwanted oversight, helping the armed forces absorb, neuter, or co-opt all but the most strong-willed and politically adept civilian officials (including service secretaries, few of whom have been more than figureheads). McNamara was strong-willed but not especially adept and his personal style aggravated high-ranking officers.[55] Some of his decisions, furthermore, were ill-founded. In perhaps the best-known instance, OSD sought to compel the Air Force and Navy to

52. Kaufmann, *The McNamara Strategy*, 173.

53. Hammond, "Super Carriers and B-36 Bombers: Appropriations, Strategy and Politics."

54. Wainstein et al., *The Evolution of U.S. Strategic Command and Control, and Warning, 1945–1972 (U)*, 30.

55. Shapley, *Promise and Power: The Life and Times of Robert McNamara*.

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purchase a common fighter-bomber, the TFX/F-111. "However, conflicting requirements between AF and Navy missions" made it "a nearly impossible task" to design a plane that could satisfy both services.[56] Even so, after McNamara exited the Pentagon and the Navy exited the program, the F-111 "served the United States Air Force well from 1967 to 1996" as "one of the most effective all-weather interdiction aircraft in the world."[57]

Large cost and schedule over-runs, and many of the other maladies of DoD acquisition, stem from the insistence of the armed forces on superweapons that over-reach the state of the art. The pattern is a post–World War II development. Narrowly it is a legacy of the Korean War, more broadly of the Cold War. Dyna-Soar was an early example, FCS the most recent. Budgetary competition creates powerful incentives to overpromise, systems are complex, and technological horizons lengthy, while choices carry life-and-death implications.

Decisions on such matters demand sound judgment. Yet while capacity for technological judgment is a core competence, depending on industry, in private firms, it has little salience within the military; put simply, it does not fall within the domain of professional military expertise. Private sector managers generally believe that technical risks are easier to assess than business risks, in part because skills in oversight of R&D and technology development can be identified by monitoring employee performance over time. Technology-intensive firms seek to identify and retain engineers and managers with such skills. Since technical change is largely incremental and evolutionary, interrupted only occasionally by bursts of Schumpeterian innovation, and since businesses seldom try to look more than a few years ahead, planning is relatively straightforward. Conversely, track record in gauging business risk means less, given that the evolution of markets is less predictable than that of technologies. The Beech Starship failed for business, not technical, reasons, as did Apple's Newton: the best and brightest in both companies were simply wrong about customer responses.

Competencies are domain-specific.[58] Skill in flying high-performance jets does not translate into skill in ship-handling. Core competencies in military organizations center on preparing for and fighting wars, including training and the development of doctrine instilled by training (e.g., for air combat), along with logistics, intelligence, and so forth; the list does not include technology assessment. Many officers

56. Richey, *F-111 Systems Engineering Case Study*, 17. More generally, see Coulam, *Illusions of Choice: The F-111 and the Problem of Weapons Acquisition Reform*.

57. Richey, *F-111 Systems Engineering*, 32, iv.

58. Alic, "Technical Knowledge and Experiential Learning: What People Know and Can Do."

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earn undergraduate degrees in engineering or science, and some pursue graduate studies in these fields. At the same time, they normally rotate through acquisition relatively quickly before returning to postings in the line of command. Because so many programs encounter so much trouble, officers on temporary assignment tend to regard acquisition as a threat to their careers rather than an opportunity to demonstrate their talents. Few, in consequence, can claim broad and deep experience-based skills of the sort that matter for technical choice. Lengthy records of success in technology management, such as that of Air Force General Bernard Schriever, are the exceptions.[59] The services employ some 30,000 civilian engineers and scientists, but not even those few who reach the Senior Executive Service have the institutional power and incentives to countervail against high-ranking officers such as General Shinseki at the time he pressed for approval of the FCS. No one should expect professional military judgment to extend to technical evaluations of prospective weapons systems.

As weapons reach the field and the services gain experience with them, evaluation becomes more reliable. Officials elsewhere in government likewise may have justifiable confidence in estimates by service leaders of relative military power internationally. On the other hand, national security itself is a political construct. The meanings assigned mix domestic political interests, some of them transient (election-year promises to strengthen defense or avoid foreign wars), with permanent geopolitical concerns shared among states: internal order and territorial integrity, implying policing and border protection; military power sufficient to offset threats to sovereignty; alliance commitments. Governments have flexibility in pursuing these interests, and national security policy as revealed by events may diverge a little or a lot from earlier pronouncements. Before the Korean War, the Truman administration had signaled, or seemed to signal, that South Korea was not fully beneath the US security umbrella. While military planners and foreign policy specialists had explored contingencies such as an invasion of South Korea, the matter had not been elevated to high levels in the US government.[60] The North Korean attack forced the issue, and the ramifications continue to play out in forms that range from the US military's determination never to be caught so poorly prepared in the future and the recent anxieties generated by North Korea's nuclear weapons program.

Compared with national security, military power is a more concrete and analytically tractable notion. The weapons inventories of

59. Lassman, *Sources of Weapon Systems Innovation in the Department of Defense: The Role of In-House Research and Development, 1945–2000*, 89–107.

60. Simmons, "American Perceptions and Strategic Options in the Korean War."

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most countries are known with reasonable accuracy and capabilities can be at least roughly compared. With the aid of methods ranging from war games to estimated life-cycle expenditures, analysts can inquire into the expected utility of new weapons (e.g., the F-35) relative to existing or updated systems (F-15s, F-16s, F/A-18s). Indeed this was the original intent of PPBS, since the method was to be applied to programs associated with similar missions, such as strategic deterrence or antisubmarine warfare. But there is no useful way to compare spending on F-35s with spending on attack helicopters or tanks or Littoral Combat Ships.

The military defines missions, hence programs, quite broadly and seeks redundancy in capabilities as a hedge against unexpected contingencies. The result is that many different weapons systems can be used to attack, say, an enemy troop concentration or supply convoy: fixed-wing attack planes or helicopters or tanks or drones or perhaps missiles launched by a Littoral Combat Ship. From the beginning, therefore, incommensurability was one of the acknowledged limitations of PPBS. Now as then, there is no useful way to compare spending across programs, to compare purchases of F-35s with attack helicopters or Littoral Combat Ships. This remains perhaps the most fundamental problem in acquisition management. With dollars as the common denominator, businesses can weigh investment proposals on the basis of financial projections. The Pentagon has no analogous means for structuring and disciplining intraorganizational competition.

Reform

Corporate conglomerates with multiple managerial hierarchies linked only at the top have found it almost impossible to compete effectively in disparate markets. The usual explanation is poor financial decision making: internal capital markets evidently cannot adequately compare investment proposals originating in unrelated lines of business. DoD has little choice but to persevere with multiple managerial hierarchies and incommensurable investment proposals. American preferences for dispersal of power and weak central governance reinforce the separation between ground, air, and naval forces common to most countries and the services can mobilize immense reservoirs of political capital and public support to resist policies they dislike. DoD is very far from a unitary organization.

The services *are* unitary organizations, each with its own hierarchy, culture, and norms.[61] Weapons and their requirements—the technical

61. E.g., Tucker, *Confronting the Unconventional: Innovation and Transformation in Military Affairs*.

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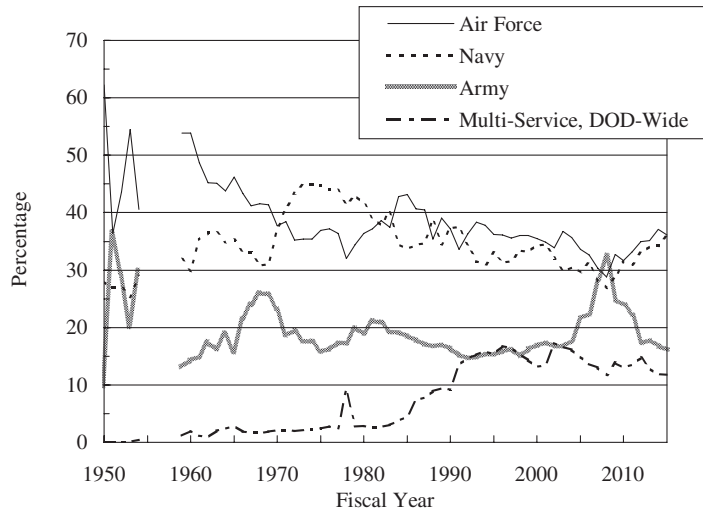


Figure 4 Distribution of Acquisition Funds. Note: Based on budget allocation figures. Navy includes Marine Corps. Data for several years in the 1950s incomplete. 2011–2015 estimated. Source: Office of the Under Secretary of Defense (Comptroller), *National Defense Budget Estimates for FY 2013,* various tables.

objectives contractors must try to satisfy in designing these weapons—reflect the dominant views within a service or service branch concerning its roles and missions, and the doctrine to be implemented in fulfilling these. Doctrine is self-defined by each service, and roles and missions largely so. The consequence, as stated by GAO, is that "DoD largely continues to define warfighting needs and make investment decisions on a service-by-service basis ...."[62] Recent illustrations include the insistence of the Marine Corps on a short takeoff, vertical landing version of the F-35. As figure 4 shows, service-centric programs still account for the bulk of acquisition spending, even though multi-service and DoD-wide undertakings have taken a higher share of the dollars since about 1980.

Service-centric acquisition has been criticized since the early postwar years for leaving some military needs unfilled because none of the services consider them central to their self-defined missions. The Navy would rather not clear mines: America's allies had to do that in the 1991 Gulf War. The Air Force prefers to spend money on fighter planes rather than transports for ferrying Army troops and equipment. While the JCS is charged with harmonization of service requests, the chiefs act as advocates for their home services and the chairman mostly referees.

62. US Government Accountability Office, *Defense Management: Actions Needed to Overcome Long-Standing Challenges with Weapon Systems Acquisition and Service Contract Management*, 4.

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The services opposed the most recent major legislated reforms, the 1986 Goldwater-Nichols Act. Intended to dampen interservice rivalry and enhance "jointness," the Navy and Marine Corps lobbied against the bill to the extent of setting up a "crisis center" inside the Pentagon.[63]

Goldwater-Nichols did strengthen the joint command structure, an increment in the reaction against poor coordination among the Army, Navy, Marine Corps, and Air Force that has been a sore point going back to World War II. Yet soon after passage the Soviet Union crumbled and in the absence of a designated enemy, "Interservice collaboration began to unravel ...."[64] Subsequently in Afghanistan and Iraq, "U.S. military operations remain[ed] an amalgamation of component operations,"[65] with each service carrying out assigned functions according to its own doctrine. These doctrines have changed surprisingly little over the past several decades and, since choice of weapons depends heavily on doctrine, Goldwater-Nichols cannot be said to have had much effect on how the United States selects, develops, and purchases weapons.[66]

Students of acquisition often claim the Pentagon would do better by making greater use of proven business practices. GAO urges DoD to treat the armed forces as "customers," establish "sound, knowledge-based business plans," and execute "those plans using disciplined approaches."[67] The DSB, similarly, concludes that "The most important action that the Secretary of Defense can take is to reform the strategic military planning system and establish a genuine business plan for DoD to discipline resource allocation in support of national security objectives." The "business plan should clearly define military missions needed to support national security objectives and outline how the Department will accomplish these objectives."[68] This is what McNamara tried to do. The DSB does not say how it might be accomplished today. And when GAO states that "DoD must demonstrate that the warfighter's needs are valid and can best be met with the chosen concept and that the chosen concept can be developed and produced with existing resources,"[69] it slides over the simple

63. Ganley, "How's That Again? You're Opposed to What?"

64. Johnson, *Learning Large Lessons: The Evolving Roles of Ground Power and Air Power in the Post–Cold War Era*, 17.

65. Lambeth, *Air Power Against Terror*, 141.

66. Leslie, Brown, and Roll, *Service Responses to the Emergence of Joint Decisionmaking*; Murdock, *Beyond Goldwater-Nichols: U.S. Government and Defense Reform for a New Strategic Era, Phase 2 Report*; Fox et al., *Defense Acquisition Reform*, 127–46.

67. US Government Accountability Office, *Strong Leadership Is Key*, cover sheet.

68. Defense Science Board, *Creating a DoD Strategic Acquisition Platform*, 10.

69. US Government Accountability Office, *Defense Acquisitions: Managing Risk to Achieve Better Outcomes*, i.

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truth that "the warfighters" are part of DoD, indeed its very reason for being, and have usually been able to determine for themselves what is needed, declare these needs valid, and go on to find them affordable. Emulation of private firms is a realistic prescription for relatively straightforward administrative functions, including the five million or so routine contract actions that DoD personnel execute each year, not for major acquisition programs. The question thus remains: in the apparent absence of workable schemes for evaluating the requests of the services for new weapons, how should the United States decide what to buy?

McNamara tried to address this question, but his role in the Vietnam War deeply tarnished the legacy of managerial reforms instituted during his years as Secretary of Defense. Little effort was made to extract lessons for acquisition reform and some of his successors seemed mostly concerned to keep the services happy.[70] The major lesson of the past half-century is this: there is only one way to arrive at more sensible acquisition decisions, by reducing the control of the military services over major programs.

In the executive branch, there are but two centers of authority above the service chiefs, the JCS chair and the Secretary of Defense. The JCS chair must perforce be a military man or woman, acculturated over decades while rising through the ranks of his or her home service. Some JCS chairs have been able to transcend their personal histories; others have not. There is no reason to expect this to change, even though "jointness" will no doubt continue to nibble away at service parochialism. This leaves the civilian side of the Pentagon.

Since the end of World War II, the effective decision-making responsibilities of Pentagon civilians have increased in piecemeal fashion, mostly through legislation. The preamble to the Goldwater-Nichols Act states bluntly "the intent of Congress ... to reorganize the Department of Defense and increase civilian authority in the Department."[71] It is past time for another such increment, a big one. This would mean, in effect, an expansion of the McNamara legacy, with all its baggage, and would no doubt incite fierce opposition, not only from the armed forces but from posturing politicians. In private, nonetheless, not all military officers would object. A few years ago, in looking back on his career, a four-star Air Force general, himself the author of a book intended to refute criticism of Air Force acquisition choices, first registered a more-or-less standard critique of civilian systems analysts, then went

70. Kinnard, *The Secretary of Defense*.

71. Goldwater-Nichols Defense Reorganization Act of 1986, Pub. L. 99–433, Oct. 1, 1986, 100 Stat. 992, § 3.

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on to say, "We have to put more power in the hands of the Secretary of Defense [and] de-emphasize the role of the Service Chiefs."[72]

Conclusion

Decision processes for major DoD investments contrast sharply with those in the private sector. Senior managers in industry routinely employ financial metrics in choosing among spending proposals. Unreliable as these may be, they help decision makers mediate intraorganizational competition by placing competing proposals on a common basis. DoD has no similar way to compare proposed new weapons systems put forward by the military services. Many such systems have similar functions, yet as investments are incommensurable. In the absence of useful methods for comparing weapons acquisition proposals, and given the political malleability of "national security," the services have usually been able to insist upon the weapons they want.

In the absence of workable schemes for evaluating requests, and with the services constantly competing for missions and for resources to accomplish these missions, the quest for technologically complex superweapons will likely continue. Meaningful reform would have to begin with legislation that reduced the influence of the individual services over choice of weapons and increased the power of civilian officials. If discretionary choices must be made, it is better that they be made by civilians able to take a broad view. Greater institutional power for OSD and less for the services would not make acquisition decisions any easier. Certainly it would do nothing to mitigate the analytical limitations described in this paper. Even so, reducing the influence of the more parochial factions in DoD would increase the likelihood of choices based on reason rather than wishfulness.

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72. Kross, *General Walter Kross Commander in Chief United States Transportation Command and Commander Air Mobility Command: An Oral History*, 101. Kross's book carried the title *Military Reform: The High-Tech Debate in Tactical Air Forces*.

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