The Information Technology & Innovation Foundation

The Challenges for America's Defense Innovation

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INTRODUCTION

As he disclosed his new "defense innovation initiative" in mid-November 2014, Defense Secretary Chuck Hagel hoped that it would invest money in "cutting-edge technologies and systems, especially from the fields of robotics, autonomous systems, miniaturization, big data, and advanced manufacturing, including 3-D printing."[1] Hagel argued that "we must do so by making new, long-term investments in innovation." It was an ambitious innovation plan for maintaining the military's technological edge, especially if tightening budgets are taken as a given.

A robust federal policy to restore defense-related innovation and production in the United States would pay significant dividends on two fronts: continued U.S. defense strength through superior technology and broader U.S. commercial global competitiveness.

Hagel compared this needed defense innovation initiative in scale to two past offset programs, including the nuclear buildup in the 1950s, as well as the 1970s development of precision-guided missiles, stealth aircraft and advanced intelligence, surveillance and reconnaissance platforms. Hagel called the new initiative the "third offsets strategy."[2] In each case, these initiatives sought substantial breakthroughs in strategy or technology that could offset an adversary's advantage in traditional military strength. But this time while the goal may be the same — develop tranformative technology so our miltary has a decided edge in any fight it engages in — the means may be quite different. For while in the past these big innovation iniatives can with a big federal checkbook, Secretary Hagel's "ask" today is much more constrained. His initiative "will put new resources behind innovation, but also account for today's fiscal realities — by focusing on investments that will sharpen our military edge even as we contend with fewer resources." Whether this new model – big goals, limited means — will succeed, remains to be seen.

Since the early days of the republic, U.S. innovation has been driven by federal support. The majority of that support has not reflected a quest for productivity, innovation or competitiveness. Rather, it has focused on the pursuit of military prowess. For example, the development of the armory practice with its precise parts tolerances and the accompanying machine tool industry paved the way for mass production, epitomized by the Ford Model T.[3]

From WWII armaments production to the 1957 launch of the Soviet Sputnik, to the 1980s defense buildup, U.S. defense R&D investments not only led the world but made a major but still under-appreciated contribution to U.S. innovation leadership. Yet since the end of Cold War, federal funding for R&D, including defense R&D, has increased much more gradually and recently has actually declined. Since the 2013 debt debacle, the sequestration — automatic spending cuts — have compounded the challenges. Congress failed to agree on a credible, bipartisan and medium-term debt-reduction program (one that would have cut entitlements while increasing taxes on individuals), and, after a brief government shutdown, the $1.2 trillion sequestration plan was activated.[4] It came with a presidential report warning that the "sequestration would be deeply destructive to national security."[5]

This report takes a closer look at America's defense innovation. First, it assesses the state of U.S. defense innovation, including military expenditures in international perspective, the history of defense R&D, the key defense R&D funders and defense R&D performers. It then examines the crossroads of defense innovation, by assessing the impact of limited budgets, the bias for short-term policies, challenges of defense acquisition, defense spin-offs and commercial spin-ons, the hollowing out of the defense industrial base, the erosion of competitive inter-service pressures, lower defense contractor R&D intensity and the rise of foreign competition.

The U.S. defense system is still the most innovative in the world, but that leadership is not assured, especially in the face of limited budgets. Moreover, U.S. defense innovation leadership has long benefited from overall U.S. innovation leadership, while at the same time robust defense innovation has spurred U.S. civilian innovation. But continued relative decline in U.S. commercial innovation will negatively impact defense innovation and capabilities, while declining investments in defense innovation will negatively impact overall U.S. innovation and competitiveness. As such, a robust federal policy to restore defense-related innovation and production in the United States would pay dividends on two fronts: continued U.S. defense strength through superior technology and broader U.S. commercial global competitiveness.

THE STATE OF U.S. DEFENSE INNOVATION

U.S. Military R&D Expenditures in International Perspective

Since World War II, U.S. defense R&D expenditures have been the highest in the world. It was not until the late 1970s that the combined military spending of France, Germany, Japan and UK exceeded that of the United States. Ironically, today their share is smaller than that of the United States, again as Europe has reduced its role in defense in favor of supporting its domestic welfare systems.

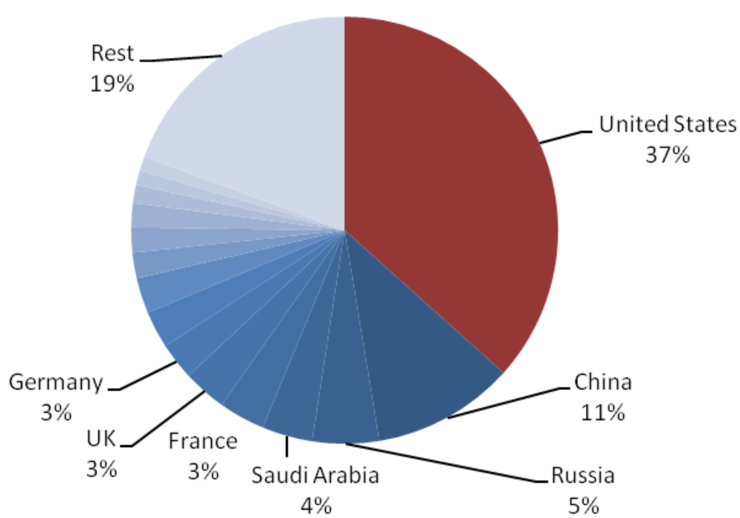

Figure 1: U.S. Military Expenditures as Percent of Global Military Expenditures[6]

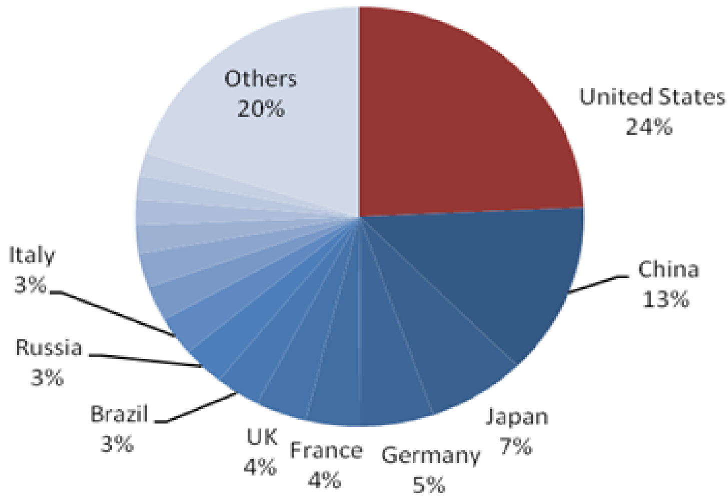

Figure 2: U.S. GDP as Percent of World Economy[7]
*2013 figures in U.S dollars at current prices and exchange rates.

Despite America's sixty year leadership in defense innovation, its position is evolving. In 2013, global military expenditure exceeded $1.7 trillion. U.S. military spending surpassed that of the next nine nations combined (China, Russia, Saudi Arabia, France, UK, Germany, Japan, India, and South Korea). (Figure 1)[8] U.S. military expenditures accounted for 37 percent of all such expenditures globally, even though American GDP is only 24 percent of the world economy. (Figure 2)

Due to the continued sovereign debt crises, military spending is falling in the West — North America, Western Europe, and Oceania — but increasing in other regions. In 2013, the U.S. military spending fell by 7.8 percent, to $640 billion as Congress sought to reduce the budget deficit.

While defense is a significant objective of government R&D funding in most major advanced economies, its share varies widely. In the United States, it accounted for 57 percent of the federal R&D support in 2011; more than three times the share given to defense in in South Korea and the UK and eight times more than in France, Germany, or Japan, respectively.[9] As a share of GDP U.S. government R&D expenditures on defense are twice as high as that of France or Russia; three times as large as that of South Korea, or the UK; nine times that of China, Germany, or Japan; and 14 times more than the European Union nations combined.[10] In contrast, the United States invests 40 percent less on non-defense R&D than do the EU nations where more government R&D funding is directed to areas with more direct commercial relevance to their economies.[11]

A (Very) Short History of U.S. Defense R&D

If World War II transformed the U.S. R&D system, the Manhattan Project ushered in the age of "big science" as scientific progress came to rely increasingly on large-scale defense projects financed by national governments, or groups of nations. In the postwar era, the Office of Scientific Research and Development (OSRD), a civilian agency led by Vannevar

Bush, was relatively small in financial terms, but it exemplified institutional innovation, by contracting with the private sector (e.g., Western Electric) and relying heavily on universities (e.g., MIT).[12] Indeed, the increase in U.S. military funding of science and technology after World War II was on a scale unprecedented in world history. Among other accomplishments, the Department of Defense (DOD) supported research on semiconductors and was an early key customer of the new technology. It pioneered advanced aviation technologies, exemplified by its support of Lockheed Martin's Skunk Works. And in perhaps the iconic case of defense spinoffs, it laid the groundwork for the development of the Internet.

By providing a source of demand for new technologies that do not have existing markets, military spending provides an important impetus for R&D that impacts broader innovation.

If World War II dramatically mobilized and expanded the U.S. national innovation system, the Cold War expanded the size and the central role of defense R&D in a way that distinguished the U.S. national innovation system from its counterparts in Europe and elsewhere. The Korean War fueled U.S. military embrace of high-technology and associated R&D. In the 1950s, the focus was on new weapons, from jet-propelled fighters and bombers to nuclear-powered submarines. After Sputnik, R&D spending soared, particularly in defense. It also very quickly led to the launch of the Defense Advanced Research Projects Agency (DARPA), which was set up to invest in high-risk, high-payoff research. DARPA was designed to be a flexible non-bureaucratic agency that focused solely on technology.[13]

Initially, the rise of the huge U.S. defense innovation engine was seen not as an unalloyed blessing, but as a tradeoff between welfare and security. In his *Farewell Address*, President Dwight D. Eisenhower warned against the dangers of the "military-industrial complex" and the potential "domination of the nation's scholars by Federal employment, project allocations, and the power of money."[14] Eisenhower made his statement at a time when U.S. global economic supremacy was at its peak. Since then it has become clearer that defense expenditures, particularly for R&D, have played an important role in the U.S. innovation system that in turn has supported U.S. global competitive advantage.

Through the Cold War era, defense R&D dominated the U.S. federal R&D budget. Thereafter its share has fallen below 50 percent of the total federal R&D obligations only a few times. In 1960, defense research accounted for 80 percent of federal R&D funds. Its subsequent relative decline converged with the growth of the NASA space program, the drawdown after Vietnam, and growing popular opposition to combat operations. Hovering around 50 percent until the early 1980s, it was boosted dramatically by the Reagan-era rearmament in both absolute and relative terms. (see Figure 3, Figure 4)

The DOD investment and military procurement in the 1970s and '80s contributed to the technology boom and high growth rate in the 1990s. Indeed, the county most dependent on defense contracts in the early 1990s was not in Texas or Mississippi but in California's Santa Clara County, Silicon Valley.

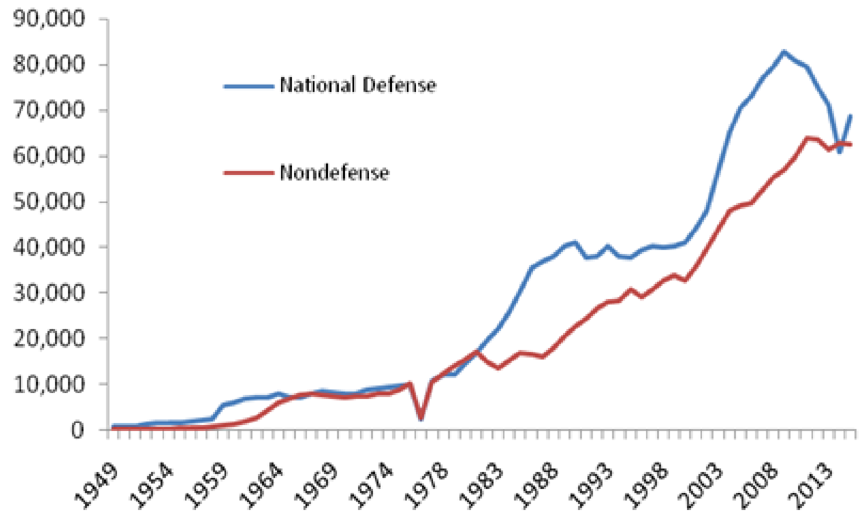

Figure 3: Historical Outlays for R&D: Defense and Nondefense (in millions of current dollars)[15]

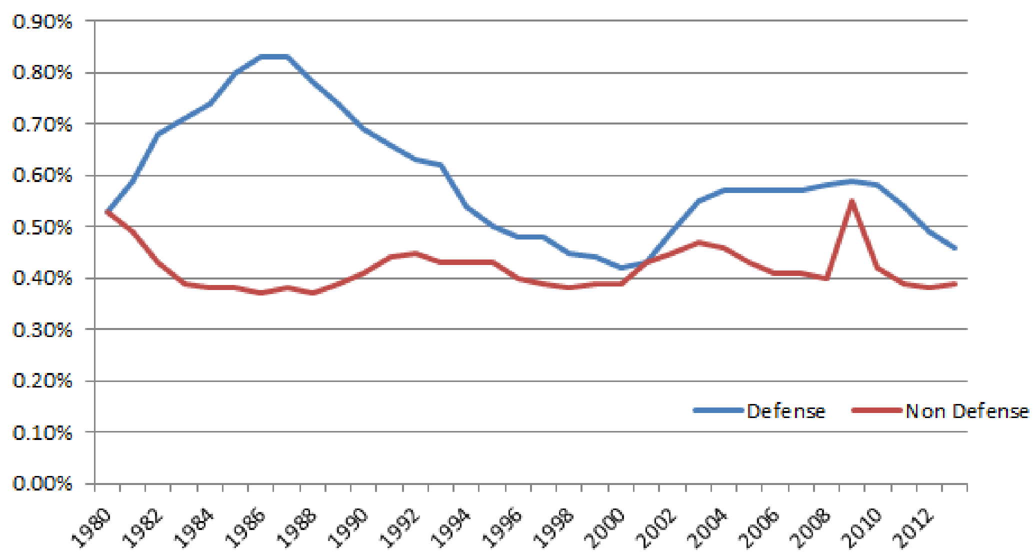

Figure 4: Defense and Nondefense R&D Budget Authority: (as percentage of GDP, 1949-2013) (Data from the National Science Foundation, 2002, 2014)[16]

Nevertheless, the DOD's commitment to advanced-technology prevailed even when the Cold War ended, the Soviet Union collapsed and defense budgets plunged worldwide. As Congress committed to doubling the NIH budget, the share of the defense R&D expenditures shrank back to just over half of the total. If the U.S. success in the first Persian Gulf War demonstrated U.S. superiority in military might and defense R&D, the technology revolution in the late 1990s intensified efforts to move defense doctrines into the networked Internet era.

However, things changed again after September 11, 2001, when defense R&D expenditures rapidly increased. In 2003, military R&D exceeded $50 billion; it peaked at

$83 billion in 2009. During the Great Recession, defense R&D plunged to about $61 billion in 2014, but is anticipated to climb back to around $69 billion by 2015.

Of total federal obligations for R&D in the early 2010s, more than half were accounted for by the DOD. The lion's share of the rest can be attributed to the Department of Health and Human Services (HHS), Department of Energy (DOE), and NASA (Figure 5).

Moreover, the composition of federal obligations for defense R&D differs substantially from that in the civilian sector. The bulk (81 percent) of DOD R&D goes to development, particularly to (6.3) advanced technology development (weapons systems, prototypes, etc.) whereas (6.2) applied research accounts for 7 percent, and (6.1) basic research barely 3 percent (Figure 6). Development accounts for just 15 percent of nondefense R&D, whereas basic and applied research account for 45 percent and 40 percent, respectively. (Figure 7)

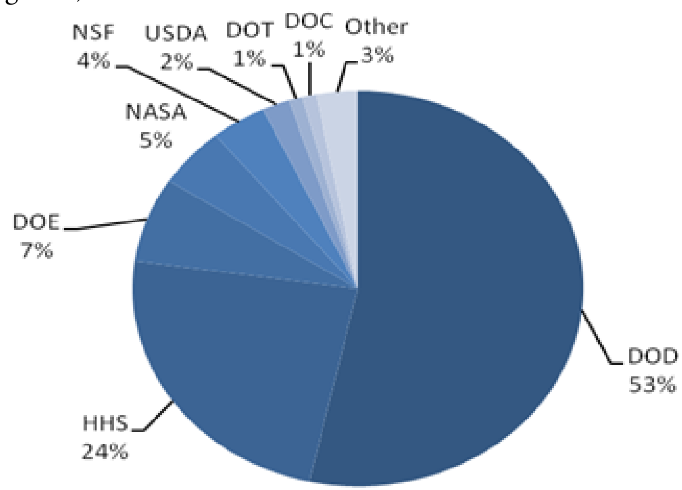

Figure 5: Federal Obligations for R&D, FY 2011[17]

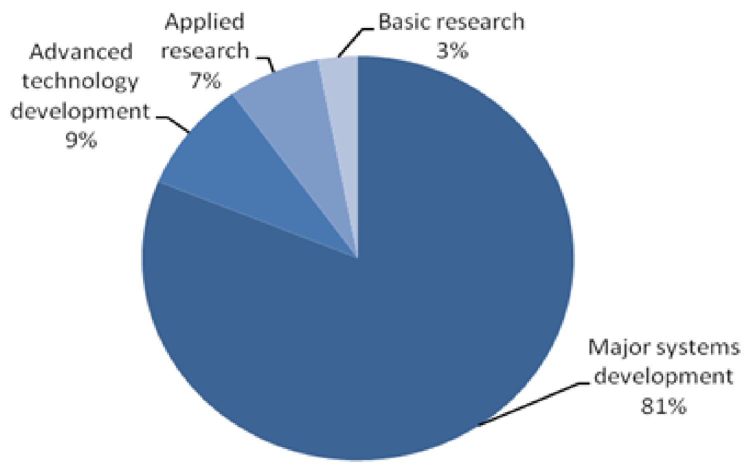

Figure 6: Department of Defense R&D, DOD, FY 2011[18]

> *Between 2005 and 2015, total defense R&D will have contracted by 21 percent. In turn, DOD weapons development and DOD science and technology will have contracted by 21 percent and 25 percent, respectively.*

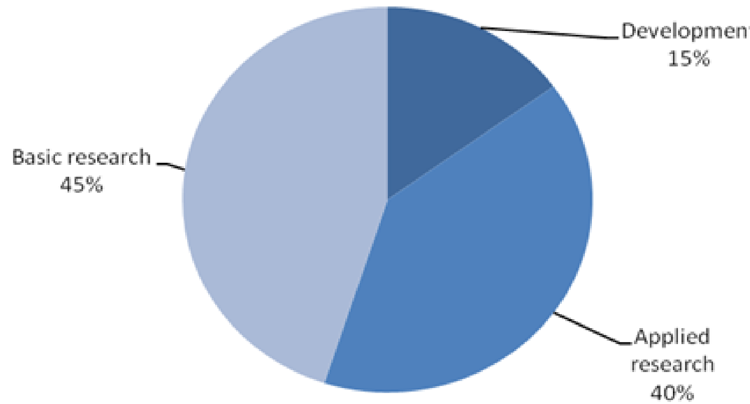

Figure 7: Federal Obligations for R&D, Other than DOD, FY 2011[19]

KEY DEFENSE R&D FUNDERS

R&D directed at national defense objectives is supported primarily by the Department of Defense but it also includes R&D by the Department of Energy and, to a lesser degree, the Department of Homeland Security.

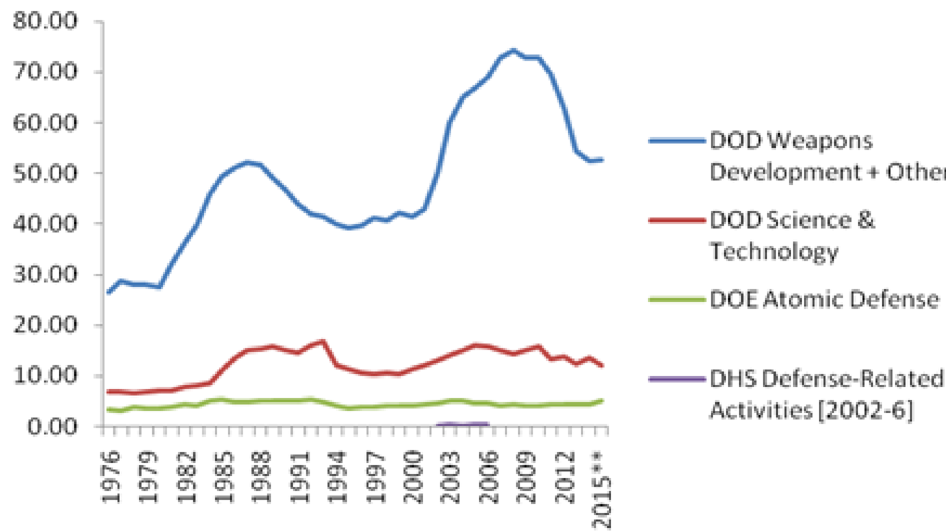

Figure 8: Trends in Defense R&D Expenditures, FY 1976-2015[20] (billions of constant 2014 dollars)

Department of Defense

Defense R&D focuses on three main areas: DOD weapons development, DOD science & technology, and DOE atomic defense. By 2015, DOD expenditures for weapons development are expected to decrease to $52.6 billion (over 75 percent of the total defense R&D), and DOD science and technology to $12 billion (17 percent), while DOE atomic defense will rise to $5 billion (8 percent). (Figure 8)[21] In other words, between 2005 and 2015, total defense R&D spending will have contracted by 21 percent (in inflation-adjusted terms). In the same time period, DOD weapons development and DOD science and technology will have contracted by 21 percent and 25 percent, respectively, whereas DOE atomic defense will have increased by 6 percent. (Figure 9)

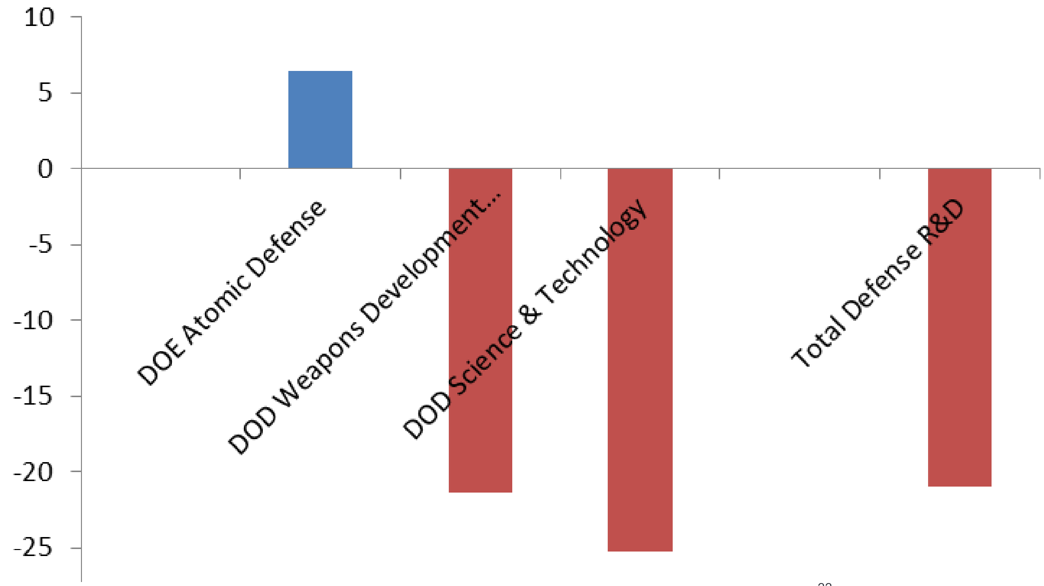

Figure 9: Percentage Change in Defense R&D Expenditures, FY 2005-2015e[22]

Based on DOD R&D expenditures by agency or department — that is, Army, Navy, Air Force, Defense Agencies (Missile Defense Agency, DARPA) — the Air Force (36 percent of expected DOD total R&D in 2015) and Navy (25 percent) have remained dominant. Between 2005 and 2015, the Army, Missile Defense Agency and DARPA each have had a minor role in DOD total R&D (less than 10 percent by 2015). (Figure 10) Through that decade, DOD total R&D will have shrunk by 22 percent. The decline has been most dramatic in Army and missile defense (over -47 percent each), while both the Navy and DARPA suffered substantial decline (-20 percent and -18 percent, respectively). Even the Air Force was no longer immune to decline (-4 percent). (Figure 11)

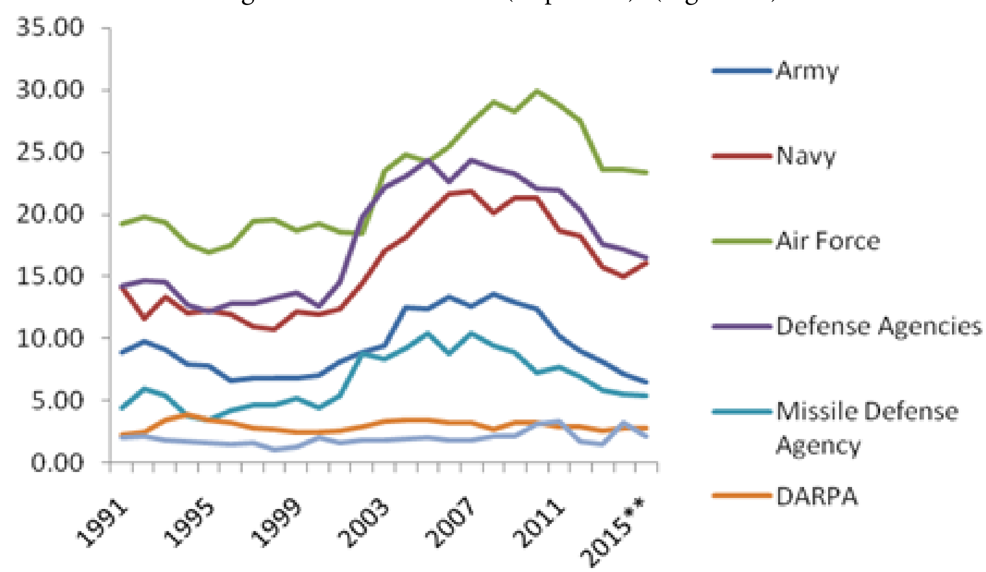

Figure 10: DOD R&D Expenditures by Agency/Department, FY 1991-2015e[23] (billions of constant 2014 dollars)

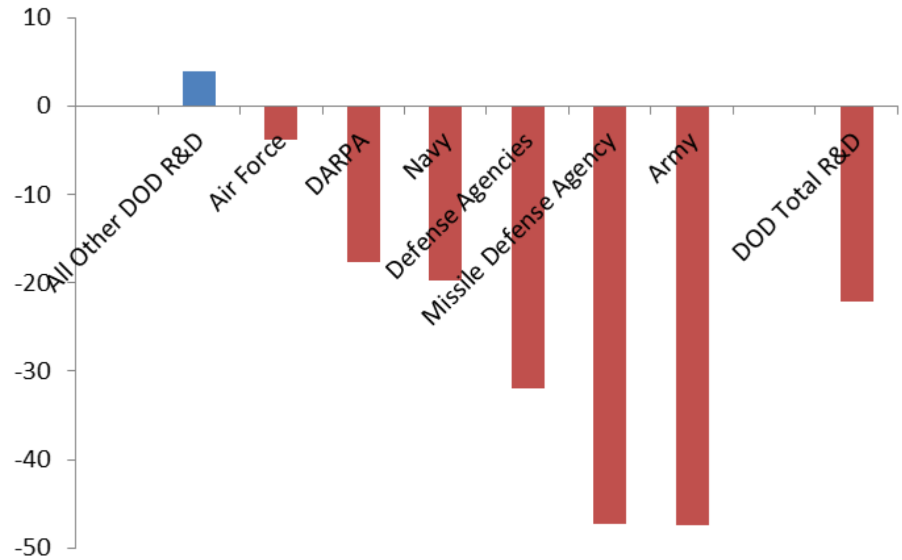

Figure 11: Percentage change in DOD R&D by Agency/Department Expenditures, FY 2005-2015e[24]

Looking at the role of DOD science and technology expenditures between 2005 and 2015, the total is expected to decline from $16 billion to $12 billion. Advanced technology development is likely to contract by 38 percent to $5 billion by 2015. Meanwhile, applied research will decline to $4.4 billion (-23 percent), whereas basic research will climb to $2 billion (13 percent) (Figure 12). Total DOD science and technology spending is likely to contract by 25 percent from 2005 to 2015. These allocations peaked at $17 billion already in 1993, when advanced technology development accounted for 56 percent of the total. In 2015, the total will be a third less, while the share of advanced technology development will be 41 percent of the total. (Figure 13)

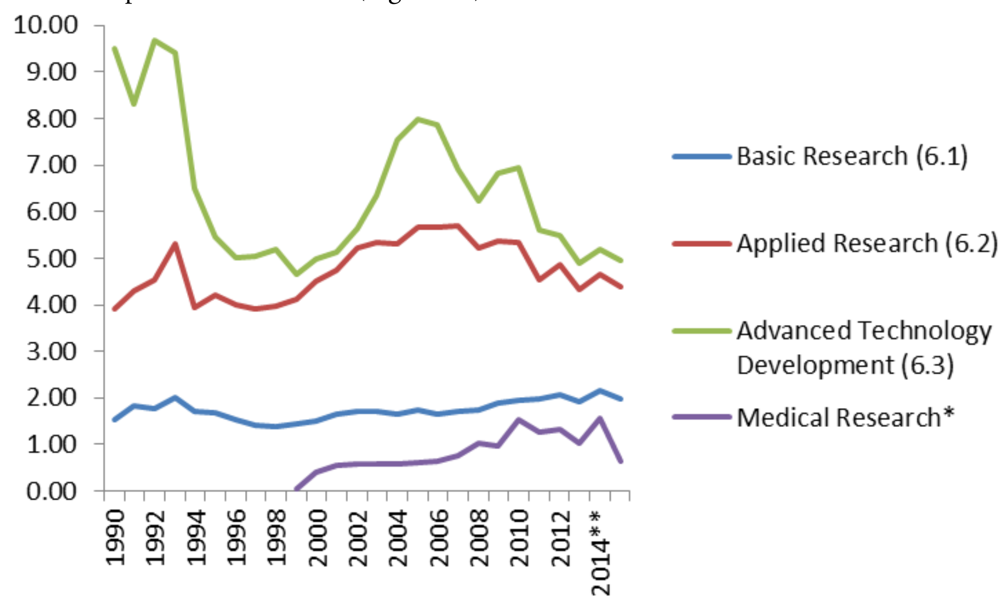

Figure 12: DOD Science and Technology Expenditures, FY 1990-2015[25] (billions of constant 2014 dollars)
*Medical research is appropriated outside RDT&E; appropriated in '6.2' accounts before 1999.

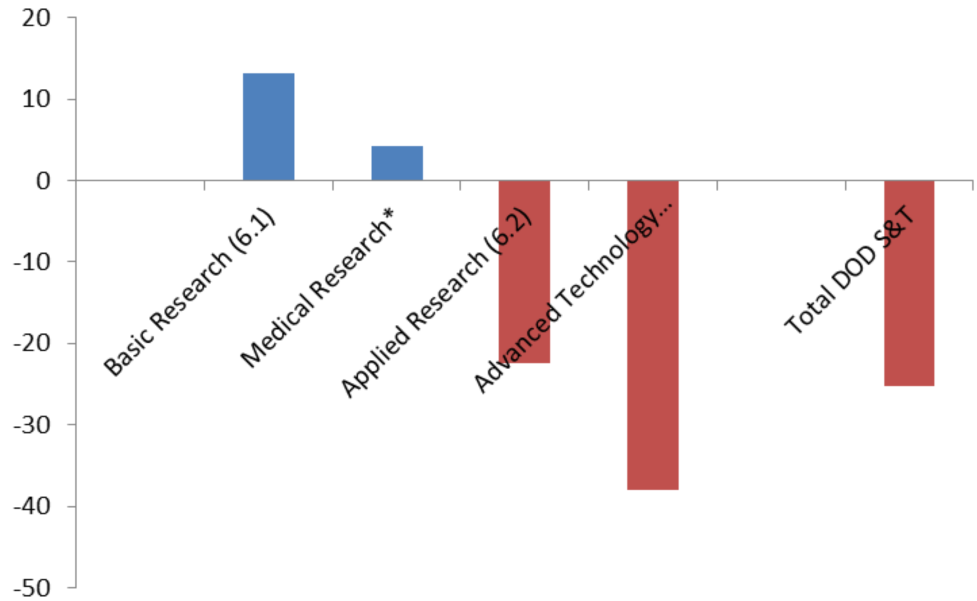

Figure 13: Changes in DOD Science and Technology Expenditures, FY 2005-2015e (%)[26]

Department of Energy

In fiscal year 2011, the DOE obligated $9.9 billion for R&D with over 90 percent for R&D and the rest for R&D plant.[27] The DOE's R&D activities are distributed among domestic energy systems, defense (much of which is funded by the department's National Nuclear Security Administration), and general science, most of which is funded by the department's Office of Science.

DOE has focused its funding on nuclear weapons, energy, and nuclear clean-up. During the oil crisis years, it spent equal amounts on defense and energy. During the 1980s defense build-up, spending on nuclear weapons was about two-thirds of the DOE budget, while energy got the rest. Since the Cold War, DOE has spent about equal amounts on nuclear weapons, energy, and defense clean-up.[28]

DOD Labs and University Affiliated Research Centers (UARCs)

In the Army, R&D and production proceeded alongside one another in the manufacturing arsenals that had been in continuous operation since the 19th century, despite actions taken by some Army leaders to separate these functions organizationally. In contrast, the Navy maintained a sharper organizational division of labor between R&D and production. Established in 1923, the Naval Research Laboratory operates independently of the Navy's material bureaus, where, as in Army's arsenals, technological innovation historically had depended on close coordination of R&D, and production. Created in 1947, the Air Force has relied more heavily than both the Army and the Navy on the private sector for new knowledge and skills. However, it has also operated an extensive network of in-house laboratories.[29] At the same time, the DOD and the services have steered funds to multiple competing technologies to support similar or identical missions, from long-range strikes on Soviet territory to tactical defense of the Navy's ships.[30]

DOD also funds University Affiliated Research Centers (UARCs) which are strategic DOD research centers associated with universities. Starting with the creation of the Applied Physics Lab at Johns Hopkins in 1942, the UARCs have sought to maintain engineering and technology capabilities of particular importance to the DOD. UARCs are nonprofit organizations considered vital to maintaining essential R&D and engineering "core" capabilities. They have long-term strategic relationships with their DOD sponsors. (Table 1)

Primary Sponsor	University	UARC
Army	Georgia Institute of Technology	Georgia Tech Research Institute (GTRI) Applied Systems Laboratory
	Massachusetts Institute of Technology	Institute for Soldier Nanotechnologies
	University of California, Santa Barbara	Institute for Collaborative Biotechnologies
	University of Southern California	Institute for Creative Technologies
Navy	John Hopkins University	Applied Physics Laboratory
	Penn State University	Applied Physics Laboratory
	University of Hawaii	Applied Physics Laboratory
	University of Washington	Applied Physics Laboratory
Missile Defense Agency (MDA)	Utah State University	Space Dynamics Laboratory
DASD (Systems Engineering)	Stevens Institute of Technology	Systems Engineering Research Center
National Security Agency	University of Maryland, College Park	Center for Advanced Study of Language
Strategic Command (STRATCOM)	University of Nebraska	National Strategic Research Institute

Table 1: Sponsors, Universities, and DOD UARCs (2014)[31]

Department of Homeland Security

In fiscal 2011, the Department of Homeland Security (DHS) obligated $1.1 billion for R&D and R&D plant, nearly all of which was focused on activities by the department's Science and Technology Directorate (the Department's R&D arm).[32] The four major areas of activity are: acquisition and operations support; laboratory facilities; R&D and innovation;[33] and university programs.[34] Of the obligations for R&D, 14 percent went to basic research, 33 percent to applied research, and 53 percent to development.

In terms of defense R&D performers, there are three main groups: federal laboratories, university-affiliated research centers (UARCs), and defense contractors. National defense represented about 58 percent of the total budget authority for R&D in fiscal 2011.

DEFENSE CONTRACTORS

In addition to significant outsourcing of research during the Cold War to entities like UARCs, the U.S. Army, Navy, and Air Force also support substantial in-house R&D as well as a network of defense contractors that build and maintain weapons systems.[35] Today, most government contractors, including defense contractors, are coping with budget cuts, contract delays and uncertainty.

Reconfiguration of Defense and Aerospace Industry

The U.S. defense industry consists of almost 2,700 prime contractor companies operating across nine program-level sectors ranging from aircraft and space systems to light arms, ground vehicles, and services. However, six percent of companies employ over 70 percent of the defense workforce. The aircraft sector is the largest and one of the few with both civilian and defense interests. Further, ten percent of companies that receive 43 percent of revenues are in the front end of the supply chain.

AT Kearney has argued that defense firms gain economic value in three ways. Infrastructure-based companies are those with production asset bases to produce and assemble their goods, especially in shipyard and aircraft manufacturing sectors. These firms account for more than half of employment and revenues, although they represent just a quarter of the number of firms. Knowledge-based companies tend to be smaller firms that provide solutions, such as intelligence and software applications. Finally, standardized-companies (59 percent of the firms in the industry) produce commodity-type products that competitors can easily replicate and create the least value. These account for only 29 percent of employment and thirty percent of revenues. (Figure 14)[36]

Defense Contractors as Public-Private Partnerships

Among all government contractors, the top-ten companies account for $131 billion, or 29 percent of all contracts. Almost all are defense contractors that also operate in non-defense industries. The industry leaders include the $46 billion Lockheed Martin Corp., which operates in aerospace, IT systems, security and advanced technology; the $87 billion Boeing, which designs, manufactures and sells fixed-wing aircraft, rotorcraft, rockets and satellites; the $32 billion General Dynamics an aerospace and defense company; the $25 billion Raytheon, a major defense contractor with manufacturing in weapons, military and commercial electronics; and the $25 billion Northrop Grumman, a global aerospace and defense technology company.

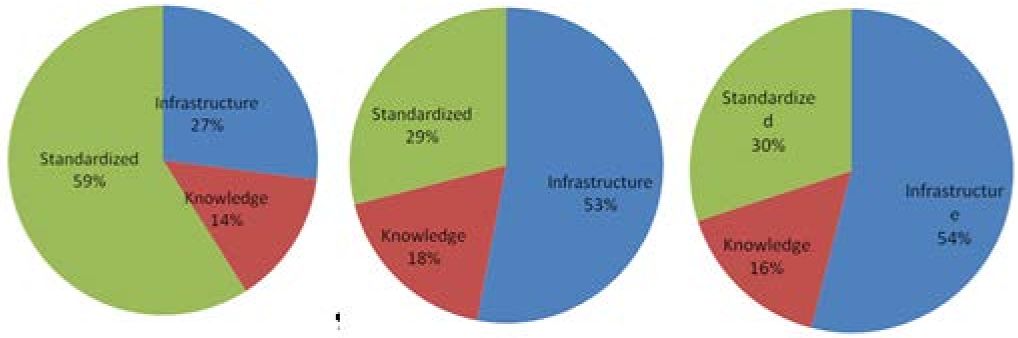

Figure 14: Share of Defense Industry Based on Solution Value Added[37]

The largest markets of these defense contractors consist of the Navy, Air Force, Army and Defense Logistics, from which the top-ten companies receive between $10 billion to $54 billion in contract awards yearly. The top-ten companies have a major share (56 percent) in each defense sub-market — from the Navy to Defense Security, but there is great variety. In certain markets — e.g., missile defense and defense microelectronics, where there is considerable advantage to scale and scope– the concentration is over 90 percent. In missile defense, Lockheed Martin (49 percent) and Raytheon (23 percent) lead the marketplace, whereas in defense microelectronics Raytheon (47 percent) and Northrop Grumman (23 percent) play large roles.[38]

New Public-Private Partnerships

As the defense industrial base becomes more focused on IT, the federal government has sought to engage in stronger partnerships with non-defense firms. That's what happened amidst the 1990s technology revolution, when the CIA's then-chief George Tenet concluded that the nation's intelligence community could no longer take on its enemies alone. That led to In-Q-Tel (IQT), a CIA-backed technology early-stage investor, which was created in 1999 as an independent, not-for-profit organization. As Tenet recalls, CIA created IQT hoping to use its limited dollars "to leverage technology developed elsewhere. CIA identifies pressing problems, and IQT provides the technology to address them."[39] Initially, IQT catered mainly to the needs of the CIA. Today it supports many of the 17 agencies within the U.S. intelligence community with a focus on the ICT sector, as well as physical and biological technologies.

In 2007, Tenet argued that "the In-Q-Tel alliance has put the Agency back at the leading edge of technology."[40] Over the years, IQT has invested in over 180 portfolio companies and claims to have leveraged more than $3.9 billion in private-sector funds. The importance of IQT should be seen in context, however. In the United States, there are some nine hundred venture capital firms, which have $200 billion of venture capital under management.[41] That translates to an average of $240 million per firm. In global venture capital, the CIA-backed firm is simply one among many in a globalizing industry.

DEFENSE INNOVATION AT THE CROSSROADS

From the launch of the Soviet Sputnik well into the Strategic Missile Defense program of the 1980s, the perceived common enemy of Soviet communism is what kept Washington united, and sustained federal funding and America's commitment to technological superiority in defense. This was reinforced by the reality that while the Soviets might field more troops and weapons, the United States could prevail in any conflict only through advanced technology. It was this "national mission" that persuaded Americans to defer their current consumption for the higher goal of winning the Cold War.[42]

After the eclipse of the Cold War, America gradually shifted resources from Pentagon-led innovation toward current consumption markets, especially in health care. At the same time, many other nations have put in place aggressive policies to prevail in international economic competition. As a result, U.S. defense, especially as it relates to innovation, now faces key challenges:

Defense procurement has a positive impact on private sector patenting and R&D investment.

- Cost pressures engendered by sequestration and limited budgets,
- Bias for short-term defense policies at the expense of investments in longer-term, higher risk activities,
- Challenges of defense acquisitions,
- Shift from defense spin-offs to consumer-market spin-ons,
- Hollowing out of the defense industrial base,
- Erosion of competitive inter-service pressures,
- Lower defense contractor R&D intensity, and
- Rising foreign defense competition, including low cost competition.

Sequestration and Limited Budgets

Defense innovation has long served a dual use purpose. It has bolstered defense as well as commercial innovation and U.S. competitiveness. Today's budget cutting threatens both. Analysts have shown that large-scale and long-term government investment has played a key role in the development of general-purpose technologies and economic growth.[43] This is true of federal support for both civilian and defense R&D. Research on the impact of military procurement spending on corporate innovation indicates that defense procurement has a positive impact on private sector patenting and R&D investment. Indeed, in some cases, according to one study, military spending can be better at stimulating innovation than civilian spending because firms are given incentives to push the technological frontier and develop new technologies.[44] This is why military spending can have positive spillovers for the rest of the economy. By providing a source of demand for new technologies that do not have existing markets, military spending provides an important impetus for R&D that impacts broader innovation. Thus, it is not surprising that through the Cold War, defense R&D served as a key contributor to the nation's growth through the large-scale development of vital general-purpose technologies.[45]

Indeed, there is widespread recognition among technology policy scholars that defense R&D was crucial to the development of the aircraft and space industries; nuclear power, the computer, semiconductor and software industries; the Internet and many other tech sectors.[46]

Those innovations were powered by robust defense budgets. But sequestration challenged that. Indeed, DOD senior officials suggest in the recent *Strategic Choices and Management Review* that the budget sequestration would result in serious challenges: "Significant reductions beyond the President's plan would require many more dramatic cuts to force structure…Under sequester-level cuts, our military options and flexibility will be severely constrained."[47] As the $1.2 trillion sequestration plan was activated, the White House did express concern that it would also be "deeply destructive to national security."[48] Yet, the administration made no serious proposals to limit or reform entitlement spending to free up budget resources, nor did Republicans make a serious effort to raise revenues, especially by raising taxes on individuals. True, the Obama administration has made a variety of proposals to reduce the defense budget, including cuts to big-ticket weapons programs like the F-22 or the F-35 Joint Strike Fighter. But these proposals would also cut defense R&D.[49]

Recently, the Air Force released an outline for its 30-year strategy. Central to the plan is the pursuit of "game changing" technologies. But whether, when push comes to shove, these longer term projects will receive support remains to be seen.

Because of these budget limitations, the Pentagon's investment in research, development, testing, and evaluation (RDT&E) has fallen 28 percent since its peak in 2009, adjusting for inflation. In 2012, the Air Force spent $26.3 billion on R&D, as much as the Navy and Marine Corps ($17.7 billion) and the Army ($8.7 billion) together. Those numbers remained fairly flat in the President's 2013 budget request, but dropped for 2014 to $25.7 billion (Air Force), $16 billion (Marine Corps) and $8 billion (Army). According to the Pentagon, R&D spending will continue to bear the brunt of defense budget cuts. As a result, senior Pentagon leaders have tried to protect R&D funding in the fiscal 2015 budget plan from sequestration budget caps.[50]

These senior leaders also express concern that the continued pinch on R&D could threaten U.S. technology superiority and harm the U.S. defense industrial base. Further, cuts to defense and civilian R&D will reduce overall U.S. economic growth and global competitiveness. As ITIF has shown, the projected decline in federal R&D will reduce U.S. GDP by at least $203 billion and up to $860 billion over 2013-2021, depending upon the pre-sequestration baseline.[51]

In theory, austerity can serve as mother of innovation. But when the pie itself is shrinking, it is not entirely clear whether the services will think harder about security threats and how the Armed Forces as a whole can meet them.

Bias For Short-Term Policies

Cost pressures are also contributing to a bias for short-term defense policies, including changes in the focus on R&D. The economy as a whole has a bias for short-term development, at the expense of long-term innovation, and not surprisingly this is affecting defense as well.[52]

This bias for near term results is exemplified even by the Defense Advanced Research Projects Agency (DARPA), which has been responsible for funding the development of many technologies that have had a major effect on the world. It was the technology race with the Soviet Union that led to the launch of the DARPA, which was initially mandated to invest in high-risk, high-payoff research. It was conceived and developed as an agile, non-bureaucratic agency that focused on technology. It could fund R&D, but not commercialize technologies. But by leveraging its linkages with the DOD, it could give a push to innovations.[53] This is how DARPA funded innovative ideas — from the Internet to GPS, to advanced materials to pharmaceuticals — that have served the military and civilians alike, including the early research of mass-market consumer products; until recently.

The role of DARPA in seeding and encouraging new technology trajectories has shifted in the past decade or two. On the one hand, it remains a uniquely adaptive organization. A few years after Tony Tether became DARPA's director in 2001, journalists suggested that America's old technology engine was sputtering. And yet, irrespective of organizational adaptations within the agency, DARPA program managers continued to use the same five-step process to seed and nurture new technology trajectories with academic and industrial communities. As Erica Fuchs wrote in 2009, with those shifts, DARPA may have been effectively narrowing the "valley of death", coordinating innovation within a vertically fragmented industry, and influencing innovation to serve military needs. At the same time, Fuchs argued that the "new DARPA", in focusing on bridging the gap from invention to innovation, and working to solve near-term problems, may leave the U.S. technology pipeline without new sources.[54]

Nevertheless, the question remains whether DARPA can boost disruptive innovation with processes that focus more on current military requirements. Again, this relates to overall levels of funding: when funding is tight, investments in longer term, more disruptive innovation are often the first to be reduced. The DARPA's current technology goals are ambitious, but limited budgets, not just within DARPA but for DOD as a whole, mean increased pressures for nearer-term results.[55]

Likewise while other services have ambitious technology goals, it's not clear whether these long-term and high-risk investments will survive pressures for near term results. Recently, the Air Force, for instance, released an outline for its 30-year strategy, highlighting technologies it plans to target. Central to the plan is the pursuit of "game changing" technologies. Some of the more promising technologies include hypersonics, nanotechnology, directed energy, unmanned systems, and autonomous systems.[56] In other words, technologies promising much faster, smaller, cheaper, dehumanized and robotized defense innovations. But whether, when push comes to shove, these longer term projects will receive support at the expense of near-term programs remains to be seen.

However, DOD has shown that it would like to preserve and keep spending on research, development, test and evaluation (RDT&E) at levels close to the $63 billion the department will spend in 2014. This is about $36 billion less than the amount that will be spent on procurement in 2014. This gap is anticipated to close to about $26 billion in 2015. Under the 2015 Future Years Defense Plan, DOD would halve spending on System Development and Demonstration, from about $20 billion in 2009 to below $10 billion by 2018.[57] The biases for short-term policies are also reflected by the challenges associated with defense acquisitions.

Challenges of Defense Acquisitions

As John Alic has argued, the origin and nature of the U.S. "military-industrial complex" continues to determine U.S. defense activities, including innovation.[58] Historically, the military-industrial complex originates from World War I, when the Army and Navy turned to private firms for aircraft design. The complex took on its current shape during the 1950s and the early days of the Cold War. Despite the broad government-to-industry shift in responsibility for design, development, and production of military systems in the middle of the last century, the armed forces remain the lead partners in the military-industrial complex by reason of their control over the technical requirements that shape and constrain weapons system design. This configuration, in turn, leaves the civilian defense industry a junior partner.

Six decades of attempts at defense acquisition reform have largely failed. True reform would require increasing the influence of civilian officials over acquisition decisions and reducing that of the armed forces.

This structure is driven by industrial innovation, yet dominated by the military. It overshadows U.S. defense acquisitions, including innovation. That creates further complications because management by government differs fundamentally from private sector management. This is particularly true in the case of defense. It differs from other U.S. government missions in that very large sums are spent on high-technology systems and equipment to meet the unknowable contingencies of an uncertain future. Due to technological complexity, the difficulties of program selection, contracting, and oversight, and the absence of metrics for assessing the performance of military systems, "civilian officials have been unable to exercise effective oversight of defense acquisition, leaving discretionary choices by military leaders largely unchecked."[59]

In this sense, six decades of attempts at defense acquisition reform have largely failed. True reform would require increasing the influence of civilian officials over acquisition decisions and reducing that of the armed forces. Instead, the current status quo seeks to achieve the impossible. Armed forces must lead increasingly advanced systems that they do not technologically control, while defense contractors are responsible for development of systems they cannot lead.

The Defense Department spends $60 billion a year — nearly a third of its annual purchases — on everyday products sold in the open market by commercial companies. It also buys items that are not sold to the general public; these fall into the narrower category of "commercial of a type." Today, government officials are pressing vendors to provide detailed justification for their prices; suppliers view these actions as intrusive and unwarranted. Some are contemplating whether to exit the military market.[60]

In the private sector, the armed services' strategy of "low cost, but high innovation" would be untenable. In private-sector competition most companies have to opt for one or another, but not both which would be seen as a "stuck-in-the-middle" position. And yet, this is precisely what the DOD is increasingly signaling to its contractors and vendors.

From Defense Spin-Offs to Consumer Spin-Ons

Between World War II and the early 1980s — prior to the restructuring and globalization of the IT sector — defense spin-offs were prevalent. The Reagan-era rearmament, for example, occurred in a government-led, top-down, and non-networked R&D environment, which was fueled by advanced economies in the West. In that paradigm, new civilian goods were generated by military or governmental research. Typically, such spinoffs included new technologies that were commercialized through DOD or NASA funding, research, licensing, facilities, or assistance. This era may have peaked in the early 1990s when Alic and his colleagues published *Beyond Spinoff: Military and Commercial Technologies in a Changing Era.*[61]

In the past decade or two, this environment has morphed into a civilian-led, bottom-up and networked R&D environment, which is also fueled by increasing activity taking place in large emerging economies in Asia. Within the IT industry, the old, rigid and vertical IT value chains that used to be concentrated in one country have morphed into flexible, horizontal value networks that are dispersed in multiple countries. At the same time, the old U.S. IT dominance has been surpassed by polycentric IT dispersion; hence, the increasing role of assembly plants and factories and, more recently, R&D hubs in large emerging economies. Among other things, this transition has contributed to the transformation of the old defense spin-off paradigm.

The shift from one environment to the other parallels the transition from the spin-off paradigm to the spin-on in the consumer mass markets. After World War II, it was initially taken for granted that defense-related R&D and military procurement would result in substantial spin-offs (from military applications to civilian usage) of technology. The spin-off paradigm prevailed as long as the U.S. technology development enjoyed superiority in cutting-edge technology and defense markets; that is, until the eclipse of the Cold War.[62]

In the early 1980s, the huge Reagan era rearmament boosted the nation's defense significantly. It gave rise to the idea of the dual use technology with both military and commercial dimensions.[63] And as time went on, commercial leadership in IT innovation led to the idea of a reverse spin-on (movement of commercial technology to the defense sector). On the one hand, the new paradigm became the tacit way to cope with rising costs after the Cold War. On the other hand, it reflected the industry transformation, from concentrated government markets to mass consumer markets, as evidenced by the information and communication technology sector and its shift from the mainframes to minicomputers, PCs, laptops, and, eventually, smart phones.[64]

In this new environment, however, government policies no longer shape industry environment as much as they did in the past. As with the CIA-backed IQT in the venture capital universe, these policies are now more at the mercy of market forces. In the immediate postwar era, defense R&D fueled nation's civilian innovation. Today, the roles have reversed. It is the nation's innovation system that is driving defense R&D. The implications are vital. As long as the nation's predominance in the global advanced technology sector is under relative erosion, the U.S. will no longer be able dominate entire global value chains, not to speak of vital nodes of these activities.[65]

When U.S.-based companies do dominate critical value activities, the latter tend to rely on strategic alliances with foreign corporations. Thus, any adequate defense innovation strategy for the 21st century has to engage in supporting dual use systems, as do the current DOD and DOE funded National Network of Manufacturing Innovation centers focused on additive manufacturing, digital manufacturing, lightweight materials, and power electronics.

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Furthermore, intriguing innovation opportunities exist in defense innovation involving sustainability. The DOD seeks to foster innovation in biofuels by holding out the promise of volume purchases of alternative fuels, should suppliers begin to market drop-in biofuels that are interchangeable with petroleum. With fossil fuels relatively plentiful and inexpensive, demand for biofuels will continue to hinge on government policies and climate mitigation will provide the only compelling justification for change.[66] The Defense Department could have a central role in U.S. efforts to narrow the uncertainties concerning sustainability, building on existing policies to encourage procurement of alternative e fuels and with the overall intent of replicating some features of past episodes of spinoff from military R&D and procurement.[67]

Hollowing Out of the Defense Industrial Base

America's ability to defend its national interests depends on its ability to maintain a strong defense industrial base. It's one thing to invent new weapons systems, but if we can't build them, including by accessing first, second and third tier suppliers domestically, U.S. defense capabilities will be limited, especially in the face of a prolonged conflict. America can rely on allies for some of these inputs, but not all.

A number of reports have warned about the loss of the U.S. industrial base and its high-tech capabilities, arguing that these trends have the potential to profoundly impact the military. For example, a 2005 Defense Science Board Task Force on High Performance Microchip Supply said the country was losing its high-tech industrial capability and that "urgent action is recommended." It warned that America's most strategic industries were not in a position to change the competitive dynamics that had emerged globally to shift the balance of production and markets away from the United States. As the National Defense Industrial Association sums up the situation, "If we lose our preeminence in manufacturing technology, then we lose our national security."[68] This is because as the U.S. industrial base moves offshore, so does the defense industrial base.

Over the last decade and half, U.S. manufacturing capabilities have been significantly reduced, in large part because of the rise of competition from China and other large emerging economies. Indeed, America lost over one-third of its manufacturing jobs in the 2000s and when measured properly, over 10 percent of manufacturing output during a period when GDP grew by 11 percent.[69] The impending emergence of other large economies — especially those in which industrialization will accelerate and rely on low-cost manufacturing — is only likely to reinforce this trend of erosion in U.S. manufacturing capabilities in the future. As Joel Yudken explains in *Manufacturing Insecurity*, "ontinued migration of manufacturing offshore is both undercutting U.S. technology leadership while enabling foreign countries to catch-up, if not leap-frog, U.S. capabilities in critical technologies important to national security."[70]

If the U.S. defense industrial base is to retain its ability to develop the most technologically sophisticated defense platforms, the United States will need to be at the forefront of advanced technology manufacturing capabilities in many areas, such as nanotechnology, advanced batteries, semiconductors, sensors, etc. Unfortunately, U.S. vulnerabilities in advanced technology manufacturing capability span a number of technologies. The mission of the Defense Production Act Title III is to target and bolster areas of high-tech manufacturing where the United States has diminishing or no capability.[71] As Title III makes clear in the defense context, "dependence on foreign manufacturers…is not an option in some cases."[72]

Additional examples of defense-critical technologies where domestic sourcing is endangered are said to include propellant chemicals, space-qualified electronics, power sources for space and military applications (especially batteries and photovoltaics), specialty metals, hard disk drives, and flat panel displays (LCDs)."[73] In fact, Michael Webber, an engineering professor at the University of Texas, has studied the economic health of sixteen industrial sectors within the manufacturing support base of the U.S. defense industrial system that "have a direct bearing on innovation and production of novel mechanical products and systems," and finds that, since 2001, thirteen of those sixteen industries have shown "significant signs of erosion."[74]

In addition, an increased reliance on foreign manufacturers increases vulnerability to counterfeit goods. According to a study conducted by the Bureau of Industry and Security (BIS), in 2008 there were 9,356 incidents of counterfeit foreign products making their way into the Department of Defense supply line, a 142 percent increase over 2005.[75] Counterfeit materials can and have hampered the military's ability to maintain weapon systems in combat operations—a major vulnerability. Moreover, many distributors surveyed in the BIS study cited insufficient steps taken by foreign governments to disrupt counterfeiting operations within their own border. More recently the Governmental Accountability Office issued a report detailing the risk of counterfeit parts in U.S. weapons systems.[76]

Absent a strong, dual-use industrial base, future defense capabilities are at risk. With the diffusion of defense R&D and advanced technology R&D worldwide and increasing economic competition from other nations, these structural trends will only increase in the future. Thus, policies like the proposed Renewing America's Manufacturing Act (RAMI), the expanded R&D tax credit and capital investment incentives, tougher trade enforcement and smart multilateral alliances are now not just domestic economic policies, but integral to maintaining a strong defense industrial base. Ultimately, as Yudken concludes, "Only a comprehensive strategy aimed at reversing the erosion of the nation's overall manufacturing base will be sufficient for preserving and revitalizing the nation's defense industrial base in the coming decades."[77]

It is a tall order. But in the absence of adequate manufacturing capabilities, innovation benefits cannot be sustained.

Erosion of Competitive Inter-Service Pressures

In the civilian economy, competition should stimulate innovation. In the defense sector, competition within and among different military services and between the U.S. and the Soviet Union drove R&D expenditures to very high levels during the Reagan years of the 1980s. Defense R&D spending was 0.67 percent of GDP in the Reagan years, but just 0.5 percent of GDP in the two Bush terms. As the threat of the Soviet Union diminished, the 'competitive stimulation' that had fueled military R&D during the Cold War era ebbed. In the 2000s, the threat of terrorism seemed to fill the vacuum and defense spending soared. However, these allocations focused more on weapons development than on true R&D, which stresses innovative activities.

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While some observers argue that competition between services can be wasteful, three commands fought independently in the Pacific during World War II, just as they developed ballistic missiles in the 1950s. Inter-service competition can offer several major advantages. First, it may generate critical information. If one service will not tell civilian leaders about its vulnerabilities, others might. Also, it provides civilian leadership leverage in efforts to control defense policy, by allowing them to play one service against another in the case of preferred policies. Third, competition spurs innovation. In the 1950s for example, the Navy's fear of losing the nuclear deterrent mission to the Air Force resulted in the Polaris submarine.[78]

Innovation tends to threaten current market dominance and attention can be diverted from important and profitable customers in the quest to do new things.[79] In the civilian economy, innovation has often not been welcomed because it tends to destabilize the incumbents. In the defense sector, innovation is defined as revolutionary change that alters significantly military doctrine, the combat role of certain technologies and the status of military groups that specialize in the use of the technology.[80] In the civilian economy, one solution is to create an independent subsidiary to take up the new product and compete against the parent (think of IBM Personal Computer in 1981). In the military economy, it translates to an endorsement of inter-service rivalry and a call to reject joint projects.

In one school of thought, the military's attachment to current technology and doctrine is so significant that revolutionary change occurs mainly through the intervention of civilians. At the start of World War II, the Royal Air Force initially sought to use its limited resources to build bombers for attacking the continent. It was the vigorous intervention of political leaders that led to a switch to fighter productionin time to defeat the Germansin the Battle of Britain.[81] A second school of thought argues that significant change tends to occur gradually in the military, requires the replacement of one generation with another, and is relatively impervious to civilian intervention, due to the strength of platform communities within services. Typical examples are inter-war development of amphibious warfare by the Marines and of carrier aviation by the Navy.[82] According to a third school of thought, major innovation occurs through competition among services for missions against the incumbent innovation communities. In this case, decisive civilian interventions can force innovation over otherwise resistant military.[83] At the end of the day, organizational innovation in the military has its price in internal conflicts among the services.

Lower Defense Contractor R&D Intensity

In the decade since 9-11, defense and security expenditures increased significantly, yet increases in R&D investments failed to keep pace. As a result, R&D spending as a share of sales by top defense contractors declined by nearly a third in percentage terms between 1999 and 2012. In 1999, Boeing's defense unit, L-3 Communications, Lockheed Martin, Northrop Grumman, and Raytheon spent a combined $2.4 billion on R&D, which represented 3.3 percent of sales (Figure 15). By 2012, that combined figure had grown by approximately 50 percent as sales more than doubled and R&D share fell to 2.3 percent of sales (Figure 16). This was in part due to the rapid increase in sales, which boosted the denominator.

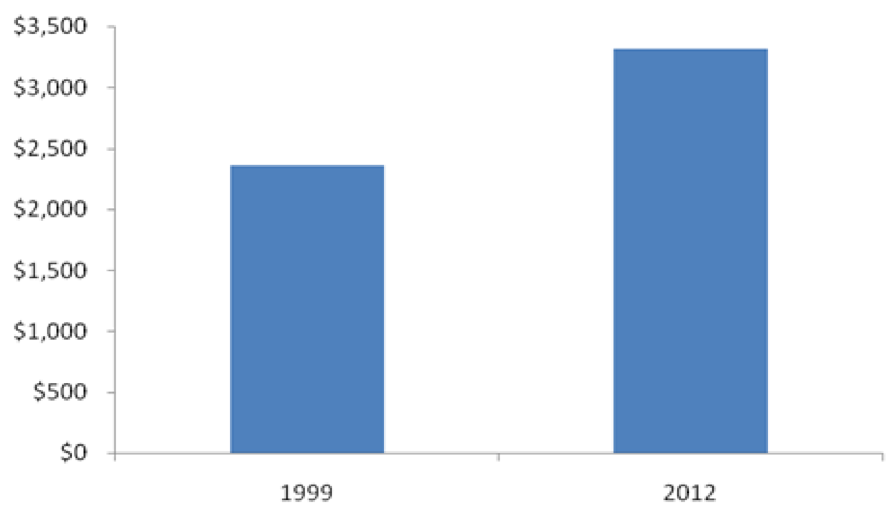

Figure 15: Defense Contractors*: R&D Expenditures (in thousands of dollars)[84]
*Boeing, Raytheon, Lockheed, Northrop, L-3

The decline of defense contractors' R&D ratio can be contrasted to the commercial technology sector.[85] Indeed, there is a large discrepancy between what the defense leaders and technology leaders are spending in R&D. In 2012, the five large defense companies — Boeing Defense, L-3 Communications, Lockheed Martin, Northrop Grumman and Raytheon — spent a total of $5.1 billion on R&D projects.[86] During the same time period, the leading five technology companies – Microsoft, Intel, Google, Cisco and IBM — invested almost $38 billion on R&D.[87]

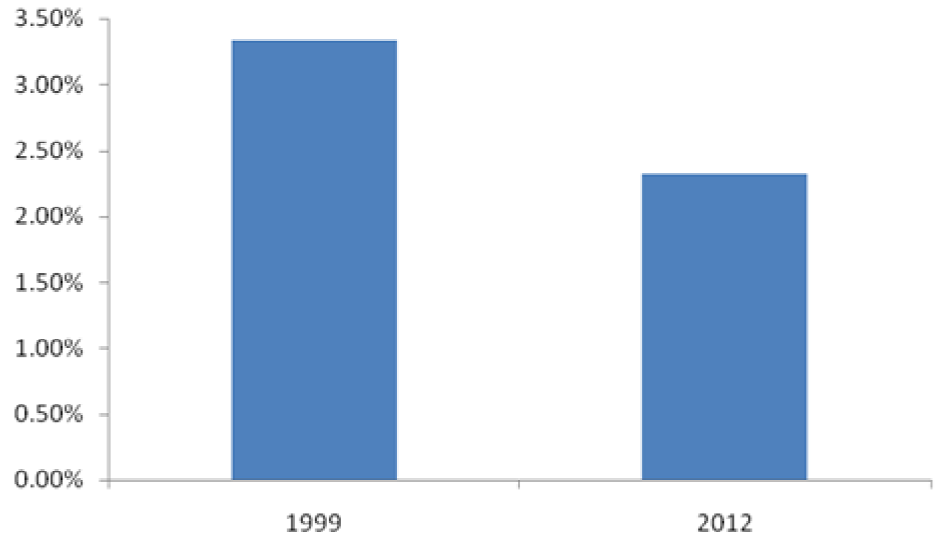

Figure 16: Defense Contractors*: R&D Intensity (R&D/Sales, %)[88]
*Boeing, Raytheon, Lockheed, Northrop, L-3

In 2013, the R&D intensity varied from 1.3 percent to 3.6 percent among the five large defense companies. The corresponding ratio of the technology giants was around 19 percent to 5.3 percent.

Changes in Pentagon procurement policy to give greater emphasis to low-cost procurement appear to have played a role as well. Industry executives argue that Pentagon's focus on purchasing low-cost products, especially the introduction of concepts like Lowest Price Technically Acceptable bid analysis, is encouraging companies to keep R&D spending low in order to win contracts.[89]

With R&D intensity (R&D/sales), the discrepancy is equally significant. In 2013, this ratio varied from around 1.3 percent to 3.6 percent among the five large defense companies. The corresponding ratio of the technology giants was around 19 percent to 5.3 percent (Figure 17). In part this is because R&D expenditures in the commercial technology sector can and do lead to significantly increased revenues from growing markets. In contrast, in an era of declining defense procurement, R&D expenditures for defense at best let a firm get a slightly larger slice of a smaller pie-- hardly a compelling proposition for shareholders.

Defense contractors also often cite uncertainty about the DOD's plan as a central reason why R&D spending remains relatively low. With little certainty about what future weapons systems will be purchased or even how much money will be allocated to them, R&D investments become riskier.

In the past, major defense contractors could count on the government to fund much of weapons system research, but that arrangement has been crumbling, in large part because of budget pressures and the prioritization of acquiring current weapon systems, rather than developing the next ones. While the DOD often advocates innovation, it has relatively few cutting-edge, major programs starting in the coming years. Due to decreasing defense spending, the Pentagon, too, has been forced to slow, defer or cancel new programs.

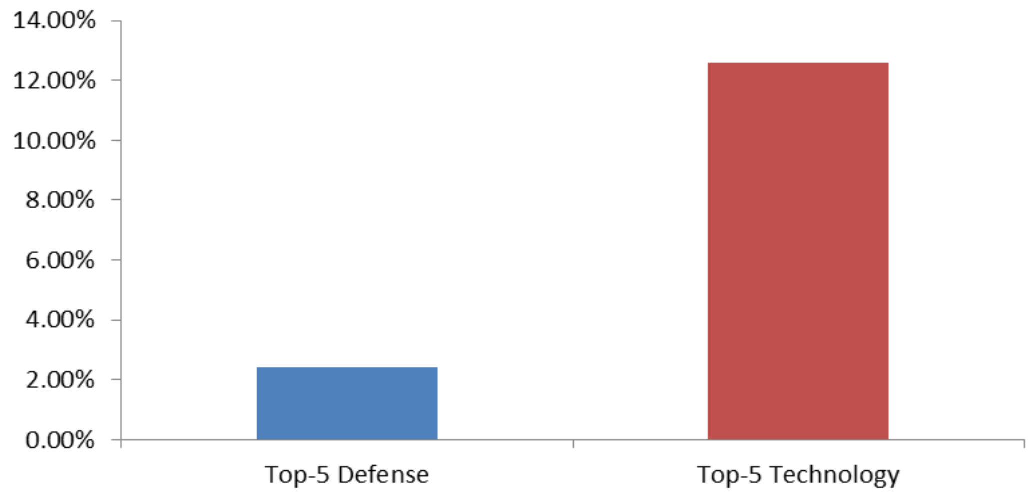

Figure 17: R&D to Sales Ratio for Top-5 Defense Contractors* and Technology Leaders**)[90]
*Boeing, Raytheon, Lockheed, Northrop, L-3
**Microsoft, Intel, Google, Cisco, IBM

In the past, the leaders of the global defense sector originated primarily from the major advanced economies in the West. The rest of the world was on the fringes. This is no longer the case.

These trends in defense R&D contractor investment have potentially adverse implications for defense innovation. The benefits of defense R&D have been historically realized during a drawdown of forces because the majority of R&D investment is made during buildups. However, since the ratio of investment in R&D to the rest of defense contract spending has been lower over the past two decades than in prior decades, the benefits that could be reaped from a drawdown in the coming years are likely to be fewer.

Rise Of Foreign Competition

In the past, the leaders of the global defense sector originated primarily from the major advanced economies in the West. In one way or another, most were affiliated with the U.S. Department of Defense and America's NATO allies. The rest of the world was on the fringes. This is no longer the case.

Today, new challengers may not offer the world's best technology, but their cost-efficient technology may suffice in the international arms market. In this regard, the recent success of China's unmanned aviation exports, including Yilong by Aviation Industry Corp., is only a foretaste of the future. Further, not all new challengers originate from the emerging world. Sweden's Saab Gripen fighter is a typical example.[91] Other examples include offsets in which regional sales can de facto close out opportunities for a U.S. or European company.[92]

According to Avascent and Reishman Hillard's June 2014 survey of nearly 350 senior aerospace and defense leaders on global competitiveness, eighty percent of executives believe the competitive landscape will increase outside their home markets in the next year, while only six percent believe their company is adequately prepared for the global competitive market.[93] The executives also believe that U.S. continues to have the most competitive markets, but emerging competitive threats reflect the future. (Figures 18 and 19)

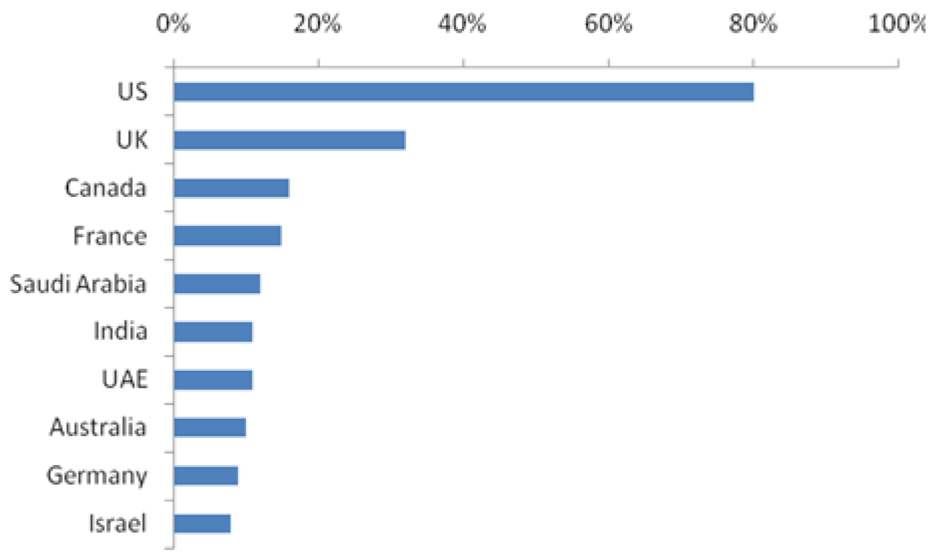

Figure 18: Global Aerospace and Defense Industry: Current Competitive Pressures[94]*
* % represents the share of executives indicating the country is 1 of 3 markets they view as an emerging competitive threat.

The U.S. defense industry may be vulnerable in strategically vital markets where America has enjoyed leadership in the past.

The U.S. defense industry may also be vulnerable in strategically vital markets where America has enjoyed leadership in the past, including unmanned aerial platforms, intelligence surveillance and reconnaissance, missiles, and satellites. What these emerging threats really represent is "cost innovation": not the world's best technologies, but cost-efficient world class technologies.[95] In the coming years, several countries can also be expected to gradually shift from cost innovation toward original technology innovation.

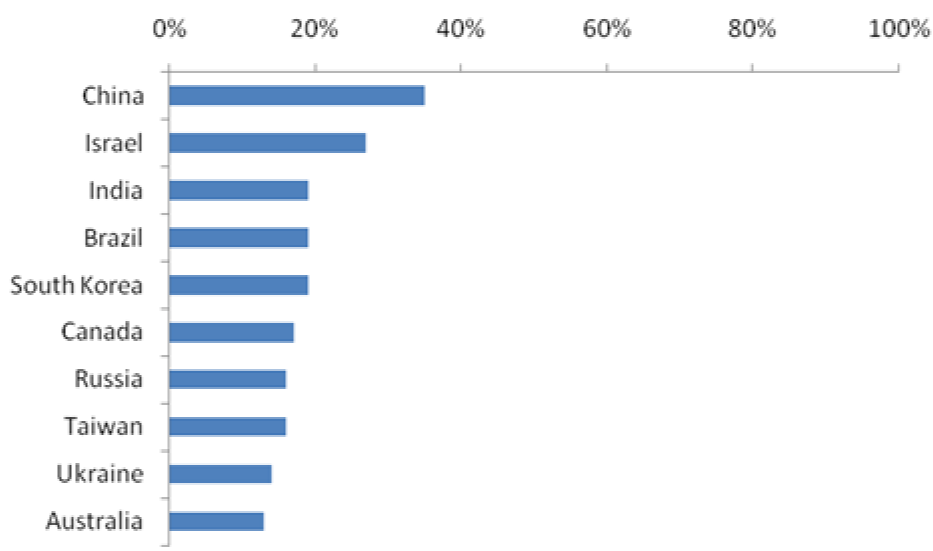

Figure 19: Global Aerospace and Defense Industry, Emerging Threats[96]
* % represents the share of executives indicating the country is 1 of 3 markets they view as an emerging competitive threat.

The new threats are not restricted to cost, but also include technology innovation as emerging and transitional economies are getting better in it. The U.S. defense industry may also be vulnerable in strategically vital markets where America has enjoyed leadership in the past, including unmanned aerial platforms, intelligence surveillance and reconnaissance, missiles, and satellites. What these emerging threats really represent is "cost innovation": not the world's best technologies, but cost-efficient world class technologies.[97] In the coming years, several countries can also be expected to gradually shift from cost innovation toward original technology innovation. The new threats are not restricted to cost, but also include technology innovation as emerging and transitional economies are getting better in it.

These changes are reflected by the international arms market in which the United States may have lost its place as the world's major weapons source. In the past decade, America led the world in arms exports, shipping more than $7 billion a year in weapons annually. But in 2013, Russian weapons exports surpassed the U.S. by more than $2 billion, marking a 35 percent increase in Russian arms sales, whereas U.S. manufacturers witnessed an average decline of over 6 percent in the top-100 defense companies' list.[98]

These shifts no longer reflect just cyclical fluctuations but structural changes. Due to the ongoing deleveraging in the advanced economies, defense spending has declined or stagnated in most G7 economies, while a series of arms races is taking place in Africa, Asia and the Middle East. Although the reasons for these accelerations are different in each region, all are fueled by the rise of emerging economies. Many of these nations cannot afford expensive, world class defense products and services. So they opt for affordable, almost world-class offerings of the kind produced by a nation like Russia.

CONCLUSION

In brief, the American military remains superior in terms of its budget, global engagement and technological capabilities. However, the state of U.S. defense innovation, despite its resilience and superiority worldwide, exhibits structural erosion and relative decline.

Absent a change in course, it appears that the days of massive U.S. defense technology leadership and significant impact of defense innovation on the U.S. economy and global competitiveness are over.

A robust federal policy to restore defense-related innovation and production in the United States would pay dividends on two fronts: continued U.S. defense strength through superior technology and broader U.S. commercial global competitiveness. Continuing to treat broader U.S. innovation as something driven only by private sector market forces while at the same time cutting defense support for technology development will result in continued loss of U.S. innovation-based competitiveness and relative erosion of U.S. defense superiority.

Only a comprehensive national defense innovation and production strategy can reverse the erosion of America's military innovation.

ENDNOTES

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2. Ibid.
3. P. Singer, *Federally Supported Innovations: 22 Examples of Major Technology Advances that Stem from Federal Research Support,* (Massachusetts: MIT, January 2014).
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7. Data from IMF, World Economy Outlook Database, October 2014.
8. Stockholm International Peace Research Institute (SIPRI). Military Expenditure Database, July 2014.
9. Science and Engineering Indicators 2014, p. 4-39. See also Rob Atkinson, et al, *The Global Innovation Policy Index* (Washington, D.C.: Information Technology and Innovation Foundation and the Kauffman Foundation, March), See Table 3-5, pp. 44.
10. Rob Atkinson, et al, *The Global Innovation Policy Index* (Washington, D.C.: Information Technology and Innovation Foundation and the Kauffman Foundation, March), See Table 3-5, pp. 44.
11. Calculated on the basis of SIPRI Military Expenditure Database, July 2014; see also Rob Atkinson, et al, *The Global Innovation Policy Index*, pp. 43.
12. See for example, “The Arsenal of Democracy” for a discussion of how federal funding of U.S. industry was central in enabling the Allies to win WWII. (2013).
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14. "The Military–Industrial Complex; The Farewell Address of President Eisenhower" Basements publications 2006.
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17. Data from Science and Engineering Indicators 2014.
18. Data from Science and Engineering Indicators 2014.
19. Data from Science and Engineering Indicators 2014.
20. Data from American Association for the Advancement of Science (AAAS) reports and agency budget data. Constant dollar conversions based on OMB's GDP deflators from the FY 2015 budget (budget authority in billions of constant 2014 dollars).
21. After September 11, 2001 — almost $1.7 billion of DHS defense-related activities — were also included in the defense account.

22. Data from American Association for the Advancement of Science (AAAS) reports and agency budget data.

23. Data from American Association for the Advancement of Science (AAAS) reports and agency budget data. Constant dollar conversions based on OMB's GDP deflators from the FY 2015 budget (budget authority in billions of constant 2014 dollars).

24. Data from American Association for the Advancement of Science (AAAS) reports and agency budget data.

25. Data from American Association for the Advancement of Science (AAAS) reports and agency budget data. Constant dollar conversions based on OMB's GDP deflators from the FY 2015 budget (budget authority in billions of constant 2014 dollars).

26. Data from American Association for the Advancement of Science (AAAS) reports and agency budget data.

27. The intramural laboratories and FFRDCs accounted for 76% of the total obligations. A fourth of obligations to extramural performers went chiefly to businesses and universities and colleges. For the $9.1 billion obligated to R&D, basic research accounted for 41%, applied research for 33%, and development for 26%, respectively.

28. Since 1978, energy R&D has declined by over 75% and its share of the DOE budget has gone from around 45% to 18%, whereas the DOE budget itself has remained more or less constant at about 1% of the federal budget.

29. Compare Thomas C. Lassman, *Sources of Weapon Systems Innovation in the Department of Defense: The Role of In-House Research and Development, 1945-2000*, (Washington, D.C.: Center of Military History, United States Army, 2008).

30. During the Cold War, these sub-optimal efficiencies were still tolerated in the name of the national mission. Such a "mindset," as one observer put it right before the global financial crisis, is "still evident today in the more than 50 anti-armor weapons in the inventories of the four services or under development, even though there is no prospect of confrontation with a tank-heavy army such as the Soviet Union maintained through the 1980s." See Alic, *Trillions for Military Technology*, pp 1-2.

31. Engagement Guide, Department of Defense, University Affiliated Research Centers (UARCs), Defense Laboratories Office, April 2013.

32. Two-thirds of the total was for agency intramural and FFRDC activities. Just under 37 percent was conducted by extramural performers; mainly businesses but also universities and colleges and other nonprofit organizations.

33. These comprise APEX R&D; border security; chemical, biological, and explosive defense; counterterrorism; cyber security; and disaster resilience, including the Department's Advanced Research Projects Agency.

34. These essentially support homeland security-related research and education at colleges and universities to address high-priority, DHS-related issues and to enhance capabilities over the long term.

35. See the section on the "erosion of competitive pressures."

36. Rene Quimet, et al.,"New Face of the A&D Industry: Victors, Victims, and Survivors," (AT Kearney, September 2013).

37 NAICS, OneSource, *AT Kearney*.

38. Other sub-segments also feature dominant companies, including Navy (Lockheed Martin 21 percent), Air Force (Lockheed Martin 16 percent, Boeing 15 percent), DARPA (Lockheed Martin 17 percent), Defense Security (Translang Ltd 17 percent), Defense Commissary (Tyson Foods 15 percent, Military

Produce Group 14 percent), and Defense Finance (Hewlett-Packard 16 percent, CACI International 11 percent).

39. G. Tenet, *At The Center Of The Storm: My Years at the CIA* (New York: Harper Press, 1997): p. 26.

40. Tenet, *At The Center Of The Storm*, p. 26

41. National Venture Capital Association Yearbook.

42. “Doing capitalism in the innovation economy,” as William H. Janeway has put it, required the government to play its vital role to promote the basic research to fuel innovation; to stabilize the economy when private demand failed to fully employ the country’s resources; and to limit the damage to the economy caused by episodic financial bubbles that contribute to the creation of new technologies, but also reflect false starts and dead ends. See Janeway, *Doing Capitalism in the Innovation Economy* (New York: Cambridge University Press, W.H. 2012).

43. See for instance V. W. Ruttan, *Is War Necessary for Economic Growth?: Military Procurement and Technology Development* (New York: Oxford University Press, 2006).

44. Rob Atkinson, “Both Guns and Butter? New Study Shows Innovation Benefits from Military Procurement,” *The Innovation Files*, April 23, 2014.

45. M. Draca, “Reagan’s Innovation Dividend? Technological Impacts of the 1980s U.S. Defense Build-Up,” London School of Economics and Political Science, Feb 2, 2012.

46. V. W. Ruttan, *Is War Necessary for Economic Growth? Military Procurement and Technology Developmen*t, (New York: OUP, 2006).

47. “The review showed that the ‘in-between’ budget scenario we evaluated would ‘bend’ our defense strategy in important ways, and sequester-level cuts would ‘break’ some parts of the strategy, no matter how the cuts were made.” See DOD press briefing by Secretary Hagel and Admiral Winnefeld, Washington, DC, July 31, 2013.

48. Andrew Bowman, "Breaking – White House Releases Sequestration Report," *The National Law Review*. (September 14, 2012). Retrieved December 1, 2012.

49. S. Ghoshroy,“Restructuring defense R&D,” *Bulleting of the Atomic Scientists*, (December 20, 2011).

50. M. Weisgerber and Z. Fryer-Biggs,“Pentagon Seeks To Protect R&D Funding in ’15 Budget,” *Defense News*, (January 11, 2014).

51. J. Hicks and Rob Atkinson, *Eroding Our Foundation: Sequestration, R&D, Innovation and U.S. Economic Growth* (Washington, D.C.: The Information Technology & Innovation Foundation, September 2012).

52. Robert D. Atkinson, *Understanding and Advancing America’s Evolutionary Economy* (Washington, DC: Information Technology and Innovation Foundation, October 2014).

53. See P. Singer, *Federally Supported Innovations: 22 Examples of Major Technology Advances that Stem from Federal Research Support,* (Massachusetts: MIT, January 2014).

54. See E.R.H Fuchs, *The Role of DARPA in Seeding and Encouraging New Technology Trajectories: Pre- and Post-Tony Tether in the New Innovation Ecosystem. Industry Studies Association* (Working Paper Series, January 2009). See also E.R.H. Fuchs, “Rethinking the role of the state in technology development: DARPA and the case for embedded network governance,” *Research Policy* 39, (2010): pp. 1133-1147.

55. Department of Defense, “FY 2015 Budget Estimate; Defense Advanced Research Projects Agency” (Accessed October 3, 2014), http://www.darpa.mil/NewsEvents/Budget.aspx.

56. America’s Air Force: A Call to the Future, July 2014.

57. Zachary Fryer-Biggs, “DoD Reshapes R&D, Betting on Future Technology,” April 20, 2014.

58. For the full argument, see John A. Alic, "The Origin and Nature of the U.S. 'Military-Industrial Complex.'" *Vulcan* 2, (2014): pp. 63-97.

59. John A. Alic,"Managing U.S. Defense Acquisition." *Enterprise & Society*, Vol. 14, No. 2, (March 2013): pp. 1-36.

60. Sandra I. Erwin,"Pentagon Will Demand 'Fair Prices' From Commercial Vendors." *National Defense*, September 1, 2014.

61. See J. A. Alic, et al, *Beyond Spinoff: Military and Commercial Technologies in a Changing World,* (Boston: Harvard Business School Press, April 1992).

62. On the spinoff paradigm and the early efforts to go beyond it, see J. A. Alic, et al, *Beyond Spinoff: Military and Commercial Technologies in a Changing World,* (Boston: Harvard Business School Press, April 1992).

63. See John A. Alic, *Trillions for Military Technology: How the Pentagon Innovates and Why It Costs So Much*, (New York: Palgrave Macmillan, 2007): particularly Chapter 1.

64. While the Clinton administration initially adopted the dual-use paradigm, its focus was primarily on shifting resources to the nation's civilian sector to foster technology development. Eventually, the dual-use efforts grew underfunded facing resistance from a White House, which hoped to benefit from the peace-premium, the DOD and the large defense contractors, which were more interested in the military dimension of the dual-use concept, and the 1994 Republican Congress, which cut the budgets of most federal technology programs.

65. On the ICT sector, innovation and global value chains, see D. Steinbock, "Globalization of wireless value system: from geographic to strategic advantages," *Telecommunications Policy*, vol. 27, issue 3-4 ((2002): pp. 207-235; "New Innovation Challengers", *The National Interest*, (Jan-Feb. 2007); "China as ICT Superpower" *China Business Review*, US China Business Council, Mar 2007); *Winning Across Global Markets: How Nokia Creates Strategic Advantage in a Fast-Changing World* (Wiley, 2010).

66. Megan Nicholson and Matt Stepp, Lean, Mean, and Clean II: Assessing DOD Investments in Clean Energy Innovation (Washington, D.C.: The Information Technology & Innovation Foundation, 2012).

67. John A. Alic,"Biofuels: Politics, Policy, and the Pentagon." *Draft*, July 2014.

68. National Defense Industrial Association, "Maintaining a Viable Defense Industrial Base," August 1, 2008, http://www.ndia.org/Divisions/Divisions/Manufacturing/Documents/MaintainingAViable DefenseIndustrialBase.pdf.

69. Robert D. Atkinson and Luke Stewart, "Worse Than the Great Depression," (Washington, DC: The Information Technology and Innovation Foundation, 2010).

70. Joel S. Yudken, "Manufacturing Insecurity: America's Manufacturing Crisis and the Erosion of the U.S. Defense Industrial Base," (working paper, High Road Strategies, April 14, 2011): 9.

71. Title III currently has active projects in lithium-ion (Li-ion) battery production, yttrium barium copper oxide high-temperature superconductors, and photovoltaic solar cell encapsulants, among others. Lithium-ion battery production is particularly troubling. According to Title III there is "at present no domestic production capability for extremely long life Li-ion cells." See Defense Production Act Title III, "Lithium Ion Battery Production," http://www.acq.osd.mil/ott/dpatitle3/projects/libp.htm.

72. Ibid.

73. Yudken, "Manufacturing Insecurity," 5.

74. Ibid., p. 6

75. U.S. Department of Commerce, Bureau of Industry and Security, Office of Technology Evaluation, Defense Industrial Base Assessment: Counterfeit Electronics, January 2010, ii,

http://www.bis.doc.gov/defenseindustrialbaseprograms/osies/defmarketresearchrpts/final_counterfeit_electronics_report.pdf

76. DOD Supply Chain: Suspect Counterfeit Electronic Parts Can Be Found on Internet Purchasing Platforms. GAO-12-375: Published: Feb 21, 2012. Publicly Released: Mar 26, 2012.

77. Yudken, "Manufacturing Insecurity," p. 5

78. The Polaris, in turn, reduced the need to deploy hundreds of vulnerable and costly strategic bombers and most liquid-fueled missiles that the Air Force was developing. See Harvey M. Sapolsky, "Interservice Competition: The Solution, Not the Problem." *JFQ*, (Spring 1997): pp. 50-53.

79. Clayton M. Christensen, *The Innovator's Dilemma: When New Technologies Cause Great Firms to Fail* (Cambridge, MA: Harvard Business School Press, 1997).

80. Harvey M. Sapolsky,"On the Theory of Military Innovation." *Breakthroughs* (Spring 2000): pp. 35-39. The description of theories seeking to explain innovation in the military draws from Sapolsky as well.

81. See Barry R. Posen, *The Sources of Military Doctrine: France. Britain. and Germany Between the World Wars* (Ithaca, NY: Cornell University Press, 1984).

82. Stephen P. Rosen, *Winning the Next War: Innovation and the Modem Military*. (Ithaca, NY: Cornell University Press, 1994).

83. See Owen R. Cote Jr, *The Third Battle: Innovation in The Navy's Silent Cold War Struggle With Soviet Submarines* (Newport Paper #16, U.S. Naval War College Press, 2003),; and Owen R. Cote Jr., *Creative Destruction: The Politics of Innovation in Military Doctrine*, forthcoming.

84. Top-5 defense contractors, 1999-2012.

85. M. Weisgerber,"Tech giants Spend Billions More Than Defense Firms on R&D" *Defense News* (May 26, 2014).

86. Boeing was the greatest innovation player, investing over $2.9 billion in R&D, as against $369 million by L-3 Communications.

87. Microsoft was the greatest innovation player, investing more than $10.3 billion in R&D, as against $5.5 billion by IBM.

88. Top-5 defense contractors, 1999-2012

89. See Zachary Fryer-Biggs and Marcus Weisgerber, "U.S. Giants Skimp on Research, Development," *Defense News*, August 19, 2013).

90. Top-5 defense contractors, 2012

91. After it was updated with advanced electronically scanned radar and electronic warfare systems that are more typical to larger and costlier jets, it has been sold in the world markets at cheap prices, which has left U.S. fighters at a strategic disadvantage.

92. Take, for instance, Abu Dhabi shipbuilding, which does not represent a global challenge, but has cornered an important regional market with its Baynunah corvette. With the fall off in global economic integration since 2008 and the decline of export-led growth, regional integration is likely to offer more such opportunities in the future.

93. Typically, the surveyed executives cited China as the top challenger, but it is coupled with a list of both emerging and advanced economies, including Israel, India, Brazil, Canada, South Korea, Turkey and UAE.

94. Data from Avascent, Reishman, Hillard's survey of A&D leaders on global competitiveness, June 2014.

95. As industry observers put it, they are redefining A&D competitiveness vis-à-vis “80 percent solutions at 20 percent cost.”

96. Data from Avascent and ReishmanHillard’s survey of A&D leaders on global competitiveness, June 2014.

97. As industry observers put it, they are redefining A&D competitiveness vis-à-vis “80 percent solutions at 20 percent cost.”

98. SIPRI Arms Transfer Database, August 2014.

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Since the 1990s, Dr Steinbock has examined innovation-led competitiveness in multiple world regions and advised regions, countries, cities, and companies. Parts of this paper and its companion piece, which focuses on the U.S. national innovation system amid global headwinds, draw from a report that explores the strengths of the U.S. national and entrepreneurial system and was funded by Tekes, the Finnish Funding Agency for Innovation.

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