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Sustaining technological superiority in an era of globalization is a major challenge for the U.S. national security community. This edition of *Research Notes* focuses on technological innovation—how the United States and others are pursuing it today, and the challenges and opportunities in fostering innovative technological developments to meet future national security needs. The individual articles summarize insights gained from past IDA research conducted for the Department of Defense (DoD) and other federal government organizations.

In the first article, **Andrew Hull** and **David Markov** emphasize that innovation in the security arena is now a global enterprise. This is particularly evident in the international arms market. Nations now have considerable flexibility and options for meeting their defense technology requirements. These options ensure the end products more closely meet the buyer nations' operational requirements and (in some cases) allow the nations' entry into areas previously denied them. Governments and defense firms of other countries are employing different approaches for acquiring defense capabilities that can collapse timelines and accelerate technical innovation. This, in turn, will challenge DoD to maintain U.S. leadership in critical technical areas in the next 10 to 15 years.

Getting early decisions on new systems right—ensuring adequate attention is given to the critical "What to Buy" decision—is crucial in DoD acquisition. **Gene Porter** addresses lessons on Defense Research and Development (R&D) management from the 1960s through the 1980s, when the Office of the Secretary of Defense (OSD) played a strong role in setting the innovation strategy and in providing senior management oversight of new acquisition system choices. Early decisions were focused on whether a proposed development was appropriate to meet real needs effectively and affordably with sound technical and operational concepts. The author suggests that OSD consider reinvigorating its role in R&D management—especially at the front end of proposed new developments and in initiating innovative technological and operating concept approaches outside traditional military department interests.

Commercial industry also has had to grapple with the issues of fostering and managing innovation in a globalized economy. The article by **Richard Van Atta** shows how leading firms have effectively employed new models and approaches for innovation. Many firms have instituted highly focused management methods to foster innovation—not just invention. Today's successful industry innovation stemmed from systematic and concerted identification and exploitation of global expertise—including open innovation, collaboration, and teaming—to solve difficult problems and reduce the costs and time associated with implementing technologies. Implementing this new organizational model for innovation often required enterprise-wide transformation—typically led by the CEO and his executive team—that broadly affected business practices and processes.

Building on its assessment of commercial R&D management, IDA compared DoD's Laboratory Enterprise to the best practices of commercial industry as summarized in the article by **David Graham**, **Robert Leheny**, and **Susan Clark-Sestak.** The authors observed that the labs' close ties to their parent military departments can create gaps in coverage in potentially important areas. Large commercial firms have parallel challenges to those of DoD as they too face tensions between the highly focused improvements in existing products and more open-ended enterprise-wide innovation needs. IDA researchers identified common commercial industry practices designed to overcome these weaknesses and encourage enterprise innovations. The IDA research team recommended stimulating DoD laboratory innovation through a "virtual central laboratory," which would identify and fund DoD laboratory projects addressing DoD-wide innovation needs. The Department has moved to implement this recommendation.

One major challenge for the DoD R&D enterprise, addressed in the next article by **Susannah Howieson**, is developing effective processes to determine how to prioritize and support the facilities and infrastructure needed for effective laboratories. The assessment identified concerns related to meeting infrastructure needs and practices to address them. A broader area of R&D management explored by IDA is laboratory governance: What features of how the laboratories are operated and overseen affect their ability to effectively address future national security challenges?

Jocelyn M. Seng and **Pamela Ebert Flattau** next discuss the challenge of DoD sustaining the quality and availability of civilian scientists and engineers in today's global economy. Significant uncertainties exist regarding the future supply of scientists in various academic disciplines as well as the future demand for scientists and engineers in the evolving global environment. The overarching question is whether DoD will maintain access to the pool of talent needed to ensure that it will keep pace with technology developments across the globe. The authors assessed recent trends in the science and engineering (S&E) workforce and offered suggestions regarding policies and practices that could help ensure future workforce viability.

In the final article, **Susannah Howieson** and **Stephanie Shipp** summarize IDA research identifying exemplar practices for DoD technology transfer. The research team identified more than 20 practices that have been employed effectively in such areas as empowering, training, and rewarding scientists and engineers and capturing and managing intellectual property.

ACQUISITION IN A GLOBAL TECHNOLOGY ENVIRONMENT

Andrew W. Hull and David R. Markov

The Problem

Governments and defense firms of other countries are experimenting with different approaches to acquiring defense technological capabilities. These strategies collapse timelines of worldwide defense acquisition and accelerate technical innovation. This, in turn, will challenge the Department of Defense to maintain U.S. leadership in critical technical areas in the next ten to fifteen years.

Introduction

Other nations have changed their approach to defense acquisition over the past two decades. During the cold war, nations had basically two choices: 1) "go-it-alone" and rely almost exclusively on domestic defense research, development, test, and evaluation (RDT&E) assets and their industrial base or 2) purchase finished systems from third parties—the performance of which was usually optimized to meet the military requirements of the supplier, not the importing customer.

Globalization of the international arms market has changed that paradigm. Nations now have a good bit of flexibility and many more options for meeting their defense technology requirements. These options ensure the end products more closely meet the buyer nations' operational requirements and (in some cases) allow the nations' entry into areas previously denied them because of cost, technical difficulty, lack of infrastructure, and/or export restraints by developers. Today, defense acquisition is, indeed, a "brave new world" for most countries.

Today's global defense industry is becoming highly competitive, more customer-oriented, more responsive to market demand, and more cost conscious.

Today's global defense industry mirrors the commercial sector. It is becoming highly competitive, more customer-oriented, more responsive to market demand, and more cost conscious. There is now a greater degree of civil-military integration in many countries. Consequently, defense planners in some nations, such as China, now specifically advocate "spinning-on" commercial/dual-use technologies for military applications, increasing the chances of asymmetric technology applications. Market pressures and fierce commercial competition among defense firms for exports also serve as forcing functions in speeding products from research and development (R&D) to serial production, increasing the overall pace of global defense technological innovation. This also facilitates the distribution of military operational capabilities (e.g., stealth, night vision, networked systems) to a wider and more diverse set of nations and non-state actors than ever before.

Alternative Acquisition Strategies

Defense acquisition in the cold war basically followed either of two paths: self-reliance on domestic resources and infrastructure or purchasing one-size-fits-all systems from other nations. In a few cases, a nation (e.g., India) would selectively employ both approaches simultaneously depending on the nature of the capability required. While some nations still follow these traditional models, others are pursuing different acquisition strategies and even following more than one of these strategies at the same time.

Concentrate on Core Competencies, Out Source the Rest (Russia)

To increase the export potential of "big-ticket" military product lines, the Russian defense industry has reached out, especially to France, for military technical cooperation at the component level in areas where Russian industry is weak. For example, the France-based manufacturer, Thales Optronics, supplies the Catherine-FC thermal imager for Russian T-90S tanks, as well as helmet and sighting system for MiG-29 fighters sold to India ("The Cooperation of Russia and France in Industrial Defense Can Significantly Increase the Export Potential of Two Countries (the Visit of Anatoly Serdyukov, in Paris)" 2010). Russia is also seeking military technical cooperation with Armenia, Kyrgyzstan, Belarus, and other former Soviet republics to replace suppliers lost in the breakup of the Soviet Union, in lieu of developing those capabilities afresh in Russia.

Privatization of the Acquisition Process (United Kingdom)

Privatizing is closely related to the previous approach in that it, too, seeks to employ outsourcing, this time turning public functions over to the private sector on a contract basis in hopes of reducing costs and increasing the efficiency of the acquisition process. In 2009, then Chief of Defence Materiel Bernard Gray proposed a radical change to the British Ministry of Defence's (MOD) basic approach to acquisition: i.e., "letting the private sector run Defense Equipment and Support" (RUSI Acquisition Focus Group 2012). Gray's proposal envisioned replacing the government employee staffed Defence Equipment and Support (organization), which is responsible for buying and supporting all army, navy and air force equipment and services, with a government-owned, contractor-operated (GOCO) entity.

Considering implementing the idea, the British MOD did what it called "soft market testing" in the summer of 2012 and attracted foreign as well as domestic bidders (RUSI Acquisition Focus Group 2012). In 2013, the MOD chose not to proceed with the proposed GOCO approach, leaving many questions connected with this acquisition management strategy unresolved: For what period would the company be appointed? Would the GOCO be responsible for making decisions or just giving advice? Would the company have the legal status of principal or just be an agent of the MOD? How would the company handle American foreign military sales (FMS) transactions or participate in international programs? What financial risks would the GOCO be asked to take? How would the private company make money and the MOD save money at the same time (RUSI Acquisition Focus Group 2012)?

Crawl, Walk, Run (People's Republic of China and India)

The upgrading and modernization of the People's Liberation Army of China have been accomplished using what might be called a "crawl, walk, run" approach over the last two decades. The first (crawl) phase entailed buying finished weapons systems off the shelf and acquiring licenses to manufacture some of those products domestically. For example, China initially purchased Su-27 fighters from Russia in 1992 and then ordered a second batch in 1993. Three years later, China acquired the rights to manufacture Su-27SK variants. Under that agreement, Russia would supply the aircraft in kit form for final assembly in China, as well as the avionics suite and AL-31F turbofan engines. In-country production was sometimes facilitated by foreign vendors sending specialists to China to help get the initial licensed production process started ("Su-27SK/UBK Air Superiority Fighter Aircraft" 2008).

The second (walk) phase featured hybrid systems that consisted of foreign systems (or derivatives of foreign systems) to which sub-systems developed and produced in the People's Republic of China were added. The Chinese were aided in the indigenizing process by the ability to purchase Russian engineering and design know-how on a contract basis. An example of this approach is the Type 052C (Lyuang II class) destroyer, which was a Chinese-built hull filled with a mixture of Russian, French, and Chinese systems ("Type 052C (Luyang-II Class) Missile Destroyer" 2009). Indigenous systems included a four-array, multi-function, phased array radar, HQ-9 air defense missile system, and YJ-8 series anti-ship cruise missiles. The ship's 100mm main gun was a Chinese derivative of the French Creusot-Loire T100C design, and the command and control system was derived from the French Thomson-CSF TAVITAC. The Type 052C also carried Russian-made fire-control radar for the anti-ship missiles and main gun, as well as a Russian Ka-28 ASW helicopter.

The third (run) phase is characterized by products of indigenous design and production. Examples of run phase products include the Chinese J-10 fourth generation fighter (see Figure 1) (currently using Russian engines while problems with Chinese aircraft engines are being worked out) and J-20 fifth generation fighter as well as Type 99 main battle tanks.

India is trying to pursue the crawl, walk, run phases simultaneously, with heaviest emphasis on the crawl

Figure 1. Cutaway Model of J-10 Fighter Displayed at AirShow China 2012

phase at present. Sixty-five years after its independence, India still imports as much as 70 percent of its weapons and defense equipment ("Dependence on Defense Imports Risky for India, Say Experts" 2012). In a few cases, like T-90S tanks and Su-30MKI aircraft, these foreign products are assembled from kits in India. This situation persists despite decades-long Indian government investments at 50 state-owned defense R&D laboratories and 40 defense plants to create indigenous defense systems.

These domestic facilities are, however, engaged in some walk projects that differ from the Chinese walk approach in that they start with Indian-designed basic platforms that rely extensively on foreign components for key operational capabilities. Hindustan Aeronautics Limited's Dhruv attack helicopter, for example, was designed in India, but also includes major foreign content: hydraulic systems from the United Kingdom (UK), avionics from Israel and the United States, self-protection equipment from Sweden and South Africa, engines from France, flight controls from Germany, and a braking system from Italy. The ratio of Indian to foreign content in walk projects is often quite small. For example, the Dhruv attack helicopter has only 10 percent and the light combat aircraft has only 30 percent Indian content (Purushottam 2011).

India has also pursued some run-type projects: Agni and Prithvi ballistic missiles, space launch/satellites and counter-space equipment, and ballistic missile defenses. Generally, these were technologies that were not available for import. The Indian defense research base has also worked on a host of projects, such as the Akash medium-range surface-to-air missile, Arjun tank, and Nag anti-tank guided missile (ATGM), all of which were designed to compete with foreign suppliers for the same Indian military requirements. They failed for a variety of reasons including cost, performance, and extended developmental timelines.

Indian political and military leaders recognize that, according to Air Marshal J. Chandra, air officer commanding-in-chief (Maintenance Command), "strategic self-reliance is a key result area for defense sector in the years to come" ("Dependence on Defense Imports Risky for India, Say Experts" 2012). Indeed, there is a "made-in-India" policy initiative that seeks to reverse the current 70/30 ratio of imports to indigenous production. Such a policy has been tried before and failed.

China and India offer contrasting cases. China approached the crawl, walk, run strategy as essentially a sequential process while India attempted to implement a process where all three phases were undertaken simultaneously. The Chinese approach appears to have succeeded while the Indian approach has not yet produced similar results.

Fellow Travelers (Russia and India, European Union)

Countries no longer need to "go it alone" when developing military systems because of the proliferation of multi-national joint ventures. Multi-national consortiums can sometimes afford projects and combine technological skills to develop and field military systems beyond the financial and technical capabilities of any one of its members. For example, the Defense Research and Development Organization of India and Russia's NPO Mashinostroeyenia formed a joint venture called BrahMos Aerospace Ltd. to market supersonic BRAHMOS anti-ship and land attack cruise missiles (see Figure 2). Collaboration made it possible to share the technological assets of both countries, with India providing inertial navigation systems, mission software, and mobile launcher technology, and the Russians supplying ramjet technology and cruise missile airframes. The Indian side brought significant financial support as well. Subsequently, BrahMos Aerospace Ltd. announced a second project to co-develop a hypersonic cruise missile called BRAHMOS II.

Airbus is another example of this approach. Unable to sustain economically viable standalone national aerospace industrial bases, BAE Systems and EADS formed a consortium of aerospace

Figure 2. BRAHMOS Inclined Launcher at Defense Service Asia 2012

manufacturers. The consortium makes a wide variety of civil and military aircraft at sixteen sites in four European countries. Military products include the A400M military transport, A330 MRTT (multi-role tanker transport), C212 light tactical transport, the multi-role CN235 tactical airlifter, and C295 tactical airlifter, a stretched version of the CN235.

The Eurofighter/Typhoon consortium is a third instance. In 1986, companies from Germany, Italy, Spain, and the UK pooled their resources to build a next generation fighter—a project no single European country could afford. A similar approach was used to develop the engines and radar. Eurojet Turbo GmbH was set up by Avio (Italy), ITP (Spain), MTU Aero Engines (Germany), and Rolls-Royce (UK) to develop the EJ200 engine for the new fighter aircraft. Likewise, the Euroradar consortium brought together EADS Defense Electronics (Germany), SELEX Galileo (UK and Italy), and INDRA (Spain) to design, develop, and produce the advanced Captor radar ("Eurofighter Jagdflugzeug GmbH" 2013).

Joint Ventures Plus Contracts That Result in Transfer of Skills and Technology (United Arab Emirates, Indonesia, and India)

This approach usually involves a technologically advanced, but funds-limited, company pairing with a technologically limited, but ambitious, partner with ample funds. The resultant "marriage" provides the original developer with sufficient funds to bring a project to completion and the technologically ambitious partner with access to advanced technologies and know-how.

The United Arab Emirates (UAE) is making a major effort to build domestic defense manufacturing capabilities to diversify its economy as well as to reduce its dependence on military imports with too many strings attached. Thus the UAE is establishing a small defense industry located primarily in a city between Dubai and Abu Dhabi. Interest extends to maintenance and repair of defense systems as well. The UAE is using a strategy that combines joint ventures with foreign firms and defense procurement contracts that commit foreign companies to transferring technology and skills to the UAE. The Multiple Cradle Launcher (displayed for the first time at IDEX 2013) is an example of this process (see Figure 3). The Multiple Cradle Launcher was designed with the help of a Serbian contractor and then assembled and integrated in the Emirates. In another case, the UAE supplied money for Russia's KBP Instrument Design Bureau to finish final development of the

Figure 3. Multiple Cradle Launchers at International Defense Equipment Exposition (IDEX) 2013

Pantsir-S1 (SA-22 Greyhound) surface-to-air missile in exchange for regional marketing rights (see Figure 4). Emirates Advanced Research and Technology Holding (EARTH) and Yugoimport also

Figure 4. Pantsir Air Defense Missiles-Gun Complex at IDEX 2011

signed an initial agreement at IDEX 2013 to jointly develop the fiber-optic guided Advanced Light Attack System (ALAS-C) missile intended for coastal defense, anti-ship, and land attack roles. According to the deputy director of Yugoimport, "This is a big investment that will significantly speed up the current process and new technological capabilities in the field of sophisticated missile technology, and the development of sensors for missile guidance and control" ("Serbia UAE Firms to Develop Missile" 2013).

Indonesia, to gain access to advanced technology, signed an agreement with South Korea in August 2012 to participate in an R&D program to produce an advanced multi-role combat aircraft by 2020. In return for paying up to 20 percent of development program costs, 30 scientists and engineers from Indonesia's state-owned R&D agency and aviation company, PT Dirgantara Indonesia (PTDI), would be permitted to participate (Hardy and Grevatt 2013). These Indonesian engineers would go to South Korea's Aerospace Industries defense facility ("Indonesia, South Korea to Build Fighter Aircraft" 2013). Indonesia will also participate in marketing the finished aircraft and receive 20 percent of the money from the export sales.

India is also pursuing this strategy in a few cases. The most prominent example is the joint Indo-Russian project to produce the Indian fifth generation fighter aircraft (FGFA), a two-seat variant of the Russian T-50 PAK FA next generation fighter (Yousaf 2013). As part of the effort, around 30 Indian engineers went to Russia to work on the preliminary designs. Participation also calls for India to have access to advanced Russian aerospace technology. And as one India journalist observed:

> What defense observers have missed is that the FGFA is a quantum leap for India's armaments industry, especially HAL [Hindustan Aeronautics Limited]. After decades of dabbling in joint production—a euphemism for screwdriver technology—India's aerospace sector will finally step up to joint development.
>
> This will catapult India to a new level where it will finally be able to develop advanced stealth aircraft on its own. Not even America's leading partners in the F-35 Joint Strike Fighter program, such as Turkey or the UK, have access to such red hot technology. Instead of being a sidekick, India will be a joint partner in a leading military project. (Simha 2012)

Final Observations

Governments and defense firms of other countries are experimenting with different approaches to acquiring defense technological capabilities. Their motives vary. Some seek access to technology and know-how otherwise unavailable. Some seek to reduce acquisition costs and/or find funding to complete projects that would be impossible to finance with resources at hand. Some seek to do both. It is also clear that nations do not confine their experimentation with acquisition to just one approach. *The bottom line: These strategies accelerate technical innovation and reduce costs for countries worldwide, proliferating more advanced technologies, better meeting individual country needs, and facilitating other countries obtaining more advanced weapons capabilities. Together these developments can collapse the timelines of world defense acquisition. This, in turn, will challenge the Department of Defense to maintain technical leadership. What used to be a clear U.S. technical dominance seems to be eroding, and the long-term implications of the trend are not clear.*

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LESSONS ON DEFENSE RESEARCH AND DEVELOPMENT MANAGEMENT

Gene H. Porter

The Problem

Getting early decisions on new systems right—ensuring adequate attention is given to the critical "What to Buy" decision—is crucial in Department of Defense acquisition. Some attributes of Office of Secretary of Defense (OSD) organization and practices in the 1970s could be effectively applied within the current structure and procedures for starting and developing new weapon system acquisition programs.

IDA research on the DoD acquisition process in recent years has repeatedly identified the importance of getting the early decisions on new systems "right"—that is, ensuring that adequate attention is given to the critical "What to Buy" decision. But the provenance of such decisions has depended on the degree to which Secretaries of Defense have chosen to exercise their authority over the military services' (hereafter services) traditional "requirements" processes.

IDA researchers ... focus on the role of "outsiders" in instigating real innovation in military technology and operational concepts.

Senior military officials generally have strong views on what characteristics are needed in the next generation of the weapons systems that will be acquired to equip the planned active and reserve forces. When a service chief makes a strong public commitment to a specific new weapon system, it generates considerable momentum. On the other hand, the Secretary's writ gives him the responsibility and the authority to make, or delegate, all major decisions within DoD, including the formulation of the budget proposals that define the weapon systems that DoD proposes to buy. This authority has been codified and refined many times since the original National Security Act of 1947 first established the Secretary of Defense position. The actual use of that authority has been, for the most part, quite circumspect, but on occasion it has led to major civil-military confrontations.[1]

IDA researchers have reviewed the history of this decision-making process; this article summarizes their findings, with a focus on the role of "outsiders" in instigating real innovation in military technology and operational concepts.[2]

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[1] Probably the most notable of these was Secretary Louis A. Johnson's peremptory cancellation of a new "super carrier," the USS *United States*, in 1949 incident to the early decisions on the roles and missions of each of the Services in the emerging field of nuclear warfare. This action resulted in what is generally known as "the revolt of the Admirals."

[2] The term "outsiders" is used to differentiate important contributors to military innovation whose primary fields of activity are outside the normal service-specific military chains of command. Such outsiders have, historically, included members of the Secretary of Defense's staff.

World War II Roots

The important role of outsiders in bringing new technology and new operational concepts to bear on the World War II effort has been widely documented in recent years (Kennedy 2013, Budiansky 2013, Conant 2002). Allied leaders, particularly Winston Churchill and Franklin Roosevelt, recognized that defeating Germany, and then Japan, would take more capability than could be achieved by mobilizing military channels alone. In the United States, President Roosevelt chartered the Office of Scientific Research and Development (OSRD) under Vannevar Bush to mobilize the science and technology community for wartime research and development.

At a cost of only about $500 million, OSRD developed a remarkable array of innovative weapons, as well as novel and effective operational concepts using the new science of operations research.[3] Many of the 5,000 OSRD scientists and engineers met with knowledgeable service personnel to discuss operations and problems, propose technical solutions, and, when they agreed that the problem had been solved, begin development. OSRD engineers and scientists worked closely with users, involving them more deeply in engineering and operational testing—often in the field of combat—until the system was ready to be handed over for production and operational service. At the end of the war, OSRD was closed down, but its image lingered.

Establishment of the Director of Defense Research and Engineering

With the end of World War II, there was an extended period of debate and adjustment as new structures for defense were worked out. The dramatic news of the Soviet Union's Sputnik satellite launch in October 1957 created a sense of threat and urgency that President Eisenhower used to demand long-desired changes. Among them was a highly centralized overall authority for defense R&D operating under a civilian official, the Director of Defense Research and Engineering (DDR&E), who reported directly to the Secretary. In response, Congress passed a sweeping reorganization act in August 1958 that gave the President much of what he asked for, including a powerful DDR&E.

In collaboration with the new office of Assistant Secretary of Defense (Systems Analysis) or ASD(SA), the DDR&Es during the 1960s and 1970s[4]

[3] This amount, equivalent to roughly $5 billion in today's terms, covered all the work on the atomic bomb through the end of 1942, and the development of all U.S. microwave radars, the proximity fuse, a wide variety of rocket weapons, specialized vehicles for waterborne invasions, pioneering guided weapons, advanced torpedoes, electronic countermeasures, new explosives, anti-malarials, DDT, penicillin production methods, and a host of other equipment and systems, as well as operations research and other support for military operations and many important advances in basic knowledge for weapons development.

[4] Of particular importance during the period 1958–73 was the fact that the DDR&Es were three experienced leaders from the nuclear weapons community—Herbert York, Harold Brown, and John Foster, who were committed to expanding U.S. non-nuclear military capabilities. They were followed by Malcolm Currie, an experienced electronics industry executive with strong credentials in sensing systems, who also strongly supported major non-nuclear transformational technology developments including stealth aircraft. It is also important to recognize that the ASD(SA) (changed to Program Analysis and Evaluation or PA&E in 1973) and the DDR&E had a close working relationship, with the DDR&E providing technical assessment and evaluation, while the ASD(SA) focused on assessing mission needs and resource aspects.

implemented mission analysis and systems engineering at the mission area level to explore the potential of technology to transform the structure of warfare, rather than simply improve the performance of individual systems. Mission area systems engineering was at the root of the DDR&E organization's greatest successes in the 1970s. In a significant number of cases, it led to innovations with broad impacts. It was also a focus of criticism from those who wished to limit OSD to policy, management, and coordination functions and reassert the authority of the services.

During the 1980s, a series of actions by the Administration and the Congress shifted the focus of innovation toward the military departments, reducing the ability of the new Under Secretary of Defense for Research and Engineering (USD(R&E)) to affect major acquisition choices and bringing the pattern set by prior DDR&Es to an end.

Accomplishments and Lessons

The 1970s are remembered as an era when DoD produced especially innovative and successful programs. There is no conclusive way to measure this, let alone distinguish among its causes. But many successful programs and systems from the period are still in front-line service, and notably, several had a transformational impact. In addition, one factor that is almost always associated with serious problems is cost growth. Yet statistical analysis shows that programs that had their inception in the late 1970s, after the DDR&E approach had fully matured, had, in general, better cost growth records than those of any other period between 1970 and 2000.

Principal factors contributing to the DDR&E organization's success included:

- Operating at the intersection between technology and military need; working in close cooperation with other relevant OSD offices; and focusing particularly on the critical period at the inception of a concept, where the success or failure of programs is principally determined.
- Use of the DDR&E's history and heritage to establish and uphold the validity of its model of civilian scientists and engineers exercising a dominant voice in deciding what programs to pursue and how to structure them.
- A compact and elite staff that had the qualifications and qualities to powerfully and creatively support the top executives of the DDR&E in meeting their objectives.
- A strong culture of objectivity and an absence of either pessimistic or optimistic bias, backed by the systematic use of comparative analysis.
- Excellent communications within the DDR&E organization and with the other organizations that played key roles in the "What to Buy" decision.
- A sharp focus on the things that made a real difference.
- Close meshing with the top management of DoD and its priorities.

Case Studies

The foregoing lessons are drawn from several detailed case studies of

"What to Buy" decisions during this period.

TFX/F-111—One of the first major non-strategic programs with extensive DDR&E involvement, it was a major learning experience for the DDR&E organization. It represents a baseline in more than one sense—no other program showed DDR&E in such a bad light. This was due, in large part, to the lack of serious mission area analysis that would have revealed the incompatibility of the Air Force desire for a high-altitude nuclear bomber and the Navy desire for a carrier-based multi-purpose fighter/attack aircraft.

Missile Defense Alarm System (MIDAS) and Defense Support Program (DSP)—These were conceived as space-borne infrared (IR) sensors high above the atmosphere that would watch for the signatures of rocket engine exhausts to warn of ballistic missiles en route to the United States or other locations of defense concern. The DDR&E urged a deliberate development program that would ensure the needed technical performance and reliability. The Air Force criticized the DDR&E approach, recommending instead urgency in deploying an operational system based, in part, on inaccurate assessments of the likely expansion of Soviet intercontinental ballistic missile (ICBM) capabilities. Without DDR&E intervention, the program very likely would have become mired in premature efforts to deploy inadequate technology.

Global Position System (GPS)—The DDR&E had become a driving force in deciding what to be acquired and how. In 1973, the Air Force sought permission from the Defense Acquisition Review Council (DSARC) to proceed with full-scale development of a global position system. Then DDR&E Malcolm Currie was sharply critical of what he correctly perceived as defects in the service's proposals, and directed the Air Force to seek input from others—the Navy in particular—which had important contributions to make. The program manager promptly reordered the program to meet the DDR&E's demands, secured approval from a second DSARC, and went on to develop the GPS.

Stealth—The DDR&E and Systems Analysis offices collaborated early in the mission area analysis that demonstrated the importance of radar cross section (RCS) reduction, if it could be achieved. The DDR&E and the Advanced Research Projects Agency (ARPA) provided the follow-on leadership to bring it to fruition. Radar stealth has been perhaps the single most dramatic development in technology for combat aircraft since the advent of jet propulsion, more than 30 years earlier. While stealth has been claimed by many fathers, reflecting its great success, the DDR&E played a significant role in crystallizing the program and securing support.

Surface Effect Ship (SES) Prototype Program—The fullest, most detailed case study concerns the 2,000-ton SES program (which grew to a 3,000-ton program). Admiral Elmo R. Zumwalt, Jr., a visionary and a reformer who became the Chief of Naval Operations in 1970, was personally devoted to the development of a "100-knot," oceangoing, SES surface combatant. Although the SES was a program of a heroic nature, it was also brought low by its own internal flaws, which the DDR&E staff (together with the Program Analysis and Evaluation PA&E staff) worked diligently to keep in view. First, no one could offer a convincing explanation of the special value of the SES's speed in surface ship missions since the inherent limitations of sensors and weapons generally restricted their combat operating speeds to no more than 20 knots. Second, key features of small test vehicles—particularly the critical hull-to-water seals—could not be scaled up with any real confidence. There were also fundamental problems with performance in high sea state.

Ultimately, the prototype program was canceled in late 1979, after the expenditure of more than $300 million dollars (a figure in excess of $1 billion in today's dollars). The SES program illustrates many of the ways that DDR&E/USDRE operated during the period to provide an objective, detached perspective on major acquisitions.

Relocatable Over-the-Horizon Radar (ROTHR)—The ROTHR case involved a new concept for long-range aircraft detection and tracking that the DDR&E staff understood could provide a cost-effective alternative to the burgeoning interest in costly airborne and space-based radars. When the service staffs could not be persuaded to seriously consider such an approach in the late 1970s and early 1980s, the DDR&E staff started briefing the regional military commanders on the concept. Their efforts garnered the support of the new Commander in Chief of the U.S. Pacific Command, Admiral William J. Crowe, who took advantage of Defense Secretary Caspar W. Weinberger's enthusiasm for responding to regional commander "requirements" to spur the development and fielding of the TPS-71 ROTHR program, just as the threat of Soviet long-range bombers collapsed at the end of the cold war. The "relocatable" nature of the system, combined with its relative affordability, led to its continued use, and today the system detects and tracks potential drug aircraft in the southern approaches to the United States.

Looking to the Future

Could attributes of the successful organization and practices of the DDR&E of the 1970s be applied effectively within DoD's current structure and procedures for starting and developing new acquisition programs? Under the current structure, the Under Secretary of Defense for Acquisition Technology and Logistics (USD(AT&L)) has both statutory and delegated responsibility and authority over all aspects of defense acquisition. He has delegated specific responsibilities for strengthening the early development planning phases of the acquisition process to the Systems Engineering Directorate in the office of the Assistant Secretary of Defense for Research and Engineering (formerly DDR&E). In consonance with that organizational framework, three recommendations from this IDA work are:

1. Ensure that personnel experienced in system design and operations analysis, and free of bias and conflicts of interest, are directly

and substantively involved in and approve the early concept formulation and requirements determinations for all new major weapon systems, prior to formal Defense Acquisition Executive approval of a new program start at the Materiel Development Decision point.

2. Increase the authority of the AT&L staff to initiate and guide promising innovative technological approaches, including Advanced Technology Demonstrations that can lead to important new military capabilities, as well as attract highly qualified scientists and engineers to government service.
3. Empower the ASD(R&E) to review and approve the adequacy of every development plan and associated funding profile as a condition for starting all new major acquisition programs.

Other supporting recommendations include positioning the ASD(R&E) organization at the technology-operations interface; making use of its heritage to reinforce its authority; continuously improving staff quality through training and emphasis on personal skills development; promoting objectivity and close communication among the staff; and institutionalizing learning from experience.

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COMMERCIAL INDUSTRY RESEARCH AND DEVELOPMENT BEST PRACTICES

Richard Van Atta

The Problem

Global competition has led major U.S. companies to fundamentally rethink their research and development practices. The Department of Defense (DoD) is also challenged by the globalization of technological knowledge. Are there best practices from commercial industry that can help DoD meet this challenge?

IDA identified current commercial industry practices for organizing and managing research and development (R&D) by focusing on the question: "How does industry place its R&D bets and manage R&D outcomes to meet corporate goals?"

Along with a detailed review of the R&D management literature, IDA researchers interviewed R&D leaders at seven large U.S.-based companies with significant R&D programs: Applied Materials (AMAT), The Boeing Company, Exxon Mobil Corporation, General Electric (GE), International Business Machines (IBM), Intel, and Procter & Gamble (P&G).

R&D Strategy and Overall Management

Changing competitive market environments have caused some U.S. companies to fundamentally refocus, reorganize, and rethink their business practices, including the R&D they conduct to keep pace with rapid technological advances and to improve their business results.

We found four common themes among leading research-oriented companies:

1. Setting and maintaining the direction of technology development is a top-level corporate responsibility.
2. R&D, even for exploratory projects, is managed for business results.
3. Companies are increasingly accessing external R&D and integrating it with internal R&D, rather than depending primarily on internal discoveries.
4. Technology thrusts are explicitly derived from the company's strategic perspective on how its R&D should be aligned with business goals.

Changing competitive market environments have caused many large U.S. companies to fundamentally refocus, reorganize, and rethink their business practices, including the R&D they conduct to keep pace with rapid technological advances and to improve their business results.

A key focus of the research was how industry leaders measure and assess the results and value of R&D, and how they use this information to manage the R&D process. Consistently, this involved the following:

- Developing a clear, coherent strategic direction and plan
- Managing to get results out of the R&D process
- Broadening the sources of new ideas and integrating them into company R&D
- Measuring and assessing the results and value of R&D.

An important step taken by most firms reviewed is a structured process for corporate and business unit management to design a clear, coherent plan and roadmap for implementing the innovation strategy. This plan elaborates on which units are in charge of what activities and when they should be completed, and connects individual project roadmaps to the overall organizational vision. It also establishes requirements for long-term success—in other words, evaluation metrics beyond the next quarter's earnings.

To achieve a more strategic, results-oriented R&D management system, companies have restructured their R&D. One major shift has been the reduced role of central R&D laboratories. Companies have sought R&D from outside the company through venture investment. They have also endeavored to make R&D more productive by creating internal corporate entrepreneurship groups and through various open innovation approaches. Open innovation—which is becoming increasingly commonplace—entails creating R&D and new product development partnerships with end-users, suppliers, competing firms, and research institutions. Many technology-focused firms have determined that partnering with other firms that have different knowledge and capabilities achieves better results in developing and implementing new concepts and products. Open innovation entails establishing relationships, not just acquisition.

In linking R&D outcomes to long-term financial performance, most of the firms IDA interviewed made it clear that the chief executive officer (CEO) and the chief technology officer (CTO) fight hard to maintain R&D funding as a strategic investment that is not affected by business fluctuations—especially overall revenue.

R&D Portfolio Planning and Assessment

Leading firms that invest substantially in R&D have well-defined and assiduously monitored assessment processes. These companies often start with an explicit definition of the value of R&D in their corporate strategy, which is usually expressed in terms of how and in what way R&D contributes to the firm's ability to effectively and competitively introduce and produce new products. In commercial business, R&D is defined by results and, thus, measured more in terms of impacts, rather than inputs and activity.

Leading technology companies focus a great deal on developing an

R&D portfolio mix and managing the portfolio relative to explicitly defined (deliberated and negotiated) strategic goals. R&D portfolio development and assessment make up a strategic enterprise usually under the CTO but with high-level business unit involvement. Portfolios may be defined in many ways, including distribution of projects across businesses; allocation to single businesses versus enabling or cross-cutting platform technologies; internal versus external capabilities; and allocation for potentially new businesses versus current businesses.

R&D Project Management

Project portfolio management refers to the management of a group of related projects within the company. The focus is on maximizing the value of the portfolio through managing resources. In another related approach, innovation portfolio management, executives develop a strategy to select and develop new concepts, connecting them eventually to project portfolios.

A key takeaway from both the literature and interviews is that R&D needs to be organized and managed in different ways at different stages. The relevant managerial question for early-stage opportunity creation is how to generate more and better targets: Which people, which structures, which strategies can be employed for more effective idea generation for these objectives? Later, as a technology is ready to be transitioned and scaled into commercialization, the focus is on deployment success with tight control.

Gate Process for Managing R&D Projects

The R&D management literature and IDA's interviews show that most technology-based firms use a gate process in their R&D management (that is, a structured process for managing R&D projects by dividing the project into phases or stages, which are assessed for progress and risk to decide whether to continue to the next phase, stop the project, or hold it at the current stage until exit criteria are met). Thus, success is not just getting through the gate; it is determining whether a potential technology should get through based on agreed upon tests and criteria. Many firms have also embraced the Technology Readiness Level (TRL) concept and use TRL assessments in the technology gate decisions.

Leading firms use rigorous, but specifically designed, gate processes to manage the cost of failure. The objective is not to prevent failure per se, because that implies a lack of innovation and exploration of new ideas. Rather the focus is on encouraging risk-taking in exploring new ideas early, while employing disciplined processes, such that:

- The rejection rate of projects is highest in the early stages of ideation when the costs of the project are lower.
- The stages represent milestones at which a new level of investment is needed to move forward.
- The objective is to manage the business risk while testing key assumptions.

Transition and Scaling

Any new product offering has a set of risks beyond the technical performance and capabilities of the product, including the unknowns of the future market, the availability of financing for scaling into production, and the firm's own internal capabilities to absorb and effectively manage the new product's entry into production and marketing. Therefore, determining how much risk to take on when introducing a new product (and attendant production processes) is a crucial decision that the firm must make—essentially it is an informed bet based on judgment and experience, as well as customer-focused competitive assessments. From the review of the literature and the interviews conducted, the most prominent lesson from this IDA research regarding transitioning technology is that frontrunner companies assiduously avoid introducing immature products and processes.

Implications for DoD

The organizational context of DoD R&D must be carefully differentiated from that of private industry. Commercial industry inherently has much clearer and specific metrics of results. Generally, commercial firms define results in terms of financial results, particularly profits and revenue growth. Many firms recognize that in technology-driven businesses, R&D can provide important means to identify, develop, and implement new products and related production processes that provide the basis for growth. Measuring the value of DoD R&D is more difficult because the desired end-goal is the broader and multidimensional goal of maintaining U.S. national security while sustaining U.S. commitments to allies and partner nations.

In addition, DoD conducts R&D within its own governmental institutions, such as the defense labs, but also funds R&D through contracts to a wide range of performers—defense contractors, universities, and private firms. DoD is the developer and acquirer of systems for its own use that it pays others as contractors to provide. Thus, DoD is a customer that specifies its needs and formulates these into requirements that become embedded into the R&D and acquisition systems for others to execute. These differentiating factors make the direct implementation of commercial industry R&D management best practices in DoD challenging and, in some cases, inappropriate.

Practices for Consideration

That said, some commercial industry best practices for R&D management merit assessment in the DoD context:

- Top corporate leadership is actively involved in setting direction for R&D and then making course corrections. The active involvement of very senior management is deemed necessary by most of these firms as essential to commercializing technologies.
- Corporate, business unit, and innovation strategies are explicitly linked.
- A coordinated and coherent corporate effort to execute open innovation guides development activities. This involves scouting for

technologies outside the company, as well as industry collaborations.

- Gate processes are successfully applied early in the flow from idea to product: at the equivalent of transitions between DoD's Applied Research to Advanced Technology Development (BA 2 to BA 3) while the DoD 5000 process picks up at milestones for Materiel Development Decision (MDD) A and B.
- Gate processes generally involve substantial early involvement of marketing and manufacturing organizations and are empowered to modify or terminate R&D efforts. An important objective is to stop low-potential projects early.
- Generally companies assign a champion, often self-selected, to a promising project. This person provides strong business guidance to the project team.
- Identifying potential customer needs involves substantive research to ascertain market potential.
- Commercial portfolio management is employed from research through development.
- Transition planning is an important issue addressed early in development by commercial companies. Leading firms do not attempt to transition immature technology to manufacturing.
- There is generally a long-term commitment of people to projects.

Observations, Questions, and Future Direction

Cost, schedule, and performance are the essential trade-offs, but existing incentives lead DoD too often to sacrifice meeting cost and schedule to meet specified performance goals. Many commercial, high-technology firms emphasize well-articulated spiral development processes. To what extent could this type of process be applicable to defense systems, which are of a much different scale, often stay in the field for decades, and for which interoperability is a key factor?

The concept of portfolio management is deeply embedded in the R&D management of commercial firms. Could such portfolio thinking be applied more routinely across DoD programs? A 2011 IDA analysis on improving the "front-end" of the DoD acquisition process affirmed that effective analytic approaches to defining, assessing, and managing such portfolios have not been implemented systematically within DoD.

A leading commercial industry R&D trend is open innovation, partnering with others in developing new capabilities. Under what circumstances could DoD adopt commercial best practices for open innovation to find and track relevant commercial and government investments? Industry executives emphasized that DoD's role in partnerships with their firms has been a crucial factor in their ability to take on risky projects.

While commercial management approaches to R&D management will be difficult to employ across the board, DoD should consider:

- Expanding efforts to attract more outside collaborations with R&D partners

- Developing and employing tools for evaluating technology development through partnering with external R&D performers linked to its own labs
- Exploring ways to improve how it finds, evaluates, and engages new R&D partners
- Undertaking a benchmarking assessment on best practices for collaborating with university R&D performers as well as others
- Assessing how gate assessment could be employed early and throughout DoD R&D so that programs that do not demonstrate appropriate value are restructured or terminated
- Analyzing how private industry processes for measuring returns on R&D investment might provide guidance for ways to measure the results of defense R&D investment
- Implementing and assessing a pilot portfolio management based on strategic objectives across DoD over distinct time horizons
- Developing platform technologies and approaches to transition platform technologies across multiple weapons systems, especially across multiple defense labs, acquisition program offices, and military services
- Developing its own incubator programs (including technical assistance and early stage commercialization-transition funds) to help it better engage small- and medium-sized enterprises and non-traditional suppliers (both large and small).

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STRENGTHENING DEPARTMENT OF DEFENSE LABORATORIES

David Graham, Robert Leheny, and Susan Clark-Sestak

The Problem

Department of Defense (DoD) laboratories primarily focus on sustaining innovation in known areas of application. What mechanisms could be used to foster greater laboratory focus on radical innovation based on commercial industry practices? To address this question, IDA proposed a virtual central lab concept for addressing DoD-wide innovation priorities.

IDA was asked to assess ways to strengthen the DoD laboratories' contributions to DoD-wide innovation priorities. This research builds on DoD's most recent efforts to increase the laboratories' focus on innovation in response to the 2010 Quadrennial Defense Review (QDR). IDA's recommendations are based on a review of current DoD practices, discussions with laboratory management and other stakeholders, and an assessment of relevant best practices for laboratory enterprise management in innovative commercial enterprises. The core recommendation is to create a virtual central DoD laboratory for science and technology (S&T).

The core recommendation is to create a virtual central DoD laboratory for science and technology (S&T).

The Laboratory Enterprise

The DoD laboratory enterprise comprises 62 facilities owned and operated by the Departments of the Army, Navy, and Air Force in 22 states with 65,000 government employees.

These facilities serve a wide range of functions across the spectrum of S&T. They operate under widely varying funding mechanisms, management approaches, and governance structures. One common characteristic, however, is their close relationship with their parent military departments (MILDEP) and their focus on anticipating and responding to the military services' (hereafter services) mission needs.

The DoD laboratory enterprise executes half of DoD's total S&T budget (about $7 billion of $14 billion). Roughly one-third of this funding supports S&T work performed within the labs, while about two-thirds supports companies and universities performing under lab oversight and management. Importantly, while S&T is an essential laboratory responsibility, it represents only a minority of the funding for the DoD laboratory enterprise. About four-fifths of the DoD laboratories' funding is to support current DoD operations, acquisition programs, and in-service engineering for fielded systems.

Methodology and Findings

To better understand the laboratories' operations, the IDA research team visited a number of DoD laboratories nominated by the MILDEPs. During these visits, a large number of case studies were presented, which IDA used to characterize and evaluate the types of innovation being pursued and supported. The team also examined the structure and associated bodies responsible for governance of the DoD S&T enterprise.

The IDA team found ample innovation within the laboratories' established areas of responsibility, but also observed that the labs' close ties to their parent MILDEPs can create gaps in coverage in areas that are not well aligned with the services' mission needs. Radical or cross-cutting innovation has historically required intervention by top DoD leadership (the Secretary of Defense, his Deputy, or the chief acquisition executive). Early examples include the actions taken to establish nuclear, strategic strike, and satellite programs.

Other notable examples include stealth, unmanned aerial vehicles (UAV), missile defense, and counter improvised explosive device (IED) capabilities. Although DoD leaders can fill such gaps, the fact that it requires extraordinary action underscores the lack of a systematic mechanism for identifying and pursuing such DoD-wide innovation needs. Currently, this weakness is evidenced in the slow response of the DoD laboratory enterprise to the S&T priorities established following the 2010 QDR.

The research team sought possible remedies by examining how leading commercial firms structure and manage research and development (R&D) to drive innovation. The analysis focused on several companies with technologies that are typical of the type addressed in DoD labs. Companies willing to share their practices included Applied Materials (AMAT), The Boeing Company, Exxon Mobil Corporation, General Electric (GE), International Business Machines (IBM), Intel Corporation, and Procter & Gamble (P&G).

The innovation management challenges in these large commercial firms have parallels with the challenges addressed here: commercial firms, too, face tensions between the business-driven innovations pursued by the individual business units and more open-ended, enterprise-wide innovation needs. Companies have failed when their focus on business-driven innovation caused them to miss broader trends in the marketplace. The IDA team identified two common commercial best practices designed to overcome these weaknesses and encourage needed enterprise innovations that are applicable to DoD:

- Top managers provide strong leadership and resources for an enterprise-level innovation process that complements the program of work designed and executed by the business units.
- Top managers treat the laboratory enterprise as a strategic asset, providing the stewardship necessary to maintain a healthy innovation environment.

Recommendations

IDA researchers recommend five actions to help create a virtual central lab for addressing DoD-wide innovation priorities. This virtual central laboratory would be made up of a set of Office of the Secretary of Defense (OSD)-funded programs that are executed through a competition of ideas among cooperating and competing laboratory research teams. This approach embraces proven commercial practices, while preserving the MILDEPs' roles in governing the laboratories. To be successful, this virtual central laboratory would require committed top management leadership and resources.

The ASD(R&E) should lead the effort to identify and fund radical or cross-cutting innovation projects for DoD labs that complement the MILDEPs' existing S&T priorities. The projects would be selected through a competitive process outlined below. The Deputy Secretary, with support from the Under Secretary of Defense for Acquisition, Technology and Logistics (USD(AT&L)), should lead the efforts to ensure that promising innovation projects are successfully transitioned into the acquisition system. To encourage responsiveness, to mitigate delays in the normal DoD multiyear budgeting cycle, and to avoid creating unfunded mandates for the MILDEPs, OSD resources should be used to fund the initial work on these DoD-wide priorities.

First, OSD should forge a DoD-wide innovation vision and process that adopts relevant commercial innovation practices to create a virtual central laboratory. The virtual central lab would be responsible for fostering DoD-wide innovation, the transition of successful innovation projects into the acquisition system, and the stewardship of necessary S&T capabilities. Proposed details on these mechanisms are described in the next three recommendations.

Second, as the first key function of the virtual central laboratory, the ASD(R&E) should lead a process employing a competition of ideas to identify and fund DoD laboratory projects addressing DoD-wide innovation needs, as depicted in Figure 1. The laboratories' governance structures would remain unchanged, and the labs would continue to address service mission needs. In parallel, the labs would respond to DoD's enterprise-level innovation priorities through OSD-funded projects. Strong preference would be given to projects that involve laboratories from more than one service.

Third, the Deputy Secretary should lead efforts to transition successful DoD-wide innovation projects into the MILDEPs' acquisition systems. The proposed mechanism, as shown in Figure 2, entails a periodic review of the portfolio of DoD-wide innovation projects by the Deputy's Management Action Group (DMAG) (or a functionally similar group chaired by the Deputy Secretary), supported by the ASD(R&E)-led Research and Engineering Executive Committee (R&E EXCOM). This review process should provide resource support to transition successful projects and should terminate projects that do not meet

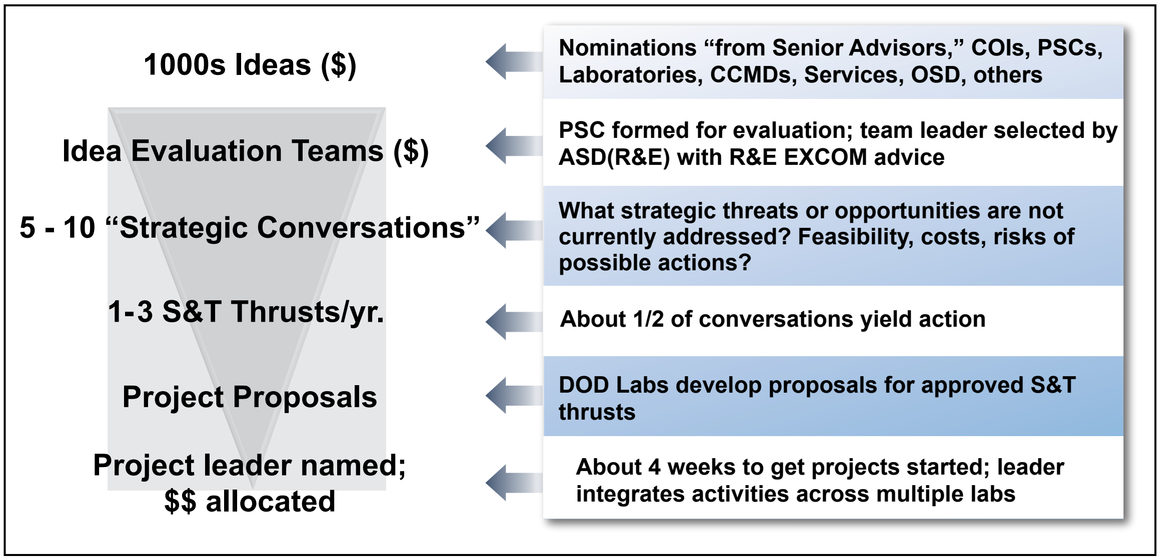

Figure 1. Competition of Ideas for Funding Innovation

milestones after a maximum of three years of exploration. The USD(AT&L) should oversee the progress of programs that successfully transition into the acquisition system.

Fourth, the ASD(R&E) should play a proactive role in the stewardship of the DoD S&T laboratory enterprise. The involvement of top management leadership is especially timely today, given the need to preserve talent and facilities through the coming years of budget stringency.

Fifth, DoD directives should be revised to codify the needed processes, roles, responsibilities, and

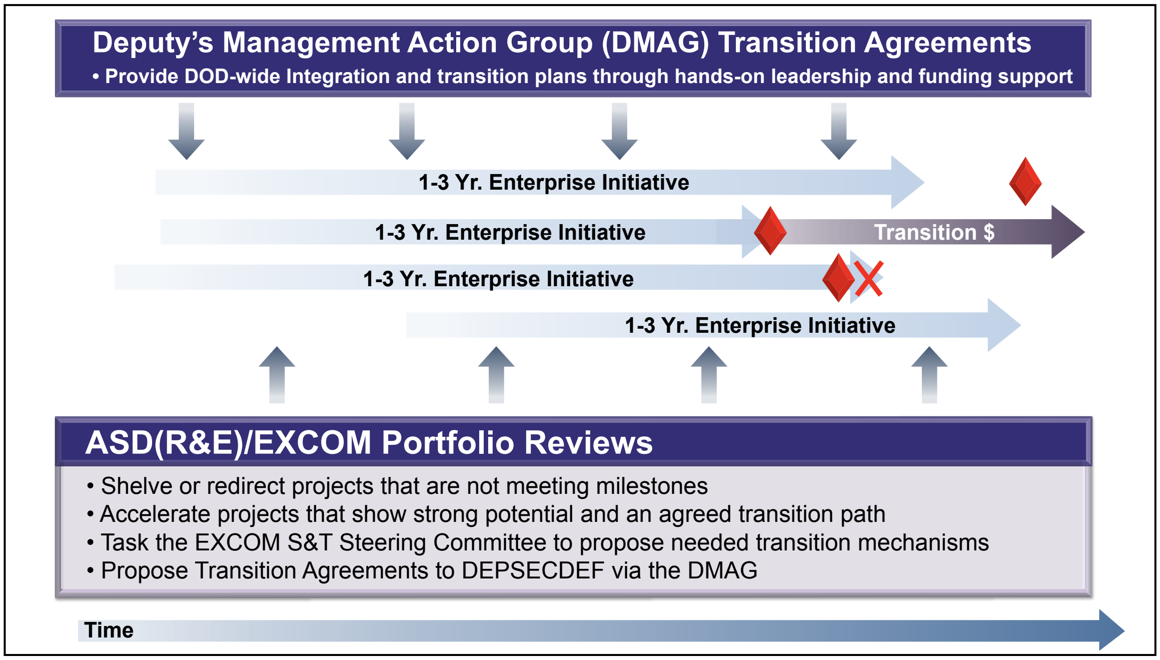

Figure 2. Periodic Review of DoD Innovation Projects

relationships. The virtual central lab should be led by the ASD(R&E), with the active involvement and support of the MILDEPs and the laboratories themselves. To facilitate the needed partnerships, it will be necessary to clarify and document roles, responsibilities, and relationships, including the financial support and administrative structure needed to support the virtual central lab initiative.

This assessment led to a pilot effort under the ASD(R&E) in the area of Autonomy, which is one of the S&T priorities established following the 2010 QDR. A competition in December 2012 was led by the Autonomy Priority Steering Council chairman at the Air Force Research Laboratory. The competition sparked significant interest across the laboratory enterprise, and the proposals included many cross-service laboratory research teams. The review panel was encouraged by the quality and creativity of the top proposals. Thus, of some 50 white papers submitted, 19 were selected for detailed proposals, which was a significantly higher number than originally anticipated. Approximately $15 million was expected to be awarded to the winning proposals in the first year of the program (likely the top six projects), with similar funding expected to be provided in the following two fiscal years.

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POLICIES OF FEDERAL SECURITY LABORATORIES

Susannah V. Howieson

The Problem

The Departments of Defense, Energy, and Homeland Security fund and/or operate about 80 facilities, including laboratories that focus predominantly on national security matters or “federal security laboratories.” IDA assessed various aspects of the Federal security laboratories, including infrastructure, governance structures, and personnel policies, seeking ways to strengthen the enterprise.

Facilities and Infrastructure

Properly maintaining and constructing F&I make up an important element of the ability of the Federal security laboratories to support mission-critical capabilities.

The federal security laboratory system comprises thousands of buildings and other structures, many of which are decades old and have not been refurbished. Aging and deteriorating facilities and infrastructure (F&I) may threaten the ability of federal agencies to sustain high-quality research in support of their national security missions. Given these concerns, IDA was asked to pilot an effort to better understand F&I planning, prioritization, and assessment at ten selected federal security laboratories.

Through a literature review, discussions with agency and laboratory personnel, and a workshop, the IDA research team identified four areas critical to federal security laboratory F&I: planning processes, prioritization criteria, stakeholder involvement and communication, and data and metrics.

Planning Processes

Federal security laboratory F&I staff lack agency and laboratory leadership support in defending the need to maintain, upgrade, and construct new F&I. As a result, there is no integrated plan to address long-term F&I needs across the agency and the national security enterprise. In addition, annual budget decisions and F&I reporting requirements are not linked with a strategic vision and investment strategy. Department of Defense (DoD) laboratories face the additional constraint of their F&I needs being prioritized against other types of F&I and military needs, such as schools, hospitals, and barracks. Laboratories from all agencies reviewed have encountered barriers to using alternative financing mechanisms for F&I projects.

Strategies to address these challenges include leveraging resources through partnerships, setting aside funding in the agency’s annual budget for large F&I projects specifically for laboratories, and using a combination of in-house capability and external architectural and engineering firm expertise.

Prioritization Criteria

Federal security laboratories prioritize F&I plans using a set of criteria based on their impact on the mission, health and safety, security, environmental compliance and zoning, energy usage and sustainability, costs and building conditions, and resource leveraging within and across laboratories. To track progress, the criteria are assessed using metrics. However, the criteria and metrics used at the agency level sometimes do not fully capture the F&I impact relative to the agency's mission because F&I staff frequently are not included in developing agency level criteria and metrics. Moreover, agencies typically develop F&I prioritization criteria in a top-down fashion. This is particularly challenging for DoD's federal security laboratories since their F&I funds are part of the much broader Military Construction (MILCON) program.

Some Federal agencies and laboratories have recently incorporated various strategies into developing F&I prioritization criteria and frameworks: using data-driven and qualitative methods to evaluate criteria, involving laboratory representatives in developing new criteria, assigning weights to prioritization criteria, and using a decision-gate approach for assessing the F&I portfolio.

Stakeholder Involvement and Communication

Multiple stakeholders are involved in the F&I planning, prioritization, and assessment processes, including the researchers and managers at the laboratories; research customers; a wide variety of firms that provide facilities services, such as architectural and engineering firms; state and local governments; Congress; executive offices, such as the Office of Management and Budget (OMB); state and federal environmental and safety regulators; and local communities.

The scientists, engineers, and laboratory management who conduct and oversee research activities must be able to communicate their F&I needs to the organization's F&I management staff and the overall Department and agency leadership. A major challenge is the lack of communication among stakeholders: those internal to the laboratory can have conflicting priorities given highly constrained funding; at intermediate levels there are disconnects between the laboratory itself and various oversight bodies; and at higher levels there are difficulties getting the attention of and priority consideration from the Departments and agencies, OMB, and Congress. Part of the problem is that laboratories individually pursue their own F&I needs and tend not to collaborate well to communicate their collective enterprise requirements.

IDA researchers identified four strategies that could improve the communication across the laboratories, agencies, and relevant F&I stakeholders: agencies could coordinate with their laboratories to develop a clear strategic vision; laboratories and agencies could develop communities of practice; laboratory F&I managers could interact with researchers in the planning and implementation of F&I and equipment; and laboratories could establish timely mechanisms to communicate with F&I-related stakeholders.

Data and Metrics

There are several challenges to using data and metrics within F&I investments. Assessments are expensive, time-consuming, and irregularly conducted. Some agencies and laboratories validate F&I data only every few years, using estimates between the years that inspections are performed. Finally, there is reluctance to share data to permit benchmarking because of the possibility that it could place laboratories at a disadvantage when competing for F&I funds or customers.

Strategies to address these challenges include providing high-level guidance to define, collect, and maintain metrics; standardizing metrics and data elements across laboratories; and engaging in benchmarking and other data-sharing efforts.

Next Steps for Facilities and Infrastructure

Based on the strategies already adopted by some laboratories and on the suggestions provided by workshop participants and interviewees, five broad recommendations were proposed:

1. Establish and participate in an interagency forum for sharing best practices.
2. Facilitate F&I planning processes and funding.
3. Establish standard criteria and methods to prioritize F&I investments.
4. Expand opportunities to involve stakeholders and improve communications.
5. Improve the collection, quality, and use of data and metrics.

Laboratory Governance

Federal security laboratories have different missions, research portfolios, budgets, and communities of sponsors and users. They also embody a mix of governance types:

- Government-Owned/Government-Operated (GOGO) laboratories, which are run by government employees and operate under varying organizational, administrative, and research arrangements established by parent agencies
- Federally Funded Research and Development Centers (FFRDC), which are run by private-sector organizations and maintain close, long-term relationships with government sponsors, within a structured regulatory environment, some of which are Government Owned/Contractor Operated (GOCO) facilities
- University Affiliated Research Centers (UARC), which are run by universities and share some but not all of the attributes and regulatory environment of FFRDCs.

IDA was asked to address the following questions related to Federal security laboratories: What are the critical trends facing Federal security laboratories today? How does governance structure relate to the operation and performance of research and development (R&D) that supports the national security missions? How can the Federal government best support the Federal security laboratories to address future national security challenges?

To assess these questions, IDA researchers organized expert panels composed of former and current federal security laboratory directors; department and agency headquarters personnel; and laboratory leaders from other federal laboratories, academia, and industry.

Trends Affecting Federal Security Laboratories

The panel sessions focused on the overarching trends that have affected R&D activities or performance at the federal security laboratories: personnel-related challenges, competition from R&D entities in foreign countries, changes to laboratory research focus and funding, and increases in regulatory requirements and oversight.

Current personnel challenges for federal security laboratories are the result of several long-term trends, including competition from the private sector, an aging workforce, and waning numbers of appropriately educated and security-clearance eligible young scientists. These trends led panelists to express concerns over the ability of the federal security laboratories to maintain a high-quality workforce.

Questions were raised about the ability of the federal security laboratories to compete with the private sector for high-quality talent, particularly in certain high-demand fields, such as cyber security. There are increasing numbers and proportions of foreign-citizen undergraduate and graduate students in U.S. academic institutions who are not eligible for security clearances. Student recruitment is key to maintaining the federal security laboratory workforce, and increases or improvements to existing student recruitment programs were recommended by the panelists.

Competitive salaries also present a challenge to recruiting employees. In particular, if GOGO laboratories had more flexibility in their personnel management systems, panelists believed the labs would likely improve their ability to recruit and retain scientists and engineers.

Panelists expressed concern about the reduced opportunities for laboratory researchers to interface with foreign-based researchers and internationally located industry collaborators. In particular, scientists at federal security laboratories were said to have difficulty collaborating with researchers overseas due to security requirements and current budget pressures to reduce travel for conferences and peer engagements.

Panelists were also concerned that emerging national security fields such as cyber security, information technology, quantum computing, bioterrorism and bioweapons, and nanotechnology have not been adequately addressed by federal security laboratories.

Two funding issues were seen by panelists as challenging DoD and Department of Energy (DOE) laboratories' ability to conduct their research—the increasing fragmentation of budgets and reliance on shorter-term rather than long-term programmatic funding. In addition, prior policy decisions have led laboratory directors to rely on outside funding support to maintain core capabilities due to declining overall budgets.

Panelists were also concerned that federal security laboratories face more regulatory requirements related to safety than non-federal laboratories, which increases the levels of bureaucracy and raises the regulatory burden on laboratory researchers. Increases in regulatory requirements often represent the cumulative effects of multiple remedial actions, each one taken in response to a single incident that was considered a liability to the laboratories or their sponsor agencies. This has an adverse effect because there is a perceived level of distrust between the agency offices and the laboratory staff conducting research.

Laboratory Roles and Governance Structures

Panelists reached four conclusions regarding laboratory roles and governance. First, federal security laboratories fulfill a unique role in U.S. national security research and development. Second, each governance model has certain advantages. Third, critical laboratory characteristics do not necessarily depend on their governance structure. Finally, both exemplar and sub-standard examples of laboratories exist under each governance model.

According to panelists, wholesale transition of all federal security laboratories from one governance structure to another is not advisable or warranted, but the best attributes of each governance structure could be incorporated into others. The general view was that the costs associated with transitioning all federal security laboratories to one governance structure would far outweigh the benefits. Panelists believed that such changes in management are disruptive and could leave lasting negative impacts. Thus, panelists recommended practices to facilitate the expanded use of the best laboratory attributes at all federal security laboratories. The primary recommendations derived from discussions with the panelists are:

- Rationalize the oversight burden on the laboratories
- Maintain or reinstitute laboratory flexibility for research budgeting
- Increase or maintain autonomy and accountability in personnel systems, particularly in GOGO laboratories.

Personnel and Workforce

IDA has performed a number of research projects addressing the national security science and technology federal workforce, including efforts focused on hiring foreign scientists and engineers at federal security laboratories, personnel exchanges, industry hiring best practices, uniformed scientists and engineers, and federal science, technology, engineering and mathematics (STEM) workforce quality. The first two of these projects are discussed in more detail below.

Hiring Foreign Scientists and Engineers at Federal Security Laboratories

There are increasing numbers and proportions of foreign-citizen undergraduate and graduate students in U.S. academic institutions who are incapable of obtaining security clearances. Non-U.S. citizen doctoral graduates with temporary visas are outpacing U.S. citizen and permanent resident doctoral graduates in national security science and technology fields at U.S. academic institutions, and more than one-half of PhDs awarded by U.S. engineering schools are earned by non-U.S. citizens.

However, it is not easy for new foreign-born, U.S.-educated, STEM researchers to work at federal security laboratories after graduation because of their citizenship and the difficulty in obtaining a security clearance. Hiring foreign nationals at federal security laboratories is challenging because the work could involve handling classified information, which may not be accessed by workers without U.S. citizenship and security clearances. Further limitations stem from recent changes in appropriations law stating that DoD cannot compensate a noncitizen, unless the noncitizen is lawfully admitted for permanent residence.

IDA helped organize and assess the results of a Government workshop convened to address these issues with representatives from multiple elements of DoD, U.S. Citizenship and Immigration Services, OMB, and the Domestic Policy Council. Subsequently, a working group was established to articulate clear paths for foreign national students studying in the United States to remain in the United States and for exceptional foreign national scientists and engineers to apply for employment at a DoD federal security laboratory and gain U.S. citizenship.

IDA supported the working group by providing background materials on immigration pathways, investigating hiring authorities, and analyzing processes available to DoD to provide foreign citizens with access to classified materials when needed. Also, we supported the development of a guidance document that outlines existing laws and regulations and clarifies current processes and procedures for employment, immigration, and granting foreign national scientists and engineers at DoD laboratories access to classified materials when eligible and qualified U.S. citizens are not available.

Personnel Exchanges

While mechanisms, such as Intergovernmental Personnel Act agreements exist for personnel exchanges between the federal security laboratories and other science and engineering, academic, and industrial organizations, they face numerous challenges, including lack of awareness of exchange opportunities and ineffective advertisement to both government personnel and outside organizations; the length and complexity of the application process; resource constraints, including unwillingness to give up valued personnel; and uncertainty over the impact on one's career and transition back to the original organization. There are also a number of legal and regulatory requirements intended to prevent conflicts of interest during and after a personnel exchange that can impede the establishment of personnel exchanges.

IDA researchers identified currently available personnel exchange mechanisms, particularly those open to for-profit organizations; investigated the exchange process at different organizations; described the roles exchange personnel fulfill; analyzed the potential benefits of personnel exchanges; summarized barriers to utilizing personnel exchange mechanisms; and developed policy options for improving existing mechanisms or creating new ones.

Preliminary results pointed to a number of policy options for improving current personnel exchange mechanisms:

- Create high level executive encouragement and support for personnel exchanges
- Streamline the agreement package and process and issue exchange procedure manuals
- Create a government-wide central repository for lists of opportunities and required paperwork
- Establish reciprocal exchanges so that organizations maintain the same number of employees
- Engage a larger group at each agency to lead to a collective commitment to an exchange program
- Establish agency-wide personnel exchange funds
- Make a commitment to employees participating in exchanges that their career trajectory will not be impeded by the exchange.

In addition, options were presented for specifically engaging for-profit exchanges. Since DoD has multiple programs for sending individuals to industry, the recommendations focused on new methods for temporarily bringing for-profit personnel into the government:

- Establish a pilot program for industry rotators in DoD
- Draft a legislative proposal establishing authority for DoD to utilize industry exchanges.

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THE CIVILIAN SCIENCE AND ENGINEERING WORKFORCE IN DEFENSE LABORATORIES

Jocelyn M. Seng and Pamela Ebert Flattau

The Problem

The Department of Defense (DoD) relies upon the skilled scientists and engineers in its laboratories to develop advanced technologies. Sustaining the quality and availability of civilian scientists and engineers in today's global economy is a challenge for DoD.

DoD meets its needs for advanced military technologies through its access to skilled scientists and engineers (S&E). Many of these specialists are employed by DoD laboratories operated by the Army, Navy, and Air Force. The civilian S&Es employed by DoD labs, comprising a workforce of 35,400 workers (in 2008, a benchmark year in which data were available to the research team), play a critical role in national security by working at the forefront of science/engineering and technology breakthroughs. For example, Thomas Edison guided the first Naval Consulting Board, which pioneered the fields of high-frequency radio and underwater sound propagation. The history of modern computing can be traced to the need for increased speed and accuracy in firing projectiles, which led the Army's Ballistics Research Laboratory to support the development of ENIAC, the first operational, general-purpose computer. Also, DoD S&Es capabilities in the core disciplines of aeronautical science, vehicle control technologies, and structures for atmospheric and trans-atmospheric vehicles, have made the Air Force laboratories leaders in the development of military aerospace vehicles.

The overarching question is whether DoD will have access to the pool of talent needed to ensure that it will keep pace with technology developments across the globe.

Over the past several decades, the number of civilian S&Es has declined, both in real numbers and relative to an increase in scientific and engineering contractors. Concerned by the implications of this changing workforce, IDA was asked to assess recent trends and the current status of the civilian S&E workforce. The overarching question is whether DoD will have access to the pool of talent needed to ensure that it will keep pace with technology developments across the globe.

The objective was to provide an assessment of the recent trends/current status of the S&E workforce as input for policy and funding decisions relative to S&E workforce development and to present suggestions regarding policies and practices that will ensure future workforce viability. The principal tasks were to:

- Determine the size and composition of current civilian S&E workforce in DoD science and technology (S&T) laboratories
- Identify recent trends in the S&E workforce and projected trends to 2020

- Estimate the anticipated future composition of the U.S. and DoD S&E workforces
- Assess current DoD workforce programs, policies, and practices relative to future S&E needs.

A customized database developed by IDA, which contains workforce information provided by the Defense Manpower Data Center (DMDC), was created to conduct the workforce analysis. Trends in DoD lab civilian S&E workforce between 1988 and 2008 were analyzed in five-year increments. The IDA team augmented data analysis with selected DoD lab director interviews, in part to understand the role of "Lab Demo" in shaping DoD S&T workforce personnel policies.[1]

Workforce Quality

In 2008, the civilian S&E workforce at DoD labs largely resembled the U.S. S&E workforce with some important differences. As shown in the workforce profiles below, unlike the overall U.S. S&E workforce, the DoD lab S&E workforce age profile is not relatively flat, but instead shows a definite dip in the 35–45 age groups due to the hiring freeze in the 1990s and worker turnover. The DoD lab S&E workforce is also slightly older than the U.S. S&E workforce, but has a similar mix of workers when analyzed by race/ethnicity. However, the number of women S&Es employed by DoD labs has not kept pace with their growth in the U.S. S&E workforce as a whole. Little is known about the quality of the S&E workforce within DoD because pertinent data, such as educational disciplines, educational institutions, and employment history prior to DoD employment, are not recorded in the DMDC database.

Recommendations

Additional DMDC data fields. Additional data to support DoD lab S&E workforce quality assessment

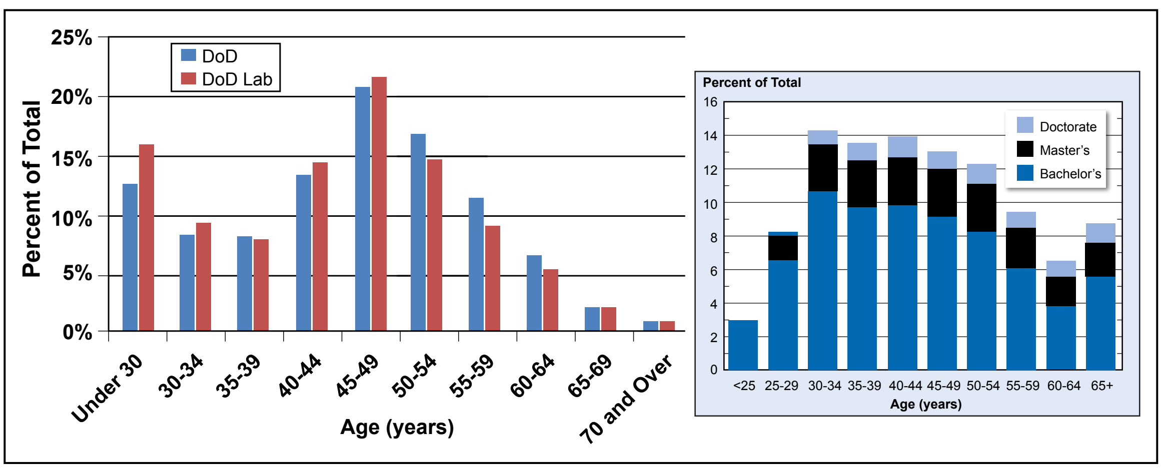

Figure 1. DoD and DoD Lab Civilian S&E Workforce Age Profile in 2008 and U.S. S&E Workforce Profile

[1] Congress has passed legislation that encouraged DoD to conduct civilian personnel demonstration projects (Lab Demos) in DoD's science and technology reinvention laboratories (S&T reinvention labs) and for the civilian acquisition workforce DoD-wide. Initially authorized by the Civil Service Reform Act of 1978, personnel demonstration projects allow Federal agencies to waive parts of Title 5, United States Code, to test innovative human resources policies.

should be provided. To achieve this, database fields could be added to the DMDC records about the source of new recruits (e.g., academia, including school and major; industry; government). Information about education and training history is also needed with respect to the names of the educational institutions and types of formal post-degree training certificates that DoD lab civilian S&E staff may have received before joining the DoD workforce.

Quality metrics. DoD should compile and document quality of workforce metrics (such as number of patents, number of publications, number of requests for invited external presentations, number of citations) as a part of the annual data call for the DoD In-House S&T Activities Report.

Lab director survey. The DMDC database should be supplemented with a formal survey/data call of DoD lab directors to collect additional information on workforce quality.

Workforce Projections

DoD can expect to find qualified engineers in the coming years because degree production in engineering at all levels has been increasing in the United States. However, the number of U.S. computer science baccalaureates continues to decline after its peak in 2003, and the number of mathematics and physical sciences baccalaureates remains low. Significant uncertainties exist relative to degree production and employment in the sciences and engineering at this time—owing in part to changing economic circumstances and student career preferences. This situation suggests that DoD might experience problems when seeking qualified workers in those three scientific disciplines and should monitor trends through enhanced modeling work and scenario development.

Recommendations

Workforce modeling. DoD should implement a formal workforce model to inform discussion and strengthen DoD strategic planning. The model should include a disaggregation of information at the occupational level to consider projection-based degree production and hiring and retention patterns for scientists vs. engineers and for individual disciplines.

Workforce development strategy. The adequacy of current DoD S&E workforce recruitment and retention strategies can only be understood using various scenarios. IDA developed three possible scenarios and found that each scenario generates a unique set of issues.

Workforce Management

DoD can expect that a significant portion of more experienced workers (in their fifties) currently employed by DoD S&T labs will begin to retire in the next five years and will have left by 2020. The recent wave of new hires will most likely dominate the DoD civilian S&E workforce by 2020 as mid-career workers, if recent patterns of recruitment and retention continue over the next ten years. The Lab Demo directors reported to the IDA team that Lab Demo provides the kind of flexibility needed to implement personnel decisions responsive to current market conditions—locally and nationally.

Recommendation

Integration of Lab Demo outcomes into ongoing redesign of DoD Personnel Management System. The 2002 *DoD Science and Technology Reinvention Laboratory Demonstration Program Summative Evaluation* should be updated by validating Lab Demo observations. Best practices and identified needs of all DoD labs should be fed into current and subsequent work on the National Security Personnel System to enable resulting policy direction to develop a permanent personnel management system that works. Since there is urgency to deploy the personnel management authorities necessary to sustain a robust S&E workforce, an interim solution for DoD labs should be implemented, if the current review of DoD's civilian personnel systems does not lead quickly to a broadly accepted conclusion.

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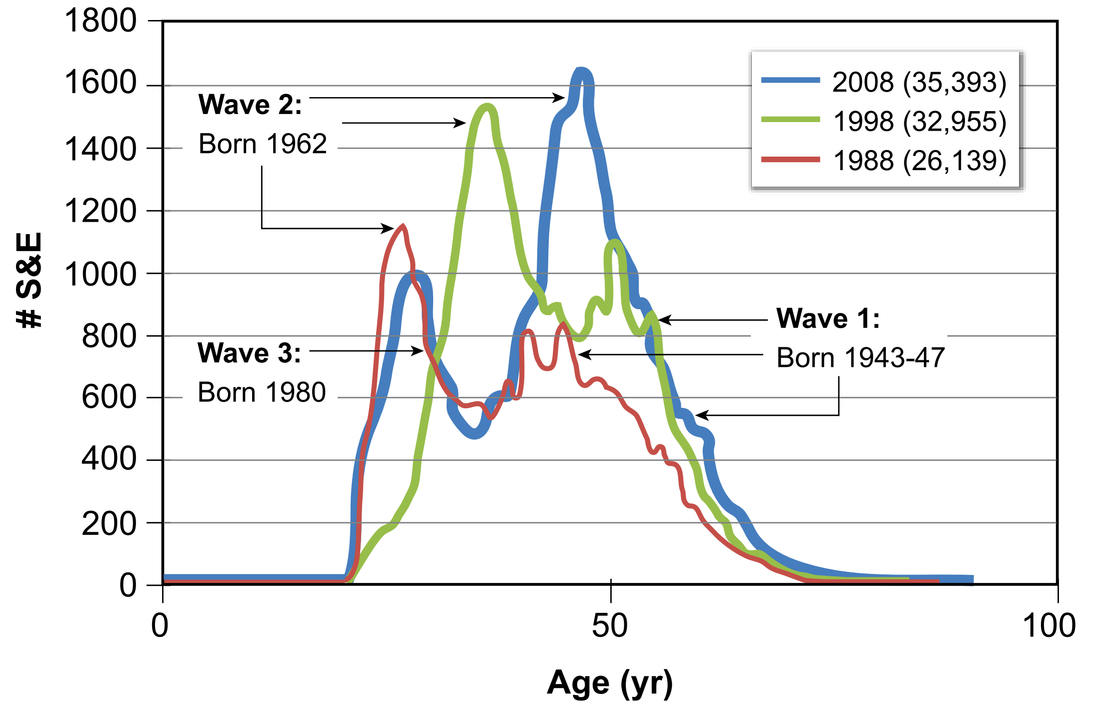

Note: The cohort of civilian S&Es born in 1962 (Wave 2) represents the peak of the workforce distribution in all three years measured. As this cohort moves toward retirement, increased numbers of new hires will be needed to maintain the same workforce size, as illustrated by the spike in workers in their 20s and early 30s in the 2008 data.

Figure 2. Age Profile Trends of Civilian S&Es in DoD Labs in 1988, 1998, and 2008.

TECHNOLOGY TRANSFER: PRACTICES FROM THE DEPARTMENT OF DEFENSE

Susannah V. Howieson and Stephanie S. Shipp

The Problem

Technology transfer is an important mandated function of the Department of Defense (DoD) laboratories. However, effective technology transfer is challenging for DoD laboratories for several reasons. IDA was asked to identify exemplar practices employed throughout DoD, along with policy and legislative initiatives that might improve DoD's overall efforts to transfer innovations to the commercial marketplace.

Technology transfer is the process of sharing, transmitting, or conveying technology, data, and information (intellectual property) between government agencies, industry, and academia. IDA was asked to identify exemplar technology transfer practices throughout DoD laboratory enterprise and technology transfer policy and legislative issues that the Office of the Secretary of Defense (OSD) could address to enhance current practices or to develop new practices. Also, the research was intended to provide information to DoD laboratory and technology transfer office personnel about best practices and encourage their adoption across DoD. The research team reviewed pertinent literature including previous IDA research on DoD laboratories related to technology transfer. The team also interviewed stakeholders, including representatives from DoD Offices of Research and Technology Applications (ORTA) and legal staff involved in the technology transfer or acquisition processes, and personnel from other agencies.

The exemplar practices presented in the literature focus on high-level strategies to improve technology transfer at DoD laboratories.

Literature Review

A review of academic literature, government reports, and legal documents on technology transfer highlighted strategies and factors for success, but not specific practices. It was noted that effective technology transfer is challenging for DoD laboratories for the following reasons:

- Defense laboratories primarily focus on technology transition and view transfer for non-military purposes as secondary.
- Defense research and development (R&D) might not be commercially relevant or could be classified.
- Defense inventions might be protected via trade secrets rather than patents.
- Defense researchers often work on weapon systems, for which performance is overriding, making it difficult to work with

industry partners who also must balance schedule and cost.

The exemplar practices presented in the literature focus on high-level strategies to improve technology transfer at DoD laboratories. These strategies include providing guidance to DoD laboratories to strategically plan and engage in technology transfer; to empower and reward researchers engaged in technology transfer; to create effective and efficient technology transfer offices; to establish processes that streamline executing technology transfer agreements; and to leverage other technology transfer resources at the local, State, and national levels.

The following are critical factors for a successful technology transfer program: an effective ORTA, engaged researchers, well-managed intellectual property, effective use of technology transfer mechanisms, efficient technology transfer processes, and meaningful interaction with industry through marketing or partnerships.

Interview Findings

Semi-structured interviews with DoD-affiliated laboratory ORTA staff and other stakeholders were conducted using the themes identified in the literature. Programs and processes identified during the discussions were considered exemplar practices for technology transfer at DoD laboratories if they resulted in measurable outputs or outcomes (e.g., reduction in the number of days to execute agreements or increase in the number of agreements); adoption by other laboratories; continued implementation of the exemplar practice; or assignment of dedicated resources. The research team identified more than 20 exemplar practices and organized them into the seven categories described in the following paragraphs.

Ensuring Effective ORTA Organization and Staffing

Exemplar practices in this category focus on organizing staff by technology or business area, building strong relationships with DoD attorneys, and providing seed money to ORTAs to pilot programs or software to facilitate technology transfer. With decentralized staff and localized control, ORTAs are enabled to make quick decisions and attract experienced staff. In addition, decisions are accelerated, and the lines of communication are opened. For example, the Department of Navy Technology Transfer Program Office funds Navy laboratories to conduct pilot projects of new technology transfer approaches. The funding amounts vary from $5,000 to $50,000 for each project. Navy laboratories compete for the funding. Examples of the outcomes of these pilot programs include the Innovation Discovery Process and the Military to Market program.

Empowering, Training, and Rewarding Scientists and Engineers

Many laboratories are using classroom and online training, boot camps, and presentations by companies and venture capitalists to inform and inspire researchers to file invention disclosures and patent applications or work with companies through Cooperative Research and Development Agreements (CRADA).

For example, a new Defense Acquisition University online course provides training on ensuring that agreements anticipate data rights for future acquisitions. Recognizing and rewarding researchers for their efforts include giving awards and plaques, and sharing royalty payments. Training administrative staff to identify novel technologies (intellectual property), and working with researchers to file invention disclosures are other exemplar practices.

Capturing and Managing Intellectual Property

DoD laboratories have developed methods for capturing and managing intellectual property (IP) during two stages: identifying IP during R&D phases and evaluating invention disclosures for licensing or commercialization. At laboratories, staff identifies IP so it can be documented in the form of invention disclosures and provided appropriate protection in the form of patents and copyrights. Then most DoD laboratories undergo some type of evaluation to determine which invention disclosures to protect. Many ORTAs use an invention review board process to determine whether to patent technologies from invention disclosures.

An exemplar IP identification practice is the Innovation Discovery Process at Naval Surface Warfare Center (NSWC) Crane Division that helps researchers identify potential IP. This process involves innovation mining where inventors discuss their research projects in front of business and engineering faculty, entrepreneurs, and industry and technology transfer experts. NSWC Crane evaluates the success of Innovation Mining Events using counts of invention disclosures, potential commercialization ideas, completed post-event disclosures, inventors trained about IP, and partners exposed to NSWC Crane through participation in the events.

Using Technology Transfer Mechanisms to Full Potential

Many DoD ORTAs and attorneys have been creative in their use of traditional technology transfer mechanisms. This creativity allows DoD laboratories to license government software, engineering drawings, and other works of technology-related authorship in the absence of a patent; conduct research partnerships with foreign governments; or use abbreviated CRADAs for material or data transfer, material evaluation, and device evaluation. These special CRADAs streamline or tailor the CRADA process to allow industry to work with laboratories or use laboratory facilities. For example, staff of the Air Force Research Laboratory Information Directorate (AFRL/RI) developed a Limited Purpose CRADA for protecting software. The mechanism is intended to provide software to first responders and other interested organizations subject to security restrictions. In exchange, AFRL/RI receives feedback about the software. The software use agreement also acts as a trial usage agreement. If an organization likes the software, a license can be purchased later. The Air Force Office of the General Counsel has approved the use of the Limited Purpose CRADA for software agreements, and AFRL/RI has entered into about a dozen such agreements.

Managing and Monitoring Technology Transfer Processes

The following categories of practices have been developed to manage and monitor technology transfer: changing processes; tracking of CRADAs and licenses; developing handbooks for commonly executed agreements and contracts; developing databases and checklists for technology transfer processes; and using software programs designed to manage intellectual property. The Aerospace Corporation, which manages a Federally Funded Research and Development Center (FFRDC) for DoD, developed the Intellectual Property Program Licensing Toolkit. The toolkit includes an initial questionnaire that inquires how the business will use the license; a licensing worksheet that asks for information on execution fees, royalties, and field of use; a standard license agreement; and a license agreement change request that divides the standard license agreement into editable sections.

Marketing Laboratory Technologies and Capabilities to Industry

Multiple approaches are used within DoD laboratories to market laboratory technologies and capabilities to industry. These activities include highlighting DoD technologies through technology showcases, training industry about working with DoD laboratories, and preparing and advertising market assessments for technologies that could be licensed and developed or implemented by companies. DoD laboratories conduct outreach to industry through presentations at events and meetings. For example, the Army Corps of Engineers Construction Engineering Research Laboratory staff participates in meetings that manufacturers attend; researchers at the Army Research Laboratory hold regular discussions with licensees, CRADA partners, and other collaborators to ensure a common understanding about agreements; and representatives of the Air Force Human Effectiveness Directorate attend trade shows and other industry meetings to showcase facility capabilities.

Building Partnerships

DoD laboratories use multiple mechanisms to form partnerships with outside organizations to facilitate technology transfer, including Partnership Intermediary Agreements, Educational Partnership Agreements, and Other Transaction Authority agreements. There are five types of partnerships (national partnership intermediaries, local partnership intermediaries, universities, venture capital organizations, and economic and technology development organizations) and a range of functions performed by partnering organizations for laboratory ORTAs (identifying patentable IP; writing invention disclosures; executing deals such as patents, licenses, and

CRADAs; developing marketing plans; funding technology development and maturation; providing seed funding to businesses; marketing laboratory technologies; running technology showcases; and connecting laboratories with universities (e.g., students and researchers) and staff of local and national businesses). Two partnerships highlighted as exemplar practices during interviews with DoD laboratory ORTA staff are the Griffiss Institute, affiliated with AFRL/RI in Rome, New York, and the NSWC Crane's partnership network.

Summary

Many DoD technology transfer organizations have implemented creative approaches within the boundaries of existing regulations, directives, and instructions. Encouraging the adoption of these exemplar practices is likely to accelerate the transfer of innovations to the marketplace.

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