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The Future of Army Science and Technology Requires Punctuated Equilibrium

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Abstract

Science and Technology is the “seed corn” for the Army’s Future warfighting systems. As such it must be exceptionally managed if the Army is to be prepared to fight and win in a Volatile, Complex, Uncertain, and Ambiguous environment. The recently released Army Operating Concept (AOC) asserts that innovation is required to ensure the Army is prepared to fight and win in that complex world. Further, the AOC highlights how the Army must be able to “continuously learn, adapt and innovate” and that this ability must not only be mastered by the operational forces, but by the institutional forces as well. Army S&T efforts are managed by bureaucratic institutional “enterprise”, which may be ill-suited in its current construct and policy limitations to meet the demands of the future. The Army S&T enterprise may require a period of punctuated equilibrium, where, as an enterprise, it must be adaptive and innovative lest the Army finds itself at a technological disadvantage in the Future Force 2025 and Beyond (F2025).

The Future of Army Science and Technology Requires Punctuated Equilibrium

> The typical twentieth-century organization has not operated well in a rapidly changing environment. Structure, systems, practices, and culture have often been more of a drag on change than a facilitator. If environmental volatility continues to increase, as most people now predict, the standard organization of the twentieth century will likely become a dinosaur.[1]

> As described by is proponents, punctuated equilibrium theory depicts organizations as evolving through relatively long periods of stability (equilibrium periods) in their basic patterns of activity that are punctuated by relatively short bursts of fundamental change (revolutionary periods)….In an environment of rapid change and uncertainty – a Revolutionary Period – companies that are complacent in their operations and organization are dying or dead, and those that are innovative, multi-dimensional and able to respond versus react to a shift in the environment will live.[2]

What will become of the Army S&T Enterprise? Will it continue to be value added or will it become an irrelevant organizational dinosaur destined to the La Brea Tar Pits? The Army Acquisition enterprise which includes Science and Technology has seen several inflection points and periods of punctuated equilibrium over the last 50 years, all to make the enterprise more efficient and effective. In 1962, the Army Materiel Command (AMC) was established, and Army Program Management was formalized.[3] By 1975 Army program managers were aligned with the AMC major subordinate command (MSC) that their portfolio supported.[4] Between 1986 and 1989 as part of the Packard Commission Report and Goldwater-Nichols Act, the Army established the Assistant Secretary of the Army for Research, Development and Acquisition (ASARDA), later renamed ASA Acquisition Logistics and Technology (ASA/ALT), as well as the Army Acquisition Corps. Program management functions were moved from AMC to ASARDA. [5] In 2007, as a result of the Gansler Commission, the Army Contracting Command was created to meet the demands of expeditionary contracting as well as increased synergy across all Army Contracting.[6] The Army in 2016 stands at another inflection point in which a period of Punctuated Equilibrium (P.E) is needed to enable the Army to continue to be the world's premier land force well into the 21st Century. Army S&T must also embrace this period of punctuated equilibrium lest the Army finds itself unable to meet the technological challenges of the future.

A Tipping Point

Changes in future military requirements are difficult to chart – but change is indeed inevitable. Clausewitz theorized the nature of war remains constant yet each period brings its own character.[7] In the 1970s and 1980s the Soviets brought forward a new theory of warfare known as the Military Technical Revolution (MTR). MTR then gave birth to the theory of Revolution in Military Affairs (RMA) that is the discontinuity in the status quo of military capability. The U.S. Army adopted this theory in the mid-1990s, principally as a lesson gleaned from the defeat of the world's 4th largest Army in Operation Desert Storm in 1991. This tactical and operational route was assumed to have been possible because of the discontinuity of military capability and the tremendous advances in military technology.[8] The U.S. Army's original RMA as described in 1995 pointed to four distinct changes:[9]

- Extremely precise, stand-off strikes
- Dramatically improved command, control, and intelligence
- Information warfare
- Non-lethality

One could argue that in the 90s and even 2000s, the U.S., its allies, and its adversaries were in the infancy of this revolution. As a corollary, according to the specific definition of Moore's Law, the number of transistors on a computer's Central Processing Unit (CPU) will double every two years.[10] Exponential growth in computer processing capacity is no doubt one of the key drivers of this new military revolution. In years to come, this computing growth will undoubtedly spur even greater discontinuity in the character of warfare to include more cyber attack and defense, artificial and conversational intelligence, nano-drones, the use of mass media and crowdsourcing just to name a few.

Two prominent Russian military theorists recently penned an essay entitled, 'The Nature and Content of a New-Generation War.' In it they describe how they view the U.S. conducting warfare in the future; however, it could easily be more reflective of how the U.S. should see Russia, and what is required to prevail in future conflict:

> The aggressive side will be first to use nonmilitary actions and measures as it plans to attack its victim in a new-generation war. With powerful information technologies at its disposal, the aggressor will make an effort to involve all public institutions in the country it intends to attack, primarily the mass media and religious organizations, cultural institutions, non-governmental organizations, public movements financed from abroad, and scholars engaged in research on foreign grants. All these institutions and individuals may be involved in a distributed attack and strike damaging point blows at the country's social system with the purported aims of promoting democracy and respect for human rights. In their propaganda efforts, these organizations can obtain information to engage in propaganda from servers of the Facebook and Twitter public networks watched over by the American special services.[11]

If this is truly the view of the next generation of warfare held by America's longtime adversary, the Army must be prepared to fight and win in a much different construct than it envisioned ten years ago. The Army has recently coined this construct as Volatile, Uncertain, Complex and Adaptive.[12]

The Army likely will continue to find itself in a VUCA environment for the foreseeable future. The recently released Army Operating Concept (AOC) identifies the first order capabilities the Army requires to win in a complex world. The AOC asserts that innovation is necessary to ensure the Army, its Soldiers, and leaders are prepared to fight and win in that complex world. The AOC explains that it may be impossible to precisely predict the future character of conflict. Planning must be sufficiently accurate so that once the future is upon us, we are not so far afield that we are unable to adjust quickly. In the AOC preface, the TRADOC Commander highlights how the Army must be able to "continuously learn, adapt and innovate" and that this ability must not only be mastered by the operational forces, but by the institutional forces as well.[13] Agencies, commands, training, doctrine, organizational structure, and end-strength (just to name a few Army artifacts) are undergoing rapid and fundamental change to meet the demands and realities of a VUCA environment. Army S&T, which is at a tipping point, should be no exception.[14]

In 1995, the Under Secretary of Defense for Acquisition stated in testimony before the Senate Armed Service Committee that "The Army's science and technology (S&T) budget is on the very edge of what is required to sustain an acceptable technology base for the future. S&T work is the seed corn that grows into future weapons systems."[15] The Under Secretary's statement could have easily been from recent congressional testimony. As in 1995, the future of the Army modernization is at a fiscal tipping point. The Budget Control Act of 2011 (sequestration) is driving the Department of the Army (DA) not only to reduce force structure but also to make hard choices in its modernization plan to ensure readiness is not sacrificed.[16] The Department of Defense and the Services are faced with stark choices to ensure the force structure is adequate to meet the requirements described in the National Security and Defense strategies and that the combat readiness of that structure is protected.

One area which has always been ripe for cuts in lean times is modernization - and now is no exception. As the DOD, Services and specifically the Department of the Army weigh options to ensure readiness is guarded and force structure is adequate, it is paramount they keep an eye towards the future. In past eras of fiscal reductions, an inflexible “salami slice” approach has been applied to live within budget cuts, however, that approach more often than not sub-optimizes effectiveness. Fortunately in 2012 and 2013, the DOD avoided “automatic, salami-slice cuts for considered funding decisions” due to language in bipartisan budget acts.[17] The Army seems to be taking advantage of the acts and is proactively safeguarding the “seed corn,” while assuming risk in reducing the funding and pace of development and production of major weapons systems. Ms. Heidi Shyu, former ASA/ALT, recently commented that S&T would be the last line item to be cut in cost saving initiatives and was at the top of the pyramid of materiel priorities. The materiel cuts will fall on the back of big bill payers such as the Ground Combat Vehicle and other major development programs. Honorable Shyu highlighted that S&T investments would be focused on critical enabling technologies that will best position the Army for major weapon system development after the Army emerges from the “fiscal bathtub” if finds itself in now.[18] Honorable Frank Kendall, Under Secretary of Defense for Acquisition Technology and Logistics (USD AT&L) recently commented that his biggest concern with the FY17 budget was R&D funding and stated, “if you don’t do the R&D you won’t have a product at all.” Like Honorable Shyu, he is focused on the future. He commented, “We’re trying to fit as much of the R&D funding in the budget as we can, at least, to move the technology forward to position ourselves for starting EMD [engineering manufacturing and development] in a few years from now."[19] Kendall further explained that there are two critical areas which need continue special attention; the nuclear triad and investment into Science and Technology (S&T). He envisioned cuts to programs while safeguarding S&T, specifically stating, "While we can always slow down existing and future production lines, fielding less, unless investments have been made into science and technology there will be no production lines to slow."[20]

Deputy Secretary of Defense Robert Work is also championing S&T prominence. Recently he described how the US is quickly losing its technological edge. Even when the U.S. continues to push the boundaries of technological advancement, our adversaries are stealing it as soon as we build it. Although Deputy Secretary Work concedes the U.S. still maintains an advantage, our adversaries have near peer status in technologies such as nuclear weapons and modernization of nuclear weapons; new anti-ship, anti-air missiles; long-range strike missiles; counter-space capabilities; cyber capabilities; electronic warfare capabilities; and special operations capabilities. This loss of overmatch is one of DoD's greatest strategic challenges. To counter this, then Secretary Hagel initiated the Defense Innovation Initiative or 'Third Offset Strategy.' In this strategy, the department must be able to work more closely with industry as they are the innovation driver behind such technologies as, "robotics, autonomous operating guidance and control systems, visualization, biotechnology, miniaturization, advanced computing and big data, and additive manufacturing like 3D printing."[21]

The Enterprise and History

The Army S&T enterprise is part of the larger Research, Development, Test and Evaluation (RDT&E) enterprise, which is a part of the Army Acquisition, Logistics, and

Materiel Enterprise. S&T traditionally and primarily is focused on the ‘research’ portion of RDT&E concentrating in the areas of Basic Research, Applied Research, and Advanced Technology Development, known in shorthand as 6.1, 6.2 and 6.3 respectively. Moving beyond S&T and into the intial stage of development, are 6.4 efforts formally named the Advanced Component Development & Prototype phase. The 6.4 phase is offended referred to as the “valley of death” between S&T and Development, which will be discussed later.[22] It is important to understand the distinction between ‘research’ and ‘development’ because the agencies responsible for execution and funding allocation/prioritization are different. At the macro level AMC is responsible for executing the majority of Army S&T but the Assistant Secretary of the Army for Acquisition, Logistics, and Technology (ASA/ALT) is responsible for S&T funding prioritization and allocation. ASA/ALT is also responsible for execution and funding of systems development and production. An initial observation might be that the synergy between S&T and Development could probably be better if both were under the purview of one chain of command, one business model, and one organizational culture.

With an appreciation of the difference between S&T and Development, a rudimentary understanding of the components of S&T might help provide greater context. Basic Research (6.1), is the systematic scientific study of a certain phenomenon or observable facts without any particular application in mind. Applied research (6.2), on the other hand, is meant to “gain knowledge or understanding necessary to determine the means by which a specific need might be met.”[23] Advanced Technology Development (6.3) is a major step forward from Applied Research and includes “all efforts that have moved into the development and integration of hardware for field experiments and tests."[24] Advanced Component Development and Prototypes (6.4) includes the integration and evaluation of technologies in as realistic and operating environment as possible focused on the potential for cost reduction and performance of the technology. With a foundational understanding of what constitutes and differentiates S&T from development, understanding of the origination of S&T in the modern Army will be helpful in appreciating why it is organized the way it is today, and lend credibility to why it might be time for a change.

Science and Technology as a discipline required for materiel innovation, advancement, and improvement is not a new phenomenon in the Army. In fact, S&T is every bit as old as the Service itself.[25] What has seen a drastic change over the years is who and how S&T is managed and executed. Until the beginning of World War II, the system of Army arsenals had been the primary driver of innovation. The Army's system of manufacturing arsenals combined science, technology, research, development and production into standalone facilities such as Picatinny, Rock Island, Watervliet, and Springfield just to name a few, to produce the Army's warfighting weapons systems such as field guns, tanks, ammunition, and rifles.[26] As the realities of World War II set in; it became apparent the Army and its arsenal system were not ready to meet the demands of the technological innovation or pace required to counter the weapon system superiority of the Axis powers and support the U.S.' wartime mobilization.[27] Between 1940 and the end of the war, Army S&T and manufacturing was largely managed and orchestrated by the newly formed Office of Scientific Research and Development (OSRD). OSRD became the clearinghouse for federal funds used in the greatest technological advancements. OSRD and government employees collaborated with industry and universities to develop the state-of-the-art weapons systems such as the "atomic bomb, microwave radar, radio proximity fuse," just to name a few.[28] At the same time funding allocated to the expansion of the production of steel, aviation fuel, synthetic rubber and other critical wartime materials was being managed by newly established emergency agencies such as the Defense Plant Corporation and the War Production Board. The inclusion and, by most accounts, the domination of non-Army laboratories for technological innovation during World War II set the stage for the Cold War period. In fact, the director of the Office of Scientific Research and Development, in his landmark report, *Science-The Endless Frontier*, argued that science and technology research conducted in universities and private industry would be the source of the Army's innovation and not science carried out by in-house government laboratories.[29] Another major reason for the divestment of government in-house science and technology research was the sheer magnitude of the diversity of science disciplines. During the post-war period, the rise of the defense contractors occurred to keep pace with the continued diversification of key technology areas. Technology fields such as solid-state physics, semiconductors, nuclear, jet propulsion, and optical were ripe for rapid defense market growth. This post-war S&T outsourcing was exacerbated in the early 1960s with the policies established by then defense secretary Robert McNamara. MaNamara further consolidated all acquisition policy and oversight of major weapons systems, to include S&T within the Office of the Secretary of Defense. Although there was a bit of a regression back to the Services in the 1970s, expansion of S&T to private industry dramatically increased again during the Reagan administration.[30]

The outsourcing sentiment continues to be echoed today by the Secretary of Defense and other senior officials within the Acquisition bureaucracy.[31] The trend of outsourcing innovation in large part continues with as much as 72% of RDECOM funded projects executed by industry and other non-Army laboratories yet still managed by an RDEC.[32] Outsourcing innovation is not an indictment or criticism. It is in fact, consistent with what Secretary Carter called for in his remarks on 28 August 2015 to some Silicon Valley executives. Secretary Carter state,"We're drilling tunnels through that wall that sometimes seems to separate government from scientists and commercial technologists - making it more permeable so more of America's brightest minds can contribute to our mission of national defense..."[33] Additionally, the Under Secretary for AT&L in BBP 3.0 specifically called for "greater and more timely innovation" of products used by the Department citing that the Services "can do a much more effective job of assessing and employing commercial technologies."[34]

Army S&T in 2016 and Beyond: A New Business Model

Army Science and Technology has been and must continue to be the critical ingredient in spurring Critical Technology Events (CTEs) that result in warfighting capability.[35] CTEs are best described as, "ideas, concepts, models, and analyses, including key technical and managerial decisions that [have,] a significant impact on the development of specific weapons."[36] Although the Army S&T enterprise has made deliberate strides in last several years to better align and synchronize S&T efforts, specifically with the creation of RDECOM in 2004, it may not be enough to maximize the innovation required to meet tomorrow's complexity and uncertainty. To remain the critical ingredient spurring CTE, which translates into technological superiority, the Army S&T enterprise must also embrace a period of truly punctuated equilibrium. The enterprise must adapt and innovate governance processes, programs and procedures to ensure a technological advantage in the Future Force 2025 and Beyond (F2025B).

It is common to narrowly limit thinking about innovation as simply a new widget or gizmo – we can see and touch the results of this type of innovation. However, according to Pierre Chao, founding member of Renaissance Strategic Advisors, and technology panelist at the Association of the United States Army (AUSA) annual conference, the majority of innovation is not physical.

> Most of the innovation coming out of the tech firms isn't about gizmos…it's been mostly about business model innovation. Amazon was a business model innovation….putting aside Apple, think Uber, eBay, and Google. They aren't known for manufacturing anything, but rather the disruption [punctuated equilibrium] they caused in their fields with new thinking. It's that kind of innovation the Pentagon needs.[37]

Articulating that most innovation has been about business models is not to imply that the Army's S&T enterprise should not think about and deliver the most innovative and disruptive "technological gizmos" possible to provide the Army with overmatch capability; it most assuredly must. However, the most efficient and effective way of delivering overmatch capability may very well come from adaptive and innovative business model governance spurred on by a period of punctuated equilibrium (P.E.).

For the purpose of discussion, P.E. in governance includes three major areas:

- Organizational structure, alignment, and objective
- Funding allocation, prioritization, and distribution
- Assessment / Metrics

Organizational Construct and Objective

The Army S&T Enterprise is large and crosscuts Major Commands as well as the Army Staff. According to Department of the Army Pamphlet 70-3, the major stakeholders include the Army Acquisition Logistics and Technology (AL&T), Army Materiel Command (AMC), TRADOC, Forces Command (FORSCOM), Army Deputy Chiefs of Staff 1 through 8, the Surgeon General, Army Corps of Engineers and the Space and Missile Defense Command. Within each of these commands, subordinate organizations are key action entities. These organizations include the Deputy Assistant Secretary of the Army for Research and Technology (DASA R&T), the Program Executive Offices (PEOs), the Army Capability Integration Center (ARCIC) and the Research, Development and Engineering Command (RDECOM) just to name a few.

As mentioned earlier, the principal agency responsible for S&T execution is RDECOM, a two-star major subordinate command (MSC) subordinate to AMC. However, DASA R&T, subordinate to ASA/ALT is responsible for funding prioritization and allocation. RDECOM executes approximately 74% of all Army's S&T efforts. The remainder of Army S&T is performed by the Army Medical Command, Corps of Engineers, Space and Missile Defense Command, and Headquarter Department of the Army G-1 at 8%, 13%, 3% and 2% respectively.[38] To reduce the scope of this topic, for the the remainder of this paper, Army S&T execution will only include the portion that RDECOM conducts.

RDECOM's subordinate organizations that execute the S&T portfolio are as follows: Army Research Laboratory, Natick Soldier Research Development and Engineering Center (RDEC), Tank Automotive RDEC, Aviation & Missile RDEC, Armament RDEC, Communications Electronics RDEC, and Edgewood Chemical Biological Center.

The Army has established several governing bodies that include the above-mentioned stakeholders to align and synchronize S&T efforts. At the very top, the Army Science and Technology Advisory Group (ASTAG), co-chaired by the ASA/ALT and the Vice Chief of Staff of the Army, provide oversight to the Army S&T program and ultimate approval of S&T investments at the macro level. The ASTAG is supported by the Army Science and Technology Working Group (ASTWG) co-chaired by DASA-R&T and the DCS G-8 Force Development, as well as three Army Science and Technology Working Group Councils: The Warfighter Technical Counsel, The Technical Council, and the International Programs Working Group. These three councils are one-star level bodies that provide guidance on specialized topics to the ASTAG.[39] There is clearly no lack of oversight when it comes to Army S&T efforts. What is not clear at the more senior level is what the standard of experience, exposure, and continuity in S&T matters these councils possess. Science and Technology is a highly technical enterprise where experience counts especially when S&T short-term is characterized as three to five years and long-term as 20+ years.

The S&T enterprise draws from numerous documents and policy directives to help inform the councils and working groups. Documents and directives include, but are not limited to; DOD S&T Priorities, S&T Investment Briefing of Global S&T, Industry and Academia, the National Military Strategy, The Chief of Staff of the Army Priorities, The Army Equipment and Modernization Plan, TRADOC Warfighter outcomes, Capabilities Needs Analysis, Wargaming, the Intelligence community including the National Ground Intelligence Center (NGIC), the annual “Mad Scientist” Conference, and ARCIC Whitepaper ST needs. Oversight and S&T documentation are inputs designed to achieve the Army's S&T approach as characterized in DASA R&T's briefing to the National Defense Industrial Association (NDIA) in April 2014, which is to:

- Align S&T and develop strategies which provide technology insertion points to Programs of Record
- Invest S&T resources in Army-specific areas and leverage from industry
- Concentrate basic research on high-payoff science with Army interest focused on 2030 and beyond
- Harness technologies that reduce operational and sustainment costs, increase combat readiness and increase reliability

All of the stakeholders above, councils, working groups and advisory boards provide input to the Army Science and Technology Master Plan (ASTMP), which is the single source document describing the S&T strategy, and is published by DASA R&T every other year.[40]

Two takeaways from the preceding description of S&T governance might be:

1. There is an abundance of oversight, technical expertise, and coordination that should optimize Army S&T efforts.
2. With all these different agencies, competing priorities, different leadership for execution and prioritization, long-term nature of S&T, high turnover rate of senior Army leadership, there is no way the Army S&T efforts are optimized.

Describing how S&T is managed, and resourced is reminiscent of how Louis Gerstner in '*Who Says Elephants Can't Dance?* described IBM when he took over as CEO. Gerstner describes the idea of a "management committee" (MC) that made every major decision.[41] Gerstner articulated that the MC was infiltrated by numerous factors such as bureaucratic compromise, competing agencies, social pressures, and poor heuristics just to name a few. David Houghton in his book about decision making titled *The Decision Point* made this same point regarding bureaucratic decision making and titled the phenomena as homo-bureucratics theory, which essentially sub-optimizes decision making. Decisions generally end up being a compromise rather than a choice among the best alternatives, e.g. the antithesis of the rational actor model.[42] Gerstner believed the committee apparatus "diffused responsibility and leadership."[43]

To mitigate against the bureaucracies and to achieve better S&T synchronization the leadership should consider several organizational structure changes. First, and foremost, RDECOM should be aligned with ASA/ALT and if possible, the command structure should be elevated to a three-star organization. Secondly, the RDECOM commander needs Planning, Programming, Budgeting, and Execution authority, to include the ability to move funds among and between RDECs. Finally, the organizational construct of the RDECs along with a renewed emphasis on S&T purpose must be further examined to increase the effectiveness of Army S&T.

The creation of RDECOM in 2004 by the AMC commander was a tremendous step forward in creating synergy. As noted by General Kern in 2002, "Right now, it is the impression of everyone out there that the laboratories take too long, they do science for science's sake, engineering for engineering's sake. We've got to figure out how to get technology in the hands of Warfighters quicker."[44] Although the creation of RDECOM was a step in the right direction, the gulf between "research" and "development" is still significant. Much like the creation of RDECOM in 2004 was meant to create better synergy; consolidating, aligning, and integrating the “research community” with the “development community” in 2016 would be a next logical step.

In addition to alignment, the command structure should be elevated from a two-star headquarters to a three-star. There are a number of reasons to consider this. From a human interaction dimension, the move would create parity among the other major stakeholders: the Deputy Chiefs of Staff as well as the Director of ARCIC. Elevating the command would also be in line with the supervisory responsibilities of a command that has operational control over seven geographically separate subordinate entities, all which are led by SES two star equivalents with more than 30 total SES employees. Finally, elevating the command may provide the necessary oversight, leadership and management that would better enable the recommended PPBE authority and may be justification reduce the current four-star level active engagement. MG (Retired) Nadeau, former commander of RDECOM, acknowledged elevating the command to a three-star organization had been discussed several times over the years but met with resistance for a variety of reasons. MG Nadeau stated he never felt like he was at a disadvantage by being a two star, but confided he did have tremendous “top cover” from the Acquisition Military Deputy, a three-star, who was in ASA/ALT.[45] Having adequate “top cover” may not always be the case.

The next aspect of organizational structure the enterprise should address is how RDECOM is organized and what skill sets are required in each RDEC for optimal effectiveness. RDECOM is not the only organization at a critical inflection point. In fact, Congress and DOD are currently evaluating concepts for the right structure, number, and type of Geographical Combatant Commands, which include consolidating

NORTHCOM and SOUTHCOM, as well as EUCOM and AFRICOM, and even consolidating the seven into three commands aligned with the three major oceans (Atlantic, Pacific, and Indian).[46] RDECOM too should conduct a thorough analysis using experts in organizational design to determine the best structure to meet the demands of the 21st century. It is inconceivable that the current structure, suitable for the 20th Century monolithic threat, is still ideal for the diffused and globally inter-connected threat we face in the current VUCA environment. The current RDECOM structure aligns each RDEC, as one might conclude by the naming convention described earlier, with a different "warfighting capability." TARDEC focuses on ground vehicles and combat service support, whereas CERDEC focuses on mission command and intelligence technologies, applications, and networks designed to connect and protect the Soldier. AMRDEC focuses on aviation and missiles where ARDEC focuses on armaments. From a technology perspective, many technology initiatives conducted in Applied Research or Advanced Technology Development span the major functional engineering domains (mechanical, electrical, software/computer). The rapid evolution of technology in the last 15 years has created the need for specialized sub-disciplines of classical engineering fields. Sub-disciplines are necessary in greater numbers at all RDECs as most systems are now interconnected. It is unlikely that today's, much less future mechanical systems will be void of electrical or software interaction.[47] With the advancement of technologies and engineering specialties, are six competing RDECs, plus the Army Research Lab still necessary? Is the correct mix of functional engineers available at all the RDECs to support the S&T initiatives or the programs of record? One minor example of where the current construct failed is with Joint Light Tactical Vehicle

(JLTV) program. The JLTV program required software/computer engineering support but the associated RDEC did not have this discipline resident. Obtaining the support from another RDEC proved administratively difficult if not impossible, therefore the PM contracted for the support.[48] Regarding cross-organizational sharing of resources, according to a senior S&T manager, he agrees there are many overlaps, but states,

> …most general Systems Engineering discipline occur at all RDECs; however, each RDEC trains and applies the SE practices differently. CERDEC, TARDEC, AMRDEC likely all employ C4/Electrical Engineers as well. There really is no sharing of the resources - or tasking out objectives to the most-skilled discipline owner - to combine for a project. Your JLTV example is good because it shows that skillsets from many organizations are sought and brought together to work on projects. It is very rare to have that cross-organizational resource sharing on S&T projects. There have been a few, but the organizational barriers are high.[49]

The current RDEC structure along warfighting systems/domains and difficulty sharing the most skilled disciplines between organizations may be an outdated organizational construct.

Similarly, RDECOM must assess the skill set required to “manage” S&T programs. As it was during the buildup of WWII and followed during the cold war, the vast majority of Army S&T work is out-sourced, e.g. not conducted in the government lab.[50] The government S&T workforce manages S&T programs, but engineers in academia or industry are, for the most part, the ones actually “turning wrenches.” Being a good engineer is crucial to managing these programs, but so are the skills brought by trained program managers. There is no Defense Acquisition Workforce Improvement Act (DAWIA) requirement for engineers to achieve DAWIA program management certification. A fortunate byproduct of level three engineering training and certification (the highest level), is level one program management certification. However, is level one certification in program management sufficient to manage multi-million dollar S&T

programs? Lack of certification and program management training is yet another example of the need for close alignment between the S&T and program management community.

Lastly, an “unwritten objective” of Army S&T (technology transfer) must be addressed. The 2015 draft S&T handbook states, “The objective of Army Science and Technology is to identify, develop, and demonstrate technology options that inform and enable effective and affordable capabilities for the Soldier.” This objective seems ideal. However, in recent years, there has been an increased focus and desire, for “technology transition.” In fact, technology transition is a key metric RDECOM currently collects. According to an S&T Senior Executive, the previous Army Acquisition Executive was a major influence on more technology transitions from Army S&T.[51]

Transitioning technology from the S&T to the product development realm is much more difficult than it may appear and as the metrics later show, is the exception rather than the rule when it comes to hardware/software transition. By focusing too much on technology transition, there is a high probability that S&T managers will avoid risk and won’t push the boundaries of technology advancement.[52] The director of the Defense Advanced Research Projects Agency (DARPA) used to consider success as a 90% failure rate! This metric told the DARPA director that he was indeed pushing the limits of science.[53] Similarly, Army S&T should be more focused on the objective of, ‘identifying, developing and demonstrating technology options,’ and less focused on “successful transitions.” Focusing on demonstrating technology options, especially considering the difficulty of technology transition discussed in the next paragraph, may better optimize the Army’s S&T contribution.

Transitioning an S&T effort to a program of record is fraught with blind spots.[54] The Army typically relies on industry to design, develop, and produce warfighting systems. When Industry is called upon to deliver a warfighting system, it employs an Integrated Product and Process Development approach. Manufacturing, Purchasing, and Integrated Logistics Support personnel are integral in the design of a system. The manufacturing representative provides input on the ability to produce the item and whether or not existing capital infrastructure and tooling exist to produce the design. The purchasing representative concurrently canvasses the marketplace for redundant and highly qualified suppliers. According to the authors of *Designing and Managing the Supply Chain,* "…it is intuitively clear that the characteristic of the supply chain must have an impact on product design…"[55] The integrated logistics support representative assesses the supportability and obsolesce of parts required for the design. All these considerations combined provide an informed cost structure and lifecycle optimized design. Maintaining that level of integrated product and process design is possible for organizations who specialize in system level "rate production."[56] It would be tough for an organization that builds "one-offs", to maintain that type of expertise. According to John Bryant, Senior Vice President for Defense Programs, Oshkosh Defense, transitioning subsystems, much less entire systems, is probably the great exception vice the rule for Army S&T. Bryant asserts there are numerous blind spots, like producibility, quality, supplier base, cost and profit in the S&T enterprise. Transitioning an entire system would be even more difficult. Even if the government were able to provide a production level technology data package (TDP) for industry to bid on, the TDP would probably be entangled with countless intellectually property issues. According to Bryant, especially in the Army ground vehicle portfolio, S&T would best serve as a conduit for informing affordable and achievable requirements. The Future Tactical Truck System (FTTS) is a great example of an RDEC working with industry to push the boundaries of the technologically feasible. The output of the FTTS Advanced Concept Technology Demonstration (ACTD) executed by the TARDEC, was the Initial Capabilities Document (ICD) for the Joint Light Tactical Vehicle Program (JLTV). The TARDEC efforts with industry proved invaluable to codifying achievable requirements.[57] If combined with industry Internal Research and Development (IR&D) dollars, the potential for identifying both evolutionary and revolutionary technology advancements is limitless.

Aligning RDECOM with ASAALT, elevating the command to a three-star headquarters, requiring greater program management training, authorizing PPBE with the ability to move funds among and between RDECs, providing greater flexibility among the engineering skillsets, and focusing on "developing, and demonstrating, technology options that inform and enable effective, and affordable capabilities for the Soldier," rather than technology transition should dramatically increase S&T efficiency and effectiveness. Unfortunately, neither a baseline nor other pertinent metrics exist to measure the efficiency or effectiveness of the current system, much less determine the best construct for the future. It is, therefore, impossible to say whether the recommendation above would definitively enhance Army S&T efficiency and effectiveness. What is certain is that the majority of organizations that do not adapt to a changing environment eventually become an irrelevant dinosaur.[58] It is time for the Army and RDECOM adapt and innovate their organizational structure to align better with the volatile and uncertain future of the 21st Century.

Funding Allocation and Prioritization

The apparatus for funding allocation and prioritization is complex, influenced by numerous stakeholders, and is seemingly contrary to the Army's idea of Mission Command. In the future, we are likely to be "confronted by decentralized, networked, and adaptive threats in complex and dynamic environments and in conditions of uncertainty…"[59] As such, LTG H.R. McMasters writes in the forward of TRADOC Pamphlet 525-3-3 (The U.S. Army Functional Concept for Mission Command, Mission Command Intrinsic to the Army Profession),

> For the future, the full understanding and application of mission command will empower all Army leaders to take disciplined initiative and succeed in three key aspects of future military operations: the contest of wills against determined enemies, the competition in space, cyberspace, and the electromagnetic spectrum, and sustained security cooperation to develop capable partners and mutually-supportive security relationships. In support of this approach, this concept serves as a foundation for future force development of mission command capabilities to support the Army's overarching philosophy of leadership and its warfighting function.[60]

The current hierarchal and laborious construct for S&T funding, prioritization and allocation are the antitheses of mission command. The Mission Command philosophy should not be limited to only the operational force. It becomes obvious when looking at the Army S&T funding documents that management committees, much like Gerstner described, are extremely influential in the ultimate decisions. In addition to the organizational structure and alignment changes, Army S&T must better allocate and prioritize funding if the Army is to be prepared to meet the challenges of the VUCA future.

In the last couple years, the Army's Total Obligation Authority (TOA) has been reduced by approximately 22%, yet the Army's Research and Development (RDA) budget has been cut by approximately 38%. Fortunately, the S&T portion of the RDA budget is deliberately safeguarded.[61] According to Kris Gardner, a senior manager in the Office of the Deputy Assistant Secretary of the Army for Research and Technology, "flat budgets are the new up." The Army S&T portion of the RDA budget, (6.1, 6.2 and 6.3) has hovered around the $2B mark for the last several years and will continue to do so throughout the FY16-20 POM[62]. RDECOM's portion of the S&T budget is averaging $1.8B from 2010 until 2022.[63] Safeguarding the S&T budget; however, will not be enough to ensure the Army is ready in the 2020 to 2023 timeframe when it emerges from the fiscal bathtub as described by Honorable Shyu. The Army must also look at the allocation, distribution, and execution of those S&T dollars to ensure the greatest efficiency and effectiveness of the S&T program. To gain an appreciation for possible benefits of having RDECOM as the a single, responsible agency, with the requisite authority to allocate and prioritize S&T efforts (following the philosophy of Mission Command) one only needs to study the complexity of the S&T funding and execution.

Table 1: RDT&E Budget

REQUEST in billions	FY13	FY14	FY 15	FY16 Base
RDT&E Total	**8.0**	**7.1**	**6.7**	**6.9**
Basic Research (BA1)	0.4	0.4	0.5	0.4
Applied Research (BA2) [S&T: BA1–BA3]	0.9	0.9	1.0	0.9 [$2.2: BA1–BA3]
Advanced Tech Development BA3	1.0	1.0	1.1	0.9
Demonstration / Validation BA4	0.4	0.4	0.3	0.5
Engineering Manufacturing Dev BA5	2.8	1.9	1.6	2.1
Testing & Management (BA6)	1.2	1.3	1.0	1.0
Operational System Development (BA7)	1.3	1.0	1.2	1.1

According to the Office of the DASA R&T, the S&T portion of the FY 2016 Army budget is approximately $2.2B or 1.8% of the Total Obligation Authority (TOA). The FY16 base budget request for Research Development Testing and Evaluation Budget totaled $6.9B as depicted in Table 1.[64] In 2014, the Army S&T enterprise appropriation was similar to the FY16 budget request at $2.4B. However in 2014, the total inflow of dollars to the Army S&T enterprise was approximately $9.43B. Other Army organizations, such as PEOs, provided $4.98B for particular task directed work. Other services, OSD, and other government agencies provided an additional $2.5B for task orders.[65] The assumption is this construct holds true for most years, including 2016, and that it will continue into the future this way. In 2014, more than $7B (72%) of the $9.73B inflow to the S&T enterprise, was executed by external organizations such as industry, academia, and other government agencies. However, the efforts were all managed from a cost, schedule, and performance aspect by an Army lab.[66] The trend of executing most S&T efforts outside Army labs appears to continue for the foreseeable future. As mentioned in the previous section, this calls into question the necessary skillsets in the RDECs. A logical assumption is that both skilled engineers and certified program mangers are required for the most efficient and effective execution of S&T efforts.

Since 2010 and projected through 2022, the distribution of Army S&T dollars has remained relatively evenly distributed across the RDECs (table 2). This even distribution is projected despite the prognosis that the character of warfare and threat conditions will undoubtedly change.

Table 2: RDEC Distribution

	FY	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021	2022
TARDEC		15%	12%	12%	12%	12%	13%	12%	12%	12%	11%	11%	11%	11%
RDECOM HQ		1%	1%	1%	1%	1%	1%	3%	3%	4%	5%	6%	6%	6%
NSRDEC		4%	6%	6%	6%	5%	6%	5%	4%	4%	4%	4%	4%	4%
ECBC		1%	1%	1%	1%	1%	1%	1%	1%	1%	1%	1%	1%	1%
CERDEC		20%	22%	22%	20%	19%	18%	18%	19%	18%	18%	18%	18%	18%
ARL		34%	36%	35%	38%	37%	36%	38%	37%	37%	37%	37%	37%	37%
ARDEC		11%	7%	8%	8%	8%	8%	7%	7%	6%	6%	7%	7%	7%
AMRDEC		15%	16%	17%	16%	16%	17%	16%	16%	17%	17%	16%	17%	17%
TOTAL		100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%

One might question how RDECOM's S&T funding allocation could remain essentially unchanged over 12 years despite the numerous indications of a significantly changing environment, especially relative to Anti-Access / Area Denial (A2AD), Cyber Defense/Attack, and nano-technology. Not only has the distribution between RDECs remained relatively constant, the distribution between S&T activities too is fairly consistent as well, despite the changing environment as depicted in Table 3.

Table 3: RDT&E Distribution

Activity/FY	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021	2022
6.1	20%	19%	20%	20%	20%	22%	21%	21%	22%	22%	22%	22%
6.2	36%	38%	41%	40%	38%	39%	39%	38%	39%	39%	38%	38%
6.3	36%	37%	34%	36%	36%	35%	35%	36%	36%	36%	36%	36%
6.4	4%	2%	0%	1%	1%	1%	0%	0%	0%	0%	0%	0%
6.6	1%	1%	1%	1%	1%	1%	1%	1%	1%	1%	1%	1%
6.7	3%	3%	3%	3%	4%	3%	4%	3%	3%	3%	3%	3%
	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%

It seems inconceivable that with the volatility and uncertainty of the future, the ever-changing character of warfare, the pace of technological growth in varying technology domains, that the allocation and distribution between S&T activities and RDECs needs no adjustment. Again, what comes to mind is what Gerstner and Houghton describe as an enterprise being managed by a bureaucracy, where consensus and status quo are paramount, and the rational actor model of choosing the best alternative is ignored.

Additionally, when analyzing RDA budget from 2011 through 2022, it is also troubling to see how little is allocated to the 6.4 funding line (System Demonstration and Validation). According to Dr. Joseph Lawrence, Distinguished Researcher Fellow at the National Defense University, and former director of S&T transition with the Office of Naval Research as well as an SES within RDECOM, 6.4 funding is the "special ingredient" necessary to advance the 6.3 efforts of Advanced Technology Development. Lawrence posits that without dedicated 6.4 funding there is much wasted effort and opportunity. With the focus on technology transition, 6.3 efforts must be low risk to achieve a sufficient Technology Readiness Level for transition. Advanced Technology Development funding is meant to prove out "viability," whereas System Demonstration and Validation, proves out "value."[67] Without 6.4 funding, Army S&T efforts are "dumbed down" to mitigate the risk of failure and failure to transition.[68] DASA R&T does manage a small pot of 6.4 funding known as Technology Maturate Initiatives (TMI). TMI should be coordinated with program management offices, but informal and off-the-record conversations with several GS15 level program management and S&T managers indicate that the depth of coordination between S&T funded TMI (6.4) initiatives and program manager funded 6.4 Advanced Component Development and Prototypes is, for the most part, no more than "power point chart deep."

Not only is additional 6.4 funding required to advance S&T, but it is also crucial to have greater flexibility to move funding among and between RDECs. MG (R) Nadeau, and Dr. Lawrence, articulate that the inability of the RDECOM commander to redistribute and prioritize Army S&T funding among and between RDECs is a major impediment to efficient and effective S&T.[69] [70] The Chairman of the House Armed

Services Committee is echoing this sentiment. He plans to include language in the 2017 National Defense Authorization Act that would allow the services greater S&T funding flexibility. During a recent interview, the Chairman indicated, "…the services would be allowed to use flexible funding, to in theory, buy and field prototype components faster and more efficiently."[71]

RDECOM/DASA R&T must begin to act like a rational actor and choose the best amongst alternatives, versus the lowest common denominator in funding allocation and prioritization. Elevating RDECOM to a three star or SES equivalent position, with funding allocation, prioritization, and execution authority/responsibility, and most importantly the ability to move funds among and between the RDECs, would greatly enhance the effectiveness of the S&T program. This move would empower the commander to execute Army S&T following the Mission Command philosophy.

Metrics

With organizational structure and funding allocation addressed, metrics is the third area of the punctuated equilibrium trinity that must be addressed to better position Army S&T for the complexity and uncertainty of the 21st Century. It is said, "What's measured improves."[72] But, what metrics does Army S&T have? Are they useful? Are they the correct? If the measurements are not relevant or have no defined purpose, are not weighted by importance and cannot be aggregated, then the measurements are simply more in a long list of bureaucratic data collections. For metrics to be useful, they should help decision makers make decisions, not collected for collection's sake.

In 2015, the Under Secretary of Defense for Acquisition Logistics and Technology released Better Buying Power 3.0 (BBP 3.0), the third installment of guidance to the Services to be used in increasing both efficiency and effectiveness of the DOD's acquisition community. BBP 3.0 addresses the lack of S&T effectiveness measurement processes. BBP 3.0 mandated that by January 2016, the Services must:

- Develop customer assessment surveys to address the strengths and weakness of all DoD laboratories,
- Develop "should cost" targets,
- Develop transition metrics to track trends in laboratory productivity,
- Reduce duplication between laboratories,
- Measure investment changes from year to year,
- Benchmark laboratory performance against other government, commercial and academic laboratories.[73]

As of the time of this writing, the results of the BBP mandate were not readily available. Suffice it to say, measurement of effectiveness and the ability to understand whether the S&T efforts are yielding the appropriate and timely technology to counter our adversaries advances is crucial if the Army is to be prepared to meet the technological challenges of the 21st century.

The U.S. Army Science and Technology Handbook describes numerous metrics for assessing the health and effectiveness of the S&T program. The metrics outlined in the handbook are a positive first step. With the USD AT&L mandate to provide regular reporting, there is a good chance the metrics will be maintained and forwarded. The metrics describe in the S&T handbook are:

> Investment Priorities. Measuring investment priorities are tightly coupled to process. S&T Investment priorities are set and monitored by the senior S&T governance body, the ASTAG. So long as those functions continue and all actions implemented, S&T investments will remain aligned to Army priorities.

Quality of Research. Quality of the research takes into account both the work being conducted and the workforce conducting the work. A highly qualified workforce is a major contributor to quality research efforts.

Leveraging External Organizations. In today's global environment where resources are limited, and advances in technology are not limited to a small segment of the population, it is important that we collaborate with partners toward common goals and look outside the Army S&T Enterprise to DoD, industry, academia, and international opportunities to ensure the Army provides the best to its Soldiers.

Transition of S&T Products. Transitions are more than inserting a technology into an acquisition program of record. It includes but is not limited to, achieving the goals of a particular research effort even though there is no immediate opportunity for its use (on the shelf), providing knowledge or expertise to solve Army problems or development of a standard of the specification that industry can use.

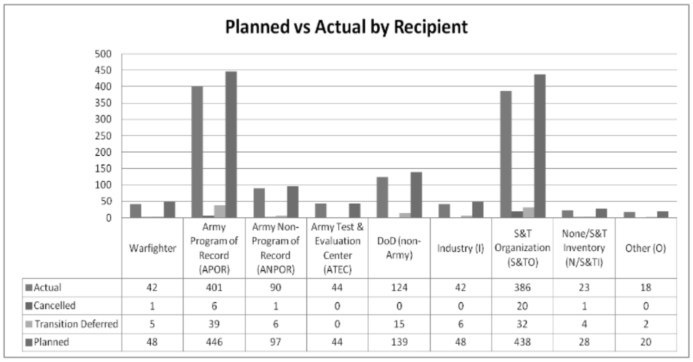
Each of these measurements are benchmarked and have a relative scale of success or failure. Table 4 summarizes the benchmarks and scales.

Table 4: S&T Metrics

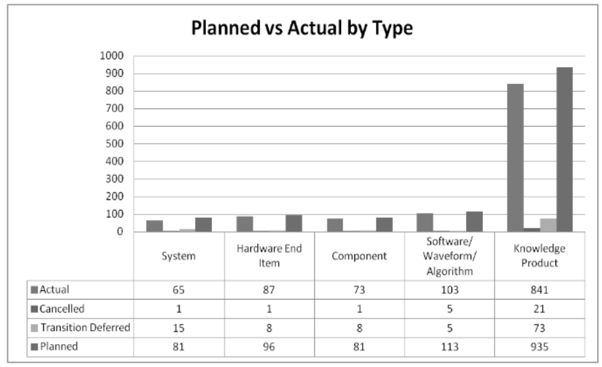
Investment Priorities					
	Benchmark	Green (Satisfactory)	Yellow (Concern)	Red (Critical)	
Alignment to Senior Leader Guidance and Action Items	None	>95% of all guidance implemented within 90 Days	95% - 85%	<85%	
Quality of Research (Track workforce professional acknowledgments)					
	Benchmark	Green (Satisfactory)	Yellow (Concern)	Red (Critical)	
Refereed Papers	Prior Year	>90%	70%-90%	<70%	
External Honors	Prior Year	>90%	70%-90%	<70%	
Patent awards	Prior Year	>90%	70%-90%	<70%	
Quality of Research (Assess research programs using focus areas)					
		Green (Satisfactory)	Yellow (Concern)	Red (Critical)	
External Reviews	25% portfolios reviewed externally	All three factors met	Two factors met	0 or 1 factor met	
Quality of Review Panel	75% review panel membership recognized as an expert in field				
Implementation of panel recommendations	75% of recommendations w/in 180 days				

Leveraging External Organizations Metrics (CRADS, Co-funded programs, MOAs with PEOs, other Services, Agencies, academia and industry)					
	Benchmark	Green (Satisfactory)	Yellow (Concern)	Red (Critical)	
External Metrics	Prior Year	>90% 3 year average	70% - 90%	<70% 3 year avg	
Foreign Technology Assessment SPT	Prior Year	>80% FTAS meeting goals achieve transition	60%-80%	<60%	
Product Transition Metrics					
	Benchmark	Green (Satisfactory)	Yellow (Concern)	Red (Critical)	
Transition technology	Annual Plan	>80% of planned transitions	60%-80%	<60%	

Although the metrics described in the draft S&T handbook, appear to be a step in the right direction, they are not yet widely distributed. According to an SES in RDECOM, as of the time of this writing, the only metric they are aware of and regularly collecting are annual transitions.[74] What is unclear from the prescribed metrics is the nature of the analytical work that went into determining the metrics and establishing the benchmarks. An example of a collected metric is that of "transitions." In FY14 RDECOM executed 1170 technology transitions out of a planned 1308 for an 89.4% transition rate. However, the vast majority of technology transfer were in what are characterized as "knowledge products." (Figure 1) According to the scale above this metric would be rated "satisfactory." An obvious question would be how does this metric assist a decision-making body. If the data were higher or lower would the decisions the ASTG make be different? Would the recommendations from the councils be different – sustain or suspend an S&T effort? How valuable were the knowledge products – who used them – did they ask for them – what decisions did they inform?



	Warfighter	Army Program of Record (APOR)	Army Non-Program of Record (ANPOR)	Army Test & Evaluation Center (ATEC)	DoD (non-Army)	Industry (I)	S&T Organization (S&TO)	None/S&T Inventory (N/S&TI)	Other (O)
Actual	42	401	90	44	124	42	386	23	18
Cancelled	1	6	1	0	0	0	20	1	0
Transition Deferred	5	39	6	0	15	6	32	4	2
Planned	48	446	97	44	139	48	438	28	20



	System	Hardware End Item	Component	Software/ Waveform/ Algorithm	Knowledge Product
Actual	65	87	73	103	841
Cancelled	1	1	1	5	21
Transition Deferred	15	8	8	5	73
Planned	81	96	81	113	935

Figure 1: RDECOM FY14 Transitions

Dr. Lawrence offered several other potential metrics that should be considered for collection:

- # of ACTD/JCTDs per year
- Ratio of in-house research versus out-sourced
- Annual transitions “accepted” by a sponsor, not just “sent”
- Growing S&T workforce: number of new hires from industry/academia
- # of S&T efforts to achieve TRL 7

Given the metrics described in the paragraphs above, the underlying question is still relevant – are the metrics and data useful in guiding senior leader decision making? In 2014, an article titled “Calculating Return on Investment for U.S. Department of Defense Modeling and Simulation[1]” authored by Dr. Tim Cooley, et al., earned first place in the Defense Acquisition University Association Research Paper Competition. The article provides substantial evidence that it is possible to develop quantitative measurements to assess the effectiveness or return from minimally tangible efforts (such as modeling and simulation or S&T) for various purposes. Determining S&T return on investment (ROI) appears to be possible using the quantitative methods described in the article.[75]

The authors state that it is imperative to "define and assess rigorous measures of merit and metrics that reflect the results of M&S across the relevant spectra of management, mission, and system." Before writing their article, defining measures of merit and metrics in M&S seemed to be as elusive as they are for S&T. They acknowledged that:

> Most M&S value assessments use metrics that are uneven in scope, very case-specific, do not allow consistent aggregation, or are not well structured. Additionally, some measures that are used, like ROI, are actually incorrectly defined; others, however, are undefined, thus making the assertions of value at best vague, and at worst incorrect. Finally, all too often important distinctions are not made between and among terms critical to consistent ROI assessment, such as metrics, measure, scale, quantity, quality, cost, utility, and value.[76]

The description of M&S metrics appears identical to that of S&T measures.

The fundamental purpose of metrics collection is to gather data for decision support. In the case of S&T and the metrics described earlier, it is not clear what decisions will be made once the data is collected. Will the collected data help inform the decision-makers who will decide what new effort will be funded next year? Will the metrics assist in determining which technology effort to sustain, delay, or end? Will the metrics give insight into the productivity of a laboratory, importance of the new technology, or the breadth and significance of the impact of the technology?

Although it would be impossible to develop true return on investment (ROI) calculation for Army S&T because the return is typically not in the same currency as the investment, (example – dollars invested to lives saved, or improved readiness), it is possible to develop an "ROI-like" set of metrics which will assist S&T decision makers. According to Dr. Tim Cooley, the first imperative to developing metrics is to determine what the metrics will inform, followed by ensuring the metrics can be aggregated, then assigning a relative weight to the metrics. Those metrics can feed what Dr. Cooley describes as a Multi-Attribute Decision Making (MADM) quantitative assessment. MADM can be used to evaluate the weighted and assessed metrics and "once established, can be executed fairly simply, and has the qualities of being robust, relatively explainable, objective, and consistent."[77]

Once the purpose for metrics has been determined, as noted above, relative weights, which help with directionality and magnitude, must be developed to produce an ROI-like characterization.[78] For example, should alignment to senior leader priorities carry the same weight as the number of refereed papers? Perhaps the estimated cost of the project, and technology readiness level should be heavily weighted metrics. What about alignment to current threat predictions? When considering the question of what is going to be evaluated (new investment, existing investment, quality of laboratory or research personnel), many of the same metrics might be used; however, they would probably be weighed differently. In the case of new investments, alignment with senior leader guidance might be weighted three times more valuable than refereed papers. The levels of the weighting would be situationally and purpose dependent, so that, for the quality of a lab and the resident research personnel, a refereed paper might be weighted two times that of senior leader guidance.[79]

The Army S&T community would be well served by commissioning a study to assess the metrics used in S&T valuation much like the authors of *'Calculating ROI'* did for the M&S community. For something as amorphous (from a deliverable point of view) as S&T, having metrics that can depict the increase in the effectiveness of S&T investments would allow for comparison of competing investments, evaluation of benefits, and application of the knowledge in a decision support tool. Determining value added S&T metrics would be money well spent.[80]

Summary

The time is now for introspection. The Army S&T enterprise must adapt to the VUCA environment. It must innovate its own business model before it can be expected to optimize resources and provide cutting edge, overmatch capability. Much like Congress, which is currently holding hearings on the organization effectiveness of the Department of Defense, the Research and Development Command must determine if its current structure, execution methodology, funding, and metrics construct are optimized to yield the most efficient and effective science and technology efforts possible. It is time for punctuated equilibrium! Several possibilities for punctuated equilibrium are available:

- Align RDECOM with ASAALT and elevate to a three-star organization.
- Give RDECOM PPBE authority and allow the command to move funding between and among the RDECs.
- Focus less on technology transition, and more on proving the value of technology through prototyping and requirements validation. This will require additional 6.4 funding.
- Review the organizational structure of the RDECs. Determine a methodology for greater engineering resource sharing between RDECs to counter the rapid and globally connected technology advancements.
- Review the requirement for program management certification.

- Review the methodology for distribution and allocation of funds with a rational actor model mindset.
- Develop metrics which can be used to help decision-makers make decisions. Define the purpose and weight of metrics, and implement a multi-directional decision-making assessment tool.

Implementing these suggestions should enable Army S&T to continue to be an extremely effective contributor to Army modernization and readiness well into the 21st Century.

Epilogue: AMC and HASC Actions

On 17 February 2016, three weeks before the final draft of this paper, the Army Materiel Command decided it was, in fact, time for punctuated equilibrium and released an operations order which significantly altered the organizational construct of RDECOM. However, the direction of change is completely contrary to recommendations provided in this paper. AMC directed that three primary RDECs would transition from RDECOM Operational Control (OPCON) and would instead have OPCON provided by their functionally aligned two-star level Lifecycle Management Command (LCMC). TARDEC is now OPCON to TACOM LCMC (formerly known as the Tank-automotive and Armaments Command), CRDEC is now OPCON to the U.S. Army Communications-Electronics Command (CECOM), and AMRDEC is now OPCON to the U.S. Army Aviation and Missile Command (AMCOM). In an era of trying to increase cross-domain synergy, this move seems to further diffuse the already diluted synergy within RDECOM.[81]

On 15 March 2016, two days before submission of this paper, Chairman Thornbery of the House Armed Services Committee released draft legislation of the Acquisition Agility Act (AAA) for 2017 which included several recommendations also articulated in this paper. Most notably section II of the bill would "further facilitate incremental improvements to weapon systems by providing the military services with new flexibility to experiment with, prototype, and rapidly deploy components."[82] The AAA cover memo states:

> The legislation would authorize and the committee expects the military services to budget some advanced component prototyping funds [6.4] in capability portfolios outside of specific projects or programs of record. The bill would require officials with expertise in warfighter requirements; research and development; and acquisition to establish a strategic plan for prototyping, as well as recommend specific prototypes projects during the year of execution. These official would also provide appropriate governance over the flexible authorities contained in the legislation.[83]

Endnotes

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