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Understanding the Valleys of Death

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Abstract

The Department of Defense (DoD) is falling behind in delivering capability at the speed of relevance. One way to accelerate capability delivery is to leverage industry and early research technologies and transition them to a program of record, cutting down on the time to deliver the capability. This also allows for small businesses, academics, researchers, and many others to support the warfighter in tangible, meaningful ways who otherwise would be apprehensive with horror stories of getting involved in DoD acquisition. To date, the focus on what has become known as the "valley of death," the gap between promising technology and transitioning it to a program of record, has been on government's unwillingness to accept new technology or "bureaucracy." What are rarely discussed are the influences of the Planning, Programming, Budgeting, and Execution (PPBE) process, the ill-defined requirements and interfaces for the new technology, or other factors that need to be better understood and highlighted so industry, academics, and researchers can better partner with willing entities to solve warfighting problems. This paper discusses those obstacles and challenges and makes recommendations to avoid the pitfalls.

Introduction

The Department of Defense (DoD) acquisition process is a monolith of complexity, intricacies, and enigmas wherein the output are products and services that support current or future service or joint weapon and support systems. The acquisition process starts with a capability gap being identified and validated through an evaluation process, and—if a material solution is deemed necessary—early development begins. During the early development phase, key technology aspects are identified and monitored for progress and planned for insertion into the program at the appropriate time. The process of assessing the level of maturing a particular technology is done through Technology Readiness Levels (TRLs; AcqNotes, n.d.-b). The purpose of TRLs is to measure the maturity of technology components for a system. The measurement allows project personnel an understanding of how much development a certain technology needs before being utilized. TRL is based on a scale from 1 to 9, with 9 being the most mature technology and 1 being basic principles observed and reported. The use of TRLs enables consistent, uniform discussions of technical maturity across different types of technologies.

The Technology and Risk Reduction (TMRR) phase is the dedicated phase for new technologies to be matured so they can be inserted into the allocated baseline of the program, thus reducing risk to the program (AcqNotes, n.d.-c). Previous iterations of the acquisition process had a System Design and Development (SDD) phase wherein it was assumed the technology would mature and be integrated into the weapon system baseline without a dedicated focus to mature the technology. The recognition of the risks associated with technology development and maturation, and specific action to track and measure it during the acquisition process, were positive and necessary adjustments. The DoD is developing and advancing the state of the art in technology with significant investment of

resources, and more assurances are necessary. In addition to new program development, new technologies could be identified or proposed to address a need during the Production and Deployment (P&D) or Operation and Support (O&S) phases of an existing program. The general process remains the same wherein technology is identified, matured to a viable state, and then transitioned to a program of record (POR). These technologies may be in the form of computational advancements and specific algorithms, new material or coatings, advanced processing systems, communication systems, or any other myriad of advancements. Regardless of the technology, they all start at some early stage of concept and mature to a point of graduation where they are viable solutions for production systems.

As weapon systems become more complex and technologies are sought to fulfill emerging needs, DoD systems are becoming more complex and taking significantly more time to develop, field, and maintain (Greenwalt & Pat, 2021, pp. 21–22). These weapons and support systems, whether new developmental programs or fielded systems, rely heavily on technology maturation and integration to meet performance goals. Technology is both an opportunity and a liability. Technology insertion may come from large defense contractors or through Small Business Innovative Research (SBIR) proposals. One the challenges with integrating technology in the DoD ecosystem is the belief that the DoD doesn't want to or can't leverage advanced technologies in a broad sense. The so-called valley of death has been coined to explain how promising technologies are identified and desired but something in the ecosystem prevents them from transitioning to a POR (Landreth, 2022). Much of the ire for this valley of death is aimed at either the belief that the DoD is unwilling to engage with industry on new technologies or the belief that the acquisition process is too inflexible with respect to its ability to fund and adapt or transition new technologies. While there is some truth to both of these challenges in certain areas, it is important to understand there are a number of other of ways this valley of death can manifest and result in new technologies not transitioning to PORs. For the purpose of this discussion, the term *valley of death* will exclude those technologies planned for during the development of new programs and instead focus on the challenges of defining, developing, maturing, and transitioning technologies during the P&D and O&S life cycle phases. The focus of this research is to highlight additional areas to be considered when discussing the so-called valley of death and not solely blame a complex acquisition process with a number of checks and balances.

DoD Acquisition Process

The DoD acquisition process starts and ends with the warfighter. Operational personnel receive products and services, and once the battlespace changes, they generate operational needs statements to fulfill the newly identified gap. The full acquisition process for a major defense system is shown below, and is commonly referred to as the "wall chart" or "horse blanket chart" (Figure 1). The chart outlines the major steps and milestones a program progresses through as it matures. Each milestone is either an assessment or system maturity or formal review with required acquisition documents signed by the respective executive agents to confirm that all technical and program reporting requirements are met and on track. Anything that jeopardizes program development timelines is carefully monitored and dealt with; programs are cancelled, and careers go "off-track" if the program does not progress as intended. Within the acquisition process, a program will need to resource to its current and future needs. These resources may be in the form of personnel with specific skill sets or funding streams to "pay the bills" with the right appropriation of funding. The major appropriation categories are Research, Development, Test and Evaluation (RDT&E), Procurement, Operations and Maintenance (O&M), Military Personnel (MILPERS), and Military Construction (MILCON). Each category has subcategories for more specialized uses, and each appropriation has a specific, lawful use. For example, the Procurement appropriation is used to fund the purchase of aircraft, ships, and so on, and

cannot be used to fund, say, depot maintenance activities. Additionally, using O&M funding for research and development of analytical infrastructure projects would also be a misappropriation of funds. The program must carefully plan the development of their weapon system with the right phasing of personnel and appropriation funds to execute and stay on track (AcqNotes, n.d.-a). Technology insertion and development is usually funded with RDT&E funds, which are more abundant in a programs' early development phases, and significantly reduced in the P&D and O&S phases. This is one of the common arguments in valley of death discussions where the case is argued that more RDT&E funding would allow new technologies to be transitioned to PORs. While this is true in theory, in practice we can look at other areas of challenges for adoption of new technologies.

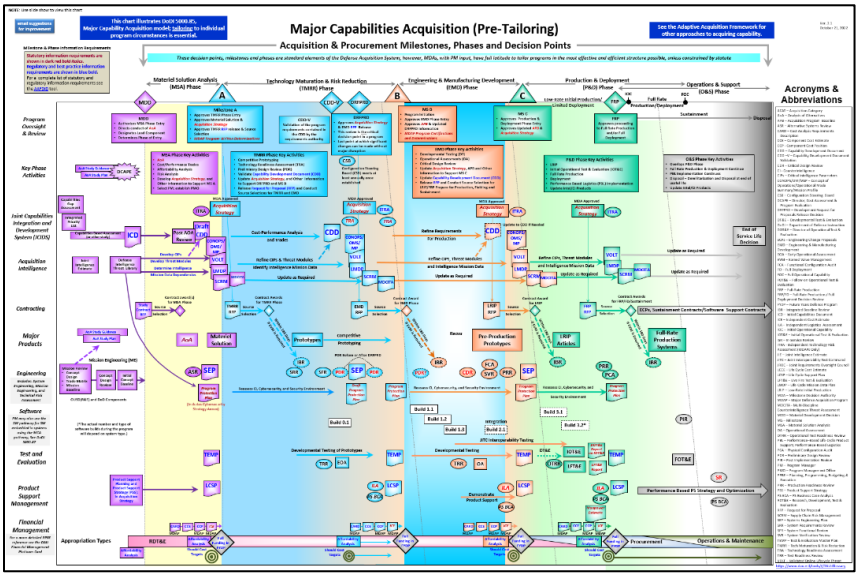

Figure 1: Major Defense Acquisition Process

Understanding PPBE

"The Planning, Programming, Budgeting, and Execution (PPBE) process is the Department of Defense (DoD) internal methodology used to allocate resources to provide capabilities deemed necessary to accomplish the Department's missions" (Defense Acquisition University [DAU], 2023). Planning in this process is less about general planning as any civilian may understand it, and more about alignment of defense to the National Security Strategy (NSS). Planning in this process is about "Big P" planning, as opposed to the act of "planning" an activity, wherein national interests are identified, the president sets priorities, and the DoD establishes a plan to meet those objectives via the National Defense Strategy (NDS). Programming is about the allocation of resources within the DoD to accomplish those goals. Here, programming is identified as both which programs (weapon systems) will satisfy the objectives as well as the forces, funding, and manpower to meet those objectives. Budgeting is led by the Under Secretary of Defense (USD) Comptroller and is where the budget is determined, across all appropriations on what will be funded and to what level. For RDT&E, some line items may be more descriptive than others, where a specific research effort is funded or, alternatively, research in a general area is funded. Lastly, the Execution phase is where programs and organizations receive their funding and execute in accordance with the appropriate and designated use. The PPBE process is a single process but with overlapping cycles and steps that span multiple years (Figure 2; Congressional Research Service, 2022c). In a given year of execution, a program must

contend with their execution year budget, planning year aspirations and requirements via the Program Objective Memorandum (POM), and programming and budgeting for years on the immediate horizon. For example, in the current Fiscal Year (FY) 2019, programs are submitting requirements for the POM2021 cycle for FY2022–2026 across all appropriations.

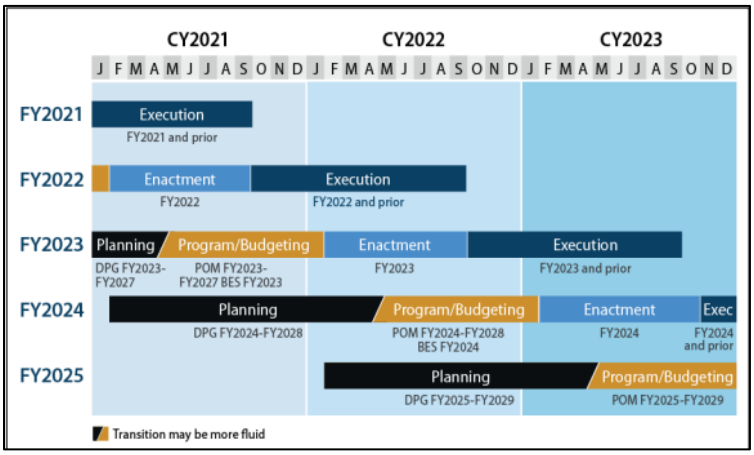

Figure 2: PPBE Process

This can be a difficult task to coordinate and align with known products and services for near term more well understood and defined compared to future year assumptions or unknowns requiring detailed planning to ensure all requirements are captured and phased appropriately. All programs follow this process and timeline; therefore, there is an incredible amount of planning, scoping, refining, defending, and evaluating of budget submittals against priorities and, ultimately, in context of what the nation can afford. Once a budget is finalized, it can be difficult to impossible to gain or move (i.e., reprogram) funding from one appropriation or "color of money" to another for emergent needs or new technologies. The unmalleable nature in reprogramming funding is a valley of death that is discussed at length because it is seen solely as an impediment for technology development, maturation, and insertion. While those arguments are valid, it also highlights a need for better awareness and socialization of needs, opportunities, and maturation timelines to fully take advantage of these circumstances. One of the main reasons for this is the intricate way the allocations and budgeting fit together to balance the entire defense portfolio, based on review and validation of capability gaps, material and nonmaterial solutions, new program starts, along with retiring older systems and other modernization efforts. While it is monolithic in nature, there is an argument to be made that this is more of a feature than a bug.

If the process were easy to manipulate and move funding about, the planning and review of requirements would mean less and less. A clear vision and strategy are required to fully leverage new technologies and the opportunities they provide, because without one it's always easy to blame the process. The associated checks and balances of the PPBE process are also its strengths and weaknesses. In the 2022 National Defense Authorization Act (NDAA), an independent commission was established called the "Commission on Planning, Programming, Budgeting, and Execution Reform." This commission is comprised of civilian employees not employed by the federal government who are skilled in data analysis and are recognized experts in PPBE within the DoD and in innovative budgeting and resource allocation methods in the private sector. The purpose of the commission is to (1) examine the effectiveness of the PPBE process and adjacent practices of the DoD, particularly with respect to facilitating defense modernization; (2) consider potential alternatives to the process and practices to maximize the ability of the DoD to respond in a

timely manner to current and future threats; and (3) make legislative and policy recommendations to the process and practices in order to field the operational capabilities necessary to outpace near-peer competitors, provide data and analytical insight, and support an integrated budget that is aligned with strategic defense objectives (Commission on PPBE Reform, n.d.). While the commission's scope was broader than speeding up technology insertion and innovation adoption in the DoD, within that broader scope it is accurate to note that the PPBE process is recognized as a large, slow-moving, difficult-to-align process that was established in 1961 by then Secretary of Defense McNamara as a framework for linking strategic objectives with resources (Congressional Research Service, 2022a). In 1961, the budgets were smaller, and there were fewer programs. Six decades on, the world is a much more complex environment, and the commission seeks an innovative approach for what truly can be called a "wicked problem."

Along with the PPBE process, other common examples of the valley of death in technology transition are the "bureaucracy" of the DoD system and the belief that the DoD is averse to accepting new technologies or innovation. Part of the bureaucratic argument is discussed above with the PPBE process, and the appearance of rigid rules and process, but additional issues emerge, from the hierarchical nature of the organizations and in a mismatch of skill sets and personnel. There is a common belief that bureaucracy will take charge of the process, stifle progress, and prevent the necessary agility of, say, a startup or an organization that needs to move quickly (RAND Corporation, 2019). There is no shortage of seemingly overburdensome rules, requirements, processes, and procedures in any government organization. An alternative view may be that these perceived impediments are the rigor required for the DoD's weapons systems given they are intended to protect national interests, carry and support the warfighter, and are built at the taxpayer expense. Or, as no less an authority than the Dalai Lama has stated, "Learn the rules so you know how to break them properly." Two primary challenges occur in these situations. The first is someone may become frustrated with a process that is not fully understood and end up quitting, trying to transition a technology, or working with a particular partner. The second primary perspective is that the process is cumbersome and has the appearance of an unwavering clutching to procedures that, at least on the surface, offers no value to the customer or provider. We must simply follow the process thus extending the timeline to transition. In both cases, funding becomes at risk, or the capability need changes and the DoD falls further behind even having expended resources in the process. The position that "DoD has a problem with innovation and technology" has been discussed at length. The perspectives and conversations tend to follow the viewpoint and experience endured, and reality may or may not be consistent with those experiences. One such summary offered some perspective and experience of where root causes may reside (Johnson, 2023).

More to the Story

As previously discussed, the DoD acquisition process, the lengthy PPBE process, and the belief of how accepting to new technologies are challenges to crossing the so-called valley of death. Also discussed were counterpoints and highlights of alternative perspectives on why those may be real or perceived. However, seldom are other areas discussed as to why more technologies and innovations are not being realized across the DoD. Some of these additional topics include the basic premise of technology TRL and how it is being applied, specific funding for the technology level, identifying a transition partner, and the acquisition workforce understanding of the technology and the warfighter requirements. These are what we'll define as "additional valleys of death" for a more complete picture of the landscape of the myriad of functions, assumptions, and dependencies required to successfully transition technology to the warfighter.

RDT&E Appropriations

Within each appropriation, Procurement, MILPERS, O&M, and so on, there are separate accounts or subaccounts specifying which funding can be used for which activities, and RDT&E is no different. Within RDT&E, there are eight budget activity (BA) codes with specific purposes (Congressional Research Service, 2022b). The BA codes span from 6.1 for Basic Research, 6.2 for Applied Research, 6.3 for Advanced Technology Development, 6.4 for Advanced Component Development and Protypes, 6.5 for System Development and Demonstration, 6.6 for RDT&E Management Support, 6.7 for Operational System Development, and a new category in the 2022 NDAA, 6.8 for Software and Digital Technology Pilot Programs. At a glance, the BA codes mirror the TRLs based on technology maturity and using those specific funds for efforts to mature the technology—for example, using 6.1 funding for TRL 1 or 2, 6.2 funding for TRL 2–3, and 6.5 funding for more mature technologies in the TRL 6–9 range. While we don't always know what technology will be needed tomorrow, the science and technology (S&T) and research and development communities are typically funded with 6.1 and 6.2 funding to ensure emergent technologies are monitored and initial evaluation is conducted. In recent years, these could be in the areas of hypersonic weapons or intelligent systems. The DoD doesn't always know the "what" but tends to understand there will be something new on the horizon that requires investigation and research. The challenge then becomes three-fold. First, what if the basic and applied research takes longer, and additional resources are consumed? Second, what if a technology simply doesn't mature or pan out as expected? Third, what if a maturing technology progresses faster and resources need to be reallocated to continue development? If any of these cases occur, the particular department, the Navy for example, may have to request a reprogramming action in accordance with the DoD financial management regulations (Under Secretary of Defense [Comptroller], 2021). In some of these cases, a formal presentation or letter must be sent to Congress and other agencies for approval, which further prevents possible available resources from being reallocated to other S&T efforts in a timely fashion. Detractors will say this is a major hindrance, while others will say it is a structured process that prevents fraud and offers stability until a definitive event has occurred. A deep technical understanding, coupled with an understanding of risk management and risk tolerance, are inherent when deciding to continue to advance the technology or when the projected path is unlikely to bear fruit. So, just as metrics are in place to measure the efficacy of the acquisition process, so too must there be metrics associated with the enabling processes, such as those which fund S&T efforts.

Sourcing Solutions

Taking advantage of cutting-edge technologies only makes sense when there is a logical program to transition it to fulfill a defined capability gap. Newer, more innovative solutions and technologies supporting programs in the P&D and O&S phases tend to come from small businesses. The Small Business Innovative Research (SBIR) and Small Business Technology Transfer (STTR) programs are highly competitive programs that encourage domestic small businesses to engage in federal research/research and development (R/R&D) with the potential for commercialization (SBIR-STTR, n.d.). Through a competitive awards-based program, SBIR and STTR enable small businesses to explore their technological potential and provide the incentive to profit from its commercialization. Companies are given a small award for a Phase 1 effort, and larger for Phase 2 and beyond. This is seen as a win-win scenario, as the DoD gains fruitful capability and inserts where needed, and the small business stimulates their company economically. A summary of the SBIR health by year is shown below (Figure 3).

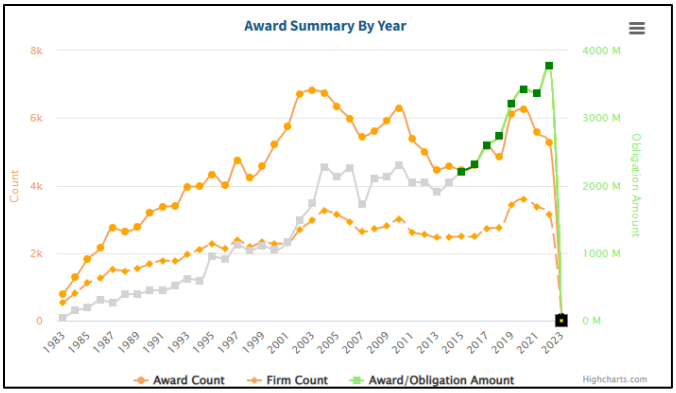

Figure 3: SBIR Awards by Year

SBIR data show an interesting trend in contract awards increasing into the early 2000s but then a cyclic pattern for the last 20 years. Over this same time, the total obligations and investments have increased. This may be one of the reasons why the valley of death appears to be discussed more in recent years. But why? In looking at the data, only 30% of the efforts make it to Phase 2 historically, and 38% in the last 4 years. That seems incredibly low given Phase 1 efforts are "to establish technical merit, feasibility, and commercial potential for the technology" and last anywhere from 5 to 12 months. There are a number of possible reasons for this, including the small business not fully understanding the solution space or the government not understanding the level of knowledge from the company and principal investigators. Another anecdotal belief is the motivations or the parties involved and if volume is the metric instead of progress. A thorough analysis of the data across a number of factors may provide insight to that belief. These are some possible reasons for the low conversation rate but are important factors when discussing the valley of death.

Technology Maturity

TRLs offer guidance on how the DoD defines the readiness or maturity of a particular technology, for both PORs and the S&T community. These establish standards, goals, and guidelines for the government to impartially test and validate assertions, as well as for partners to strive to and build out a development plan. Some technologies require significant investment and are truly game-changing (i.e., hypersonics, artificial intelligence [AI], etc.) and require multiyear investments to mature the technology, applications, and form factors. This is a challenge with any technology maturation effort and can vary from technology to technology, as some areas of research and applications are more mature or well-established than others. Another consideration is the technology in an operationally relevant environment. Informal surveys and anecdotal experiences from within the government yield a general impression from companies approaching PORs directly, which is usually "good idea, but not mature enough." This has led to the integration of S&T professionals in a number of PORs, as well as at the warfare centers, to guide and assist industry to interpret the level of maturity needed and work a transition strategy and identify potential POR partners. The warfare centers are comprised of research, S&T, and acquisition professionals that develop, integrate, test, and field technologies and capabilities for the warfighter. These warfare centers are usually the entry point for SBIRs and STTRs, and are considered the experts in the current state-of-the-art for a given domain and application of technology. PORs also have the option to reach out to an industry partner directly, but with some risk if they don't have extensive knowledge of the technology landscape and solution space. While TRLs offer guidance as to how to measure the readiness or maturity of the technology, it

does not explicitly state the assumptions or specific criteria for some applications. Expert knowledge and experience play a role in defining technology maturity. For example, a commercial-off-the-shelf (COTS) product may state the product has been fielded in its final form under mission conditions and has been successful (TRL 9); however, the use case was less rigorous than other customer needs and environments and, therefore, can be assessed as the basic components are integrated reasonably well, but a prototype is needed in that environment (TRL 4–5). If this circumstance arises, the impression is that the DoD is unwilling to work with the partner and is imposing additional regulations, rather than a more detailed understanding of what an operational environment means to the DoD customer. Another example may be in the data analytics and AI realm. The public are consumers of AI every day, whether they know it or not. From applications to weather predictions, route recommendations, or purchase patterns, AI is integrated into the commercial space in a number of applications. In the 2019 *Department of Defense Posture for Artificial Intelligence* report, the RAND Corporation (2019) found that "the current state of AI verification, validation, test and evaluation (VVT&E) is nowhere close to ensuring the performance and safety of AI applications," and that while "this is not a problem unique to the DoD, it is one that significantly affects DoD." AI in one application is fielded and being used today (TRL 9), but with the DoD and poor data quality measures and handling and preparation for AI, the TRL is much more immature. Data are a unique case as well, but there is a systems-of-systems approach to how it is moved, curated, stored, access, handled, and used that can affect its readiness for use in a wide range of applications. Without understating the full value chain, environment, applications, and desired end-state, technology readiness may be a valley of death even with defined guidance.

Transition Partner

Another challenge for industry and academics is the knowledge of a suitable DoD organization and customer for the technology. The technology may be mature or in its infancy, but there is a lack of knowledge of who to speak with, the idea remains in a state of potential and doesn't migrate to kinetic. For engagement on technology transition partners, a company should consider one of the many DoD S&T organizations in addition to specific PORs (DAU, n.d.). For example, the Office of Naval Research (ONR) coordinates and sponsors scientific research and technology development for the U.S. Navy and Marine Corps through partnerships with academia, industry, and government (Office of Naval Research, n.d.-a). In the case of ONR, their mission areas are defined by a specific focus to help facilitate which group may be best suited for willing partners to engage. The belief that researches or S&T within the Navy is cumbersome or confusing is assisted with clear delineations of focus areas to enhance success. ONR also defines funding opportunities to accelerate integration and maturation of technologies. While these measures are helpful, it is important to review the specific details and translate what is being portrayed. For example, some groups may have a "research division" and an "applications division." These are important nuances, as the BA codes for funding will align more accurately to the work being proposed or sought. Not knowing the differences or the implications on funding or demand signal may give the impression the DoD is unwilling to work with partners or has the ability to work with partners, and therefore resulting in a valley of death experience.

Workforce Understanding of the Problem and Needs

Within any organization, there are different groups and teams supporting various functions, from business development, contracting, finance, life cycle management, product development, engineering, testing, and more. The DoD is no different with its diverse set of skills and perspectives to design, test, build, certify, and support complex weapons systems. The DoD S&T community is comprised of warfare centers, research labs, and collaboration

with industry and academia. Researchers and S&T professionals invest an inordinate amount of time and years researching, developing, analyzing, and testing theories, applications, and solutions to address needs of the warfighter via capability gap assessments and innovative solutions. It is generally agreed that those closest to the area of focus may be both the most informed on a topic, but also the most biased. A researcher may be so focused on an area of expertise and sees it as ground-breaking but not know how it directly applies to a warfighter need. In these cases, someone may be motivated to see that solution or area of application be transitioned and implemented. Additionally, the individual may have zeal for a technology, which may blind them to its proper use or shortcomings, the technology maturity for the given application, or its readiness for employment given a full picture of needs and considerations. Conversely, you may have someone who spent 20 to 30 years in the military or working in the space for years and knows the challenges, but also may not know why they are manifesting, or have a predetermined solution in mind but without knowledge in the full array of options or considerations to implement the change needed. In both cases, there exists a misalignment of needs and solutions.

There are a number of ways these gaps are being addressed. First, services are leveraging their respective reserve component personnel to "translate" between operational warfighting and S&T disciplines. Two examples are the ONR Reserve Component (RC) and the Air Force Reserves (Office of Naval Research, n.d.-b; U.S. Air Force, 2023). In both cases, the service is leveraging personnel with advanced degrees in S&T and warfare-qualified personnel to help bridge a knowledge gap and understanding between warfare centers, academics, researchers, operationally supported warfighters and other DoD leaders. Another initiative to help bridge the gap is the Scientist to Sea program (Tropiano, 2005). Directed out of ONR, the Scientist to Sea program gives civilian personnel who support the Navy an opportunity to learn about life at sea for military personnel and to observe naval equipment and procedures. This is a critical initiative as even those supporting DoD acquisition may only see defined requirements without a full understanding of the projected operational environment or required operational capabilities in the specifications. When industry and academics engage with "the DoD," it is important to consider how well-informed the DoD personnel are of the challenges and what technologies and technical advancements are needed. Some technologies may show promise and meet operational performance measures but are not operationally suitable in the military environment.

Conclusions and Recommendations

When discussing the valley of death in DoD acquisition and S&T, it is critically important to understand the various perspectives, processes, procedures, and levels of understanding from all involved. To say the DoD doesn't want to partner or collaborate with industry, academia, or other partners would be inaccurate. It is also incorrect to state unequivocally that the acquisition and PPBE process are overburdensome and unnecessary. The DoD acquisition system is a monolith that has inefficiencies that need to change for it to deliver capabilities at the speed of need. This must be balanced with considerations as to the number of guardrails in place to offer stability and a focus for investments and definition of what technology maturity means. Also highlighted were the workforce's understanding of the challenges and technology, an understanding of the funding complexities, the various transition partners available, and how to source the right solutions. S&T cannot be a one-way street. At the 2023 Sea-Air-Space Expo, Rear Admiral Keith Hash, Commander Naval Air Warfare Center Weapons Division (NAWCWD) and Vice Admiral Carl Chebi, Commander Naval Air Systems Command (NAVAIRSYSCOM) both stated that if the technology is valuable and "moves the needle," you have to "pull it through

the valley of death and not push it through" (NAVAIR, 2023). Critical thinking remains the most important skill set when operating in the technology development space. A clear and objective understanding of not just the technology but also the business elements for its use are cornerstones to crossing the valleys of death. Additional guidance or research into other supporting areas may be required by all involved to achieve success. It is recommended that additional analysis be done on specific trends and root causes of conversion rates across the services, entry points, technology types, and more to extract and highlight areas in need of improvement or further refinement. Lastly, PORs, warfare centers, S&T organizations, and the community at large should define a vision and strategy for what are the capability gaps and needs for different time horizons. This will assist in workforce development and establishing baseline for the current and projected state of technology, and investing resources in the most important things. This will also assist in budgetary planning and flexibility.

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