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Accelerating Innovation—From S&T Labs to Acquisition Programs

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Abstract

The current emphasis on innovation in the DoD and the imperative to maintain our technology edge in DoD weapons and vehicle systems requires that all avenues to meet this objective be reviewed. In this paper, we look in the DoD research labs and, specifically, the Tank Automotive Research, Development Engineering Center (TARDEC), to understand the challenges and successes of integrating and transitioning promising technologies into fielded programs. The paper examines several core activities and TARDEC's role in bringing new technologies into programs. The paper describes the successes and challenges of technology integration and transition, and abstracts the systemic issues in the process. The objective is to identify process changes to address these issues, thus providing another path to maintaining, and in some cases, establishing the DoD advantage in various performance aspects of weapon and vehicle systems.

Introduction

The DoD and the Army are focused on technology innovation, especially with respect to weapons systems, to maintain the overwhelming superiority we have achieved over the past 75 years. There is concern that our technology superiority is decreasing and that new cyber and other threats are emerging, thus driving the urgency to maintain superiority in systems with a focus on driving innovative technology into programs. Innovative solutions might originate from basic research conducted at universities, the Defense Advanced Research Projects Agency (DARPA), and the Army laboratories. These are then refined and further developed in the Research and Development Engineering Centers (RDECs). The developments from the RDECs are transitioned to programs via requirements and prototypes to program offices, which are then reflected in solicitations to OEMs and prime contractors to be realized in programs.

This topic has been studied over the years, and many best practices have emerged and are in use across the systems and technology enterprise. In this paper, we are focused on the Tank Automotive Research, Development Engineering Center (TARDEC) and have used TARDEC and RDEC interchangeably. TARDEC supports the PEO Ground Combat Systems (GCS) and PEO Combat Support and Combat Service Support (CS&CSS) and is focused on combat and tactical vehicles and systems. In this paper, we have studied and are reporting on experiences of personnel from TARDEC and program offices to understand best practices that have been used and challenges encountered in innovation and transitioning technology to programs.

Methodology

The approach included a questionnaire that covered several topics:

- Current state of technologies developed in labs

- Technology development in universities and other organizations
- Changes required to drive technology from labs to programs
- Program success in technology transition
- Participation in technology transfer programs
- Management practices in technology integration
- Aids and barriers to successful integration
- Integration issues
- OEM/Contractor dependencies
- Communication and organizational alignments
- Crossing the chasm from technology development to programs

The interviewees included senior-level leaders or directors, chief engineers from PEO offices, mid-level systems engineers, and integration engineers with significant experience in RDEC and program offices. Traditional studies have focused on measuring results by, for example, the number of programs transitioned. In this study, we attempted to capture from the practitioners what has worked and issues they have encountered to get an unfiltered view of technology innovation and technology transitions.

This is a very broad field, and we have tried get an in-depth view of a small portion of the enterprise. As such, we make no attempt to broadly generalize these results to other RDECs even in the Army because programs and underlying technologies can vary significantly across PEOs and RDECs. However, some of the communication, planning, and alignment aspects discussed in this study should be applicable to other organizations as well.

Discussion of Interview Results

Current State of Technologies Being Developed in Labs

To establish a baseline on the usefulness and utility of technologies being developed in the labs, we attempted to understand the interview subjects' views on the value of these technologies with specific examples.

The consensus view was that significant technology is being developed in the labs and that many specific technologies are tied to programs of record (POR). Examples include lithium ion batteries in the form factor required by army vehicles, light weight track, transport armor on JLTV, combat transmission systems, advanced combat engines, active development of a combat vehicle prototype, lightweight armor, integrated modular occupant protection, manufacturing techniques for welding improvements, and composite armor.

One view is that labs and TARDEC in particular are very good at niche technologies such as armor, but that they place less emphasis on the development and integration of emerging technologies such as mobility solutions in the commercial industry automotive industry. That said, recent initiatives suggest that technologies from the automotive industry are being explored for prototype development.

Innovation and Development in Universities and Other Organizations

We next compared innovation and development in the labs with innovation and development in other organizations such as universities, non-governmental labs, and defense contractors.

Some views stated that basic research and some level of applied research originated from universities but development and effort was required to transition this research to RDECs. Others noted that universities supported science and technology in other ways, for example, by providing tools for systems engineering. An example of a tool is the Vehicle Health Management capability at Wayne State University that was supported by the program office.

Visibility into IRAD spending by defense contractors is limited, so it is not clear whether innovation is coming from defense contractors. In addition, it appears that defense contractors' spending on IRAD was focused on requirements in programs of record and not specifically on innovation. Therefore, unless innovation was reflected in the requirements, it would not make it to programs of record. Some interviewees suggested following up the requirements development with prototypes or demonstrators by the labs to further inform the requirements. Another point of view suggests that, in some instances, it is difficult for TARDEC to take innovation risk. To accelerate innovation, then, TARDEC has had to use non-traditional defense partners under non-Federal Acquisition Regulations (FAR).

Another factor that impedes innovation is cost, both for development and unit cost of production. This also leads to risk minimization both by the program office and the defense contractor.

One conclusion that can be drawn from these responses is that universities, Army research labs, and DARPA provide basic research. Applied research, however, must come from RDECs, which must also oversee early phases of the acquisition cycle, while program offices manage engineering and development in the later phases of the acquisition cycle via defense contractors. In this way, RDECs would provide the valuable input to programs with well-informed requirements derived from advanced development and prototypes. Program offices would then be better positioned to solicit solutions from contractors.

Changes Required to Drive Technology Developed Into Programs

A recommended strategy to drive technology from the RDECs to programs is by getting the Army Training and Doctrine Command (TRADOC) to drive requirements to both the RDECs and program offices. This would allow the development of technology and prototypes in the RDECs, and, because program offices would be working to the same requirements, the transition from the RDECs to programs would be easier. A second potential feature of the above approach would be to get results from RDEC efforts to feed requirements in RFPs.

There are other systemic issues however. First, PMs are focused on incremental changes to programs managing risk and cost and shorter term EMD goals, while the RDECs are focused on technology goals and revolutionary changes, and the Army is focused on strategic initiatives. These viewpoints need to be aligned to enable an efficient approach to innovation. Second, funding requests need to be aligned. Currently, PMs' Program Objectives Memoranda include funding requests for what they know now and not for what may be coming down the pike. However, on occasion, PMs also require technology upgrades or better "gizmos" to address threat and priority changes and need a quick turnaround; while the RDECs are willing to respond, the technology maturation can be a lengthy process. This is especially true of technology changes to the underlying vehicle platform.

So with little coordination and no targeted funding, transitioning from the RDECs to programs presents serious challenges.

Program Success in Technology Transition

This topic revealed several views on transitioning technology. One view is that there is no discernible trend in the rate of successful integration. This then leads to a question about the availability of metrics that measure successful integration, the lack of which makes it difficult to understand the roadmap to successful integration. Another view is that integration success has been opportunity-driven, especially over the last two years, exemplified by the Armored Fighting Vehicle, which has seen several integration efforts that have informed the requirements process. A different approach to measuring the success of integration must start with the definition of success. For example, with respect to armor capability, the integration efforts in TARDEC informed the requirements for final design, which led to an improved vehicle. Thus RDEC provided a feasible solution, which drove to a better product even though the specific work effort may not have transitioned.

The strategy of modernizing rather than initiating new development programs led to modernizing at the lower level subsystems rather than the system level. The focus on the subsystems has led to successful integration efforts; however, when contingency requirements drive modernization, the enhancements are fielded, but sustainment efforts are challenged due to lack of program ownership. This lack of program ownership also limits additional quantity buys and further improvements. Finally, there is the view that integration efforts are hampered by the level of oversight at various leadership levels and contribute to lower success rates in technology integration.

The summary of the above discussion leads to several conclusions:

- Successful integration needs to be defined to include informing requirements in addition to transitioning specific development into programs.
- Appropriate metrics to capture all the value of RDEC efforts need to be defined and captured.
- Integration and transitions must have a program owner identified even for efforts driven by contingency requirements.

Aids and Barriers to Successful Integration

Successful integration has been driven by demand from the acquisition or PM functions for risk-reduction efforts or capability improvements. Several examples of successful integration include armor protection, Victory architecture, throttle control software, and lightweight track among many others. In addition, contingency requirements, urgent fielding requests, and a focus on controlling sustainment costs also drive integration. Natural conflicts exist between RDEC leadership and PEO/PMs, as they operate in different environments with different objectives, but strong personal relationships can overcome these conflicts and lead to successful integrations.

Challenges to successful integration include an understanding of the technology development effort as either being exploratory in nature, which would require close cooperation between the RDEC and program office to mature and succeed, versus a specific deliverable that can be driven by a transition agreement. Transition agreements ensure that the RDEC capability meets schedule and functional requirements and that the program is ready to accept the deliverable. Another challenge to integration, expressed by one interviewee, was that PMs focus on thresholds and "do not lose sleep on objectives," while TARDEC focuses on objectives. With limited interaction between PM engineers and TARDEC, technology is not incorporated into programs. If PMs can focus on objectives and drive the process, TARDEC can help reduce the risk in programs; so, while a specific technology integration may not be the final result, informed requirements and risk mitigation might be the benefits that need to be recorded. Finally, several interviewees articulated that limited funding was a common challenge and a significant barrier to integration.

To summarize, lack of funding can be a significant barrier to integration and transitioning of RDEC efforts to the programs. PM demand for improvements, risk mitigation, and contingency requirements are the primary drivers for successful integration. In all cases, a thorough understanding of the specific technology development and integration effort versus conceptual deliverables must be defined and agreed to between the RDEC and the program office.

Participation in Technology Transfer Programs

Several technology development and transfer programs have been in existence along with various funding avenues. The following are some of the programs:

- Joint Concept Technology Demonstration
- Foreign Comparative Testing
- Quick Reaction Fund
- Rapid Reaction Fund
- Small Business Innovative Research (SBIR)/Small Business Technology Transfer(STTR)
- Agile Integration and Development
- Collaborative Technology Alliances
- Technology Transfer Initiatives
- Technology Enabled Capability Demonstration (TECD) and Army Technical Objective (ATO)

All of the above programs have been used on different technology development efforts; SBIR and STTR have been used extensively. The JCTD was used for the Trailer program; Foreign Comparative Testing was used on the Howitzer program; and Agile Integration and Development was used on the lightweight track development. Several Technology Transfer Initiatives have been used at TARDEC.

These initiatives are a necessary condition for technology innovation and transition to be successful, and their widespread use must be viewed as an advantage for TARDEC and the PMOs.

Management Practices in Technology Integration

Management practices also bear on the possibility of technology transition. The following are some of the common practices:

- Roadmap reviews of technology plans between organizations
- Technology requirements and alignment with program requirements
- Formal collaboration between TARDEC and Program Offices
- Technology Transfer Agreements or equivalent
- Metrics to measure success of technology integration

We determined that several of these practices are in use, including requiring twice-a-year requirements reviews, a 30-year plan review, strategic engagement at the leadership level, and soliciting long-range input from TRADOC. Systems agreements are another mechanism to align TARDEC and PMO offices. One caution was sounded on TTA (Technology Transition Agreements), which are binding on the RDEC to deliver and on the

PM to implement except when PMs are not sure of the risks and challenges of integration. TTAs can be signed without guarantees, which can impact future transition efforts.

These practices are necessary conditions for successful transitions but need a greater emphasis on the alignment to ensure PMOs and RDECs are working towards the same program goals. In some instances, these efforts will focus on emerging requirements and may not result in capabilities that can be transferred to programs. In other instances, specific technologies are ready to be integrated into programs of record. The key factor in successful transitions is the agreement and alignment between the RDEC and the program offices.

Integration Issues

A discussion on integration issues identified that a propensity for low risk drives both RDEC and PMOs. PMs focus on low technical risk to ensure programs can meet objectives, while the S&T manages to a TRL 6, resulting in few game changers and fewer revolutionary improvements. In some instances, a 5% improvement in combat vehicles can take up to 10 years. A second issue that arises in integration is the lack of clarity around the integrator's role and who plays this role. Informal requirements communicated to the RDECs can lead to technology demonstrators, but the work effort to convert these technology demonstrators to a capability with specific platform-integration goals is a gap that needs to be filled to facilitate successful transitions. The lack of alignment of RDEC strategic priorities with PM requirements results in funding issues to integrate and transition technology from the RDEC to programs. The lack of coordination results in some efforts getting funded and in other instances the PM turning to the OEM or prime contractor to meet the requirement.

OEM/Contractor Dependencies

Innovations from RDECs go through multiple development efforts and eventually require integration by OEMs or prime contractors. The TARDEC prototype integration facility and systems integration lab have led to clearer requirements and informed the integration efforts by the prime contractors. The efforts on the Active Protection System and double V hull based on an open systems architecture resulting in transition specification are examples of TARDEC development efforts that have or will result in a handoff to the contractor or OEM for integration into a vehicle platform for production. Integration into vehicle platforms will require knowledge and expertise in manufacturing and high-volume production. The OEM or prime contractor is the appropriate resource. This discussion highlights the interdependencies between the program office and the RDEC in ensuring that funding is available for the RDECs to develop the technology and prototypes for integration. Solicitations can then reflect the design requirements that emerged from the RDEC efforts, and funding can be programmed for development and production to include these transition efforts.

The consensus opinion of the interviewees was that 90% of the transition efforts in the RDECs will require integration by the prime contractors and the OEMs, and funding and resources must therefore be planned.

Communications and Organizational Alignments

Organizational changes such as reorganizing TARDEC research groups to focus on programs and the appointment of CIEs (Chief Integration Engineer) have supported technology transition efforts. Formal communications between PMO and TARDEC are also critical for continued integration success. The Active Protection System is an example of how significant input from the PMO has influenced the project's development in TARDEC. Senior leadership summits, review of 30-year planning documents, subject-matter-expert communications, and formal exchanges supplemented by personal relationships reinforce the importance of communication in supporting technology transitions.

Crossing the Chasm

In this section, we cover the changes that are required to successfully cross from the RDECs to programs. Greater interaction between subject matter experts in the labs and program offices on an ongoing basis, including participation in preliminary and critical design reviews should benefit the technology transition process. The use of TRADOC to drive requirements to both the RDECs and PMOs with a short, medium, and long-term horizon should assist in directing RDEC efforts appropriately, and when coordinated with PMOs, should support the development of a strategic and tactical plan.

There is a recognition that mobility initiatives in the commercial automotive and transportation industries are driving innovation that should be explored for use in programs and by TARDEC. TARDEC is using an innovative business approach to allow a consortium consisting of small technology companies, larger defense companies, and automotive companies to develop prototypes based on technologies emerging in the auto industries, such as autonomous vehicles. These prototypes can then inform requirements, capabilities, and designs for future solicitations. Similar consortiums are also being used to explore other technology prototypes in areas such as sensors and robotics that have more immediate applicability to ground vehicles, both combat and tactical. These consortia respond to requests for technology prototypes under Other Transaction Authority (OTA) provided by Congress to the DoD specifically to attract nontraditional defense and technology companies. The OTA provides more flexibility in dealing with smaller companies in the areas of intellectual property rights and speed to market when compared to contracting under the FAR regulations.

Funding program transitions explicitly is a key driver of ensuring transfer of RDEC efforts to programs. Leadership plays a key role in the realization of successful integration efforts by supporting the successes and challenges of technology transitions and stressing the importance of these efforts.

Current Literature on Technology Transitions

A limited survey of literature on technology transitions suggests similar views to those discussed in this paper. In *The Future of Army Science and Technology Requires Punctuated Equilibrium*, Col. John R. Cavedo (n.d.) describes a broad strategy for reorganizing and managing Army Science and Technology with a new business model. One of the key recommendations from this paper is that S&T should "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." The paper also refers to the Deputy Assistant Secretary Research and Technology (DASA RT) goal of "Align S&T and develop strategies which provide technology insertion points to Programs of Record." The paper posits that "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," and that "transitioning an S&T effort to a program of record is fraught with blind spots."

DASA policy on Transition Agreements (TA) for Army Science and Technology Projects requires TAs be developed for all Advanced Technology Development (6.3), Advanced Component Development and Prototypes (6.4), and Manufacturing Technology (6.7) executed projects. The TA captures RDEC responsibilities and deliverables, PEO or Recipient responsibilities and mutual responsibilities. This template provides the basis for an organized formal process for transition agreements that should lead to success.

In “Bridging the Valley of Death,” Anthony Davis, Director of Agile Acquisition for U.S. Special Operations Command, and Tom Ballenger, aviation systems analyst with JHNA Inc., have outlined a Transition Confidence Level Scale from 1 to 9 similar to the Technology Readiness Level model to track the steps for transition from uncertainty to a completed transition (Davis & Ballenger, 2017). “Like the TRL chart, the steps enable status scoring for a project, and form a roadmap for progress and coordination typically needed for transition success.” This promising approach enables a data-driven standardized approach to measuring the progress of technology transitions. Similar models have been recommended in the RDECs, and these models allow for agreements with program offices on metrics to support the transition, and these can also be added to the TA template from DASA RT.

This study and the above literature have focused on the Army S&T enterprise, but future studies should review the best practices in the Air Force and Navy for possible use by Army RDECs.

Conclusions

- Universities, laboratories, DARPA, and defense contractors play a role in technology innovation, but primarily RDECs support the realization of the innovation and its transfer to programs.
- OEM contractors perform best when requirements are informed by advanced development and prototypes from RDECs developed internally or through non-traditional technology development organizations. There exists a significant interdependency between the RDECs and OEM contractors, with PMO offices interfacing with both; 90% of integration efforts will require OEM contractor participation.
- RDECs need to extend their reach by partnering with non-traditional companies to drive technologies and capabilities from smaller companies or large non-defense contractors into programs.
- Integrated efforts by TRADOC, RDECs and program offices to coordinate a view of the future both in the short term and medium term would benefit innovation and transition efforts.
- POM funding requests should be aligned so that they include not only the short- to medium-term requests but also include funding to translate innovation into prototypes and transitioning into programs.
- RDEC value is realized via many different avenues: transitioning technology prototypes to programs, informing requirements to improve solicitations, and engineering or manufacturing process improvements. Appropriate metrics to measure this value must developed. Transition Confidence Levels or other similar measures are a valuable tool to assess transition efforts and direct resources.
- Lack of funding is an obvious roadblock to technology innovation and transition, while risk-mitigation-based demands from program offices, contingency requirements, and threat changes seem to be significant drivers of innovation.
- Technology Transfer programs like SBIR, STTR, JCTD, TECD, and ATO are a necessary condition to foster innovation.
- OTA can be used to engage non-traditional companies to access the latest technology from smaller companies and the commercial marketplace.

- Integration and transitions must have program owners in both the RDEC and program offices who are aligned and in agreement to deliver successful transitions.
- Communications at the strategic level, communication of long range plans, senior leadership summits, and exchanges between subject matter experts are all important activities to support effective transitions.

Crossing the chasm from technology innovation and development to programs successfully requires many organizations and activities to come together. The conclusions above reflect many practices that are currently in place. The challenge, however, is to align the practices and operate them as part of a system for effective transition of innovations.

Figure 1 depicts an operational view of a process for technology transfers

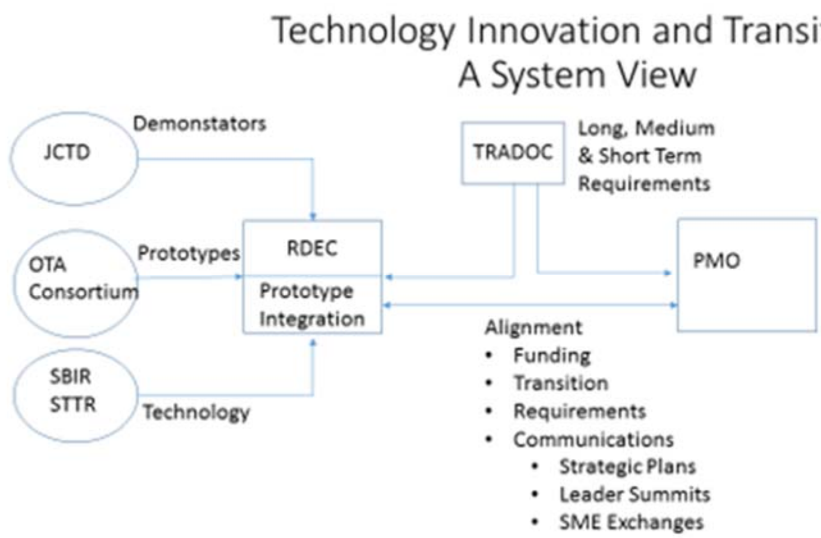

Figure 1. Technology Innovation and Transition: A System View

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