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Research Report

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Accelerating the Transfer of Training Technologies to Support Evolving Department of the Air Force Mission Capabilities

A Framework, Lessons Learned, and Recommendations

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About This Report

This report documents findings and recommendations from a RAND Project AIR FORCE study focused on helping the Department of the Air Force (DAF) identify promising advanced training technology investments and identify steps it can take to track and integrate the most-promising technologies. This report is the companion of another report—*Assessing the Landscape of Advanced Technologies for Department of the Air Force Training and Education*[1]—generated by the same project, which documents our work conducting a landscape analysis of relevant advanced learning technologies and an expert panel to determine which technologies were most promising for DAF training.

In this report, we focus on the process of technology transfer for these new training technologies. We present our findings from a literature review from academic, industry, and government sources about technology transfer and use those to construct a framework for training technology transfer. The framework provides a view of the steps in the process and the potential barriers and enablers associated with each step. We also examine six use cases from ongoing efforts across the U.S. Department of Defense to provide further insights into the challenges of training technology transfer.

The research reported here was commissioned by Maj Gen Daniel DeVoe (AF/A5/7) and conducted within the Workforce, Development, and Health Program of RAND Project AIR FORCE as part of a fiscal year 2023 project, "Exploring the Use of Advanced Learning Technologies to Enhance the Efficiency and Effectiveness of Air Force Training."

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[1] Mark Toukan, Emmi Yonekura, Prateek Puri, Maria C. Lytell, Jon Schmid, Andrea M. Abler, Meyer Thalheimer, Eddie Ro, and Isabelle Winston, *Assessing the Landscape of Advanced Technologies for Department of the Air Force Training and Education*, RAND Corporation, RR-A2326-1, 2024.

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Summary

Issue

Training and education in the Department of the Air Force (DAF) is undergoing a major transformation as part of an effort to maintain an asymmetric advantage over competitors. As part of this transformation, the DAF wants to invest in advanced training technologies—such as augmented and virtual reality, gaming, and synthetic training environments—that are emerging from the academic, industry, and government sectors. To reap the benefits of these new training technologies, the DAF must successfully transition them to the force. In this report, we examine what factors enable a successful technology transfer and how those factors have come into play in select use cases.

Approach

We used a mixed-methods approach to build a framework for training technology transfer. We reviewed academic, industry, and government literature on technology transfer and conducted semi-structured interviews with stakeholders across the DAF and the wider U.S. Department of Defense (DoD) training enterprise. Using our findings, we outlined the steps of a technology transfer process and then identified factors that enable or create barriers to training technology transfer at specific steps in the process.

We then selected six use cases from real-world training technology programs: Generalized Intelligent Framework for Tutoring, Synthetic Training Environment–Information System, Joint Simulation Environment, Standard Space Trainer, Special Operations Center for Medical Integration and Development, and Integrated Technology Platform. For each case, we conducted additional interviews with the relevant program experts and reviewed technical documents to identify technical and nontechnical factors that contributed to the success or failure of transitioning the training system. These factors were compared with those that were indicated by our framework.

This research leveraged findings from a companion report that identified which advanced training technologies might be the most promising investments for the DAF and connected each promising technology to next steps to enable a transition into the DAF training and education enterprise.[2]

Key Findings

Our key findings are as follows:

[2] Mark Toukan, Emmi Yonekura, Prateek Puri, Maria C. Lytell, Jon Schmid, Andrea M. Abler, Meyer Thalheimer, Eddie Ro, and Isabelle Winston, *Assessing the Landscape of Advanced Technologies for Department of the Air Force Training and Education*, RAND Corporation, RR-A2326-1, 2024.

- The factors that facilitate or hinder the transition of training technologies correspond to policy levers for the DAF and are not limited to financial factors but also include aspects of personnel, social factors, technology attributes, return on investment, absorptive capacity, and processes.
- Across the six advanced training technology use cases, the most pervasive and critical barriers relate to insufficient funding, scalability, program understanding and socialization, inconsistent incorporation of technologies, enabling multilevel security for distributed training, and misalignment with science and technology plans.
- Examples of key enablers to a successful technology transfer based on the lessons learned from the use cases are using agile software development, using a single vendor with a modular architecture, ensuring that training systems align with operational systems, ensuring continuity in development, securing advocacy, and ensuring funding continuity.

Recommendations

We make the following recommendations:

- **The training technology transfer framework should be used at the enterprise or organization level to make periodic (e.g., yearly) assessments of where the bottlenecks are in the process** and pinpoint specific actions that can be taken to eliminate them. For example, systematic deficiencies in the necessary information technology (IT) architecture to facilitate expansion of technologies might point toward a need for action at the enterprise level.
- At a more tactical level, **the framework should be made available and used by innovation cells and training and education management at the major commands** to troubleshoot and plan for specific ongoing or future training technology transfers. Use of the framework at the tactical level would be more appropriate for identifying local enablers and barriers to transition.
- **Air Force Futures (AF/A5/7) should be responsible for enterprise-level application of the framework** in coordination with other major commands and for making it available to other stakeholders to facilitate planning and troubleshooting.
- **The DAF should codify and socialize the lessons learned from our use cases as training technology transfer guidance** for all DAF stakeholders and potentially a wider DoD audience.
- **Major training technology transfer barriers and challenges should begin to be addressed now** to pave the way for the major transformation of the training and education enterprise. This is not only a matter of technology and funding: Prominent barriers also require addressing communication, alignment between organizations, and cultural resistance.
- The DAF should **consider investments in adaptive training, performance assessment, virtual and augmented reality, natural language interfaces, and gaming technologies and take steps to enable their transition**.
- The analysis of emerging technologies is inherently iterative, and an **updated assessment of the technology landscape, potential use for DAF training and education, and means of**

transitioning promising technologies should be conducted within the next five years. Experts indicated that many of the technologies we examined would reach promising maturity in five to ten years.

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Chapter 1

Introduction

Training and education in the Department of the Air Force (DAF) is undergoing a major transformation as part of an effort to maintain an asymmetric advantage over competitors. Former Chief of Staff of the Air Force General Charles Brown emphasized that the DAF must "[t]ransform the way we learn across all facets of USAF education and training curricula."[3] As part of this transformation, the DAF wants to invest in advanced training technologies—such as augmented reality (AR) and virtual reality (VR), gaming, and synthetic training environments—that are emerging from the academic, industry, and government sectors. However, to reap the benefits of these new training technologies, the DAF must both choose the right technologies and successfully transition them to the force. In this report, we focus on the latter challenge, which we call *training technology transfer*, something the DAF has encountered issues with recently.[4] With sponsor input, we defined the training technology transfer for DAF (T3D) process to start with a concept and end when the training technology is fully implemented in the training community. The scope of this report covers technologies that are relevant to both education and training in the DAF, from initial skills to advanced training. We refer to *training technology* as technologies that can apply to training or education applications.

Ushering a capability through the T3D process generally follows other generalized technology transfer frameworks in that those frameworks describe a process that creates products (both material and nonmaterial) from ideas or prototypes at various stages of maturity.[5] Government, military, and academic thinking has explored many aspects of how technology transfer can be improved, generally grouping these improvements in bins that address barriers, magnify enablers, produce better measures, or innovate the technology transfer process itself. For example, Hilkevics and Hilkevics (2017) provides a brief history of how the technology transfer process has evolved, as shown in Table 1.1.[6]

[3] Charles Q. Brown, "CSAF Action Orders," U.S. Air Force, December 4, 2020, p. 6.

[4] U.S. Government Accountability Office (GAO), *Advanced Pilot Trainer: Program Success Hinges on Better Managing Its Schedule and Providing Oversight*, GAO-23-106205, May 2023.

[5] Technology transfer is sometimes referred to as "technology transition." As to technology maturity, technology transfer is often characterized using technology readiness levels (TRLs) on a scale of 1 to 9 that measure the progress of a technology. For instance, technology transfer would be at level 1 when a basic principle is observed and reported, at level 5 when a component is validated in a relevant environment, and at level 9 when the actual system is proven through successful mission operations.

[6] Sergejs Hilkevics and Aleksejs Hilkevics, "The Comparative Analysis of Technology Transfer Models," *Entrepreneurship and Sustainability Issues*, Vol. 4, No. 4, June 2017.

Table 1.1. Abridged History of Technology Transfer Process Maturation

Era	Technology Transfer Concept	Description
1940s–1950s	Appropriability model	"Technology transfer occurs when technology has found users," i.e., the user stumbles on the technology
1960s–1970s	Dissemination model	Technology developers seek out users of the technology
1980s	Bayh-Dole Act	Eased universities' ability to gain legal rights for work done with federal funding
1980s	Knowledge utilization model	Explicit management of the process helps break communication barriers and organizational barriers
1990s	Communication model	Advent of information technology (IT) enabled parallel tasking/pathing to achieve technology transfer faster; switch from linear to nonlinear technology transfer models
1990s	Valley of death challenge	Gap between prototype to industrialization hampers technology transfer; financing options provide a solution
1990s	Cyclical management models	Enables industrialization of the technology transfer process, increasing capacity
1990s	Parallel sequential models	Enables the pursuit of multiple simultaneous lines of effort
1990s	Feedback models	Enables pre- and postdeployment improvements, leading toward greater suitability

SOURCE: Features information from Hilkevics and Hilkevics, 2017.

Initially, in the 1940s and 1950s, technology transfer was largely the result of the end user "stumbling" on a technology. Industry perceived a need to develop management processes to guide this otherwise serendipitous transfer. By the 1990s, the technology transfer process had matured into a formalized cyclical process that included internal and external engagements, established financial solutions, improvement loops, and parallel steps.[7] When practiced, these concepts can bring multiple technologies to fruition simultaneously, possibly for the same end use. Not all technology transfer efforts use the entire amalgamation of techniques shown in the table; some technology transfer efforts are more straightforward than others. However, an enterprise approach to technology transfer would likely benefit from many of the elements learned from this historical development of business practices. We adopted many of these concepts to formulate a tailored process for T3D that specifically considers technologies relevant for training and how the process looks for the DAF.

[7] By *formalized*, we mean scalable and flexible processes that are explicitly managed rather than ad-hoc, one-off, and tailored individual efforts.

Objectives and Approach

In this report, we identify innovation best practices and T3D pathways to field advanced training technologies (e.g., synthetic environments, AR, VR, artificial intelligence). The results are meant to inform DAF investments in training technologies by providing tangible guidance for transitioning different types of training technologies into the DAF training communities.

We structured our research around the following research questions, the latter of which considers some technology-specific findings from the companion report:[8]

- What factors facilitate or hinder transition of training technologies?
- To what extent are these factors present or absent in select use cases?
- What technologies should DAF invest in, and what steps should it take to facilitate transition?[9]

To answer these questions, we used a mixed-methods approach to build a framework for T3D and then selected use cases from real-world training technology programs.

To create the T3D framework, we reviewed academic, industry, and government literature on technology transfer. Using this review, we outlined steps in the T3D process and then identified factors that enable or create barriers to training technology transitions. We refined the framework through interviews with stakeholders in operational, R&D, and acquisition communities.

We then validated the framework using six cases selected based on sponsor inputs, findings from expert discussions, and a systematic down-selection analysis. For each case, we conducted semi-structured interviews with the relevant program experts and reviewed technical documents to identify technical and nontechnical factors that might have contributed to the success or failure of transitioning different training systems. These factors were compared with those that were indicated by our framework.

Further details about our methods are contained in the individual chapters and Appendix A.

Organization of This Report

In Chapter 2, we provide a detailed methodology for building our T3D framework and discuss its different components. In Chapter 3, we follow with a description of how the use cases were selected and then develop a narrative of each technology transition. We conclude the chapter with a discussion of the various challenges identified by the use cases. We close the report in Chapter 4 with a summary of our overarching findings and recommendations to our sponsor and the wider DAF training and

[8] Mark Toukan, Emmi Yonekura, Prateek Puri, Maria C. Lytell, Jon Schmid, Andrea M. Abler, Meyer Thalheimer, Eddie Ro, and Isabelle Winston, *Assessing the Landscape of Advanced Technologies for Department of the Air Force Training and Education*, RAND Corporation, RR-A2326-1, 2024.

[9] The companion report (Toukan et al., 2024) provides an overview of the advanced training technology landscape using a quantitative modeling approach to review hundreds of thousands of documents that reflect training technology research and development (R&D) within the DAF, the U.S. Department of Defense (DoD), commercial industry, academia, and allies and adversaries. The report also documents stakeholder perspectives on technologies currently in use and developmental priorities, and it presents the results of an online expert panel, in which training technology experts rated and discussed the maturity, benefits, scope of applicability, and adoption barriers for a subset of training technologies.

education community. We also include as appendixes our interview protocols (Appendix A), a detailed discussion on the T3D process (Appendix B), additional considerations for technology transfer (Appendix C), and a list of the types of advanced training technologies and programs that we considered (Appendix D).

Chapter 2

DAF Training Technology Transfer Framework

In the companion report,[10] we identify relevant technologies that hold promise to improve DAF training. In general, once the DAF has identified new ideas or tracked emerging technologies that could improve DAF training, the next challenge is to execute a successful transfer of that idea or technology and shepherd it all the way through to scaled implementation in the DAF. In this chapter, we postulate a framework for training technology transfer that includes an assessment of best practices that apply to DAF advanced learning and training technologies. We call this the *T3D framework*.

We first examine the process that training technologies must traverse as part of a technology transfer into the DAF. We then leverage a variety of sources—representing academic, industry, and government perspectives—to catalog the factors that enable and pose barriers to the process. The framework consists of mapping out the technology transfer process and factors associated with each stage. We first take a wider view of enablers and barriers, from literature beyond the DAF or DoD, and then use a lens specific to DAF training technology based on interviews and our team expertise to tailor the T3D framework for DAF training technology. In the next chapter, we also turn to recent DAF examples to validate our framework.

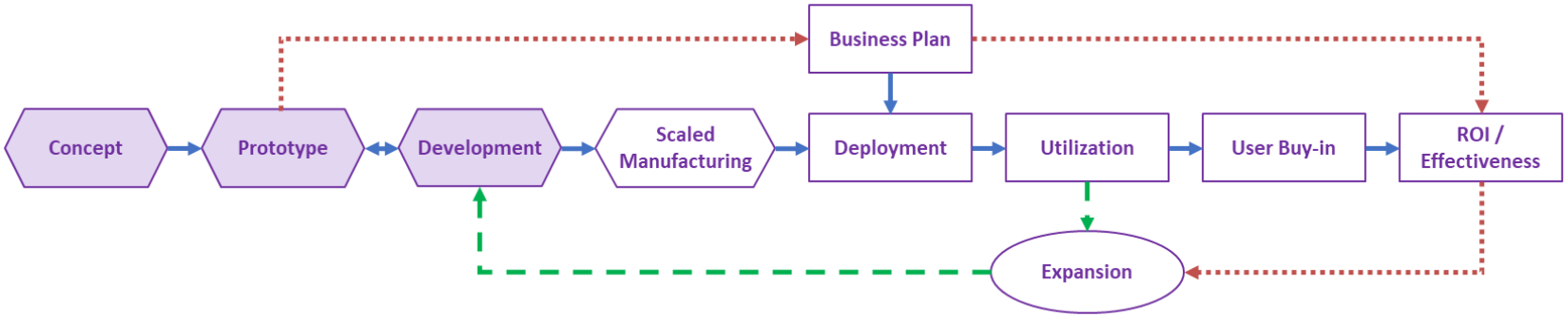
Understanding the DAF Training Technology Transfer Process to Improve Successful Transition

The training technology transfer process describes the actions that organizations execute as a training technology moves from idea to a fielded product. We describe these actions as ten distinct steps illustrated in the flow diagram in Figure 2.1.[11] This model, which can be self-contained within one organization, is one that many industries roughly follow. Steps that a technology progresses through during its lifecycle can also be broken up between multiple parties. The DAF can intervene at all steps: By knowing the steps and leveraging practices that overcome barriers and bolster enablers to technology transfer, the likelihood of a successful training technology deployment increases.

[10] Toukan et al., 2024.

[11] This process was developed after an extensive literature review, discussion with stakeholders, and RAND team refinement. Substantive contributions were from the following works: Hilkevics and Hilkevics, 2017; Mahdi Yadegari, Shahriar Mohammadi, and Amir H. Masoumi, "Technology Adoption: An Analysis of the Major Models and Theories," *Technology Analysis and Strategic Management*, 2022; and Vander Luiz da Silva, João Luiz Kovaleski, and Regina Negri Pagani, "Fundamental Elements in Technology Transfer: An In-Depth Analysis," *Technology Analysis & Strategic Management*, Vol. 34, No. 2, 2022.

Figure 2.1. DAF Training Technology Transfer Process



NOTE: Shaded steps concern a single technology, and nonshaded steps imply that a system of technologies continues to mature together. The hexagon shapes are steps in the process prior to technology deployment. Red dotted arrows represent process flows that inform subsequent steps. Green dashed arrows are optional flows that essentially make this entire process iterative. The iterative prototype-to-development flow is represented by a bidirectional arrow.

The process flow depicted in Figure 2.1 moves from left to right and is iterative in two places. First, prototypes might undergo repeat development until suitable to move to scaled manufacturing. Second, the entire process is iterative when the need for expansion is realized. We suggest that only one technology at a time flows through the first three shaded blocks according to a schedule, independent (but loosely related) to other technologies. However, a system of interconnected technologies should reach production (i.e., scaled manufacturing) at roughly the same time and continue through the process at roughly the same rate (nonshaded blocks).

The steps represented in hexagons occur before a technology is deployed. The red dotted arrows indicate where one action informs another. The process might proceed without this information, but we suggest that the subsequent step would be more effective otherwise. Lastly, the green dashed arrows are flows that lead to an optional step, expansion, and represent when the process would be repeated to expand the training capability that the technology delivers (the oval step). In this chapter, we provide a short description of each step and discuss what it looks like for a technology to successfully traverse the process. Appendix B presents a more detailed discussion of each step that includes further insights from the background literature.

The ten steps in the T3D process are as follows:

- **Concept:** The initial idea, originator, and mechanism that starts the transfer of the technology. Success at this step relies on identifying a potential real-world setting and application with a market or a training need for a specific audience or training tier (i.e., use case).[12]
- **Prototype:** One or a few implementations of the concept. It is successful if it validates practical learning applications, serves as a demonstrator for business development, and identifies early challenges or opportunities for the T3D process.
- **Business plan:** The documentation that establishes the purpose of the training technology transfer and guides the process after the prototype phase. Ideally, the business plan will involve analysis of initial and changing conditions to generate dynamic plans and measures that guide the entire T3D process. It should include intended use cases, a schedule for deployment, a plan for ensuring user buy-in, sustainment considerations, courses of action for expansion, planned financials, and metrics for success.
- **Development:** Iterative enhancement of the prototype, including testing and evaluation, such that it meets learning outcome expectations. The development step is successful if it increases alignment with probable use cases. This includes considerations of environment requirements (e.g., access to electricity, support personnel needed, facility security level) in deployed settings,

[12] According to Chairman of the Joint Chiefs of Staff Manual 3500.03E, tier 1 emphasizes national forces and combatant command–level organizations and the strategic- and operational-level mission and mission environment and focuses on integrating the efforts of various agencies, nongovernmental organizations, and international partners. Tier 2 emphasizes the Joint Task Force level and the operational-level mission and mission environment and focuses on preparing national or international organizations to unify their efforts for a specific mission and/or mission environment. Tier 3 emphasizes the functional and service component level and the operation-level mission and mission environment and focuses on the ability of systems, units, and/or forces to operate in an interagency, nongovernmental, or international environment. Tier 4 emphasizes the individual unit level and the tactical-level mission and mission environment and focuses on basic technical and operational capabilities in support of Joint Force Commanders (Chairman of the Joint Chiefs of Staff Manual 3500.03E, *Joint Training Manual for the Armed Forces of the United States*, Joint Chiefs of Staff, April 20, 2015).

improvements in the feasibility of production, and the creation and validation of learning content. There must be clear benchmarks outlined in the business plan to enable the decision of whether to further pursue the technology or to move forward with scaled manufacturing.

- **Scaled manufacturing:** The building out of the end product and, in the case of an information product, the means to deliver for a large population of end users. This step is successful if manufacturing is completed with acceptable defects and validated with consideration of the end user environment.
- **Deployment:** The end product is delivered to the consumer but is not explicitly utilized. This step is successful when the training technology is made available for end users according to the schedule specified in the business plan.
- **Utilization:** Use of the training technology by learners. Utilization is successful when the intended training audience both conducts training with the technology and collects and records metrics that capture the effectiveness of the technology.
- **User buy-in:** The acceptance by the community of end users that a training technology is worthwhile and desirable over other learning methods. This step is assessed by measuring the engagement and satisfaction of learners. Success at this step requires that such an assessment be conducted and that options are available if user buy-in is low.
- **Return on investment (ROI) and effectiveness:** Determining whether the desired learning outcomes are being achieved at a sustainable and reasonable cost. This step is successful if appropriate metrics can be established and measured and are accompanied by benchmarks to guide decisions for expanding or discontinuing the technology.
- **Expansion:** The increases in the training technology capacity or accessibility such that more end users might learn from established content or the content itself might be expanded. Expansion is successful when it is accompanied by the requisite materiel and supporting infrastructure and personnel.

These ten steps form a straightforward flow that brings a training technology from concept to use by learners across the DAF. Iteration within the process occurs, especially at the development step, and the entire process deliberately repeats after the value of all activities has been ascertained. The T3D framework is based on existing technology transfer literature that is agnostic to the type of technology, and the framework pulls in DAF training and education specifics that distinguish it from prior frameworks. These specifics become more apparent in the later steps and include ways to think about ROI or effectiveness for DAF training and learning and the types of education and learning communities and organizations that exist in the DAF (e.g., Air Education and Training Command [AETC]). Now that the process is described, we discuss practices that might hamper or help T3D.

Understanding Enablers and Barriers at Each Stage of the DAF Training Technology Transfer Process

To identify enablers and barriers to the T3D process, we conducted a literature review of academic, government, and industry studies and combined findings with information gathered from stakeholder subject-matter expert (SME) discussions.

For the literature review, we reviewed 62 documents, including academic and government studies on technology transfer and relevant conference proceedings from the Institute of Electrical and Electronics Engineers (IEEE) and Portland International Center for Management of Engineering and Technology to represent perspectives from industry. Relevant literature was identified by searching documents for keywords, particularly "technology transfer," and then filtering results for relevance based on a review of the abstracts. Documents were initially sourced from most-recent years (i.e., 2020 or later), but we expanded the range to the past 15 years, to about 2008, for relevant work that was referenced by recent publications and for government reports to capture perspectives from more organizations.

For each relevant document, the reviewing team member identified recommendations and characterized the findings as either enablers or barriers to the technology transfer process. Enablers and barriers were further categorized to indicate whether they occur on the supply side or the demand side of the technology transfer process. We define *supply-side factors* as factors that are inherent in technology developer organizations or the technologies themselves, and *demand-side factors* are factors that are inherent in technology consumer organizations.

We combined results from the literature review with technology transfer enablers and barriers reported by stakeholders. We conducted semi-structured interviews with 31 individuals representing different perspectives: AETC (n = 6), U.S. Air Force (USAF) major commands (MAJCOMs) (n = 8), other DAF organizations (n = 11), and other non-DAF organizations (n = 6). The protocol for our interviews can be found in Appendix A. We then performed a thematic analysis on the interview notes to identify common themes defined by our team, which supported our investigation of enablers and barriers to technology transfer. Then, we synthesized the factors identified in the interviews with those derived from the literature review for a total of 51 candidate factors for our framework.

To maximize the utility of our framework, we assessed our initial list of factors based on the criteria commonly used to assess the quality of metrics: measurability, policy relevance, timeliness, and validity.[13] The criteria are defined as follows:

- **Measurability:** whether the factor is something that can be measured and assessed
- **Policy relevance:** whether the factor is something that a decisionmaker (not just the DAF) can do something about
- **Timeliness:** how quickly the measurement of the factor can be incorporated into decisions (i.e., before the process is complete)
- **Validity:** how important the factor is to the success of a technology transfer.

In our assessment, we evaluated each proposed factor according to these criteria on the scale shown in Table 2.1.[14] The assessment eliminated 23 proposed factors, leaving 28 final enabling or

[13] For example, see Stephanie Young, Henry H. Willis, Melinda Moore, and Jeffrey Engstrom, *Measuring Cooperative Biological Engagement Program (CBEP) Performance: Capacities, Capabilities, and Sustainability Enablers for Biorisk Management and Biosurveillance*, RAND Corporation, RR-660-OSD, 2014.

[14] The scale of evaluating the proposed factors is binary because of the level of detail of the proposed factors; a more granular assessment (e.g., high, medium, low) would require making quantitative assumptions that would introduce inconsistencies in the evaluation.

barrier-creating factors.[15] The next subsections walk through the final set of factors that are part of our framework.

Table 2.1. Scale for Assessment of Proposed Framework Factors

Scale	Measurability	Policy Relevance	Timeliness	Validity
High	Required data and information are readily available	Can be changed by a policy lever or decisionmaker	Can be measured quickly or before the end of the technology transfer	Directly affects success of technology transfer
Low	Required data and information would be challenging or infeasible to collect	Is static or unchangeable by a decisionmaker	Can be measured only after completion of technology transfer	Might only be of minor importance

Supply-Side Enablers and Barriers

Supply-side enablers and barriers include personnel, social, and technological factors. These are summarized in Table 2.2 and discussed in the following sections. With the understanding that the lack of an enabler can be viewed as a barrier and the opposite of a barrier can at times be an enabler, here we frame all as enabling factors, keeping in mind that they can be recast as barriers.

Table 2.2. Supply-Side Factors

Category	Factors
Personnel	• Supplier has dedicated technology transfer office (TTO) or function, ideally with marketing experience
Social	• Supplier receives clear, consistent feedback from senior leadership, program, and end user levels • Close geographic proximity facilitates supplier interaction with stakeholders • Supplier establishes early touch points with industry • Inventor and/or technology developer are involved in technology transfer • Recipients are involved during the R&D phase
Technological	• Initial and sustained costs are financially feasible • Technology does not require higher levels of technological expertise • Technology has high maturity (already in use elsewhere versus cutting-edge technology)

[15] For example, one candidate factor, "hindrance from standard acquisition processes," was eliminated for being rated low under policy relevance and timeliness. The underlying rationale for this rating is that the DoD acquisition process is not something users of this framework can change, and the factor might not be measurable early enough to mitigate. Factors that were eliminated but were worth documenting as significant in our assessment are listed in Appendix C.

Personnel

Dedicated TTOs at the supplier can enable the technology transfer process by enhancing the ability of organizations that develop technology to transmit internal knowledge to external parties (called *desorptive capacity*).[16] In a 2006 study of technology transfer events at Air Force Research Laboratory (AFRL), the majority of successful transfers involved a developer organization with a dedicated TTO, and a majority of the failed transfers lacked one.[17] A later study showed that marketing experience can increase the benefit of a TTO; however, both the existence of a TTO and whether it has marketing experience are less important to successful technology transfer than are other factors, such as financial feasibility and support from upper level leadership.[18]

Social Factors

Social factors have been found to be among the most-impactful factors in successful technology transfer.[19] These factors can include clear communication, strong working relationships, and heavy involvement between stakeholders (e.g., DAF leadership, training communities) and technology developers (e.g., science and technology community, contractors). In some cases, the technology developer is the same as the supplier (i.e., the entity that provides the technology to the DAF); however, there are cases in which these are different entities.

An enabling indicator for stakeholder communication is for the technology developer to make sure that they receive clear, consistent feedback from the stakeholders. Strategic guidance from senior leaders helps technology developers structure development around long-term goals; this guidance is particularly important for groundbreaking technologies that might not have a clear near-term military relevance.[20] Similarly, feedback from stakeholder program levels and end user levels helps ensure that the program is being developed consistent with the needs of the end user.[21]

Close relationships between stakeholders and technology developers are another enabling factor in successful technology transfer efforts. Two indicators of a close relationship are early touch points and geographic proximity of the stakeholder to the technology developer, which can facilitate frequent and effective interactions. In a 2015 GAO study of ten Defense Advanced Research Projects Agency

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[16] Desorptive capacity and its corollary, absorptive capacity, will be discussed in more detail later in this chapter (Davy van Doren, Saeed Khanagha, Henk W. Volberda, and Marjolein C. J. Caniëls, "The External Commercialisation of Technology in Emerging Domains—the Antecedents, Consequences, and Dimensions of Desorptive Capacity," *Technology Analysis & Strategic Management*, Vol. 34, No. 3, 2022).

[17] Richard M. Franza and Kevin P. Grant, "Improving Federal to Private Sector Technology Transfer," *Research-Technology Management*, Vol. 49, No. 3, 2006.

[18] Judith Estep and Tugrul U. Daim, "A Framework for Technology Transfer Potential Assessment," *Portland International Conference on Management of Engineering and Technology: Technology Management for Social Innovation, Proceedings*, 2016, p. 2851.

[19] In Estep and Daim (2016), "understanding the recipient"—which can be strengthened by clear stakeholder communication and strong relationships and involvement between stakeholders and developers—was found to be one of the most impactful factors in successful technology transfer (p. 2851).

[20] Richard H. Van Atta, Michael J. Lippitz, Jasper C, Lupo, Rob Mahoney, and Jack H. Nunn, *Transformation and Transition: DARPA's Role in Fostering an Emerging Revolution in Military Affairs*: Vol. 1, *Overall Assessment*, Institute For Defense Analyses, April 2003a, p. 66.

[21] National Research Council, *Accelerating Technology Transition: Bridging the Valley of Death for Materials and Processes in Defense Systems*, National Academies Press, 2004, p. 12.

(DARPA) technology transfer efforts, all five of the successful technology transfer case studies incorporated early stakeholder involvement. In contrast, the five failed transfer case studies included only partial or no early touch points between the stakeholder and the technology developer. The study notes that having a military SME in the technology developer organization—either a program manager with military background or a military liaison officer—facilitates these early touch points and can significantly enrich effective collaboration.[22] A stakeholder's geographic proximity to the technology developer can also facilitate interaction and enable successful technology transfer; however, geographic proximity affects technology transfer outcomes to a much lesser degree than other factors.[23]

Heavy stakeholder and developer involvement during both the development phases and technology transfer phases also enables successful technology transfer. Frequent feedback from stakeholder program levels and working levels is important during technology development to ensure that the technology is developed in a way that is effective and useful to its consumers.[24] Conversely, the expert knowledge possessed by the technology developer is an important factor to aid the technology progress through the technology transfer process.[25]

Technology Attributes

Attributes of the technologies themselves—including affordability, complexity, and maturity—influence the success or failure of a technology transition effort. Along with social factors, Estep and Daim (2016) find the financial feasibility of initial and sustained costs to be one of the most influential factors of successful technology transfer efforts.[26] Related to technology affordability, funding was a major concern voiced by SMEs during our interviews. Funding concerns from the user community were especially prevalent among those in MAJCOM organizations, mentioned by four out of eight MAJCOM SMEs.[27]

Technology transfer outcomes are also affected by the complexity of a technology. As technology becomes more complex, it is increasingly difficult to acquire and involve SMEs that are knowledgeable enough about both the technology capabilities and the customers' needs to facilitate a successful technology transfer.[28]

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[22] GAO, *Defense Advanced Research Projects Agency: Key Factors Drive Transition of Technologies, but Better Training and Data Dissemination Can Increase Success*, GAO-16-5, November 2015a, p. 15.

[23] Jaime Roberto Pohlmann, Jose Luis Duarte Ribeiro, and Arthur Marcon, "Inbound and Outbound Strategies to Overcome Technology Transfer Barriers from University to Industry: A Compendium for Technology Transfer Offices," *Technology Analysis & Strategic Management*, 2022, p. 4; Franza and Grant, 2006, p. 39; Estep and Daim, 2016, p. 2851.

[24] DoD, *Department of Defense Report to Congress on Technology Transition*, July 2007, p. 4; Pohlmann, Ribeiro, and Marcon, 2022, p. 4; Estep and Daim, 2016, p. 2849.

[25] Pohlmann, Ribeiro, and Marcon, 2022, p. 4; Estep and Daim, 2016, p. 2849.

[26] Estep and Daim, 2016, p. 2851.

[27] MAJCOM SMEs, interviews with the authors, December 13, 2022, January 11, 2023, January 25, 2023, and January 30, 2023; AETC SMEs, interviews with the authors, November 28, 2022, and January 18, 2023; non-DAF SMEs, interviews with the authors, January 17, 2023, and January 26, 2023; other DAF SMEs, interviews with the authors, January 6, 2023.

[28] L. L. J. Meijer, J. C. C. M. Hujiben, A. van Boxstael, and A. G. L. Romme, "Barriers and Drivers for Technology Commercialization by SMEs in the Dutch Sustainable Energy Sector," *Renewable and Sustainable Energy Reviews*, Vol. 112, 2019, p. 118.

Finally, technology transfer tends to be more successful when the technology is already mature, i.e., having a higher TRL. Technologies that are already in use elsewhere or that are completely developed and have been proven in tests, demonstrations, and missions (TRLs 8 and 9) carry less risk during acquisition because they require less time and resources to bring the technology to deployability.[29] Although there is no official DoD requirement for a technology to reach a minimum TRL before acquisition, technologies generally reach TRL 6 or TRL 7 before they are considered for adoption.[30] Although a requirement to reach a certain TRL is appropriate for some organizations that desire prompt fielding of a technology, it is perhaps too draconian a requirement for nascent advanced technologies. In practice, many organizations—including DoD—adopt technologies across the full range of TRLs; adopting technologies at a lower level of readiness might happen when the risk of adopting a technology with a lower TRL is offset by greater anticipated benefit or less technical risk.[31]

Enablers and Barriers at Each Stage of the DAF Training Technology Transfer Process

Table 2.2 summarized the supply-side enablers and barriers that comprise personnel, social, and technological factors; Table 2.3 maps where each of these occur in the T3D process.[32]

[29] TRL 6 demonstrates a prototype in a relevant environment; TRL 7 demonstrates in an operational environment. TRL 8 has the "actual system completed and qualified through test and demonstration." TRL 9 has the actual system successful in mission operations (GAO, *Technology Readiness Assessment Guide: Best Practices for Evaluating the Readiness of Technology for Use in Acquisition Programs and Projects*, GAO-20-48G, January 2020, p. 11; Pohlmann, Ribeiro, and Marcon, 2022, pp. 3–5).

[30] GAO, 2020, pp. 14–15.

[31] GAO, *DoD Rapid Innovation Program: Some Technologies Have Transitioned to Military Users, but Steps Can Be Taken to Improve Program Metrics and Outcomes*, GAO-15-421, May 2015b.

[32] This mapping in Table 2.3 and that in Table 2.5 was conducted by two analysts from our team who were familiar with the factor research and the T3D process. Disagreements were resolved by discussions led by a third analyst in our team. These mappings are illustrative and represent a subjective judgment.

Table 2.3. Where Supply Factors Occur in the DAF Training Technology Transfer Process

Factor	Concept	Prototype	Development	Scaled Manufacturing	Business Plan	Deployment	Utilization	User Buy-In	ROI/ Effectiveness	Expansion
Supplier has dedicated TTO or function, ideally with marketing experience	X	X	X	X	X					X
Supplier receives clear, consistent feedback from senior leadership, program, and end user levels		X	X	X		X		X	X	
Close geographic proximity facilitates supplier interaction with stakeholders	X	X	X	X				X		
Supplier establishes early touch points with industry	X	X						X		
Inventor and/or technology developer are involved in technology transfer	X	X	X	X	X				X	
Recipients are involved during the R&D phase	X	X	X					X		
Initial and sustained costs are financially feasible				X	X	X			X	X

Factor	Concept	Prototype	Development	Scaled Manufacturing	Business Plan	Deployment	Utilization	User Buy-In	ROI/ Effectiveness	Expansion
Technology does not require higher levels of technological expertise	X	X	X				X	X		
Technology has high maturity (already in use elsewhere versus cutting-edge technology)	X	X	X	X					X	

Demand-Side Barriers and Enablers

The demand-side enablers and barriers, summarized in Table 2.4, include considerations of ROI, the ability of DAF organizations to take in external knowledge (i.e., absorptive capacity), processes, and financial factors. Descriptions of the indicators for each of these areas are in the following subsections.

Table 2.4. Demand-Side Factors

Category	Factors
ROI	• Learning impact based on technology is easy to determine • Metrics can track benefits and implementation of technology • Gains (e.g., productivity, quality, learning faster) outweigh costs (e.g., retooling, training)
Absorptive capacity	• Technical capabilities or resources for operationalization are available • Technology has good alignment with end user language and staffing • A transition strategy exists for tools, culture, and people • End users have existing knowledge and experience of the technology (i.e., technology literacy) • Technology has endorsement from senior leader (i.e., champion), program managers, and intended users • Technology is in an area of sustained interest
Processes	• A clear prioritization of requirements is established • Technology requirements are consistent during development • The TRL appropriate for each stage is determined • Formal transition agreements align requirements to technology • There is a clearly defined business plan (e.g., refresh rates, implementation) • The risk, cost, and schedule (e.g., scope creep, technology transition timeframe) are managed • Consumer efforts are coordinated and well communicated throughout the organization • Records are kept of deliverables or activities to avoid loss (e.g., knowledge, key data rights)
Financial	• Government incentives for the developer or supplier (e.g., exclusive licenses) are used • Supplier has the ability to share technology (e.g., data rights)

Return on Investment

There can be difficulty associated with collecting the right metrics to inform the ROI of a training technology. One challenge stems from training and military programs not having an overall, quantitative metric to gauge performance (e.g., profit in the commercial sector). Another challenge in measuring a learning-oriented ROI arises from the impact that a specific human trainee or training audience (e.g., background and personal aptitudes) can have on learning outcomes on top of the independent effect of the training technology that delivers the content. This echoes a knowledge barrier to ROI: Measuring improvements in test scores, reduced training cost, or reduced training time might inform the technologies effectiveness, but it does not directly inform whether the military

has achieved "enhanced operational effectiveness" from that training improvement.[33] For additional discussion on ROI, please see Appendix B.

We identified two enablers for ROI. The first is having established metrics that can track the benefits and the implementation of the technology. This factor focuses on metrics again, but this time in the context of technology transfer itself. Historical technology transfer metrics include the filing ratio and transfer rate, which indicate how many inventions an organization files patents for and the number of patents that have been granted licenses, respectively. This measure might make sense for the first part of the proposed T3D framework but falls flat because it fails to capture the many pitfalls a new technology might face before it is used by consumers. Instead, tracking the rate of progress through the T3D framework might indicate the rate of progression and thus the process efficiency. One can also extract the presumed benefits of a technology—within the context of use cases—along this timeline, which would also inform the intangible benefits that feed into this larger definition of ROI.[34] The second enabler is that the gains should outweigh costs to have a positive ROI, in the more traditional sense of a cost-benefit analysis. With advanced technology, it becomes especially critical to identify and weigh the costs dealing with the installation, adoption, and institutionalization of that technology. Equally capturing the benefits—which can be opaque for a new technology—must be done with enough confidence to overcome these costs.[35]

Absorptive Capacity

Absorptive capacity is an academic concept that describes the ability of an organization to take in external knowledge.[36] For example, an organization needs the technical capacity and skill to identify and pursue opportunities "advertised" by technology developers, but there must also be resources and leadership support to seek out or understand these technologies when presented. Increasing absorptive capacity is within control of the DAF because absorptive capacity characterizes the ability to discover, understand, and accept technology transfer from external organizations.

Although a goal to increase absorptive capacity can be achieved at a lower-echelon level, an overarching TTO might improve absorptive capacity at the DAF level while offering mechanisms for external parties to improve their own desorptive capacity. The enablers and barriers we identified center on either operationalizing absorptive capacity or increasing buy-in among stakeholders. Without the technical expertise or resources early in the technology transfer, it will be difficult to gain the benefit of aligning a technology to end-use cases or arranging a coherent strategy to transition the technology to end users (who likely will not have the same in-depth knowledge on how the technology transfer works or why it was obtained).[37]

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[33] Robert Foster and J. D. Fletcher, "Toward Training Transformation," *Military Psychology*, Vol. 25, No. 3, 2013.

[34] Vidita Choudhry and Todd A. Ponzio, "Modernizing Federal Technology Transfer Metrics," *Journal of Technology Transfer*, Vol. 45, 2020.

[35] Thomas F. Reid, "Technology Transfer Is Not Just Training," *Proceedings of 6th International Workshop on Computer-Aided Software Engineering*, 1993.

[36] van Doren et al., 2022.

[37] Adam Mazurkiewicz, Tomasz Giesko, Beata Poteralska, and Kim Hua Tan, "Crossing the Chasm: Overcoming Technology Transfer Barriers Resulting from Changing Technical Requirements in the Process of Innovation Development in R&D Organisations," *Technology Analysis & Strategic Management*, Vol. 34, No. 10, 2022; Ribeiro and Marcon, 2022; Reid, 1993.

Buy-in from all echelons of stakeholders (champions, implementers, and end users) sets conditions to increase the DAF's overall absorptive capacity. However, if those stakeholders do not have the technical literacy to absorb the technology transfer, that can lead to lack of interest, suspicion, and communication failures.[38] Endorsement from stakeholders, especially in technology areas where there has been sustained interest, can enable successful technology transfer. This endorsement should come early and can take the form of advocacy or funding. Regardless of the medium, endorsements should be clear and articulate the stakeholders' commitment to the technology.[39]

Processes

Within the processes category, the DAF can influence several factors related to requirements and selection, which are key at the onset of a technology transfer but also aid the process as it progresses. Regarding requirements, several government sources, including DARPA, GAO, and DAF interviews, underscored how a clear prioritization of requirements helped with technology transfer.[40] Another source noted that when technology requirements change during development, this has adverse effects on the technology transfer.[41] In terms of the selection process for technologies, we identified three enablers that speak to setting expectations and vetting of the supplier for the technology transfer. First, it is important to determine the TRL appropriate for each stage of the technology transfer to provide specific development benchmarks; for the case of T3D, the DAF can set this benchmark.[42] Second, the DAF can also make formal transition agreements that align requirements to the technology.[43] Lastly, it is important to have a clearly defined business plan associated with the technology, to lay out future expectations, such as implementation and technology refresh rates.[44] Such a business plan is something the DAF can assess from potential technology suppliers during the selection process.

Another important consideration related to processes is program management, which becomes relevant in the latter part of the technology transfer process. Program management includes the management of risk, cost, and schedule to avoid such problems as scope creep and expanding timeframes.[45] However, related to scope creep and the earlier point about keeping requirements fixed,

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[38] da Silva et al., 2021.

[39] This commitment does not imply that stakeholders are not allowed to be critical of the technology or its progress through the technology transfer (GAO, 2015a; GAO, *Defense Technology Development: Technology Transition Programs Support Military Users, but Opportunities Exist to Improve Measurement of Outcomes*, GAO-13-286, March 2013a).

[40] Richard H. Van Atta, Alethia Cook, Ivars Gutmanis, Michael J. Lippitz, Jasper Lupo, Rob Mahoney, and Jack H. Nunn, *Transformation and Transition: DARPA's Role in Fostering an Emerging Revolution in Military Affairs*: Vol. 2, *Detailed Assessments*, Institute for Defense Analyses, November 2003b; Van Atta et al., 2003a; GAO, *Small Business Innovation Research: DoD's Program Supports Weapons Systems, but Lacks Comprehensive Data on Technology Transition Outcomes*, GAO-14-96, December 2013b; GAO, 2015a.

[41] Mazurkiewicz et al., 2022.

[42] Van Atta et al., 2003a; Van Atta et al., 2003b; DoD, 2007; GAO, 2015a; GAO, 2015b.

[43] Marcy E. Gallo, *Small Business Research Programs: SBIR and STTR*, Congressional Research Service, August 2021b; GAO, 2013a; GAO, 2013b; GAO, 2015a; GAO, 2015b.

[44] Estep and Daim, 2016.

[45] Van Atta et al., 2003a; Van Atta et al., 2003b; Marcy E. Gallo, *Defense Advanced Research Projects Agency: Overview and Issues for Congress*, Congressional Research Service, August 19, 2021a; GAO, 2013b; GAO, 2015a.

there is a trade-off in that some flexibility in requirements can better accommodate changes in training needs (e.g., ensure that the training content is still relevant).[46]

In terms of barriers, a stakeholder interview brought up that innovation efforts for different technology consumers (i.e., different training communities across MAJCOMs) can be fragmented and not well-communicated across the organization (e.g., DAF or DoD), which hampers the spread of successful pockets of innovation in training. A related barrier under program management occurs when proper records are not kept for technology deliverables or activities, which can result in loss of knowledge or key operational pieces, such as data rights.[47]

Financial

The DAF can address the financial factors we identified through contracting with the technology supplier. One potential technology transfer enabler would be for the government to provide a financial incentive to end users for implementing the technology from a specific developer or supplier to increase the appeal of using the technology in the DAF.[48] A potential barrier would be if the seller of a technology has a limited ability to share the technology to a wide audience, for example, if data rights are restricted.[49]

Mapping Demand Factors to the T3D Process

In Table 2.5, we indicate which step each enabler is relevant to within the T3D process.

[46] Michael G. Shanley, James C. Crowley, Matthew W. Lewis, Susan G. Straus, Kristin J. Leuschner, and John Coombs, *Making Improvements to The Army Distributed Learning Program*, RAND Corporation, MG-1016-A, 2012.

[47] A loss of data rights could later result in barriers to updating or expanding the use of the technology because the data that were leveraged before can no longer be accessed. See Choudhry and Ponzio, 2019.

[48] Estep and Daim, 2016.

[49] da Silva, 2021.

Table 2.5. Where Demand Factors Occur in the DAF Training Technology Transfer Process

Factor	Concept	Prototype	Development	Scaled Manufacturing	Business Plan	Deployment	Utilization	User Buy-In	ROI/ Effectiveness	Expansion
Learning impact based on technology is easy to determine					X				X	
Metrics can track benefits and implementation of technology					X	X	X	X	X	X
Gains (e.g., productivity, quality, learning faster) outweigh costs (e.g., retooling, training)				X	X				X	
Technical capabilities or resources for operationalization are available	X	X	X	X		X	X	X		
Technology has good alignment with end user language and staffing				X		X	X	X		X
Transition strategy exists for tools, culture, and people							X	X		

Factor	Concept	Prototype	Development	Scaled Manufacturing	Business Plan	Deployment	Utilization	User Buy-In	ROI/ Effectiveness	Expansion
End users have existing knowledge and experience of the technology (i.e., technology literacy)			X		X		X	X		
Technology has endorsement from senior leader (i.e., champion), program managers, and intended users	X	X	X			X		X		
Area of sustained interest					X		X	X		X
Clear prioritization of requirements			X		X					
Consistent technology requirements during development			X	X						X
Determine TRL appropriate for each stage					X					
Formal transition agreements align requirement to technology					X					

Factor	Concept	Prototype	Development	Scaled Manufacturing	Business Plan	Deployment	Utilization	User Buy-In	ROI/ Effectiveness	Expansion
Clearly defined business plan (e.g., refresh rates, implementation)		X			X			X	X	
Manage risk, cost, and schedule (e.g., scope creep, technology transition timeframe)			X	X	X	X				
Consumer efforts are coordinated and well communicated throughout organization	X	X			X		X			X
Records are kept of deliverables or activities to avoid loss (e.g., knowledge, key data rights)			X	X	X				X	
Government incentives for the developer or supplier (e.g., exclusive licenses)	X	X			X					
Supplier has the ability to share technology (e.g., data rights)				X		X				X

Conclusion

To successfully transition a training technology into the DAF training and education enterprise, there is a process that moves the technology, or combination of technologies, from concept to implementation such that ROI and effectiveness can be realized and measured. Our framework defines each of the steps and cyclical pathways of the comprehensive T3D process, which in large part can be generalized to non-training-specific technology transfer. The framework also identifies and organizes enabling factors relevant at each process step that can be considered for troubleshooting or planning purposes.

The framework can be used at the enterprise level to examine all DAF training technology transfers to identify where common bottlenecks appear and what enterprise policy adjustments can be made to eliminate the bottlenecks. It can also be used for an individual technology transition case to troubleshoot transition issues and plan ahead for factors that might need mitigation. In either case, to use the framework, the user would first identify the step in the process that is of interest and then use the mapping of process steps to enablers to examine the options for what barriers to mitigate for and what enablers to enhance. In the next chapter, we examine several use cases for advanced training technologies and discuss how real-world barriers and enablers affected, or are affecting, their transition into DoD.

Chapter 3

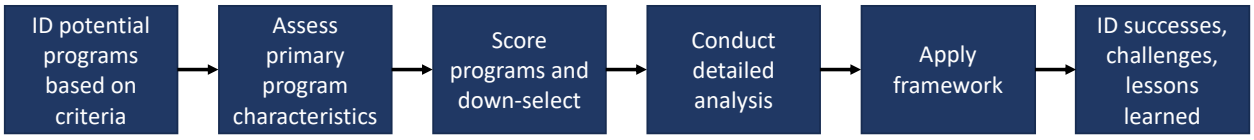
Applying the Framework to Use Cases

The framework in this report was formulated with training technologies in mind but has more general applicability. Similarly, the enablers and barriers identified in the previous chapter are technology agnostic. Following an initial assessment of various training technology programs, we conducted a series of case studies to assess the utility of the T3D framework. These case studies serve both to validate the framework and to illustrate how T3D enablers and barriers have influenced technology transfer success in a set of DoD programs that employ advanced training technologies.

Approach

To compare the framework with real-world use cases and assess how it stands up from those perspectives, we reviewed R&D programs (and corresponding systems), assessed a broad set of those programs, and selected six use cases. Figure 3.1 shows the steps of the selection of candidate programs and the down-selection process of identifying the actual use cases.

Figure 3.1. Use Case Analysis Process



Review of Programs Across DoD as Basis for Use-Case Selection

Through review of open-source literature and discussion with SMEs, we identified and assessed 37 candidate advanced-training DoD R&D programs across the services and joint community, using the following criteria:

- potential for use to validate the proposed T3D framework
- ability to demonstrate lessons-learned for future programs
- ability to reflect both successful and failed transfers[50]
- incorporation of different advanced learning technologies.

[50] The intent was to form a set of programs, some of which were generally successful and some of which were less successful with respect to technology transfer within the respective service.

These candidate programs are listed in Appendix D. We then coded and characterized each program based on the following metrics:

- advanced technologies (selected from the set in Appendix D) used by the relevant system
- DoD organization responsible for developing and transitioning the program
- technical developer
- user group (the primary DoD organization either using or having plans to use the system)
- relevant training tier[51]
- whether the system is commercial off-the-shelf (COTS)
- technology transfer benchmark (whether a program is a program of record [POR] at the point of advanced technology deployment and/or formally fielded).

This step in the process not only reflected the initial step in identifying use cases but also involved analysis of a broad set of programs involving the advanced training technologies listed in Appendix D.

Use Cases Selected to Capture Important Variation in Technology Development and User Communities

Given a comparison matrix that characterized the 37 programs, we scored each program subjectively from 1 to 3. A score of 1 indicated that the program was not appropriate as a case study, a score of 2 indicated that the program met some of the selection criteria to be a case study, and a score of 3 indicated that the program was appropriate as a case study. If there were differences between team members' scores, the average score was used (see Appendix D for average program scores). The selection criteria that informed the program scores were as follows:

- reflects a broad use of various technologies
- reflects different types of programs (i.e., different types of training systems)
- reflects work by various DoD organizations in different services
- reflects different types of developers (e.g., companies of various size and sectors)
- involves programs at various stages of development and technology transfer.

We selected the use cases based on these scores, as well as direction from the sponsor to include the Joint Simulation Environment (JSE) program and to include at least one program from the U.S. Space Force (USSF).

The programs selected as use cases are shown in Table 3.1 and are listed generally from less mature to more mature phases of transition.

[51] Chairman of the Joint Chiefs of Staff Manual 3500.03E, 2015.

Table 3.1. Selected Use Cases

Program	Description	DoD Owner	Technology Transfer Step
Generalized Intelligent Framework for Tutoring (GIFT)	Open architecture; open-source framework for creating, delivering, and managing adaptive training	U.S. Army Combat Capabilities Development Command (DEVCOM)	Prototype/ development
Synthetic Training Environment–Information System (STE-IS)	Collective training capability to enable leaders, soldiers, and units to train in relevant, complex environments alongside partners; composed of One World Terrain (OWT),[a] training simulation software, and training management tools	Army Synthetic Training Environment Cross-Functional Team (CFT)/Program Executive Office (PEO) Simulation, Training, and Instrumentation (STRI)	Development
JSE	Scalable, expandable, high-fidelity modeling and simulation environment for fifth-generation testing and training that can integrate with training federations[b] and ultimately incorporate live, virtual, and constructive (LVC) (currently just virtual and constructive) elements[c]	U.S. Navy/USAF	Development/ scaled manufacturing
Standard Space Trainer (SST)	Space command and control operator simulator for controlling different virtual space weapon systems; simplifies and integrates all training components into one system	USSF/Space Training Acquisition Office (STAO)	Developing/ deployment
Special Operations Center for Medical Integration and Development (SOCMID)	Center that provides facilities for training, recertification programs, and some R&D for medics and pararescue specialists, using physical training aids and the Virtual Advancement of Learning and Operational Readiness (VALOR)	24th Special Operations Wing (Joint)	Expansion/ ROI/ effectiveness
Integrated Technology Platform (ITP)	AR and VR capabilities for aircraft and vehicle maintenance and operations training	USAF AETC	Expansion

[a] OWT includes a 3D global terrain capability and associated information services that support a fully accessible virtual representation of the physical Earth accessible through the Army network (U.S. Army, "One World Terrain (OWT)," PEO STRI, webpage, undated).

[b] In this context, a software federation is an architecture that supports integration and concurrent use of multiple underlying software systems (federates).

[c] Live training involves real people operating real systems in the context of a military training scenario. Virtual training involves real people operating simulated systems. Constructive training is used in conjunction with simulations; it involves computer-generated entities with simulated actors operating simulated systems. The LVC concept often refers to a system that combines all three elements. However, it is sometimes used to refer to systems that use only one element, a combination of virtual and constructive elements in a "synthetic" environment, or a "blended" combination of virtual or constructive elements with live elements (Emmi Yonekura, Tim Marler, Brian Dolan, Ajay K. Kochhar, David Schulker, Carra S. Sims, Charles Barton, Karen Schwindt, and Moon Kim, *Training Guardians for the Fight: Leveraging Live, Virtual, and Constructive Systems for U.S. Space Force Readiness*, RAND Corporation, forthcoming, Not available to the general public).

Analysis of Use Cases Using the DAF Training Technology Transfer Framework

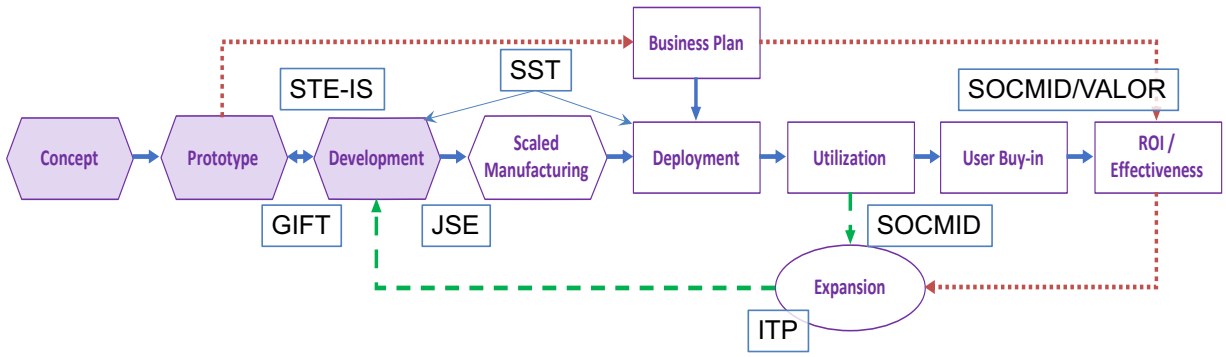
Once we identified the set of use cases based on the process outlined above, we reviewed the characteristics of these programs further. This involved three stages: (1) additional literature review to refine the metrics listed above; (2) site visits, demonstrations, and engagement with program-specific SMEs; and (3) application of the enabler-barrier framework discussed in Chapter 2. We coded the use cases using the factors discussed in Chapter 2. We considered primarily those enablers and barriers from Tables 2.3 and 2.5, which aligned with the current stage of the program being considered.

Results: Analysis of Use-Case Programs

Technology Transfer Status

In the first step in the analysis of the use cases, we mapped each of the use-case programs onto the technology-transfer timeline, as shown in Figure 3.2.

Figure 3.2. Technology Transfer Status of Use-Case Programs



Any timeline is critical for assessing and communicating the status of a program, but, especially with software, programs might align with different stages of the framework concurrently (e.g., SOCMID, SST). SOCMID is primarily a training center, and VALOR is used for recertification and, to some extent, training-related R&D. SOCMID is fully constructed and in use at the University of Alabama Birmingham Hospital for the 24th Special Operations Wing. However, it is still growing, and there is interest in broadening the user base and consequent buy-in. SST is essentially a modular software system. The program began approximately 20 years ago, around 2003, and aspects of SST have been fielded broadly and are in use across the USSF. However, the overall program is still working toward a minimal viable product and is not yet fully deployed. ITP has completed a full development cycle and is fielded at approximately 120 units across DoD, but it is currently at different stages in the framework depending on where it is being used.

In addition to our findings of ambiguity of the actual developmental stage of a particular program, we found that SMEs themselves might differ slightly in their assessment of the state of a particular

program. This ambiguity can make program management more complex. For instance, there are different enablers to consider depending on what step a program is on in the technology transfer process. If there is a lack of agreement on where the program is in the process, program managers or innovation managers might find it difficult to determine which enablers to focus on.

The subsequent sections provide an overview of each use case (shown in Figures 3.3 to 3.8) and identify each case's state of technology transfer, successes and lessons learned, and challenges. Each use case is then discussed in detail, followed by the applications of the framework discussed in Chapter 2. In some cases, barriers and enablers identified during SME interviews are more specific or highlight a new factor that was not one of the factors listed in our T3D framework. These are indicated, as needed, in the tables that capture enablers and barriers in the discussions that follow.

Generalized Intelligent Framework for Tutoring

GIFT is an online framework of tools, methods, and standards that was created to support adaptive instructional systems (AIS).[52] It is effectively an intelligent tutoring software system that helps improve learning and allows curriculum developers to customize digital curriculum and syllabi and export for students.[53] GIFT was initially a framework to support R&D. It focused primarily on the benefits of intelligent tutoring and adaptive instruction and how such tutoring systems could be applied within Army training domains. Currently, GIFT is developed around course objectives, which are used to structure the learning experience (e.g., the ordering of a sequence of learning events, how a learner will interact with the system and other learners).[54] The development of GIFT is led by Adaptive and Intelligent Training Systems at the Learning in Intelligent Tutoring Environments Laboratory, which is part of the U.S. Army DEVCOM Soldier Center's Soldier Effectiveness Directorate.[55] Figure 3.3 contains an overview of GIFT.

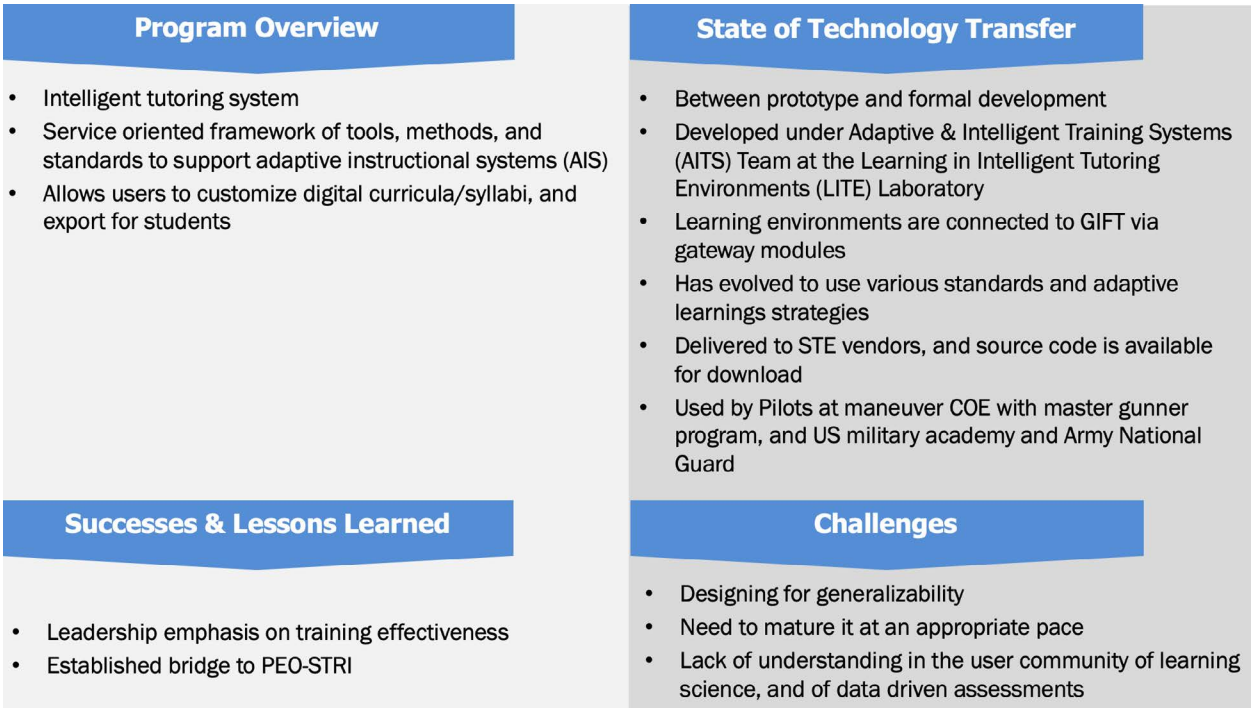
[52] GIFT Tutoring, "Overview," webpage, undated. An AIS is an instructional approach meant to accommodate different individuals' learning styles with multiple teaching methods that can be tailored to each individual.

[53] SME, interview with the authors, July 10, 2023.

[54] Robert A. Sottilare, Keith W. Brawner, Benjamin S. Goldberg, and Heather K. Holden, "The Generalized Intelligent Framework for Tutoring (GIFT)," U.S. Army Research Laboratory–Human Research & Engineering Directorate, 2012.

[55] GIFT Tutoring, undated.

Figure 3.3. Overview of Generalized Intelligent Framework for Tutoring



NOTE: COE = Center of Excellence.

GIFT's state of technology transfer is between the prototype and formal development stages. Although development is not yet complete, GIFT is readily available for download.[56] Users can find learning environments connected via gateway modules. GIFT has evolved to use various standards and adaptive learning strategies. The program emphasizes personalization and adaptation, allowing for broad ownership and use. It is currently used by helicopter pilots at the Maneuver Center of Excellence in its master gunner program and by the U.S. Military Academy and the Army National Guard.[57]

GIFT has reportedly provided an initial successful alternative to traditional approaches to training and has received anecdotal praise from leadership for its training effectiveness.[58] It has also played a role in establishing a bridge of communication with the Army training proponent office and acquisition partners at PEO STRI.[59]

Despite its overall success, GIFT faces several challenges. SMEs noted that, despite the program's name, effective system design for generalized use can be challenging. There can be insufficient understanding of learning sciences and the value of data-driven and personalized assessments.[60] Consequently, stakeholders might simply invest in higher fidelity visualization and capabilities when

[56] GIFT Tutoring, undated.

[57] SME, interview with the authors, July 10, 2023.

[58] SME, interview with the authors, July 10, 2023.

[59] SME, interview with the authors, July 10, 2023.

[60] SME, interview with the authors, July 10, 2023.

they might not be necessary.[61] This is sometimes enabled by design documents and requirements that are too "shallow," with insufficient information.[62]

Table 3.2 shows the results of applying the framework detailed in Chapter 2 and identifies supply and demand enablers and barriers. Supply-side enablers for GIFT include availability and customizability of source code that is readily available for download. However, GIFT has only been used by small community of users thus far, and SMEs noted that GIFT needs to be matured to encourage wider use.

On the demand side, users have emphasized its effectiveness, and customization allows users to target specific needs.

Table 3.2. Enablers and Barriers for Generalized Intelligent Framework for Tutoring

	Supply Side	Demand Side
Enabler	• Source code is available for download[a]	• Users emphasized data and training effectiveness
Barrier	• Technology still has room to mature	

[a] Factor was identified during discussions with SMEs but is not part of the T3D framework.

Synthetic Training Environment–Information System

STE-IS is a collective training capability that enables leaders, units, and soldiers to train as they fight, with the partners they will fight with, within operational environments (desert, urban, woodland, jungle, and sub-terrain) before the fight begins.[63] It is supported by a variety of vendors and led by PEO STRI under the STE CFT. STE-IS comprises OWT, the Training Simulation Software, and the Training Management Tools.[64] As part of STE-IS, the Reconfigurable Virtual Collective Trainer allows units to train using Combined Arms Training Strategies collectively.[65] The Squad Immersive Virtual Trainer is the immersive training capability delivered as part of the Integrated Visual Augmentation System (IVAS) for the close combat squads that enables IVAS to be a fight, rehearse, and train platform. STE Live focuses on developing 11 engagement types and five instrumentation enablers.[66] Figure 3.4 contains an overview of the STE-IS.

[61] Susan G. Straus, Matthew W. Lewis, Kathryn Connor, Rick Eden, Matthew E. Boyer, Timothy Marler, Christopher M. Carson, Geoffrey E. Grimm, and Heather Smigowski, *Collective Simulation-Based Training in the U.S. Army: User Interface Fidelity, Costs, and Training Effectiveness*, RAND Corporation, RR-2250-A, 2019.

[62] SME, interview with the authors, July 10, 2023.

[63] William Gullion and William Lybrand, 1st Security Force Assistance Brigade, "Synthetic Training Environment: Forging the New Frontier," U.S. Army, August 14, 2023.

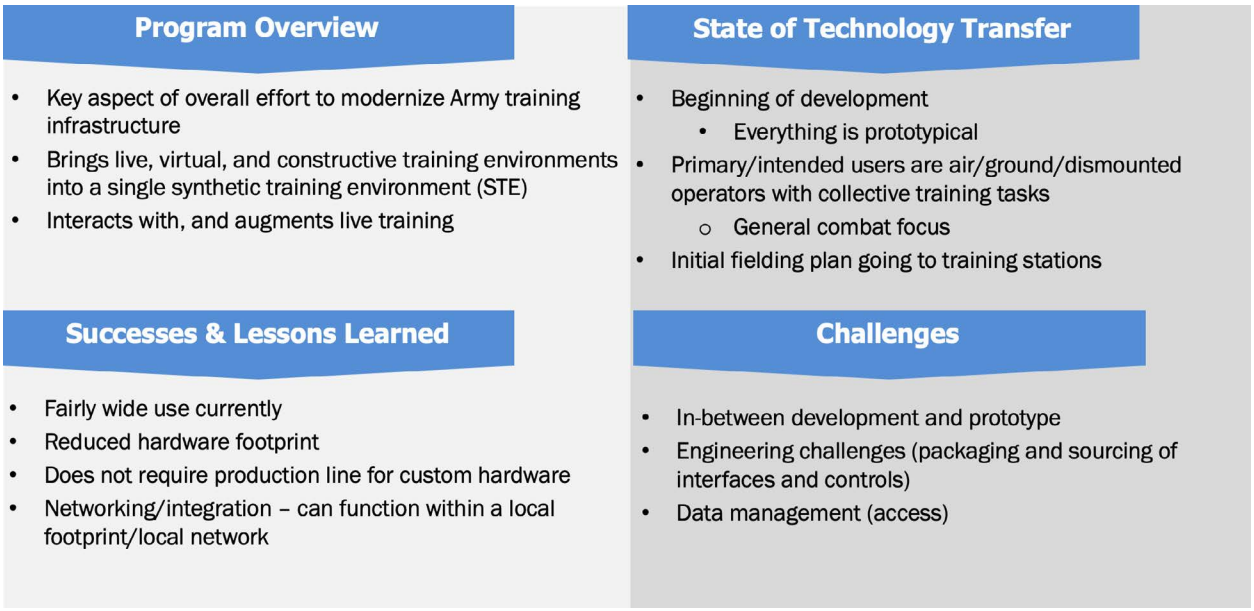
[64] PEO STRI Public Affairs, "PEO STRI Offers Platform Development Kit to Streamline STE Product Development," press release, March 10, 2022.

[65] SME, interview with the authors, July 14, 2023.

[66] U.S. Army, "Department of Defense Fiscal Year (FY) 2024 Budget Estimates," March 2023. The engagement types are autonomous weapons, counter-defilade fire, cyber, direct fire, directed energy, dropped objects, guided weapons, indirect fire, placed objects, plume, and radiant energy. The instrument enablers are calculations, networks, sensors, terrains, and transmitters.

STE-IS's state of technology transfer is not clear cut, but the program is roughly in the development step. Most existing capabilities are considered prototypes, but these prototypes are considered mature enough for initial deployments to Army installations that conduct training. The intended audience is air, ground, and dismounted operators with collective training tasks. The first formal rollout is planned for 2024.

Figure 3.4. Overview of Synthetic Training Environment–Information System Use Case



Despite being relatively early in the technology transfer cycle, STE-IS is in use and has reportedly been successful. This success is attributed to its ability to advance training by providing repetition at the point of need for improved proficiency, thus improving soldier survivability and lethality. As a simulation-based training system that functions much like a video game, STE-IS does not rely on hardware in the same way that, for example, a physical flight simulator might. It does not require a traditional production line for hardware that has to be customized to ensure concurrency with an associated real, physical system. STE-IS also allows each user the ability to use different VR headsets, reduces hardware needs, and addresses integration challenges associated with running systems on a local network.[67]

Despite its maturity, challenges for STE-IS remain. One such challenge has been implementing value-added haptic feedback. Some aspects of medical training, in particular, can benefit from haptic feedback, and STE will eventually include medical-training capabilities.[68] Additionally, there is a need for an instrumented system to collect the right data with the right tags for an effective after-action review.

[67] SME, interview with the authors, July 14, 2023.

[68] SME, interview with the authors, July 14, 2023.

Table 3.3 shows the results of applying the technology transfer framework to the STE-IS program and highlights supply-side and demand-side enablers and barriers. Supply-side enablers for STE-IS include scalability and affordability.[69] SMEs note that the program has scaled the software to be more efficient and reduce the necessary hardware. STE-IS is also reportedly more affordable and accessible than live training. Regarding supply side barriers, there is limited access to authoritative sources of threat, environment, and learning data to build scenarios that achieve specific learning objectives.

On the demand side, STE-IS does not require a production line for custom hardware; users can integrate their own devices. There is added buy-in, because there has been significant progress with providing networking and system integration. STE-IS can function on a local network or across the Army network.[70] However, STE-IS still has room to mature and address the challenges noted.[71] One SME noted the need to integrate haptic feedback for some types of training. Although there are plans to address this need, it is not a high priority.[72]

Table 3.3. Enablers and Barriers for Synthetic Training Environment–Information System

	Supply Side	Demand Side
Enabler	• Technology can grow in scalability[a] • Technology is affordable with less hardware and ability to use own headset	• Users can integrate their own devices • End users have buy-in
Barrier	• Technology still has room to mature • Technology development requires highly complex engineering[a]	• Users have limited access to data

[a] Factor was identified during discussions with SMEs but is not part of the T3D framework.

Joint Simulation Environment

JSE is a scalable, expandable, high-fidelity, government-owned modeling and simulation environment, as summarized in Figure 3.5.[73] It is currently used at Naval Air Station Patuxent River (Pax River), with plans for implementation at Nellis Air Force Base (for tactics and training) and Edwards Air Force Base (for test and development). It is an advanced test and training environment for fifth-generation aircraft, and it can integrate legacy training federations and LVC capabilities. However, JSE does not currently provide a complete LVC solution; it involves only integrated virtual and constructive capabilities. It is used primarily for advanced training and is typically employed as an "eight ship" (eight simulators being used together collectively). It is often paired with the Next

[69] SME, interview with the authors, July 14, 2023.

[70] SME, interview with the authors, July 14, 2023.

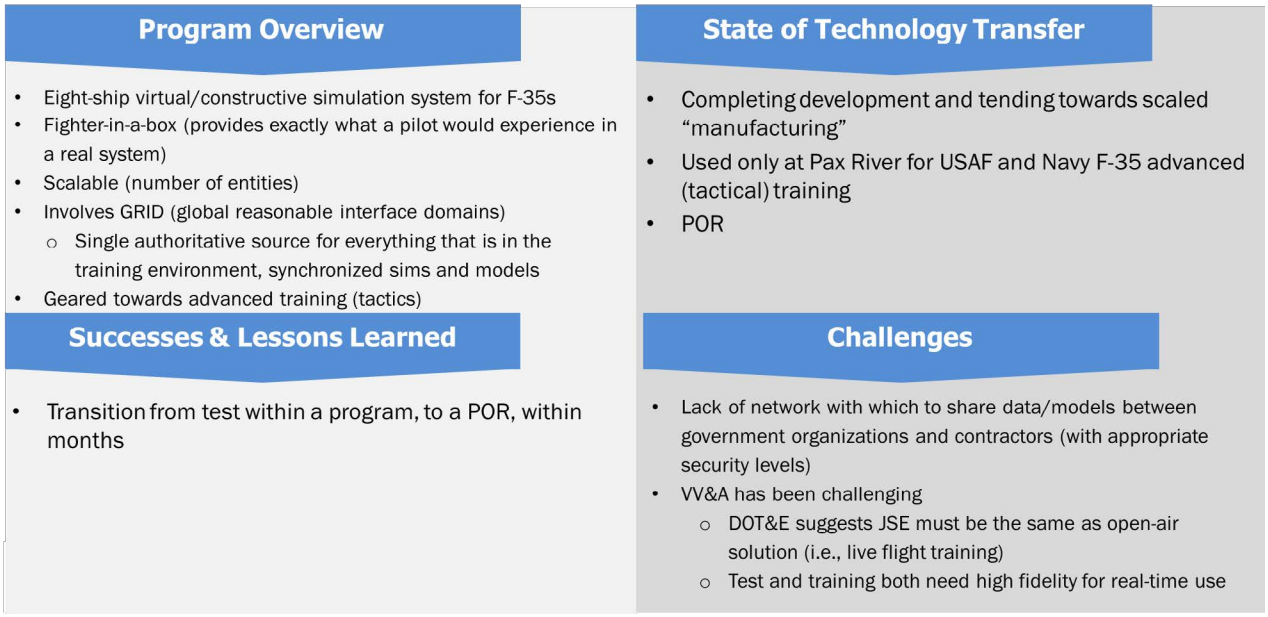
[71] SME, interview with the authors, July 14, 2023.

[72] SME, interview with the authors, July 14, 2023.

[73] Giancarlo Casem, "Joint Simulation Environment Inches Closer to Reality," U.S. Air Force, January 24, 2019.

Generation Threat System (NGTS),[74] and it is an enabling requirement for the USAF's broader Strategic Tanker Transport Capability concept.

Figure 3.5. Overview of Joint Simulation Environment Use Case



NOTE: DOT&E = Director, Operational Test and Evaluation; VV&A = verification, validation, and accreditation.

JSE comprises six primary components: an extensible and modular software battlespace environment; a physical computing infrastructure that implements the battlespace; one or more simulated platforms that constitute the system under test; cockpits and visual display systems that provide the pilot interface; planning, control, and briefing rooms that facilitate mission execution; and an overarching facility that contains all of the above and the manpower to operate it.[75]

The novelty of JSE entails a combination of capabilities. First, it provides a "fighter in a box" for the F-35 weapon system, which means JSE provides exactly what a user would expect from a real F-35 with respect to system control and operation. Second, JSE provides significant simulations at scale; a user can interact with a relatively large number of entities within the virtual environment. Third, it uses the global reference interface domain to synchronize simulations and models as a single authoritative source for everything in the virtual environment. Fourth, JSE allows users to fly (virtually) with six manned simulator cockpits as adversary air. Finally, JSE is geared toward advanced tactics training, intended to replicate dense-threat environments.[76]

[74] NGTS models friendly and adversary aircraft and surface-based platforms and weapon systems (Huntington Ingalls Industries, "Huntington Ingalls Industries Completes Acquisition of Alion Science and Technology," August 19, 2021).

[75] I/ITSEC, "Air Force Highlights Joint Simulation Environment at I/ITSEC 2022," *I/ITSEC 2022 Official Daily News Digest*, November 28, 2022.

[76] Frank Wolfe, "U.S. Air Force Joint Simulation Environment for F-35A, F-22, Other Platforms to Build on F-35 JSE," *Defense Daily*, July 23, 2021.

As of December of 2022, Secretary of the Air Force Headquarters created the PEO JSE (an official POR) with Air Combat Command (ACC) as the lead MAJCOM. SMEs suggested that the primary development of JSE is complete, led by both the Navy and the Air Force, and that the program is moving toward scaled manufacturing, with additional capabilities to be incorporated as they are developed and tested.

SMEs noted two primary challenges regarding the advancement of JSE. First, accessing a network with which to share data and models between government and contractors (with appropriate security levels) has been a challenge. Second, VV&A has been challenging, given the DoD DOT&E expectation that the JSE must be the same as an open-air solution (i.e., live flight training). Both test and training capabilities must have the same high fidelity for real-time use. Despite challenges, SMEs noted that the primary success for JSE has been the accelerated path to obtaining a POR. Within months, the program transitioned from test to an official POR in large part because of the championing and advocacy from the operations (i.e., A3) community to move fifth-generation aircraft high-end training to the virtual environment.

Table 3.4 uses the technology transfer framework and summarizes the enablers and barriers for JSE. The program's history provides context for relationships with industry. JSE began as a technology development program in 2016 for F-35 Initial Operational Test and Evaluation. Initially, Lockheed Martin was the vendor, but because of delays and cost overruns, the F-35 Joint Program Office selected Naval Facilities Engineering Systems Command as the new vendor. Thus, JSE is government owned, and interaction with industry is minimal with respect to technology transfer. In 2022, efforts to develop—or at least lay out requirements for—the Common Synthetic Training Environment (CSTE) were well underway, with plans for CSTE to supplement or perhaps replace JSE. CSTE was intended to be a distributed, platform-agnostic, large-force training environment to advance tactical air training capabilities for fourth-, fifth-, and sixth-generation platforms.[77] However, given initial positive feedback with the use of JSE at Pax River, the Air Force decided to adapt JSE for use with high-end advanced training and tactics rather than advance CSTE, which was still somewhat nascent.[78]

As Table 3.4 suggests, a dedicated POR can stand in as a dedicated TTO, which is a supply-side enabler. Because the government is the developer, it is inherently involved in the technology transfer as JSE matures. In addition, the user community has been involved in system testing to some extent during JSE R&D. However, JSE reflects the complexity of a fifth-generation aircraft; its development and use require a high level of technical expertise. As discussed above, accessing secure networks and executing VV&A present additional supply-side barriers.

With respect to the demand side, and as part of the PEO JSE responsibilities, there is a technology transition strategy. We, however, are unaware of any strategy that specifically addresses culture. In general, there has been strong support for the JSE concept. The shift from plans to pursue CSTE to augmenting JSE reflected a significant change, but, to some extent, the underlying requirements for new capabilities did not change.

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[77] Emmi Yonekura, David Schulker, Irina A. Chindea, Ajay K. Kochhar, Andrea M. Abler, Mark Toukan, and Matthew Walsh, *Air Force Readiness Assessment: How Training Infrastructure Can Provide Better Information for Decisionmaking*, RAND Corporation, RR-A992-2, 2023.

[78] SME, interview with the authors, July 17, 2023.

Table 3.4. Enablers and Barriers for Joint Simulation Environment

	Supply Side	Demand Side
Enabler	• Supplier has dedicated TTO or function Inventor and/or technology developer are involved in technology transfer • Recipients are involved during the R&D phase	• A transition strategy exists for tools, culture, and people • Technology has endorsement from senior leader (i.e., champion), program managers, and intended users • Technology is in an area of sustained interest
Barrier	• Requires higher levels of technological expertise • Accessing a secure network is difficult[a] • Users face challenges conducting VV&A[a]	• Technology requirements change during development

[a] Factor was identified during discussions with SMEs but is not part of the T3D framework.

Standard Space Trainer

SST is a virtual software-based space training system to train USSF space operators in operation of many space weapon systems. It has five key elements: an underlying and scalable software architecture, a user interface, a suite of mission specific vendor plug-ins (MSVPs), threat visualization simulations, and a virtual space training exercise environment. The interface allows trainers to control multiple MSVPs with a single interface and see multiple users concurrently. In addition, it "[i]ncludes a software development kit (SDK) to allow development of new training systems that will be deployed from the SST Architecture."[79] SST in general, and the MSVPs specifically, has been developed to look and operate exactly like the real weapon systems. Yet, since its inception, the intent for SST has been to address the different hardware, operating systems, and proprietary software with no clear training standard.[80] Figure 3.6 contains an overview of the SST.

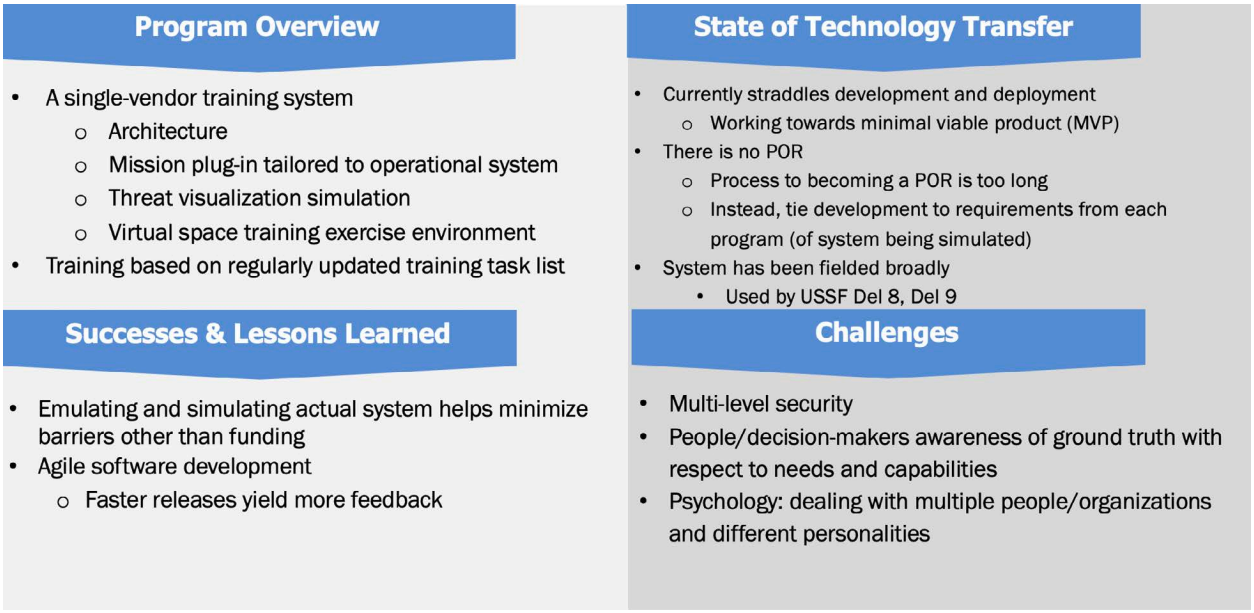
SST is developed by Sonalysts and managed by the USSF STAO. It is used primarily for command and control space operator training that employs COTS personal computer hardware and operating systems.[81] Currently, SST has been fielded broadly, and it is used by operational units in the USSF, such as Delta 4, which conducts missile warning; Delta 8, which conducts the military satellite communications and position, navigation, and timing missions; and Delta 9, which is responsible for conducting orbital warfare.

[79] Sonalysts, "Standard Space Trainer (SST)," webpage, undated.

[80] Scott Prater, "New Training Simulator Debuts at Schriever," Air Force Space Command, press release, February 9, 2011.

[81] Sonalysts, undated.

Figure 3.6. Overview of Standard Space Trainer Use Case



Relative to traditional DoD practices, and somewhat enabled by unique training needs within the USSF, SST is uncommon with respect to its single vendor and its ability to support multiple different weapon systems. Sonalysts is the only vendor, and this centralization has saved time and money by avoiding siloed development and inefficient coordination. However, the design of the underlying architectures allows any third-party vendor to develop and sustain a unique MSVP. This structure is possible in large part because SST is software, and each of the MSVPs is essentially a software module.

Currently, SST straddles the development and deployment stages of technology transfer. Although SST has been deployed broadly, Sonalysts is working toward a minimal viable product. Intentionally, there is no POR; the process to secure one is viewed as taking too long. Instead, the SST program is tied to requirements from each operational program that SST simulates or emulates.

According to SMEs, one of the challenges with the development of SST has been multilevel security—allowing collective training and integration across different levels. Given the strategy of emulating and simulating actual systems, which presents minimal technical barriers, there have been few additional technical barriers other than funding. SMEs, however, do note that ensuring that senior leaders are aware of the "ground truth" with regard to SST's capabilities and state of deployment can be a barrier. This is likely because of conflicting perspectives of SST implementation between the end users and developers, and efforts to increase communication and transparency between those groups are underway.

With regard to lessons learned, SMEs note the benefits of agile software development, with more frequent releases and thus more user feedback that can be incorporated during the development and deployment processes.

Table 3.5 itemizes the primary enablers and barriers for SST, based on the technology transfer framework. In general, there have been relatively few barriers, and from the perspective of technology transfer, the nature of SST allows for effective transition. With respect to the supply side, an agile

approach to development has ensured relatively consistent engagement between industry developers, program management, and end users.[82] A focus on leveraging COTS personal computer hardware and operating systems has facilitated efficient transition as well. As discussed above, enabling multilevel security has presented challenges to the SST program (a common issue with software development and distributed use).

On the demand side, again, ties between the user base and the developers have been helpful. Although we are unaware of the existence of a formal and complete business plan, according to discussions with SMEs, key aspects of traditional business plans regarding needs and product definition have been addressed to a large extent.

Table 3.5. Enablers and Barriers for Standard Space Trainer

	Supply Side	Demand Side
Enabler	• Supplier establishes early touch points with industry • Inventor and/or technology developer are involved in technology transfer • Recipients are involved during the R&D phase • Technology has high maturity (already in use elsewhere versus cutting-edge technology)	• Technology has good alignment with end user language and staffing • Technology is in an area of sustained interest A clear prioritization of requirements is established • There is a clearly defined business plan (e.g., refresh rates, implementation)
Barrier	• Enabling multilevel security is challenging[a]	• People and decisionmakers lack establishment of technology ground truth[a]

[a] Factor was identified during discussions with SMEs but is not part of the T3D framework.

Special Operations Center for Medical Integration and Development

SOCMID is a medical training and readiness center for Air Force pararescuemen and special operations medics. It is organizationally attached to the 24th Special Operation Wing, but it is physically located at the University of Alabama at Birmingham Hospital.[83] SOCMID primarily provides prehospital combat casualty care training through a two-week course using a variety of teaching methods, including standard classroom instruction, hands-on clinical instruction, and supplementary lessons using advanced training technologies.[84] These lessons include practicing combat casualty care techniques while wearing VR headsets that project the visuals of a hostile environment. Students also practice care on smart mannequins that simulate the vital signs and

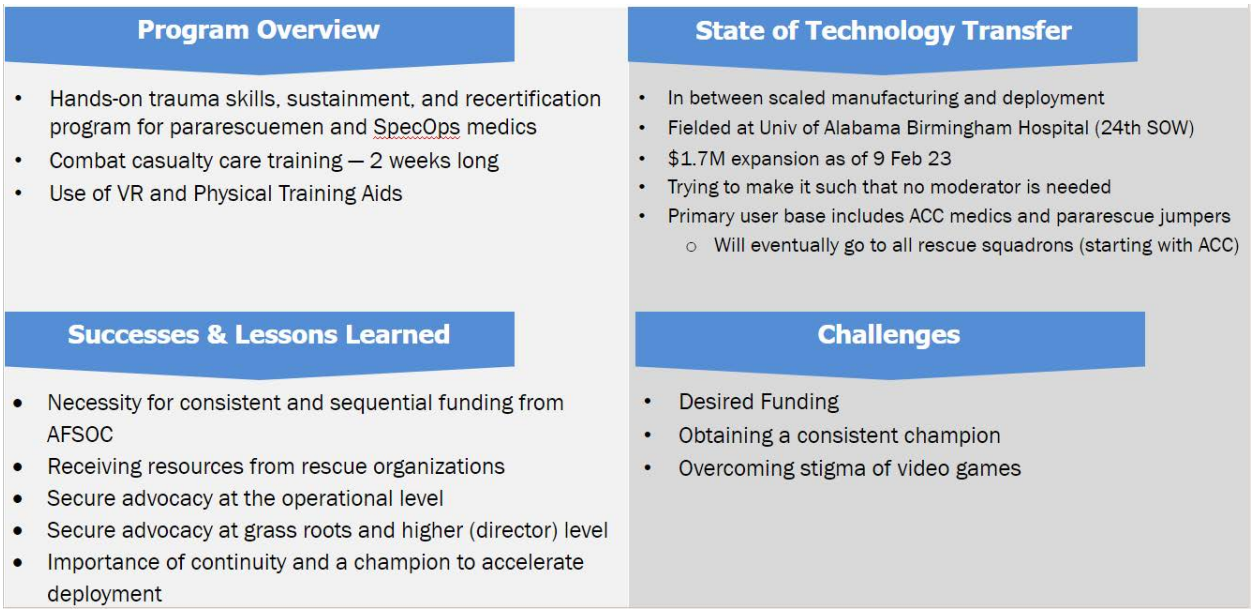
[82] In this context, agile development entails progressing through many software build-test-refine cycles, whereby user feedback is incorporated regularly into new software versions and updates.

[83] Allie Hulcher, "Division of Trauma and Acute Care Surgery Hosts Air Force Meeting on Pararescue Medical Training at UAB," University at Alabama at Birmingham, January 20, 2022.

[84] SimX, "VALOR Program for Next-Gen VR Medical Simulation Training," webpage, October 29, 2020.

symptoms of patients with various medical emergencies. These lessons are provided using the VALOR program developed by SimX.[85] Figure 3.7 provides an overview of the SOCMID program.

Figure 3.7. Overview of Special Operations Center for Medical Integration and Development Use Case



NOTE: AFSOC = Air Force Special Operations Command; SOW = Special Operations Wing.

During its development, SOCMID has faced challenges primarily regarding consistent and sequential funding. The program has been successful in gathering adequate resources, but funding sources have been wide-ranging and tied to its user base. SOCMID needs a consistent funding source that is willing to meet the needs of a diverse user group to overcome this technology transfer barrier—in this case specifically, likely from the Air Force Medical Service. Additionally, SMEs noted the need to have a champion—an advocate with preferably operational medical experience at the wing command level who believes in the mission of the program and will vouch for its benefits. Similarly, permanent change of station cycles of the SOCMID leadership were a barrier in the transfer and maturation of the program, and retraining new leadership quickly was critical for continuity. Lastly, experts stressed the need for the user community at large to abandon the stigma of video games and virtual environments as simply entertainment and instead recognize the benefits they have for training and learning.

Among the lessons learned, gaining support and funding from leaders was a common theme. Experts highlighted the need to gain consistent funding from AFSOC and to secure advocacy across a diverse group of supporters, from the grassroots level to higher echelons. Creating lessons specifically tailored toward the rescue mission of special operators was an important step forward. There are plans to implement SOCMID in all rescue squadrons, starting with ACC. Deploying such a program is a

[85] SimX, "Virtual Reality Operational Military Medical Training" webpage, undated.

slow process however, so SMEs reemphasized the need for a leader to stay committed to developing a curriculum, such as the one SOCMID provides.

Table 3.6 summarizes the enablers and barriers for SOCMID, derived from the T3D framework in Chapter 2. Looking at the supply-side enablers and barriers of SOCMID, SimX was involved throughout the development and technology transfer process, receiving and implementing consistent feedback from the leaders of the SOCMID program. These leaders were involved from early on, at the R&D phase of VALOR. Among barriers, program managers uniquely specified that the slow uptake of technology, especially when this process encountered changing of commanders, was a barrier to the transfer.

On the demand side, SOCMID benefited from having the wing surgeon of the 24 Special Operations Wing strongly support the entire program from the beginning and throughout development. Sustained interest in advanced training in the special operations community also drove support for the program. However, SOCMID lacked supporters with technical capabilities and resources for operationalization in its early stages. Leaders additionally noted the negative stigma of video games as a barrier to implementation.

Table 3.6. Enablers and Barriers for Special Operations Center for Medical Integration and Development

	Supply Side	Demand Side
Enabler	• Inventor and/or technology developer are involved in technology transfer • Recipients are involved during the R&D phase	• Technology has endorsement from senior leader (i.e., champion), program managers, and intended users • Technology is in an area of sustained interest
Barrier	• Deploying technology can take a long time[a]	• There is a lack of technical capabilities or resources for unit operationalization • Video games carry a negative stigma[a]

[a] Factor was identified during discussions with SMEs but is not part of the T3D framework.

Integrated Technology Platform

ITP is an online software-based simulation program developed by Mass Virtual, built on the Unity game engine, and led by AETC. It provides synthetic training through 3D virtualized aircraft. With VR headsets, airmen can access over 300 maintenance and aircrew training modules for 29 aircraft and four ground vehicles.[86] The virtual content resides in a centralized cloud-based repository that is accessible across the Air Force.[87] Examples of learning modules include C-130J Electrical Systems, E-4B Aircraft Egress Procedure, and C-5M Towing and Parking.[88] ITP is currently deployed at multiple units across eight MAJCOMs and most prominently within AETC, ACC, Air

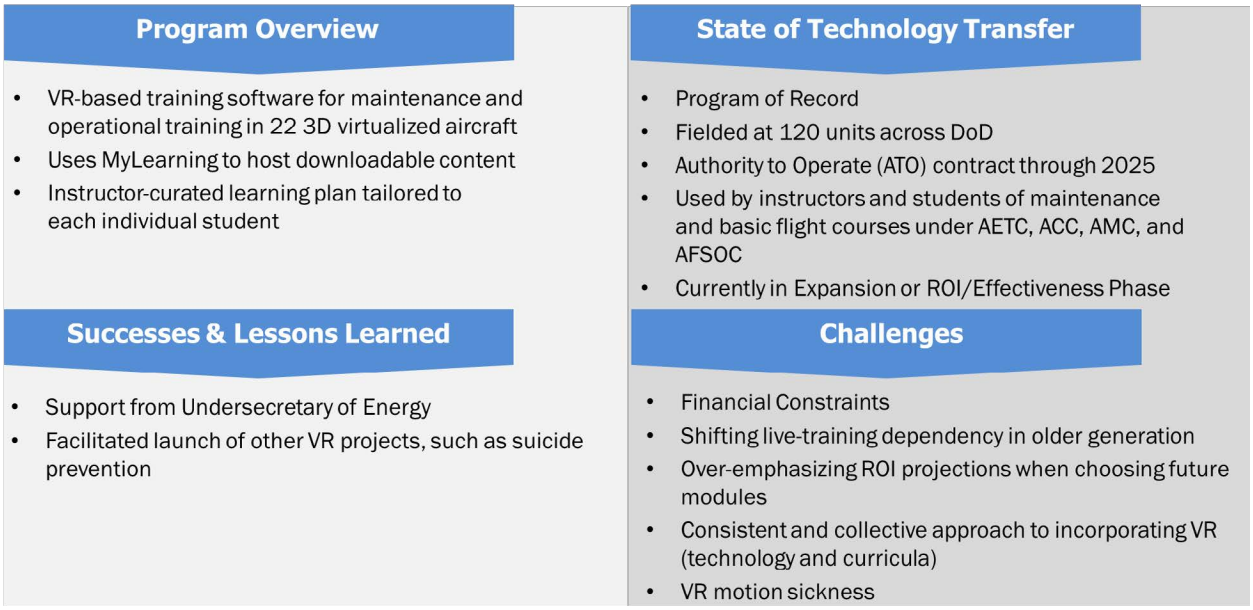
[86] USAF Air Education and Training Command, ITP program flyer, 2022.

[87] Although content is accessible to many sites across the Air Force, it is not possible for multiple sites to use the content in a simulation concurrently.

[88] USAF Air Education and Training Command, 2022.

Mobility Command, and AFSOC—reaching over 24,000 students yearly.[89] ITP currently uses the MyLearning[90] learning management system (LMS) to host the downloadable content, but Mass Virtual is developing a LMS with various capabilities, including the ability to allow instructors to curate unique curricula by selecting and arranging modules depending on the specific needs of the individual student or classroom. The aircraft data and learning modules are all stored within a software application called Virtual Hanger, which is proprietary to Mass Virtual. ITP is not a POR, and, although it has a program management office, there is no sustainment funding in place. It has an Authority to Operate (ATO) contract through 2025.[91] Note that although ITP has an ATO contract, it does not have the ATO necessary to integrate concurrent use at various sites, which could facilitate collective training between locations. That said, the current focus on maintenance training does not often require collective training. Figure 3.8 provides an overview of the ITP.

Figure 3.8. Overview of Integrated Technology Platform Use Case



SMEs noted a variety of barriers to the implementation and dissemination of ITP. Financial constraints, specifically finding funding for development and sustainment, were a significant barrier. SMEs also noted the cultural difficulty associated with shifting away from live training, especially among established instructors and trainees. Another pressing barrier was the challenge of establishing a consistent approach to incorporating VR technology–based content into current curricula that were originally designed before such technology was available and thus do not provide flexibility for incorporating different training methods. Furthermore, integrating advanced technology, such as VR,

[89] Masoud Rasti, "Integrated Technology Platform (ITP): Learn Faster, Remember Longer, Apply Better," briefing, September 15, 2021.

[90] MyLearning is the DAF's learning management system developed as part of an effort to centralize all training requirements throughout the Air Force.

[91] Mass Virtual, "The 2022 ITP Program Management Partnership," webpage, undated.

is different and more difficult than introducing more basic IT systems, yet the ITP infrastructure was initially prototyped and developed as if it were a basic system. Specifically, the immersive nature of VR headsets can bring about symptoms of motion sickness in users, limiting how long students can learn in simulated environments and scenarios. Finally, as ITP begins to gain traction for further expansion from numerous units across multiple MAJCOMs, SMEs suggested that developers are beginning to feel a sense of "choice overload." They are spending too much time optimizing ROI (i.e., predicting the ROI for different modules to decide which to pursue), when any new lesson would be of benefit relative to existing training technology, according to one SME.[92]

Despite these barriers, ITP has also benefited from successes during its development. Gaining involvement and support from the Under Secretary of Energy has led to more-successful and consistent funding support. Additionally, the success of VR maintenance and aircrew training under ITP has kickstarted VR training for other Air Force efforts, such as suicide prevention.[93]

Table 3.7 applies the T3D framework from Chapter 2 to the ITP program. Among the supply-side enablers in the technology transfer process for ITP, Mass Virtual has maintained clear lines of communication with its clients and has received consistent feedback from program leaders. Mass Virtual was also involved in the expansion process, as more units across the DAF began using ITP. Program leaders also noted that the 3D aircraft renderings and module visuals were of exceptional fidelity and quality, helping to combat VR motion sickness and elicit trust, especially with younger users accustomed to gaming-level fidelity.

Regarding supply-side barriers, ITP users noted that the software did not have the IT architecture to support centralized access, so units only had access to the ITP license and version that was installed at their location. This might limit scalability of the program. In addition, populating the repository involves a cumbersome process, whereby developers provide new content to a unit point of contact, who then verifies the legitimacy of the content. This process needs to be streamlined to enable scalability and expansion.

On the demand side, program managers recorded and followed metrics to track ITP's benefits. The program kept records and lessons learned throughout the development process and used them during setup at every new location. ITP was also developed with end users (i.e., instructors) in mind, aligning with end user language and staffing. The program remains an area of sustained interest and has endorsement from program managers and users, but it does not yet have strong support from leadership. SMEs highlighted leaders' reliance on traditional methods (e.g., classroom courses and live training) as a barrier. Additionally, because of lack of centralized access, there is limited ability to share technology, and isolated efforts in units are fragmented and not well communicated.

[92] SMEs, interview with the authors, July 6, 2023.

[93] SMEs, interview with the authors, July 6, 2023.

Table 3.7. Enablers and Barriers for Integrated Technology Platform

	Supply Side	Demand Side
Enabler	• Inventor and/or technology developer are involved in technology transfer • Supplier receives clear, consistent feedback from senior leadership, program, and end user levels • Program features high-fidelity and quality software[a]	• Metrics can track benefits and implementation of technology • Technology has good alignment with end user language and staffing • Technology is in an area of sustained interest • Technology has endorsement from senior leader (i.e., champion), program managers, and intended users • There are well-kept records of lessons learned from original implementation location
Barrier	• Multiple stakeholder organizations are spread across multiple geographic locations • There is no IT architecture to support centralized access[a]	• Seller has limited ability to share technology • Efforts by different units to develop training technology are fragmented and not well-communicated throughout the organization • Leaders prefer traditional training methods over VR training[a]

[a] Factor was identified during discussions with SMEs but is not part of the T3D framework.

Analysis of Existing Programs Suggests Opportunities for Future Investments

Our process of characterizing existing programs yielded relevant findings regarding the broader sample. The analysis of these programs suggests potential opportunities for future investments regarding advanced technologies for training.

First, with regard to the supporting technologies, the most common technologies included synthetic environments, performance assessment, learning analytics, and synthetic agents; neurostimulation and aural reality were not used in any of the programs.[94] The programs we considered are listed in Appendix C, sorted by technology type.

Second, in general, most of the programs were relatively mature, having reached the stage of advanced technology demonstration or operational use. Although this set of programs is not necessarily representative of training technology efforts across DoD and did not include basic-research efforts, there might be opportunities to explore more applied research in the field of advanced training technologies.

Finally, most of the programs apply to tier-4 training, which involves individual units (tactical level missions, focused on basic technical and operational capabilities). Thus, there might be opportunities for development of additional training technologies that support collective training for tiers 1–3 and command staff.

[94] Neurostimulation—and the topic of brain computer interfaces more generally—is relatively immature, but its minimal use in active training programs might suggest an opportunity for beneficial investment (Anika Binnendijk, Timothy Marler, and Elizabeth M. Bartels, *Brain-Computer Interfaces: U.S. Military Applications and Implications, An Initial Assessment*, RAND Corporation, RR-2996-RC, 2020).

Common Barriers and Enablers for Advanced Training Technology Transfer

In this chapter, we evaluated the proposed T3D framework using multiple real-world use cases from DoD. In doing so, we laid out a systematic process for coding and selecting relevant advanced-training-technology programs. The intent was to concurrently demonstrate how the framework could be used and validate the framework. Nonetheless, in addition to facilitating selection of six exemplary programs, the selection process helped extract lessons learned that might benefit the acquisition community more broadly. First, the aggregation and coding of the initial 37 programs provided insight into the current state of R&D within the DoD advanced-training-technology community. Second, analysis of the final use cases provided insight regarding barriers and enablers that might have broad relevance.

Key, overarching barriers and enablers are discussed more extensively in Chapter 4. Certain barriers occurred across multiple case studies. On the supply side, issues with data and multilevel security were mentioned in two cases, as were issues with the technical complexity of the projects. On the demand sides, two cases surfaced issues relating to cultural acceptance of novel or unfamiliar technologies. At least in this sample of cases, certain barriers seem to have been avoided, including issues with technical literacy and insufficient recordkeeping.

There was greater commonality across cases in the enablers. On the supply side, four cases had the benefit of having the inventor or developer involved in the transfer, and three had the benefits of having users involved at the R&D phase. On the demand side, four cases had the endorsement of senior leaders, champions, program managers, and intended users. In three cases, SMEs noted that working in an area of sustained interest enabled transition success. Finally, in two cases, alignment with end user language and staffing were highlighted as enablers.

Table 3.8 aggregates the enablers and barriers that SMEs identified and that are not explicitly included in our original framework. Some of these are somewhat program specific, but they highlight the nuance and variability in technology transfer in general. Although the proposed framework is robust and general enough for broad application, there will often be more-specific enablers and barriers that should be considered as well.

Table 3.8. Additional Enablers and Barriers Not Captured in the Original Framework

	Supply Side	Demand Side
Enabler	• Program features high-fidelity and quality software	
Barrier	• Enabling multilevel security is challenging Accessing a secure network is difficult • Users face challenges conducting VV&A • There is no IT architecture to support centralized access • Deploying technology can take a long time	• People and decisionmakers lack establishment of technology ground truth • Changing inflexible perspectives is difficult • Video games carry a negative stigma

Chapter 4

Conclusion and Recommendations

The DAF is looking to identify the most-useful training technologies and efficiently and effectively transition them into DAF training and education. Within the DAF, there are many stakeholders for training technologies, which include AETC, AFRL, operational MAJCOMs, and Air Force Futures (AF/A5/7). In this chapter, we conclude with a discussion of training technology transfer best practices and transition pathways that are drawn from the analysis of our use cases and the framework. Using our findings, we provide recommendations that are meant to inform DAF investments and provide guidance for transitioning training technologies. Given the many stakeholders, we specify, where possible, the logical office of primary responsibility for our recommendations.

Use Cases: Pervasive and Critical Barriers

When comparing the use cases, several pervasive and/or critical barriers were apparent. Although these barriers are extracted from a limited set of SME interviews and use cases, they nonetheless point to potential challenges with technology transfer in general, and they provide insight for the S&T and acquisition communities. When there was a closely associated solution, we include it here. These six challenges or barriers are summarized as follows:

1. **Funding:** Although most developers will always prefer more funding, SMEs often cited insufficient funding as a barrier for accelerated technology transfer and broad deployment. Although additional funding can often facilitate increased development and dissemination, objectively determining to what extent specific funding amounts (or lack thereof) contributed to insufficient technology transfer would require additional research.
2. **Scalability:** Many of the programs we reviewed, even before selecting the six case studies, had success with initial development but encountered a significant barrier with broader scalability and generalizability. In the case of hardware, these barriers can stem from manufacturing challenges (e.g., cost risk, disconnect with end users), but, in the case of software, the most significant barrier to scalability can be cultural resistance. Regardless, this barrier aligns with the traditional challenge of traversing the "valley of death."[95]
3. **Program understanding:** Especially with more complex systems, SMEs noted the challenge of program understanding and consequent socialization. Above and beyond developing technical capabilities, advocates often underestimate the challenge and importance of socializing the value proposition for a technology program. Pursuing this earlier in the program can help overcome cultural resistance to new technologies.

[95] John Dillard and Steve Sark, "Understanding Acquisition: The Valley of Death," U.S. Army Acquisition Support Center, October 6, 2021.

4. **Consistent incorporation of technologies:** SMEs noted that VR capabilities can be developed and implemented in an uncoordinated fashion, and this can stifle integration because they lack common standards and their developers do not consider interoperability from the start. This challenge can apply across the technologies we examined here, and inconsistent implementation or incorporation practices can inhibit distribution of new capabilities. If everyone uses VR differently, for example, deploying new VR capabilities broadly can run into resistance. Although ease of development and use can be beneficial for some technologies, they can lead to siloed and uncoordinated development. These problems can apply to related curriculum development and to hardware and software development. Often, this can be an enterprise-level issue, resolved in part by improved transparency and communication.
5. **Multilevel security:** Gaining access to secure networks can be a substantial challenge, especially when working with systems for distributed training, which requires connectivity between potentially disparate users. This is only magnified when engaging with the joint community or with partners and allies. As with consistent incorporation of VR, addressing the need for multilevel security often requires involvement from enterprise-level management.
6. **Alignment with S&T plans:** If technology transfer does not align with S&T plans and past expertise, it can become opportunistic and not forward-thinking. This, in turn, presents a challenge for scalability and sustainability.

Use Cases: Key Enablers and Lessons Learned

In addition to barriers, the use-case analysis uncovered key enablers, successes, and lessons learned, all of which might help inform ongoing and future programs. As with most R&D programs, any reduction in program costs or training costs in general were noted as significant successes. The same is true of reductions in development or training time. Additional key enablers are noted as follows:

1. **Agile software development:** All of the use-case programs involved software development, and SMEs noted the benefits of agile development. There are countless definitions for agile development that are sometimes disputed, but, in this context, SMEs touted the benefits of developing capabilities incrementally with faster releases and of frequent incorporation of user feedback. The primary benefits of agile development are adaptability, risk reduction, and use focus. This development approach can run counter to traditional approaches to DoD acquisition, but it is nonetheless increasingly more common across DoD.
2. **Use of a single vendor with modular architecture:** SST presents an example where leveraging a single vendor for multiple modules or components of a single system can provide significant benefits. This approach inherently fosters system coordination, avoids costly siloed development, and allows developers to leverage preexisting code when appropriate. To avoid known issues with vendor lock, in which a single vendor essentially monopolizes development, schedules, and intellectual property, the SST case used of an underlying modular architecture that allows additional vendors to provide different modules in future expansions.

3. **Training systems that align with operational systems:** Ensuring that training capabilities emulate and simulate actual operational systems can minimize barriers to adoption, stemming from perceived or actual training-system ineffectiveness. To be sure, training goals and objectives do not always necessitate high-fidelity training systems, and both developers and practitioners should manage system fidelity appropriately, balancing it with available funding. Nonetheless, when feasible and/or required, training systems that mimic real systems tend to be well received.
4. **Continuity in development:** There is a necessary balance between rapid acquisition that responds efficiently to immediate needs and holistic long-term plans that foster continuity and enable intentional training strategies. Although rapid acquisition is critical to responding to decentralized training needs that vary from organization to organization, it can be beneficial to strive for R&D efforts that align with overarching S&T plans.
5. **Securing advocacy:** The success and progress of a program can depend as much on advocacy and support as it does on technical capabilities. Even with successful technical capabilities and a proven ROI, it is important to ensure visibility of such successes and garner advocacy from user groups and leadership to foster overall program success. Especially with smaller efforts and cases where there is not yet a POR, there can a be a risk of advancing in isolation (within a relatively small user groups). Thus, it can facilitate technology transfer to secure advocacy as early as possible, from both user and leadership communities. This applies for both the DAF and DoD more generally.
6. **Funding continuity:** Although securing the desired amount of funding can be a challenge, consistent funding is a significant enabler. SMEs noted that the overall technology transfer process can be lengthy, especially when pursuing broad deployment, and any consistency during that period is beneficial.

Recommendations to Improve the Technology Transfer Process

There are several measurable, policy-relevant, timely, and valid factors that facilitate or hinder the transition of training technologies, and they come into play at different steps in the T3D process. We have mapped out this process and shown where each factor applies within our T3D framework. The factors we identified can be thought of as levers for the DAF to better enable the T3D process, and they fall under the following categories: personnel, social factors, technology attributes, ROI, absorptive capacity, processes, and financial. The T3D framework and use cases highlighted several ways that the DAF could facilitate training technology transfer in a more efficient and effective manner. Using those findings, we have several recommendations for the DAF that relate to the technology transfer process:

- The DAF should **use the T3D framework at the enterprise or organization level to make periodic (e.g., yearly) assessments of where the bottlenecks are in the process** and pinpoint specific actions that can be taken to eliminate them. This assessment can be the responsibility of AF/A5/7; however, it should be coordinated with stakeholders at AETC, AFRL, and other MAJCOMs in the DAF. For example, systematic deficiencies in the necessary IT architecture to facilitate expansion of technologies might point toward a role for action at the

enterprise level. Beyond the DAF, there would also be a benefit of a comparable DoD-wide effort.

- At a more tactical level, **the T3D framework should be made available and used by innovation cells and training and education management at the MAJCOMs** to troubleshoot and plan for specific ongoing or future training technology transfers. Use of the framework at the tactical level would be more appropriate for identifying local enablers and barriers to transition. Similar to the previous recommendation, AF/A5/7 could be centrally responsible for making the framework available with associated guidance to facilitate planning and troubleshooting.
- AF/A5/7 should codify and socialize **lessons learned from our use cases as training technology transfer guidance** for all DAF stakeholders and potentially a wider DoD audience. They should also continue to collect and refresh ongoing use cases to take stock of the lessons learned.
- The DAF should **start addressing major T3D barriers and challenges now** to pave the way for the major transformation of the training and education enterprise. This is not only a matter of technology and funding; prominent barriers we identified will also require addressing communication, alignment between organizations, and culture. Specifically, the DAF can act on the pervasive and critical barriers we identified in our use cases in the following ways:
  - To address issues of insufficient funding, the DAF, and DoD more widely, should designate an office to identify training technology efforts in need of bridge funding between phase 2 and phase 3 Small Business Innovation Research funds.[96]
  - Regarding scalability, program understanding, and S&T alignment, the DAF and DoD should require innovation cells and new training programs to have a strategy for socialization and communication early in the technology transfer process that includes the S&T community and conveys the value proposition of the technology.
  - To ensure consistent incorporation of technology, the DAF (in coordination with the wider DoD community) should identify an office of primary responsibility to publicize information and best practices for priority technologies, such as AR and VR. Similar to the previous recommendation, this office would need a communications strategy to increase transparency across the DAF and DoD.
  - Finally, when multilevel security poses a barrier, technology development efforts should adopt the Simulator Common Architecture Requirements Standards (SCARS) where appropriate and feasible.[97]

[96] See U.S. Department of Defense, "Small Business Innovator Research, Small Business Technology Transfer," webpage, undated.

[97] For details on SCARS, see John Kurian, "Simulators Division (AFLCMC/WNS) Update," briefing slides, Agile Combat Support Directorate, May 4, 2022.

Recommendations for Improving the DAF's Ability to Transfer Particularly Promising Technologies

The research discussed in this report is part of a larger effort that included a landscape analysis and horizon scan for the different advanced training technologies with an assessment of which of them might be the most-promising investments for DAF training and education. Leveraging the technology-specific recommendations from the landscape analysis and horizon scan, here we include recommendations for both what technologies the DAF should consider investing in and what steps it should take to facilitate their transition:

- In both our stakeholder interviews and expert panel, **adaptive training and performance assessment technologies** were identified as having a broad potential benefit and applicability across the DAF training and education enterprise. Both types of technologies have developments emerging in other DoD services.
  - In terms of technology transfer, **the DAF should consider ways to enable iterative development and expansion to leverage advancements already being made by other services**.
- The DAF has already made investments in VR and synthetic environments with examples highlighted in our use cases for ITP and JSE, respectively. **For VR and AR, we recommend that the DAF address the predominant issue of centrally coordinating disparate efforts by appointing an office of primary responsibility to coordinate, track, and govern DAF efforts.** This might also enable more-holistic solutions for IT infrastructure and cultural barriers.
  - **With regard to synthetic environments, the DAF should manage and minimize requirement changes to better enable efficient development of capabilities.** The companion report presents a method and database for tracking advanced technology development efforts for the training enterprise.[98] As described in that report, the DAF should make this capability available to aid transition for these and other technologies where a lack of centralized coordination hinders transition. For example, the database could be used to identify similar technology development efforts for similar or different end uses. Those involved in technology transition could use these other cases to inform their business plans or draw other lessons learned relevant to overcoming transition barriers.
- **Natural language interfaces** were identified as a relatively mature technology with modest promise for DAF training. With the Office of Naval Research and the Army Research Laboratory already pursuing research in this area, **we recommend that AFRL coordinate with other DoD efforts to track and develop training and education applications for natural language interfaces**.

[98] Toukan et al., 2024.

- **Gaming technology** was assessed as mature but facing barriers to wide implementation in the DAF training enterprise. **To better assess utility for DAF training, we would recommend tracking any measurement of ROI and effectiveness where gaming has been implemented, for instance, in the Army or Intelligence Advanced Research Projects Activity.** These inputs can inform further decisions to invest in T3D enablers to address cultural resistance, cyber security, and cost concerns.
- This type of analysis of emerging technologies is inherently iterative, and **we recommend an updated assessment of the technology landscape, potential uses for DAF training and education, and means of transitioning promising technology be conducted within the next five years**. Participants in our expert panel indicated that many of the technologies we examined would reach promising maturity in five to ten years.

The potential benefits to the DAF from adoption of more advanced training technologies might be considerable, both in terms of economizing time and resources and in terms of operational benefits. This report developed a framework that can help the DAF identify particularly promising technologies and shepherd them through the transition process. The T3D framework can be used to improve processes at both the enterprise and tactical levels, and the DAF should take steps to make it available for use at multiple levels. The DAF should also apply this framework to additional use cases to generate lessons learned and to identify barriers or enablers that might be unique to developmental contexts or user communities that were not addressed in this analysis. This report highlighted certain promising technologies and the means to aid in their transition, but the DAF will need to revisit both the landscape analysis and key enabling factors as the technological landscape shifts and new constraints and opportunities for technology transition arise.

Appendix A

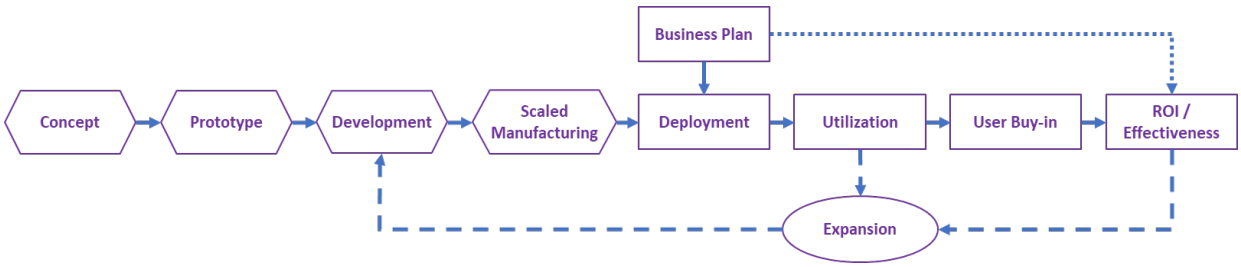
Interview Protocols

Protocol for Stakeholder Semi-Structured Interviews

1. Describe your role with respect to advanced training technologies.
2. Overview of technologies:
    a. Could you characterize technologies in development, in use, or that are investment priorities at a high level (i.e., characterize the mix)?
    b. What types of technologies hold the most promise for the future that [the DAF/your organization] ought to invest in? Could you describe high-leverage use cases for these technologies?
    c. What specific programs hold promise?
    d. (For the operational community) Are there any non-program-of-record technologies that you have developed or adapted for local use?
3. What data sources could you point us to that catalogue training technologies in your community?
4. How does your office maintain awareness of other such efforts in the DAF? Elsewhere in the DoD?
5. What does the process of training technology transfer look like, from technology origin to training implementation?
    a. Does it change depending on the technology source (i.e., U.S. government, commercial, academic)?
    b. What are the main stages/hurdles?
    c. How do you secure an internal customer?
6. Tell us about your technology transition greatest success story.
    a. What factors contributed to the success?
        i. How did you overcome the valley of death?
    b. And conversely, what have been the greatest barriers toward transitioning other promising training technologies?
        i. Can you give examples? (Ask about non-budgetary/valley-of-death factors if response is focused on those.)

Protocol for Use Case Deep Dive Interviews

1. What is the overall intent/objective of the program?
    a. What new capabilities does the program provide?
2. What is the current state of the program?
    a. Can you provide any relevant publications?
    b. Are there any complete or provisional patents?
    c. Is there an active program of record?
    d. Has the technology been fielded? If so, where?
3. Where does this program sit with respect to the following process:



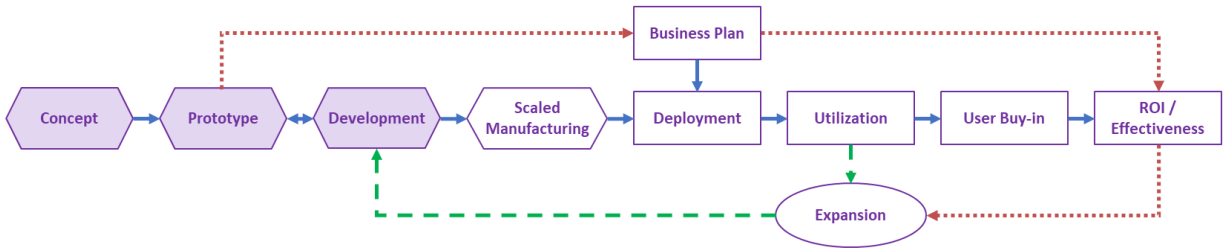
4. Who are the primary users?
5. What are the main training-related technologies involved in the program?
6. What has been, and will be the necessary budget?
    a. Can you point us towards any relevant supporting data?
7. What were/are the primary barriers to technology development and maturation with this program?
8. What have been the primary successes with technology transfer for this program?
9. What have been the primary lessons learned with respect to technology transfer?
10. Can you recommend any additional literature we should review or POCs we should speak to?

Appendix B

Further Discussion of DAF Training Technology Transfer Process Steps

In this appendix, we provide a discussion of the different steps in the T3D process (shown in Figure B.1) to supplement the definitions provided in Chapter 2. This discussion serves to provide further details from the literature and contextualize the steps within the DAF training and education enterprise. For commercial products, there are pathways where the DAF would be working with a commercial partner as far back as the concept and prototype steps, and there are other pathways (e.g., COTS product) in which commercial products are integrated at the deployment step.

Figure B.1. DAF Training Technology Transfer Process



NOTE: Shaded steps concern a single technology, and nonshaded steps imply that a system of technologies continues to mature together. The hexagon shapes are steps in the process prior to technology deployment. Red dotted arrows represent process flows that inform subsequent steps. Green dashed arrows are optional flows that essentially make this entire process iterative. The iterative prototype-to-development flow is represented by a bidirectional arrow.

The **concept** step concerns the original idea but also includes the origin of the technology in terms of source (i.e., originator) and the mechanisms that allow the concept to mature into a prototype.[99] Consumers within the DAF might signal a need that is answered by the market (via formal solicitation), but a concept is more likely to already have been generated independently as the result of research or internal development. Some concepts might also originate directly from review of information contained in academic papers or contracted reports. Other concepts might arise from a rearrangement of exiting mainstream commercial offerings.

Some mechanisms (summarized in Table B.1) that start technology transfer are well defined in Air Force publications; although written from the perspective of transferring U.S. government (USG)

[99] Conventional business practices would identify a use case and market before turning a concept into a prototype. This is still true in this process; we explicitly acknowledge that concepts can and do exist well before the prototype, development, and business plan steps are realized.

technology to other parties, the mechanisms can work in reverse. When flowing from other sources for USG end use, there might be considerations that negate some benefits (e.g., academic and industry originators are not legally mandated to maximize patent licensing at the expense of revenue).[100]

Before these mechanisms or other funding vehicles start the process, parties must be aware that a technology is desired or available. Absorptive capacity and desorptive capacity describe this organizational ability; some of the enabling factors discussed in Chapter 2 focus on enhancing absorptive and desorptive capacity.

[100] AFRL, *Air Force Technology Transfer Handbook*, AFRL-2020-0196, September 2020.

Table B.1. U.S. Government–to-Partner Technology Transfer Mechanisms

Type of Mechanism	Normal Flow Description	Reverse Flow Cons
Cooperative research and development agreement (CRADA)	Allows DAF and partners to "provide or share personnel, services, facilities, equipment, intellectual property (IP), and other resources,"[a] and protects each parties' contributions; allows sharing of technology developed within the CRADA	• Does not permit transfer of appropriated federal funds to the partner • Likely need to shift to another funding vehicle to acquire the technology for operational use
Patent license agreement	Purchasing the "right to make, use, and sell" patented inventions[b]	• High licensing costs • USG acting as the middleman when production is not USG organic
Software agreements • Patent license agreement • License as vendor • License to distributor • Open source license • Unilateral open source license • Information transfer agreement • CRADA	Seven distinct agreements that enable sharing, licensing, and collaborative development of software	• Other than direct evaluation and USG advocacy to other potential customers, few benefits to partners that would choose open (i.e., ability for USG to modify) agreements versus licensing, improving, and maintaining the end product directly
Education partnership agreements	Promotes increased interactions between DAF organizations and educational or nonprofit institutions. Has other tacit benefits, such as cultivating and recruiting a DAF-focused workforce and enhancing USG "visibility and image in the community"[c]	• Greater focus on people relationships or temporal information instead of a supported end product. • Likely requires significant DAF management to link all the interactions toward an end product.
Commercial test agreements	Makes defense laboratory facilities and services available to an outside party for an appropriate fee	• Not applicable; USG would simply lease private facilities and might be subject to less favorable terms (such as extended leasing versus ad hoc)
Partnership intermediary agreements	Funds a state and local government or nonprofit organization to identify and obtain technology transfer from the DAF	• Not applicable; academia and industry would instead establish their own solicitation capacity or form a separate group that connects to DAF via a different mechanism (such as requests for information or quotes)

SOURCE: Features information from AFRL, 2020.
NOTE: The DAF is used as the USG example; these agreements might apply more widely than a military service.
[a] AFRL, 2020, p. 22.
[b] AFRL, 2020, p. 41.
[c] AFRL, 2020, p. 79.

The **prototype** step includes one or a few implementations of the concept to validate proposed practical applications. It serves as a demonstrator for business development and identifies challenges or opportunities that might appear later in the technology transfer process. This step is the first point in the process where potential customers (end users) and applications (missions) are identified and the development of a business plan begins. The business plan should be frequently updated as more experience with the technology is gained later in the process.

The **development** and prototype steps occur iteratively until a prototype that meets end user expectations is realized. Within the development step are enhancement of the original concept, refinement (or replacement) of the interface to align with probable use cases, and improvements that increase production feasibility or meet deployment environment requirements (e.g., size, weight, power).[101] For training technologies, this could include extensive creation and validation of content.[102] Testing and evaluation should occur in this step as part of the refinement process. These early evaluations might also serve as indicators that the technology will never meet expectations despite numerous iterations and that the technology should not be pursued.[103]

Because we assume that development is an iterative process, there are no "natural" or obvious milestones that determine whether a technology should pass on to the next step, which is scaled manufacturing. This is one reason why acquisition activities set clear milestone requirements that are determined by external factors or use case needs. However, a technology might partially satisfy a pressing need and still bring value to the end user despite not meeting set threshold requirements and before comprehensive evaluation (the heuristic of satisficing).[104] Bringing a technology to "market" (i.e., proceeding with the T3D process) to realize value early on does not inhibit opportunities for additional development cycles to improve the end product.[105] This type of iterative development is only feasible if the end product can be easily changed without significant retooling of manufacturing equipment or overhaul of deployed technology; COTS, modular components, and software-centric solutions tend to benefit from this postdeployment adaptability.[106]

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[101] Compared with other products, training is highly dependent on the interface or medium through which content is delivered to the student. While some training technology is the interface itself (e.g., computer-based training or VR), the content can also be manipulated to improve its perceived quality. In either case, the end use can dictate the type of interface as much as the operational environment where the training is conducted. For example, touch labor roles like aircraft maintainers or pilots might need physical or haptic feedback to experience (and thus learn) skills that they will employ on the job (Khanh-Phuong Thai, Scotty D. Craig, Jim Goodell, Jodi Lis, Jordan Richard Schoenherr, and Janet Kolodner, "Learning Engineering is Human-Centered," in Jim Goodell and Janet Kolodner, eds., *Learning Engineering Toolkit*, Routledge, 2023; Katherine McEldoon, ed., *Learning Design Principles: A Toolkit for Evidence-Based Learning Design*, 2023).

[102] Most of the training technologies we have explored in this project do not stand alone but form parts of a training system. For example, VR and AR will likely be the interface to a synthetic environment, the content of which will be driven by adaptive training technologies. While it is simpler to think of each technology as monolithic, interdependent (but not necessarily dependent) maturation begins in earnest at the development step.

[103] Setting expectations is part of the ROI and effectiveness step.

[104] *Satisficing*, coined by Herbert Simon in 1956, is a form of decisionmaking where acceptable options are chosen rather than the most optimal one.

[105] National Research Council, 2004.

[106] Using designs that are amenable to future modification (future-proofing) also increases this opportunity at some cost of additional upfront work and the risk of never leveraging these features.

Development is repeated if the expansion step is pursued. Although material products might be infrequently revised, software and training content have the potential to be expanded often (e.g., the addition of new performance metrics or expansion of the curriculum).

Scaled manufacturing occurs after a prototype is deemed feasible (in terms of cost and application) and is expected to bring value to the end user.[107] Training technologies are likely to have both physical and information products as part of the developed solution. For physical products, manufacturing on a limited scale with acceptable defects would first need to be arranged and validated. Often, this takes a considerable time and might ultimately show that insufficient quantities can be provided to meet the initial demand timeline. For information products, secure and reliable delivery of content, easily accessible by the end user, would need to be similarly arranged and vetted. This might include building and stress-testing the network and data infrastructure to stream or download content (especially if the end user environment is austere or classified),[108] on-demand content and software developers to implement corrections and improvements, and traditional help desk services to troubleshoot interface issues.[109]

A business plan is the set of documents that establishes the end use of the training technology and guides the process after the prototype phase when sufficient knowledge of the concept's practicality and benefit are realized. Although the business plan arguably must be in place before deployment, it should be informed by and created alongside earlier steps in the process. Although business plans are familiar outside the military, we emphasize the business portion for the DAF; business aspects are essential for successful technology transfer but are easy to overlook for advanced (and probably new, relatively untested) training technologies.[110]

The plan should describe intended use cases, a schedule for deployment, means of increasing user buy-in (i.e., advocacy and advertising), sustainment and full lifecycle considerations, courses of action for expansion, planned financials, and metrics for success. All these elements are obvious for traditional consumer or military products but might need special treatment for training technology.[111] For example, the schedule for deployment will not be driven by market forces but by the availability of personnel, which is driven by the operational tempo. Similarly, the financial analysis will not be driven by profit, but by ensuring sustained execution. One of the most challenging aspects will be the assessment of training technology effectiveness to determine ROI.

The purpose of training is to enhance the performance of the trainees. In the military, this ultimately means increasing force lethality while simultaneously increasing survivability. This goal is

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[107] TRL is often used to describe system maturity but leaves out critically important production considerations. However, manufacturing readiness level (MRL) is another criterion that represents when pilot production (MRL 8), low-rate production (MRL 9), and full-rate production (MRL 10) can be achieved (GAO, 2020).

[108] DAF stakeholders, discussions with the authors, January 26, 2023.

[109] *Interface* is broadly used to mean the computer device through which the training content is accessed, just as it would be through a traditional textbook, in-person lecture, or practice on a mock-up. Some examples of technology-enabled interfaces could be adaptive websites, laptops, tablets, content servers, extended reality (XR) headsets, and instrumented manikins. Although not deeply discussed, some items, such as laptops and tablets, could fall under commodity IT assets that are generally addressed by the established IT department. However, even these commodity assets might be highly modified with nonstandard software that would require more-advanced help desk experience (typically called Tier 2 or 3 services; see Chairman of the Joint Chiefs of Staff Manual 3500.03E, 2015).

[110] Estep and Daim, 2016.

[111] Roger Lewis and Quentin Whitlock, *How to Plan and Manage an E-Learning Programme*, Gower, 2003.

likely too broad a metric to tie back to the use of a specific training technology. Instead, the business plan should first identify the missions and the operators that the training technology will benefit. Measures of performance tied to those missions and operators can then be used to assess effectiveness of the training technology compared with other means of training delivery. Generally, determining military ROI for training technology has been challenging and is discussed in more detail later in this section.[112]

Deployment is the step in which the training technology is either made available for or delivered to end users, but it does not explicitly include whether the end users begin using the training technology (the reason for this is discussed in the utilization step). The schedule of deployment should be informed by the business plan based on the earlier identified learning environment, target audience, and implementation risks. We formulated the following examples:

- A limited trial rollout might identify issues not discovered by quality assurance activities executed during the development and scaled manufacturing phases.
- Recognizing high-use locations or high-impact missions for deployment might result in an earlier and greater ROI while providing more opportunities for improved feedback.
- Ensuring that already deployed systems have sufficient sustainment before delivering more training technology can allow steady growth and acceptance that is historically bucked when early "bad press" is received.
- Deployments might be delayed or reassigned, depending on military operational needs.

The deployment step repeats as additional end users are equipped or as revisions are made to the content. Digital content that is downloaded seemingly magnifies the challenge of version control, especially when the operational environment does not have consistent network connectivity. Although all users will have authoritative content, not all will have the latest content that invariably will include corrections and refinements. Conversely, downloaded content is available and ready for training in environments with limited internet connectivity.[113] Another IT concern regarding deployment is pacing security updates that are largely driven by other requirements. Without coordination, automatic updates to the underlying interface (e.g., issued tablets, notebooks, specialized interactive display equipment) might prevent the content from being delivered or accessed.[114]

Utilization describes when end users employ the training technology. It is treated as a discrete step because many external military factors beyond the scope of deployment will affect the feasibility, frequency, and extent to which the training technology is employed. Existing training cycles will need to be augmented (or perhaps deliberately replaced) because training with advanced training technology will likely not be an initial requirement. Although ensuring that the training technology is available and performing as expected is requisite for utilization, it is likely that cultural acceptance of training techniques that replace the status quo will be barriers to utilization.

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[112] Mark P. Schroeder-Strong, Brian Schreiber, and Winston Bennett, "A Methodology for Projecting the Return on Investment of Training Technologies," *Military Psychology*, Vol. 36, No. 1, 2022.

[113] Some commercial content providers require an internet enabled license or version verification at each use; this would likely hamper military training utilization even at a home station where connectivity might not be consistent or available (in the case of a secure facility).

[114] DAF stakeholders, discussions with with the authors, January 26, 2023.

If the training technology is centrally managed, scheduling can become a dominating factor, especially if the number of interfaces is limited (e.g., virtual cockpits). Utilization is a basic metric that should be collected to help inform ROI. However, simply collecting the data on operational availability or when a training technology is being used does not necessarily indicate whether learning objectives salient to the trainee's mission are being met or whether that learning translates to improvements to on-the-job training.[115] Additionally, metrics regarding the modality of the interface should also be collected. This is because effective training can be critically dependent on how the content is delivered,[116] and the interface itself might impede learning.[117] There might be effects of "negative training," in which the artificiality of the training technology or the training vignettes translate into undesirable habits when operating the real systems or when on a real mission.

User buy-in is not ubiquitous to all technology transfer frameworks but is included here because acceptance of the training content is critical for success. A commercial parallel is market capture—supplying a sufficient portion of demand such that a business venture achieves its business plan goals.[118] This step is different from utilization because it implies acceptance by the community of end users that a training technology is worthwhile and desirable; end users will seek it out over other forms of training delivery. Understanding whether a market is captured is more complex than simply tracking sales or prevalence of a product. Post-use surveys and critical reviews are two methods among many others to gather indicators of this acceptance, informing the ROI and effectiveness step.[119]

ROI and effectiveness is the assessment step that weighs input gathered from the utilization and buy-in steps to determine whether the training technology is meeting the effectiveness measures set in the business plan. If the training technology is deemed effective, expansion might be pursued. However, if the cost (in dollars and burden on the end user) of the implementation is too high, then the ROI might be correspondingly low, and it might not be reasonable to expand. In the worst case, a drastically low ROI might suggest the need to terminate the deployment if other more cost-effective and similarly effective means of training delivery are available. The salient point is that training systems are not immune to the same fiscal or feasibility requirements that guide other products.

Training (and the use of technology in support of training) will require more human-centric measures compared with those commonly used in business, industry, and military operations (e.g., operational availability, mean-time-to-failure). One framework that learning professionals use to

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[115] Straus, 2019.

[116] At a foundational level, this occurs because different learning processes are at work depending on the content and the delivery. While it is common to suggest that some learn better by doing versus listening, recent research has also shown that the learning rate is strikingly similar among students undergoing the same course of instruction despite starting at different initial levels of competency (Kenneth R. Koedinger, Michael V. Yudelson, and Philip I. Pavlik, Jr., "Testing Theories of Transfer Using Error Rate Learning Curves," *Topics in Cognitive Science*, Vol. 8, No. 3, July 2016; Kenneth R. Koedinger, Paulo F. Carvalho, Ran Liu, and Elizabeth A. McLaughlin, "An Astonishing Regularity in Student Learning Rate," *Proceedings of the National Academy of Sciences*, Vol. 120, No. 13, March 28, 2023).

[117] One example of such an impediment is VR interfaces causing motion sickness (although repeated use might lower adverse effects) (Ryo Takata, Mitsugu Kanehira, Yoichiro Kato, Tomohiko Matsuura, Renpei Kato, Shigekatsu Maekawa, and Wataru Obara, "Improvement of Three-Dimensional Motion Sickness Using a Virtual Reality Simulator for Robot-Assisted Surgery in Undergraduate Medical Students: A Prospective Observational Study," *BMC Medical Education*, Vol. 21, No. 1, 2021).

[118] These goals can include, inter alia, targeted customer segments, growth, profitability, and long-term sustainability.

[119] Sae Schatz, Khanh-Phuong Thai, Scotty D. Craig, Jordan Richard Schoenherr, Jodi Lis, and Janet Kolodner, "Human-Centered Design Tools," in Jim Goodell and Janet Kolodner, eds., *Learning Engineering Toolkit*, Routledge, 2023.

improve learning is the Learning Engineering Process (LEP).[120] LEP can be applied on top of the T3D process, bringing a substantial body of education practice validated by engineering principles. LEP is an iterative, feedback-driven framework with this basic flow:

- Challenge: understanding the opportunity to improve learning or learning conditions
- Creation: creating designs, solutions, data instrumentation, and implementation plans
- Implementation: delivering the solution with real learners in a real environment
- Investigation: analyzing the collected data to validate improved outcomes and improve the solution.

With regard to measures, LEP explicitly focuses on the instrumentation, collection, and analysis of data to determine whether the introduced training improves learning.[121]

Our literature review identified research-derived ROI metrics for specific technologies, which we summarize broadly as used for training in physical (touch labor) skills and academic disciplines. For physical skills, **haptics** was the most common technology in the literature, and experiments suggested improved learning outcomes over the control.[122] To evaluate haptic-improved learning outcomes, three important metrics were force regulation ("Did you use the appropriate amount of force?"), completion time, and error rate. Other studies used questionnaires and performing the actual action as metrics.[123] In general, measuring proficiency for these physical, specialized tasks is more straightforward than measuring proficiency in academic disciplines.

For academic disciplines, such technologies as **adaptive training** and **gaming** were commonly used for subjects ranging from mathematics to foreign language.[124] To measure learning outcomes, most researchers use course grades or tests (both before and after instruction).[125] Normally, these assessments occur within a school year;[126] for time horizons greater than that, knowledge retention is

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[120] Erin Czerwinski, Jim Goodell, Steve Ritter, Robert Sottilare, Khanh-Phuong Thai, and Daniel Jacobs, "Learning Engineering Uses Data (Part 1): Instrumentation," in Jim Goodell and Janet Kolodner, eds. *Learning Engineering Toolkit*, Routledge, 2023.

[121] Czerwinksi et al. recently summarized current practices, including those tailored to military applications. One notable approach mentioned in Czerwinski et al. is the use of an IEEE standard called xAPI to capture metrics associated with experiential learning. The U.S. Army is integrating this across training domains (gaming, virtual, mixed, and live) so that all metrics can inform how successful the training program is at increasing a trainee's tacit knowledge (Czerwinski et al., 2023; Shelly Blake-Plock, Andy Johnson, Kevin Owens, and Benjamin Goldberg, "STEEL-R: Connecting Synthetic Training and Experiential Learning to the Total Learning Architecture and IEEE LTSC Data Standards," session presented at 2023 ICICLE Conference on Learning, July 24–26, 2023).

[122] Verena Nitsch and Berthold Färber, "A Meta-Analysis of the Effects of Haptic Interfaces on Task Performance with Teleoperation Systems," *IEEE Transactions on Haptics*, Vol. 6, No. 4, 2012.

[123] David Checa and Andres Bustillo, "A Review of Immersive Virtual Reality Serious Games to Enhance Learning and Training," *Multimedia Tools and Applications*, Vol. 79, 2020; Alexandra D. Kaplan, Jessica Cruit, Mica Endsley, Suzanne M. Beers, Ben D. Sawyer, and Peter A. Hancock, "The Effects of Virtual Reality, Augmented Reality, and Mixed Reality as Training Enhancement Methods: A Meta-Analysis," *Human Factors*, Vol. 63, No. 4, 2021.

[124] Umit Tokac, Elena Novak, and Christopher G. Thompson, "Effects of Game-Based Learning on Students' Mathematics Achievement: A Meta-Analysis," *Journal of Computer Assisted Learning* Vol. 35, No. 6, 2019; Kam Leung Yeung, Shana K. Carpenter, and Daniel Corral, "A Comprehensive Review of Educational Technology on Objective Learning Outcomes in Academic Contexts," *Educational Psychology Review,* Vol. 33, No. 4, 2021; Nitch and Färber, 2012.

[125] John F. Pane, Beth Ann Griffin, Daniel F. McCaffrey, and Rita Karam, "Effectiveness of Cognitive Tutor Algebra I at Scale," *Educational Evaluation and Policy Analysis*, Vol. 36, No. 2, 2014.

[126] Andrea Phillips, John F. Pane, Rebecca Reumann-Moore, and Oluwatosin Shenbanjo, "Implementing an Adaptive Intelligent Tutoring System as an Instructional Supplement," *Educational Technology Research and Development*, Vol. 68, No. 4, 2020.

not studied well.[127] Additionally, the science of adult learning is treated differently from kindergarten to high school (K–12) education: Although some principles translate, other adult considerations mitigate the effectiveness of those principles.[128] Researchers can also observe classrooms while the technology is used in lessons; this can provide helpful qualitative insights but might be untenable for a DAF-wide implementation.[129]

Linking a training technology directly to military outcomes would be ideal for demonstrating ROI, but doing so would be difficult. The nature of military formations and operations serves as an argument against the need for military outcome–based ROI metrics.[130] Intermediate measures of ROI, such as task proficiency demonstrated by routine operations, are more achievable and are widely used today. However, military researchers have recently formulated an ROI framework based on military readiness that is derived from both tangible and intangible elements (wars that do not occur, lives that are not lost, buildings that are not destroyed).[131]

Expansion is a deliberate step to increase the training technology capacity or accessibility such that more end users might learn from existing content or the content itself might be expanded. Because many training technologies deliver digital training content, one of the perceived benefits is the ability to disseminate a curriculum widely without the need to substantially increase the number of skilled instructors or facilities. However, increasing the number of interfaces (points where trainees might interact with the learning content) might still have materiel or licensing constraints, and improvements in accessibility might require changes in the interface or expansion of supporting infrastructure. Even if materiel aspects are held constant, content expansion might require SMEs, software developers, and media specialists, such as those employed during the development phase.

[127] Maya Escueta, Andre Joshua Nickow, Philip Oreopoulos, and Vincent Quan, "Upgrading Education with Technology: Insights from Experimental Research," *Journal of Economic Literature*, Vol. 58, No. 4, 2020.

[128] Layering military and professional education on top of "basic adult education" adds more complication (Blaise Cornell-d'Echert, Jr., "Beyond Training: New Ideas for Military Forces Operating Beyond War," *New Directions for Adult and Continuing Education*, No. 136, 2012).

[129] Phillips et al., 2020.

[130] Eduardo Salas, Laura M. Milham, and Clint Alan Bowers, "Training Evaluation in the Military: Misconceptions, Opportunities, and Challenges," *Military Psychology*, Vol. 15, No. 1, 2003.

[131] Schroeder-Strong, Schreiber, and Bennett, 2024.

Appendix C

Additional Considerations Outside the DAF Training Technology Transfer Framework

While we were selecting key factors to T3D following the approach described in Chapter 2, there were some factors that were eliminated from the final framework by our established criteria but still warrant documentation to acknowledge the challenges they pose to T3D. These factors are shown in Table C.1.

Table C.1. Additional Factors to Consider in Technology Transfer

Side of Process	Category	Factor
Supply or Demand	Processes	(–) Longer tech transfer timeline
Supply	Social Factors	(+) Creating an atmosphere of trust through communication
Supply	Technology Attributes	(+) Tech application is specific to one line of business[a]
Supply	Technology Attributes	(–) Technology presents new cybersecurity requirements or risk
Supply	Technology Attributes	(+) Niche application domain for tech with no competitors (i.e., only has single source)[a]
Supply	Technology Attributes	(+) Common codes and standards exist and are supported
Demand	Absorptive Capacity	(–) Bureaucracy too slow to adopt technologies that develop quickly
Demand	Financial	(–) Lack of investment vehicles to support infrastructure
Demand	Processes	(+) DAF does long-term planning for training capabilities
Demand	Processes	(+) Government leads interoperability efforts between multiple vendors and between existing tech
Demand	Processes	(–) Hinderance from standard acquisition processes (i.e., red tape, ATOs, reciprocity, etc.)
Demand	Processes	(–) Technology transfer “valley of death” (more than low TRL)

SOURCES: Choudhry and Ponzio, 2020; da Silva et al., 2021; Estep and Daim, 2016; Hilkevics and Hilkevics, 2017; Mazurkiewicz et al., 2021; Van Atta et al., 2003a; Van Atta et al., 2003b.
NOTE: (–) denotes a barrier, and (+) denotes an enabler.
[a] These factors may not be fully generalizable as enablers or barriers.

Appendix D

Training Technology List

In a companion report, we performed a landscape analysis of advanced training technologies.[132] Table D.1 provides the list of technologies we focused on, which led to our technology-specific recommendations for what the DAF should pay attention because of their promise for future DAF training and education. We also provide a brief description of each technology.

Table D.1. List of Advanced Training Technologies and Applicable Programs

Technology	Description
Adaptive training[a]	Technologies that recommend and/or deliver training content based on user performance or engagement histories
AR[a]	Technology that layers computer-generated information, often images, over real-world images or modifies the appearance of real-world objects
Aural reality	Technology that replicates environmental noise
Content tagging	Technology that tags training or learning content in an automated fashion
Gaming[a]	The application of commercially available, entertainment-oriented software for training or learning role playing events
Haptics[a]	Wearable devices that simulate the touch and feel of virtual objects or objects that provide physical feedback
Learning analytics	Use of data science techniques on data collected from a computerized learning, training, or education process
Natural language interfaces[a]	Text- or speech-based agents with which humans can interface in training or learning contexts
Neurostimulation[a]	The application of electrical currents targeted to specific areas of the brain to speed or strengthen the learning of a skill
Performance assessment[a]	Technologies that automatically score or estimate trainee or learner performance using objective data sources
Physical training aids	Surrogates for physical objects for training or learning events where physical touch is required
Physiological sensors and wearables[a]	Sensors, often worn, that record physiological data, such as heart rate, body temperature, eye movement, or composition of body fluids
Synthetic agents	Software-generated agent that can participate in training or learning events

[132] Toukan et al., 2024.

Technology	Description
Synthetic environments[a]	Computer-run simulations that represent semi-persistent environments relevant to learning or training involving a human participant
VR[a]	Technology that enables human visual, aural, and physical interactions in computer-generated synthetic environments

[a] These technologies were included in the expert panel.

As part of our use case analysis, we began with the list of programs shown in Table D.2. Each program was scored by four of our team members on a scale of 1 to 3 according to the criteria discussed in Chapter 3. The resulting average scores are shown in the table.

Table D.2. List of Candidate Programs Considered with Criteria

Program	DoD Service	Average Score
Airborne Tactical Augmented Reality System (ATARS)	DAF	2.5
Linguist Next (LxN)	DAF	2.25
Mage Duel (part of LxN)	DAF	2
Missions Essential Competencies (MECs)	DAF	1
Performance Evaluation Tracking System (PETS)	DAF	2.5
Pilot Training Transformation (Formerly Pilot Training Next [PTN])	DAF	2.5
Predictive Performance Optimizer (PPO)	DAF	2.5
MyTraining	DAF	1.25
Secure Live Virtual Constructive Advanced Taring Environment (SLATE)	DAF	1.75
Experiential Air Refuelling Lightweight Simulator (EARL)	DAF	2.5
Integrated Technology Platform (ITP)	DAF	2.25
Technical Training Transformation (Formally Maintenance Training Next)	DAF	1.5
Gaming Research Integration for Learning Lab (GRILL)	DAF	1
Basic Military Training (BMT) Learning Management System app	DAF	2.5
Member, Operations, Training, and Reports (MOTAR)	DAF	2.5
VR for suicide prevention	DAF	1.5
Virtualized Operational Flight Plan (OFP), integrated within Virtual Reality Aircrew Training Device (VRATD)	DAF	2.25
C2 Simulation Environment for Training (C2SET)	DAF	1.25
Air, Space, and Cyberspace Constructive Environment (ASCCE, ACE) and Information Operations Suite (IOS)	DAF	1.5
Future Synthetic Environment (FSE)	DAF	2
Sprint Advanced Concept Training (SACT)	DAF	1.25
AFFORGEN Virtual Assistant	DAF	3

Program	DoD Service	Average Score
Standard Space Trainer (SST)	DAF	2.75
Tactical Combat Training System (TCTS) II/P6 Combat Training System (P6CTS)	Navy/USMC	2.25
Joint Simulation Environment (JSE)	Navy/USMC	2.75
Next Generation Threat System (NGTS)	Navy/USMC	1
Navy Continuous Training Environment (NCTE)	Navy/USMC	2.5
Project Tripoli	Navy/USMC	2.25
Generalized Intelligent Framework for Tutoring (GIFT)	Army	2.75
I-MILES	Army	2
Virtual Operations and Rehearsal Tool—Extended (VORTX)	Army	2.25
Synthetic Training Environment–Information System (STE-IS)	Army	3
Striker Virtual Collective Trainer (SVCT)	Joint	1
Joint Live Virtual and Constructive (JLVC)/Joint Training Tools (JTT)	Joint	1.5
Special Operations Center for Medical Integration and Development (SOCMID)	Joint	2.75
Pervasive Learning Systems (PERLs)	Joint	2.25
Eolian Augmented Reality Tactical Assault Kits (ARTAK)	Joint	1.25

NOTE: USMC = U.S. Marine Corps.

Abbreviations

ACC	Air Combat Command
AETC	Air Education and Training Command
AF/A5/7	Air Force Futures
AFRL	Air Force Research Laboratory
AFSOC	Air Force Special Operations Command
AR	augmented reality
ATO	Authority to Operate
CFT	Cross-Functional Team
COTS	commercial off-the-shelf
CSTE	Common Synthetic Training Environment
DAF	Department of the Air Force
DARPA	Defense Advanced Research Projects Agency
DEVCOM	Combat Capabilities Development Command
DoD	U.S. Department of Defense
DOT&E	Director, Operational Test and Evaluation
GAO	U.S. Government Accountability Office
GIFT	Generalized Intelligent Framework for Tutoring
IEEE	Institute of Electrical and Electronics Engineers
IT	information technology
ITP	Integrated Technology Platform
JSE	Joint Simulation Environment
LEP	Learning Engineering Process
LVC	live, virtual, and constructive
MAJCOM	major command
MSVP	mission specific vendor plug-ins
NGTS	Next Generation Threat System
OWT	One World Terrain
PEO	Program Executive Office
POR	program of record
R&D	research and development
ROI	return on investment
SME	subject-matter expert
SOCMID	Special Operations Center for Medical Integration and Development
SST	Standard Space Trainer

STAO	Space Training Acquisition Office
STE-IS	Synthetic Training Environment—Information System
STRI	Simulation, Training, and Instrumentation
T3D	training technology transfer for the Department of the Air Force
TRL	technology readiness level
TTO	technology transfer office
USAF	U.S. Air Force
USG	U.S. government
USSF	U.S. Space Force
VALOR	Virtual Advancement of Learning and Operational Readiness
VR	virtual reality
VV&A	verification, validation, and accreditation

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PROJECT AIR FORCE

Training and education in the Department of the Air Force (DAF) is undergoing a major transformation as part of an effort to maintain an asymmetric advantage over competitors. As part of this transformation, the DAF wants to invest in advanced training technologies, such as augmented and virtual reality, gaming, and synthetic training environments. To reap the benefits of these new training technologies, the DAF must successfully transition them to the force.

In this report, the authors examine what factors enable a successful technology transfer and how those factors have come into play in select use cases. They use their findings from a literature review from academic, industry, and government sources about technology transfer and DAF subject-matter expert interviews to construct a framework for training technology transfer in the DAF. This framework provides a view of the steps in the process and the potential barriers and enablers associated with each step. The authors also examine six use cases from ongoing efforts across the U.S. Department of Defense to provide further insights into the challenges of training technology transfer. The use cases examined are the Generalized Intelligent Framework for Tutoring, Synthetic Training Environment–Information System, Joint Simulation Environment, Standard Space Trainer, Special Operations Center for Medical Integration and Development, and Integration Technology Platform.

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