Re-Engineering Aviation Training: Applying human-focused learning engineering processes to modernize training pathways, interventions, and use of simulation

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ABSTRACT

For decades, an industrial model of training pilots has been used to maximize throughput, guarantee mastery, and ensure readiness to fly pre-defined missions. However, these goals are no longer sufficient to compete in the contested high-end fight. Rather, it is necessary to prepare for a novel “Night One” fight that will test the cognitive agility, physiological-management, awareness, team coordination, metacognition, physical readiness, and decision making under stress of pilots across multiple platforms. In short, human optimization during training will be required to maintain readiness of aviators for the volatile, ambiguous, chaotic, and unpredictable environment.

To accomplish this, recent data was collected and suggests that a conceptual shift in how training is designed, how it is focused, how to choose technologies, and how to write requirements for engineers is needed. Leaders in aviation training have been trying to answer these questions through a variety of commissioned studies, reviews, and interviews but these efforts answer independent questions and lack the strategic efficiency and effectiveness needed. It has become clear that a holistic design of the process that addresses the myriad issues and dependencies across the aviation learning ecosystem is required.

Specifically, aviation training concerns have been launched into the forefront of leadership as investments in large-scale multi-platform simulation environments connected across USN and USAF are being considered and designed. Yet, strategic training clarity that connects whole-person pilot readiness to training for the high-end fight, technology requirements, and learning science interventions is needed to inform policy and investment planning. Accordingly, this paper provides a strategic learning engineering design map of the recent extensive modernization efforts. It highlights the qualitative, quantitative, and previous research data collected through this extensive process that can be used to drive joint training planning, program management, future research, and industry requirements.

ABOUT THE AUTHORS

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JJ Walcutt is a scientist and strategic designer of large-scale learning programs. Her current work focuses on optimizing human cognition and performance across a wide spectrum of learning programs including neuro-informed military training, data-driven higher education planning, and talent development optimization. Through varied service to the U.S. Government, she has led strategic design projects focused on optimizing USAF pilot readiness, modernizing learning across the US DoD, and expanding innovation across the US government. Dr. Walcutt has over 25 years of experience in research and development for training and education with specific interests in improving educational systems nationwide as well as internationally.

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INTRODUCTION

As the contested fight looms before us, all domains of warfare are trying to determine what that future fight will look like and more importantly, how to prepare for it. As technology and the use of that technology worldwide has begun to level, it means that peer and even near-peer adversaries are able to compete and win against the US (National Security Strategy, 2018). Stated another way, it means that the humans in charge of wielding technology are going to be the lynchpin for success, but only if trained and prepared at a level and in a way that allows them to perform measurably better in these expected volatile, uncertain, chaotic, and ambiguous scenarios.

Specific to pilot training, there are some significant concerns connected to these anticipated changes in how adversaries are progressing. One of the most pressing concerns focuses on the approach to training – it's organization, focus, and content. Related, but often missed, include the associated technologies and those elements that are being developed. In other words, too often, we try to incrementally improve training, but we do so using the same methods we've been using for the past 70 years – an industrial model that treats humans like widgets along an assembly line: with each new advancement, we add a new "feature" to the widget. The assumption is that as new mission expectations develop or as new airframes are created, pilots will adjust to emergent requirements to operate advanced systems.

However, the human brain has limitations. The timeline to train has limitations. Collateral duties further take attention and time. Additionally, budget constraints further limit the development, procurement, and use of technology that can enhance training (SATIP: Repository D, 2021). Summarized, pilot training has been maxed to the breaking point using current approaches to training, development, and procurement. It is no longer possible to simply add more information to doctrine and associated programs of instruction or to allow wing commanders to purchase one-off technology pieces to try to work into their instructional programs. Rather, a full scale, strategic level overhaul is required. The pressing question is: How?

CURRENT STRUCTURE

Training Pathways

USAF training, across the airframes, begins with Formal Training Unit (FTU) or initial pilot training, and continues through several advancements specific to a certain airframe, including instructor training and for the elite pilots, Weapons Instructor Course (WIC) at the USAF Weapons School. Training delivery includes classroom academics, and sorties. Sorties are the mission tasks and descriptions that are executed either in the simulator or in the aircraft. Academics are assessed through written testing or instructor approval and sorties are assessed by instructor description and noted in the Ready Aircrew Program (RAP) Tasking Message (RTM). The benefits of this system are the clarity of pilot development tasking and the ability to maintain basic airmanship skills while building mission-specific experiences. The primary challenges to this system are lack of individualized pathways that build on previous experience or capability, the focus on specific mission sets versus competencies for novel scenarios, and the need to learn more cognitive capabilities that will affect time and quality of decision making and action in the contested, peer fight (Walcutt, Harley, Spohn, & Bockelman, 2022). Further, when the investment in human capital is made and developed, the staffing structure often does not allow for the true return on investment by allocating time to allow the investment to blossom and be utilized.

Navy and Marine Corps pilot training begin on similar paths for training aviators, starting with Navy Flight Introduction Evaluation (NIFE) exposing students to basic topics related to aviation. Student naval aviators (SNA) and student naval flight officers (SNFO) then proceed to their Primary, Intermediate, and Advanced training at Training Wings (TRAWING) in Florida, Mississippi, and Texas. Prior to reporting to operational fleet squadrons, aviators report to the Fleet Replacement Squadron (FRS) to be trained on the specific airframe, associated systems, and procedures. Aviators continue to work to earn qualifications and designations and develop their expertise in tactics at the fleet squadrons. Aviators that have advanced may be called on to become tactics instructors through the Navy's Fighter Weapons School, or Marine Corps' Marine Aviation Weapons and Tactics Squadron (MAWTS-1). These schools set the standards for instruction, tactics, airmanship, and professionalism which flows back to operational squadrons.

Business and Management

The procedural side of the business of creating these training plans follows a pathway which creates key issues, stemming from the junction of funding, policy, and planning. Specifically, the National Defense Authorization Act (NDAA) sets the tone for all DOD spending, which can trace its roots to Title 10 appropriations and other policies which ensure that the services are being trained, organized, and equipped. The budget sets forth what is available and supported by existing policy. This is an issue because they are mutualistic in nature, and therefore require extra effort to ensure changes align. Specifically, the current flow of money, policy, data, and information is disconnected, unfocused, and non-linear (see Figure 1). As a result, research is duplicated, engineers fail to obtain accurate requirements, commanders are forced to make their best guesses about what to purchase to enhance training, and ultimately, pilot readiness suffers while resources are overly expended. It is not the case that modernization can occur by incrementally addressing each of these elements individually. Rather, a full-scale overhaul is required.

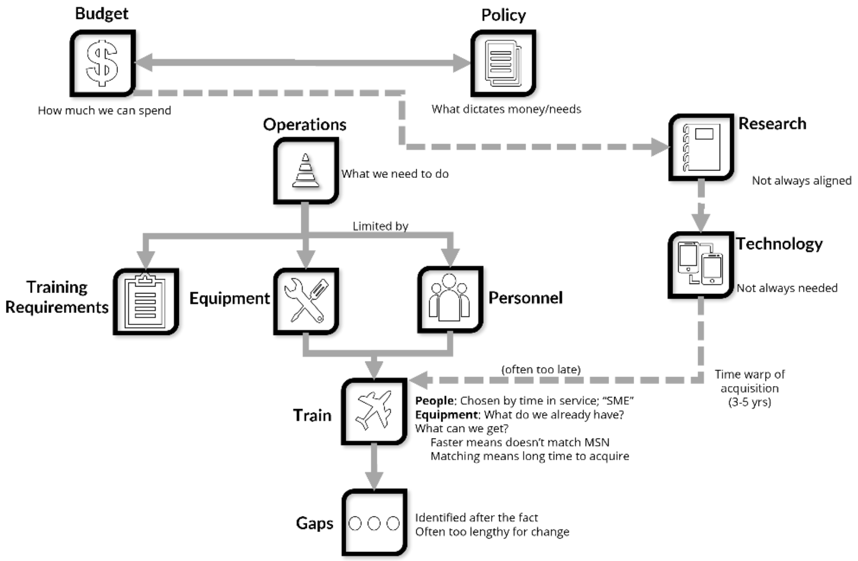

Figure 1. Current Aviation Training Design.

The Big Picture

For an evolution of this scale, it is necessary to invoke a human centered design approach that first describes the end goal and then use that vision to drive the planning and organization of the pathways to get there. Specifically, for a strategic pilot training evolution to occur, several areas of concern need to be addressed simultaneously because it is no longer viable to make incremental changes and frankly, it is not necessary because so much research and development has occurred that it is wiser to connect the dots than it is to re-invent the wheel. In other words, the issue isn't that we lack the elements needed to prepare for the contested fight, the issue is that we haven't organized them and developed a strategy for implementation. Thus, the goal of these extended and connected efforts for improvement is to evolve the training planning, processes, content, and delivery into a modernized fluid system-of-systems that allows training to be conducted anywhere, anytime, and which maximizes whole human capacities as well as technological enhancements and training aids.

METHOD

Data was collected across numerous sources and across several projects and activities conducted by or commissioned by both the USAF and USN. There is an increasing awareness at the strategic level that research, policy, and testing being conducted across both services can, and should, be shared to most efficiently modernize and improve pilot training writ large. Accordingly, the findings across multiple major projects, research, and programs have been compiled here and used to design a human-technology-aircraft system-of-systems strategic engineering plan.

Paper Review: Over 150 recently commissioned research papers and doctrine analyses were reviewed to understand the work that has been invested in by the services to better understand pilot training, the challenges, and the needs (SATIP: Repository D, 2021). Additionally, scientific research papers (N=320) across the training, learning science, cognitive, physiological, and neuroscience literatures were reviewed to drive an understanding of the art of the possible for future pilot training (Armendariz, 2022a)

Technology Review: Technology elements (e.g., VR, AR, embedded training, simulators, digital highways, etc.) were reviewed to understand how technology is purchased, used, and the associated challenges with rules, interoperability, and training impact (Walcutt, et al., 2022).

Financial Review: Budget allocations and rules were reviewed to understand spending, allocation, and approval patterns, challenges, and concerns (Walcutt & Spohn, 2022).

Training Review: A deep dive into training elements per airframe was conducted to understand the common issues, concerns, and competencies needed for the future peer, contested fight that are, or are not, being addressed or developed currently (Walcutt, Spohn, & Bockelman, 2022).

Interviews: Finally, 28 pilots, instructors, and supporting staff (e.g., physio instructors, strategic technology planners) across 17 airframes and both services participated in semi-structured interviews to understand their concerns, expectations for future challenges, and training needs to maintain and extend readiness levels across pilots. Airframes included: F-22, F-35, F-16, E-3, B-2, B-52, EA-6B, MC-130J, KC-135, C-17, MQ-9, RQ-9, RQ-150, F/A-18C, F/A-18E, AC-130, and MH-60S.

Human Centered Design Process: Taken together, a strategic engineering approach with a human centered design analysis process was conducted to determine how to address system-level changes that together, can enable full modernization of the training pipelines, whole-human training, and cognitive extension to enhance readiness for the future contested fight (Walcutt, et al., 2022).

FINDINGS

Paper Review

At the strategic level, the USAF Air Superiority 2030 Flight Plan (2016) identifies key target areas to improve including training effectiveness, cognitive modeling, and application to the operational environment. Similarly, the Naval Aviation Vision (2020) outlines the importance of training, staffing, and technology strategies to carry Naval aviation into the future. These include understanding the true capabilities of the Naval Aviation Enterprise (NAE) and determining how to best address a unit's mission essential task list (MET). To address these issues (e.g., identify them, understand them, and determine their root causes) numerous studies by both services have been conducted (SATIP, 2022) but little action has been taken to address them. As many of these documents are not for public release, they cannot be fully outlined here but the majority of releasable issues are named repeatedly in a report provided to congress focused on: (1) how pilots are assessed for proficiency and consequently deemed "ready" for combat is not effective, (2) the definition of pilot proficiency is arbitrary and yet still used to allocate resources and define training pathways, and (3) the US needs to invest in ways to collect data about pilots, analyze it, mine it, manage it, and use it to drive training plans and readiness assessments (Ausink, et al., 2017). To date, these issues have not been addressed.

Research Review

In complement, scientists have been studying these issues and developing solutions for decades. Thus, the research review was substantive (N=320) and covered topics as wide as modeling and simulation theory (Ziegler, Kim, & Praehofer, 2000), instantiation of simulation into pilot training (Pennock, 2007), neuro and physiological science for pilots (Lodge & Harrison, 2019), and cognitive and learning sciences (Sweller, van Merrienboer, & Paas, 2019). Combined, this wide understanding of what is possible based on scientific findings and technology advancement allows the most pressing points to surface. First, an understanding about how the brain and body operate under stress is deeply recognized (Vartanian, Saint, Herz, & Suedfeld, 2020) and the ability to measure these differences in real time exists (Walcutt, Horton, Jeyanandarajan & Yates, 2020). The development of models and simulations that can aid pilots to learn faster, better, and less expensively also exist and have demonstrated significant gains in research efforts (Myers, Starr, & Mullins, 2018). AI algorithms and other data science capabilities, when provided the necessary volume and variation of data, can prove highly valuable in detecting issues, enhancing learning, and creating personalized pathways to improve efficiency (Yang, Ogata, Matsui, & Chen, 2021). Studies commissioned by the DoD to look at these research advancements and translate them to improvements for pilots has also been extensively conducted (SATIP: Repository D, 2021). Finally, theories about how to combine these elements at the theoretical level have been in publication for decades (Yang, Ogata, Matsui, & Chen, 2021). One of these theories, the framework of 4E cognition (extended, enactive, embodied, and embedded), has significant evidence flowing throughout the aviation training and education pipeline that could act as a structural foundation for training modernization (Newen, DeBruin, & Gallagher, 2018). It is therefore glaring that while three decades of research has been conducted by several related areas of study, the combination of these findings has not been widely shared across the services for training design nor instantiated into modernization efforts for active-duty pilots.

Technology Review

There are four technological training environments used by the USAF and USN: classroom, live fly, range, and simulator. These ranges vary in complexity and scale, but unfortunately, even the most advanced ranges lack the ability to simulate many of the threat capabilities and densities that are required. Furthermore, the cost and limited availability of ranges like the NTTR make them necessary yet insufficient to meet current and projected training requirements. The complications of training are similar in the Navy and Marine Corps. The challenge of being able to train to compete against near-peer 5th generation and beyond fighters often runs headfirst into availability of aircraft, time to train, ranges, and pilots available to do so. EW ranges are faced with several issues from continuing to own adequate airspace to providing the highest quality training – whether with foreign material exploitation (FME) systems, or threat emitter simulators. EW is also challenged by the ability to fully test its capabilities on aging and shrinking ranges across the US. Like the Air Force, the Navy has committed to upgrades to work towards the integration and enhancement of the training environment. This will work to support the Navy Enterprise Tactical Training Network and the Navy Integrated Training Environment (NITE). In addition to the high-end, integrated training environments, significant development has occurred in the lightweight simulator space that is yielding promising training outcomes at a substantially reduced cost. In fact, a recent review of defense training companies at Interservice/Industry Training, Simulation and Education Conference (SATIP Repository D, 2021) found 150 companies focused on modeling and simulation training platforms for flight training. The primary benefit of these technologies is that they target decision making under stress but as both services struggle to determine how to assess the impact of these technologies for training, they are not being procured or used at the rate they could and are needed.

Financial Review

In the USAF, the typical financial process is split between A3T who oversees the post-UPT, ACC who overseas UPT under Air Education Training Command (AETC), and wing commands. In the first two, there are strategic decisions made and large allocations for research, training, policy, and procurement for items such as full-scale simulators. At the wing level, purchases can be made in smaller amounts at the discretion of the commander and without a clear reporting structure to the strategic planners as well as without guidance from across the fleet. The benefit is speed-to-acquire and knowledge of the specific issue being addressed but the cost is an often substandard and short-term impact. No standardized training impact guidance, rubric, or policy is provided to decisions makers of any level for determining how technologies and training supports purchased will translate to measurable improvements in readiness. In the NAE, funding is appropriated from Operation & Maintenance (O&M) and training costs are split between fleet training, training support, and recruiting. The main goal of fleet operations funding is to enable the Carrier and Expeditionary Strike Group power projections and dynamic deployment (Department of the Navy, 2021). The request for FY23 was $10.1B for air operations (Correll, 2022) and funding is broken down to the Navy's Flying Hour Program (FHP) as well as for flight operations and maintenance (Philips, 2001). The Navy gathers readiness metrics and analyzes them for any changes in the upcoming budget. This helps determine the number of hours that the FHP should allocate to the squadrons, including those supporting Fleet Air Training, such as the FRS.

Training Review

Looking into the near (2027) and longer term (2035) future, primary training concerns for the USAF fall into three key categories: a) technology, b) human, and c) instructional elements. Technologically, the complexity of threats is expected increase exponentially in both depth and breadth. Current simulators cannot meet the training needs for this future complex, contested environment and live-fly training is not an option due to operational security (OPSEC) and pragmatic issues (e.g., range size). On a human level, once the ability to collect real time data during training and operations is fully utilized, the ability to train human-technology combinations will fundamentally change the way humans learn, what they learn, and the pace of knowledge acquisition. Thus, as the complexity and pace of change increase, reliance on individual human instructors will not realistically be able to keep pace. Rather, the use of artificial intelligence, big data analytics, and brain-based interventions will be necessary to drive instructional decisions. Replicated across the USN, the complexities seen in recent changes in the training pipeline also extend to fleet training concerns. First, replacing an aging fleet is challenging. The fleet concerns are similar in the transitions to the F-35C, as well as considerations of how to get existing F/A-18 E/F models into the Service Life Modification program to extend the service life (Shelbourne, 2022). Maintaining the training and operational fleet impacts the ability to train by ensuring airframes are available, and standardized training occurs. Additional gaps involve the concerns of modernizing and providing for distributed mission operations by providing interoperable and interconnected training systems (Air Force Magazine, 2022). Without the upgraded training systems and ranges, aviators are left without actual deliberate practice or experience before facing threats in the real world.

Interviews

Several platform training commanders were interviewed to better understand the challenges currently facing USAF instructors and trainees including fighters, C2, bombers, tankers, mobility, and remotely piloted aircraft (SATIP, 2020). Findings suggest (1) readiness needs to be defined by pilot capabilities rather than the number of hours or sorties flown, (2) high-end training in the future will be almost entirely done in virtual environments, and (3) unscripted, high-end, contested fight scenarios with fog and friction are needed for deliberate and extensive practice. USN interviews yielded a similar picture in several areas including concern that simulators are too pristine and planned for them to be useful for training for the contested fight. Other concerns included: (1) data overload and the impact on the brain, (2) the need to ensure that pilots can display flight automaticity/embodied cognition (being one with the plane) and do not rely solely on technology, (3) cognitive and physiological functioning for optimal performance must be a focus for developing pilots, and (4) selection practices need to recognize the differences in capabilities (e.g., pilot skills are not synonymous with commanding skills).

Summary

Combined, significant resources have been expended to understand the training problems and future fight that face pilots across both USAF and USN. Substantial scientific research has been conducted to address these issues. Technology has been engineered and developed and much more is being created. Big visions have been written and published and the lack of action and clarity of modernization is measurably resource costly. Ultimately, and most importantly, readiness is threatened. These extensive efforts which have not yielded the expected return on investment drive the question: Is there another way to approach these challenges that may lead to a better outcome?

MODERNIZED DESIGN

Using human centered design principles, the first step is to clearly define what systems are needed and how they will connect. This includes how information, data, people, and resources should flow as well as how policy needs to be updated to help support the structure with guidance and requirements. Specifically, the most important piece of the future puzzle is to start with a proper definition of the operational need and mission essential tasks (METs; see figure 2). Learning engineering, as opposed to industrial instructional systems design (ISD), practices that define competencies and associated assessments will be necessary to avoid the RAP issues noted earlier. At the next layer, the 4E cognition model can be used to help shape training practices, research and development goals, and policy structures for design and procurement to ensure that training and technology can be measured for effectiveness and impact. Remaining capability gaps can then be identified and used to drive the budget, requirements, data to gather, and drive future research. It almost seems simple but given the size of the US DoD, too often, siloed programs, initiatives, offices, and competing goals make changes seem nearly impossible. So what is different about this approach compared to others? Simply put, what is different is that it is not a set of new ideas. Rather, it is a small revision of flow that capitalizes on current scientific and technological consensus. It brings to bear all the research, training practices, and technology capabilities championed across the department and industry and uses them to inform the entire system rather than only siloed pieces. A deeper description of each recommendation is provided below.

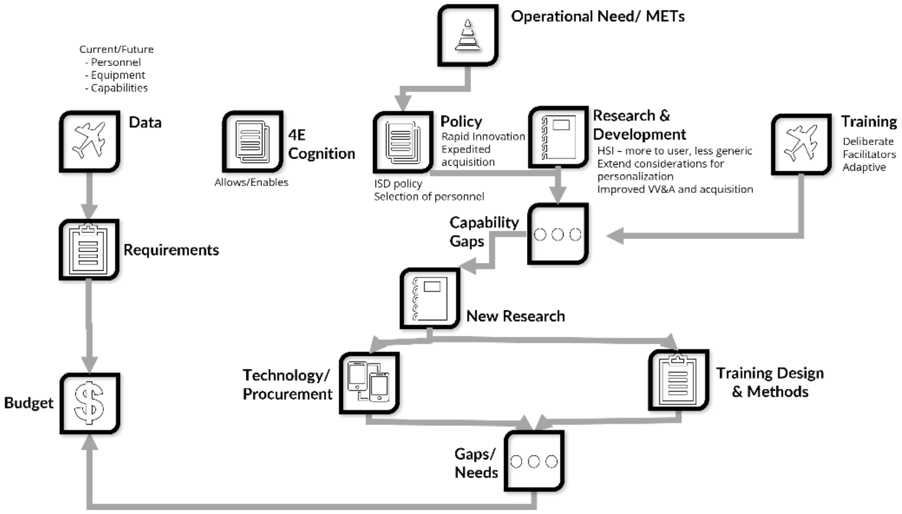

Figure 2. Modernized Design

#1: Operational Need: Using Learning Engineering to Define the Path

The process of defining operational needs and METs cannot simply reflect wing level observations, otherwise the RAP issues noted to congress will continue. Rather, they have to additionally take into account the findings of research, technology development and future capabilities, as well as human needs, to include neuro-cognitive elements. Thus, the first requirement is to transition to using learning engineering (LE) processes for defining training goals, needs, interventions, and pathways. LE is a modernized version of training design that focuses on developing pilots' competencies versus executing training based on mission practice alone (Walcutt & Spohn, 2022). Making this change will not only improve the definition of readiness and improve training but it will allow the development of mission essential tasks to be data driven. Analysis of the data gathered through the LE process will help expedite decision-making as well as improve decision efficiency by helping make sense of the information available and focusing the attention of decision makers (Kuziemski & Misuraca, 2020).

#2: Research and Development: Human centered design (HCD) and human systems integration (HSI) must be the focus of all efforts because if it cannot be used effectively, it will be waste.

Two key principles are needed to replace the belief that the only way to drive development is to create a list of requirements. Rather, using HCD methods, (1) the finalized design or vision should be the primary method for communicating with engineers whether in planning or contracts. (2) HSI must also become part of the delivery process. If new elements, be they data, training, or technology, do not connect to the greater training ecosystem, then they will become essentially unusable. Contracts should begin to reflect this requirement. The goal will no longer be to treat pilots as widgets along a conveyor belt that receive one-size-fits-all training. Rather, it will be necessary to be able to first assess the human's unique capabilities, understand their connection to the 4Es, and accordingly, provide experiences and learning opportunities to help create a human-technology-aircraft symbiotic unit. Specific to pilot training, significant investments in the development of virtual and constructive enhancements are made each year but too often, the requirements written in contracts fail to provide enough information to the developers to create solutions that fit the needs of trainees and as a result, lead to reduced training impact at best or negative training at worst (Walcutt, et al., 2022). Accordingly, it is imperative that a holistic human-technology approach to training be considered. To accomplish this, three layers of scientific findings need to be considered: (1) human neuro-physiological baseline, (2) expanded cognition, and the (3) impact of technology on human performance.

#3 Policy: Setting the stage for change.

Policy that defines the systems acquisition process currently delineates appropriate milestones to check for research and development progress along the assembly line but needs to build in a component in which the end-user is considered from both a utilization and cognitive perspective. This can be injected at the design level or in the verification, validation, and accreditation (VV&A) process. The 4E cognition framework has been briefed to the Navy's VV&A working group as a consideration for acquisition professionals to use when working through the VV&A process for a given system. This structure for assessing training impact will enable them to anticipate end user effects as it provides a formalized, replicable method for assessing impact. This is needed because technology advancements have evolved rapidly, particularly in the commercial sector, and have therefore slowed, if not crippled, the ability of the DoD to maintain pace with adversaries who are exploiting emergent technologies. Accordingly, three areas in policy must be addressed to maintain technological superiority: (1) funding for these technologies, (2) management of these technologies and their acquisition, and (3) talent management of those working in these fields (Sayler, 2020). Specifically, this will require an assurance of not just rapid innovation funding, or earmarked dollars for emergent trends, but also accounting for maintaining efforts over the horizon for stability. Secondly, policy changes must reflect the need for off-ramps in the systems acquisitions process that allow emergent technology to stay ahead of the competition by providing it to the end user before the technology is obsolete. Further, policy will need to change the way that funding is categorized to adjust for modernized acquisition. Currently, software is a difficult acquisition because it falls under both R&D and procurement and sustainment funding. This adds to confusion and is further amplified considering that software is an important element of nearly every acquisition (Bush, 2022). Finally, talent management must consider recruitment and retention policies to bring aboard the most qualified professionals to foster the development of these technologies and trends (EO 13932, 2022). But, policy improvements to the budgets for training innovation requires more than just allocating to innovation lines. There must be a culture change in which decision makers and stakeholders alike are not crippled by risk aversion. R&D and innovation are progressed through lessons learned by failure, thus avenues for funding should be flexible to allow for rapid funding, or non-traditional means of support, such as Other Transactional Authorities. The DoD has tried to push innovation through funding with more than 50 additional external funding programs (Bresler, 2018) and there is still room to reform, because complexity breeds new issues. Simplify the process, clarify the avenues and entry points, and reduce stove pipes for funding and the innovation will flow.

#4: Training: Training practices must become deliberate, adaptive, and facilitated by instructors trained in the learning sciences.

Training Readiness

Aviation training over the past 70 years has been largely procedural and habit driven. The nature of operations did not ask for complex cognitive engagement and focused on memorization, conditioning, and muscle memory. However, cognitive readiness and technology-performance-enhancements are significantly more important as the complexity of the material and the tax on the body increase (Walcutt, Armendariz, & Jeyanandarajan, 2021). Understanding the integration of mind, body, and brain is key to the holistic nature of training. For example, the amygdala acts as a watchtower for threats (Van der Kolk, 2014). A student being screamed at will perceive a threat and lose focus on required inputs and information – which then have little to no chance of being encoded properly, or available for retrieval later in long term memory (LTM). As such, being ready to learn is the first step in creating effective training (Armendariz, 2022b). It means the base of an effective training plan begins with intentional design of the learning environment itself to be neurologically and physiologically conducive to optimizing the impact of training. Accordingly, research scientists have been building on this idea of cognitive and physiological readiness to learn for decades and not solely from an observation or awareness level but from an objective technological level that focuses on measuring the whole human and then using that information to drive interventions. Yet to date, across both the USAF and the USN, pilot training readiness is assessed based on mission-oriented training experiences rated subjectively. This feedback loop is short sighted because it fails to take advantage of all tools available. Pilots, in particular, face dramatic cognitive and physiological impacts during flight and can be highly affected by cognitive overload prior to take off. Further, because these impacts are not readily visible to an instructor, they are too often ignored and their affects underestimated. Safety is not only compromised but the learning that the trainee will experience will be limited. Worse, when a gap in the knowledge sequence creates a break in thought process, the ability to connect new learning to prior experiences or to store that information in LTM is hindered. The impact in theater could be reduced reaction time or poor decision making (Euston, Gruber, & McNaughton, 2012). Yet, had the pilot been properly "diagnosed", "treated", and then allowed to fly once ready, learning would have been more impactful, and no interruptions would have been created in the cognitive chain. Readiness would be increased.

Training Design

An important distinction that often goes unrecognized is that the process of cognition is not solely within the brain or mind. In aviation, pilots must understand through a concept called embodied cognition that the brain relies on the physical body (extra neural) as an input for cognitive processes (Farina, 2021). Pilots must operate as if they are one with the aircraft. It is therefore neither efficient nor effective to first train pilots to fly and then separately train them to use technology. Rather, the symbiotic state of human-machine cohesion must be the focus of the future. Specifically, given the technological advancements for training pilots available, we can better assess individual learning, focus, and practice as well as use that data to drive readiness understanding and personalized learning. However, if there are no metrics for procuring learning technologies, then haphazard spending at the wing level will continue to be the pervasive means of gathering elements. Thus, a formalized, policy-level, set of standards must be created to clarify for all procurement what the individual, team, and force-level impact will be once these elements are used for pilot training. Thus, two key training design elements, influenced by the concept of 4E Cognition, can help drive the needed structure of future pilot training. First, lessons-to-learn need to be linked to missions, sorties, and how the human-machine team can best operate. As noted previously, this begins with consideration of the affordances in the environment. Embedded cognition is one of the four "E"'s that make up 4E cognition and it is used to guides designers on how to make use of the environment by creating relationships and connecting resources with the processes of the body and cognition (Overmann & Malafouris, 2018). In aviation, this means beginning the design process with consideration of both the training plan and the cockpit environment, especially the trainer systems. It means creating a learning environment that incorporates human systems integration (HSI) principles, which applies foundations from human behavioral science to find improvements to human factors related issues (Landsburg, et al., 2008), to allow for a symbiotic learning space that exploits embodied cognition for increased learning efficiency. As the complexity of the competency-to-learn increases, so too should the fidelity of the training system in order to build training which closely replicates the operational environment for the learner. The second key design element uses extended cognition. Specifically, aviation is a dynamic environment and as such, with advancing technologies of all platforms, consideration must be given to the affordances in the cockpit – the tools, instruments, displays, and panels providing information or control to the aviator. Extended cognition posits that the body works with the resources in the environment and acts upon them to support parts of the cognitive process (Kiverstein, 2018). Understanding the design of trainers and cockpits, as well as the relationship and intended affordance between the environment and the human, is crucial. It will lead designers of training plans to more intentionally leverage these elements to operate effectively during scenarios that mirror operational missions.

Training Interventions

Thousands of interventions to enhance learning have been studied across education (Vogel-Walcutt, Fiorella, & Malone, 2013) however, too often, they are under, over, or misused by military instructors because the underlying principles are not taught. We need to lean on a framework that can help shape and define when to use these training aids. From a design perspective, the key steps for instruction include: Encoding, Storage, and Retrieval then Acquisition, Compilation, and Automaticity. More specifically, trainers need to be deliberate in knowing which way they are planning to deliver the material for encoding/acquisition, then how long they expect the student to use it (working, short-term, long-term), and how fast the student needs to retrieve it. It is necessary to broaden the scope and concept of training to account for virtual learning, individual learning, informal learning, and specific to military learning, changing conditions, operational tempo, and mission interruptions. To this end, ecological cognition accounts for the relationship between an organism and the environment which provides a framework for shaping understanding (Turvey, Shaw, Reed, & Mace, 1981) for instructor pilots regarding when and how to enhance the environment through interventions such as complexity, diversity, and novelty (Redick, et al., 2013). Further, deliberate planning in cockpit design to consider the addition and placement of key panels and instruments to aid in aviation, navigation, or communication to take advantage of these environmental affordances is key. Thus, the modernized concept of the "learning environment" must involve a more generalized and expanded view of the space around the learner which provides affordances to the learner, whether tangible or perceived, and the enhancing support elements provided to the learner (e.g., technology or training aids).

#5: Technology: The benefit of technology is not as a solution but as an enabler.

It is too often assumed that technology is, in and of itself, a solution. Rather, technology for the near future must accomplish two goals: (1) Information management and (2) Information delivery. Information management refers to the assessment of trainees as well as management of all incoming other data to include the analysis and mining of that information to drive both automated decisions (e.g., AI-driven learning pathways) and human decision-making (e.g., arming commander with information superiority to improve strategic awareness and enhance quality of decisions). Information delivery refers to providing learning opportunities to trainees using technological media (e.g., simulators, ebooks, etc.). Both are described below.

Digital-Data Highway

To accomplish the first goal of acquiring and managing information about both the human and the environment, sensors of all types will be required and are extensively described in the earlier sections of this paper. But while gathering the data is necessary, it is insufficient alone to affect decisions. Rather, it needs to be connected, analyzed, packaged, and accessible to be useable for driving decisions. Accordingly, a data-digital highway that connects data from unlimited systems must be created.

Simulation

A second major concern is the use of simulators, especially in aviation training. Hands-on opportunities are key to training pilots because the necessity to understand what they learn how to learn to apply it in novel situations, practice is not enough to become connected with the plane or to coordinate physical skills with cognitive processes. But which level of simulation should be used for which type of practice is not often intentionally chosen. Light-weight simulations (e.g., AR, VR, MR, etc.) are best used for single person procedural practice (e.g., reps and sets). At a relatively low cost, these types of simulations are highly portable, easy to use, and can allow a trainee the extensive practice on specific flight patterns or events needed to build a robust library in LTM from which to elicit and drive decisions in high stress operational environments. Full-scale simulators can vary in size and capability but are beneficial for aviators to learn both how to fly the aircraft but also how to connect physical and cognitive concepts together in a full mission series. Distributed and connected simulators used in a common environment (e.g., the Joint Synthetic Training Environment [JSE]) is the primary training environment goal for both services because it will allow for joint planning, novel, joint mission test (and hopefully practice), and a better ability to connect the mind across several layers: physical, emotional, cognitive, and team.

IMPLEMENTATION FOR CHANGE

Technology advancements will continue to improve and near-peer adversaries will peacock to demonstrate superiority. The difference between success and defeat will be the human element, the pilot in the box. The DoD must take full advantage of the findings in learning sciences, technology advancements, and the multitudes of data to improve the way that we train, procure training aids, and recruit/retain those to perform. To facilitate lasting implementation for change, accountability requires a deliberate plan to find champions for change to carve a path towards enhancing the DoD's ability to train aviators for the next fight. In addition to the areas outlined above, the takeaways should be to focus on the policy, research, and training interventions.

Policies need to continue to be shaped to be flexible and adaptable to urgent needs, emergent requirements, and innovative findings in R&D. The primary policies this would need to see revision in are in DODI 5000.73, DODD 5000.71, and DODI 5000.81, which deal with cost analysis, urgent capabilities, and rapid fulfillment in acquisitions to build common paths to meet urgent demands with innovative solutions. Policies such as DODI 5000.87, *Software Acquisition* and DODI 5000.74, *Acquisition of Services*, need to ensure cross-coordination to make procurement of common goods and services (like software) for multiple domains is streamlined as much as can be.

Catapulting R&D over the horizon will build from these open and adaptable policy changes to allow for an influx of innovative thought, creative solutions, and breakthroughs in science to maintain superior readiness and performance in the DOD. Decision makers and stakeholders alike should pause prior to awarding funding and ask whether the research they fund is merely maintaining the status quo or if it truly will bring marked ROI to their program or organization. Fund research that looks to integrate the best resource we have – the human mind, because when technology is equal, that is the difference between victory and defeat. Seek new methods of training frameworks, like 4E cognition, which can shape the way that training is thought of and executed.

Finally, the edge to training does rely on deliberate plans, facilitators to execute the plans, and students ready to encode, store, and retrieve the information in the most efficient manner possible. Choosing against new innovations in cognitive and neurosciences is much the same as ignoring an innovation in stealth technology or weapons improvements. The ability to outmaneuver the enemy begins with the ability to outthink them. Understanding first, as with the 4E cognition framework, how the mind, body, brain, and environment interact with one another to process information to think, make decisions, and act is critical. Once the framework is understood, then training policy, research, and implementation should follow. Creating the next phase of superior aviation training is the perfect candidate for implementing these changes due to the multi-layered approach to training.

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