Applying Learning Engineering Process to Existing Military Training Programs: F-35 Demonstration

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ABSTRACT

The contested fight has leveled the technological playing field and consequently created a necessity to enhance the capabilities of airmen to not only learn more information at a faster rate but also across multiple platforms and specialties. Thus, as the complexity of warfare increases, training must enable pilots to create solutions to novel Night One, first night combat situations that will require them to anticipate and respond to complex cues (e.g., dynamic data streams, multiple layers of threats, and unknown scenarios). Unfortunately, current training reflects procedures and missionized focus areas used for the past century. Trainees advance through a series of graduated mission sets that represent the scenarios like those experienced in theater. Trainees are "ready" if they have completed the requisite number of sorties, but completion quality is based on qualitative approvals.

In the future, the complexity of battle, data, and technologically-enhanced threats will not permit this format of training. There will be too much to learn and not enough time to learn it. Thus, the primary need is to create a training structure, process, and pathway that focuses on creating a library of experiences during training, uses data-driven training methods to enhance and expand cognition, and uses technology to provide personalized support that maximizes pilot capabilities. Accordingly, a study of F-35 training demonstrated how to use the learning engineering process to modernize USAF training. Primary findings and recommendations to augment training include providing: a) a deeper understanding of how the brain works and how training interventions can maximize impact; b) the ability to collect objective data to inform training practices; c) technological tools that will help trainees learn, practice, and study and reduce time-to-train; and d) insight and guidance on how various technological tools can be used to enhance training experiences and impact. Implementation options are discussed.

ABOUT THE AUTHORS

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Patricia Bockelman, Ph. D., is a Learning Engineer and Modeling & Simulation professional emphasizing human performance in synthetic systems. Her research has supported work for US Army, US Navy, USMC, USAF, FAA, and DHS partners as well as private sectors including healthcare, energy, and cyber/information security. Dr. Bockelman launched her career in public education, which has provided an anchor for over 20 years of teaching, research, and learning design.

Flight Training Modernization: Applying Learning Engineering to Enhance F-35 Pilot Cognitive Capacity

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BACKGROUND

The purpose of this exercise was to demonstrate the process of learning engineering, the ways in which it differs from previous instructional design methodology, and the impact these changes in structure and organization can provide. To that end, a process was developed that aims to: (1) understand what training currently exists, the needs of the trainees, and their expectations in theater, and (2) re-organize the content needing to be trained to support the development and measurement of competencies.

The major shift from assuming that a certain number of experiences (e.g., sorties) defines an airman's capability to one that measures the competencies, skills, and capabilities of the airman to determine their level of expertise may seem like only a slight change but in fact, conceptually, it creates the need for a significant modernization in combat training structure and practices.

To illustrate, current training utilizes an assembly line industrial–based methodology. Metaphorically, it assumes that each airman is akin to a product being created. Moving along the line, each element of the product is added until the product is finished. However, as in this metaphor, it makes three major assumptions that all final products: 1) need to have the same attributes, 2) will be used similarly, and 3) will be sufficient so long as each needed element (skill/experience) is added along the assembly line (e.g., quality of the elements is not measured or observed).

By contrast, in the learning engineering process, the "product" is defined by what it will eventually be used to do. Because there are so many different and constantly evolving requirements needed in the contested air space, an assembly line that makes all airmen the same will not meet the needs of the fleet. Accordingly, training can no longer be accomplished in an assembly line fashion because it is not possible to constantly change the elements on the line nor is it possible to provide unlimited elements. Rather, a reconfiguration of the approach to developing training is needed that emphasizes the end state goals, provides personalized pathways for training, and capitalizes on the unique capabilities of each airman.

Learning engineering is a modernized instructional design process that incorporates best practices from the fields of learning science, technology, and analytics to create competency-based learning pathways (Walcutt & Schatz, 2019; Goodell, & Kolodner, 2022). By combining all these elements in the design process simultaneously, it allows for an optimized use of the combination of their effects. The process follows five key steps: Capability Assessment (identify the key competencies to be achieved), Competency Modeling (five-stage model development, USAF Handbook 36-2647), Instructional Technology and Resources Review (determine available elements), Framework Design (organize the model and current instructional elements; identify gaps in materials and technologies), Recommendations (define content and technology that needs to be developed), and Assessment and Personalization (define what to measure and how to personalize learning pathways for efficiency).

STEP I: Capability Assessment
The primary goal of the capability assessment is to determine the key competencies a pilot needs to be ready for the contested fight. Traditionally, this is established by asking expert pilots to outline skills and associated tasks or through an interview process called cognitive task analysis. In the learning engineering process, the goal is to understand the operational environment, challenges that will be met, and supporting skills that are needed. The result is a set of cognitive, physical, and self-regulatory competencies that once learned will allow the individual to operate successfully in the designated environment.

STEP II: Competency Modeling
Once the data is collected, analyzed, and key competencies are identified, five stage models have to be developed. These models clarify and describe what a person can do at each stage of development. The purpose of these models is to: a) understand at a deeper level how well someone can perform a skill or how deeply a person understands certain information, b) to use the capability measurements per competency to drive personalized learning interventions, and c) to measure more accurately the difference between the capability needed to perform a job adequately and already learned skills or knowledge. These models can therefore be translated to data to drive individual assessment, training efficiency, and team or fleet level aggregated readiness measurement.

STEP III: Instructional Technology and Resources Review
The goal of this step is to identify resources and technological capabilities already available that can be used to train individuals and teams through each developmental stage. The process to achieve this involves a procurement, research, and development review. For each of these reviews, interviews and a review of program and research reports are the primary methods of data gathering. Once the resources are identified and described, the next step is to organize them by both instructional content and delivery method. The goal is to connect this information to each stage of development and to determine which resources can be reused for other content.

STEP IV: Framework Design
Once all the data is collected and organized from interviews, the resources are reviewed, and the models are developed, the next task is to organize all the information into a framework that can define training goals, sequence materials and experiences, and in digital environments, drive personalization decisions. Gaps in materials and technologies will also be determined during this step.

STEP V: Recommendations
Based on the framework design, a modularized set of content elements including lessons and experiences can be designed and the optimized delivery methods defined. Typical delivery methods include self-study, classroom learning, practical live applications, virtual experiences, and live practice. Much of the current training program and technologies used for delivery can be reused in this new structure. However, this process typically identifies additional needs requiring tool creation or procurement.

STEP VI: Assessment and Personalization
Once the content elements are created and the delivery technologies procured, it is necessary to finalize what to measure and how to personalize learning pathways for efficiency. Assessment focus and delivery methods are also determined in this step. These elements define the unique pathways of each trainee. Essentially, individuals are initially assessed to determine what capabilities they possess at the start of the course and to what level of mastery. Based on the initial assessment, the most needed areas to focus on can be identified and used to determine which lessons and experiences need to be applied to the personalized pathway. Assessments can focus on content knowledge, skills, or capabilities but can also include neuro-physiological metrics. Whole body assessments can help determine how much information a person can handle as well as their depth of understanding.

The result is a living ecosystem of content elements combined with recommended delivery methods or technologies, a set of knowledge, capability, and whole-body assessments, and an algorithm for personalized training pathways that maximize individual capabilities, speed of learning, and mission requirements for readiness.

STEP I: Capability Assessment (current training)

Figure 1. Standard F-35A course progression

Courses
The coursework review focused on the training of an F-35 pilot from the Initial Qualification Course (B-Course) through Mission Qualification Training (MQT), Flight Lead Upgrade (FLUG), Instructor Pilot Upgrade (IPUG) and F-35 Weapons Instructor Course (WIC). Each of the five courses are described below. The goal was to clarify the time spent in each course, the focus of each of the training elements and segments, as well as gain a deeper understanding of how the courses are taught.

B-Course: The F-35 B-Course, or Basic/Initial Qualification Course, is a 129-training day formal course designed to train a recent USAF pilot training graduate to fly and employ the F-35 across various mission sets, day or night and in all weather conditions.

MQT: MQT is the process by which the Combat Air Force (CAF) squadron commander certifies that the recent B-Course graduate is qualified to perform the unit's Operational Plan (OPLAN)-assigned tasking (e.g., expected types of combat missions to be flown) in the anticipated Area of Responsibility (AOR) or theater of operations.

FLUG: Flight Lead Upgrade (FLUG) training focuses on the two key skills: 1) FLUG Flying Training: Leadership of a flight of two to four aircraft in the conduct of non-missionized F-35 missions (Basic Fighter Maneuvers [BFM], Basic Surface Attack [BSA], Air Combat Maneuvers [ACM], and Tactical Intercept [TI]) and missionized OPLAN-assigned missions (Offensive Counter Air [OCA], Defensive Counter Air [DCA], and Suppression of Enemy Air Defenses [SEAD]) and 2) Functional Team Lead: Duties required of a Continuation Training (CT) team-lead to coordinate and execute up to an 8-ship offensive counter air (4+4vX OCA) effectively.

IPUG: Instructor Pilot Upgrade (IPUG) trains an F-35 flight-lead to instruct all missions in the F-35. Like FLUG, IPUG uses a building-block approach to developing the requisite CAF Instructor Pilot (IP) skills in the IPUG student.

WIC: The F-35 Weapons Instructor Course (WIC) is 160 day long, graduate-level course aimed at training expert instructors at their given Mission Design Series (MDS) who are capable of not only being experts in the art of instruction but also of serving as their assigned unit's chief instructors and as Subject Matter Experts (SMEs) on their MDS and advisors to squadron, group, wing, and senior leaders across the USAF.

STEP II: Competency Modeling

Competencies
In total, the learning engineering team identified nine F-35 key competencies as necessary to achieve readiness requirements: Airmanship, Weapons management, Self-regulation (mental, physical, & emotional), Professionalism, Task & procedure management, Strategic thinking and awareness, Decision making, Prioritization, and Cognitive

efficiency/teamwork. For each of these competencies, associated KSAs were identified based on current training goals but were organized and regrouped by competency to drive decisions about how, when, and which media (e.g., technology) to use for training (see Table 1 for a summary).

Knowledge, Skills, Abilities (KSAs)

For each competency, the learning engineering team identified KSAs based on the analysis of each course, its tasks, and ultimate goals. For this analysis, "Knowledge" defines the cognitive domain from memorization of information to prioritization and decision-making. "Skills" refer to those actions required to complete a variety of procedures. "Abilities" include the mindset, approach to training, and general abilities needed to be an effective pilot. This review and analysis identified redundancies and gaps. Namely, while trainees can, and currently do, effectively study before sorties to ensure they know the details and understand the goals of their next sortie, common training technology can reduce training time and error frequency. Specifically, technological interventions could provide micro-experiences, collect data, and communicate information to instructors, students, and commanders to better quantify each trainee's progress and needs. Today's training uses variations on simulated sorties (both in live fly and simulation). While these experiences provide intentional practice, the current syllabi do not explicitly link the practices to competency goals. Consequently, fewer iterations of concrete competency-based practice are experienced and readiness for unexpected scenarios in theater may be hindered.

Course Goals

F-35 pilot courses aim to develop neophyte pilots into skilled experts, taking them from the Initial Qualification Course (B-Course) through Mission Qualification Training (MQT), Flight Lead Upgrade (FLUG), Instructor Pilot Upgrade (IPUG), and F-35 Weapons Instructor Course (WIC). However, in a learning engineering plan, the goal is to achieve certain levels of competencies, known at the beginning of graduate training and separated by time in training, rather than completing courses of study. The result is a continually developing pilot whose skills correspond to levels of general readiness and identify key areas of personal challenge to target through continual training.

Table 1. Initial Competency Framework

	Competency	Expertise Level				
		(1)	**(2)**	**(3)**	**(4)**	**(5)**
Knowing what to do	**Airmanship skills**	Imprecise and slow action	Recognizes aircraft capabilities and limitation; Memorizes terrain differences	Anticipates issues 50% of the time; Plans ahead	Works well with others; Coordinates for self and team; Flies with automaticity even under stress	Tight planning, tight action, accuracy and anticipating
	Weapon system knowledge	Awareness of the system	Memorizes how instruments work together; Aware of incoming data	Proficient in system knowledge; Can teach others basics	Fluid with the system; Connected with the aircraft in understanding and action	Knows every element of the system; Knowledge like a book
	Emotional/ physiological regulation	Surprised by physiological and emotional responses; negatively affects ability to focus, process, and make decisions	Aware of phys/emo responses; Reacts and adjusts to body's reactions but there is a delay	Anticipates affects; Takes anticipatory action to ensure continued safe flight	Includes phys/emo effects in planning process and instruction	Anticipates personal responses to situations and events; Compensates pre-emptively; Maintains clarity under stress
	Professionalism	Distracted; Unaware of risks; Focus can suffer; 'wings it'; talks versus listens	Follows orders but lacks seriousness and personal curiosity	Treats training and planning as a job; Balances work and home time; Treats training as mission preparation	Collaborates and leads as needed; Focuses on learning to ensure readiness for mission	Hungry to complete the mission; Focused; Serious

	Procedural Effectiveness	Follows procedures; Many errors; Slow to react; Slow processing	Follows procedures with confidence; Knows the actions to take but hesitates	Knows procedures well and completes them with speed and assurance; makes few errors	Follows flight procedures fluidly and also follows personally developed procedures to enhance effectiveness	Anticipate issues; Act before problems occur; Reduce negative impact
Knowing how to do it	**Strategic Awareness**	Operates in a personal bubble; Lack awareness of surroundings	Follows a pre-planned script; Struggles to deviate even when mission is threatened	Understands the field and mission intent beyond procedures; Adjusts with some hesitation as needed	Recognizes what's missing as well as observable problems	Constantly processing; Anticipates problem variables; Plans ahead; Acts efficiently and effectively
	Cognitive Efficiency/ Team Coordination	Assess all information and surroundings equally; slow to react; much "fog"; Works independently	Memorizes what information is important and acts automatically based on preplanning reactions; reaction time quicker but adjustment hindered; stays in a role	Recognizes differences in importance and adjusts based on personal rubric; processing speed enhanced further and adjustment to unexpected events effective; works with other roles	Distinguishes important variables and processes quickly to act swiftly; optimizes use of teammates skills	Fluidly assesses current situations and compares them to past experience, mission goals, and strategic plans to act efficiently; optimizes use of team dynamics and expertise
	Decision Making Capability/Risk assessment	Reacts without a plan	Preplans missions; struggles to adjust when issues emerge	Preplans mission but includes contingency plans	Fluidly adjusts to unexpected issues but pulls from a limited set of experiences rather than creating solutions	Combines experience, strategic understanding, and level of risk to determine action and does so efficiently
	Task Prioritization	All priorities are equal	Tasks are prioritized based on preplanned decisions	Tasks importance is decided in the moment but based on a preplanned rubric	Uses personal experience to determine priorities but is also limited to only book knowledge or personal experience	Knows when system, or mission, or safety takes precedence based on personal and others' experiences

*Re-printed from Walcutt, Bockelman, & Sohn, 2022

STEP III: Instructional Technology and Resources Review

In step three, the goal is to review both what is available to use for training across science, technology, the USAF, and US DoD. Typically, all programs, especially those at the enterprise level, have access to already tested, developed, and or similarly used elements that can aid the current program. It is rarely necessary, or even wise, to build entirely from scratch. Rather, it is significantly more efficient both financially and time wise, as well as more effective in application, if 80% solutions that can be borrowed or adjusted to fit the current system can be used. Each of the key areas of interest are summarized.

Scientific Research: Instructional Strategies

To improve training efficiency and impact, learning, cognitive, and neuro-scientists have been studying replicable and generalizable training interventions that can be infused into in-person and technology-based training systems. A significant number of large companies and small businesses have developed technology interventions like lightweight and full-scale simulators, but few are infused with these training elements that elevate a system from an environment where learning can occur to one where training is driven by intentional activities and organization. Accordingly, a significant amount of research, supported by the US Navy and Marine Corps have led to the creation of generalizable recommendations for instructional strategies and tools (ONR Grants N000140710098, N000141010113; USMC PMTRASYS Contract M67854-10-C-8040, Vogel-Walcutt, Fiorella, & Malone, 2013). While a large number of recommendations exist, generalized interventions are provided below (see Tables 2 and 3).

Table 2. Ideal Training Timeline

Expertise	Complexity	Length	Feedback	Goal types	Practice	Instructor
Novice	Low	Short	Immediate, Focused	Identify	Massed	Instructor
Intermediate	Medium	Medium	Short Delay, Focused w/ explanation	Assess	Massed + Segregated	Instructor, Peer-to-peer
Expert	High	Long	Delayed, Explained	Judge	Segregated	Peer-to-peer, Independent

Table 3. Ideal Training Elements/Scaffolding

Knowledge	Task	Question	Intervention Timing	Techniques
Declarative	Identify	What is it?	Pre/During	Drill & practice Highlighting
Conceptual	Assess, Evaluate, Analyze	What does it mean? Does it matter?	During	Part-task Training Advance Organizer Metacognition Exercises Worked Examples
Integrated	Determine, Judge	What do I do?	During/Post	Intuitive vs. Recognition-Primed Decision Making exercises Vicarious Learning After Action Review (AAR) Display downstream outcomes (Simulations)

Vogel-Walcutt, Phillips, & Ross, 2012

Technology and Engineering: Instructional Systems

Technology is not a trainer, but it can serve as a training device, a medium within which training can occur. Over the past three decades, the possibilities of these individual devices have become more sophisticated (e.g., able to embed training interventions or real time monitoring and assessment) and complex (e.g., infusing advanced analytics such as artificial intelligence or head mounted displays connected to virtual reality gloves). Below are examples of technology most relevant for training (see tables 4 and 5), examples of how they are currently being used (see figure 2, and some examples of advanced technologies being developed or in use within the USAF. Of note, to date, these technologies cannot connect to each other. A digital-data highway (DDH) will be required to allow for shared data capture, analysis, and future decision-making. Finally, to ensure that these efforts align across the enterprise and to help coordinate/synchronize efforts, target funding, as well as guide implementation, it is recommended that a Chief Training Officer (CTO) be embedded into the A3 organization. Without a coordinating expert, procurement, planning, and best practices usage of these technologies will fall on the shoulders of wing commanders. Stove-piped planning and purchasing leads to one-off solutions, a lack of coordinated effect, and hinder readiness.

Table 4: General Learning Technologies

Technology	Types	Most Effective Use
Mobile Devices	Micro learning (e.g., PERvasive Learning System (PeRLS))[1]	Rapid memorization & Decision-Making Practice
Desktop Computers	Distributed coursework (e.g., USAF MyLearning)	Professional Development
Tablet	Hyperlink-enabled eBook (e.g., using Psychology Experiment Building Language (PeBL)[2])	Digesting & Connecting dense learning material (e.g., 3-1 Manual)

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[1] **PERLS (PERvasive Learning System)** is a personal assistant learning application designed to support adult self-learners. It provides an extensible platform for diverse instructional technologies, especially including those developed under the DoD's Advanced Distributed Learning (ADL) Personalized Adaptive Learning (PAL) program.

[2] **PEBL** (**Psychology Experiment Building Language**) is an open source software program that allows researchers to design and run psychological experiments.

Lightweight Simulators (LWS)	Augmented Reality (AR)[3], Virtual Reality (VR)[4], Extended Reality (XR)[5], Mixed Reality (MR)[6]	Experiential Learning for mental model development
Full-scale Simulators	Immersive training	Experiential Learning for mental model assimilation
Full-scale Sim Environments	Multi-platform training environment (TBD)	Experiential Learning for joint mental model assimilation & coordination
Digital-Data Highway	Open source, Open architecture streaming architecture for optimized analysis (e.g., Total Learning Architecture (TLA)[7], MOTAR[8])	Real-time data collection and analysis for data-drive decision making, knowledge mgmt., & training personalization

Table 5: USAF Synthetic Environments

Syn Env	FOC	Interoperable	Integrated Platforms	Proprietary	Distributed	Able to integrate future tech	Description
DMON	Current	Yes	Yes	?	Yes	?	networks geographically separated Mission Training Centers (MTC) and disparate training systems
VTTC	?	No	No	?	No	No	complex, multi-domain, peer-adversary scenarios for integrated warfighter training, tactics development, and capability test
JSE	FY24	Yes	Yes	No	No	?	high-fidelity gov-owned, M&S environment to test fifth-plus generation aircraft and systems
JTIC	FY30	Yes	Yes	No	Yes	Yes	Training events specific to employment of tactical air platforms

Note: Distributed Mission Operations Network (DMON). Virtual Test and Training Center (VTTC), Joint Synthetic Environment (JSE), Joint Integrated Training Center (JITC), Reference: Rated Aircrew Strategic Training Plan, Operational Test and Training Infrastructure (OTTI), 2021. USAF A3T

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[3] **Augmented Reality (AR)** is the integration of digital information with the user's environment in real time. Unlike virtual reality (VR), which creates a totally artificial environment, AR users experience a real-world environment with generated perceptual information overlaid on top of it.

[4] *Virtual reality* (*VR*) is a simulated experience that employs pose tracking and 3D near-eye displays to give the user an immersive feel of a virtual world.

[5] **Extended Reality** (*XR*) is an umbrella term encapsulating Augmented Reality (AR), Virtual Reality (VR), Mixed Reality (MR), and everything in between.

[6] **Mixed reality** (**MR**) is a term used to describe the merging of a real-world environment and a computer-generated one. Physical and virtual objects may co-exist in mixed reality environments and interact in real time. Mixed reality is largely synonymous with augmented reality. Mixed reality that incorporates haptics has sometimes been referred to as Visuo-haptic mixed reality.

[7] The TLA is a project by the ADL Initiative to develop a set of technical specifications, standards, and policy guidance that define a uniform approach for integrating current and emerging learning technologies into a future learning ecosystem.

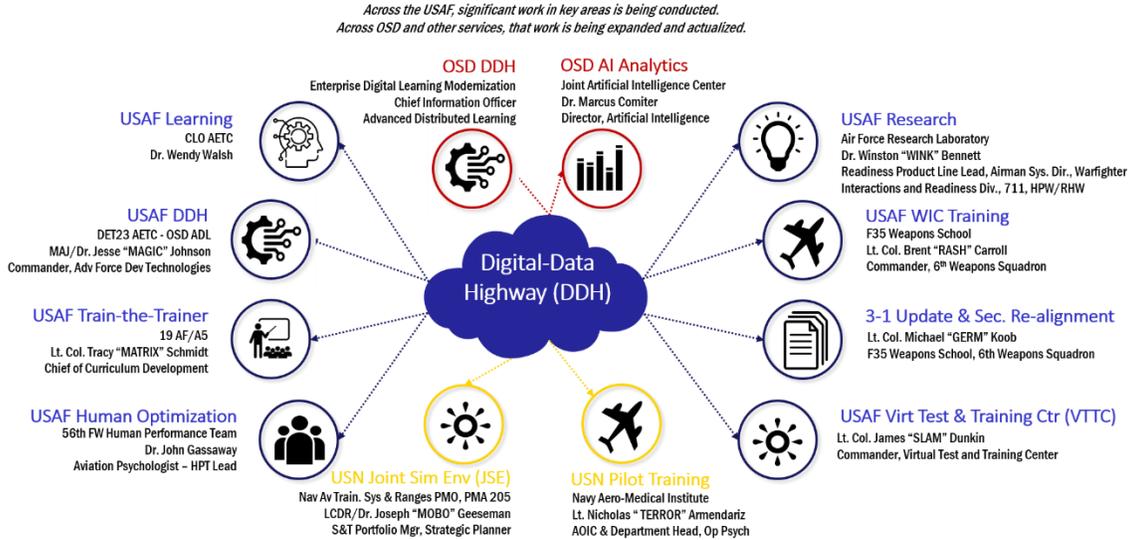[8] Member, Operations, Training, Analytics, Reports (MOTAR), USAF

Figure 2. Current deployable/replicable programs across USAF and related areas

Step IV: Framework Design

Framework design begins with considering the end goal state required (e.g., developmental model) and the current elements that can support individuals to get to that point (e.g., teaching tools, strategies, technology, etc.). One additional need is to understand the current daily flow of training practices. In other words, it is important to understand how "the work" is done today so that interventions initially recommended will dovetail seamlessly into the current flow with as little disruption as possible. Once initial interventions become the new normal, then additional changes can be implemented until the full vision is realized. It is as important to manage the change process as it is to manage progress toward the final goal.

Training Pathway

Accordingly, the first step is to connect all the elements that have been gathered and create a general timeline of events, tags that will inform what happens next, and assessments that will both inform how, when, and what material will be presented next. In paper-based instructor-driven training scenario (like those used today), each of the pathways and decisions noted in Figure 3 are driven by the human teacher. When the DDH is developed, these pathways will be driven by advanced AI analytics. Each element noted below will be tagged with descriptive pieces and those tags will be used to track, assess, and create personalized pathways. The result will be a more streamlined, personalized process that maximizes learning quality and impact and optimizes readiness capabilities.
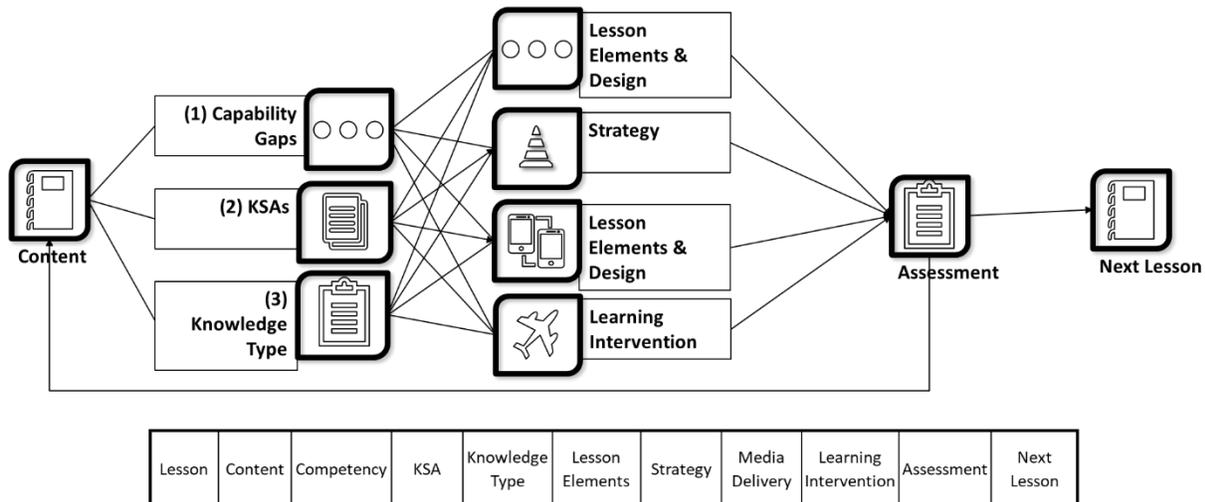
Figure 3. Generalized training pathway structure

Initial Interventions and Timeline

The second step is to create initial paper-based instructional interventions (see table 6) then translate those into digital formats. Once developed, data tagging that aligns with Institute of Electrical and Electronics Engineers (IEEE) standards for learning (e.g., Experience Programming Application Interface (xAPI[9])) can be attached. When the DDH has reached full operational levels, these tags can be used to optimize readiness development and measurement (see Figure 3 for the development timeline).

Table 6. Pathways and Instructional Tasks by USAF Training Courses

B course	MQT	FLUG	IPUG	WIC
Key Competencies: Airmanship Self-regulation Professionalism Task & Procedure management	**Key Competencies:** Airmanship Weapons Self-regulation Situation awareness Task & Procedure mgmt	**Key Competencies:** Airmanship Teamwork Situation awareness Risk assessment	**Key Competencies:** Teamwork Decision-making Risk Assessment	**Key Competencies:** Teamwork Decision-making Professionalism Risk Assessment Strategic Thinking
Key Skills: 3-1 Manual memorization Basic F-35 flight skills Basic Flight tasks F-35 mission sets	**Key Skills:** 3-1 Manual memorization F-35 mission sets F-35 tactics & techs	**Key Skills:** Weapon sys memorization Team leadership/mgmt F-35 flight lead skills Flight mission sets	**Key Skills:** 3-1 Manual instruction Teaching F-35 flight skills Teaching Flight TTPs	**Key Skills:** 3-1 Manual update and validation Joint, adv F-35 flight mission planning Creating TTPs for joint mission sets
Skill Level: 1 (*memorize* details and procedures) **Capability Level:** 1 (*rote*: able to answer when questioned and follow basic procedures in flight)	**Skill Level:** 2 (*operationalize* details and procedures) **Capability Level:** 2 (*operational*: able to adeptly complete common procedures and mission sets in flight)	**Skill Level:** 3 (*apply* details and procedures in flight) **Capability Level:** 3 (*tactical [flight]*: able to understand the big picture and apply knowledge to improve decision making in flight)	**Skill Level:** 4 (*compile* knowledge and teach) **Capability Level:** 4 (*tactical [instruction]*: able to combine an understanding of the big picture with instructional techniques to teach others)	**Skill Level:** 5 (combine knowledge, experience to lead, teach, and *create* best solutions under stress) **Capability Level:** 5 (*strategic*: able to create solutions to novel problems and develop new training tactics to meet future needs)
Initial Interventions: 1. 3-1 Memorization *Micro learning & Test* *PeBL* 2. Prioritization Procedures *Micro scenarios lvl 1* *PeRLS* 3. DM Procedures *Micro scenario (flt)* *PeRLS* 4. Mission rehearsal Lightweight Simulators (*LWS*): *Flight pathway rehearsal*	**Initial Interventions:** 1. 3-1 Memorization and Extension *Micro learning & Test* *PeBL* 2. Prioritization Procedures *Micro scenarios lvl 2* *PeRLS* 3. DM Procedures *Micro scenario (mission)* *PeRLS* 4. Mission rehearsal *LWS: Mission set rehearsal*	**Initial Interventions:** 1. 3-1 Application *Micro scenarios: DM & prioritization* 2. Mission planning LWS	**Initial Interventions:** 1. Teaching 3-1 Instructor's manual PeBL 2. Teaching mission planning and rehearsal *Micro scenarios lvl 3* *PeRLS* 3. Instructional techniques & tools: *Abbreviated instructional manual*	**Initial Interventions:** 1. Instructional techniques & tools: *Instructional manual and course*

Step V: Recommendations

Based on the current syllabi review, interviews with pilots and instructors, and observations, several key points were noted. Specifically, (1) there is great concern about the need for updated tools and training techniques, (2) findings suggest duplicate research and technology development efforts are occurring across the USAF and DoD, and (3) pilots and instructors are ready, willing, and interested in supporting modernization efforts. It was also repeatedly stated that collateral duties make training difficult, taxing, and harder to complete. Comments made about the training content, focus, and structure included:

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[9] xAPI is a data and interface standard that lets software applications capture and share (big) data on human performance, along with associated context information (i.e., "experience" data). Combined with learning analytics, xAPI promises to revolutionize the way education and training are conducted, managed, and measured. xAPI can be incorporated into nearly any (new or existing) learning technology, and it is agnostic about the type of learning content being delivered. https://adlnet.gov/projects/xapi/

a) <u>Classroom training times are too long</u> to maintain adequate focus (e.g., up to 11 hours)
b) <u>Memorization expectations for the 3-1 (operations manual) are challenged</u> by the length, depth, and structure of the manual; ability to apply the information is hindered
c) <u>Syllabi</u> provide a list of what needs to be experienced (tasks) but <u>do not provide competencies or methods for assessment</u> that measure competency quality
d) <u>Instructor pilots do not have the tools or general "how to teach" training knowledge</u> needed to modernize techniques, flow, and focus of instruction
e) Live fly technology tools to replicate adversary air are creating <u>negative training outcomes</u>
f) <u>Simulators do not provide live data output</u> or connected data to previous training events
g) <u>Multi-platform simulation environments are not available</u> to allow for full mission planning, training, and test events

Step VI: Development to Support Assessments and Personalization
To address these issues, a set of graduated development tasks are recommended that begin with paper-based modernization efforts and end with a digital-data highway that connects simulators, training tools, and advanced analytics to assess and report readiness levels. Specifically:

Phase I: Paper-based and Digital Tool Development
Addressing a, b, and c above, it is recommended that a first phase of development focus on modernizing the structure of training pathways and providing tools that exist in other branches and programs that can be easily converted to USAF content and needs. Specifically, five lines of effort are recommended:

1. **Syllabi Re-alignment:** Syllabi are currently organized by mission sets, intentionally designed to become more complex and provide opportunities for discussions with instructors. This method is adequate for memorizing common missions that will likely be used in combat scenarios. However, to support the agile airman concept, prepare for novel combat scenarios, and make possible the ability for airmen to be multi-capable, more efficient training that focuses on building competencies will be required. Creating this competency-based training syllabi will comply with USAF Handbook 36-2647 and will allow training experiences and assessments to be tagged for integration into future DDH.
2. **3-1 Training Manual:** The current version of the 3-1 manuals provides significant necessary information that is organized by topic. A training manual would provide a structure and presentation that would make it significantly easier to not only remember the information provided but also make it easier to translate it to the real world. It would make training more efficient and effective.
3. **Micro-learning:** Micro-learning is a well-proven way to provide focused learning experiences for trainees that can increase the effectiveness of training and significantly decrease the time required to learn both declarative (memorized pieces of information) and applied (e.g., decision making, prioritization). Borrowing from other services, this is a low-cost, effective way to provide immediate support to combat airmen.
4. **Lightweight Simulators (LWS):** LWSs provide less expensive, more agile, targeted training, practice, or assessment compared to full-scale simulators that can support training application. A variety of options exist including, but not limited to virtual reality, augmented reality, and mixed reality. Which ones to use and when will be decided based on each airframe's specific needs.
5. **Instructional Science Module:** Specifically for IPUG and WIC, a four-week train-the-trainer course to include an accompanying trainers manual is recommended. Per request, a course such as this can enhance the instructional tools and techniques usage by instructor pilots that are expected to improve the quality and efficiency of training.

Phase II: Data Tagging, DDH, and AI
Addressing d, e, f, and g above, a data collection open architecture already in existence can be implemented at the Virtual Test and Training Center (VTTC) at Nellis AFB to create interoperability across personnel records, training assessment data, and technology capabilities. Consistent with DoDI 1322.26, Distributed Learning, the architecture, data standards and specifications, and vision for connecting training across services has been developed.

> *"Interoperability allows data to easily flow, even among applications developed for different purposes, using a standardized vocabulary, structure, and cadence. Interoperability implies common standards that promote system-to-system communications, potentially across organizational boundaries and institutional firewalls, using specified data formats and communication protocols. These standards form the fundamental building blocks for technology-enabled lifelong learning by establishing consistent protocols that can be universally understood and adopted by related systems to enable data exchange about learners, activities, and experiences." – DoD Modernizing Learning, 2019*

With the implementation of an interoperable data highway, real-time training data such as performance, neuroscience, and physiology metrics can be tracked and used to design and drive training optimization. Personnel tracking, readiness metrics, AI analyses, and knowledge superiority can be enabled. For this to occur, all syllabi, training, and technology elements will need to be data tagged. Standards such as xAPI have been developed by OSD and approved globally by IEEE. Once tagging is applied, artificial intelligence (AI) can be used to analyze the data and provide insights beyond human capacity.

To coordinate an effort as large as this at the enterprise level across the CAF, will require a systems integrator that is a subject matter expert in learning engineering and all the sub-areas of knowledge connected to it. Accordingly, a Chief Training Officer, acting as the SME in design, architecture, development, implementation, and assessment, is recommended. It is a common characteristic across the DoD, for a variety of reasons, to act in silos. However, for an effort of this magnitude to be implemented effectively within the USAF, a technical meta-expert would enable the use of the most current research findings in operational training spaces to improve impact of training and reduce time and resource expenditures and coordination across the service to improve quality of purchases and sharing of resources. Figure 3 provides a recommended timeline of efforts that build upon each other focusing first on paper-based interventions and then on digital modernization of the same.
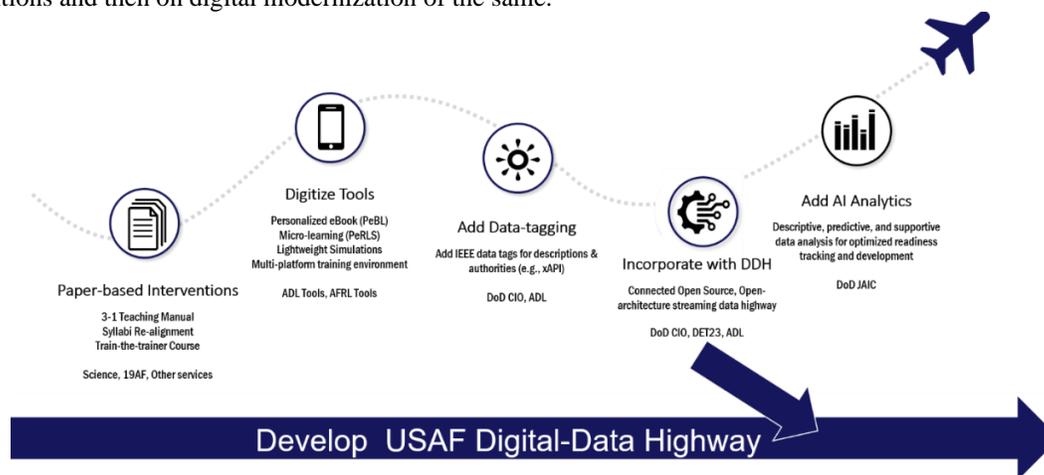

Figure 4. Development Timeline

SUMMARY

The current military training environment emphasizes traditional mission-focused training, where pilots progress through predefined mission scenarios to achieve readiness. However, the evolving complexity of warfare, characterized by contested environments and technological advancements, necessitates a shift towards enhancing cognitive capabilities and adaptability in pilots. This includes the ability to process complex data, devise innovative solutions, and make rapid decisions under stress. Key gaps in current training methods include the inability to develop a sufficiently diverse and robust experiential library solely through mission-based scenarios. Thus, pilots must often rely on real-world experience to supplement their training, which may not be adequate for future warfare scenarios.

Currently, instructor pilots are adept at designing effective training exercises and debriefing methods that emphasize decision-making rationale. However, they express a need for a deeper understanding of cognitive processes, access to objective training data, and advanced technological tools to enhance training efficiency and effectiveness. Accordingly, there is a critical need to reform training structures to focus on building this experiential library during training itself. This reform should incorporate insights from learning and cognitive sciences, utilize data-driven

training methods, and leverage technology to provide personalized training support. These tools should facilitate accelerated learning, improve retention, and prepare pilots for the dynamic and technologically-enhanced threats they will face in modern warfare. Overall, there is a recognized necessity to evolve training paradigms from traditional mission-centric approaches to more adaptive, cognitive-focused methodologies that can better prepare pilots for the complexities of future warfare environments.

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