Learning Next: Self-Improving Competency-based Training Rooted in Analytics

Jennifer Lewis, Kathryn Thompson and Tobie Smith
SAIC
Huntsville, AL
jennifer.e.lewis@saic.com, kathryn.a.thompson@saic.com, tobie.a.smith@saic.com

ABSTRACT

During the past two years, the US Air Force (USAF) Air Education Training Command (AETC) graduated more than 20 pilot candidates from an exploratory Undergraduate Pilot Training (UPT) program called Pilot Training Next (PTN). AETC envisioned PTN as an aviation-centric use case for a greater "Learning Next" initiative, oriented on changing how institutions instill requisite knowledge and skills effectively using the latest commodity technologies. Working in collaboration with the Aviation and Missile Center (AvMC) under the US Army Futures Command Combat Capability Development Command (CCDC), AETC trained two separate classes of PTN students using similar paradigm-changing methodologies but with different execution. The focus during the first class was to make training tools more accessible using creatively applied Commercial Off the Shelf (COTS) systems and sensors. The focus during the second class was to revamp holistically the learning environment to enable self-improving competency-based learning rooted in solid data analytics. Competency-based learning is a game-changing shift for AETC by creating aviators who are skilled pilots as well as self-directed learners and critical thinkers that can adapt to complex and changing adversarial tactics. This paper discusses the execution of the second PTN course with a focus on how AETC and AvMC created PTN's adaptive learning framework, including its ability to evolve based on data collected from the learning environment. This paper provides examples of how collected data transform into insights for the student, the program and the USAF, using a methodology designed to provide valuable near-term data for effective training today while continuing to learn how students learn over time. Finally, this paper describes other initiatives building on the Learning Next concept, providing the opportunity to transfer lessons learned and technical solutions to new training challenges.

ABOUT THE AUTHORS

Jennifer Lewis is a principal software engineer who has developed interoperability solutions for distributed training and analytic live virtual and constructive (LVC) simulation environments for the US Army and US Air Force for the past 17 years. She holds a Master of Science in Computer Science with an emphasis in Telecommunications and Networking from the University of Texas at Dallas and is a Certified Modeling and Simulation Professional.

Kathryn Thompson is a senior human performance and learning expert with specialization in human performance improvement, training development and instructional systems design. She has contributed to the design, development and delivery of complex, dynamic training solutions for the US Army, US Air Force and Federal Aviation Administration. She holds a Doctorate of Education in Kinesiology from the University of North Carolina at Greensboro and a Master of Science in Human Movement and Performance from Western Washington University. She is a Certified Professional in Learning and Performance and a Certified Mental Performance Consultant.

Tobie Smith is a principal data scientist specializing in data transformation, analysis and visualization. For the past 10 years, she has led data science efforts to create decision support systems and common operating pictures for the US Army, US Air Force and Missile Defense Agency. She holds a Master of Science in Aerospace Engineering from Georgia Institute of Technology and Bachelor of Science in Mathematics and Physics from Morehead State University.

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MISSION STATEMENT

Learning Next is an initiative from the US Air Force (USAF) Air Education Training Command (AETC) with a mission to revolutionize the way warfighters learn. This mission statement is intentionally broad, allowing Learning Next to evolve its medium and long-term objectives based on data from near term experiments and exploration. Learning Next's overarching approach follows a triple feedback loop, as illustrated in Figure 1. The first loop focuses on the individual student, delivering a training program with individualized feedback through execution of their coursework. The second loop focuses on the learning environment, using student data to draw conclusions on the effectiveness of the course. The final loop uses data from multiple classes to inform talent selection efforts for increased learning success rates within any given competency area. Learning Next hypothesizes this approach provides valuable near-term data for effective training today while continuing to learn how students learn over time.

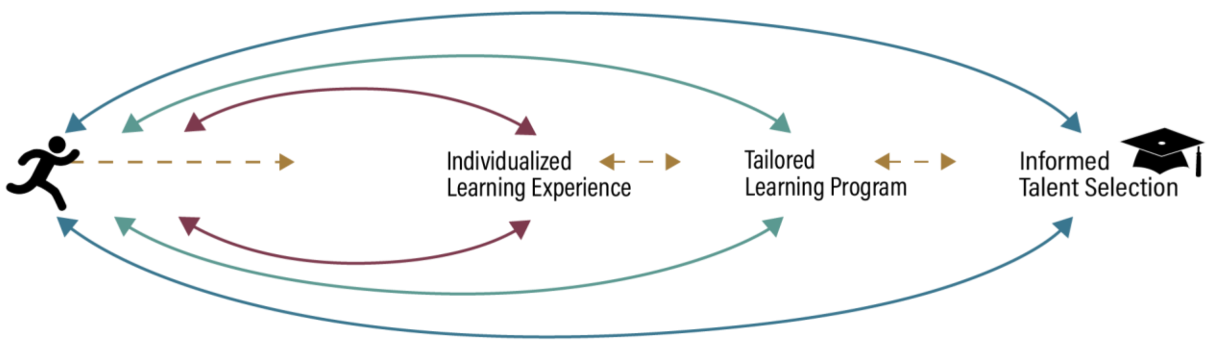

Figure 1: Learning Next's triple feedback loop iteratively improves the learning environment

This paper describes the implementation of the triple feedback loop as part of the USAF Pilot Training Next (PTN) program, the first and most robust use case of the Learning Next concept. The paper begins by comparing the execution of PTN to traditional training. It then details tools and processes used in PTN's triple loop approach as well as current insights and near-term work in each loop. Finally, the paper introduces other initiatives implementing Learning Next concepts.

PILOT TRAINING NEXT

AETC graduated more than 20 pilot candidates from an experimental Undergraduate Pilot Training (UPT) course, known as PTN, and will begin another training course in early 2020. Similar to UPT, PTN students interact daily with instructor pilots (IPs) for simulated and live flight. However, the course varies from traditional UPT in multiple ways. Traditional UPT students begin with a month-long academics phase using both instructor-led and computer-based lecture-centric training with weekly multiple choice-style assessments. Following the classroom-based academics phase, students begin instructor-led live flight training in a T-6A where each student performs the same set of pre-determined flight events. Students have access to a high fidelity, formally validated simulator during this practical skills phase of training, but access is limited. Traditional UPT encourages students to learn many of the nuances of flying an aircraft on their own by using a visualization technique, known as chair flying, and by reviewing and memorizing lengthy aircraft and procedural manuals and publications.

PTN, on the other hand, merges the academics and practical skills phases of training. On the first day of training, students begin using a low cost, virtual reality (VR) simulator that Subject Matter Experts (SMEs) have assessed as realistic enough for training. In some cases, students begin using the PTN simulator several months before the start of class as part of a distance learning initiative that allows students early access to select academic topic modules. PTN designed training to consist of five to 10 minute micro-learning sessions, followed by part-task training using the simulator. PTN students learn, plan and execute their simulated and live flight missions based on their individual progression through the learning content. Therefore, PTN students may never fly identical training events nor fly similar events in the same order through training.

The PTN simulator is one component of the program's larger learning ecosystem, which includes a Learning Management System (LMS) for easily accessible academic content, integrated biometric tracking for practical activities, a software agent for real-time automated coaching, and a variety of flight debrief and data analysis and visualization tools. A multi-disciplinary team of engineers from US Army Futures Command Aviation and Missile Center (AvMC), along with multiple organizations from the military, academia and industry, perform the systems integration, modeling and simulation, data analysis, instructional systems design and gaming functions necessary to implement PTN's learning ecosystem. The cost-benefit analysis of available commercial solutions heavily influenced PTN's technical approach (Lewis & Livingston, 2018). The current approach allows more than 400 students to access PTN's learning ecosystem for the cost of one high fidelity simulator typically used by UPT students. This low cost technical solution enables widespread, unrestricted student access to PTN's learning ecosystem, which is essential to the execution of the program.

TRIPLE FEEDBACK LOOP

This section will describe the tools, processes and current insights from the feedback loop approach as PTN currently implements the process.

Individualized Learning Experience

In the first loop, PTN delivers an individualized learning experience that balances workload and performance using cognitive enhancement and artificial intelligence (AI) techniques. The key elements are the low cost flight simulator, biometric devices and automated individualized coaching. The flight simulator is the main learning tool, which provides the primary training workload and serves as the tool students use to train cockpit familiarization, physical aircraft control, basic airmanship as well as contact, instruments and formation flight with multiple aircraft types. To understand how to balance the workload with the student's experience, students wear multiple biometric monitoring devices during training. The team uses this biometric data, such as heart rate variability and sleep effectiveness, to affect the simulated training environment as well as to ensure an effective real-life training environment.

The Virtual Instructor Pilot and Exercise Referee (VIPER) is a software agent that listens to data from the simulated environment to provide coaching in real-time and proficiency assessments over time. VIPER listens to flight and gauge data from the simulator as well as biometric readings to determine how well a student is executing a maneuver or mission (Snyder et al, 2013). VIPER provides visual and verbal coaching based on a student's overall proficiency. For example, it provides step-by-step audio instruction for novices while limiting audio cues and feedback for more advanced learners. VIPER also can modify the complexity of the scenario in real-time based on biometric data such as gaze point, heart rate and cognitive load readings (Sharp & Potts, 2011). For example, VIPER can reduce radio communications to make the experience easier or can increase cross winds to make the experience more difficult. This approach is consistent with the work of Anders Ericsson in deliberate practice and expertise development (Ericsson, 2009).

Outside of the simulator, students view daily snapshots of their biometric data through the LMS, similar to data a user would see from mobile fitness applications such as Fitbit or Runkeeper. These snapshots provide instantaneous results, which motivate students to wear the biometric devices consistently. However, the true value of this data comes from longer-term analysis of trends. Based on their individual trends, students receive specific performance feedback from

PTN's Health and Human Performance team every two weeks, with the intention of helping students maintain high levels of functioning throughout the course. This holistic human performance feedback addresses cognitive and physiological concepts students can implement to improve their overall performance during pilot training, including skills related to stress management, attentional control and optimizing performance states. Pilot training can be extremely stressful, and research indicates that increased stress typically leads to decreased learning and performance (Arshandi & Damiri, 2013; Bashir & Ramay, 2010). However, as shown in Figure 2, PTN students did not experience diminishing performance even as their stress levels increased. The output of Welch's two-sample t-test on data collected from the second PTN class confirms significant increases in both student stress and flight performance during course execution. Despite increased stress levels, students maintained a high level of learning engagement and flight performance proficiency during the entire duration of the course.

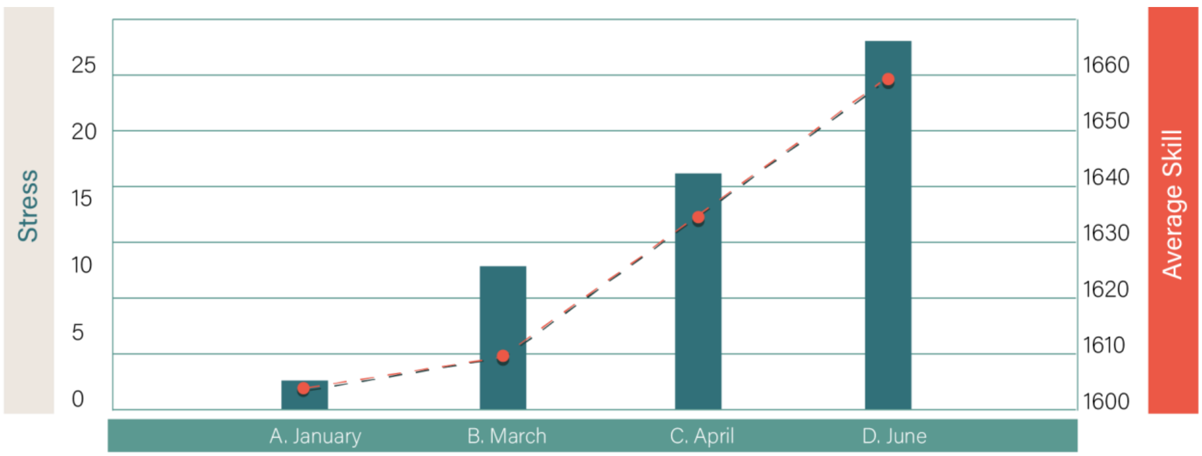

Figure 2: Human performance feedback prevented decreased learning as stress increased

PTN analysts calculate the average skill shown in Figure 2 using a variation of the Elo rating system for adaptive educational systems (Pelanek, 2016). This method mimics the rating system used to rank chess players. However, a student's opponent is a flight maneuver, such as a loop or a landing, instead of another chess player. An accurate rating system is critical to providing feedback from the individualized learning experience – and the only way to effectively close the first loop. In addition to the Elo rating system, PTN scores student skill in multiple ways, including both subjective methods, such as instructor ratings based on observation, and objective methods, such as analysis of data based on deviations from ideal flight parameters within the flight simulator. PTN is attempting to shift the traditional AETC grading paradigm to remove the burden of grading from the instructors and rely more on automated data analytics, allowing instructors to teach more students at a time without degrading the quality of instruction.

Tailored Learning Program

In the second loop, PTN synthesizes data from each individual's learning experience to understand the effectiveness of the current training program as a whole. To help understand which maneuvers are most difficult for students, PTN compared in-flight maneuvers, such as a loop or a landing, to the knowledge or skill areas required to complete them successfully. Analysts then overlaid student's flight skill ratings to the knowledge areas. Analysis of this data provided insights into areas students were most or least successful. Initial data indicates the lowest overall scores are in instrument flying, patterns and emergency procedures. Limitations in PTN's simulation environment affect each of these knowledge areas. For example, limited Global Positioning System (GPS) functionality in the student's primary aircraft flight model prevented ideal instruments training in the simulator. Similarly, students did not have access to a comprehensive set of simulated emergency procedure training, limiting their ability to practice these skills. The results of this initial analysis yield information that is intuitive to PTN leadership since they are aware of the environment's limitations and the reasons behind those limitations. However, moving forward, analysis of skill rating by knowledge area will allow the team to evaluate how technology improvements affects student performance over time.

Ongoing work in this area focuses on further mapping of a refined list of knowledge, skills, and pilot-specific applied performance tasks to all learning content, not just maneuvers. This work also includes the implementation of an adaptive learning framework, known as Keystone Six, which merges competency-based training principles with a data-driven adaptive learning system to further refine and personalize learning to fit individual student needs. The immersive training technology used in PTN produces a wealth of data related to student performance. However, without Keystone Six, analysts cannot make effective use of the data to tailor the learning program. The Keystone Six section, below, describes this work in more detail.

Informed Talent Selection

In the third loop, PTN aims to correlate performance to student demographics to identify salient characteristics of top-performing pilot candidates. In addition to typical demographics, such as age, race and education levels, PTN students report interests and life experiences, such as sports activities, computer skills or video game usage (Lewis, 2018). The ultimate goal is to identify specific candidates or pools of candidates with an especially high or low probability of success. To date, PTN has graduated more than 20 students during the course of two classes, which is not enough data to inform selection decisions. In fact, AETC expects the process for the final loop to take up to 10 years to produce actionable data. However, initial insights can help determine what analytic questions the team should pursue with regard to talent selection. With this in mind, PTN correlated its student performance data to existing USAF recruitment assessments such as the Pilot Candidate Selection Matrix (PCSM) and Air Force Officer Qualification Test (AFOQT). Initial data suggests these tests are effective measurements of a PTN student's performance in live flight. Figure 3 shows the results from 27 students, comparing their PCSM scores to their live flight ratings on the left and their AFOQT scores to their live flight ratings on the right. The Pearson correlation results in p-values less than 0.01, indicating statistical significance. However, significant outliers do exist. The goal of the third loop is to identify characteristics of these outliers that will augment existing assessments, allowing a larger pool of candidates with high probabilities of learning success.

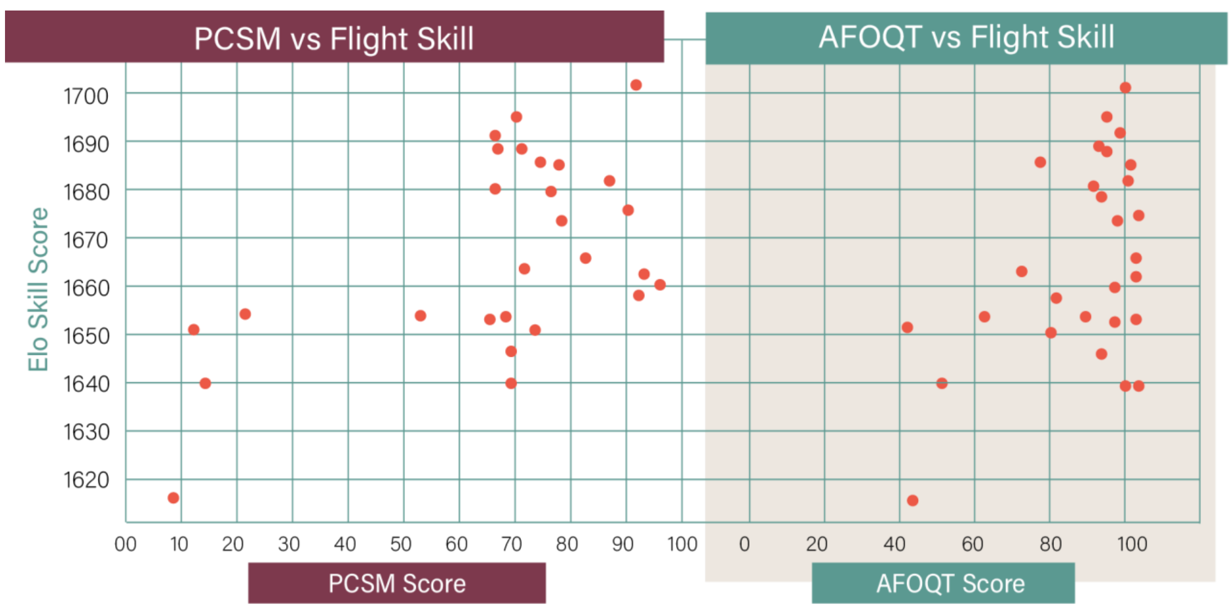

Figure 3: Existing talent assessments are good predictors of flight performance

KEYSTONE SIX

The next iteration of PTN will continue to build upon best practices and lessons learned to inform further development of Keystone Six, PTN's adaptive learning framework. Moving forward, Keystone Six will provide a foundation for teaching using AI-driven technology to provide real-time, adaptive training. The following sub-sections describe the high-level design of Keystone Six, its specific implementation in PTN, and the path forward for this work.

Design

The team designed Keystone Six to guide intentional choices of various learning modalities in order to produce personalized learning experiences that are grounded in job-relevant knowledge, skills and performance tasks, all while providing a framework machine learners can use to future proof training. Implementation of Keystone Six evolved from research in multidisciplinary fields, including adult learning theory, educational psychology, cognitive science, neuroscience, and human performance improvement (Mayer, 2011). Keystone Six is one component of a larger shift from traditional curriculum development methodologies to curriculum design in line with the principles of four-dimensional education. These principles emphasize the development of multi-domain competencies that allow students to be more effective and adaptable in complex, ambiguous environments (Fadel, Bialik, & Trilling, 2015). In addition, Keystone Six leverages the revised version of Bloom's Taxonomy, a well-known and widely-used tool that aids in the identification and classification of the complexity level of the cognitive processes learners move through as new information is learned (Krathwohl, 2002; Mayer, 2002). Bloom's Taxonomy levels are Remember, Understand, Apply, Analyze, Evaluate and Create. Each level is dependent on the one before it, so learners must master a level prior to moving on to the next. For example, if a learner does not remember what the steps are in a given checklist, they cannot successfully perform the checklist at the appropriate time. Keystone Six applies these levels to expected goals for specific learning content, known as learning objectives.

Implementation in PTN

The traditional legacy UPT training curriculum included learning objectives that lacked the specificity necessary to inform content development and data collection using immersive training technologies currently available on the market. In addition, the legacy learning objectives required only a basic level of rote memorization and rudimentary comprehension of information. The learning objectives did not address the need for pilots to apply knowledge and skills within complex, dynamic operating environments where rapid and accurate evaluation, creative problem solving, and multifaceted decision making is required for performance success.

Since the wording of the legacy learning objectives, e.g. "Define contact flying", only reached the Remember and Understand levels of cognitive processing, the instructional design team began development of Keystone Six by revising existing learning objectives to reflect the complexity of pilot training. Working together with instructor pilot SMEs, the team conducted an in-depth analysis of UPT curriculum. They added new learning objectives, e.g. "Plan a sequence of aerobatic maneuvers that demonstrates comprehension of required airspace and energy development", to reflect the higher levels of Bloom's Taxonomy and to ensure the curriculum addressed the more complex, dynamic knowledge and skills necessary to complete in-flight activities successfully. Additionally, the team conducted a job-task analysis to determine the Knowledge, Skills/Abilities, Attitudes, and Other Characteristics (KSAOs) required of pilots. The team linked all learning objectives to related KSAOs and mapped those KSAOs to pilot-specific PTN tasks. The team also created a wide variety of academic content, which allowed student pilots to gain proficiency in KSAOs that directly relate to PTN tasks. For example, students read student guides, view infographics, watch videos, complete quizzes, and engage in interactive eLearning modules in the LMS, part-task scenarios in the flight simulator, and check-rides in live flight. Finally, the team mapped PTN tasks to competencies. Competencies are the higher-level dimensions of human performance that describe elements related to successful performance on the job, which are manifested and observed through behaviors that mobilize KSAOs to perform PTN tasks under specified conditions. Figure 4 illustrates the Keystone Six model, specifically how the PTN learning content nests into Bloom's Taxonomy and PTN's tasks, KSAOs, learning outcomes and competencies.

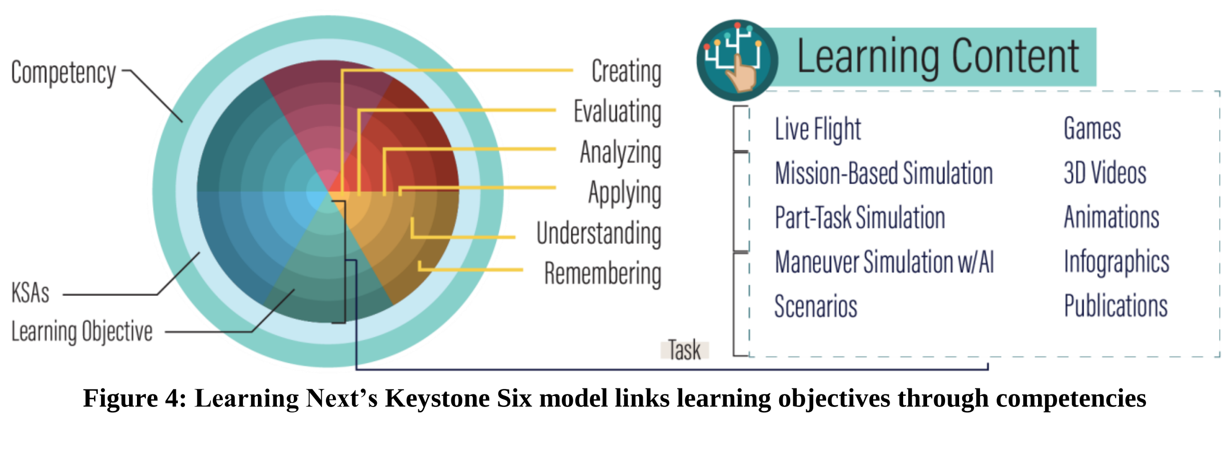

Figure 4: Learning Next's Keystone Six model links learning objectives through competencies

Path Forward

Armed with this new framework, an AI capability can ingest student performance data associated with knowledge, skill, and task proficiency to identify potential issues with a student's overall competencies much earlier than in traditional training. The AI engine can also begin to provide students with an individualized learning journey based on their proficiency level. This responsive learning environment engages and motivates learners in individualized ways that traditional UPT cannot. The system can present the most relevant learning content to the learner based on a variety of characteristics, such as learning style, knowledge level and skill proficiency, while avoiding learning content that includes knowledge the learner has already mastered or learning experiences for which the learner is not ready. When fully implemented, Keystone Six will impact every aspect of the triple loop approach by tying together the learner's experience, preferences and proficiencies to the program's overall objectives.

LEARNING NEXT INITIATIVES

PTN is the most robust use case of the Learning Next concept to-date, focusing on learning how students learn to inform decisions about individuals, courses and talent selection. PTN's initial results are positive enough to encourage other organizations to build on the concept, providing the opportunity to transfer lessons learned and technical solutions to new training challenges. This section describes other Learning Next initiatives currently in progress.

Undergraduate Remotely Piloted Aircraft (RPA) Training Next

Undergraduate RPA Training Next (URTN) is an initiative from the 558 Flying Training Squadron (FTS) at Randolph Air Force Base (AFB) to reduce reliance on high cost simulator systems while increasing student throughput by more than 12% during the next year. Unlike UPT, students in URT develop instrument and basic aviation skills in a simulator-only environment. Therefore, the 558 FTS did not recruit a group of students specifically for an experimental version of URT. Instead, they introduced six instructional applications into their existing training classes. The squadron used existing iPad assets and purchased 26 sets of commercial gaming laptops to increase availability of training tools with an overarching goal to shorten the total calendar training time to meet throughput demands. Moving forward, AETC's RPA Next program will include the progress at the 558 FTS as part of a larger effort to reduce the total time an RPA pilot spends in training, not just the calendar days spent in URT.

Aviator Training Next

Aviator Training Next (ATN) is an initiative of the US Army Aviation Center of Excellence (USAACE) that builds on the lessons learned in PTN and aims to quantify the return on investment of using immersive COTS simulators in lieu of live flight hours to determine if they can produce a better basic aviator using VR. USAACE created a design of experiments (DOE) that uses a control group and two experimental groups in each test class for Initial Entry Rotary Wing (IERW) at Ft. Rucker, Alabama, which began in summer 2019.

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