Tracking Our Trainees: Integrated Learning Enabling Personalization and Prediction

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ABSTRACT

For more than two years, Learning Next initiatives out of the US Air Force (USAF) and US Army (USAR) have used experimental tools, techniques and technologies to revolutionize military training with the orienting goal of ending the global pilot shortage. A key hindrance in the experimental programs, however, is the lack of an integrated learning platform that provides a physics-based world in which to conduct all lessons, skills and activities in a single learning flow. Such a system would not only improve the student's user experience but would also enable a new level of data collection and analysis to personalize the learner's journey and to predict future skills and competencies. This paper describes an extended reality (XR)-based approach to integrated learning that allows a student's successes and failures to affect their options later in the learning flow. This approach allows students to train to specific learning objectives through consequences rather than multiple-choice assessments. More importantly, this approach allows detailed data collection for any action or decision the student makes, setting the stage for predictive analysis of a student's potential piloting skill, his strategic thinking ability, and his specific competencies to help respond to emerging operational and political risks. This paper focuses on the missing gaps and technical challenges of creating a fluid learning system from traditional web-based content and quizzes through to an immersive, realistic training world that allows open-ended interaction.

ABOUT THE AUTHORS

John Williamson has worked as a commercial game designer and producer on nearly three dozen titles in nearly every gaming genre and platform. In addition, he has worked with virtual reality since the mid-1990's, first as research toward his Masters and later to create serious games for the US military.

Dr. Andrew Wilson is an aerospace engineer, applied mathematician and data scientist. With experience in human interface design, fielded aviation sensor data collection and analysis, and computational modeling, he brings a unique perspective to his projects. He holds a PhD and Master's of Aerospace Engineering from the University of Tennessee Space Institute, and a BA in Physics and Mathematics from the University of Chicago.

Jennifer Lewis is a simulation engineer who has developed interoperability solutions for distributed simulation and training environments for the past 18 years. She holds a Master of Science in Computer Science from the University of Texas at Dallas and is a Certified Modeling and Simulation Professional.

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BACKGROUND

For more than two years, Learning Next initiatives out of the US Air Force (USAF) and US Army (USAR) have used experimental tools, techniques and technologies to revolutionize military training with the orienting goal of ending the global pilot shortage. A key hindrance in the experimental programs, however, is the lack of an integrated learning platform that provides both learning content and a physics-based virtual world in a single learning flow. Creating such a system is difficult, requiring both a detailed understanding of learning objectives and the ability to provide exciting, nuanced games addressing these objectives. The paper first describes a basic user story to bound the scope of the system. This story is then used to describe the system being implemented to meet this scope. The paper next describes the motivation and design implementation of a physics-based, multi-device simulator environment, built from the ground up to generate data that links to specific learning objectives within the user story. Finally, the paper provides an analysis of the data generated from the system and its relevance to current and future training methodologies.

INTEGRATED LEARNING: A USER STORY

The following is a user story of a student pilot named Jason and his instructor, Marina. This story, developed as a result of experience with the Learning Next project, represents the primary design goal of a pilot training system. Importantly, this user story is not possible with current tools.

Jason begins his day as a full-time student pilot by strapping on his biometric sensors and logging in to the primary Learning Portal. He gets his bearings on the day when he sees his scheduled events, his current course progress, and recommended new and refresher activities. Today’s a big day; Jason’s got one last virtual check ride this morning before his scheduled first solo flight this afternoon. He has some time before the virtual check ride is scheduled with Marina, so he follows the shown recommendations and reviews the check ride standards. The website presents him with some questions concerning what he needs to qualify for the solo flight. After these questions, the site shows him that he is a bit weak in his knowledge of pattern altitudes and distances, and provides some refresher materials for him to review.

These review activities carry him to the scheduled time for his virtual check ride. A reminder pops up, and he clicks on it, launching the virtual reality (VR) enabled simulation preconfigured with the expected flight conditions (time of day, visibility, cloud cover, location). Marina joins him in the simulation bay, saying simply that this is his flight and he is in charge. Jason must perform everything necessary for a safe solo flight undirected.

Jason puts on his headset, and the simulation takes Jason not to a cockpit, but to a hangar, and he proceeds with the required pre-flight inspection, following the checklist on his (virtual) kneeboard. He is a bit nervous, and misses an oil cap that is not securely closed (Figure 1). Marina catches this, but decides to let natural consequences be today’s teacher. Still in VR, Jason enters the cockpit. He communicates with the ground crew, starts the engine, obtains needed clearances from the tower, taxies, and takes off.

As all this takes place, Marina watches Jason’s biometrics. She notes that Jason’s stress levels are slightly elevated but normal during take-off. She expected this; Jason is nervous because he really, really wants to do his solo flight today. As he takes off and climbs out, she notes that Jason is regularly scanning his instruments, as he has been trained to do, but he apparently does not notice the falling oil pressure. He is forced to take note when an engine temperature warning pings.

Figure 1: Unseated oil cap creates in-flight emergency

Marina watches Jason’s stress spike as he levels off the aircraft. She watches his gaze rapidly scan the instrument panel, looking for the origin of the warning. Before he can determine the problem, the engine catches fire. After a momentary freeze, Jason correctly moves into his emergency procedures (EP) checklist, moving the PCL to off and pulling the firewall shutoff handle. The fire is still visible, he has no more actions to take to mitigate or recover the aircraft, so he pulls the handle to eject. His chute opens and his stress levels out as the simulation ends, taking him to an after-action report.

Marina joins Jason in VR to review the flight (Figure 2). Shown in 3D with important events marked, she tells him simply that this was avoidable and asks him to work out why. He works his way backward from the fire, realizing that oil pressure was dropping the entire flight. Eventually he realizes it was not a mistake he made during the flight, but instead that the aircraft was not ready for flight. Marina shows him a screen capture she took of the missing oil cap, and reinforces that this is the reason for checklist discipline: people forget things, the checklists don’t.

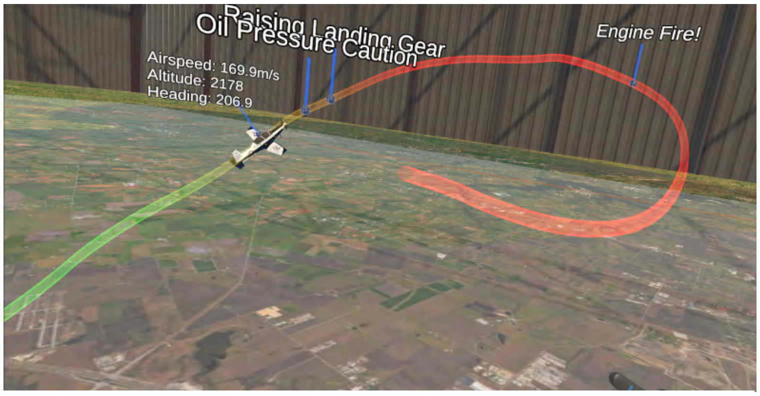

Figure 2: After Action Report illustrates significant in-flight data

SYSTEM WALKTHROUGH

Accomplishing the seamless transitions and transparent decision-making described in the preceding story requires using many systems, talking to each other in the right ways.

The learning portal (Figure 3) is a web browser interface, which provides to the student and instructor the necessary tools to identify themselves, and access the various learning resources (schedule, videos, quizzes, tests).

Once logged in to this portal, the various system users can access the schedule. The schedule accesses the current master flight and simulation schedule, current weather data, and maintenance data and schedules for aircraft and simulators. The student is shown all master scheduled activities, and is shown recommended supporting activities for any blocks of time that are self-determined. If weather or previously unexpected maintenance suggest that a master-schedule flight or simulation is unlikely to take place, then it flags those parts of the schedule for potential cancellation. Instructors see their own flight schedule, with additional power to cancel flights (for weather, student status, or instructor status).

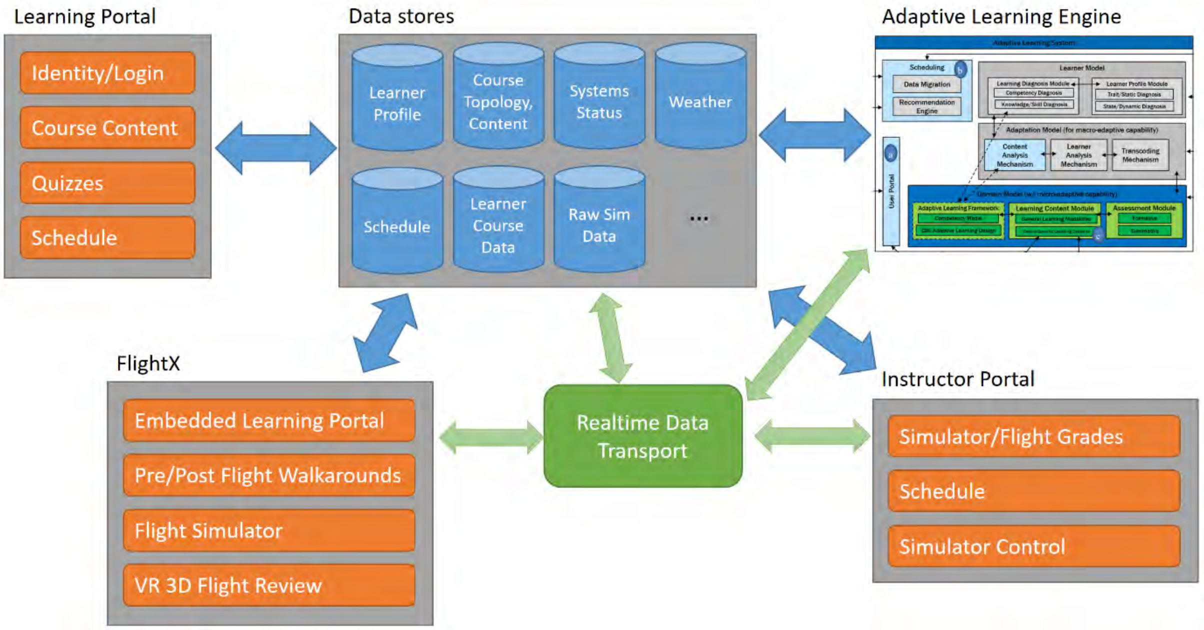

Figure 3: Adaptive Learning System connects real time data, course design and learner profile data to recommended content, activities and certification testing

The master scheduler has access to multiple views of the schedule, including per-instructor, per-student, and per-resource. In addition to actually scheduled events, the master scheduler can see suggested flights based on course design and current student grades for keeping students moving through the curriculum towards certification.

In the story, Jason sees he has a block of time before his next scheduled event, and sees some recommendations for how to use that time. This is generated by the Adaptive Learning Engine (ALE) (Figure 3) which utilizes a carefully designed curriculum and detailed information on learner's past performance to determine what activities are most likely to be beneficial for accomplishing short-term (e.g., an upcoming check ride) and long-term (e.g., graduating on a set schedule) learning objectives. Currently, this involves providing recommended reading, video viewing and other traditional knowledge acquisition activities. As integration with other tools increase, and in particular as sophistication in curriculum design increases, this will also include recommended task-drills for skills (e.g., practice landing cross-wind five times).

Next, it is time for Jason to perform his virtual check ride. This requires more capability than can be delivered in a browser or on a mobile device, and instead uses a specialized device. In this case, the specialized device is a newly realized flight simulator (Figure 3, FlightX), running on a COTS virtual reality (VR) gaming computer. This new flight simulator is described in more detail in the following section. The portal website reminds him of this scheduled event, and (since he is already logged in to the VR computer) provides him a download link for the specific scenario configuration. While running through a full simulated flight process (preflight inspection, startup, takeoffs and landings, flight activities, postflight), the simulator is transmitting data to the central learning repository databases.

This data is then analyzed, visualized, and presented to an instructor for grading (Figure 3, Instructor Portal). These grades as well as the detailed data from FlightX provide feedback to the ALE. Using this information, the ALE updates the recommendations for subsequent independent learning activities for the student and provides instructors and schedulers updated qualification status and recommended schedule slots for next activities. Then both student and instructor can proceed to check their schedule and recommendations, starting another round of the learning loop.

PHYSICS-BASED LEARNING ENVIRONMENT

Central to the success of this system is a newly developed flight simulator, FlightX, which is currently a minimum viable product iterating through improvements before release at the end of the calendar year 2020. While there are many excellent existing commercial and retail flight simulators, a recent attempt to use several of these for pilot training revealed a number of deficiencies. Further market research revealed that no simulator fully met the wide variety of requirements necessary to take advantage of current technologies and learning design.

Some existing systems are truly excellent, and faithfully recreate the flight experience at a phenomenal level of fidelity. Unfortunately, these systems suffer from a lack of economics of scale. They require unique dedicated hardware and software, and often unique integrated configurations of multiple small-distribution hardware and software. These systems sometimes cost more to purchase and maintain than the aircraft they model, especially for introductory flight.

Meanwhile, a survey of COTS flight simulator software for standard gaming computers revealed a number of weaknesses. For brevity, here is a list of features demanded by the current market for modernized trainers:

- Gaze tracking to objects in the world (cockpit instruments, terrain features, other aircraft);
- Support for the current generation of inexpensive COTS virtual reality (VR) and augmented reality (AR) head mounted displays (HMDs);
- Integrated and extensible biometric monitoring;
- Integrated and extensible voice-responsive agent;
- Support for modern USB control systems (stick, pedal, throttle);
- Inexpensive integration process for additional airframe designs;
- Effective close-formation multiplayer flight;
- High quality scenery and cockpit graphics suited to the current quality level of VR/AR HMDs;
- Close data integration with central instructional systems for adaptive learning;
- A scenario editor design for pilot instructors.

FlightX focuses on delivering this unique list of features, for the purpose of delivering an inexpensive and effective training experience that makes best use of commonly available modern tools (biometric sensors, VR/AR HMDs, adaptive learning, big data).

Additionally, FlightX is designed to deliver a seamless experience for a full simulated pilot sortie, including preflight and post flight walkaround, with VR interactive emergency procedures training in the same environment. Currently, the simulation includes more than 120 defects that can occur during pre-flight inspections: flat tires, missing static wicks, low O2 pressure, hydraulic leaks, worn brakes, and broken lights. Each of these defects are fed into FlightX and can realistically affect the performance characteristics during the operation of the flight sim.

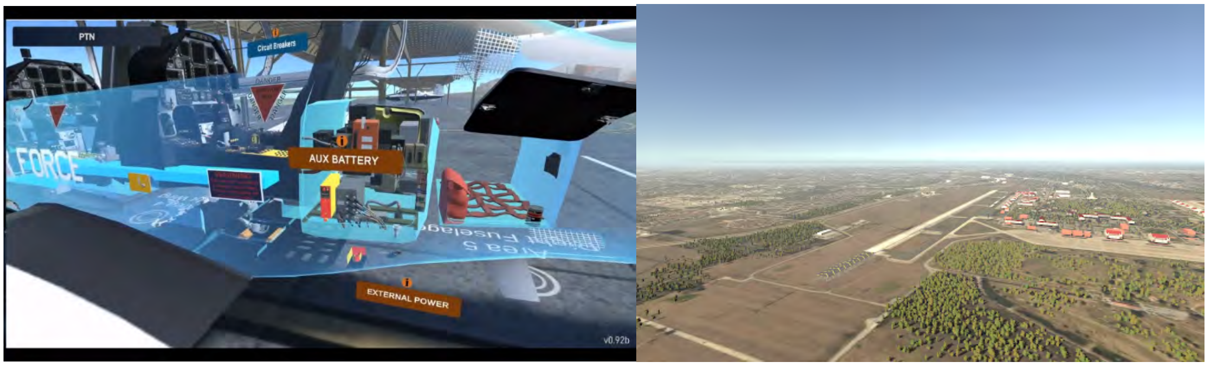

Figure 4. Flight X’s integrated academics (left) and improved visuals (right)

ADAPTIVE LEARNING SYSTEM

Contrary to popular belief, collecting data is not an end unto itself. Data is useless unless it is used somewhere, for something. The primary objective of collecting very detailed data, down to mouse clicks, keystrokes, and gazed-at-objects in the FlightX, is to improve the learning process. Traditionally, humans have been the primary engine by which data updates learning. Teachers can use grades to provide focused instruction to needed pupils. Quizzes provide a more specific diagnostic, indicating exactly which areas a student or class are missing. Indeed, pilot instruction at its core is a real-time data-driven experience, with the instructor pilot providing both immediate and debriefed feedback on the student's performance.

The Adaptive Learning System (ALS) accesses collected data from the flight simulator (including flight biometrics), the web-based instruction system, the instructor grading system, and from sleep/general-health biometric sensors. It integrates these diverse data sources into recommendations to the students and the instructors. Here are some ways the ALS can process the data into meaningful, and otherwise difficult to determine, recommendations:

- A component that parses the FlightX data stream into individual maneuvers, noting start/stop times, maneuver types, a suitable standard to compare to, and (if possible) some form of automatic grade.
- A component that takes flown maneuvers, grouped by type, and looks at stress over time. If there is a maneuver that is causing the pilot consistent stress, even if he is flying it well, it flags it for review so that the pilot can become comfortable.
- A component that tracks flown maneuvers over time, keeping track of the last time a pilot refreshed a particular skill. Using a space-time-repetition algorithm, it recommends a best-practiced-now maneuver to ensure the pilot is retaining their learning.
- A component that takes the web-based instruction lessons, and instructional design, and previously flown maneuvers, to recommend the next maneuver to learn or practice in sequence.
- A component that takes flown maneuvers, and known accessed learning content, and discovers that one maneuver is badly flown, even though the pilot has access the learning content several times, a text description of the flown maneuver with figures. It suggests using a different learning content for the same maneuver, such as watching one performed in a video, or perhaps watching in the flight simulator as the program executes a previously recorded one.
- A component takes flown maneuvers, and instructional design, and gaze tracking data, and determines that a student is looking at their airspeed indicator too much and not enough at their altitude or vertical airspeed. It recommends review of instrument scanning learning content.

This highly complex collection of interrelated processes are gathered in Figure 3 under the component described as the ALE. Figure 5 shows that portion of the system in greater detail, including all the various ways that course design and modeling design interact with learner performance and behavior data to generate recommendations.

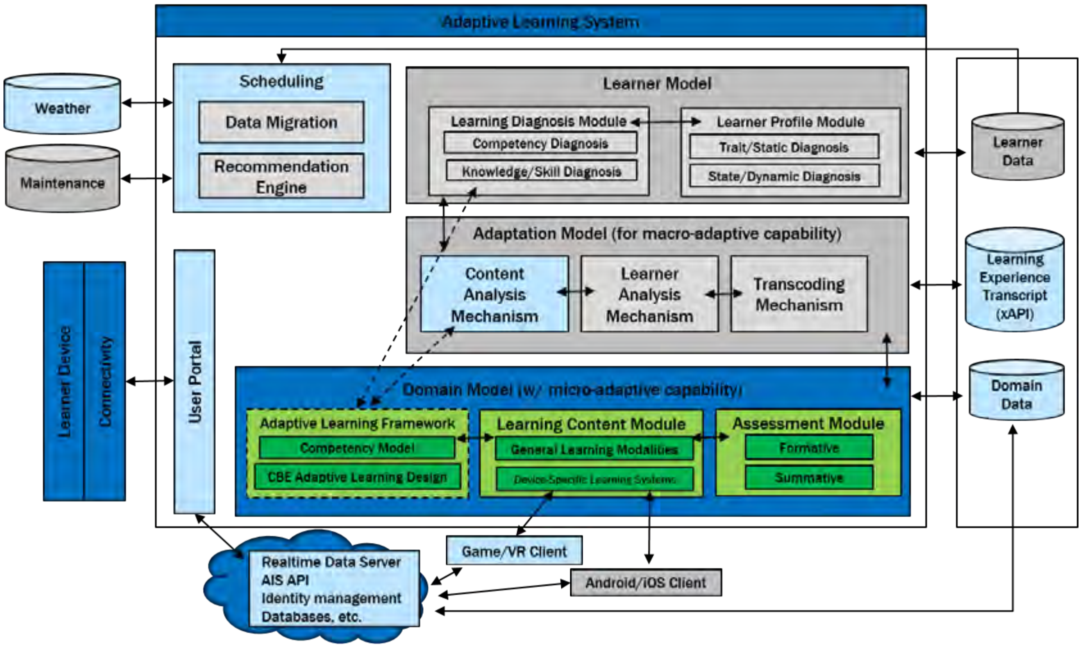

Figure 5. The Adaptive Learning System links up key systems and data to deliver a multi-modal learning experience that adapts to the learner's needs

CONCLUSIONS

This paper presented a new learning and VR simulator training ecosystem actively being developed, why such a system is desired, and many of the challenges that are being overcome. The described system is in active development and early testing. Early results, shown in Figure 6, show that training with immersive, COTS systems and accelerated, adaptive curriculum can have significant effects on training time and effectiveness.

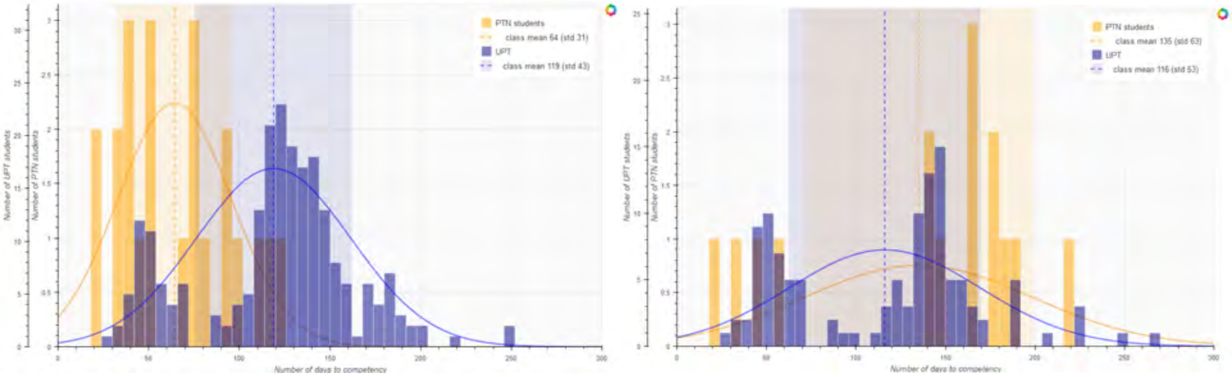

Figure 6. Learning Next approach decreases time to standard for maneuvers when allowing for regression