Project Final Report

SPTT001 – Optimize Simulation
Close-out Date: March 8, 2018

PI: Dr. Shafagh Jafer, Embry-Riddle Aeronautical University

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a. Abstracts of Theses

Although the use of simulation training devices in aviation saves time, money, the environment, and provides safer flying experience, there exist technology-related challenges that hinder the use of simulation in aviation training. One of the biggest limitations in this area is the rapid update and change of real devices. Maintaining and updating simulation technologies to match this rapid growth has been a major concern. In this project, we tackled such issues that are in the face of using simulation for FAA ATC training purposes. We conducted a thorough survey report on current areas where the FAA Academy benefits from the use of simulation for ATC training by analyzing AMA-500 courses extensively. We reported on utilization of simulation in developing and improving training curriculum, and we proposed a process to keep simulation technologies up-to-date with real devices. To carry out the project activities, five major objectives were identified to address project goals, including: (1) Literature review on currently used training simulation technologies; (2) Benefits and potential return on investment (ROI) of simulation vs. live training; (3) Utilizing simulation-based training into the curriculum development process; (4) Maintaining up-to-date simulation-based training in accordance with rapid technology growth; (5) Updated and new simulation-based courses. Each objective included a set of activities to produce outcomes. A list of resulting outcomes produced during the course of the project are listed as follows: (A) a literature survey report; (B) survey questionnaire distributed to industry partners and simulation providers; (C) survey results and analysis report; (D) a report on simulation usage ROI; (E) a report on a recommendation process for keeping simulation in sync with real devices; (F) AMA-500 courses analysis report; (G) a report on recommendations for AMA-500 curriculum updates/improvements. The results of this project can be directly used to complement and update training material and modules used at the FAA Academy in training air traffic controllers. Several other COE tasks will also benefit from the results of this project. The results of this project will also provide a recommendation process to simulation vendors on effective ways to keep training technologies in sync with real world devices. We see current and future vendors significantly benefiting from the results of this project in addressing current and future FAA needs to modernize and advance ATC by replacing "air traffic control" with "air traffic management" by the means of using NextGen solutions. A follow-on research proposal was submitted proposing to utilize the outcome of this research in improving, proposing new, and updating simulation-based training at the Academy.

b. Publication Citations

- Updegrove, J. & Jafer, S. (2017). Recommendations for next generation air traffic control training. 1-6. 10.1109/DASC.2017.8102129.
- Updegrove, J.A. and Jafer, S., (2017). Optimization of Air Traffic Control Training at the Federal Aviation Administration Academy. Aerospace, 4(4), p.50.
- Jafer, S., Updegrove, J.A. and Chhaya, B. Towards a Common Air Traffic Control Simulation Scenario Development. Submitted as a book chapter for publication at SCITEPRESS, January 2018.

c. Data on Scientific Collaborators

- Dr. Shafagh Jafer, PI, Assistant Professor, Software Engineering, Embry-Riddle Aeronautical University
- Ahrash Aleshi: Masters of Cybersecurity Engineering student, Embry-Riddle Aeronautical University
- Bharvi Chhaya: PhD Candidate of Software Engineering, Embry-Riddle Aeronautical University
- Khushboo Dhala: Masters of Software Engineering student, Embry-Riddle Aeronautical University
- Ashok Raja: Masters of Software Engineering student, Embry-Riddle Aeronautical University
- Jessica Updegrove: Masters of Software Engineering student, Embry-Riddle Aeronautical University

d. Information on Inventions

N/A.

e. Technical Summary

In order to conduct this project, the following activities, approaches, and outcomes were identified and fulfilled to satisfy project objectives. Appendix A – G include outcome studies and reports generated throughout the course of this project.

Obj. 1 – Literature review on currently used training simulation technologies

- Activities: A thorough literature review was conducted to generate a comprehensive report on simulation technologies (tools, methods, vendors) used by academia and industry for FAA training purposes.
- Approach: Training organizations such as educational institutions (including Embry-Riddle and other COE partners) and private corporates/schools were contacted and surveyed. Relevant FAA reports and documents were also investigated and summarized.
- Outcome: A literature survey report documenting the use of simulation for FAA training.

Obj. 2 – Benefits and potential ROI of simulation vs. live training

- Activities: Areas where simulation can be used to enhance and complement live device training were identified and a list of benefits and potential ROI elements were recognized for each area.
- Approach: Industry vendors were contacted to identify areas where simulation can be used for training. Cost/benefit analysis were conducted to report on potential ROI.
- Outcome: A research report documenting the benefits and ROI of simulation vs. training.

Obj. 3 – Utilizing simulation-based training into the curriculum development process

- Activities: Based on outcome achieved in Objective #2, research conducted to identify whether simulation is a viable medium in terms of implementing it as part of the training curriculum. AMA-500 courses were extensively analyzed. Potential improvement areas were identified and suggested in a summary report.
- Approach: The AMA-500 curriculum was analyzed, and course content were investigated thoroughly.
- Outcome: A summary report with AMA-500 course analysis and a discussion of utilizing simulation technologies in developing/improving the curriculum.

Obj. 4 – Maintaining up-to-date simulation-based training in accordance with rapid technology growth

- Activities: FAA simulation suppliers and industry vendors were surveyed on their maintenance mechanisms. A list of simulation-based training manufacturers were first identified and interviewed on their upgrade/update policies and techniques.
- Approach: Techniques and potential standards that can be used by simulation devices manufacturers to maintain their simulation technologies in sync with rapid real device growth were identified.
- Outcome: A report on our proposed process to maintain and update simulation technologies in accordance with equipment updates/changes.

Obj. 5 – Updated and new simulation-based courses

- Activities: Based on the outcomes achieved in Objective 2 and 3, recommendations were made on AMA-500 courses that are/would benefit from use of simulation over actual equipment training (based on training objectives, complexity of training, length of training, etc.).
- Approach: Analyzed AMA-500 courses and identified areas were simulation could be utilized for enhancing training and learning experience.
- Outcome: A recommendations report on a list of potential courses benefiting from use of simulation.

f. Other (specify)

N/A

Appendix A: Literature Review Summary Report

Airservices Australia – Improving Quality and Efficiency in ATC Training and Simulation

Case study describing updates to training simulation via Re/Vue video recording. The Airservices Learning Academy supports 140 trainees per year and delivers courses in enroute, approach, and tower. The Academy was looking for a way to capture quality image and video from simulation scenarios. It was determined that hardware-based video recording and streaming could complement the training, particularly via the ability to remotely monitor activity on the students' screens at any time. The Re/Vue Mini device demonstrated potential for improving training and simulation. The device features quick and easy installation, non-intrusive passive video signal split, and superior quality of lossless video recordings with synchronized audio. The quality is superior to others and allows instructors to zoom in and capture images with high quality for inclusion in training materials or training documents. In addition, the files are extremely portable and enable students to take home instructor designed pre-recorded data for further learning on their own time. This allows instructors to create specific training scenarios for replay on PCs, laptops, or tablet devices. Multiple devices can be networked to monitor multiple screens at once in real time.

Multimodal Production of Second Pair Parts in Air Traffic Control Training

Analysis of ATC training in regards of stimulus and response pairs to discern the temporal and sequential organization of ATC training. ATC is a joint multiactivity project involving multiple objects, actors, and artifacts which amounts to the management of multiple parallel tasks. Verbal and non-verbal activities intertwine smoothly as a part of the multiactivity. Pairs consist of a first pair part (FPP) and a second pair part (SPP), with additional expansions included when necessary. In ATC training, the trainer prompts condition the ATC trainee to accomplish tasks, creating the sequential multimodal aspect. Sequential components of an instructional sequence minimally involves 1) communication by an aircraft or a contextual change, 2) trainee insufficient action or engagement, 3) trainer prompt, 4) trainee multimodal task accomplishment. The trainer prompt is the FPP, but it is not a free-standing activity; it is instead conditioned by the contingencies of the air traffic system that made the ATC task immediately relevant. By intervening, the trainer prompt dually checks and measures the trainee's competence in recognizing and organizing his/her tasks and prompts the trainee to carry out those tasks. The trainer prompts are a requisite for the trainee's SPP only if the trainee has failed the execution of the ATC task. It is noted that the accounting of the timely accomplishment of ATC tasks is challenging at times because ATC is less standardized than other interactions, such as cockpit interactions. In ATC training, there is a reflexive loop between the controllers' work and the state of the aviation system. Training must emphasize reflexively adapting, shaping, and making sense of a trainee's activities to maintain the mobility of the objects they coordinate.

Application of Advanced Technologies for Training the Next Generation of Air Traffic Controllers

Research intended to develop a more comprehensive view of the state-of-the-art controller training throughout the world and to identify ways in which training could be improved. Reported is a set of technology and process changes that could result in substantial gains in the efficacy of FAA controller training, notably a reduction in certification time, improvement in the utilization of training resources, and more systematic and objective assessment of student performance. FAA controller training requirements are standardized and defined in FAA Order 3120.4, Air Traffic Technical Training. At the Academy, there are four training phases: Air Traffic Academics, Part-Task Training, Skills Building, and Performance Verification. The Academy has automation display systems that accurately mimic the radar displays in enroute facilities, but does not yet have the User Request Evaluation Tool (URET) that is operational at the radar associate position in all 20 enroute facilities, but is expected to be installed by late 2006. For enroute, simulation is conducted using the Host System's Dynamic Simulation (DYSIM) capability and training which typically takes 12-16 weeks. Opportunities for improvement include increasing realism, accounting for wind effects, control of speed adjustments, reducing the dependence on human pseudo-pilots, ability to pause and resume, and the ability to replay a scenario run. For TRACON, the Automated Radar Tracking System (ARTS) and Standard Terminal Automation Replacement System (STARS) are used to support both operations and training to provide a more realistic training environment than DYSIM does. Tower training provides little opportunity for independent practice in ATC skill application. . The United States Air Force (USAF) overhauled its training program after experiencing shortages, which included the introduction of self-paced, web-based training such as learning-game applications, interactive simulation, and high-fidelity training and increased simulation training times which reduced qualification times at facilities. Classroom instruction and CBT are effective for acquiring basic knowledge, but a practice environment with high-fidelity simulation is critical for acquiring the specialized and complex skills of ATC in an efficient manner. Voice recognition and synthesis (VR&S), intelligent tutoring, and instructor support capabilities can substantially improve the simulation training environment. VR&S can replace necessary human pseudo-pilots with automation and supports self-paced, independent learning while enforcing the teaching and use of standard ATC phraseology. Intelligent tutoring provides accurate and objective feedback that helps focus skill acquisition and reduce training times.

NextSim: A Platform-Independent Simulator for NextGen HF/E Research

Article describing the NextSim simulator as it relates to human factors and ergonomics. Notes that the effectiveness of a simulator is contingent not on how high in fidelity it is, but on how much the skills learned in the simulator transfer to the environment. NextSim is a platform-independent, medium-fidelity simulator that captures many of the proposed innovations of NextGen which permits the researcher to modify the simulation as details of NextGen implementation become better understood. The simulator distinguishes among class airspace, trajectory-based operations (TBO), and flow corridors. Researchers can also customize routes in NextSim. It uses a physics engine that produces realistic aircraft consequences, such as required time to descend or turn. One of the major changes in NextGen is the concept of sky-based separation, where planes use ADSB to separate themselves without operator intervention; this ability is incorporated into NextSim. In addition to verbal communication, Data Communications (DataComm) allows digital communication between the air and ground. At the end of each scenario, participants receive a summary of performance measures. In addition, several behavioral measures can be gathered, including workload and situational awareness (SA). Scenarios can be interrupted for a researcher-determined amount of time to collect data or perform other actions. Automation aids, such as conflict disks, conflict prediction, and conflict alerts help reduce operator workload. In the simulator, aircraft are created using two methods: random aircraft generators and scripting aircraft. The simulator is inexpensive and flexible, making it a valuable resource for research. NextSim is freely available to researchers at educational institutions.

Air Traffic Technical Training

In-depth reference that conveys instructions, standards, and guidance for the administration of ATC technical training. Was not read in-depth until necessary. Provides details in the topics of training of non-FAA personnel, roles and responsibilities, training evaluation, training requirements, records and reports, on-the-job (OTJ) training, computer-based instruction (CBI), CBI use, CBI courseware and lesson development, instructions for completing various reports, and instructional program guides.
The Use of FAA Flight Training and Aviation Training Devices at UAA Institutions

Study to determine the composition of the simulation fleet available to UAA institutions and about the financial and cultural impacts of the FAA policy change that altered the creditable training conducted in Aviation Training Devices (ATDs). Identified as not relevant as the scope of this research was narrowed to ATC training. Potentially still a good resource for general information about aircraft simulators and certification methods.

Using Scanpaths as a Learning Method for a Conflict Detection Task of Multiple Target Tracking

Study to determine whether the scanpaths of experienced ATCs could be used to improve the performance of novices in a conflict detection task. Expanded studies in other domains showing improvement after exposure to experts' scanpaths, with this study providea a new application to aircraft conflict detection. Scanpaths of experts were recorded, analyzed, and shown to novices. The false alarm rates were significantly decreased by those shown the scanpaths versus those that were not, thus providing evidence of improved performance due to scanpath training intervention. Therefore, implementing experts' scanpaths into novices' active learning process shows promise in enhancing training effectiveness and reducing training time. Scanpaths of experts showed general search patterns of circular sweep, moving left to right while zigzagging up and down, and observing closest pairs or dense areas first, with circular sweep being the most popular technique used in ATC and other domain studies. The Simscope/Simtarget software suite was used to simulate the enroute air traffic radar display. It was determined that showing novices a graphical depiction of the scanpath provides a benefit over and above verbal instructions only. After the test, novices were given a survey regarding the effectiveness of the training and helpfulness of being shown the scanpaths. It was noted that the scanpaths given not only provide motivation to the students but may also enforce the participants to follow a specific search pattern. Observations of the search strategies suggest two important visual search strategies that may contribute to efficient conflict detection: circular scanning seems to ensure that the observer does not miss any aircraft on screen and focusing on reading aircraft altitudes seems to help reduce the observer's workload during loss of separation (LOS) detections.

2010 Top Simulation & Training Companies

Compilation reporting on simulation and training companies and which core competencies they excel in. Of value to this research is Adacel, Lockheed Martin, UFA Inc., and Computer Sciences Corporation (CSC). Adacel is the premier supplier of ATC simulation solutions for training civil and military ATC.

Simulators improve realism and reduce instructor workload and dependency on human role players. CSC develops training solutions for a broad range of clients. Lockheed Martin is a leader in the development of military training, simulation and integrated logistics, support, and test equipment solutions for customers worldwide. UFA Inc. is a global leader in ATC simulation technologies for ATC training and air traffic management planning. They are differentiated by market-leading voice recognition and response systems and highly realistic flight training scenarios.

Nontechnical Skills Training in Air Traffic Management Including Computer-based Simulation Methods: From Scientific Analyses to Prototype Training.

An introduction of a simulation-based non-technical skills training for ATC by presenting a scientific analysis for the training development and prototype training. ATC requires advanced nontechnical skills such as scanning, comprehension of the situation, anticipation, workload management, decision-making, communication, and teamwork. These skills may be acquired via effective training. These skills are often treated synonymously with crew resource management (CRM) skills. The FAA catalogue of training lists a training course called air traffic team work enhancement (ATTE) as an approach of applying CRM training concepts. In ATM, nontechnical skills are commonly trained using a combination of lectures, discussion, role-play, exercises, case studies, accident analyses, and video re-enactments of accident scenarios. These methods limit practical training of necessary skills. Instead, practice-based skills are the most effective method to train nontechnical skills, with additional advantages of time and cost savings. It was found that there were transfer problems in current TRM trainings and that transfer effects did not last very long. There is a necessity to shift from traditional frontal teaching to practice-based training in which active participation of trainees receives high priority. Training was based on the Radar Operation Simulator & Editor (ROSE) which is a radar simulation software that is easy to use and runs on standard computers. NTS training modules should include stress and workload management, situation awareness, decision-making, communication, teamwork, threat and error management, and fatigue management. It was noted that human pseudo pilots were needed for each scenario, that direct and reliable feedback is essential for learning and has a motivating effect, and that other feedback tools such as eye tracking could enhance ATC training.

A Comparative Analysis of Aviation Student Knowledge, Skill, Self-Efficacy, Motivation, Deep Learning, and Commitment to an ATC Career Before and After ATC Simulation

Study conducted to determine the level influence simulation had on student perception of air traffic control knowledge, ATC skill, academic self-efficacy, student motivation, and their commitment to a career in ATC. Results showed that all aspects increased after training in an ATC simulation lab course. In addition, there were strong correlations between dimensions. It was recommended that educators utilize simulation.

The majority of this research is considered not relevant to this research as it studies student attitudes and perceptions to training and not the simulation features themselves.

Training Device Types, Use, and Credit

PowerPoint slides containing a basic overview of aircraft simulator categorizations and uses. This information is considered not relevant after the research was focused to ATC simulation training.

Review and Evaluation of Air Traffic Controller Training at the FAA Academy

Review and evaluation conducted in response to the 2012 FAA Modernization and Reform Act of 2012 which was enacted to streamline programs, create efficiencies, reduce waste, improve aviation safety and capacity, and provide stable funding for the NAS and other purposes. The Air Traffic Division (AMA-500) of the Academy delivers initial, advanced, and specialized air traffic training by delivering supervisory/managerial and technical training that meets the Air Traffic Organization's (ATO) requirements, administering examinations, and providing resources. The document includes recommendations for improving AMA-500 ATC training. Three key areas were evaluated: roles and responsibilities, communication of roles and responsibilities, and accommodation of developmental ATCs. The Safety and Technical Training (AJI) division designs, develops, updates, and maintains course curriculum to meet ATO training requirements including course content, assessment tests, and evaluations. Regarding roles and responsibilities, it was found that the Academy has several processes in place to carry out roles and responsibilities, responsibilities span multiple organizations, and individuals know their roles and responsibilities well. Some barriers were a change in organizational structure that resulted in a lack of understanding which organization is responsible for certain tasks, limited visibility into the whole process, and a lack of documentation for processes. Regarding communication, multiple networks are in place and communication is personal and frequent; however, there is limited formal communication and documentation, no process to show and communicate roles and responsibilities, and limitations on feedback loops. Regarding developmental ATCs, the Academy historically has had no issues accommodating developmental ATC demands. It was noted the number of available simulators could affect the number of developmental ATCs that the Academy can accommodate; however, there were no major barriers to the Academy's ability to accommodate developmental ATCs identified. It was recommended that the FAA show the whole process for communication and roles and responsibilities, use RACI-type tools, capture details of "trial and error" process successes, and share best practices throughout the organization. In regards to the accommodation of developmental ATCs, it was recommended that the Academy explore use of more online and mobile learning applications, primarily for specialized courses, noting that less than 10% of the Academy courses were web-based. Projectors and Smartboards are the primary means of viewing presentations. It was noted that enroute courses have several e-learning modules that are similar to CBI methods, which allow students to learn at their own pace and discretion. However, the FAA does not require any classes to include online training. It was also noted that the Academy began entering an iPad development stage where iPads may replace most paper-based training materials. In addition, a terminal simulation program called Practical Radar Approach Control Training Interactive Computer Exercises (PRACTICE) was being developed as a standalone program on any computer for developmental training. The need for new technologies to develop and deliver training will increase in the near future and will become highly influential on the Academy's ability to develop and maintain training content as well as on the ability to train developmental ATCs more effectively. In addition, the availability of funding was restricted in recent years and a higher demand in ATC workforce needs is a potential weak point for training capacity at the Academy. It was noted that the acquisition and implementation of a new Learning Content Management System (LCMS) had the potential to streamline a number of processes for developing, updating, modifying, and sharing courses and course content.

Can Simulator Immersion Change Cognitive Style? Results from a Cross-Sectional Study of Field Dependence-Independence in Air Traffic Control Students

ATC performance is heavily dependent on visual processing; it is important to understand how to screen for or promote relevant visual processing abilities. It was thought prior that such abilities are largely innate and stable; however, recent research shows promise that suggests increased exposure to visually intensive technologies like video games can improve these abilities. This study showed no benefits of videogame play were found; however, more fourth-year ATC students were field-independent (FI) than first-year students and the general population. The study poses the question of researching ways to train people in ways that could change supposedly stable abilities, thus allowing for an increase in both the number and quality of ATC operators. Such techniques include visually intensive technologies such as videogames and simulators. Although it was found that videogames did not improve the FD-I capabilities of students, it was shown that intensive ATC training and experience may increase FI. If so, research into how this happens and determining the reasons behind the increase can make significant emotional and financial differences in the lives of at least 25% of the population and could forever change the training process in a multitude of domains.

Although interesting, this research is regarded as not particularly relevant to our research task as it focuses on the effects of training more than the way training itself is conducted.

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(List of Vendors/Facilities with ATC Training Simulators)

Institution	Location
Aims Community College	Greeley, CO
Arizona State University	Mesa, AZ
Broward College	Pembroke Pines, FL
Community College of Beaver County	Beaver Falls, PA
Daniel Webster College	Nashua, NH
Eastern New Mexico University — Roswell	Roswell, NM
Embry Riddle Aeronautical University - Daytona	Daytona Beach, FL

Embry Riddle Aeronautical University - Prescott	Prescott, AZ
Florida Institute of Technology College of Aeronautics	Melbourne, FL
Florida State College at Jacksonville	Jacksonville, FL
Green River Community College	Auburn, WA
Hampton University	Hampton, VA
Hesston College	Hesston, KS
InterAmerican University of Puerto Rico	Bayamón, P.R.
Jacksonville University	Jacksonville, FL
Kent State University	Kent, OH
LeTourneau University	Longview, TX
Lewis University	Romeoville, IL
Metropolitan State University of Denver	Denver, CO
Miami Dade College	Homestead, FL
Middle Georgia State College	Cochran, GA
Middle Tennessee State University	Murfreesboro, TN
Mount San Antonio College	Walnut, CA
Purdue University	West Lafayette, IN
Sacramento City College	Sacramento, CA
The Community College of Baltimore County	Baltimore, MD
Texas State Technical College - Waco	Waco, TX
Tulsa Community College	Tulsa, OK
University of Alaska Anchorage	Anchorage, AK
University of North Dakota	Grand Fork, ND
University of Oklahoma	Norman, OK
Vaughn College of Aeronautics and Technology	Flushing, NY
Western Michigan University	Battle Creek, MI

Appendix B: Survey of Industry Vendors and Professionals

The following survey intends to gather information from industry vendors and professionals regarding the current state of ATC simulation technology as it pertains to ATC training. The survey should take around 15-20 minutes of your time and consists of multiple choice and short answer questions. Please answer the following questions with as much detail as you are free to give and as accurately as possible, to the best of your knowledge. Participation at this survey is voluntarily and you may opt-out of taking the survey at any time. The survey is anonymous.

1) How long have you personally worked in the field of ATC simulation and training?
   a) Less than 5 years
   b) Between 5 and 10 years
   c) Between 10 and 20 years
   d) 20 years or more

2) Do you provide ATC simulation technologies to the FAA? If so, which technologies?
   a) No
   b) Yes, ____
   ____
   ____

For questions 3 - 6, please consider the following simulation technologies:
   a) Desktop simulators
   b) Part-task trainers
   c) Low-fidelity Tower/Enroute/TRACON simulators
   d) Medium-fidelity Tower/Enroute/TRACON simulators
   e) High-fidelity Tower/Enroute/TRACON simulators
   f) Voice recognition/synthesizing
   g) Web-based trainers/Cloud-based trainers
   h) Virtual Reality
   i) Other (please expand on your answer and provide which technology you are referring to)

3) Which of the listed simulation technologies have you directly experienced, either through the use of the simulation technologies or involvement in the creation and delivery of the simulation technologies?
   ____
   ____

4) Which of the listed simulation technologies are used the most for ATC training, to the best of your knowledge?
____
____

5) Which of the listed simulation technologies do you feel has the most potential for reducing training costs and time and why?
____
____

6) Which of the listed simulation technologies do you feel has the most potential for increasing trainee learning and understanding of material and why?
____
____

The following questions pertain to the maintenance of all ATC simulation technologies currently being used for the purposes of ATC training. Please consider all simulation techniques you are familiar with and answer considering the average of all technologies.

7) In your experience, do you feel ATC training simulators are current and up-to-date with present technologies available in the field? Please explain why you feel this way.
____
____
____

8) How often are ATC training simulators' software updated or maintained while in use at a training facility? If you do not provide simulation technologies, please answer "Not Applicable".
   a) Not Applicable
   b) Every week
   c) Every month
   d) Every 2-3 months
   e) Every 6 months
   f) Once a year
   g) Once every two years
   h) Less than once every two years

9) How long, on average, does it take to CREATE an update for an ATC training simulator after a new technology is implemented? If you do not provide simulation technologies, please answer "Not Applicable".
   a) Not Applicable
   b) Less than 1 month

c) 1-3 months
d) 3-6 months
e) 6-12 month.
f) 12-18 months
g) 18-24 months
h) More than 24 months

10) How long, on average, does it take to INSTALL or IMPLEMENT an update on an ATC training simulator? If you do not provide simulation technologies, please answer “Not Applicable”.
a) Not Applicable
b) Less than 5 minutes
c) 5 – 10 minutes
d) 10-30 minutes
e) 30-60 minutes
f) Greater than 60 minutes

11) Will NextGen concepts need to be implemented into simulators in the near future? If so, which preparations being made to update all educational materials to include NextGen concepts?
a) No
b) Yes, ____
____
____

The following questions focus on how simulation affects the training process.
12) Do you feel simulation enhances the ATC training experience? If yes, in what ways?
a) No
b) Yes, ____
____
____

13) Do current ATC simulators provide personalized feedback and/or instruction depending on a student’s needs? If so, how?
a) No
b) Yes, ____
____
____

14) Which of the following concepts does simulation address in the ATC training process? Please consider all simulation technologies. Please circle all that apply.
a) Separation of aircraft using altitudes, vectors, and speeds
b) Miles-in-Trail (MIT) spacing

c) Application of aircraft sector transfer protocols
d) Emergency events and procedures
e) Weather events and procedures, such as reroutes and change requests
f) Understanding of airspace and airspace markers (NAVAIDS, airports, etc)
g) Traffic flow management (TFM) concepts
h) Clearance deliveries
i) Approach/Take-off procedures
j) Navigation guidance (in air and on ground)
k) Flight plan entry/aircraft entry (ERAM)
l) Multitasking skills, prioritizing, and maintaining situational awareness
m) Radar scanning techniques
n) Phraseology
o) Military aircraft protocols
p) Strip marking
q) Other, ____

15) Do you feel that incorporating virtual reality (VR) components, which allow students to actively participate in the simulated environment, will improve simulator transfer of learning? Please explain why you feel this way.

____
____
____

The following questions focus on the features available in simulation technologies and the simulation technologies themselves. Please answer while considering only current features and technologies (that you are aware of) and mention in which of the listed technologies the features are most common. Please consider the following features:

a) Scenario audio and video recording and playback
b) Starting/Stopping/Pausing of scenario
c) Ability to interact with human “pseudo-pilots” for scenario runs
d) Ability to interact with computer or voice recognition and synthesis automated “pseudo-pilots” for scenario runs
e) Control of speed adjustments for simulated aircraft
f) Ability to account for wind effects on simulated aircraft maneuvers
g) Ability for trainees to run scenarios without an instructor present
h) Ability to train a specific ATC skill
i) Ability to train a combination of ATC skills
j) Ability for trainees to train in a self-paced manner
k) Phraseology enforcement
l) Weather depictions in scenario run
m) Ability for trainees or trainers to increase or decrease scenario complexity

n) Ability to interact/link up/cooperate with other simulator stations
o) Ability to monitor all student screens from a central location in real-time
p) Eye tracking techniques
q) Ability to mimic and/or automate trainer prompts in response to trainee task failures or delays

16) Which of the listed features do current ATC simulation technologies include? Please elaborate on which features are most common in which technology.

____

____

____

17) Which of the listed features do you feel should be included in most, if not all, ATC training simulators?

____

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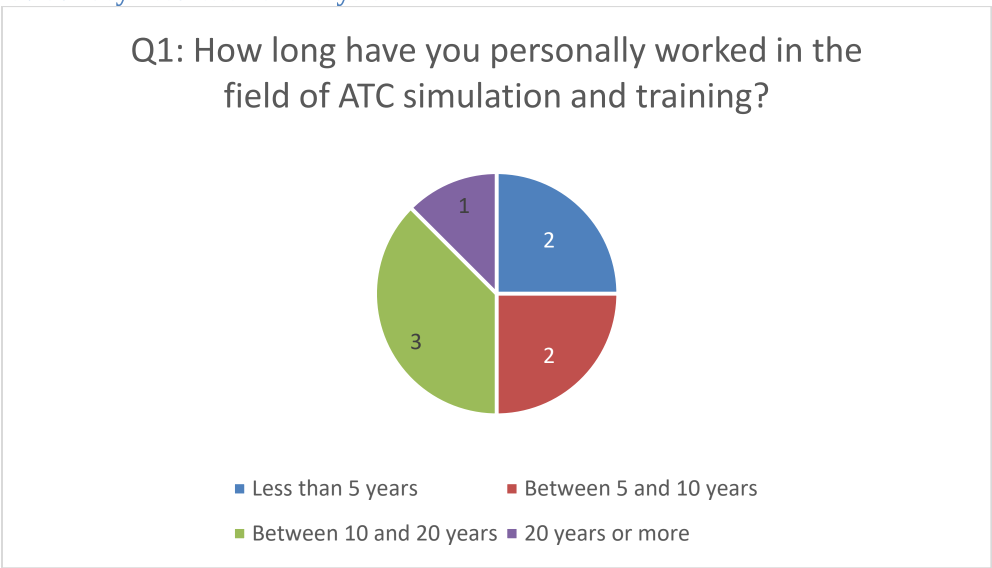
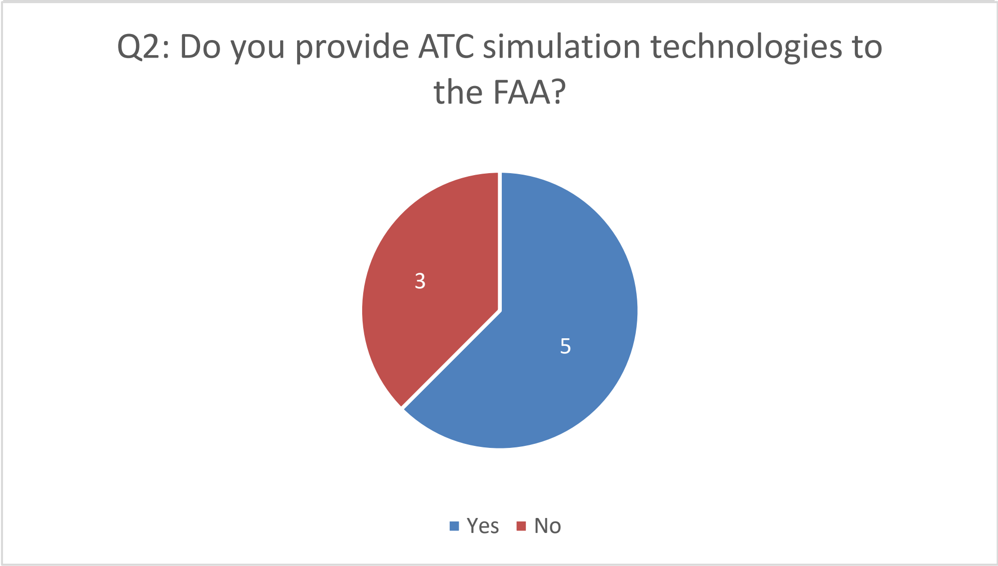
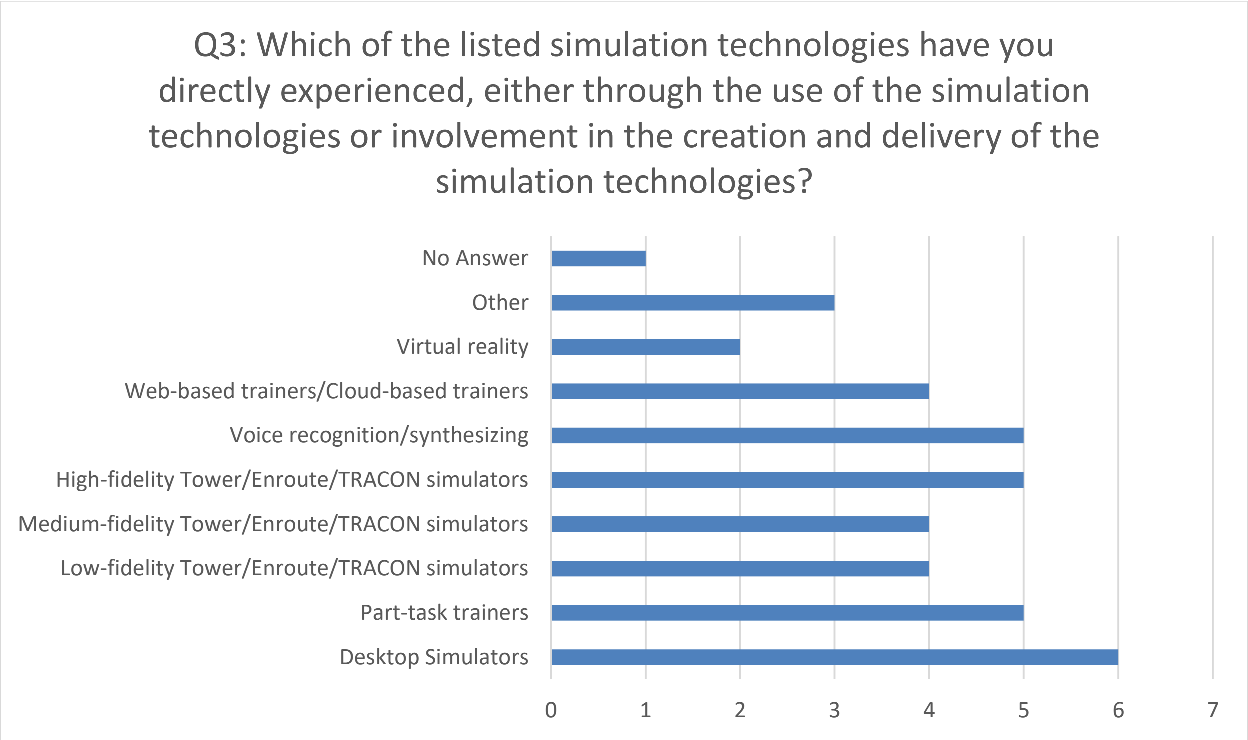
____

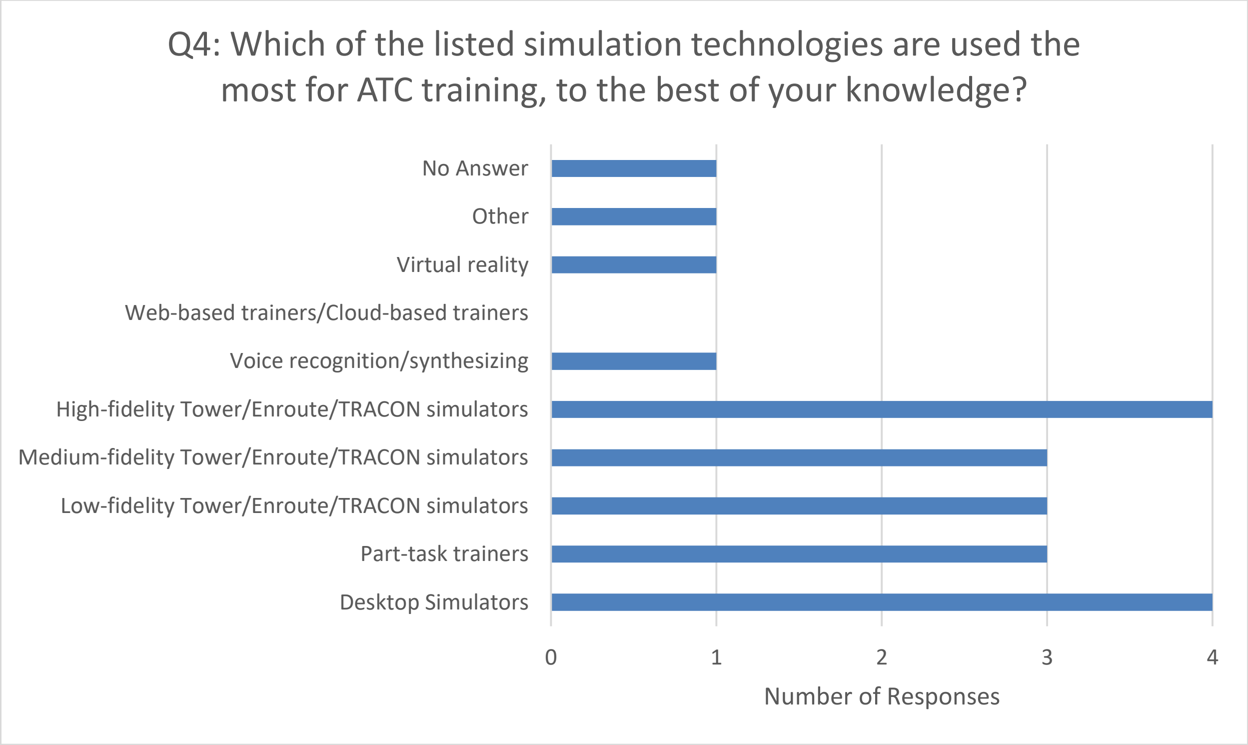
This concludes the survey. Thank you for your time and participation.

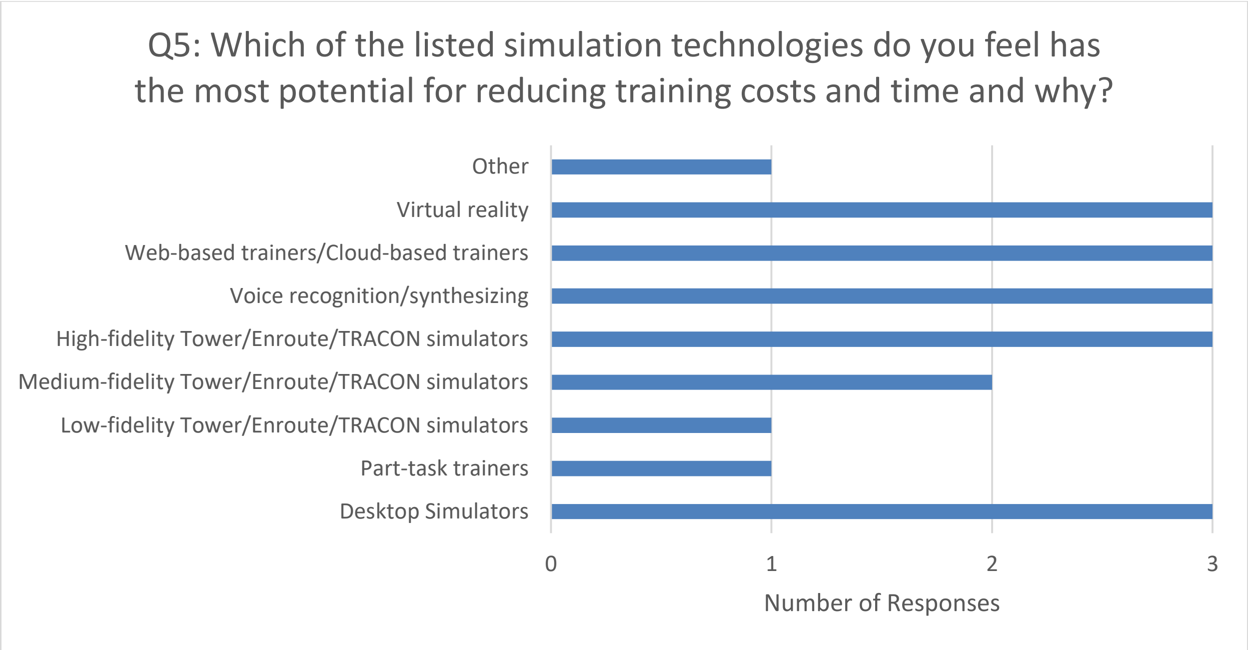
Appendix C: Survey results and analysis

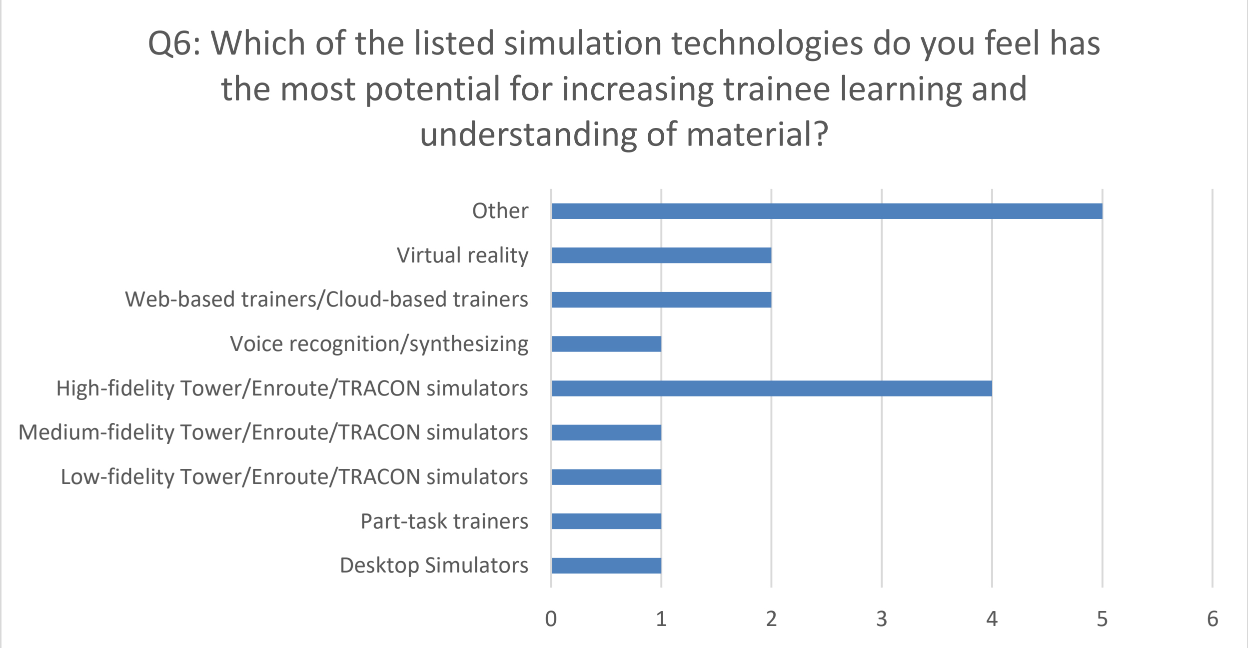


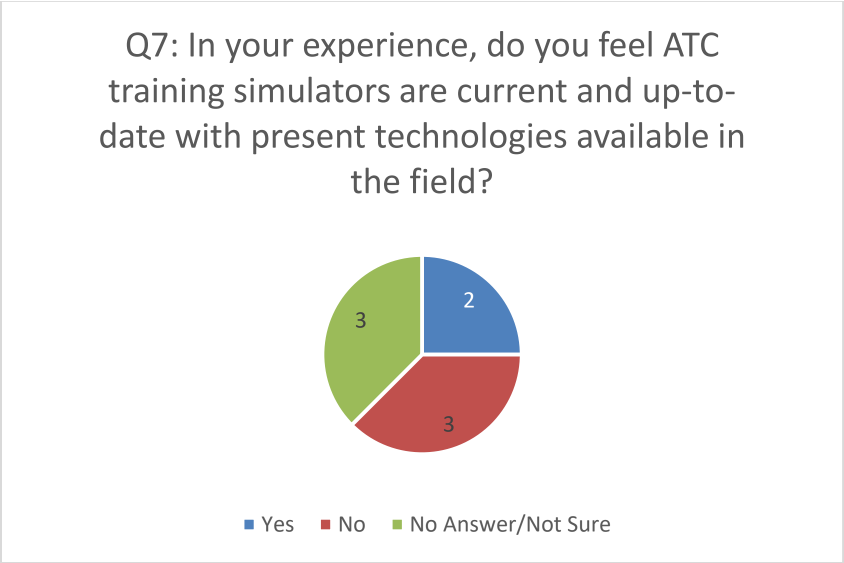


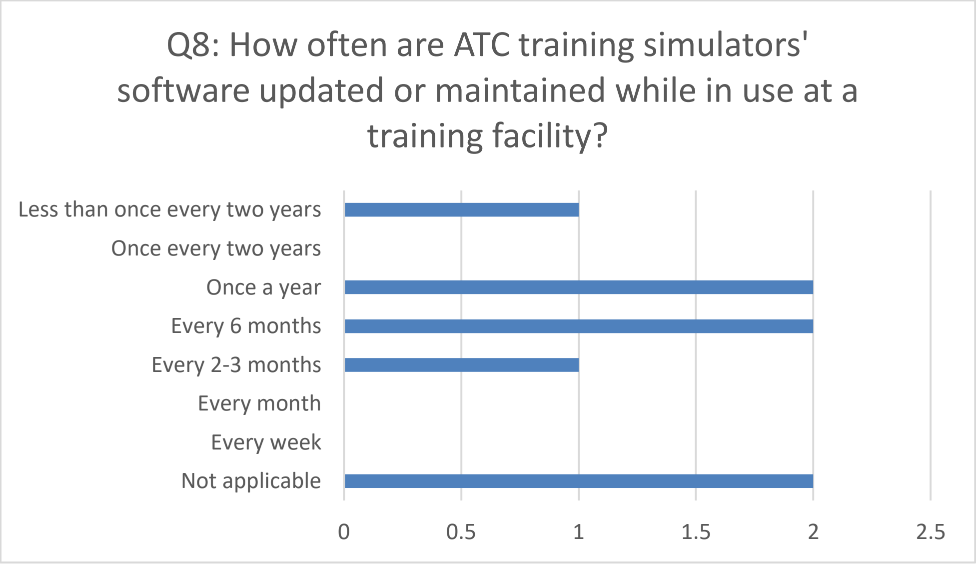

Q3: Which of the listed simulation technologies have you directly experienced, either through the use of the simulation technologies or involvement in the creation and delivery of the simulation technologies?
No Answer
Other
Virtual reality
Web-based trainers/Cloud-based trainers
Voice recognition/synthesizing
High-fidelity Tower/Enroute/TRACON simulators
Medium-fidelity Tower/Enroute/TRACON simulators
Low-fidelity Tower/Enroute/TRACON simulators
Part-task trainers
Desktop Simulators
0
1
2
3
4
5
6
7

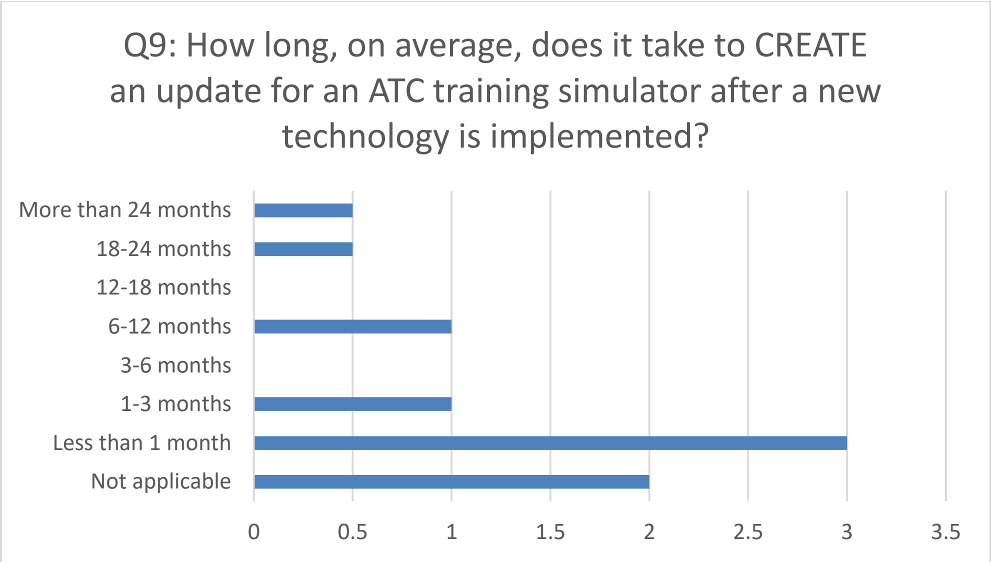

Q4: Which of the listed simulation technologies are used the most for ATC training, to the best of your knowledge?
No Answer
Other
Virtual reality
Web-based trainers/Cloud-based trainers
Voice recognition/synthesizing
High-fidelity Tower/Enroute/TRACON simulators
Medium-fidelity Tower/Enroute/TRACON simulators
Low-fidelity Tower/Enroute/TRACON simulators
Part-task trainers
Desktop Simulators
0
1
2
3
4
Number of Responses

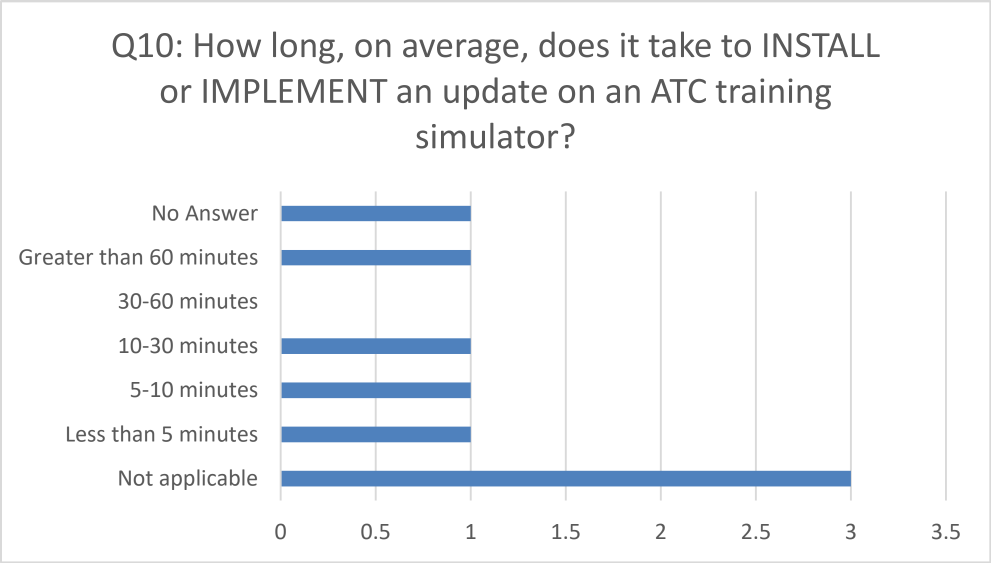

Q5: Which of the listed simulation technologies do you feel has the most potential for reducing training costs and time and why?
Other
Virtual reality
Web-based trainers/Cloud-based trainers
Voice recognition/synthesizing
High-fidelity Tower/Enroute/TRACON simulators
Medium-fidelity Tower/Enroute/TRACON simulators
Low-fidelity Tower/Enroute/TRACON simulators
Part-task trainers
Desktop Simulators
0
1
2
3
Number of Responses


Q6: Which of the listed simulation technologies do you feel has the most potential for increasing trainee learning and understanding of material?
Other
Virtual reality
Web-based trainers/Cloud-based trainers
Voice recognition/synthesizing
High-fidelity Tower/Enroute/TRACON simulators
Medium-fidelity Tower/Enroute/TRACON simulators
Low-fidelity Tower/Enroute/TRACON simulators
Part-task trainers
Desktop Simulators
0
1
2
3
4
5
6

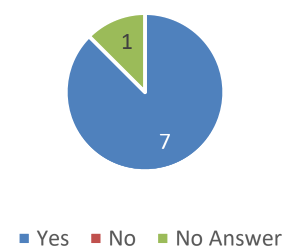

Q7: In your experience, do you feel ATC training simulators are current and up-to-date with present technologies available in the field?
2
3
3
Yes
No
No Answer/Not Sure


Q8: How often are ATC training simulators' software updated or maintained while in use at a training facility?
Less than once every two years
Once every two years
Once a year
Every 6 months
Every 2-3 months
Every month
Every week
Not applicable
0
0.5
1
1.5
2
2.5

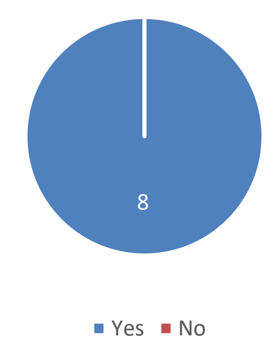

Q9: How long, on average, does it take to CREATE an update for an ATC training simulator after a new technology is implemented?
More than 24 months
18-24 months
12-18 months
6-12 months
3-6 months
1-3 months
Less than 1 month
Not applicable
0
0.5
1
1.5
2
2.5
3
3.5

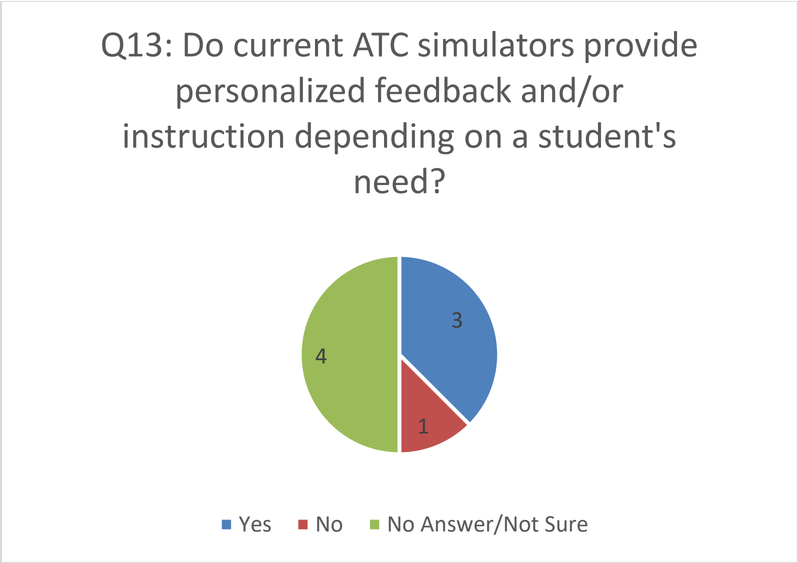

Q10: How long, on average, does it take to INSTALL or IMPLEMENT an update on an ATC training simulator?
No Answer
Greater than 60 minutes
30-60 minutes
10-30 minutes
5-10 minutes
Less than 5 minutes
Not applicable
0
0.5
1
1.5
2
2.5
3
3.5

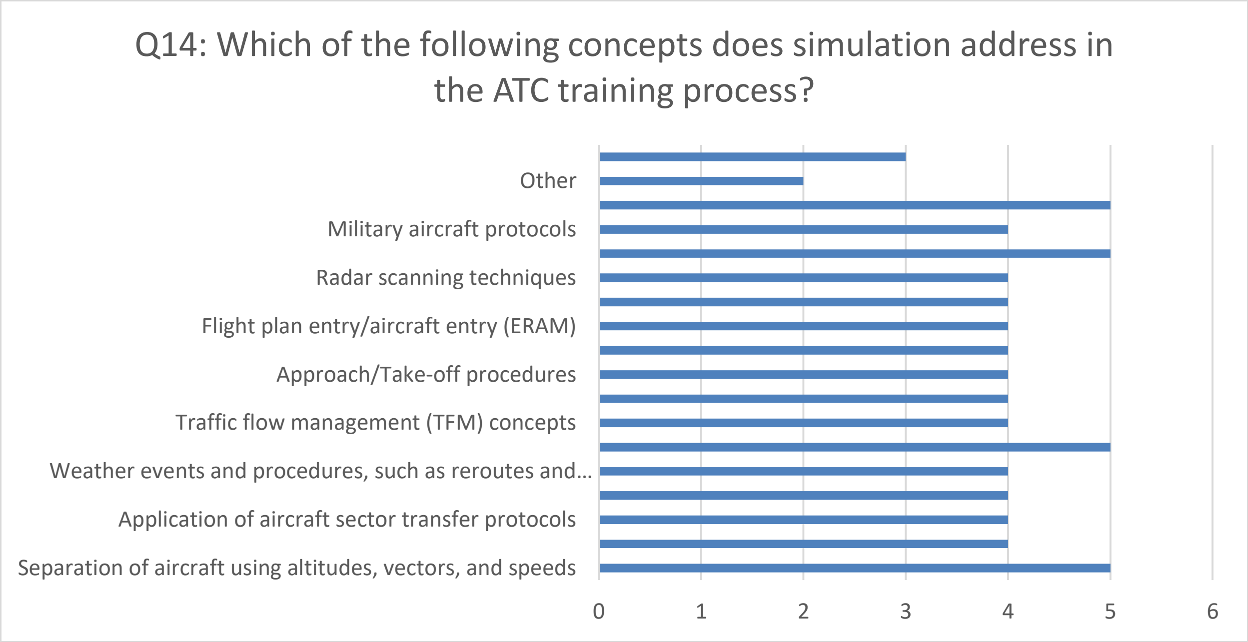
Q11: Will NextGen concepts need to be implemented into simulators in the near future? If so, are preparations being made to update all educational materials to include NextGen concepts?



Q12: Do you feel simulation enhances the ATC training experience?




Q13: Do current ATC simulators provide personalized feedback and/or instruction depending on a student's need?
3
1
4
Yes
No
No Answer/Not Sure


Q14: Which of the following concepts does simulation address in the ATC training process?
Other
Military aircraft protocols
Radar scanning techniques
Flight plan entry/aircraft entry (ERAM)
Approach/Take-off procedures
Traffic flow management (TFM) concepts
Weather events and procedures, such as reroutes and...
Application of aircraft sector transfer protocols
Separation of aircraft using altitudes, vectors, and speeds
0
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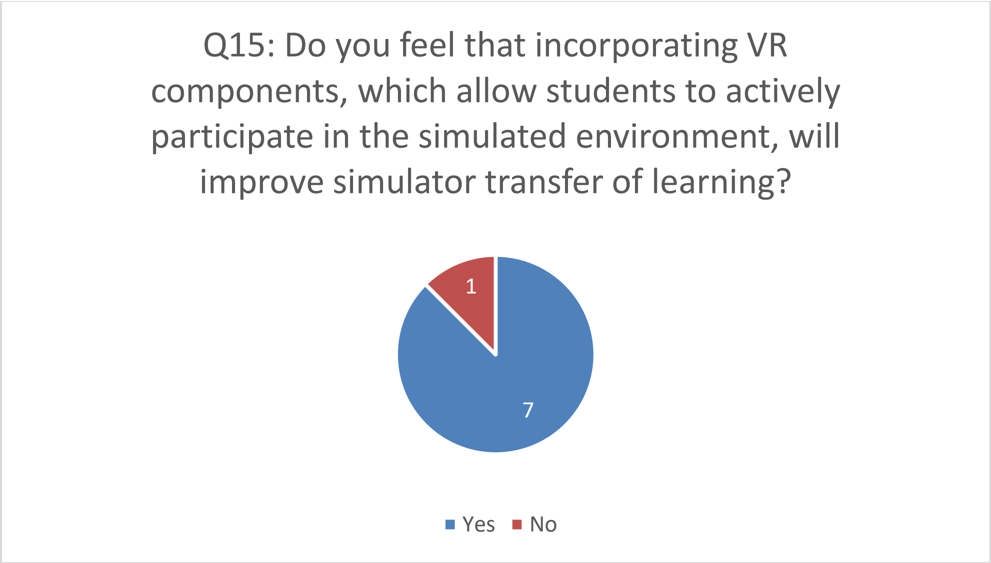
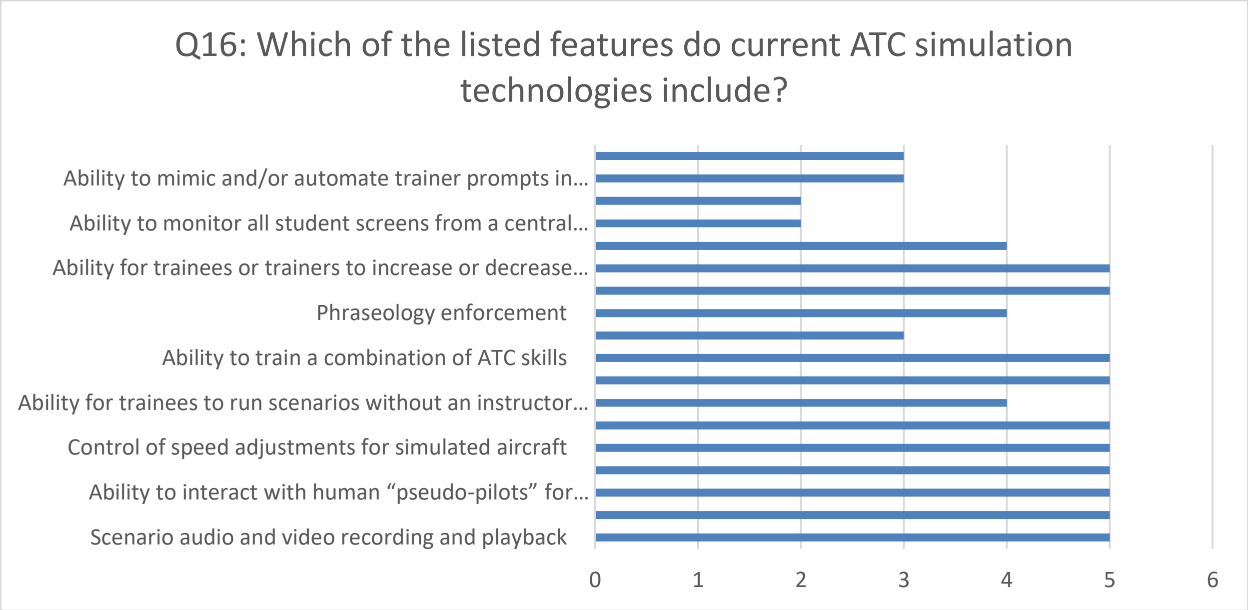
4
5
6


Q15: Do you feel that incorporating VR components, which allow students to actively participate in the simulated environment, will improve simulator transfer of learning?
1
7
Yes
No


Q16: Which of the listed features do current ATC simulation technologies include?
Ability to mimic and/or automate trainer prompts in...
Ability to monitor all student screens from a central...
Ability for trainees or trainers to increase or decrease...
Phraseology enforcement
Ability to train a combination of ATC skills
Ability for trainees to run scenarios without an instructor...
Control of speed adjustments for simulated aircraft
Ability to interact with human “pseudo-pilots” for...
Scenario audio and video recording and playback
0
1
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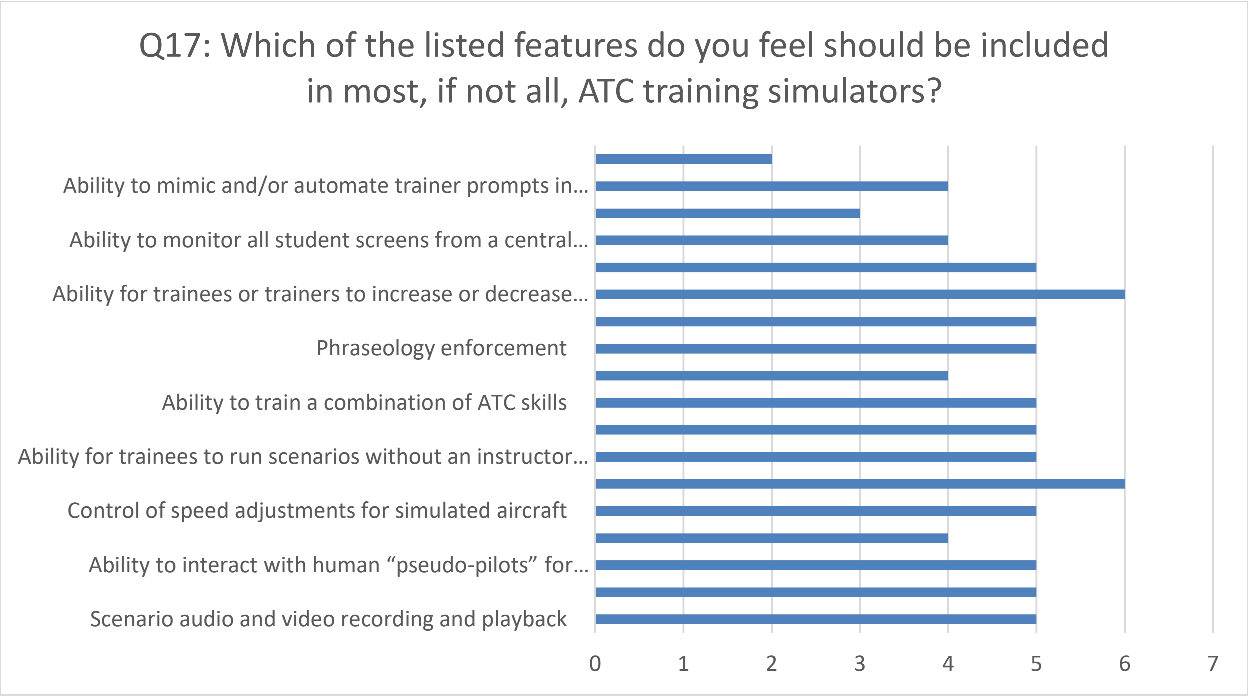
3
4
5
6


Q17: Which of the listed features do you feel should be included in most, if not all, ATC training simulators?
Ability to mimic and/or automate trainer prompts in…
Ability to monitor all student screens from a central…
Ability for trainees or trainers to increase or decrease…
Phraseology enforcement
Ability to train a combination of ATC skills
Ability for trainees to run scenarios without an instructor…
Control of speed adjustments for simulated aircraft
Ability to interact with human “pseudo-pilots” for…
Scenario audio and video recording and playback
0
1
2
3
4
5
6
7

Appendix D: Simulation Use ROI

From the literature survey and analysis of industry survey responses, the following improvement areas were analyzed, and benefits and potential ROI were concluded:

1. **Pseudo-pilots**
   a. Using simulation for pseudo-pilots instead of a trainee or instructor would have multiple benefits.
      i. Training can be accomplished with only one person (the ATC trainee) instead of two (the ATC trainee and a pseudo-pilot partner). This allows for longer training times for each student as students do not need to take turns acting as the pseudo-pilot. In addition, students have more freedom to train on their own time as they again do not need to schedule time with a partner.
      ii. Training would be more consistent across students as one human factor to the training scenario is eliminated. Only the trainee's actions will affect the scenario outcome. In a traditional simulator, a mistake from the pseudo-pilot can cause scenario failures.
      iii. Instructors can focus more on the ATC trainees' actions and will not have to split time between questions from pseudo-pilots.
      iv. Trainee phraseology can be more strictly enforced as the scenario will not respond to incorrect phraseology. This can potentially reduce overall training time as it requires students to really memorize and understand the phraseology before complicating it with additional scenario requirements, such as flow control and miles-in-trail spacing.

2. **Virtual Reality for Hands-On Modules**
   a. Instead of only seeing the planes from the screen, students could potentially reach out and interact with the tower scenario. This would be a vital training style for students who rely heavily on touch and interaction to learn, a common skill among ATC trainees.
   b. VR could be used in some of the following example topics:
      i. Aircraft identification
      ii. Understanding traffic flow management
      iii. Understanding miles-in-trail separation
      iv. Aircraft/airport safety modules
      v. Aircraft maintenance topics
   c. In addition, due to the growing availability of smartphone-accessed VR, it is possible that students could potentially train on their own time if VR modules were made available via the classroom LMS.
   d. This technology would be more viable in future applications after the technology matures more.

3. **Allowing students to learn at their own pace**
   a. Less instructor dependence
      i. Smarter simulation can reduce the currently high dependency on instructors. Simulators should include the ability to pause, rewind, speed up, record, share, and replay scenario sessions in high quality. This way a student can review previous

scenarios to learn from mistakes. In addition, a student could record a scenario and review it with an instructor at a later date. This would allow students to train more individually.

ii. Lessening instructor dependence would allow for larger class sizes and/or shorter training times. Allowing students to use hands-on training more often will greatly reduce overall training times.

iii. Utilizing technologies such as eye tracking and voice recognition can personalize scenario feedback to each student, providing each individual student with a personalized report with their specific strengths and weaknesses explained. This would greatly reduce the workload of already busy instructors and would increase feedback usefulness to each student.

iv. Oftentimes, an instructor must prompt a trainee to perform a desired action if the trainee is incorrectly analyzing a scenario. This requires constant interaction between an instructor and the trainee/scenario. The ability to mimic and/or automate trainer prompts in response to trainee task failures or delays could greatly reduce instructor interactions and can greatly enhance the trainee's learning experience. For example, if a trainee fails to maintain proper miles-in-trail spacing, the simulator itself could notify the student that they are spacing aircraft improperly and prompt the student for a corrective action. This corrects trainee actions in real-time, reducing the number of mistakes a trainee can "get away with" and creating a more consistent training session.

b. Web-based training

i. Online learning tools such as web-based training, iPad-based training, or stand-alone training can all reduce the reliance on long lectures to teach initial training materials, such as regulations and basic procedures.

ii. Online tools allow students to learn at their own pace and in a manner that suits them best.

iii. Students can use online training tools to complete learning activities or collaborate on group activities.

iv. This training also provides more consistent access to resources outside the classroom, which can be very important for the retention of knowledge.

Cost-Benefit Analysis

After careful analysis of the literature review suggestions, interview responses, and survey responses and recommendations, five potential improvement areas were selected for further analysis: (1) the replacement of live pseudo-pilots with simulated pseudo-pilots, (2) the use of VR, (3) updating current simulation systems' features, (4) reducing the dependence on instructors during training, and (5) utilizing web-based training solutions. These improvement areas were chosen after considering a variety of factors; however, many were selected due to popularity among responses, feasibility of implementation, and potential for improving the current training process.

To better compare these five improvement areas, a cost-benefit analysis was conducted. Each area was examined, and potential benefits and costs/disadvantages were identified from the literature review, interview responses, and survey responses. Each benefit was given a benefit value between 1 and 10, with 1 indicating the benefit is of low value to improving the training process, and 10 indicating the benefit is of high value to improving the training process. These values were subjectively chosen and were given based off all previously-gained knowledge and in consideration to the other listed benefits. Each cost was given a cost value between 1 and 10, with 1 indicating the cost is of low value to improving the training process, and 10 indicating the cost is of high value to improving the training process. These values were also subjectively chosen. In addition to the cost value, costs were also given a time cost, or cost-to-implement, value between 0 and 10. This value takes into consideration how long it would take to implement an identified cost and/or how expensive the cost could be to the organization implementing the change. A time cost of 0 is given when a cost does not require a change to be implemented, such as when a cost is a disadvantage of the improvement area and not a change in technology. A time cost of 10 is given when an identified cost would require substantial changes to the current training process or training technologies. After all benefits and costs were assigned their corresponding values, an overall estimated value/feasibility value was determined by dividing the sum of all benefit values by the sum of all cost values added to the sum of all time cost values. The overall estimated value creates a comparable value by which all five improvement areas can be ordered by feasibility, while also accounting for all costs and benefits. Finally, all five improvement areas were given an overall recommendation rank based off the overall estimated value.

Table 1 Cost-benefit analysis overview

Potential Improvement Area	Overall Estimated Value/Feasibility	Overall Recommendation Rank
Simulated pseudo-pilots	-6	4
Virtual reality	-16	5
Updated simulation systems	-4	3
Reducing instructor dependence during training	22	1
Web-based training solutions	16	2

In the interest of length, only the overall estimated value and overall recommendation rank are shown here, as shown in Table 1. An overall estimated value less than 0 indicates a potential improvement area evaluated with more costs than benefits. As a result, these improvement areas would not be as easy, cost-effective, or feasible to implement. An overall estimated value greater than 0 indicates a potential improvement area evaluated with more benefits than costs and would therefore be a better investment of time and/or resources. Simulated pseudo-pilots and VR each had eight identified benefits and five identified costs. Updated simulation systems had five identified benefits and four identified costs. Reducing instructor dependence during training had five identified benefits and two identified costs. Finally, web-based training solutions had ten identified benefits and three identified costs. As shown in Table 1, reducing instructor dependence during training was identified as the most feasible improvement area. This was due primarily to a multitude of potential benefits with very low implementation costs. This improvement area would focus primarily on improving the capabilities of simulation systems (with separate costs and benefits identified under updated simulation systems) and improving the teaching process in ATC training programs.

Recommendations

After considering the cost-benefit analysis results, it is recommended that the top three potential improvement areas be implemented. First, a focus should be made to reduce the dependence on instructors during training. A reduction on instructor dependence allows for larger class sizes and would require fewer instructors overall. In addition, instructors would have more opportunity to increase the quality and frequency of feedback during a training session as the number of tasks an instructor must manage could be significantly reduced with the aid of technologies such as voice recognition and personalized student feedback. However, one downside of reducing instructor dependence would be the need to update current simulator features to support this change, leading to implementation and/or replacement costs. Second, web-based training technologies should be utilized more heavily during the training process. These technologies can reduce the reliance on long, in-person lectures, allow students to learn at their own pace, allow materials to be more easily accessible, and can allow students to prepare for in-person training on their own time. However, some disadvantages include the need to create and manage new web-based courses and potential security issues as training materials would be hosted online. Third, current simulation systems should be updated to include additional features deemed beneficial to ATC training. These features include the ability to pause, rewind, record, share, and replay scenario sessions, the ability to provide personalized training feedback for each student, and the ability to display simulated trainer prompts that can notify trainees when an action that must occur was done incorrectly or missed completely. Some disadvantages include the potentially large cost to implement these new features and higher maintenance costs. While the remaining two improvement areas are still being considered potential improvement areas, they are not being recommended at this time due to high implementation costs. In addition, these technologies must first mature before they can be deemed feasible for use in ATC training. However, it is recommended that these potential improvement areas be considered again in future studies.

Appendix E: Recommendations for Keeping Real-World Devices and Training Simulators in Sync

As technology matures, it also develops rapidly. This rapid development makes it more and more difficult to maintain current simulator systems while incorporating new technologies and improvements. This is particularly seen in the aviation domain and even specifically within the air traffic control (ATC) domain. As new technologies are developed for use in ATC facilities, simulation systems at the Federal Aviation Administration (FAA) Academy become more and more outdated unless they are continuously updated and maintained.

The FAA ATC training process is currently divided into two main segments: training at the FAA Academy and training at an on-site facility. The FAA Academy utilizes a variety of courses and simulation components to deliver realistic control scenarios in a safe manner. After completing training at the FAA Academy, a student moves to his or her assigned facility and continues training until finally being fully certified as a Certified Professional Controller (CPC). This division of training results in two pools of simulators: FAA Academy simulators and on-site facility simulators. In addition to the on-site facility simulators, which allow developmentals to train on the site's specific airspace and procedures, facilities also contain the actual ATC equipment used to control live air traffic. As new technology is developed, it is often deployed in facilities first, either through the simulators or the actual control equipment. However, these new updates are not well-reflected in the FAA Academy. As a result, developmentals moving from the FAA Academy to an on-site facility may suffer from technology shock, where the technology they trained on and originally learned ATC actions for may differ slightly or significantly from the technology they are required to use in the field. In addition to causing discomfort to the developmental, this difference in training technologies and technologies seen in the field can result in longer training times as students are required to adjust or even relearn certain maneuvers and procedures on the new equipment. This can lead to increased costs and hinder the training program as a whole.

Updating an ATC simulator requires a large array of professionals and a large communication network. A major change in the systems or features being utilized in ATC would require a large change in how a simulator represents that system. When this new technology is available, a simulator vendor must be made aware of the change in technology. This vendor must then update or redesign the simulator to reflect the change. Once updated, the simulator update can be distributed to the FAA Academy, where a team of technology professionals installs the update. After the update is complete, instructors using the simulator must be made aware of the change and be formally instructed on how to use the new technology. This process of communication between the FAA Academy and simulator vendors is not defined for simulator updates. As a result, the responsibility for designing and creating updates to simulators often falls on the vendors themselves. Unless the vendor updates the simulator to match current technology and subsequently reaches out to the FAA Academy with the update, the update is often never incorporated at the FAA Academy. However, these updates may be incorporated into facility simulators, resulting in the differences seen between FAA Academy and on-site facility technologies.

In an effort to reduce these differences between ATC Academy training simulators and simulators and equipment being used in the field, the FAA Academy Review Panel (FARP) is being suggested. The main goal of FARP is to increase and standardize communication between the FAA, the FAA Academy, and facilities in regards to equipment, simulation technologies, and simulator updates. FARP will be a subdivision of the AMA-500 branch of the FAA Academy, which is responsible for all ATC-related training at the FAA Academy, and consists of an organization of managers and teams who are responsible for different portions of the technology update process. Each manager is responsible for organizing his or her portion of the update process. Some example FARP positions could include:

1) an IT manager, who is responsible for overseeing the current simulator implementations at the FAA Academy,

2) a vendor manager, who is responsible for communicating with the FAA Academy simulator vendors regarding simulator updates and maintenance schedules,
3) a research manager, who is responsible for maintaining up-to-date information regarding the development of new technologies, such as the NextGen program, which may influence training simulators in the future, and
4) a curriculum manager, who is responsible for maintaining a course curriculum that is up-to-date with any new technologies that have been incorporated into the training simulators.

Each manager is required to maintain frequent communication with other managers and is focused on organizing and standardizing communication between all facets of the simulator update process. Through FARP, the simulator update process at the FAA Academy can become proactive instead of reactive like it is today. As a new technology is researched for use in the ATC domain, FARP is responsible for following the lifecycle of this new technology and planning how to appropriately incorporate the new technology into the current training program. As a result, the new technologies can be incorporated as soon as possible after they are released for use at on-site facilities.

In addition to staying up-to-date on current simulator technologies, FARP is also responsible for ensuring the current simulators being used for ATC training at the FAA Academy are up-to-date and reflect the current state of the ATC field. This includes updating the course curriculum at the FAA Academy. FARP will maintain frequent communications with the AJI division to ensure course curriculum content reflects any new technologies and/or updates and these technologies are being used properly. In addition, FARP is responsible for ensuring instructors are educated on using any new technologies.

As FARP consists of a large span of responsibilities, a technology review process is being suggested, shown in Figure 1. This process is meant to standardize and simplify the simulator update process and provide a well-defined solution for incorporating new simulator technologies at the FAA Academy. Following this process, FARP meets quarterly to discuss any new technologies being developed and to determine if these technologies will have an impact on the current simulator implementations. This quarterly meeting also provides a formal means of communication between all managers in FARP. If a new technology is identified, FARP will create a Technology Implementation Plan (TIP). The progress of the TIP is reviewed every 2-4 weeks, or as determined by FARP during the quarterly meeting. A TIP defines how the new technology will be incorporated into the FAA Academy simulators and the timeline for the incorporation. Any number of TIPs can occur at any one time, as there should be one TIP for every new simulator update or technology. Different vendors may require different TIPs, and it is the responsibility of FARP to maintain the communication necessary to successfully complete all active TIPs.

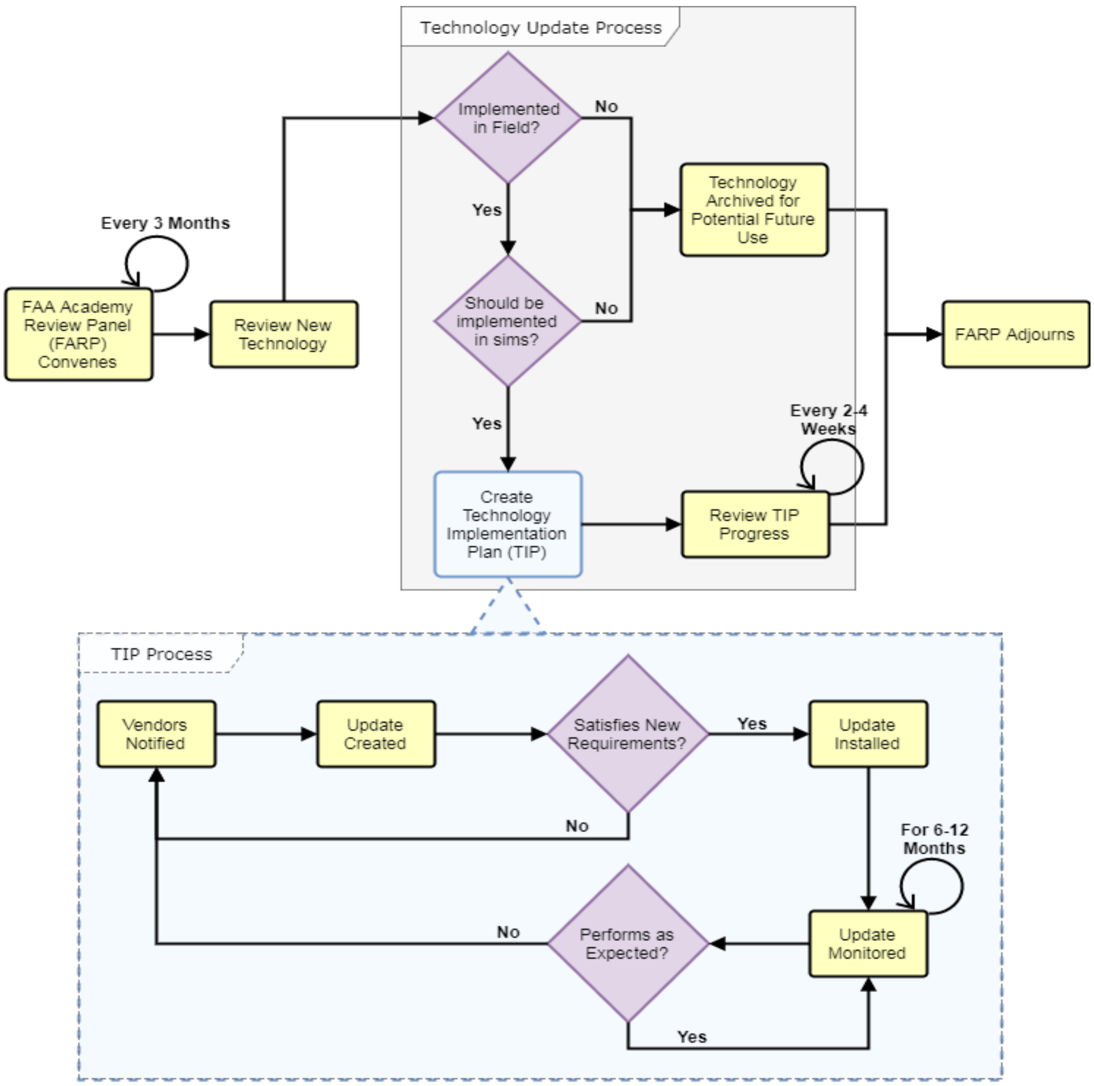


Figure 1: FAA Academy Proposed Technology Review Process

Each TIP can vary greatly depending on the significance of the technology and the difficulty of incorporation. However, every TIP will include four main steps: (1) notification of vendors, (2) creation of simulator update, (3) installation of simulation update, and (4) monitoring of simulation update. After a new technology is identified as needing to be incorporated into the FAA Academy simulators, the simulation vendors that are affected by the change are notified. Each vendor manager is responsible for communicating between the simulation vendor and the FAA Academy to ensure that the technology is properly incorporated. Next, the simulation vendor is given a specified length of time to create the simulator update. The length of time specified will depend on the significance and complexity of the technology update. Once created, the update will be installed or incorporated into the FAA Academy simulators. If the update cannot be installed or incorporated or does not perform as desired, the vendor will be notified, and the creation process will repeat. If the update is successfully installed or incorporated, the update is then monitored for a specified period of time. During the monitoring period, the simulator update is verified for accuracy. If any problems occur, such as incorrect behavior or system slowdowns, the vendor is notified and the creation process repeats. When the monitoring period is complete, the update is considered fully incorporated and will no longer be actively monitored or reviewed.

Current and potential vendors of air traffic control simulation technology for the FAA Academy were spoken to and surveyed. Once identified, these vendors can be contacted by FARP and serve as points of communication for both new technologies and how to implement them. Table 2 provides an overview of identified vendors, their areas of application, and how the technologies they provide may be used at the FAA Academy.

Table 2: List of ATC Technology Vendors and their Areas of Application

Vendor	Areas of Application	Uses
TetraTech	Communication, Navigation, NextGen	NextGen
Frasca	Aircraft simulators	None
Northrup Grumman	Desktop simulators, Curriculum development	Part-task training, curriculum development
UFA, Inc.	ATC Training Sims (tower, cloud-based, web-based, voice recognition)	Training sims, web-based applications
CSSI	Technical Operations	Technical Operations
Metacraft	SimSuite ATC Training Simulation Suite	Incorporation of new technologies
AVT Simulation	Flight simulations	Training requirements process, curriculum development
Heartwood	No information provided	None
CSD	Electronic learning management systems (eLMS)	Web-based training programs

Through the creation of a new review panel and the implementation of a technology review process, a proactive simulator and course curriculum update process can be achieved at the FAA Academy. Increased communication between the many facets of simulation maintenance can be better regulated and standardized, reducing gaps in communication and missed technological improvements. In addition, by making simulator updates a priority of FARP, simulator updates and improving technology will move to the forefront of the FAA Academy's improvement process. Not only will these suggestions reduce developmental technology shock when moving to a facility, they can also reduce costs and training times, allowing a larger number of developmentals to become fully certified CPCs in a shorter amount of time.

Appendix F: AMA-500 Courses Analysis Report

1. Introduction

Simulation is used throughout the Air Traffic Control (ATC) training process and is the most important method currently available to provide hands-on experience to students. Hence, it becomes important to ensure that simulation is used when it is advantageous and that simulators are updated with current technologies. To understand the importance of simulation technologies used in FAA Academy courses, a review of existing courses was conducted to generate a report on simulation-based ATC training (simulation elements, fidelity, labs, exam, instructors, hours, course duration, course content type, training, proposed area of simulation, and other remarks) used by the Academy for FAA training purposes. This report presents the analysis results of the FAA Academy AMA-500 courses.

2. Purpose

Within the ATC domain, simulators are essential for training in order to adequately prepare controllers for their tasks at their facilities. The FAA Academy makes use of scenario-oriented training modules to teach trainees how to respond to situations they encounter. While it is not possible to make such training exhaustive as scenarios still need to be designed by instructors, it helps them get familiar with different tools and technologies, and with the critical thinking process which is essential in a fast-paced, high-risk environment like that experienced by controllers. The research and analysis of AMA-500 courses revealed that the training is predominantly accomplished via traditional classroom-based instructions, with complementing low-, medium-, and high-fidelity simulation labs. Recommendations have been made on proposed areas of simulation for FAA ATC training courses in order to overcome the existing problems and update the current courses that can improve the simulation training process.

3. Process

A thorough analysis and review of AMA-500 courses was conducted. Various documents and contents that are available to researchers online have been uncovered and analyzed in order to get an in-depth understanding of FAA courses.

3.1 Division of courses

In order to understand the role of simulation in Academy courses, an analysis of the objectives and curricula of all classes was deemed necessary. As the catalog had 348 courses listed, it was determined that different methods of analysis would be required depending on the course. For the purpose of this project, which aims to optimize the use of simulation in ATC training, the categories chosen for division of courses were: 1) courses that certainly use simulation for a majority of training (Have Simulation), 2) courses that may use simulation for parts of training (May Have Simulation), and 3) courses that do not involve simulation as part of training (Have No Simulation).

A list of all courses and their descriptions was obtained from the AJI curriculum division. Based on their descriptions, the courses were deemed to belong to one of the three categories. The "may have simulation" category is thus a little uncertain as this qualification was assigned before the course material was analyzed. In the authors' view, courses that either had some form of practical training or could conceivably use it were added to this category. Others were assigned based on their descriptions and the use of keywords such as "lab training" (Have Sim), "use of simulator" (Have Sim), "practical work" (May Have Sim), "on a computer" (May Have Sim), "classroom training" (No Sim) or other lack of mention of activities other than classroom training (No Sim). This list may have some outliers in the wrong category as, once again, this was done to better categorize findings prior to the analysis process.

The number of courses found in each category have been shown in Figure 2.

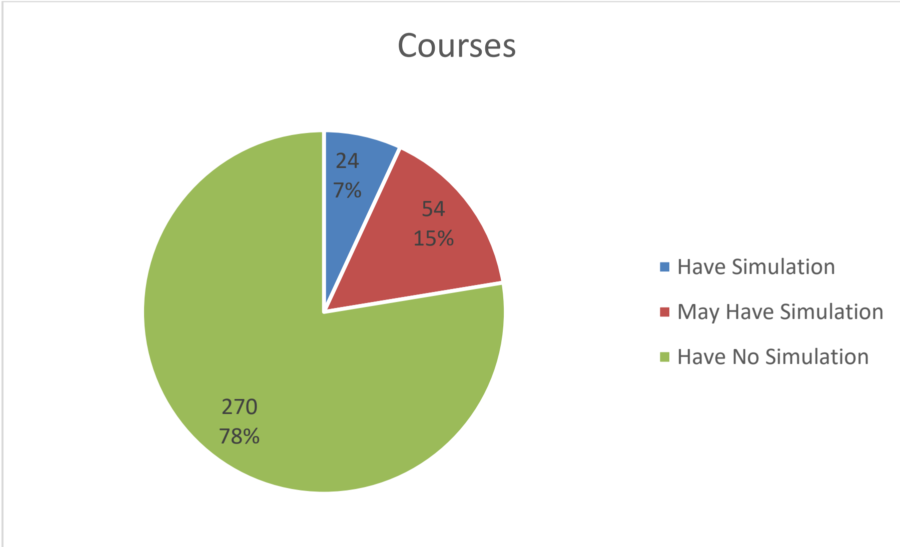


Figure 2: Division of 348 courses into sub-types

3.2 Analysis of courses

Once the courses were separated, analysis had to be performed for courses in each category. Due to time limitations, it was determined that priority would be given for analysis of courses that already utilize some form of simulation, and that recommendations would be made for the courses that could potentially have additional simulation components. Thus, only the first two categories of courses identified were analyzed.

In order to thoroughly investigate the current use of simulation technologies, several documents in the course material were analyzed where available. These were: course design guide, student's guide, instructor's guide, course report, instructional materials, lecture slides, handouts, lab guides, course memo, and maintenance files. Unfortunately, this material was not available for all courses. Analysis was only possible for courses where it was present, and this number can be seen in Figure 3.

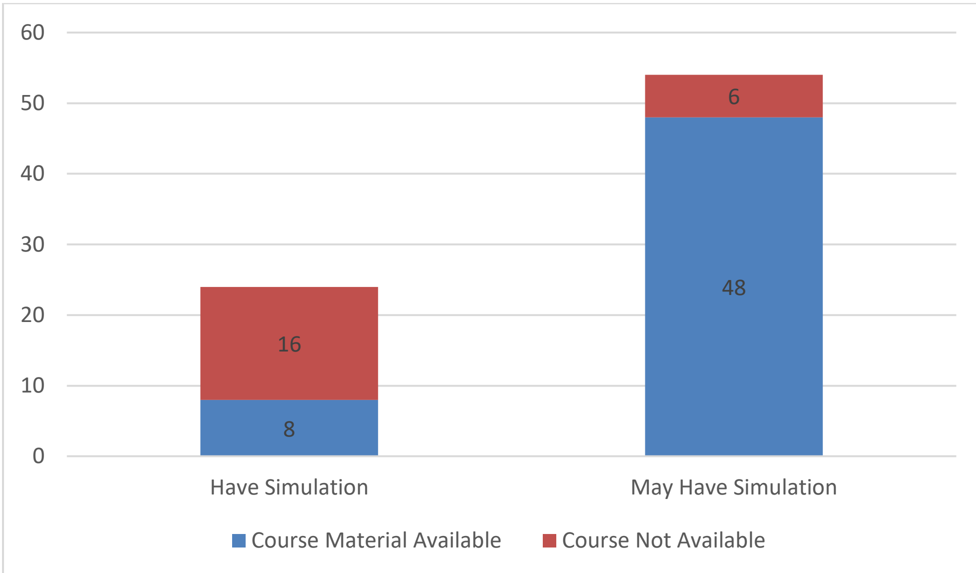


Figure 3: Courses for which material was available from the Academy

4. Analysis

The analysis of the FAA course was carried out by reviewing all courses available online. The analysis of AMA-500 ATC training program courses shows that it uses classroom instruction to introduce basic concepts, laboratory activities for skill-building and part-task training, and simulation-based training which closely replicates the control room environment. The FAA Academy multiple technologies to deliver ATC training, which are based on the class type. For example, Academy classrooms training was designed to allow developmental controllers to learn through presentation slides (e.g. power point slides) and lesson plans from their desks. Projectors and smartboards are also used for viewing presentation slides. Developmentals also use low- and medium-fidelity simulation such as tabletop and 2D simulators in the classroom, which is a stepping stone to high-fidelity Tower Simulation System (TSS) simulators. En Route developmentals have several e-learning modules which are similar to computer-based instruction (CBI) methods. The FAA academy ATC training courses have three major flight control components: Tower, TRACON and En Route. The Terminal track covers the first two and En Route track covers the third component. The developmental ATCs work with one of the two tracks, which is usually based on the current need and previous skills. On completion of each track, developmentals are assessed on the basis of how well they perform in both classroom and simulations.

The courses analysis task was divided into the sub-categories listed in Table 3.

Table 3: Metrics for Course Analysis

#	Sub-category	Metric	Definition
1	Simulation Elements	Yes/No	Check whether any simulation elements are present in the course.
2	Fidelity	Low/Medium/High	Check whether the simulation elements have low, medium or high fidelity.
3	Simulation Laboratory	Yes/No	Check whether any simulation lab activities are present in the course.
4	Simulation Assessment	Yes/No	Check whether any simulation assessments are present in the course.

5	Simulation Instructors	Yes/No	Check whether any instructors are required for the simulation component of the course.
6	Simulation Training Hours	<Number>	List the number of simulation training hours in the course.
7	Course Duration	<Number>	List the total number of days/hours in the course.
8	Course Content Type	<Material Types>	List the course materials used in analyzing the course.
9	Additional Remarks	<Notes>	Any additional comments or remarks on the analysis of the course.

4.1 Courses that "Have Simulation"

The courses listed in Table 4 were identified as having simulation components.

Table 4: All courses identified as having simulation components ("Have Simulation")

#	Course #	Course Name
1	50046	Initial Tower Cab Training
2	50053	Targets Application Software User Training
3	55039	(55039) PRECISION RUNWAY MONITOR (PRM)
4	55086	Remote Arts Color Display (R-ACD) For Air Traffic
5	55087	URET Training For Air Traffic Control Specialists
6	55402	STARS FSL/ESL FOR CERTIFIED PROFESSIONAL CONTROLLERS
7	57096	ASR-11 Air Traffic Training
8	59028	Ocean 21 Air Traffic Operator Training
9	59033	(59033) OCEAN 21 FOR AIR TRAFFIC SUPPORT SPECIALISTS
10	59035	Ocean 21 for Supervisor/Controller-In-Charge
11	59041	(59041) EDC TO FULL STARS DELTA AIR TRAFFIC OPERATORS TRAINING
12	59047	Ocean 21 for Pseudo-Pilots
13	59048	Ocean 21 for Air Traffic Scenario Developers
14	59049	OCEAN21 FOR AIR TRAFFIC QUALITY ASSURANCE
15	50056001	TRACON Skill Enhancement Workshop
16	50148001	Initial En Route Qualification Training
17	50302001	AIR TRAFFIC CONTROL WORKSHOP FOR EXECUTIVES
18	55001001	(55001001) Integrated Control and Monitor System (ICMS) Air Traffic Control Training-Cadre
19	55001002	(55001002) Integrated Control and Monitor System (ICMS) Air Traffic Control Training
20	55152001	EN ROUTE AUTOMATION MODERNIZATION (ERAM) GHOST PILOT PART 2
21	55154001	En Route Automation Modernization (ERAM) Scenario Generation
22	57050001	(57050001) Maxsim4 Tower Simulation System (TSS)
23	59050001	(59050001) TOWER SIMULATOR SYSTEM (TSS) BASIC OPERATOR AND PSEUDO PILOT TRAINING
24	60004673	(60004673) ERAM Creating and Running a Multi-OPSIM Simulation

Out of these 24 courses, only 8 had any material available online for analysis. The analysis of these courses can be found in Table 5.

Table 5: Analysis for Courses that Have Simulation

Course	**Course Name**	**Sim**	**Fidelity**	**Sim Labs**	**Sim Exams**	**Sim Instructor**	**No. of Hrs (for sim training)**	**No. of Course Hrs**	**Additional Remarks**
50046	Initial Tower Cab Training	Yes	L, M, H	Yes	Yes	Yes	1) 28.3 Hrs (Table Top) 2) 4.8 Hrs (Tower 3D) 3) 7.4 Hrs (TSS) Total: 40.5 Hrs	198.60 Hrs / 37 days course	
57096	ASR-11 Air Traffic Training	Yes	-	-	-	-	No information	No information	No course design details available
59033	OCEAN 21 for Air Traffic Support Specialists	Yes	-	-	-	-	No information	No information	No course design details available, but OCEAN 21 simulator is used
59048	OCEAN 21 for Air Traffic Scenario Developers	Yes	-	-	-	-	No information	No information	No course design details available, but OCEAN 21 simulator is used
59049	OCEAN 21 for Air Traffic Quality	Yes	-	-	-	-	No information	No information	No course design details available, but OCEAN 21

	Assurance								simulator is used
50056001	TRACON Skill Enhancement Workshop	Yes	H	Yes	Yes	Yes	No information	No information	No course design details available
50148001	Initial En Route Qualification Training	Yes	L, M, H	Yes	Yes	Yes	1) 61.95 Hrs (Non Radar) 2) 16.15 Hrs (Radar) 3) 110.75 (Radar Associate) Total: 118.85 Hrs	324.55 Hrs / 59 days course and can be extended to 63 days	
50302001	Air Traffic Control Workshop for Executives	Yes	L	Yes	No	Yes	No information	No information	Short course - only exercises, no assessment

4 out of the 8 courses with information available have some data that shows the fidelity of the simulation used. This can be seen in Figure 4.

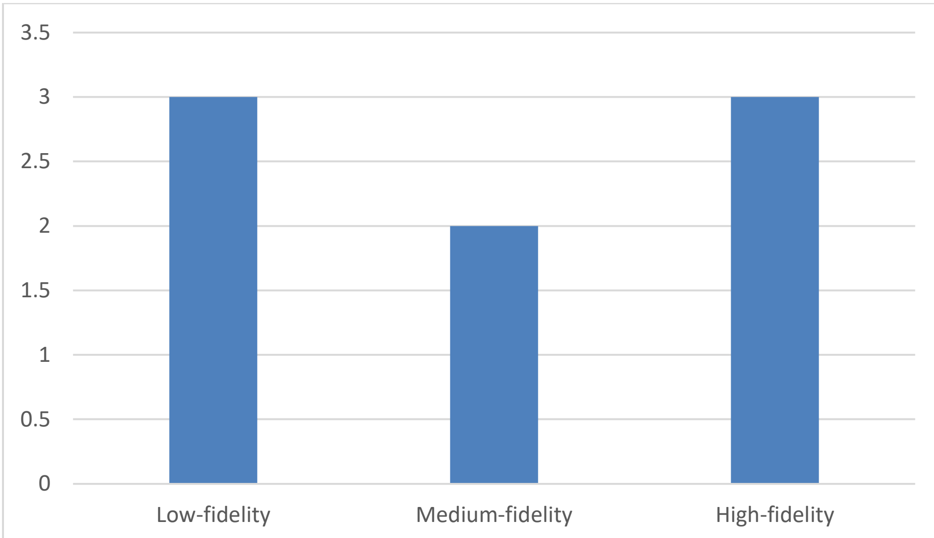


Figure 4: Number of courses with simulation of each fidelity type

In the Initial Tower Cab Training course, simulation takes up 40.50 hours out of 198.60 hours of class time, and makes up 20.39% of the total time spent. This course needs to be taken by all trainees in the Terminal track, and shows the importance of simulation within the field. In the same vein, the Initial En Route Qualification course uses simulation for 188.85 hours out of 324.55 hours, or 58.18%of total training time. This can also be seen in Figure 5.

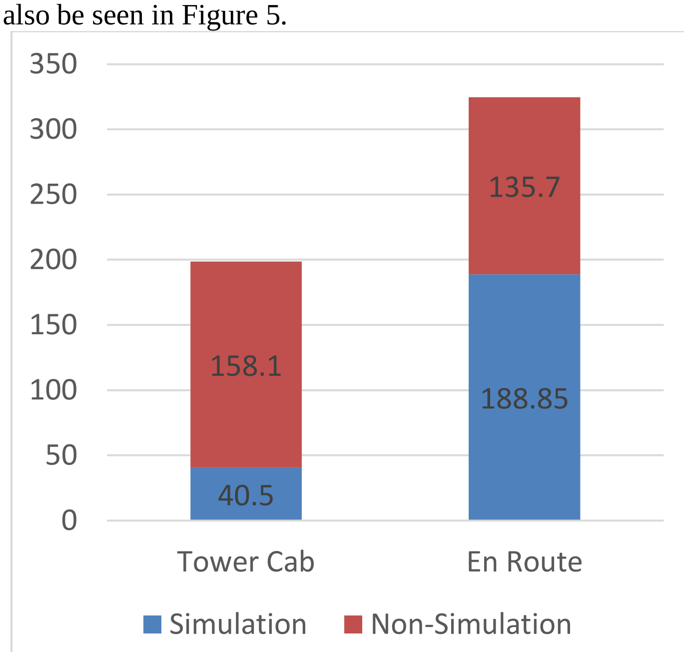


Figure 5: Hours of simulation in core FAA Academy courses

The distribution of class time for each course between low, medium and high-fidelity simulators is shown in Figure 6 and Figure 7.

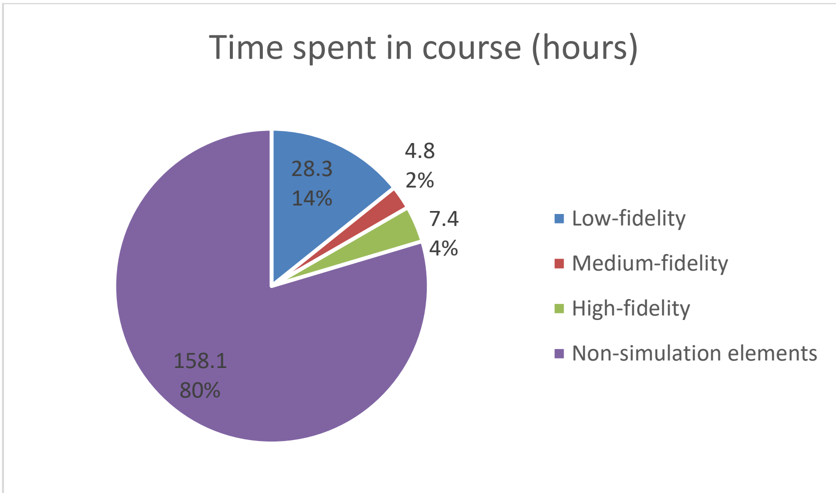


Figure 6: Distribution of course time for Initial Tower Cab Training

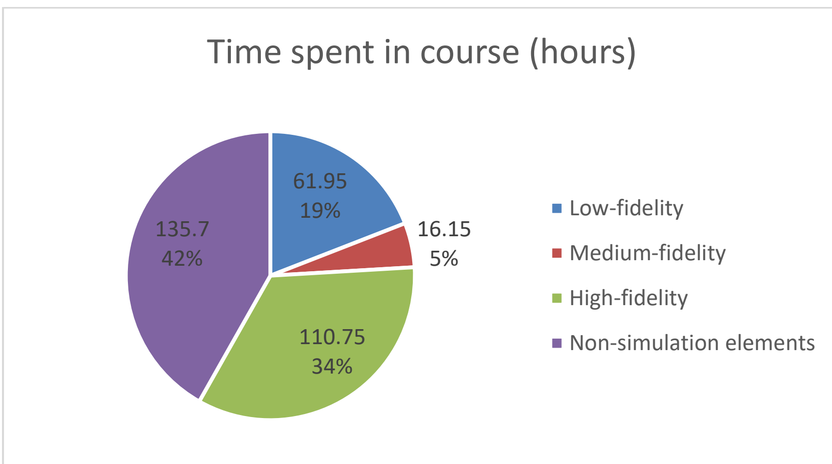


Figure 7: Distribution of course time for Initial En Route Qualification Training

A total breakdown of courses per simulation element can be seen in Figure 8.

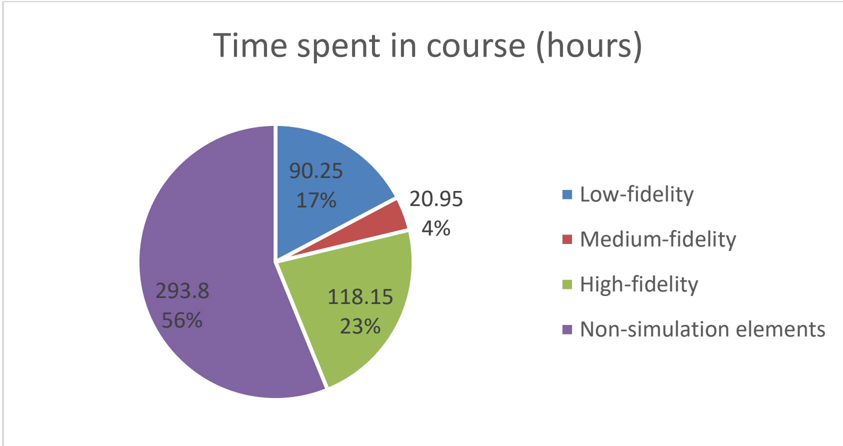


Figure 8: Total breakdown of hours per course element for courses that have simulation

Unfortunately, there weren't many materials to be analyzed in other courses within this category, as very little information was provided.

4.2 Courses that "May Have Simulation"

The courses listed in Table 6 were identified as may be having simulation components.

Table 6: All courses identified as may be having simulation concepts ("May Have Simulation")

#	Course #	Course Name
1	50019	Airspace and Procedures
2	50034	Terminal Basic Radar Training
3	50115	Enhanced Traffic Management Coordinator (ETMC)
4	50128	Air Traffic System Administrator for ETMS (Linux O/S)
5	50310	Air Traffic Facility Training Administration
6	53004	Common ARTS for Air Traffic Support Specialists
7	53034	Full Stars AT Coach Scenario Generation Training
8	55038	Airport Surveillance Radar, ASR-8
9	55040	Airport Surveillance Radar, ASR-9
10	55042	Airport Surface Detection Equipment (ASDE) - 3
11	55079	ARTS Color Display Training for Air Traffic Controllers
12	55097	MOSAIC Controller Training
13	55114	ENROUTE INFORMATION DISPLAY SYSTEM (ERIDS)-SYSTEM USER TRAINING
14	55115	ENROUTE INFORMATION DISPLAY SYSTEM (ERIDS)-DATA MANAGEMENT TRAINING
15	55117	ENROUTE INFORMATION DISPLAY SYSTEM-SPECIAL OPERATIONS TRAINING
16	59034	Raytheon, Full Stars AT Coach Scenario Generation Training
17	59402	STARS CADRE FSL/ESL AIR TRAFFIC OPERATOR'S TRAINING
18	59403	STARS ATCOACH EXERCISE SETUP AND PILOT TRAINING.
19	50059001	Tower Visibility Certification Exam
20	55146001	(55146001) EN ROUTE AUTOMATION MODERNIZATION (ERAM) AIR TRAFFIC CONTROL SPECIALIST

21	55147001	En Route Automation Modernization (ERAM) Scenario Generation
22	55148001	En Route Automation Modernization (ERAM) Scenario Execution
23	55149001	En Route Automation Modernization (ERAM) Ghost Pilot
24	55151001	EN ROUTE AUTOMATION MODERNIZATION (ERAM) GHOST PILOT CADRE TRAINING
25	57311001	(57311001) Digital Audio Legal Recorder (DALR) for Quality Assurance Specialists
26	57312001	Digital Audio Legal Recorder (DALR) for OSET, FLM, and OM
27	57405001	(57405001) (CBI) STARS ELITE Air Traffic Operator Training for the Terminal Controller Workstation
28	57406001	(CBI) STARS ELITE Air Traffic Operator Training for the Tower Display Workstation
29	60004624	rnwy-incrsns
30	60004625	Line up and wait
31	60004626	winter-weather
32	60004628	enrte-wk-turb-vis-sep
33	60004701	Wake Turbulence– Tower
34	60004702	Wake Turbulence – TRACON
35	60004703	Weather and Other Conditions that Affect Flight
36	60004704	Bird Activity Series 2
37	60004705	Fatigue Awareness and Countermeasures
38	60004706	Unusual Situations
39	60004707	Overlooked Traffic-Causes and Potential Outcomes
40	60004708	Runway Incursions Series 2
41	60004709	Scanning
42	60004715	LAWRS - Limited Aviation Weather Observer
43	60004744	TBFM En Route ATCS
44	60004807	(60004807) En Route Wake Turbulence and Visual Separation Recurrent Training July 2014
45	60004809	(60004809) Safety Alerts and Traffic Advisories (Recurrent Training July 2014)
46	60004818	(60004818) Runway Safety Series 5 (Recurrent Training, January 2015)
47	60004819	Weather Deviations into Special Activity Airspace (Recurrent Training, January 2015)
48	60004820	Vectors below the Minimum Vectoring Altitude (MVA)/Minimum IFR Altitude (MIA)
49	60004821	Initial Departure Separation (Recurrent Training, January 2015)
50	60004822	Tower Applied Visual Separation (Recurrent Training, January 2015)
51	60004823	Weather Dissemination (Recurrent Training, January 2015)
52	60004971	TBFM Terminal ATCS
53	60005177	Holding Instructions
54	66004788	ERAM Adaptation Lab

Out of these 54 courses, 48 courses had folders available online but most of them did not have any details about the course design. Out of these 48, only 11 courses had significant material available online which could be used for analysis. The analysis of these courses can be found in Table 7.

Table 7: Analysis for Courses that May Have Simulation

Course	Course Name	Sim	Fidelity	Sim Labs	Sim Exams	Sim Instructor	No. of Hrs (for sim training)	No. of Course Hrs	Additional Remarks
50019	Airspace and Procedures for AMA 500	No	No	No	No	No	-	83 Hrs / Course length 12 days	-
50034	Terminal Basic Radar Training Course 50034 for AMA- 500	Yes	M, H	Yes	Yes	Yes	22.5 Hrs (Medium or Full Fidelity)	76.25 Hrs / Course length 21 days	-
50115	Enhanced Traffic Management Coordinator for AMA - 500	No	No	No	No	No	No such information	64 Hrs / Course length 8 days	-
60004625	Line up and wait (LUAW)	Yes	M	Yes	Yes	Yes	Medium Fidelity 0.25 Hrs	Total hours – 1 hour Total instructional days (at 6 hours per day) – .017 days	1. Complex 2D-3D simulations and game type environment. 2. Simulations are primarily text or narrative driven, with multimedia enhancing the experience
60004628	En Route Visual Separation (Recurrent Training November 2012)	Yes	M	Yes	Yes	Yes	No such information	Total hours – 1 hour Total instructional days (at 6 hours per day) – .017 days	1. Complex 2D-3D simulations and game type environment. 2. Simulations are primarily text or narrative driven, with multimedia enhancing the experience
60004807	(60004807) En Route Wake Turbulence and Visual Separation Recurrent Training July 2014	No	No	No	No	No	No such information	Total hours – 1 hour Total instructional days (at 6 hours per day) – 0.2 days	Learner will view a 2-D simulation of an en route radar display CDG does not describe Fidelity, sim lab

60005177	Holding Instructions	No	No	No	No	No	No such information	Total Time - 0.5 hours	CDG does not describe Simulation, Fidelity, Instructor, Lab, Exam details
55146001	(55146001) En Route Automation Modernization (ERAM) Air Traffic Control Specialist	Yes	H	Yes	Yes	Yes	16.3 Hrs for Simulation Training	Simulation portion of the course is 3 days long	The Test and Training lab is required for the simulation training portion, as well as a classroom with the ability to show PowerPoint slides.
55148001	En Route Automation Modernization (ERAM) Scenario Execution	Yes	M	Yes	Yes	Yes	Medium Fidelity 37.71 Hrs	Course length 15 days	TTL simulation/training software used.
55149001	En Route Automation Modernization (ERAM) Ghost Pilot	Yes	M, H	Yes	Yes	Yes	2 Hrs Simulation	Course length 5 Days	ERAM laboratory is used during initial En Route Air Traffic Controller Training. CDG does not provide more detail information about Simulation and Medium/High Fidelity.
60004626	winter-weather	No	No	No	No	No	No such information	Total hours – 1 hour Total instructional days (at 6 hours per day) – 0.17 days	The Winter Weather course will be delivered via eLMS and Simulations are primarily text or narrative driven, with multimedia enhancing the experience.

Out of the 11 courses with information available and expected to have simulation elements, only 6 courses had simulation details.6 out of the 11 courses with information available have some data that shows the fidelity of the simulation used. This can be seen in Figure 9.

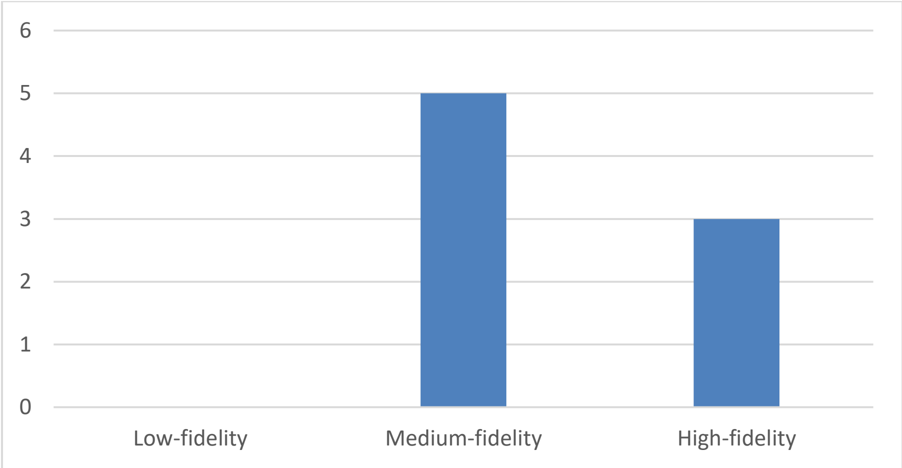


Figure 9: Number of courses with simulation of each fidelity type

For these courses, a summary of the number of hours spent on simulation compared to total course hours can be found in Figure 10. The simulation details for course Line Up and Wait (60004625) and course En Route Visual Separation (60004628) have not been graphed as the hours for those courses are negligible (0.25 hours simulation; 1.0 hour course).

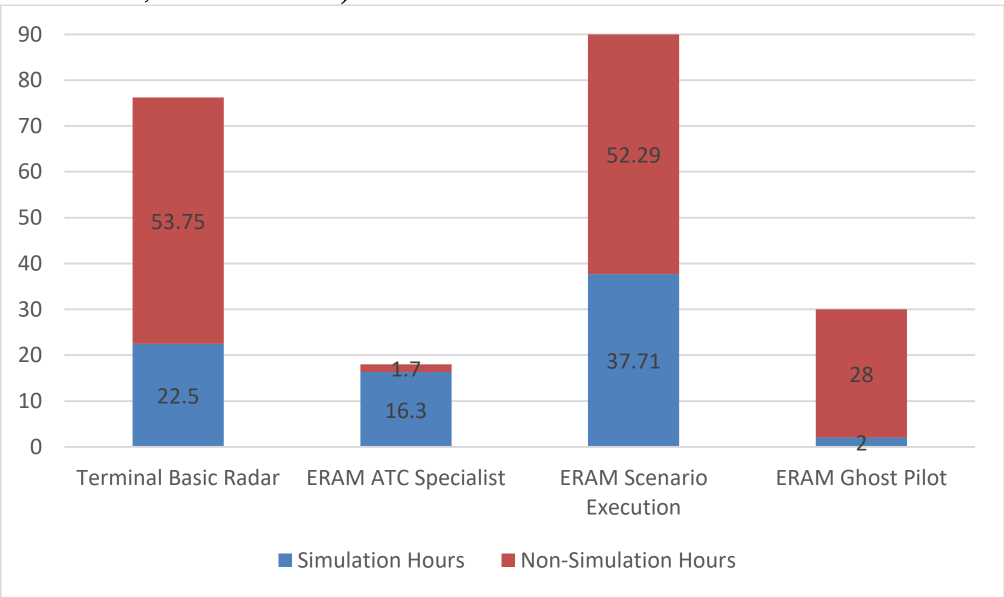


Figure 10: Hours of class time broken into simulation and non-simulation categories

The division of time overall for these courses is shown in Figure 11.

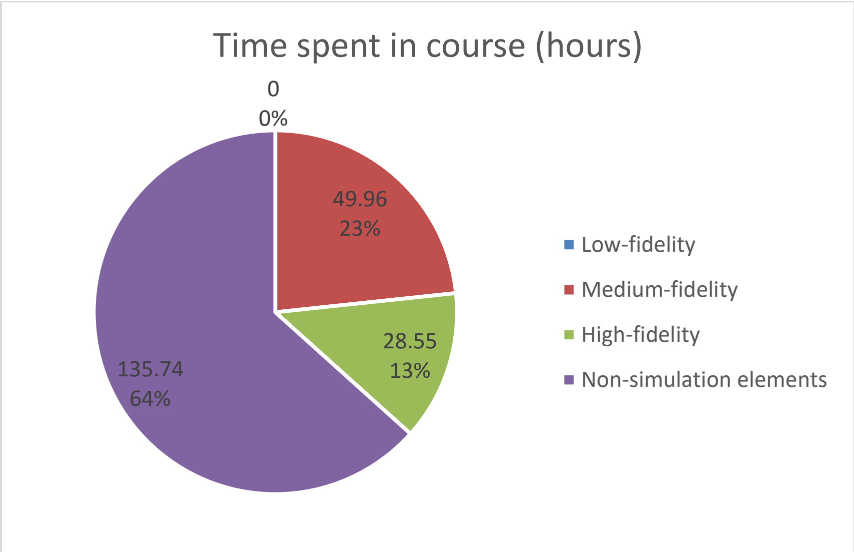


Figure 11: Total breakdown of hours per course element for courses that may have simulation

Unfortunately, there weren't many materials to be analyzed in other courses within this category, as very little information was provided.

4.3 Overall Summary

Only 10 courses with simulation elements were available to be analyzed with sufficient data present in the course design guide (4/8 in "Have Simulation" and 6/11 in "May Have Simulation" categories). It was found that they had simulation elements with varying degrees of fidelity. The fidelity level is measured as "Low", "Medium and "High" fidelity simulation environment. After analysis of these courses, it was found that the courses use tabletop and other computer-based 2D simulators as their low fidelity simulation environment. For the medium fidelity simulation environment, courses use the Tower3Dsimulator. For high/full fidelity environment, courses use the Tower Simulator System (TSS) and En Route Automation Modernization (ERAM) systems. The number of courses identified in total using the three simulation environment types can be seen in Figure 12.

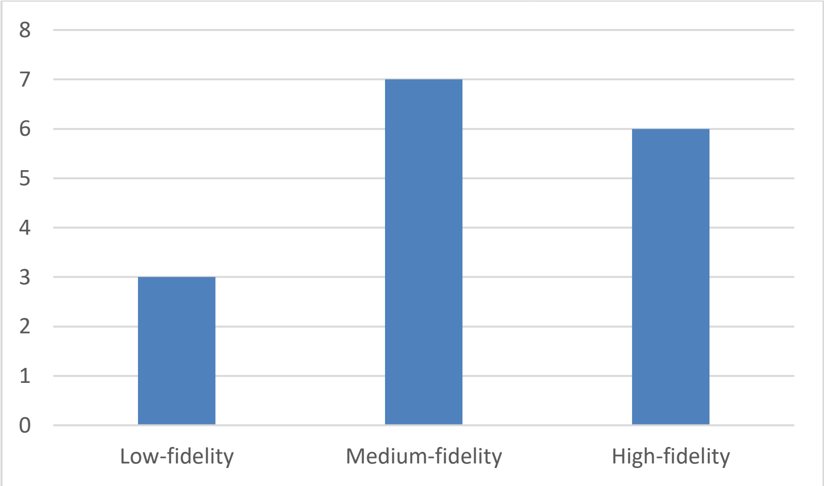


Figure 12: Number of courses with simulation of each fidelity type

The number of hours spent on each type of activity in total can be seen in Figure 13.

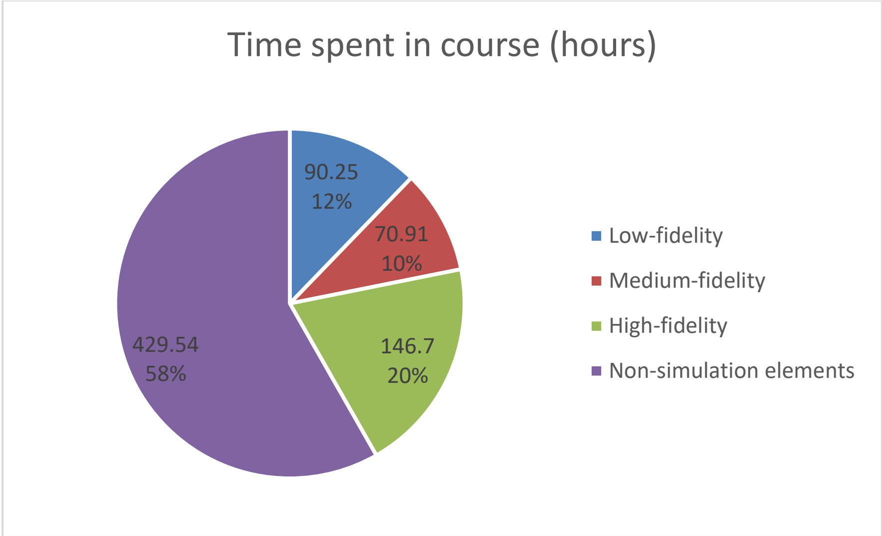


Figure 13: Total breakdown of hours per course element for all courses with details about simulation use

5. Conclusion

This report presents the AMA-500 course analysis of the Air Traffic Control training program at the FAA Academy. To meet the objective, a review and analysis of current training techniques used for simulation training were conducted. Analysis of all the FAA courses available online revealed that training was conducted via classroom-based instruction, with complementing low-, medium-, and high-fidelity simulation labs. Additionally, it was also observed that a few courses used Web Based Training (WBT). Out of an overall number of 10 courses (with enough detail in the design guides) analyzed, the number of courses seen using each type of simulation were found to be 3, 7 and 6 courses for low-, medium- and high-fidelity simulators respectively. Interestingly, the presence of a certain type of fidelity of simulation did not guarantee that it would be used greatly. For instance, 7 out of 10 courses used medium-fidelity simulation, but that only made up 10% of overall class time for all 10 courses combined whichwas the lowest division. Low-fidelity simulators took up 12% of class time and high-fidelity simulators made up 20% of total class time. The remaining 58% of all time was spent on non-simulation activities.

Based on this analysis, it has been observed that a significant amount of time is spent on high-fidelity simulation elements. As these are the closest to real-world experiences the trainees will have, the time spent on this is justified. Ideally, most class time should be spent at this level, but high-fidelity simulators are also very expensive, and time spent on them needs to be divided between all the classes at the Academy. We do not recommend any changes to that at this point in time.

On the other hand, low- and medium-fidelity simulation elements do not make up a lot of class time and may be incorporated into training earlier so that trainees get used to the work environment, such as a 2D or 3D computer-based simulator. A software-based training environment would allow students to get familiar with the tools at their disposal without using Academy resources or instructors. An overall simulation use greater than 50% of total class time would ensure that students get maximum exposure to the ATC environment and practice with the procedures and phraseology required.

Appendix G: AMA-500 Curriculum Improvement Recommendations

The rapid pace of change in the technological world means that there is always a potential to improve the functionality of computer-based tools. As new technologies are developed for use in ATC facilities, simulation systems at the Federal Aviation Administration (FAA) Academy become more and more outdated unless they are continuously updated and maintained. The recommendations listed in this report are of two types:

1. Recommended changes to course curriculum to incorporate more simulation-based training; and
2. Recommended improvements to simulation technologies currently being employed in the classroom.

1. Changes to course curriculum

Not enough material is available to analyze for this section of the report, so the recommendations are made in general and could be applied to most classes with simulation components. It is suggested that following a thorough review of all available coursework at regular intervals, recommendations be made about changes to the curriculum in order for training to remain effective with the constant changes in technology. Once recommendations are made, a study should be conducted to see if following those changes affect overall understanding of the material and course grades in order to finalize curriculum changes. This recommended process can be seen in Figure 14.

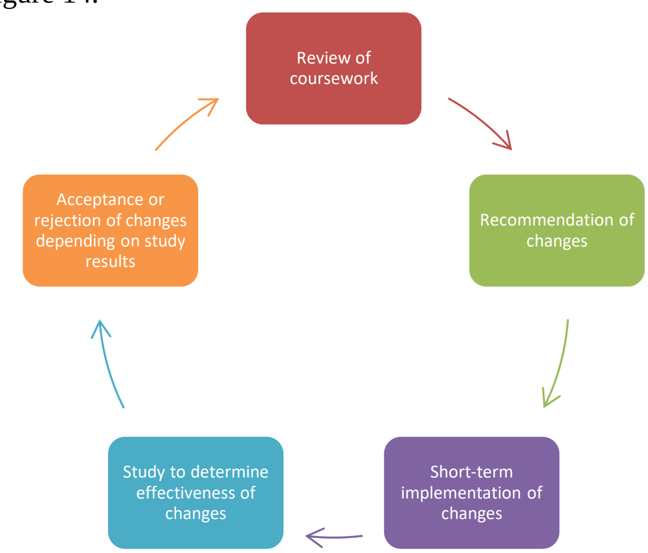


Figure 14: Recommended process of implementation of curriculum changes

One of the major bottlenecks discovered while looking at course data was due to the limited ability of students to practice simulation scenarios. The high-fidelity simulators are very expensive to obtain and maintain, so they are limited in number and the amount of time they are available as this has to be split between students in all classes.

It is possible that if a long time is spent on theoretical instruction, the information does not carry over to a fast-paced real-world ATC environment. An overall simulation use greater than 50% of total class time would ensure that students get maximum exposure to the ATC environment and practice with the procedures and phraseology required, compared to the current use of simulation in courses, which ranges between 20% to 60% depending on the course.

One solution is to use a software-based training environment, which would allow students to get familiar with the tools at their disposal without using Academy resources or instructors. A web-based interface would allow students to practice on their own time without the presence of an instructor, and pseudo-pilots and ghost controllers, who are otherwise part of the simulation team and use a great deal of Academy resources to run smoothly. This would be a self-paced, take-home component of the relevant courses, which is currently not attempted by the Academy.

It is also recommended that more emphasis should be spent on computerized 2D and 3D training tools, as well as speaking exercises, so that students get used to the idea of typing in details quickly and without error, along with always using the correct phraseology.

2. Improvement to current simulation technology

In addition to the changes being made to coursework to incorporate more use of simulation technologies, the technology itself is in need of improvement in order to better serve students and trainees.

The current training simulators do not account for changes in the industry immediately. For example, it was found that NextGen concepts are not being incorporated into the simulators or curriculum currently. These need to be added in order to closely resemble the working environment. An example of this is performance-based navigation (PBN) as these approaches have not been added to simulators yet. PBN specifies that aircraft required navigation performance (RNP) and area navigation (RNAV) systems performance requirements be defined in terms of accuracy, integrity, availability, continuity, and functionality required for the proposed operations in the context of a particular airspace.

Another functionality that could be added to existing simulators is the ability to record scenario audio and video and play it back. The exercises done by the trainees during class time with the help of the instructor and ghost pilots and controllers on a high-fidelity simulator can be reviewed by them at their own time, which would help with retention. Being able look at the same scenarios again can also help them explore any other options they may have had, which would not be possible within the scenario and class time constraints.

The last suggestion is to incorporate voice recognition, both into the existing simulators as well as the web-based tool discussed earlier. Voice recognition abilities would mean that trainees would be required to use correct phraseology, or their actions would not be recognized by the computer. This would mean that the students are trained to always use the correct terms as mandated by the FAA and ICAO to avoid any potential misunderstanding which could count against them during exams or in the field. This would also open the door for newer technology to enable automated grading of scenario performance and personalized feedback if voice input can be processed by the simulator.

3. Summary

Based on the analysis of the FAA curriculum for ATC training, recommendations were made in two different categories: changes to the curriculum, and updates to the simulator technology currently in place. A summary of these recommendations can be seen in Figure 15.

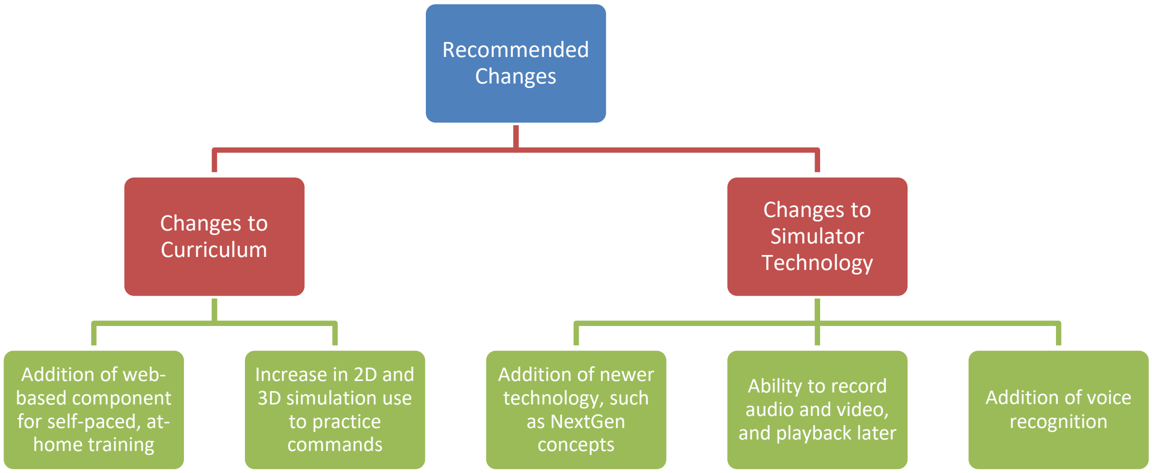


Figure 15: Summary of recommendation to improve curriculum and simulator use