Recommendations for Next Generation Air Traffic Control Training

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***Abstract*— This paper investigates the current uses of simulation in FAA Academy ATC training in an effort to identify potential improvement areas to the current training program in the areas of simulation and course content. Once identified, recommendations for changes to the current training program can be made. A thorough literature review of current training techniques used at the FAA Academy and training centers was conducted. The primary findings of this research revealed that training is predominantly accomplished via traditional classroom-based instruction, with complementing low-, medium-, and high-fidelity simulation labs. Recommendations made regarding the FAA ATC training process include the incorporation of web-based training technologies, the addition of voice recognition and synthesis technologies to current simulators, and updating current simulators to include recording and playback features.**

Keywords—ATC; training; simulation; literature review

I. INTRODUCTION

With the increased advancements in computer simulation and visual graphics capabilities, the use of advanced flight simulation training devices in general aviation has increased significantly. The aviation community regularly uses simulation technologies to increase training effectiveness at a much lower cost and in risk-free environments. Today's training devices go beyond full flight simulators, by providing support in the form of flight training devices and aviation devices. From airline training and corporate flying to the private pilot in general aviation aircraft, almost every pilot has gone through a phase of simulation-based training. This has led the Federal Aviation Administration (FAA) to release an advisory circular (AC 61-136A) documenting approval of aviation training devices and describing how the FAA approves such technologies and how pilots may use supporting devices.

Simulation is used throughout the Air Traffic Control (ATC) training process and is one of the only methods currently available which gives trainees hands-on experience in learning such a high-skilled and detail-oriented occupation. Although incredibly valuable to the learning experience of ATC trainees, simulation often becomes outdated or ineffective as equipment changes faster than the agency can update simulators. To optimize the use of simulation in ATC training, the FAA must ensure that simulation is used when it is of benefit and that simulators are updated in tandem with current technologies.

In order to make recommendations on how ATC training at the FAA Academy can be optimized for the future, current training and simulation techniques must first be understood. In this paper, a brief background of the ATC training process and FAA Academy courses is presented. In section III, a thorough literature review investigating the current training techniques and technologies being used at the FAA Academy and other training sites is presented. Section IV presents a summary of recommendations which can potentially improve and optimize the ATC training process. A brief introduction to future work being conducted as an extension to this research is described in section V. Finally, section VI offers a brief conclusion.

II. BACKGROUND

A. ATC Training Process

ATC training occurs over two main phases: FAA Academy training and on-site facility training. All official training starts at the FAA Academy, located in Oklahoma City, Oklahoma; however, all developmental ATCs are hired from one of three paths: previous controllers, Air Traffic-Collegiate Training Initiative (AT-CTI) developmentals, or the general public. First, previous controllers include individuals who have prior civilian or military ATC experience. Second, AT-CTI developmentals include individuals who have successfully completed an aviation-related program of study from a school with the AT-CTI program, which was created in an effort to increase the skills of developmental ATCs and reduce failure rates at the FAA Academy. Finally, the general public includes any individuals who do not have prior ATC experience. [1]

Prior to 2015, the training process at the FAA Academy consisted of four main phases: air traffic academics, part-task training, skills building, and performance verification [2]. A list of courses taught at the FAA Academy can be found in the FAA catalog of training [3]. Air traffic academics, also known as the FAA ATC Basics course [1], uses classroom instruction to introduce the very basic concepts of aviation and air traffic control, such as regulations, aircraft performance, and weather. Part-task training consists of classroom lectures and basic laboratory activities. The purpose of this phase of training is to introduce more complex ATC concepts, such as separation techniques, and begin application of previously acquired knowledge. The skills building training increases the complexity of the part-task training activities. Generally, simulation that closely replicates the control room environment is utilized to create additional realism to training. A Performance Verification (PV) is the final stage of training. The purpose of this phase is to allow operational supervisors from the field to assess if

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students are ready to proceed to on-site facility training [2]. In 2015, the PV phase was replaced with cumulative scoring on all job jeopardy courses, or courses which are essential to ATC, and failure of any of these select courses will result in a dismissal from the FAA Academy. This score is used in lieu of the final performance verifications.

All developmental ATCs experience a similar training experience at the FAA Academy; however, some exceptions do exist. Only general public hires must complete the air traffic academics course before starting one of these three tracks: (1) Tower, (2) Terminal Radar Approach Control (TRACON), and (3) En Route (see Section B for details) [1]. Former military controllers may bypass the FAA Academy and proceed directly to a terminal facility [2]. In addition, former civilian controllers must complete a refresher course [2].

Upon successful completion of the FAA Academy training program, developmental ATCs proceed to on-site facility training at their assigned facility. On-site facility training varies slightly depending on location; however, training generally consists of a combination of classroom, simulation, and on-the-job training (OJT), with OJT comprising the majority of training. Average training times vary with a number of factors, including trainee motivation and aptitude, the effectiveness and quality of OJT time, and the complexity of the airspace the facility manages. However, training generally lasts between six months and three years. After this phase of training is complete, the developmental ATC is recognized as a Certified Professional Controller (CPC) and can begin working on live air traffic as needed by the facility. [2]

B. FAA Academy ATC Training Divisions

There are three major flight control components in ATC: Tower, TRACON, and En Route [1]. Each component has a unique training track, with each track specifically designed to teach the required materials for only one division. Developmental ATCs start in one of the three tracks, usually based off current need and previous skills. At the end of each track, developmentals are evaluated on how well learning is applied in both academics and simulation.

1) Tower: The tower track focuses on air traffic management activities within a radius of a few miles of the airport. Major concepts include take-off and taxiing instructions, as well as clearance deliveries. Concepts such as minimum separation distances between landing and departing aircraft and transferring control of aircraft to TRACON controllers must be applied in this track. Simulators are used to replicate real ATC towers and train developmentals [1]. This course takes 37 days to complete and consists of five written tests and four performance assessments totaling 100 points.

2) TRACON: TRACON training occurs in the Terminal Basic Radar Training Course (RTF), which is the job jeopardy course for developments going to a standalone radar facility. The RTF course incorporates classroom training and simulation focused on managing traffic outside the radius managed by Towers. However, TRACON control generally extends only to a 40-mile radius from the primary airport. Concepts learned in this track included ascending departing aircraft, descending arriving aircraft, maintaining separation distances, and transferring control to En Route Center controllers. This course takes 21 days to complete and consists of two written tests and three performance assessments totaling 100 points. Developmentals must meet a minimum score of 70% or more to proceed to facility training [1].

3) En Route: En Route courses are the most detailed courses as the FAA Academy is the only place developmental ATCs receive this type of training of managing air traffic along defined routes. The course consists of classroom instruction, medium fidelity skills practices utilizing interactive computer-based instructional systems, and full-fidelity En Route Automation Modernization (ERAM) simulation in an En Route lab. Due to the complexity and amount of information provided, training is primarily oriented towards procedural studies and demonstration of control scenarios. This course takes about 63 days to complete and consists of four written tests and six performance assessments totalling 100 points. Developmentals must achieve a score of 70 or more to proceed to facility training. [1]

III. LITERATURE REVIEW

In order to understand the current state of ATC training, current literature was reviewed and analyzed. Two major publications were utilized to form a thorough understanding of current FAA Academy procedures, as well as to provide a look into the training processes and practices found throughout the training process.

In January 2013, the FAA conducted a review and evaluation of air traffic controller training at the FAA Academy and reported their findings, detailed in [1]. The study was conducted in response to the FAA Modernization and Reform Act of 2012, which required a study focused on the training program for developmental ATCs. The Air Traffic Division (AMA-500) delivers initial, advanced, and specialized air traffic training at the FAA Academy. Three key areas of AMA-500 training were evaluated in this study: (1) roles and responsibilities, (2) communication of roles and responsibilities, and (3) accommodation of developmental ATCs. The study approach included data collection, where data was collected via on-site visits and interviews, findings development, and report development. Whereas the Reauthorization Act was directed "at the national level", this study focused on training only at the FAA Academy and findings and recommendations reflect the FAA Academy environment and AMA-500 specifically. The study findings for each of the three key areas, which were further divided into findings and barriers, can be summarized as follows:

1. Roles and Responsibilities

   First, the FAA Academy has a number of processes in place to carry out roles and responsibilities. Training processes were documented and posted in an online tool made available across all lines of business and organizations of the FAA. Second, responsibilities for processes around hiring and training ATCs span across multiple organizations. Therefore, while AMA-500 is responsible for training ATCs, other divisions use processes for hiring, training, and certifying of these ATCs. Finally, individuals

included in these processes were aware of their roles and knew their roles and responsibilities well.

Barriers included organizational change, limited visibility, and undocumented or altered processes. As the FAA releases changes to the organization, some gaps in understanding of whom or what FAA organization is currently responsible for completing tasks can be seen. This compounded with limited visibility into the whole process. In addition, because processes span multiple lines of business, roles and responsibilities often became fragmented or complex. Therefore, organizational change and limited understanding of the whole process can lead to ineffectiveness in management. In addition, some processes were passed along verbally or created via "trial and error" processes. This presents a risk of consistency and completeness of the process and increases potential for duplication of efforts and lost organizational knowledge.

2. Communication of Roles and Responsibilities

Communication networks at the FAA Academy are in place, active, and highlight strong ties within FAA Academy divisions. There is a willingness to share information through meetings, emails, and verbal interactions. In addition, communications were personal and frequent, supporting the development of personalized and frequent communication around responsibilities, processes, and deliverables. However, this attitude creates communications that appear to be more informal in nature, which can create gaps in communication or inconsistent communication beyond the initial message recipient(s). In addition, no overarching process to show and communicate roles and responsibilities exists, hindering opportunities to build efficiencies, understand large-scale change initiatives or process improvement exercises, and can create confusion around responsibilities and accountability. Finally, a feedback loop could be helpful in maintaining roles and responsibilities.

3. Accommodation of Developmental ATCs

First, the FAA Academy has historically had no issues accommodating developmental ATC demands. Once the number of developmentals is established, the FAA Academy works with AJI-215 to develop the master course schedule and assign developmentals to appropriate training tracks. Second, the FAA Academy currently employs 40 total FAA instructors and 342 contract instructors; however, the number of instructors needed can be altered as necessary when given an adequate amount of notice. The developmental-to-instructor ratio varies depending on the course and number of developmentals in the class. However, there are always two instructors per classroom, with the En Route course designed with a ratio of 18-to-2, and the RTF and Tower courses designed with a ratio of 24-to-2. In the simulation labs, the ratio is much smaller due to the level of involvement needed by the instructor, with ratios of 4-to-1 for the medium fidelity Tower course and 1-to-1 for the high fidelity course. RTF has a ratio of 1-to-1 whereas En Route has a ratio of 1-to-2. Third, the FAA Academy features 26 classrooms with a breakdown of five En Route, four Tower, five RTF, six Basics, and nine Specialized Training classrooms. There are no established standards to identify the number of developmentals that can be accommodated based on classroom space; however, courses can be scheduled in multiple shifts as a short-term approach to increase capacity. Fourth, the study team noted that the number of available simulators could affect the number of developmental ATCs that the FAA Academy can accommodate. The FAA Academy uses 70 total simulators for ATC courses. AMA-500 leadership noted that the number of simulators available ultimately limits the number of developmentals the Academy can accommodate. However, if given enough time the FAA Academy can alter the master course schedule to accommodate additional developmentals. Fifth, according to several interviewees, the number of developmentals who enter the FAA Academy is determined by the Air Traffic Organization (ATO) based on projections in the annual Controller Workforce Plan and the number of controllers needed at the facilities; training requirements do not determine the number of developmental ATCs. However, requirements do influence the training material and duration of the courses. Standards ensure that all developmental ATCs get the same training. Finally, the FAA Academy is not directly affected by the number of new personnel already in training. Developmentals currently in training move through the set course duration for respective training tracks with little impact on the FAA Academy's ability to accommodate the next wave of developmentals.

In addition to the findings previously presented, this study offered a multitude of recommendations addressing the shortcomings discovered in the training process. A summary of these recommendations is as follows:

1. Roles and Responsibilities

First, the study team recommended that the FAA develop master, high-level process flows showing decisions and touch points to improve coordination and accountability, as providing start-to-finish visibility into a process improves awareness. Next, it was recommended that processes be accompanied by a Responsible, Accountable, Consult, and Inform (RACI) Matrix or tool that maps key actions and decisions to responsible, accountable, consulted, and informed stakeholders. Finally, it was recommended that "trial and error" process details be captured properly, as variations in approach and ownership can impede the ability to replicate success and efficiency and maintain consistency and accountability.

2. Communication of Roles and Responsibilities

It was recommended that steps be taken to better coordinate the dissemination of information. First, a communication or change management plan can be developed to communicate upcoming changes around roles, responsibilities, and processes. Second, because some processes change faster than their corresponding documents, a repository of best practices can be created and made readily available to anyone engaged in a process. This document can minimize the impact of changes when formal process documents are not appropriate. Finally, course feedback should be made available to all interested parties, when appropriate.

Additional feedback can improve the quality of data and response rates for courses.

3. Accommodation of Developmental ATCs

Although focused on roles and responsibilities, communication, and the FAA Academy's ability to accommodate developmental ATCs, additional factors that can influence the FAA Academy's training delivery capabilities were identified. First, the need for new technologies to develop and deliver training is necessary for the FAA Academy to develop and maintain training content and train developmental ATCs more effectively. Most courses are built around traditional classroom-based instruction, with some high-, medium-, and low-fidelity simulation done in labs. In addition, less than 10% of Academy courses were web-based and no classes were required to add online training. Second, lack of funding and financial support can make course maintenance and updates more challenging to complete in a timely manner. Third, FAA-wide ATC workforce changes, when analyzed annually in the Controller Workforce Plan, do not account for the two- to three-year training process. Therefore, large deviations from the projections can lead to a rippled effect for the training capacity at the FAA Academy. Finally, the FAA Academy holds three accreditations: National Education Association (NEA), the North Central Association (NCA), and International Standards Organization (ISO). Accreditation standards changes can potentially force the FAA Academy to make decisions that alter responsibilities or processes around the development, delivery, maintenance, and evaluation of courses in order to maintain accreditation status.

Brudnicki, Chastain, & Ethier [2] provide an in-depth overview of training technologies currently being utilized in the FAA Academy and on-site facility training, as well as recommendations for future applications of technologies. According to [2], a practice environment with high-fidelity simulation is critical for acquiring the specialized and complex skills of air traffic control in an efficient manner. High-fidelity, intelligent training systems technologies such as voice recognition and synthesis, intelligent tutoring, and instructor support capabilities can substantially improve the FAA's simulation environment and provide benefits in both training quality and certification times. Voice recognition and synthesis can be used to automate pseudo pilots and ghost controllers, where a pseudo pilot is a trained operator who manipulates several aircraft according to clearances issued by the controller trainee on a simulated radio channel and a ghost controller is a trained operator who plays the role of controllers at surrounding sectors. Some complex scenarios can require multiple pseudo pilots and ghost controllers; automating these dependencies can improve the overall practice environment for skill development, support self-paced and independent learning, enforce the teaching and use of standard ATC phraseology, and reduce costs. An Intelligent Tutoring System (ITS) is a set of automated capabilities combined with human performance models that provide for an objective assessment of learned skill levels, infer strengths and weaknesses of a student, and enable tailored instruction. A variety of human performance models can be used for various training complexities, providing flexibility to tutoring. ITS technologies are proven in several domains with similarities to ATC cognitive processes and complexities. In addition, these technologies can provide reduced training times and increased instructional quality via accurate and objective feedback. Instructor support includes recording and playback simulation capabilities, where the video and audio recorded from a previous scenario run is reviewed, analyzed, and used to provide instructional feedback. In addition, pausing can allow for real-time feedback during a scenario. Finally, the ability to skip to a particular time or event provides a mechanism to quickly and conveniently call up specific actions for review and feedback and possibly to test alternative control actions from that point forward.

Web-based instruction is another potential avenue for increasing training effectiveness and reducing training times. As stated by Brudnicki, Chastain, & Ethier [2], web-based instruction is a learning method that utilizes the resources of the internet. A general classroom-based course, such as the ATC Basics course at the FAA Academy, could potentially be replaced or supplemented with web-based instruction. Benefits include self-paced learning in geographically separated locations, the reduction of FAA Academy resources, broadened access to courses, the ability to test aptitude before entry into the FAA Academy or a field facility, and increased instructor focus on training more advanced ATC skills.

Finally, Brudnicki, Chastain, & Ethier [2] describe methods to create location-independent, site-specific training, where networking and video teleconferencing technologies can enable physically dispersed educators, experts, and trainees to work together and run air traffic simulation exercises in a type of "virtual training environment." Location-independent training can greatly reduce training time and costs while improving quality. A training process could, for instance, have trainees reach a "near-certification" level before even entering their target facility. Training simulations could be run at a centralized location, similarly to the FAA Academy. A centralized training location would enforce standardization of instruction and use of dedicated educators, help alleviate bottlenecks at field facilities, and promotes the concept of introducing the trainee to specific operations of a facility as early as possible. It is expected to be particularly effective in a terminal environment, where it is often difficult to maintain local instructors at many of the smaller facilities located throughout the country.

In addition to the publications previously mentioned, multiple other publications were reviewed and analyzed when formulating future recommendations and improvements for future ATC training processes and practices. In the interest of length, only major recommendations and improvements will be discussed further. A 2016 study by Knecht, Muehlethaler, & Ethier [4] presented a scientific analysis for training development and prototype training. It notes that ATC nontechnical skills such as scanning, comprehension, anticipation, workload management, and decision-making, which are generally taught in a classroom environment, would be better suited in a practice-based environment as transfer of knowledge can be increased and time and costs reduced. In addition, it is recommended that a shift occur from traditional frontal teaching methods to practice-based training in which active participation of trainees receives high priority. Finally,

feedback tools such as eye tracking tools could further enhance ATC training [4]. Similarly, a study by Kang & Landry [5] additionally explores using scanpaths as a learning method for conflict detection. This study showed significant improvements in the conflict detections of trainees after being shown and/or taught a scanpath used by an experienced ATC. Furthermore, additional motivation and encouragement to follow the presented paths was observed. Similar to some recommendations made by Brudnicki, Chastain, & Ethier [2], a 2015 case study by Airservices Australia, detailed in [6], recommends utilizing the Re/Vue video recording and streaming technology to compliment student training, including recording, pausing, and replaying scenarios. In addition, the ability to port files onto flash drives allows instructors to design prerecorded learning scenarios that students can analyze on their own time. Multiple devices could also be networked to monitor multiple screens at once [6]. Finally, Arminen, Koskela, and Palukka [7] analyzes the stimulus and response pairs of ATC training to identify activities and stimuli in the training process. Of importance to this research is the observation that trainees respond either to the scenario itself or to an instructor prompt; trainer prompts are only necessary when a trainee fails to execute an ATC task when needed. Therefore, in ATC training, a reflexive loop between the controller's work and the state of the aviation system can be observed. It is recommended that training emphasize reflexively adapting, shaping, and making sense of a trainee's activities to maintain the mobility of the objects they coordinate [7].

IV. Recommendations

Based on the literature review, the following primary recommendations can be made:

- Web-based training courses that support self-paced, location-independent learning should be added to the FAA Academy course catalog. These courses should either support or replace current courses being taught at the FAA Academy. Web-based training creates a larger pool of practice, allowing students to exercise a variety of situations, stimulate their critical thinking, and increase preparedness for in-person training.
- Voice recognition and synthesis which can reduce the dependence on or replace pseudo pilots and/or ghost controllers should be added to current simulator technologies and utilized in training courses. However, significant research must be conducted in order to make this recommendation a possibility as voice recognition and synthesis technology continues to struggle with accuracy and precision when understanding developmentals' commands.
- Intelligent tutoring systems that personalize feedback to each student should be added to current simulator technologies and utilized in training courses.
- Current simulator technologies should be upgraded to include instructor support features, such as recording and playback capabilities, as well as eye tracking tools and capabilities.

These recommendations are made with emphasis as each recommendation was either mentioned by multiple publications or mentioned in an official FAA training review. Each recommendation is regarded as highly valuable and worth pursuing immediately due to the high potential for training improvements. One of the greatest challenges in ATC training is providing ample opportunities for students who struggle with a concept to practice on their own time. ATC coursework requires a vast amount of knowledge to be memorized and quickly accessible. In addition, individual simulator training is difficult because trainees often need a partner acting as a pseudo pilot, spaces on the simulators are often strictly limited, and instructors almost always need to be present and supervising in order for a student to receive any useful feedback from a training session utilizing advanced control tactics.

The primary recommendations presented directly address this continuously challenging aspect of ATC training. Whereas traditional frontal teaching methods emphasize listening and memorization of materials, web-based training modules encourage student participation and utilization of material and offers a state-of-the-art approach to learning the vast amounts of required modules for ATC training. Some examples of potential web-based training courses and/or subject areas include phraseology memorization and utilization, aircraft identifiers, airport identifiers, safety modules, and emergency procedures. Voice recognition and synthesis supports students who wish to train alone or repetitively on more advanced simulation concepts and modules. The ability to run a highly complex miles-in-trail spacing scenario without the need for a human pseudo-pilot to support the trainee has the potential to completely overhaul current training techniques at the advanced level and expedite an individual developmental's training. When added to web-based courses and voice recognition capabilities, intelligent tutoring systems and updated simulation technologies can greatly expedite the training process.

With these primary recommendations in place, a developmental could potentially utilize a web-based course at home to strengthen his or her phraseology in a complex module, enter the FAA Academy high-fidelity simulation lab to practice the complex scenario, train the scenario individually while utilizing the previously learned phraseology and an automated pseudo pilot, and receive intelligent support and feedback from the simulator itself in order to improve his or her individual weaknesses, all without the additional support and resources of instructors and peers. This student-driven learning process has the potential to revolutionize ATC training as we currently know it.

The following secondary recommendations are made as potential improvements, with less emphasis than the previous recommendations:

- FAA Academy courses should include nontechnical skills training in a practice-based environment, including scanpath training, teamwork, and decision-making.
- Networking and video teleconferencing technologies can potentially be utilized to train new applicants online in a location-independent manner.
- Training courses can potentially emphasize reflexively adapting, shaping, and making sense of a trainee's

activities to maintain the mobility of the objects they coordinate.

These recommendations are made with less emphasis as these recommendations were either made by only one publication or the potential for training improvements was considered not as high or immediate in nature when compared to the primary recommendations.

While all primary recommendations are considered highly valuable, feasibility should also be considered. Whereas web-based training, voice recognition and synthesis, and intelligent tutoring systems could potentially change the field of ATC training as it is currently known, all three recommendations would require substantial changes to the current training regime, thus lowering the feasibility of inclusion. However, upgrading current simulator technologies to include additional features is a feasible option as the simulators in use are already accounted for in training regimes. Updates for these simulators can be expected to be completed in a reasonable amount of time and with fewer changes to the current training program in comparison to the previous three recommendations. Therefore, it is recommended that simulators be updated first while also working towards creating a training program that includes web-based training, voice recognition and synthesis, and intelligent tutoring.

In addition to the primary recommendations, the secondary recommendations, while less valuable in regards to potential for training improvements, have relatively high feasibility for inclusion into the current training program. All three recommendations could be implemented with few changes to the current training program as all three recommendations include only a change in program content or an addition to program content (as seen in the video teleconferencing recommendation). However, although more feasible, these recommendations are still regarded by the research team as secondary to the primary recommendations due to the much lower potential for overall training improvements.

V. Future work

An extension of this work under preparation, detailed in [8], includes a comprehensive survey of industry simulation providers to the FAA Academy, as well as FAA Academy instructors and students. This survey investigates the current state of simulation technologies at the FAA Academy and assesses the potential of the recommendations made in this review. In addition, insight into current simulator software and hardware updates is investigated further to determine if training simulators are keeping pace with current technology. The survey results are presented and a detailed cost-benefit analysis is performed. Survey results and recommendations are formally ranked via an overall estimated feasibility value, as determined through the cost-benefit analysis. This ranking is then utilized to make new or altered recommendations based off the survey results and cost-benefit analysis and recommend the order in which these recommendations should be implemented.

VI. Conclusion

This paper investigated the currently used training techniques for the FAA Air Traffic Control training program at the FAA Academy. A thorough literature review of current training techniques used at the FAA Academy and training centers was conducted. The primary findings of this research revealed that training is primarily accomplished via traditional classroom-based instruction, with complementing low-, medium-, and high-fidelity simulation labs. Recommendations made regarding the FAA Academy ATC training process include the incorporation of web-based training technologies, the addition of voice recognition and synthesis technologies to current simulators, and updating current simulators to include recording and playback features. An extension to this work is currently being conducted and new or altered recommendations will be made from the results.

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