Accommodating ATC System Evolution through Advanced Training Techniques

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The Federal Aviation Administration (FAA) expects air traffic volume and complexity to continue to increase, and with it the demand for air traffic control (ATC) services. The present controller training process and methods need to be enhanced to deal effectively with projected hiring increases, workforce changes, and operational changes anticipated in the future air transportation evolution. Advanced training techniques, such as scenario based instruction, voice recognition and synthesis and Intelligent Tutoring Systems (ITS) will reduce the time and costs required to attain Certified Professional Controller (CPC) status. Benefits such as increased flexibility in scheduling, more rapid response to facility staffing needs, and reduced stress on training resources such as instructors can be realized. The expected introduction of advanced ATC automation capabilities will affect the skills and knowledge mix of the controller workforce and may provide the opportunity for controller specialization that would result in increased efficiency while lowering overall costs. This paper summarizes the recent MITRE CAASD research into training methods, provides a high-level overview of the advanced ATC automation capabilities that could be introduced, presents recommendations for changes to the training process and its potential impact on training for both the current and future systems.

I. Introduction

In 1981, thousands of controllers who participated in a nationwide strike were fired, and the Federal Aviation Administration (FAA) hired thousands of new controllers to rebuild its controller workforce. These controllers are now approaching retirement eligibility and will leave the FAA over the next several years. Attrition scenarios developed by the Department of Transportation's Office of Inspector General [1] show that 70% of the entire controller workforce and about 93% of current supervisors are eligible to retire by 2011.

The FAA expects that during that same period of time rapid growth in the demand for air transportation will increase air traffic volume, complexity and the demand for Air Traffic Control (ATC) services. The FAA's plans for modernizing and expanding the National Airspace System (NAS) are predicated on accommodating the rapid growth. A key assumption in the FAA's aviation forecasts has been that the ATC system will not be a constraint to future growth, and that new ATC facilities and equipment will be deployed where and when needed to meet demand. A study by the Government Accountability Office [2] estimated that 2400 additional controllers would be required to handle the expected traffic growth over the next 10 years, not considering any productivity gains. The FAA's *Air Traffic Controller Workforce Plan* [3] contains detailed estimates on attrition per year. It also provides an estimate of the improved controller productivity that can be gained by implementing several workforce initiatives. Based on the estimates in the *Workforce Plan*, the FAA will need to hire 12,500 controllers between 2005 and 2014.

Current FAA training delivery methods have not kept pace with advances in simulation technologies and scenario-based instruction. Enhancements to the present training delivery methods are also needed to accommodate the implementation of new automation capabilities and the operational changes that will result from their use.

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Through extensive collaborative efforts over the last decade, the aviation community has given careful consideration to the evolution of the NAS. A broad overall community consensus [4-6] has been achieved for a proposed NAS evolution that addresses expected traffic growth, while increasing the flexibility and predictability afforded to NAS users. This proposed evolution relies on investments by NAS users and the Federal Aviation Administration (FAA) to sustain the current level of service, to strategically position the NAS to facilitate its evolution, and to provide new and improved services.

The on-going deployment of the User Request Evaluation Tool (URET) [7] has begun the transition to a more strategic ATC system. URET replaces paper flight progress strips with electronic flight data. In addition, URET provides a conflict probe capability that notifies the controller of predicted aircraft-to-aircraft and aircraft-to-Special Activity Airspace (SAA) problems and allows the controller to create trial plans for possible flight plan amendments. The controller can use trial planning to check for predicted problems before issuing a clearance and entering the amendment. The availability of problem prediction through URET is the initial step in a shift away from tactical operations that rely on the controller's ability to maintain a mental image of aircraft current and projected positions, toward strategic operations that begin using the ATC automation to predict problems. The URET national implementation is scheduled to be completed in 2006.

The proposed new automation capabilities are expected to be deployed incrementally, moving toward an end state that relies on the automation to predict problems and identify NAS-effective potential resolutions. For example, trial planning will be integrated into menus used to assign speeds, altitudes, or routes; problem prediction and trial planning will become available on the radar console; and the types of problems addressed by problem prediction and trial planning will be expanded to include weather and traffic flow problems. Each of these increments will change the way controllers perform their jobs, and each will require its own training regiment with dedicated controller hours and training support personnel. In combination, the new automation capabilities will affect the needed skills and knowledge mix of the controller workforce. It will also provide the opportunity for controller specialization that would result in increased efficiency while lowering overall costs.

Since controllers will rely less on their ability to predict problems using radar and flight plan information – the automation will support the controller in predicting problems and identifying solutions – their skills and training must prepare them to understand the strategic nature of system generated information and respond to it by appropriately applying decision support and communication capabilities. The selection of controllers and development of training curriculum must be forward looking. It must respond to this expected shift in skills and training needs to create a controller workforce able to maintain safety and promote efficient traffic movement through the NAS.

II. Advanced Training Technologies

The MITRE Corporation's Center for Advanced Aviation System Development (CAASD) recently reviewed the current controller training process and curriculum in order to make recommendations for a possible restructuring of the FAA training program. In addition to reviewing training programs at several FAA operational facilities, MITRE CAASD also:

- Reviewed airline and military training programs for jobs that require similar skills and levels of proficiency
- Reviewed state-of-the-art training systems currently offered by industry
- Estimated the levels of fidelity that can be obtained with simulations
- Examined how advanced technology can play a more prominent role in the controller training process

Based on the review, MITRE CAASD provided recommendations to the FAA [8] that would lead to shorter training times to achieve Certified Professional Controller (CPC) status, reduced training costs, and improved overall training effectiveness. These recommendations include:

- Move the acquisition of basic ATC knowledge as early as possible in the process
- Centralize more of the training program in order to reduce field facility requirements
- Perform concurrent Radar and Radar Associate training
- Facilitate accelerated learning (mitigate weaknesses)
- Train for a specific facility/area as early as possible
- Integrate advanced simulation technology into the training process

A summary of CAASD's review of advanced technology in the areas of military training, scenario based instruction, voice recognition and synthesis, and intelligent tutoring systems is presented below.

A. Military Training

In 2000, the United States Air Force had the challenge of meeting a forecasted increase in civil and military air traffic while experiencing chronic controller shortages in their tower and radar approach facilities. Controller shortages were forcing a reduction in operating hours at 30 of 75 operating bases. These problems were solved by overhauling the training program over a two year period. Academy curriculum was changed to focus on projected assignments for either tower or radar approach facilities. The new curriculum with advanced simulation and concentrated specialized training mirrors the Air Force's training program for pilots.

Self-paced, web-based training, which included learning-game applications, interactive simulation, and high-fidelity simulation training were implemented. The goal was to increase simulator training time in both tower and radar labs to produce a higher-quality trainee with more exposure to the complexities of the career field to help reduce qualification times in the facilities. According to "USAF ATC Tower Operator Course Takes Off" in Intercom [9], the number of graduates from the ATC Operator Apprentice School at Keesler Air Force Base went from 120 to 619 a year with the same instructor staffing level. Appraisal scores improved and the time for certification was reduced.

Currently, tower simulation systems with voice recognition are being deployed for tower facility training. With the simulator at the facilities, there has been a reported reduction in site-specific training time of 50%. Additionally, at low traffic density towers, the new simulator has aided in providing critical refresher and remedial training for certified controllers. Steps have been taken to introduce facility specific training at the academy. The goal is to provide site-specific airspace indoctrination training prior to arrival at the new facility thereby reducing the time required for On-The-Job (OJT) training and initial certification.

B. Scenario-Based Training

Scenario-based instruction is learning by immersing the trainee in operational situations with great frequency and in a compressed timeframe. The trainees are able to replicate their behavior with increasing skill as they practice. In order to provide sufficient practice to bring a trainee to a high level of proficiency prior to the OJT, a robust set of scenarios is needed for each sector in the facility. The scenarios will contain all of the normal and most of the less frequent operational conditions that require practice. Multiple scenarios are needed for the more difficult operational situations so that the trainee can practice with realistic variations in the traffic.

Building the number of scenarios that the FAA will need to use this instructional approach will require the integration of live traffic data recordings and simulation capabilities that can use that recorded data. Data that contains tracks, flight plans, amendments, and other important information will be needed to construct the scenarios. Scenario authors will select data recordings based on training objectives and knowledge of the traffic and environmental conditions that occurred for a date and time period. Scenario generation tools will filter the data for a sector and time period relevant to the operational context needed for training. During the training exercise, the traffic will be subject to change in response to clearances issued by the trainee. All other flights perform as they did in the live recording.

This process will allow scenarios to be created for different operational conditions very quickly as compared to the traditional methods used for creating simulation scenarios. It will be possible to make a traffic situation available to the trainees that occurred the day before.

A scenario can also be modified through manual entry by the author and then saved as a new scenario. Modifications include adding new data such as a new flight or modifying existing data, such as changing a flight's altitude or coordination time. It is expected that a scenario created initially from recorded data will require some modification to add information such as text messages for presentation to the trainee to simulate weather reports and traffic restrictions and messages for voice synthesis to simulate pilot initiated communications.

Learning not only requires practice with realistic scenarios but also feedback from instructors or the system as to the trainee's performance during the simulation. Instructor feedback can be immediate with frequent replays of the events until the trainee understands the mistakes and can make corrections. Feedback can also come from the system or in an after action review.

C. Voice Recognition and Synthesis

In traditional ATC training simulation, aircraft targets are typically controlled by pseudo pilots; that is, trained operators who manipulate multiple targets according to commands received via the simulated radio channels from a trainee controller. Similarly, "ghost" controllers are used to simulate inter-sector communications for coordination. Running a simulated exercise typically requires several pseudo pilots and ghost controllers along with administrative staff , thereby significantly increasing the cost of a simulation exercise.

Assuming technological effectiveness, the use of voice recognition to process trainee commands can solve many of the shortcomings in traditional ATC training simulation. Voice Recognition and Synthesis (VR&S) allows the trainee to operate simulations and run scenarios without the need for pseudo pilots, ghost controllers, or administrative staff. Simulations using VR&S can be developed for specific sectors allowing the trainees to develop skills by practicing in realistic situations and prepare for specific assignments. They can practice at their own pace and focus on identified weakness that could be improved with additional practice.

Another benefit is that VR&S teaches standard ATC phraseology. Pseudo pilots and trainees can let non-standard, easily recognizable language slip into their ATC communications. The VR&S ensures that pseudo pilots and ghost controllers respond correctly to any non-standard language, thereby reinforcing proper phraseology.

In order to explore issues related to the use of speech recognition and synthesis to support ATC training, CAASD developed a prototype trainer to serve as a test and demonstration system. The prototype was built on top of the existing CAASD en route ATC experimentation capability. A fully-automated VR&S pseudo pilot capability was developed to operate as a replacement for the existing human-assisted capability. This fully-automated pseudo pilot capability incorporated commercial-off-the-shelf automated speech recognition and text-to-speech software, which was adapted to handle the vocabulary, grammar, pronunciation and prosody of controller-pilot radio communications.

The fully-automated capability performs several key functions. For controller-initiated communications, it recognizes the controller's speech, synthesizes an appropriate pilot readback, and passes appropriate aircraft flight instructions to the simulation trajectory modeler to simulate the aircraft's response to the ATC clearance or other control instruction. For pilot-initiated communications, such as aircraft call-in, it synthesizes and delivers the pilot's speech to the controller. The rules for controller phraseology were extracted from *Air Traffic Control* [10]. The rules for pilot phraseology were adapted from examples provided in the *FAA Aeronautical Information Manual* [11]. A subset of the rules and phraseology sufficient to support ATC operations at a Dallas-Fort Worth Center approach sector was implemented.

The prototype trainer is a valuable tool for communicating key concepts, identifying potential problem areas, and allowing the evaluation of alternate software designs. The experiences with the prototype trainer, along with research into the use of voice recognition in tower simulations, confirmed that voice recognition and synthesis technology has significantly matured and is viable for ATC simulation applications.

D. Intelligent Tutoring System

While VR&S allows for more independent operation, it is strengthened by the use of intelligent tutoring features. An Intelligent Tutoring System (ITS) provides an environment for a trainee to learn, practice, and receive automated feedback on ATC skills at various levels of training in a more self-paced environment that accelerates skill acquisition [12]. Classroom and Computer Based Training methods are effective for acquiring basic knowledge. Simulation and live practice are needed to acquire more specialized and complex skills. Practice allows the trainee to continually go over a problem area, correct errors, and obtain informative feedback.

ITSs are a proven technology in several domains similar to ATC in cognitive complexity, where they have been shown to deliver significant benefits in terms of increased instructional quality and reduced training time. The following are examples of ITSs in use.

<u>Modeling Complex Cognitive Skills.</u> The skills of an F-18 Naval aviator were modeled in an ITS prototype air tactics tutoring system, which was integrated with shipboard mission rehearsal systems. The ITS can provide carrier-qualified pilots with instructional feedback automatically while they are deployed at sea, where no instructors are present. [13]

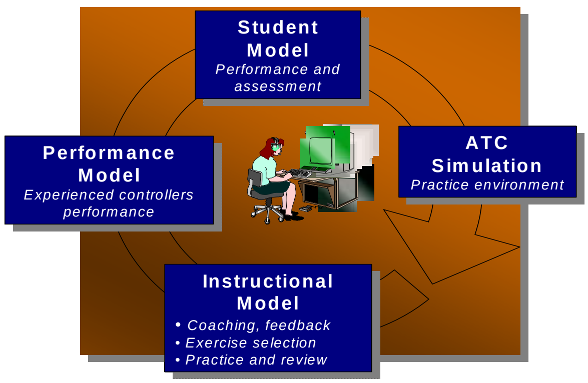
<u>Increased Opportunity to Practice.</u> The most important factor for maintaining a U.S. Navy Tactical Action Officer's (TAOs) tactical decision-making skill is the opportunity to practice making decisions and the receipt of timely feedback. The TAO ITS in shipboard use since 2001 increased the amount of such practice by a factor of ten. [14]

<u>Reduced Time to Skill Mastery</u>. Air Force technicians who practice with SHERLOCK, a computer-based coached practice environment, show marked improvement in difficult troubleshooting skills: After practicing for 20 hours in SHERLOCK, technicians' troubleshooting skills tested equivalent to those of technicians with four years of

experience. SHERLOCK's strategy is to provide holistic practice in a realistic context, supported by tailored coaching on request [15].

Significant Learning in a Simulated Environment. The Virtual Environment for Submarine Ship Handling Training (VESUB) technology demonstration system was evaluated for training effectiveness. Improvement of 30%-50% was found on eleven of the fifteen variables for trainees at all experience levels. [16]

An ITS consists of four primary components as shown in Figure 1.



The **ATC Simulation** Suite provides a realisti emulation of the operational environment that "developmental" (i.e., a controller in training) i expected to interact with to practice job tasks Simulations will include air traffic scenarios appropriat for the instructional objectives and skills that the traine needs to practice. From this environment, the ITS wil monitor and record the trainee's performance.

The **Instructional Model** identifies and prioritize activities recommended for the mastery of specifi skills. These activities consist of providin coaching/feedback, review of relevant materials, an follow-on scenario recommendations.

The **Performance Model** specifies the desired an baseline expected performance against which the traine will be compared. The ITS will compare the traine records against expected performance and use th instructional model to recommend the next activities fo the trainee.

The **Student Model** (Developmental Model) keep track of trainee performance for the scenario, course topic/skills, and any other learning activities that th trainee is performing.

Figure 1. Primary Components of Intelligent Tutoring Systems

III. ATC System Evolution

The evolution of the NAS is outlined in the RTCA document *National Airspace System (NAS) Concept of Operations*[4], and the Federal Aviation Administration (FAA) documents *Air Traffic Strategic Vision* [5] and *An Integrated Plan for the Next Generation Air Transportation System* [6]. Included in these documents are descriptions of new airborne and ground system automation capabilities that will affect the way controllers provide ATC services. There is broad agreement that controllers' highest priority activities will continue to be safety related, for example, issuing clearance changes to resolve predicted problems with other aircraft and implementing flow constraints associated with Traffic Flow Management (TFM) strategies. However, specific controller tasks are expected to change with increased automation support. For example, routine tasks, such as handoffs, pointouts, transfers of communication for data link equipped aircraft, and updates to display postings, will be accomplished automatically with controller action required only for exception situations. Decision support tools will help the controller with strategic problem prediction, problem resolution, and implementation of TFM strategies. These changes will produce increased controller productivity and sector capacity. Training will be needed for each new automation capability introduced.

URET provides electronic flight data and a conflict probe capability that notifies the controller of predicted aircraft-to-aircraft and aircraft-to-SAA problems and allows the controller to create manual trial plans as possible flight plan amendments. It automatically creates and maintains a Current Plan for any flight plan it receives from the Host Computer System (HCS) or a URET system in another facility. Current Plans are modified automatically to reflect flight plan amendments received. For each Current Plan, the system creates and maintains a trajectory, which is a sequence of converted fixes and route segments, altitude data, and time at fixes that describe a flight.

Current Plan trajectories represent the predicted path of the flight, and are checked for conflicts by the Automated Problem Detection function. It predicts aircraft-to-aircraft and aircraft-to-SAA conflicts by probing an aircraft's trajectory up to 20 minutes into the future (40 minutes for airspace) and provides notification of those conflicts to controllers. The controller can also check a proposed flight plan amendment for problems using the trial planning capability. When the controller creates a trial plan, automated problem detection checks for problems with the trajectories of all Current Plans. The results for the trial plan are displayed to the controller who created the trial plan and indicates whether the trial plan has conflicts or not. The URET Computer-Human Interface (CHI) is presented on the data console that contains a 20-inch flat panel on an articulating arm used to display aircraft and conflict information, as shown in Figure 2.

Figure 2 Radar Associate and Radar Consoles

The console has its own computer input devices (keyboard and trackball) to access the URET capabilities and send flight plan amendments to the HCS. The CHI consists of several display windows and a menu-based message entry capability, including a list of aircraft identifications and relevant flight data for each aircraft of interest to the controller. Automated problem detection results, including notification of any problems, are displayed to the controller. The controller can request a graphic representation of problems showing the trajectories of each aircraft involved in the problem.

A. Conflict Information on the Radar Console

While URET is implemented on the radar associate console, the underlying operational concept is derived from earlier research that supports an evolution toward a more integrated implementation of conflict information at the sector. Recent operational feedback has supported this, indicating that specific enhancements can increase the usefulness and benefits of URET conflict information. One such enhancement is to "tune" the conflict detection logic to perform better in a tactical timeframe, i.e., for encounters that are predicted to occur only a few minutes into the future. Another is a redefinition of alert coding logic that would enable the controller to better plan and prioritize the resolution of those predicted conflicts. These enhancements are expected to be beneficial in themselves, but in a broader scope, are considered prerequisites to the next evolutionary step of integrating URET conflict information on the radar console. Providing conflict information on the radar console involves the integration of URET conflict information with the information currently provided by the HCS on the radar console. The HCS processes flight plan and radar data, and provides the backbone for en route automation. Networked to the HCS is a set of display systems at the sectors, known as the Display System Replacement (DSR) or simply the

Display System. The radar console contains a 20-inch by 20-inch display and associated display hardware used to display radar and aircraft position information. The console has computer input devices (keyboard and trackball) to compose messages for input to the HCS.

The HCS architecture inhibits the integration of conflict information at the sector. However, the introduction of the En Route Automation Modernization (ERAM) system will significantly reduce the difficulty of that integration. ERAM has been designed to provide the platform and processes for major functional enhancements and new capabilities. It provides a modular, expandable, and supportable infrastructure based on the DSR, URET, and other existing baselines. It replaces the HCS and Direct Access Radar Channel (DARC) hardware and software, along with the associated interfaces, communications, and support infrastructure. ERAM consolidates ATC flight data processing into a single entity and controls both sector position interfaces through an expanded DSR, thereby providing an infrastructure that promotes information sharing across the consoles.

The integration of problem prediction at the sector is either closely related to, or will be a building block for, additional capabilities as the NAS evolves. Based on prior CAASD work [17, 18], the following sections describe some of the expected advanced capabilities and their relationship or dependence on integrating problem information at the sector.

B. Assisted Trial Planning

URET provides menus to facilitate the entry of new assigned altitudes, speeds, and route modifications including direct-to-downstream fix maneuvers. Each menu contains a set of respective altitudes, speeds, and fixes. Assisted trial planning is an enhancement to these menus that utilizes a series of trial plans in the particular dimension, for example, a set of trial plans for a range of altitudes above and below the current cruise altitude. The trial plan results are used to color-code the corresponding menu entries, for example., a menu entry for a climb to FL330 would be coded red if the trial plan to that altitude has at least one conflict that is coded as red. Thus, a determination of which alternatives are conflict-free can be made by simply viewing the menu. Assisted Trial Planning can also be used to quickly determine whether a maneuver requested by a pilot is predicted to have any problems. Since the trial planning capability already exists, only the color of the entries is affected on the menus and no new displays are required, Assisted Trial Planning is likely to be considered as an early enhancement to the ERAM system.

The implementation of the Air Traffic DSR Evolution Team (ATDET) “Full Data Block” capability on the radar console situation display provides a set of menus for the selection and entry of altitude and speed amendments, similar to those provided by URET. Although these are independent in the HCS architecture, the expanded DSR in the ERAM architecture would facilitate the integration of Assisted Trial Planning information across the sector. As with URET, only the color-coding of the existing menu entries would be affected, making this integrated capability a likely candidate for an early ERAM enhancement. Further, Assisted Trial Planning represents an initial trial planning capability without the need to (necessarily) provide a graphic trial planning capability on the radar console, a potentially more complex endeavor.

C. Reduced Separation Minima

Area Navigation (RNAV) is a method of navigation that permits aircraft operations on any desired course within the coverage of station-referenced navigation signals or within the limits of self-contained system capability. Required Navigation Performance (RNP) is a probabilistic approach to evaluating an aircraft’s deviation from its intended course. RNP values, for example, RNP-2, indicate a distance in nautical miles and probability level that the aircraft will be within that distance from its intended course.

RNAV will allow aircraft to fly routes that do not necessarily follow the ground-based navigational aids but rather fly direct from (latitude/longitude) point to point. Although this increases the user’s efficiency, it presents a more complex traffic picture to the controller. Presenting conflict information on the radar console will augment the controller’s ability to monitor and project future aircraft positions as the complexity of the traffic increases, allowing the controller to focus on the higher level tasks of analysis and decision making.

RNAV RNP will also present the opportunity for the FAA to reduce separation minima between suitably performing aircraft. Applying different separation minima based on aircraft and aircrew performance would add to controller workload. The impact on workload can be limited, or alleviated, by trajectory modeling and conflict detection that accounts for specific aircraft and crew performance characteristics. In an environment consisting of mixed levels of aircraft and air crew performance, automated conflict detection based on the specific minima applicable between aircraft pairs provides the best opportunity for the controller to apply the appropriate minima. This information will be of particular value when presented on the radar console.

D. Conflict Information for Additional Types of Problems

The conflict prediction capability is expected to be enhanced to address problems other than aircraft-to-aircraft and aircraft-to-SAA conflicts. It will continually check the trajectories of aircraft to determine whether the aircraft will be predicted to have aircraft-to-severe weather forecast, aircraft-to-congestion Flow Constrained Areas (FCA), and aircraft-to-Miles in Trial (MIT) or aircraft-to-Meter Fix Time (MFT) problems. As these capabilities become available, the existing alert definitions will be augmented to provide recognizable, problem-specific alerts to the controller.

Severe weather conditions are a major source of user delays in today's NAS. Forecast changes in traffic loads, patterns, and characteristics will add to weather's impact. TFM flow strategies are developed to manage the reduction in NAS resource capacity due to severe weather and air traffic congestion. Expected improvements in weather information at the sector include:

- Distributing current-time and forecast severe weather information to the sectors, and providing notification when a flight is predicted to enter a severe weather area
- Providing problem prediction and resolution support to prevent the controller from inadvertently rerouting aircraft into congestion FCAs they have previously been excluded from entering
- Providing problem prediction and resolution support to controllers to assist pilots in avoiding severe weather

In response to severe weather and air traffic congestion, en route TFM personnel can constrain air traffic flows in an effort to balance demand and capacity, and to keep from overloading sector controllers. These flow constraints include congestion FCAs and flow rate constraints such as arrival and en route MIT and MFT constraints. Congestion FCAs define areas of air traffic congestion due to high traffic volume or complexity. They can be defined for either limiting air traffic through the airspace, or for excluding all air traffic from the airspace. Aircraft-to-FCA problems will be presented to the controllers to ensure aircraft are not inadvertently cleared to enter congestion FCAs and as a result, negatively impacting TFM flow strategies.

Currently MIT restrictions are conveyed to controllers verbally and visually by operational supervisors, or via General Information messages through the HCS. There is little automation in place in today's NAS to assist controllers in ensuring that aircraft complying with MIT restrictions. Controllers are required to determine which aircraft are subject to MIT restrictions by scanning individual aircraft flight plans. Without MIT automation support, controllers frequently maneuver aircraft in order to line them up in single file to visually assess their success at meeting the MIT restriction. This technique can cause unnecessary maneuvering, put faster aircraft behind slower aircraft, and underutilize space in the stream. Integrating notification of MIT restrictions into automated problem prediction will assist controllers in meeting the MIT restrictions, and decrease the number of last minute, large adjustments needed to meet them.

E. Automated Conflict Resolution

URET presents conflict information at the sector where the conflict is predicted to occur, even if the aircraft involved are not yet under the control of that sector. In theory, the controllers in that sector can use trial planning to determine a resolution and coordinate with the upstream sector currently controlling the aircraft to be maneuvered. However, coordination adds to the controller workload and in practice this type of coordination has seen limited use. Alerting the sector currently controlling one of the aircraft involved in the conflict (rather than the sector where the conflict is predicted to occur) would eliminate the need for this type of coordination. However, a capability to determine which of the two aircraft to maneuver is needed in order to identify which sector to alert.

An automated conflict resolution capability would generate several resolutions in different dimensions for a predicted problem and rank those resolutions according to operational considerations. Operational considerations could include minimum deviation from the flight plan, minimum deviation from a TFM reroute, the geometry of the problem, airspace characteristics, and constraints such as other aircraft, restricted airspace, and flow rate constraints. The set of resolutions could then be ranked to determine a most preferred, or highest-ranked resolution. The highest ranked resolution could then be used to determine the sector to notify of the predicted problem.

The highest ranked resolution could also be presented to the controllers with the notification of the predicted problem. The controllers in the notified sector could use the highest-ranked resolution or trial planning to resolve the predicted problem. Since the sector controlling the aircraft implements the resolution, the need for coordination is removed. Providing the notification to the sector in control of an aircraft involved in a conflict, rather than notifying the sector where the conflict is predicted to occur, allows for more strategic resolutions that will be more efficient than those provided tactically.

IV. ATC System Evolution and Advanced Training Techniques

Effective use of the potential automation capabilities described above presents a number of training challenges and opportunities to the FAA. A high-level discussion of these is presented below.

Each capability will require its own training regiment. The capabilities described above will be introduced incrementally, in an evolutionary manner. For example, the problem prediction capability currently will be enhanced to predict airspace-to-severe weather and airspace-to-TFM initiative (congestion flow constrained areas and flow constraints such as miles-in-trail) problems. It will migrate from the URET displays at the data console to the situation display on the radar console. Automated problem resolution may follow a similar evolutionary path. Each increment will require controller training before it can become operational. The need for multiple training regiments could affect both the training budget and the deployment schedule.

The introduction of advanced capabilities will affect the skills and knowledge mix of the controller workforce and will raise complex human resource issues. Reliance by the controller on problem prediction and resolution capabilities will shift the controller's focus to strategic planning tasks and away from tactical monitoring, problem prediction, and coordination. These changes will create a need for new controller procedures, training, performance evaluation criteria, and controller selection criteria.

Areas of specialization may include distinct work domains and tasks. As the advances in automation become available, the controller roles and responsibilities will evolve to support a more strategic approach to air traffic control and management. The current Radar Controller will evolve into a Tactical Controller who relies less on creating and projecting a mental image of the traffic in the sector and more on the automation’s capability to predict problems and present problem resolutions. The current Radar Associate Controller will evolve to a Strategic Controller that assists in managing varying levels of sector workload by resolving strategic problems and implementing flow constraints for one or more sectors. Evolving roles and responsibilities will impact not only the training regiments, but also the skills required and, as a result, the selection and screening process.

Proper application and use of advanced capabilities will require in-depth training of controllers, TFM personnel, and Operational Supervisors. Although many of the advances allow the controller to rely on the automation, an understanding of more than just “button pushing and message format training” will be necessary to ensure the safe and efficient control of aircraft. The controller must have a firm grasp of how the automation is to be used, the mechanisms underlying problem prediction and resolution capabilities, management of the CHI, and the applicable operational procedures. Appropriate training in the use of automation and procedures will be needed to help controllers acquire situational awareness in non-typical situations, ensuring that controllers can effectively intervene and maintain safety in those situations. It has been suggested that the controller training need goes beyond the current technical training paradigm and should move into a more professional education and training process. [19] This would start by requiring a college degree with specific subjects such as statistics, probability, aircraft performance, airline business models, and other industry related classes. The screening tests for controller hiring would have reduced emphasis on tactical conflict detection skills and more emphasis on management of flows and dealing with the various parts of the ATM system.

Operational changes resulting from the new automation capabilities may simplify or generalize the training requirements in some areas or domains. For example, controllers in high altitude airspace will not be concerned with ground hazards, since the airspace will be far above ground-level. When all aircraft within a high altitude strata become equipped with RNAV, RNP, and data link communication capabilities, the use of navigation aids and air routes can be replaced by latitude/longitude points (or grid points) and user-preferred routes, so knowledge of the names and placements of navigation aids in a particular sector will become less important. As a result, controllers specializing in this airspace may be trained and certified for the “domain” rather than for a specific high altitude sector or for domains where knowledge of ground hazards and navigation aids are needed. Training costs could be reduced, and preparation for the tasks that apply across high-performance sectors could be emphasized.

A. Incorporating Lessons Learned from the URET Training Experience

When the URET Prototype was first installed at the Indianapolis and Memphis ARTCCs in 1997, CAASD developed the training materials. These included briefings and several desktop display systems that could run the URET software in simulation mode. After CAASD conducted the first few training sessions, the facility training specialists took over the training and continued to use the CAASD materials.

For the URET deployments that followed shortly after the initial deployments at Indianapolis and Memphis, the training emphasized the use of URET as a flight data management system, supporting the tasks of the Radar Associate Controller such as quicker entry of flight plan amendments. This training consisted of computer based instruction, lecture, and interactive work in the Dynamic Simulation laboratory. Controllers were trained on the automated conflict detection and trail planning capabilities, however, the use of these capabilities was not emphasized. Consequently, when controllers started using URET on the control room floor, the first features of URET with which the controllers gained proficiency were the flight data management features. When the controllers were ready to start using the URET conflict detection and trail planning capabilities, too much time had elapsed and they had lost much of the knowledge acquired during the initial training.

Subsequently, the training program was revised by the FAA's URET national training cadre with much more emphasis on interactive controller involvement with the conflict probe capabilities. The training contains more information on the management of predicated conflicts and the use of "best practices". The revised program is being delivered to the remaining URET facilities by training staff and specially trained controller cadres. The training package also has a module for area supervisors to help them recognize when staffing should be adjusted and how to use URET for special conditions, such as a radar outage.

This URET training experience indicates the need for extensive use of scenario based instructions and the limits to the effectiveness of using experienced controllers to provide training instructions.

B. Importance of Scenario Based Instruction

The URET training experience illustrates the need for scenario based instruction using advanced simulation technology for training controllers to properly use the new automation capabilities. URET flight data management features were effectively trained using traditional techniques, in part, because the desired outcome immediately followed the action. For example, an entry action to access flight information, enter an amendment, or resort a list, was immediately followed by a change in the information presented to the controller.

However, learning to use the strategic problem prediction and trial planning capabilities requires training that allows the controller to experience the results of an action that does not have an immediate effect. The goal of using problem prediction and trial planning is to strategically alter a situation that would result in a conflict at some time in the future. The avoidance of the conflict will occur in the future, at a time separated from when the action is taken. With such strategic capabilities, training scenarios must have a duration that encompasses the time that the tactical problem would have occurred, but didn't because it was solved strategically, in order for the controller to recognize the benefit.

Similarly, the training must provide the controller the opportunity to gain trust in the new automation capabilities, possibly by allowing the scenario to proceed until tactical intervention is needed, thereby illustrating that the strategic alert was, in fact, valid. Trust in the automation is most easily accomplished through repetitive training that encompasses the application of the capabilities in multiple situations and an understanding of the underlying algorithms and decision criteria. From a benefits perspective, it is important to understand the role of training as the means to ensure new automation capabilities and procedures are used as intended. Training the use of new ATC automation tools requires more than just learning the mechanics of the entry options that are available.

C. Role of Experienced Controllers in Training for New Capabilities

Current FAA controller training includes substantial OJT under the guidance of an experienced certified controller. Since by definition there will be no controllers with experience on a new capability, the role of controllers in providing training will be limited. The new training paradigm must rely on advanced simulation technology to instruct the controllers. The training must instill an understanding of the big picture, particularly in the case of benefits measured from a strategic or system perspective, rather than a tactical one. The use of ITS can ensure that the training materials provide a consistent description of the optimal use of the capability, thereby creating the maximum benefit from the capability. Experiencing the benefits must be part of training; a bulleted summary on a briefing slide will not be sufficient to convince the controllers of the value of the new capability.

V. Conclusions

The simulation capabilities of ERAM, that will be deployed in 2009, will resolve many of the deficiencies in the current simulation training capabilities that have plagued the system using the Dynamic Simulation (DYSIM) in the HCS. However, these enhancements still fall short of a complete solution for the delivery of training and skills development. The quality and cost effectiveness of training can be greatly improved by using advanced training technology as part of the training program. The extensive use of scenario based instruction, VR&S, and ITSs will be needed to ensure that controllers are trained in the proper application of new capabilities as the ATC system evolves.

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