PRESENTATIONS

## FAA AIR TRAFFIC CONTROL DIRECTIONS

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This presentation describes the Federal Aviation Administration's (FAA) Advanced Automation Program (AAP). Emphasis is on the program element referred to as Automated En Route Air Traffic Control (AERA), which touches on a few possible areas for future research in artificial intelligence (AI). The Advanced Automation System replaces the National Airspace System (NAS) Stage A with enhancements such as sector suite, functional enhancements and AERA 1. This will provide increased reliability, maintainability and availability; increased ability for the system to predict air traffic control (ATC) operational problems; and increased ability to accommodate future hardware/software/human operations (HW/SW) system capabilities.

FAA has a commitment to the nation, Congress, and industry to improve safety, improve productivity of air traffic controllers, and reduce maintenance and user costs. AERA has the objectives of allowing users to fly direct, fuel efficient routes, increasing controller productivity, and reducing operational errors.

### Advanced Automation Program

The FAA has divided the AAP into several individual elements in order to ease the transition and realize benefits on an evolutionary basis during the National Airspace System modernization. To go from today's system to a fully automated system in one step would be difficult and unwise. The first phase is the rehosting of the existing software on modern computer hardware. The next phase is to replace the existing plan view displays with a multiple display environment, which FAA refers to as a sector suite along with the development of a new hardware and software system. This system will include the first capabilities of AERA. The objective of this first phase is to remove existing operational constraints that limit the number of direct routes that can be safely granted. It has been estimated that this will result in a 3 percent fuel saving to air carrier and commuter operators. FAA refers to this first automation enhancement as AERA 1.

The next planned automation enhancement, AERA 2, has the objective of increasing controller productivity while maintaining all the advantages of the first phase. The FAA is in the process of developing a functional specification for this phase and plans to add this requirement to the AAS development when it is sufficiently well described so that the contractor can develop the software.

There is a final phase where all of the capabilities are tied together and the AAS will automatically generate and deliver to controlled aircraft conflict free, fuel efficient clearances. As this presentation describes the AERA capabilities in greater detail, the potential for application of AI techniques will become clearer. Figure 1 describes the AERA objectives.

### AERA Objectives

AERA 1 is now incorporated in the AAS specification and both of the design competition phase contractors are incorporating it into their designs. It was added to the contract in two pieces. AERA 1 is primarily an early detector of potential problems and tools that can help the controller in solving the identified problems. Problem identification specified by air traffic includes:

- Violation of safe separation distance
- Incursion into restricted airspace
- High sector workload.

AERA 1 has been generated in two parts:

- AERA 1 AAS Base Specification
- AERA 1 AAS Modification.

AERA 1 AAS modification was generated based on current operators' position that the base AERA 1 would not meet AERA 1's stated goal. However, the base AERA 1, if developed as a partial package, would increase workload with no payoff to airspace users. Therefore, AERA 1 is being developed in its entirety to achieve FAA acceptance.

The first AERA 1 was composed of a 4-dimensional trajectory estimator, an aircraft-to-aircraft conflict detector, an aircraft-to-airspace conflict detector, and a sector workload estimator.

Figure 1. AERA objectives.

**AERA 1**

- TO INCREASE THE NUMBER OF USER PREFERRED ROUTES GRANTED RESULTING IN MORE EFFICIENT USE OF THE AIRSPACE AND GREATER FUEL ECONOMY FOR USERS OF THE SYSTEM

**AERA 2**

- TO INCREASE CONTROLLER PRODUCTIVITY WHILE MAINTAINING OR ENHANCING SERVICES UNDER INCREASING DEMAND. AUTOMATION AIDS AND ADVICE WILL BE SUBJECT TO CONTROLLER APPROVAL.

**AERA 3**

- TO FURTHER INCREASE PRODUCTIVITY BY AUTOMATICALLY PERFORMING MANY CONTROLLER FUNCTIONS. SOME OF THE ACTIONS WILL BE UNDERTAKEN WITHOUT CONTROLLER INTERVENTION.

The 4-D trajectory estimator will project an aircraft's 3-dimensional position in time along the planned path that the pilot has filed. This capability is the foundation on which all the other FAA functions are built. It will make these projections for all controlled aircraft.

The aircraft-to-aircraft conflict probe will use these projections to determine when aircrafts' paths are predicted to cross within a specified distance and time. The accuracy with which it will predict position will determine the look ahead time that will be useful to display the predicted conflict to controllers. The present estimate is that this will be about 20 minutes. Naturally, the goals of minimizing false and missed alarms will conflict with the look ahead time. The engineering and operational tradeoffs will be made during the operational testing.

Similarly, the aircraft-to-airsapce conflict probe will look for predicted aircraft incursions into military operations areas and other types of restricted airspace. This look ahead capability could conceivably be for the entire flight since the restricted areas are precisely defined. The need for this capability becomes more important as more aircraft fly on the structured route system and controllers will be less able to look at a direct route and determine if there is going to be an incursion several sectors away.

Finally, the original AERA 1 sector workload factor will predict sector workload for each active sector. It will look at, as a minimum, traffic pattern complexity, predicted communications, number of aircraft in the sector, and number of climbing and descending aircraft. Both the raw data and an index will be provided to the controller and to supervisors.

Because the basic objective of AERA 1 was to increase the number of fuel efficient routings, an FAA Air Traffic Service sponsored AERA advisory group was established to review the AERA 1 functions in light of the stated objective. This group consisted of 6 en route and 4 terminal area active controllers who had the charter to conduct the review and make recommendations to FAA management on any changes necessary in the basic concept needed to achieve the objective. This team spent approximately 12 weeks reviewing the existing documentation, questioning the design and system engineers, reviewing AAS documents, and examining the implications that each of the proposed tools would have on their operations and how they might be applied in the AAS/sector suite environment. This review resulted in the recommendation that 6 additional functional capabilities be added to the AAS/AERA 1 system. After a review in headquarters, the AAS contract was modified to include essential parts of the group's recommendations and these are now considered to be integral parts of the first implementation of the AAS.

These additional capabilities are:

- Trial plan processing - Provides a controller with the capability to construct temporary flight plans that can be tested for problems by other automation capabilities,
- Conformance monitor - Periodically compare the trajectory of an aircraft with its track position to ensure that positions agree within parameter tolerances in the lateral, vertical and longitudinal direction,
- Reconformance aid - This function will create a trial plan that provides assistance to the controller for re-establishing vertical or lateral conformance between track and trajectory position,
- Detection of flow restriction violations - This function will detect and flag to controllers violations of local flow, central flow, metering, and airport restrictions,
- Controller reminders - Controllers will be alerted to planned changes in altitude with restriction notices, and expect further clearance information,
- Limited resolution aid - This capability will generate up to four trial plans when a problem is identified by other AREA tools and the controller requests help. The maneuver menu will include altitude change, lateral route offset, speed change, and vectors.

AERA 2

Next, the AERA 2 functional capabilities will be discussed. The objective of AERA 2 is to increase controller productivity. Current projections indicate that the volume of aircraft operations will increase substantially over the next decade. Studies and actual experience have shown that there is a maximum number of aircraft that an ATC specialist can safely control for a particular operational situation. Thus to handle this anticipated increase in traffic either the number of controllers must be increased or the control environment must provide more automation tools to reduce the workload per aircraft. Increasing the number of controllers and sectors quickly yields small marginal improvements in system capacity due to increased controller-to-controller communications and coordination. The FAA has decided that the best way is to increase the level of automation in order to allow ATC specialists to handle more aircraft and has bundled these automation tools into a program called AERA 2.

AERA 2 has the goal of providing automated problem resolution and clearance coordination and will allow the use of data link for clearance delivery. The problems that have been identified for automated resolution are aircraft-to-aircraft, aircraft-to-airspace, and flow restriction problems. The generation of these resolutions is complicated by the requirement that each of the resolutions be cross-correlated to assure that resolution of one problem does not cause another problem. In addition the resolutions should be acceptable and understandable to controllers and operationally feasible and fuel efficient for the system users.

Considering the mix of aircraft, the various operational environments, the total system demand and the localized high-use airport demands, reaction times of pilots and controllers in various workload environments, hardware and software capabilities and limitations on the ground and in the air, designing software that satisfies these complex and sometimes conflicting conditions will not prove to be easy. In fact, it will be a great challenge to build this system.

There are also several enhancements to the AERA 1 functions that will become operational concurrent with the implementation of AERA 2. These are:

- Enhanced situation monitor - This adds the capability to identify aircraft which were previously denied a route or altitude request due to airspace or flow restrictions when the restriction is changed or eliminated.

- Enhanced conformance monitor - Adds a capability to notify a controller when an aircraft -- still in conformance -- appears to be headed for a violation of the conformance region,
- Enhanced trial planning - Adds a capability for the automatic re-evaluation of a trial plan at time intervals specified by the controller,
- Enhanced controller reminders - Reminders are extended to provide a more complete list of reminders for the controller.

Reviewing the above functions it becomes clear that the core and critical element of AERA 2 are automatic problem resolution (APR). A plan is being laid out to demonstrate the feasibility of developing an operationally useful APR function. This has been one of the concerns expressed by staff members of the General Accounting Office. They believe that it is important to demonstrate feasibility and productivity gains from implementing AERA functions. A method being looked at for this demonstration is the use of expert systems and rapid prototyping to build in incremental steps towards a full AERA 2 demonstration capability.

AERA 3

The final phase, AERA 3, has the goal of automatically generating conflict free, fuel efficient clearances to pilots without controller intervention. This program is in the early stages of research and functionally is undefined. Yet, it appears that AI could be used to advantage in automating many of the cognitive tasks that controllers perform today.

Finally, there are two important areas for future research:

(1) Development of an AI base simulation capability to use as an AERA evaluation tool;

(2) Degree of resolution intelligence that can be developed and used to solve ATC problems.

In conclusion, there is a real need to examine the proposed ATC system enhancements relative to the real and anticipated AI technologies to help FAA plan for their incorporation into our future systems.

DISCUSSION

Question When you say "Limited Resolution" do you mean that the resolution is limited or the aid is limited?

Paul J. Neumann Both - the way the system is currently envisioned there would be a limited number of resolution strategies resident in the machine and, if no resolution was identified, the controller would be notified of the failure of the machine to find a resolution. The controller could not expect to find a machine generated solution to every problem. In addition the resolutions might not supply a resolution that was problem free for the probe time horizon. For example, a conflict could be resolved but the resolution would cause a future flow problem.

However, the limited resolution aid provides an opportunity for the introduction of artificial intelligence into the ATC system. It should be noted that this is an opinion not shared by all in the FAA. It appears that techniques now employed in expert systems would yield resolutions that would be more acceptable to controllers and pilots than a strictly mathematical solution of trajectory equations and conflict avoidance maneuver strategies. Introduction of AI technology into a tool that was not necessary for operational safety, since the traffic in this environment would be essentially the same as in the pre-AAS environment, would allow the evaluation of AI performance in the ATC environment and provide a knowledge base for the development of the more sophisticated AERA 2 resolution strategies.

Question You have been talking primarily about things related directly to controller productivity. In reducing costs there are other avenues for reducing operational costs and increasing controller productivity. I am thinking primarily of the maintenance area where AI could have an application and system reconfiguration when you have hardware failures. Do you have any idea of how relative operational costs of control versus these other support capabilities stack up?

Paul J. Neumann The primary expense to FAA is salaries of both controller and maintenance personnel. Maintenance costs are being controlled through the replacement of existing equipment with highly reliable solid state equipment, including the current 9020 computers with IBM host computers. The application of AI to maintenance of electronic equipment was being looked at by Dr. Siewierek of Carnegie Mellon University. The FAA was jointly funding research on building an expert diagnostician but unfortunately the program ran out of funding. Steve Alvania from AES-320 may speak about that later.

The major personnel costs to the FAA are incurred in the Air Traffic Service. FAA looks at gains in controller productivity as being relatively more important because of the larger cost saving if the same percentage is applied to that side of operations.

Question The user is troubled today because of severe flow control restrictions. In AERA 1 it seems that you are planning considerable research in automation. Why are flow restrictions, metering, and airport restrictions included?

Paul J. Neumann FAA is looking for more flexibility in the AERA 1 system that will minimize reliance on imposing restrictions. However, considering the projected growth in traffic, it seems to be prudent to plan for some restrictions in capability limited and impacted areas.

Question It seems rather than expediting traffic through the use of AREA 1, you are continuing to plan for the imposition of restrictions.

Paul J. Neumann At the moment no one envisions that flow control will go away in the near future. FAA cannot control weather events which may reduce capacity or close airports. Nor can FAA control the demand that users put on airports at specific arrival and departure times. Someone here may be smart enough to come up with a way to devise an AI system that devises a solution.