DOT/FAA/AM-03/19
Office of Aerospace Medicine
Washington, DC 20591

FAA Strategies for Reducing Operational Error Causal Factors

Julia Pounds
Civil Aerospace Medical Institute
Federal Aviation Administration
Oklahoma City, OK 73125

Anthony S. Ferrante
Federal Aviation Administration
Air Traffic Investigations Division
Washington, DC 20591

November 2003

Final Report

U.S. Department of Transportation

Federal Aviation Administration

NOTICE

Technical Report Documentation Page

1. Report No.	2. Government Accession No.	3. Recipient's Catalog No.
DOT/FAA/AAM-03/19		

4. Title and Subtitle	5. Report Date
FAA Strategies for Reducing Operational Error Causal Factors	November 2003
7. Author(s)	**6. Performing Organization Code**
Pounds J[1], Ferrante AS[2]	8. Performing Organization Report No.
9. Performing Organization Name and Address	**10. Work Unit No. (TRAIS)**
[1]FAA Civil Aerospace Medical Institute P.O. Box 25082 Oklahoma City, OK 73125 [2]FAA Air Traffic Services 800 Independence Avenue, SW Washington, DC 20591	11. Contract or Grant No.
12. Sponsoring Agency name and Address	**13. Type of Report and Period Covered**
Office of Aerospace Medicine Federal Aviation Administration 800 Independence Avenue, SW Washington, DC 20591	14. Sponsoring Agency Code

15. Supplemental Notes

Work was accomplished under approved subtask HRR-524.

16. Abstract

The FAA has historically tried to understand and mitigate the incidence of operational errors (OEs), focusing on the critical component of the system—the closest person to the air traffic situation and the last point of prevention—the air traffic controller. With the human element as the foundation of such a complex system, several initiatives by the FAA Office of Evaluations and Investigations Staff include: have focused on human performance within, and interacting with, the larger system. These have included implementing a coordinated system of investigations to identify causal factors, fielding automation to re-create events, developing metrics to categorize OE severity, and sponsoring unique performance enhancement programs.

17. Key Words	18. Distribution Statement
Air Traffic Control, Causal Factors, ATC Performance, Operational Errors, Human Factors	Document is available to the public through the National Technical Information Service, Springfield, Virginia, 22161

19. Security Classif. (of this report)	20. Security Classif. (of this page)	21. No Pages	22. Price
Unclassified	Unclassified	14	

Form DOT F 1700.7 (8-72) Reproduction of completed page authorized

FAA Strategies for Reducing Operational Error Causal Factors

Introduction

The US Federal Aviation Administration (FAA) oversees the largest, safest, and most complex aviation system in the world, relying on a workforce of highly trained air traffic control specialists who interact with an environment of radar, computers, and communication facilities to maintain the safety and efficiency of the system. In fiscal year (FY) 2000 alone, the US air traffic system handled 166,669,557 operations. Calculated as a percent of facility activities, the operational error (OE) rate per 100,000 activities increased from .60 in calendar year (CY) 1999 to .69 in CY00 and .74 in CY01, then declined by 11% to .66 in CY02[1] (FAA, 2003a). Although air traffic declined after the events of September 11, 2001, the OE rate reflects the continuing need to identify mitigation strategies.

The FAA has historically tried to understand and prevent the incidence of OEs. To accomplish this, an elaborate and detailed incident reporting system evolved to capture causal factors related to their occurrence. The data were intended to supply information about where to target intervention strategies, with several initiatives focusing on one critical component of the system—the air traffic control specialist (ATCS). Because the controller is the closest person to the air traffic situation and the last point of prevention, much attention was logically focused on controller performance. Indeed, a controller's action or inaction provides a channel through which pre-existing system vulnerabilities can be manifested. As Fisher (2002) noted, human error is the mechanism that translates this potential for making a mistake into an occurrence. Thus, performance of the controller will always be at the sharp end of the operational system (Dekker, 2002) in the complex and multifaceted environment of ATC. Whereas past initiatives focused on remedial training and targeted deficient performance, several recent initiatives have focused on human performance within, and as it interacts with, the larger ATC system, and viewed the human element as a fundamental part of this complex environment.

Initiatives

In recent years, the FAA Air Traffic Evaluations and Investigations Staff began several programs that focused more attention on skill building and performance maintenance rather than on remedial training. This approach is based on the philosophy of adult education and individual responsibility for maintenance of best performance rather than viewing training from a directive "schoolhouse" approach, often disparagingly referred to as the "blame and train" method. Initiatives included fielding automation to re-create traffic situations, developing safety metrics, analyzing incident data to identify performance enhancement opportunities, and sponsoring research to further develop the capability to identify causal factors.

Incident Re-creation

As computer capabilities increased, the idea that computer processing could be harnessed to re-create operational errors became a reality. During the 1990s, the FAA Civil Aerospace Medical Institute (CAMI) collaborated with the FAA Air Traffic Evaluations and Investigations staff and Atlanta air route traffic control center (ARTCC) to develop automation to graphically re-create radar data that were routinely recorded by en route air traffic control facilities.

Referred to as the Systematic Air Traffic Operations Research Initiative (SATORI), it was developed, tested, and fielded to all en route facilities and regional quality assurance offices with the goal of gaining "a better understanding of the interaction between the various elements of displayed information, verbal interactions, and the control actions taken by air traffic control specialists" (Rodgers & Duke, 1993, pg. 1). SATORI is still currently in operational use and enables its users to re-create segments of operational traffic in a format similar to what was displayed to the ATCS, for example, showing relative location and separation, speeds, and headings of aircraft. Among other things, SATORI can display full and limited data blocks, beacon targets, and conflict alerts. Video and audio are synchronized, and the air traffic situation can be displayed in four dimensions.

[1]Calculations of rates use 15 decimal places but are rounded to 2 places for the table on page 6 of the FAA Administrator's Fact Book.

Figure 1. SATORI system in use.

At en route facilities, SATORI systems enable the facility quality assurance staff to re-create OE situations for the controllers involved (see Figure 1).

It is important to note that the system was not intended to be used to "call" an OE; that is, to identify when an OE occurred. An OE was first determined to have occurred and *then* SATORI was used to review the situation. Systems located at regional and headquarters offices enable further incident review. FAA Order 7210.56 provides guidance for the use of all replay tools.

> As technological advances are made, the ATC system must adjust to these changes and ensure that radar reduction tools are used correctly and consistently throughout the system in order to provide the most accurate re-creation possible (FAA Order 7210.56, pg. 1-4).

After an OE is identified (or "called"), SATORI re-creations are useful in determining aspects of controller and/or pilot performance involved in the event. Re-creations can also be used to review peak periods of traffic flow ("pushes") and the effects of weather on traffic flow. Viewing the re-creation also helps to target specific skill enhancement programs for those employees involved in the event. In addition to helping with the identification of performance issues, re-creations of randomly selected traffic samples not related to OE situations have also been productively used to assess controllers' technical proficiency in relation to training.[2]

The first of its kind to harness the capability of computers to re-create air traffic situations, SATORI re-creations have also been used to provide assistance to other agencies' investigations of incidents involving aircraft. These have included the National Transportation Safety Board (NTSB), US Department of Justice, and the National Aeronautics and Space Administration (NASA).

In addition to performance management and investigation, re-creations of traffic samples not related to OEs have been used in human factors research at CAMI. For example, traffic samples were used to study sector complexity, controller workload, and performance (Manning et al., 2001; Mills, Pfleiderer, & Manning, 2002). TRACON SATORI, a prototype system for the terminal environment, was used to examine how controllers use information about aircraft relative position to maintain "the picture" of the traffic situation (Pounds, in review).

[2] Technical performance issues consist of areas of knowledge and application that might benefit from training. These issues are not necessarily areas of deficiency. An employee may demonstrate overall acceptable technical proficiency but might benefit from technical training in the application of a particular skill or task (FAA Order 7210.56, pg. 3-1).

Used effectively, the capability to re-create traffic situations can bring about beneficial changes in procedures, airspace, and future ATC systems. SATORI re-creations are currently being used in diverse ways to enhance system performance. It is anticipated that next generation re-creation tools currently being developed will continue to provide added value.

Calibrating Incident Severity

The FAA Evaluations and Investigations Staff monitors the frequency of operational errors to determine the system vulnerabilities contributing to each incident so that they can be identified and reduced. Once a relevant separation standard is violated by ATC, an OE is recorded. Every violation of separation standards provides an important opportunity for lessons learned and system improvement, although not all operational errors share the same characteristics. Separation standards and procedures differ depending upon, for example, the type of airspace, weather conditions, type of aircraft, and altitude.

A study conducted by Rodgers and Nye (1993) investigated whether the number of aircraft being worked by the controller or the traffic complexity at the time of the OE was related to its severity, defined in terms of vertical and horizontal separation between aircraft. Three categories were created by assigning a maximum of ten possible points each to the horizontal and vertical separation reported.[3] Based on the total point value, OEs were partitioned into categories of major (20 points), moderate (14-19 points), and minor (13 or less points) severity.[4]

Results of the Rodgers and Nye study were counterintuitive and demonstrated that neither number of aircraft nor traffic complexity was significantly related to major, moderate or minor OE severity, although the analyses revealed ways that the reporting process, and thus the resultant data, could be improved. The authors recommended gathering more normative rather than descriptive data, increasing the reliability of the reported data, and using a re-creation capability to permit investigators to review the dynamics of the air traffic situation.

The U.S. Department of Transportation, Office of Inspector General (December 2000) recommended that the FAA Air Traffic Investigations Division tackle the problem of modeling and defining severity for OEs in flight to describe the degree that the applicable separation standard was violated. The purpose was to group airborne OEs as low, moderate, or high severity and thus be able to focus resources on the most severe events and to identify factors related to specific categories of events. Data about systemic causes of OEs could then be used to more explicitly direct action towards prevention of future occurrences.

The FAA Air Traffic Evaluations and Investigations Staff developed a classification system to distinguish between OEs on these dimensions. Classification categories were developed to reflect the operational environment. In the first version of the index, an OE was classified on each dimension according to its severity—the *extent* to which separation distance was reduced—as low (39 points and below), moderate (40-89 points), or high (90 points and above) using a 100-point scale. Objective distances were used to minimize subjective interpretations of the data. Actual radar data from numerous operational errors representing en route facilities nationwide were used to test the adequacy of the categories and the classification methodology. The components of the model included elements associated with loss of standard separation, such as the relationship of the aircraft in conflict to one another (e.g., converging versus diverging courses), closure rate, and level of ATC involvement – whether the event was a "controlled" or "uncontrolled" OE. The point distributions for en route radar OEs are shown in Table 1. A similar table was developed for OEs in terminal and en route airspace with single-site radar.

The initial step in calculating error severity was to determine the lateral and vertical proximity between the involved aircraft. The horizontal and vertical distances were defined as the minimum separation based on the radar data just prior to aircraft divergence. Situations with faster aircraft closure rates, coupled with converging, opposite direction flight paths were assumed to present a greater threat than slower closure rates and diverging flight tracks. The idea was that head-on encounters with high rates of speed, coupled with minimum radar data separation distance prior to divergence should account for the greatest total point value in the model. An assumption was made that aircraft not crossing each other's paths greatly reduces the threat to safety, and consequently, does not receive severity index points (see Table 1). In addition, if aircraft are not converging, closure rates become less significant when the other parameters are properly factored.

This model does not imply in *any* way that any minimum separation less than those required by FAA Order 7110.65 is acceptable from an operational perspective. The main purpose of the ATC system is to preserve safety. To learn from the occasional shortfall in the ATC system, the controller's action prior to the OE was also included in the assessment of the total severity of an event. A "controlled" OE was defined as an OE where the controller was aware of the impending conflict and took corrective

[3] Vertical separation was subdivided depending upon whether the incident occurred below or above 29,000 feet (FL290).

[4] Of the 1053 OEs in their sample, only 15 (.01%) were coded as "major" severity.

Table 1. Radar OE Severity Index terminal and en route single-site chart (FAA Order 7210.56)

VERTICAL SEPARATION	POINTS	HORIZONTAL SEPARATION* 3-mile separation requirement	POINTS
Less than 500 feet	25	Less than ½ mile	25
500 feet to 599 feet	20	½ mile to 0.999 mile	18
600 feet to 699 feet	16	1 mile to 1.499 miles	14
700 feet to 799 feet	12	1.5 miles to 2 miles	10
800 feet to 899 feet	6	2 miles to 2.499 miles	6
900 feet to 999 feet	2	2.5 miles to 2.999 miles	2
CLOSURE RATE	POINTS	HORIZONTAL SEPARATION 2.5-mile requirement	POINTS
700 knots and greater	10	Less than ½ mile	25
300 knots to 699 knots	8	½ mile to 0.999 mile	20
100 knots to 299 knots	6	1 mile to 1.499 miles	16
Less than 100 knots	4	1.5 miles to 1.999 miles	10
FLIGHT PATHS	POINTS	2 miles to 2.499 miles	4
Converging - Opposite Courses	20	ATC CONTROL FACTOR	POINTS
Converging – Crossing Course	18	Uncontrolled	20
Same Course	10	Controlled with TCAS RA	15
Diverging/Non-Intersecting	0	Controlled with no TCAS RA	4
* When wake turbulence separation standards are governing, DO NOT include any vertical point value. Instead use the appropriate in trail separation index below, as well as other applicable factors.			

action to increase separation. An "uncontrolled" OE was defined as an OE where the controller was unaware of the conflict, took no corrective action, and/or became aware of the conflict but did not have enough time to effectively mitigate the loss of separation.

The severity model assigns a total of 100 points. Component categories are used to allot point values corresponding with their relative significance during the event. Table 1 shows the distribution of points possible for terminal and en route facilities with single site radar. For example, horizontal separation of less than one-half mile in airspace requiring at least 3 miles horizontal separation would be assigned a point value of 25; closure rate of 700 knots and greater would be assigned 10 points. These values would be summed with points from the other appropriate categories. The remainder of the 100 points left after the assigned points have been subtracted is the "safety factor." Figure 2 shows a hypothetical example of how the points in each category of the severity index can be used graphically to display the various elements of one OE. A different table is used for en route OEs requiring 5-miles' separation.

This severity index is an algorithmic approach, based on objectively measurable and observable variables in the operational environment. As the method was further developed, the initial three categories were split into four: High Severity (A); Moderate Severity, uncontrolled (B); Moderate Severity, controlled (C); and Low Severity (D). The four category model made it conceptually similar to, and potentially confusable with, less objective methods being used by other groups to classify incident types such as runway incursions.

Data-driven Focus on Performance

Analysis of OE data by the FAA Office of Investigations revealed several recurring causal factors, for example, readback/hearback errors and position relief briefings. As a result, interventions were initiated to address them. A series of videos was also produced to communicate several types of complex system vulnerabilities.

Readback/hearback errors. Readback/hearback errors occur if the pilot incorrectly repeats back to the controller the instruction or information just received from the controller and if the controller fails to catch the pilot's incorrect response. As an example, a readback/hearback error would be noted when the controller instructs "Piper 123 climb and maintain 1 – 0 thousand," but the pilot repeats back to the controller "Roger. Piper 123 climbing to 1 – 2 thousand." If the controller does not catch the pilot's error in the response, it would be classified as a readback/hearback error. Although these are human errors, they do not necessarily lead to an OE.

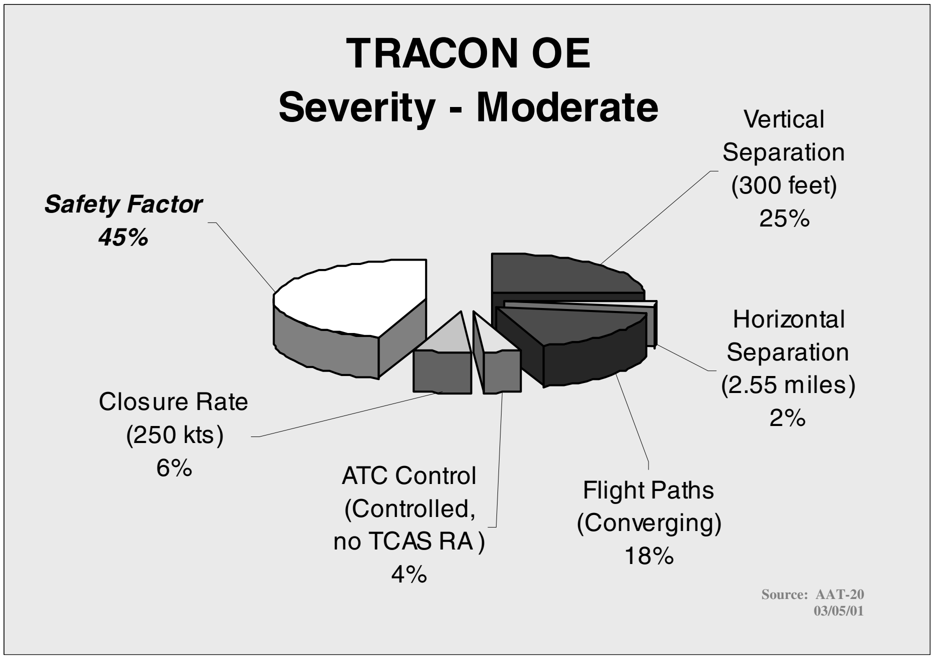

Figure 2. Sample of a moderate severity OE, with the percent of total points for each element shown.

Awareness programs targeting readback/hearback errors were developed by headquarters staff as well as by regional and facility groups. Facility programs included "tape talks" where voice recordings for the ATCS on a position were reviewed by the ATCS and/or facility staff specialists to assess communication performance. The Air Traffic Investigations Division Staff produced a video — "Preventing Readback Errors" – highlighting how different influences, such as ambient noise and distraction, can contribute to the occurrence of this type of error. The video was sent to all facilities as a mandatory briefing item. Based on its initial success, this awareness program became an annual event with January inaugurated as *Hearback – Readback Awareness Month*, which included constant emphasis on good communications skills, random tape monitoring to highlight examples of correct phraseology, and positive coaching.

Position relief briefings. Position relief briefings take place when one controller assumes (takes over) responsibility for a position from another controller, transferring responsibility from one controller to the other. The position relief briefing is a standard operating process designed to optimize transfer of responsibility while at the same time minimizing the additional workload associated with the task of transferring duty. The relieving controller previews the position and then indicates to the controller being relieved that the verbal briefing may begin. A checklist covers items to be noted prior to the relieving controller assuming responsibility for the position. The relieving controller observes the position and then the controller being relieved points out any abnormal items, traffic situation, and any other issues of concern using the checklist. Thorough coverage of the checklist items is meant to ensure that the relieving controller "has the picture" of the situation. That is, the controller being relieved ensures that the relieving controller sees all relevant information, understands the situation, and is aware of any potential conflicts or problems. After the relieving controller assumes responsibility for the position, the controller being relieved observes the overall position operation to determine if assistance is needed and provide or summon it as appropriate.

Trends in the OE data showed that OEs frequently occurred within 10 minutes of a controller taking over a position. Figure 3 shows the distribution of 1,056 OEs between 1997 and 2000, and the number of OEs that occurred within 5, 10, and 20 minutes of the controller taking over a position. As a percent of the total number of OEs (Figure 4), approximately 9% occurred within the first 5 minutes, 18% within the first 10 minutes, and 35% within the first 20 minutes on position.

An initiative to address this problem required all managers to validate position relief checklists, as well as provide a capability for recording the briefing. Shift

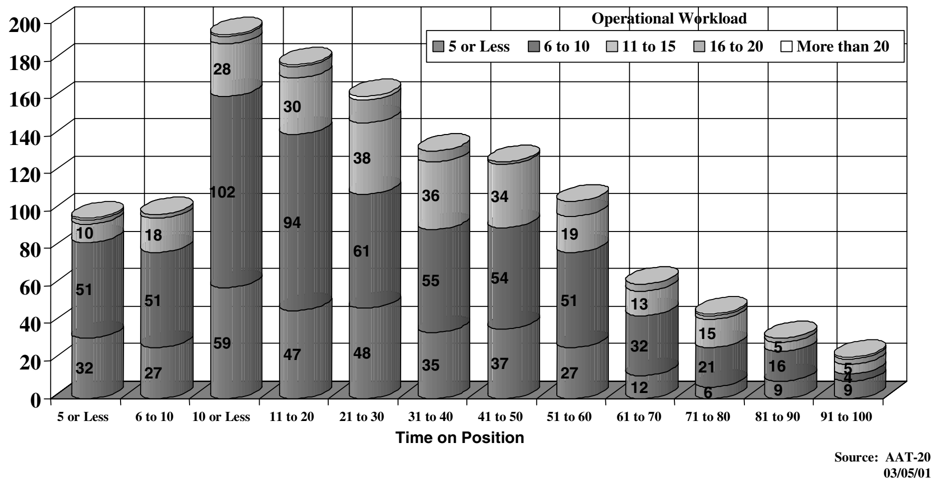

Figure 3. Number of 1056 OEs occurring relative to the controller's time on position and workload (FY 1997 through FY 2000).

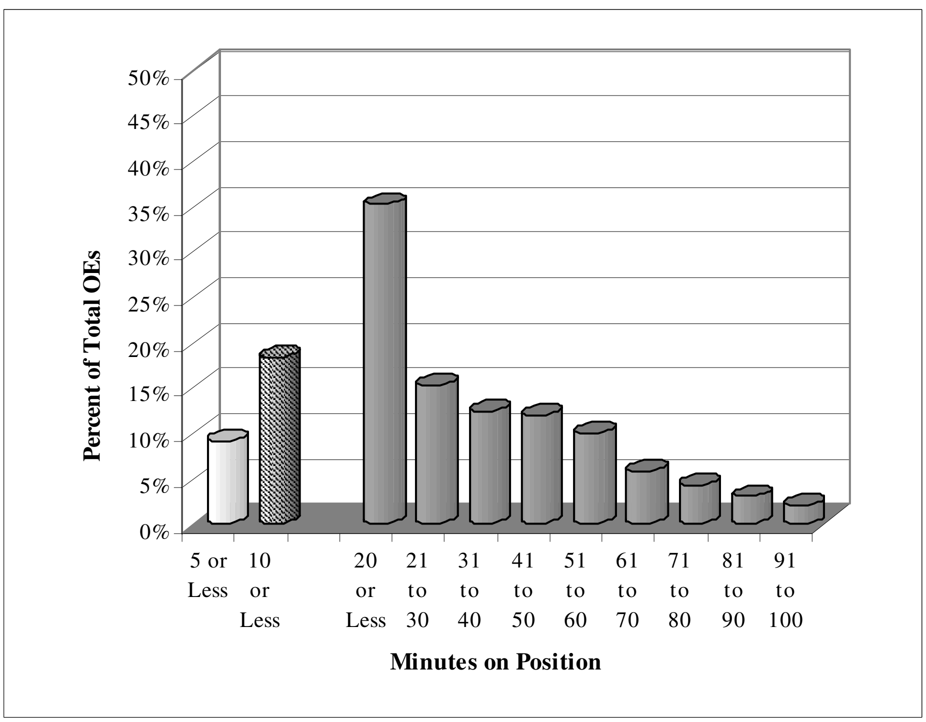

Figure 4. Percent of 1056 OEs occurring relative to the controller's time on position (FY 1997 through FY 2000 from Figure 3).

supervisors were required to ensure the use of a position relief briefing checklist and, where available, ensure that position relief briefings were recorded. Controllers were trained and encouraged to accept position responsibility only after they were fully aware of the traffic, and the relieving controller and the controller being relieved were to establish an appropriate overlap period to complete the transfer of responsibilities. Some facilities mandate a specific amount of time that the relieved controller shall remain at the position. Other facilities adopted this as a good practice and permit the overlap period to vary depending upon traffic demands. The intent in this latter practice is that basing the overlap period on traffic demand reduces the likelihood of potential distractions associated with multiple personnel remaining on the same operational position unnecessarily.

Video briefing materials. The Air Traffic Investigations Division Staff produced four videotapes to focus awareness on different types of causal factors found to be related to OEs.[5] Copies of these were sent to all FAA air traffic facilities to be used for briefing materials.

Accidents often occur after a series of inconsequential events that create links in a chain during which individuals have had a number of opportunities to intercede and break the chain. The "Break the Chain" video illustrates how events, if uninterrupted, can culminate in an accident and how attending to details can help break the chain of events and prevent accidents and incidents. The episode portrayed in the video is fictional but was compiled from actual events. A small business-owned aircraft is carrying a group of business executives to a meeting. The flight departs later than expected due to the passengers' late arrival and delays in air traffic services. The original plan was to depart ahead of developing stormy weather; however, the delay and the quickly developing storm result in moderate icing conditions. An aircraft mechanic, the passengers, both pilots, an airway facility staff specialist, and multiple air traffic control specialists (both terminal and en route) all either contributed in some way to the chain of events or failed to interrupt the sequence when they had the opportunity.

"Collision Course: What are the odds?" depicts an actual event, demonstrating how rare and improbable events can and do occur. Individually, each event would be fairly benign. However, as part of a chain of events, seemingly inconsequential errors can set in motion a series of events that cannot be undone. Outwardly insignificant errors committed, for the most part, by controllers in two air route traffic control centers, put two large jet aircraft on a converging course and that information could not be relayed from the ground to the aircraft because radio communications were lost. The video demonstrates how the failure to accomplish routine procedures such as switching an aircraft to another frequency, becoming momentarily distracted, or being complacent about an evolving situation can potentially result in *large* and unexpected adverse outcomes, although a midair collision was avoided in the event depicted.

"Consequences of Simple Omissions" is a compilation of actual events. This video illustrates examples of how small omitted actions, lack of attention, failure to follow operational practices, compounded by poor facility practices, and lack of self discipline or professionalism resulted in incidents ranging from operational errors to fatal accidents. The video advocates adhering to individual professionalism and remembering the importance of maintaining standards and accuracy for safety.

The video titled "Preventing Readback Errors," mentioned earlier, focused on communication strategies to reduce misunderstandings between controllers and pilots. Strategies include reducing the complexity of each communication and chunking information within the communication to facilitate understanding. Information is presented in a humorous manner to illustrate strategies to overcome common blocks to good communication.

Identifying OE Causal Factors

The need for a formal reporting process was recognized early in the FAA's evolution and by 1965, FAA Order 8020 had established the ATS System Error Reporting Program. Early on, recommendations were developed regarding the conduct of incident investigations and the use of the resulting information, many of which were incorporated into the Order (O'Connor & Pearson, 1965). For instance, O'Connor and Pearson suggested that any reporting system should be based on a system view, including controller performance, the influence of personal capacities and skills, the design and operation of the system, and modifiers of the working environment such as supervision, operating procedures, health, morale, and work schedules. Notably, recommendations made by O'Connor and Pearson remain as relevant today as they were then.

> Air traffic control has become an increasingly complex system involving men and equipment in a continuous and dynamic decision-making function. Future developments point to the rising use of complex equipment, including high-speed computers, as aircraft speeds and the system's load continue to rise. By projecting current trends, it can be anticipated that future system changes involving equipment, personnel, and/or procedures point to the need for longer and longer lead times as complexity grows. The above considerations point to the need for close scrutiny of the ongoing system failures and/or incidents in order to provide the most accurate feedback information for system correction or modification (pg 1).

Additionally, O'Connor and Pearson recommended an approach to system error evaluations, asserting that "the man-machine system will never be perfectly reliable, efficient, and error free because of the inherent limitations and idiosyncrasies of the human component" (pg. 1) and that a deliberate and objective process would be better than "shooting in the dark for sources of error and possible solutions" (pg. 1).

Later, other changes were periodically made to the incident reporting form. For example, in 1997 a version was fielded having three additional causal factors under the category of *Inappropriate use of Displayed Data.* This category was associated with the controller's use of the

[5] Ms. Christine Soucy, a safety investigator with AAT-200 wrote and helped direct the videos for this program.

radar display and situation awareness associated with use of the radar data. The three added items—*failure to detect displayed data, failure to comprehend displayed data,* and *failure to project future status of displayed data*—were included to address the controller's situation awareness. This change proved initially successful, with subsequent OE data showing that use of the *Inappropriate use of Displayed Data - Other* category decreased and the data that would otherwise have been attributed to this *Other* category distributed across these three new categories (Rodgers, personal communication). Although this change brought finer detail to the description of the OE, the issue of reporting reliability raised by Rodgers and Nye (1993) was still an issue.

Currently, the FAA Air Traffic Investigations Division oversees and coordinates the OE reporting process governed by the FAA Air Traffic Quality Assurance Order 7210.56 (FAA, 2002). The order "provides specific guidance on investigation, reporting, and recording types of incidents that impact the quality of air traffic services" (pg. i). Specifically, section 5-1-2 (pg. 5-2) stipulates:

> 5-1-2. SUSPECTED EVENT
>
> a. In order to maintain an effective Air Traffic System, it is imperative that we identify all deficiencies within our system and take appropriate corrective actions necessary to fix any associated problems. Operational errors and deviations are reported for just that reason, so those problems (either systemic or individual) can be corrected to enhance system integrity. The identification of operational errors and deviations without fear of reprisal is an absolute requirement and is the responsibility of all of us who work within our system.
>
> b. Accordingly, it remains Air Traffic Policy that any employee who is aware of any occurrence that may be an operational error, deviation, or air traffic incident (as defined in paragraph 4-1-1, Definitions), immediately report the occurrence to any available supervisor, controller-in-charge (CIC) or management official.

To develop information so that data-driven decisions about causal factors and intervention strategies could be made, the Office of Investigations determined that a method for identifying causal factors related to human performance was needed—a method that viewed human performance as one among several potential points of system vulnerability. Resulting information about human factors could then be proactively used to mitigate the potential for future incidents. This effort was responsive to goals in the FAA's 1999 Strategic Plan, including the goal to "eliminate accidents and incidents caused by human error" (FAA, 1999). The FAA's National Aviation Research Plan for 1999 also echoed the intended outcome of developing enhanced measures of human performance and increased understanding of factors that lead to performance decrements.

An initial effort was undertaken in coordination with the FAA's Civil Aerospace Medical Institute (CAMI) to determine whether retrospective analysis of existing OE reports could extract additional useful information by using a human factors approach (Pounds & Isaac, 2001; Pounds & Scarborough, 2002). The retrospective analyses relied on data from existing OE reports that were based on standardized procedures specified by FAA Order 7210.56. Outcomes from this work suggested that standard reporting procedures did not require facilities to collect the type of data necessary to perform a thorough human factors analysis. That is, although the report forms captured descriptive data about the OE, little information was collected about events and causal factors preceding and during the loss of separation.

As these retrospective analyses were being completed, the FAA Office of Aviation Research entered into a collaborative agreement with Eurocontrol and signed Action Plan 12 (AP12): Management and Reduction of Human Error in ATM. The initial goal of this project was to examine two existing techniques for identifying human error and to determine whether they could be harmonized into one technique.[6] If so, the FAA and Eurocontrol member states would be able to use the technique retrospectively to examine existing incident reports for information related to human factors trends in the data, and to leverage this information to develop and share mitigation strategies.

As AP12 activities progressed, ATC subject matter experts from both FAA and Eurocontrol judged that the harmonized technique – JANUS – also showed promise as a supplement to existing reporting processes (Pounds & Isaac, 2001). That is, rather than serving merely as a retrospective data mining tool, the new technique might also have value if integrated directly into existing OE reporting processes. Based on this hypothesis and after successful harmonization (Pounds & Isaac, 2001), the course of AP12 was modified to include further refinement and testing of the technique. Validation activities posed unique challenges to both the FAA and Eurocontrol. Based on discussions of these differences, it was decided

[6] The two techniques used for the harmonization were the Human Factors Analysis and Classification System (HFACS; Shappell & Wiegmann, 2000) and the model for Human Error in Air Traffic Management (HERA; EATMP, 2003). The Human Factors Analysis and Classification System (HFACS), a human factors taxonomy for analysis of existing aviation accident databases, was originally developed for the US Navy to investigate military aviation accidents. HFACS is currently being used by the FAA to analyze civil aviation accident databases. HERA is a model of human error for air traffic control that was developed as a tool to increase the effectiveness of human error identification.

that parallel and complementary approaches be used based on the particular requirements of each to conduct the validation activities. Thus the FAA and Eurocontrol developed the technique to reflect their individual system needs, resulting in two structurally parallel techniques.

The FAA method is a structured interview process that leads the analyst through a series of questions designed to identify the mental error and the contextual conditions surrounding it. Questions related to the controller's perceptions, memory, and decision-making processes that lead to execution of a plan are included. The method of using the technique considers the dynamic ATC traffic environment and treats each OE as a potential chain of events (or human errors) that result in the final loss of separation.

This line of work expanded on efforts by the Air Traffic Evaluations and Investigations Staff to improve causal factor information. For an inexperienced analyst of an OE, the technique is a potential aid to ask the right questions for eliciting causal factors and relevant human factors. For an experienced analyst, the technique ensures that he or she considers a broad range of causal factors rather than relying on experience and focusing on "the usual suspects." Figure 5 illustrates the general categories of contextual conditions included in the technique.

A research project to test and validate the JANUS technique was conducted in collaboration with the Air Traffic Evaluations and Investigations Staff and the National Air Traffic Controllers Association. A parallel project was conducted by Eurocontrol. The research proposed to answer several basic questions related to validity: Does the technique work? How well does it work? Is it better than the current method? Is it ready for operational implementation? Will the results from the technique help to improve safety management?

Validation activities also posed unique challenges to both the FAA and Eurocontrol. Based on discussions of the organizational differences, it was decided that a harmonized approach could be defined that would allow the other organization to leverage the potentially complementary work, findings, and lessons learned while also meeting the particular requirements of each organization. Methodologies for testing the technique were adapted to accommodate the respective organizations' testing environments, including use of operational resources and test constraints.

Results from the validation activities conducted to date by both organizations suggest that information provided by the JANUS technique will help improve safety management through the more effective identification of

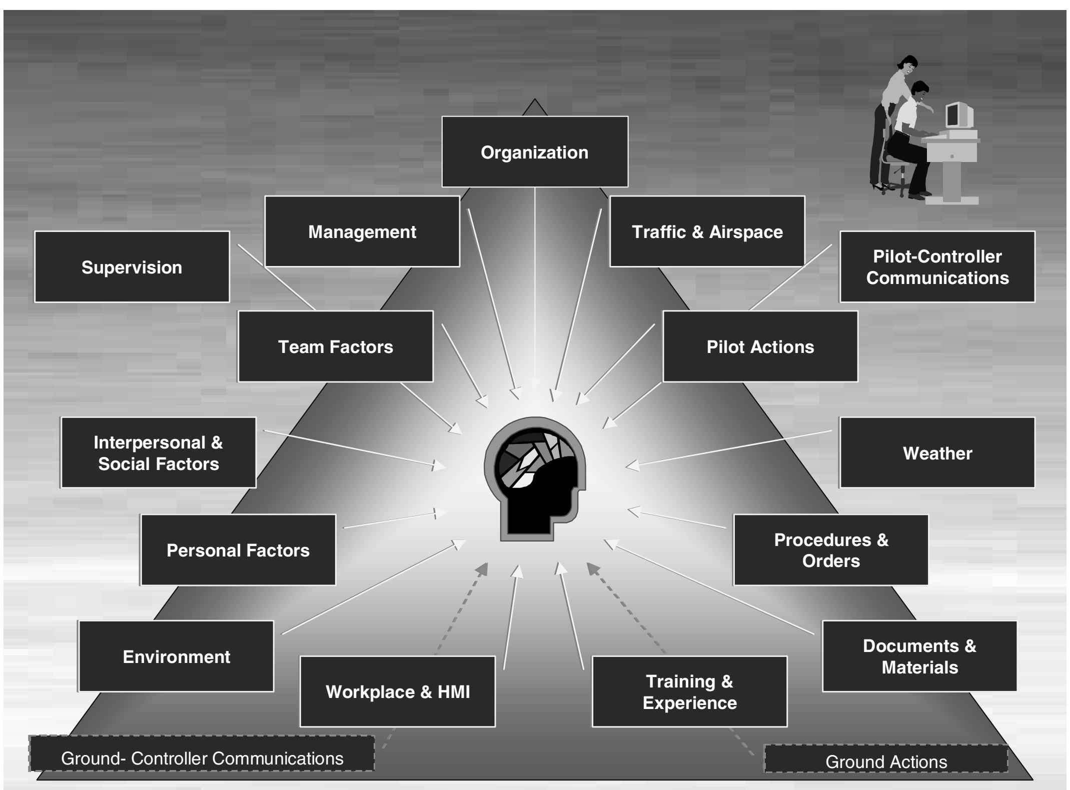

Figure 5. FAA JANUS taxonomy showing the categories of contextual conditions included in the technique.

human factors associated with OEs. However, a definitive answer can only be scientifically determined by a longitudinal analysis of data gathered using this technique. The information can then be evaluated for its usefulness as strategies are identified with which to mitigate the potential for future operational errors. Indeed, the ancient Roman symbol of Janus, after which the harmonized technique was named, was attributed with the ability to look back so that an understanding of past events could lead to insight about future events.

Keeping The Mental Edge

The National Air Traffic Professionalism (NATPRO) project is an example of how information identified by OE analysis can be turned into strategy and skill enhancement.[7] NATPRO is a new training approach sponsored by the FAA Air Traffic Investigations Division. Rather than relying solely on knowledge-based training, this approach integrates the concept of "performance coaching," using an awareness seminar coupled with a practicum.

Facility personnel first participate in the coaching clinic developed by Breedlove (2003) that covers the knowledge and critical skills of effective coaches. The coaches then conduct the seminar and practicum at their facility. The coaches help participants understand how the seminar concepts relate to performance by pointing out the connection between the seminar material and the practicum experience when participants practice the activities. For example, the coach might try to distract the participant during practice to demonstrate the influence of environmental distractions on performance.

The initial NATPRO program is focused on cognitive skills related primarily to visual attention, such as detection of information, focusing on relevant information and multitasking. The practicum includes activities to exercise the mind and improve concentration through distributed practice. The basic concept is not only limited to concentration. The NATPRO program concept is designed to also include other ATC skills such as auditory attention, decision making, and planning.

The seminar on cognitive skills was developed to increase an individual's understanding of the mental process of concentration, factors that affect mental processes, and how mental skills relate to performance. Although the skills are generic, we hope that by improving general skills, individuals will demonstrate a corresponding improvement in controller performance. Once armed with the knowledge provided by the seminar, participants then experience their own strengths and limitations during the Practicum. Interactive web-based computerized skill challenges permit participants to gain insight about their own skills. By testing themselves against the computer and experiencing how performance can vary in relation to factors such as distraction, fatigue, boredom, and so on, participants gain increased understanding of their own performance and identify strategies to improve it. Putting the challenges in a web-based application gives individuals and teams the opportunity to compete for high scores, should they desire to do so. Although the competitive aspect is available to participants, it is not required. It is included to enhance the experience for those participants who want to engage in interpersonal competition.

Admittedly, the successful transfer of skills from this program to actual air traffic control performance will be difficult to measure objectively. There are several measures that may be partially influenced as a result of this training, including a reduction in the number of operational errors; however, because the air traffic system is complex, there are many factors not related to controller preparation and awareness that also affect the number of operational errors. Other less tangible measures may include an increase in efficiency and higher job satisfaction. Success of the program could be captured by evaluating data from several sources. Initially, we plan to compare the practicum skill levels and subjective evaluations from participants before and after participating in the program. However, whether skill enhancement realized in the NATPRO program will translate to working traffic cannot be objectively evaluated at this time. Measurement of performance using high-fidelity air traffic simulations or medium fidelity standalone simulation tools would supply more substantive evidence for evaluating the effectiveness of the program.

If this type of program is successful, it would demonstrate a more cost-effective, personally rewarding delivery of training. The NATPRO approach may improve air traffic safety and efficiency by increasing the controller's attention and perception skills, sustaining a highly skilled work force. Although targeting ATC performance, the skills themselves are generic. Participants would be expected to also benefit by transfer of skill to other activities beyond their professional ATC work environment.

Conclusion

A philosophy of individual leadership combined with joint accountability guides these efforts and others, all part of the FAA's ongoing efforts to maintain and enhance aviation safety by identifying system vulnerabilities and developing mitigation strategies. Air traffic control is a high-demand, high-consequence activity, and controllers

[7] The NATPRO project was developed by Mr. Randall Breedlove with assistance from Mr. Jimmy Mills (ASO-150) and the Air Traffic Southern Region Learning Council.

must rely on their mental skills to successfully orchestrate air traffic. The initiatives described here reflect a human-centered approach but situates the human as the crux of a larger, more complex, dynamic system of other people and computers in a fast-paced environment of radar information, communications, and aircraft movement. Although any single initiative may not be a solution in itself—no silver bullet that will immediately eliminate all human error and every operational error—mitigation and reduction is a journey of many single steps that progress in the same direction toward prevention of these events.

References

Breedlove, R. (2003). NATPRO. Creating the cognitive advantage for high performance ATC professionals. Unpublished materials.

Dekker, S. (2002). *The field guide to human error investigations*. Aldershot, UK: Ashgate.

EATMP. (2003). *Short report on human performance models and taxonomies of human error in ATM (HERA)*. HRS/HSP-002-REP-02. Brussels: EUROCONTROL.

Federal Aviation Administration. (1999). *National Aviation Research Plan*. Washington, DC: Author.

Federal Aviation Administration. (1999). *Strategic Plan*. Washington, DC: Author.

Federal Aviation Administration (2002). *Air Traffic Quality Assurance* (FAA Order 7210.56). Washington, DC: Author.

Federal Aviation Administration. (2003a). *Administrator's Fact Book*. Washington, DC: Author.

Fisher, B. (2002), *Study looking at runway incursions identifies contributing factors and recommends solutions*. *ICAO Journal*, *57*(1), pp. 13, 27-28.

Manning, C.A., Mills, S.H., Fox, C., Pfleiderer, E., & Mogilka, H.J. (2001). *Investigating the validity of performance and objective workload evaluation research (POWER).* Washington, DC: Federal Aviation Administration Office of Aviation Medicine. DOT/FAA/AM-01/10.[8]

Mills, S.H., Pfleiderer, E.M. & Manning, C.A. (2002). *POWER: Objective Activity and Taskload Assessment in En Route Air Traffic Control.* Washington, DC: Federal Aviation Administration Office of Aviation Medicine. DOT/FAA/AM-02/2.[8]

O'Connor, W.F., & Pearson, R.G. (1965). *ATC System Error and Controller Proficiency*. Washington, DC: Federal Aviation Agency Office of Aviation Medicine.

Pounds, J. (in review). *Using static and relational information to maintain the "picture" in ATC.*

Pounds, J., & Isaac, A. (2001). *Preliminary Test of Two Models for Human Factors Analysis of Operational Errors*. Proceedings of the 11th International Symposium on Aviation Psychology, Columbus, Ohio, pp. 1-5. [CD-ROM].

Pounds, J., & Isaac, A. (2001). *Development of an FAA-EUROCONTROL approach to the analysis of human error in ATM*. Washington, DC: Federal Aviation Administration Office of Aviation Medicine. DOT/FAA/AM-02/12.[8]

Pounds, J., & Scarborough, A. (2002). *Retrospective human factors analysis of US runway incursions*. Paper presented at ICAO NAM/CAR/SAM Runway Safety / Incursion Conference. Mexico City.

Rodgers, M. D. & Duke, D. A. (1993). *SATORI*: *Situation assessment through the re-creation of incidents.* Washington, DC: Federal Aviation Administration Office of Aviation Medicine. DOT/FAA/AM-93/12.[8]

Rodgers, M.D., Mogford, R.H., & Strauch, B. (2000). Post-hoc analysis of situation awareness in ATC incidents and major aircraft accidents. In M.R. Endsley & D.J. Garland, (Eds.), *Measurement and analysis of situation awareness in complex systems*. Mahwah, NJ: Erlbaum.

Rodgers, M.D. & Nye, L.G. (1993), 'Factors associated with the severity of operational errors at air route traffic control centers.' In M.D. Rodgers (Ed.), *An examination of the operational error database for air route traffic control centers*. Washington, DC: Federal Aviation Administration Office of Aviation Medicine. DOT/FAA/AM-93/22.[8]

Shappell, S.A., & Wiegmann, D.A. (2000), *The Human Factors Analysis and Classification System–HFACS.* Washington, DC: Federal Aviation Administration Office of Aviation Medicine. DOT/FAA/AAM-00/07.[8]

[8] This publication and all Office of Aerospace Medicine technical reports are available in full-text from the Civil Aerospace Medical Institute's publications Web site: http://www.cami.jccbi.gov/aam-400A/index.html