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Human Error in Airway Facilities

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16. Abstract

This report examines human errors in Airway Facilities (AF) with the intent of preventing these errors from being passed on to the new Operations Control Centers. To effectively manage errors, they first have to be identified. Human factors engineers researched human error literature, analyzed human errors recorded in AF databases, and conducted structured interviews with AF representatives. This study enabled them to categorize the types of human errors, identify potential causal factors, and recommend strategies for their mitigation. The results provide preventative measures that designers, developers, and users can take to reduce human error.

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EXECUTIVE SUMMARY

The Federal Aviation Administration Airway Facilities (AF) environment is designing and developing a new operations concept, which will result in a new way of conducting their business. Their focus is on improving customer satisfaction in managing the National Airspace System (NAS) infrastructure services.

The new AF concept consolidates management and maintenance functions into fewer, more centralized facilities, combined with an increase in remotely monitored, unmanned facilities. Three centrally located, regional Operations Control Centers will be responsible for monitoring and controlling the facilities in their region, assigning personnel and resources, and coordinating AF and Air Traffic information.

Engineering research psychologists from the NAS Human Factors Branch (ACT-530) conducted this study to identify potential causal factors of human errors, classify errors by type, and investigate strategies to mitigate the occurrence of errors. They researched documents on current AF operations, analyzed reported human errors, interviewing presently assigned NAS Operations Managers and NAS Specialists, and consulted with subject matter experts. This report summarizes and documents the results of the research.

The study identified three major sources of error. These included: communication and coordination, the introduction of new software or equipment, and procedural errors. Although fatigue related to shift work was not directly traceable as a causal factor in the database analysis, structured interviews with AF specialists indicated that fatigue related to shift work might indeed be related to some of the errors that occur. To mitigate the errors identified in this study, additional research on ways to optimize communication and coordination is needed. Additionally, special attention should be paid to the prevention of errors any time new systems, equipment, or procedures are introduced. Furthermore, it may be worthwhile to conduct a study examining the contribution of fatigue related to shift work on human error in AF.

Researchers also identified procedural errors as an area of potential concern for the future AF environment. They recommend that designers pay special attention to developing clear and effective procedures and ensuring that AF specialists are adequately trained on the procedures. Human factors research may benefit this area by identifying procedures that may benefit from checklists or other user aids.

Finally, the researchers also identified the need for better tracking of human errors, not for the purposes of assigning blame, but rather to identify possible design or procedural shortcomings. Tracking the causal factors leading to human error will enhance error mitigation efforts.

1. Introduction

The Federal Aviation Administration (FAA) faces many challenges in its plans to modernize the National Airspace System (NAS) Airways Facilities (AF) environment. Modernization of the existing NAS AF environment necessitates changes in technology, workload, and procedures. These changes have the potential to introduce new types of errors and compounding existing sources of error.

1.1 Background

In the current AF environment, there exists one National Maintenance Control Center (NMCC) located in Herndon, VA and approximately 40 Maintenance Control Centers (MCCs) strategically placed throughout the United States. The NMCC provides national coordination of facility restoration and monitoring of critical situations that have a national impact. The MCCs schedule, coordinate, and track personnel and equipment resources and perform certification, maintenance, and restoration of system/services and equipment.

To meet the needs of NAS modernization, AF is reorganizing itself and changing how it does business. AF plans to consolidate its management and maintenance functions into fewer, more centralized facilities combined with an increase in remotely monitored, unmanned facilities. Centrally located Operations Control Centers (OCCs) will be responsible for monitoring and controlling these facilities, assigning personnel and resources, and coordinating AF and Air Traffic (AT) information. The new AF environment will include one National OCC (NOCC), three regional OCCs, 32 Service Operations Centers, and numerous Work Centers located throughout the United States.

In their modernization efforts, AF has outlined seven major measures of success: reduced equipment-caused delays; increased customer satisfaction; reduced number of outages; reduced duration of outages; increased number of favorable inspection reports; reduced time and cost to implement new technologies; and improved employee job satisfaction (FAA, 1997). The 1999 National Aviation Research Plan reinforces these measures in their Air Traffic Services performance plan, which includes goals to increase system safety, decrease system delays, increase system flexibility, increase system predictability, increase user access, increase availability of critical systems, and increase productivity.

Improvements in technology are already moving in a positive direction toward accomplishing the AF goals. However, these goals cannot be achieved without focusing on the human side of the equation. According to the NAS Architecture version 4.0, "Advances in technology have increased the reliability of most NAS components; however, the number of accidents and incidents attributed to human error has remained constant" (FAA, 1999, p. 10-9). Increasing workload changes in organizational structure, and working with new and different systems all can contribute to an increase in human error.

1.1.1 Why look at human error?

Researching human error makes economic sense. Human error can cause direct costs in physical damage to equipment and indirect costs incurred by increased numbers of outages and increased

outage duration. Although one can cite anecdotal evidence and case studies, it is difficult to estimate the total financial impact that human error has on the system. One example of the impact that AF human error can cause to the FAA, the airlines, and the flying public is that a single incident of human error in 1998 caused a 2-hour outage and reportedly was responsible for 265 delays (Source: AF TechNet, AF Delays Report FY 1999).

1.1.2 What is an error?

Sanders and McCormick (1987) defined human error as an inappropriate or undesirable human decision or behavior that reduces or has the potential for reducing effectiveness, safety, or system performance. Two things should be noted about this definition. First, an error is defined in terms of its undesirable effect or potential effect on human performance and systems operations. Second, an action does not have to result in degraded system performance or an undesirable effect on people to be considered an error. It is enough that the decision or action has the potential for adversely affecting the system operations or human performance for it to be considered an error.

Human error can take many forms. Often human error in the NAS is defined in the context of safety (accidents, incidents), events that clearly violate set standards (e.g., operational errors in the Air Traffic Control realm), or personnel-induced outages. These can be thought of as the more severe results of human error but also the ones that are the most evident. The most frequent types of human error do not result in compromised safety, operational errors, or outages. Instead, most errors are caught before they cause any problem. Anecdotal evidence from specialists underscores that for every one outage that occurs, there are multiple "saves." (A save refers to an incident or event that could have resulted in an outage but, due to the efforts of a specialist, the outage was averted.)

In the analysis of human error in industrial plants, 80 to 85% of errors that occur are attributable not to human characteristics, but to error-likely conditions (Steinbrink, 1997). In these situations, people are "set up" for error by the system design. These error-inducing situations include deficient procedures, poor communication, inadequate training, misleading information, and poor equipment design. Many of these errors are entirely preventable. Identifying error-likely situations is a first step toward minimizing or eliminating errors.

1.1.3 How can we look at errors that currently exist in Airway Facilities?

In addressing human error reduction, Wiener (1988) states that the first step in error reduction is to identify the errors. Identifying human errors is not always a straightforward task. Errors can be obvious but are more often subtle. There are six methods of identifying potential errors that have been used successfully in other areas. They include brainstorming using representatives of the area of interest; critical incident techniques; structured walkthroughs or reviews of standards, procedures, or systems; surveys and questionnaires; observation; and analysis of confidential reporting systems. Once potential errors are identified, a risk assessment should be done to weigh the potential errors according to their severity. The next steps in effective error management are to identify the current defenses, evaluate the effectiveness of the current defenses, and identify additional defenses needed. Finally, an effective mechanism should be established for reporting potential errors and addressing them once they are identified.

A prior study on human error in OCCs used a combination of structured walkthrough and brainstorming techniques to identify potential errors and propose mitigation strategies for the future AF environment (Ahlstrom et al, 1999). Each of the errors identified was given a risk estimate based on a combination of the severity of the impact on operations if the error did occur and the probability or likelihood that it would occur. This study provided insight on potential errors and potential mitigating strategies in the future OCCs.

The current research study takes a different approach, focusing on error that are occurring now rather than looking toward the future. The current study analyzes current reported incidents of human error with the goal of finding ways to ensure that these errors are not carried to the future AF environment.

2. Method

Engineering research psychologists from the NAS Human Factors Branch (ACT-530) of the FAA William J. Hughes Technical Center conducted this study. Initially, they researched functions and tasks of the NAS Operations Managers (NOMs) and NAS Specialists. They examined job task analysis, FAA Technical Notes, and other reports and conducted field visits to the NAS Premiere Facility (NPF), the NOCC, the Prototype Operations Control Center (POCC), and the Pacific Desert Systems (PDS) MCC.

2.1 Database Analysis

The first task in this study was to identify sources of human error. The first step in identifying human errors that may affect the future environment was to examine the human errors that were occurring in the present environment. The researchers did this by analyzing data from AF reports that contained information on human error in the current AF environment.

In AF, cause codes are assigned to all service interruptions to provide data for future analysis. The researchers obtained and analyzed the reported human errors that were recorded for a 1-year period from July 20, 1998 to July 20, 1999. (Note: They only focused on the errors attributed to AF personnel, not AT or contractor-induced outages.) They also obtained and analyzed the AF delays report for the 1999 fiscal year for additional information.

2.2 Field Study

When analyzing human error, researchers would like to have quantitative data accurately recording actual errors committed by personnel. However, these data do not exist in the case of human error in MCCs, so they used structured interviews instead. They conducted a field study, collecting data from structured interviews and observations at several key field sites. The field study included the following sites: the NPF, the NOCC, the POCC, and the PDS Management Office and MCC.

2.3 Error Categorization

Previous research (Ahlstrom et al., 1999) on human error in OCCs identified potential errors in future OCC operations using a combination of structured walkthrough and brainstorming techniques. In that study, AF subject matter experts developed and designed four scenarios to

simulate events that would take place in future OCC environments. As the participants of that study stepped through the specially designed scenarios, researchers asked them to identify potential error situations and propose possible strategies for preventing or mitigating errors. The errors were given a risk estimate (called <u>importance</u> in the study) based on the likelihood of the error occurring and the impact on operations if the error did occur. Researchers then asked the participants to sort the errors into major categories. The errors with the highest identified risk estimate fell into 13 major categories. These categories formed the initial list of potential errors.

The researchers supplemented the error categories derived from the Ahlstrom et al. (1999) study with information from the AF Job Task Analysis (CTA, Inc., 1992) and the Airway Facilities outage assessment inventory (Blanchard, 1994). The AF Job Task Analysis provided information on the current functions (activities) and tasks in the AF environment, which include 6 high-level functions, 31 subfunctions, and 548 tasks. The Airway Facilities outage assessment inventory identifies and maps potentially significant contributors to AF maintenance downtime within a system structure. The outage assessment inventory is a form that has 11 categories of factors, conditions, or events that can be used to describe a functional framework of the maintenance process at the General National Airspace System. It represents the sequential progression of events, beginning at the onset of a facility outage and ending when the facility is returned to service. These 11 categories are further broken down into subcategories. The first category is called Outage Causes, and there are 12 subcategories under that category. The researchers looked at these 12 subcategories when trying to create a taxonomy that captured outages induced by human error. By examining previous research on error mitigation, the AF Job Task Analysis, and the outage assessment inventory, they derived 13 categories and 77 subcategories of AF human errors (see Appendix A).

3. Results

3.1 Analysis of Database Errors

In the AF database that records outages, cause codes are assigned to all service interruptions to provide accurate data for future analysis. Cause Code #89 is the code for unscheduled outages or service interruptions in the "Other" category, which includes outages induced by AF personnel. Of the 50 Cause Code #89 errors reported in the ad hoc reports during the July 20, 1998 to July 20, 1999 period, 35 of the incidents were attributed to AF personnel. Researchers identified 13 additional personnel-induced outages that did not overlap with the ad hoc reports in the AF Delays Report. They analyzed these 48 errors and attributed them to nine major categories.

    a. <u>Procedures.</u> Seventeen percent of the errors may have occurred either because proper procedures did not exist or the specialist may not have been aware of or did not follow the proper procedures.

    b. <u>New equipment or software.</u> Twelve percent of errors occurred in conjunction with new equipment or software installations or modifications.

    c. <u>Communication/coordination.</u> Insufficient communication or coordination was blamed for 10% of the errors. Errors that occurred due to a break in communication or coordination tend to involve the specialist not being aware of the status of the equipment

receiving maintenance. For example, a specialist took equipment off line without coordinating with AT.

d. <u>Labeling.</u> Ten percent of errors were due to improperly or poorly labeled equipment or equipment that did not have a label but would benefit from one.

e. <u>Equipment bumps or trips.</u> Six percent of the errors involved switches that were inadvertently bumped or cables or plugs that were disconnected when someone bumped into them or tripped over them. These errors were attributed to a lack of safety guards or insufficient room to maneuver and usually were resolved by installing equipment guards where necessary. These types of errors tend to be commonly reported and easily fixed.

f. <u>Data entry/keyboard entry errors.</u> Six percent of errors were due to incorrect data entry. It was not possible to determine whether the inadvertent keyboard commands were due to specialists accidentally hitting the wrong keys (commonly called "fat-fingering" the keyboard) or other reasons, such as the confusion of similar commands.

g. <u>Oversights (forgetting).</u> Four percent of the errors occurred when specialists forgot to return a switch to the correct position after maintenance.

h. <u>Incorrect information.</u> Two percent of the errors were attributed to specialists using incorrect information such as drawings or schematics.

i. <u>Other.</u> This category doesn't seem very descriptive, but 33% of the incident descriptions in the report did not contain sufficient information to properly categorize the data (e.g., "frequency interruption by FAA personnel prevented landings"). This description does not give enough information about the source of the error to be useful. There could be numerous causes for such an error. Was this error a violation of proper procedures? If so, this kind of violation could have been caused by a lack of experience or training, excessive workload, fatigue, or poor equipment design. Table 1 lists some examples of error descriptions with insufficient detail.

Table 1. Error Descriptions With Insufficient Detail to Categorize

Frequency interruption by FAA personnel prevented LDA landings.
Power interruption occurred during installation of a new power panel.
The computer operator inadvertently reloaded the program on the on-line processor causing an interruption. The reload was performed following a switchover due to buffer overload caused by a printer failure.
Specialists disconnected beacon control unit cable while troubleshooting system.
Specialists powered down Cabinet 4 and entire system failed. Ops transitioned to ADW sensor.
Radar data failed.

We have plotted incidents by month and time of day in Figure 1. This figure implies that most errors occur during the evening hours with the highest proportion occurring between 8:00 PM and midnight followed by the 4:00 PM to 8:00 PM time slot. These data seem to imply a

connection between time of day and errors. However, these conclusions are premature based on the limited available data. A possible explanation is that managers are scheduling riskier work during times when the impact to AT operations may be minimized. There are many other possible explanations as well, and to decide on a particular course of action would require more extensive research, data, and analysis. The point is that, with accurate data on what errors occur and when they occur, preventative actions may be instituted to minimize such errors.
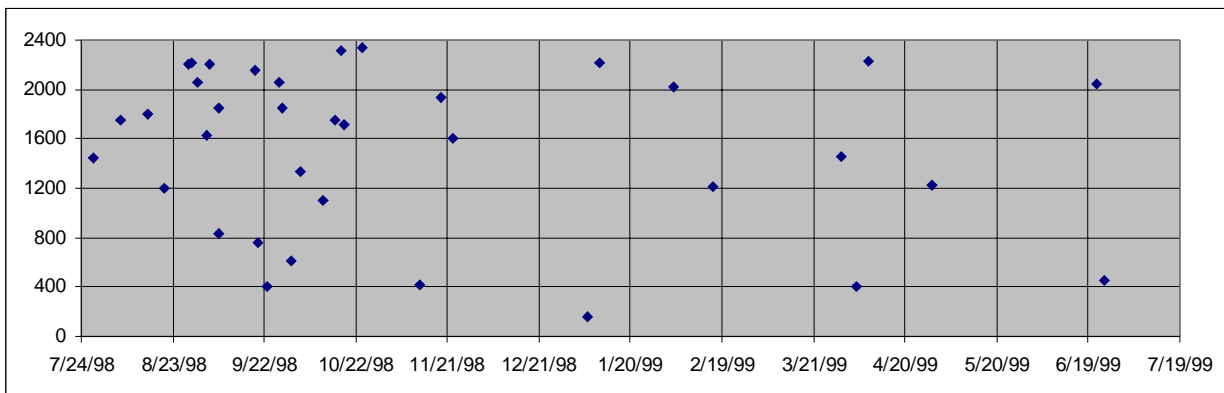

Figure 1. Incidents Plotted by Month and Time of Day.

Almost all of the errors reported in this database were attributed to field technicians. However, there appears to be little record of MCC errors. Lack of documented MCC errors does not mean that MCC specialists never commit errors. AF specialists from MCCs indicated that MCC errors might be less likely to be directly linked to an outage. According to the AF specialists, some of the errors that MCCs might make include calling a field technician who was not available or sending field technicians to the wrong site. Thus, to supplement the data from the AF databases, they conducted structured interviews with AF specialists in the field, particularly focusing on those who work in MCCs.

3.2 Field Study

Field interviews with AF specialists revealed some common types of human error that occur in MCCs (Appendix B). The predominating causes of current human error are described in the following list.

    a. Communication/coordination errors – During field interviews, specialists rated communication errors as the principal current and potential source of errors. The AF Job Task Analysis (CTA, Inc., 1992) lists 548 tasks for which the NOMs and NAS specialist are responsible in the current work environment. A large number of these tasks, 245, are voice-communication tasks. This means that the majority of the specialists' time is spent on transfer or exchange of information with another person via a telephone or face-to-face. Communication problems may arise due to failures in communication among OCC team members or between OCC team members and others (e.g., terminology differences between AF and AT). A recent example of an outage caused by a communication error was when the terminal radar service was lost when transferring from engine generator to commercial power without coordinating with the FAA Terminal Radar Approach Control.

b. <u>Errors due to incomplete or incorrect information</u> – Specialists reported that status information and information in other databases are not always maintained and up-to-date. This can cause errors such as calling a field technician who is unavailable to fix a problem thus increasing outage durations. They also indicated that weather plays a critical factor in AF decision-making. However, observation and structured interviews revealed that specialists often do not have current weather information for their area.

c. <u>Critical facility errors</u> – Critical facility errors result from not being aware of the impact of events and resolution on other facilities. AF services, facilities, and equipment have differing levels of criticality under different circumstances based on the current status of other NAS elements. An example of a critical facility error would be taking a facility offline for maintenance when it is required for backup purposes.

d. <u>Shift work errors</u> – Although there is a vast amount of literature on shift work, to date, the contribution shift work in AF may make to human error is unknown. Shift work is not an issue for all MCCs in that many are only open during regular working hours (however, OCCs are intended to be open 24 hours a day, 7 days a week). Accurate data on when errors are occurring can give insight on the contribution shift work may have to these errors.

e. <u>Workload errors</u> – Work in the MCCs tends to come in waves; that is, many events will occur within a short time, causing a very high workload followed by a period of lower workload. This phenomenon is documented in the workload analysis study (AFHF Research, Engineering, and Development, 1997). Specialists reported that during high-workload periods, it is easy for the specialist to get interrupted while performing an action and consequently forget to complete the action.

These errors overlapped with the potential errors anticipated by specialists in conjunction with changing from an MCC to an OCC environment. They expressed concern that the changes from an MCC working environment to an OCC working environment (and the associated increase in geographic area of responsibility) would cause increases in these types of errors and introduce new errors associated with learning new business practices.

According to the specialists interviewed, the following categories of errors have the potential of increasing with the introduction of OCCs:

a. <u>Procedures/business practice errors</u> – Occasionally, errors occur because procedures are unclear or are not followed. This may be due to lack of training on the part of the specialist or memory overload. These errors occur in the present MCCs, but there is also the potential for increased human error of this type with the introduction of new procedures and business practices associated with the OCCs. As one specialist said, "In the MCCs, everyone is a generalist. In the OCC, the need to communicate and collaborate between specialty positions is especially important and could potentially be problematic."

b. <u>Remote maintenance monitoring (RMM) errors</u> – An increasing number of AF communication, navigation and surveillance facilities including both hardware and software are being remotely monitored. RMM interfaces for different facilities are not always consistent with one another or well integrated into the current system. Furthermore, some MCC specialists were not familiar with using RMM to do remote

certification. Interface design and integration should be examined for usability, and specialists should be trained on the use of RMM.

    c.   <u>Insufficient training/insufficient experience errors</u> – The AF workforce is aging and new specialists are replacing those with years of experience. Many of the specialists that will work in the OCCs may come from the field and may lack experience in a monitor and control environment. By consolidating operations, the OCCs will risk losing area-specific knowledge that the specialists at the MCCs have gained over the years. Some examples given were a VORTAC that was only accessible by boat and the Alaskan Moose that had a tendency to attack equipment during mating season.

3.3 Current Error Mitigation Strategies

The general strategy for error mitigation is to limit the occurrence of errors and to limit the consequences of errors if they do occur. Before any corrections are introduced to minimize deleterious effects or prevent errors from occurring, the error-prone areas must first be identified. Once these are defined, appropriate mitigation strategies can be developed. For example, a nuclear power industry analysis of errors found that reassembly is more error prone than disassembly (Maddox, 1998). The key is to know where the errors are likely to occur and draw attention to this (wrong reassembly may not be obvious on later inspection).

Examination of the lessons-learned database, which addresses the human-error incidents recorded in the AF databases, found that the primary solution was to counsel the person who committed the error, to install equipment guards where necessary, and to create new procedures to avoid the situation.

The management and staff at the POCC were aware of the probability of many of the errors revealed by the field interviews and were working with the NAS Infrastructure Management Project Office (AOP-30) to develop mitigation strategies.

4. Conclusions

How do we ensure that we learn from our mistakes instead of being doomed to repeat them? First, the data analyzed in this study show that there is a need for more accurate error-tracking systems in AF. Errors cannot be investigated and analyzed until they are identified. In the majority of the cases reported, there was insufficient information to remedy the error-inducing situations in which the AF specialists find themselves. AF maintains a lessons-learned database that, among other things, contains information on outages caused by human error and the steps taken to prevent future errors. Presently, the outage reporting system (of which the ad hoc and lessons-learned reports are a part) is the method of tracking human error in the AF environment. However, this system was not put into place to examine human error but rather to track equipment performance. There is a definite need to develop a new method of tracking AF human errors. However, the purpose must be to document the errors, investigate them, and come up with solutions, not to place blame.

Establishing an error-reporting system has many advantages. It can create a framework for critically evaluating and continually improving the integrity of AF and allow for the identification of error-prone tasks including the identification of which tasks might be

automated. Error-reporting systems have also been used as a formal communication channel for identifying weaknesses in procedures and equipment design, allowing for preventative corrective action before the problem becomes an outage. This approach allows AF to take a proactive rather than reactive approach to errors, a positive step toward meeting their goals of minimizing the occurrence and duration of outages.

There are also many restraining forces to the establishment of an error-reporting system. In general, people tend to resist change and may be concerned about the risk for misuse of such a system. It is important when establishing such a system that the focus is on the system or situation instead of individual blame. In order to identify and mitigate error-causing situations, AF needs a system that encourages accurate reporting and provides protection for the respondent. Such a system requires a commitment on the part of the FAA, setting aside resources at a time when the FAA is already faced with tight budget.

In spite of restraining forces, anonymous reporting systems have been used effectively in many other areas, particularly for reporting personnel errors or hazards that may lead to safety violations. Some examples of such systems are the Aviation Safety Reporting System, Maintenance Error Decision Aid, and Managing Engineering Safety Health. Recently, the FAA announced a new initiative called the Aviation Safety Action Program. This program is intended to address safety issues, but a similar system could be used to examine human error in AF.

Second, new systems and communication/coordination are leading categories of AF error both in the interviews and in the analysis of errors from the database. Communication and coordination errors were also the top potential errors identified in a previous study (Ahlstrom et al., 1999). Coordination points and channels of communication should be clearly defined and may need to be included on checklists or other mnemonic aids. Communication about the equipment status is of particular concern and can lead to critical facility errors. Redundant channels of communication should be identified and eliminated, and research should be conducted on ways to enhance the communication and coordination process, particularly in relation to facility status. Special attention should be paid to the effect that new systems or equipment will have on the existing system. Any new system or equipment should be evaluated for its potential impact on existing systems before installation. Specialists should have clear instructions on how to install new systems without compromising existing systems.

Third, there are a high percentage of procedural errors identified in the analysis of the database as an area of potential concern for the future. It is essential that the future AF environment pay attention to developing clear and effective procedures and ensuring that AF specialists are adequately trained on the procedures. Future research is warranted in this area to identify procedures that may benefit from checklists or other user aids.

Finally, one of the concerns expressed in the structured interviews is the contribution of shift work and shift work-related fatigue to the commission of errors. Although there is a wealth of literature on the effects of shift work and fatigue and AF has worked shifts for many years, there is no current research on the effects of shift work and fatigue on AF errors.

ACRONYMS

AF	Airway Facilities
AT	Air Traffic
FAA	Federal Aviation Administration
MCC	Maintenance Control Center
NAS	National Airspace System
NMCC	National Maintenance Control Center
NOCC	National Operations Control Center
NOM	NAS Operations Manager
NPF	NAS Premier Facility
OCC	Operations Control Center
PDS	Pacific Desert System Management Office
POCC	Prototype Operations Control Center
RMM	Remote Maintenance Monitoring

REFERENCES

Ahlstrom, V., MacMillan, J., Tenney, Y., Pew, R., Cranston, R., & Mogford, R. (1999). *Human error mitigation in future operations control centers* (DOT/FAA/CT-TN99/14). Atlantic City International Airport, NJ: William J. Hughes Technical Center.

Airway Facilities Human Factors Research, Engineering, and Development. (1997). *Workload site study memorandums. Unpublished manuscripts.*

Blanchard, R. E. (1994). *Human factors in Airway Facilities maintenance: Development of a prototype outage assessment inventory.* Springfield, VA, (National Technical Information Service DOT/FAA/AM-94/5).

CTA, Inc. (1992). *Airway Facilities job task analysis, vol. II, ARTCC NAS operations manager.* Atlantic City International Airport, NJ: Federal Aviation Administration Technical Center.

Federal Aviation Administration. (1997). *Airways Facilities strategic plan.* Washington, DC: Federal Aviation Administration.

Federal Aviation Administration. (1999). *National Airspace System architecture*, Version 4.0. Washington, DC: Department of Transportation, Federal Aviation Administration.

Maddox, M. (Ed) (1998). *Human factors guide for aviation maintenance.* Washington, DC: Federal Aviation Administration Office of Aviation Medicine.

Sanders, M. S., & McCormick, E. J. (1987). *Human factors in engineering and design.* New York: McGraw-Hill Publishing Company.

Steinbrink, J. (1997). Human error plagues maintenance activities. Industrial Maintenance & Plant Operation, March (www.impomag.com) retrieved January 1999.

Wiener, E. L. (1988). *Human factors in aviation.* San Diego, CA: Academic Press, Inc.

Appendix A

AFCC Potential Human Error Categories and Subcategories

1. Communication Errors

    1.1. Failure of Air Traffic (AT) and Airway Facilities (AF) to communicate effectively

    1.2. Failure to acknowledge and coordinate information

    1.3. Failure to report aircraft accident/ incident in a timely manner to NAS Operations Control Center (NOCC)

    1.4. Misunderstandings between Operations Control Center (OCC) Specialists and System Management Office (SMO)

    1.5. Interruption problems due to communicating over remote link versus face-to-face

    1.6. OCC specialists and field specialists terminology differences

2. Errors Due to Incomplete or Incorrect Information

    2.1. Status board information incorrect, insufficient, or misleading

    2.2. Provides incorrect status information to others

    2.3. Equipment certification not always known

    2.4. Inaccurate status

    2.5. Lack of access to real time data

    2.6. Not able to locate correct contact information

    2.7. Inability to verify if backup is in service

    2.8. Database Errors

        2.8.1. Contact database out of date

        2.8.2. Directions to site needing service not available

        2.8.3. Database is incomplete, not all needed data has been entered

    2.9. Fault history information not available to specialist

3. Critical Facility Errors

    3.1. Difficulty in tracking the role of each facility under different operating conditions

4. Event Ticket Errors

    4.1. Lack of responsibility for an event ticket

    4.2. Failure to update event ticket

    4.3. Incorrect event ticket closeout (i.e., ticket closed when it should remain open, or open when it should be closed)

    4.4. Data entry errors

    4.5. Multiple event tickets are open for a single event

    4.6. Failure to open event tickets in a timely manner

    4.7. Delays caused by failure of retrieving the wrong event ticket

4.8. OCC specialist over reliance on information on event tickets

4.9. Incomplete event tickets

4.10. Event ticket procedures not standardized

4.11. Incomplete problem description on ticket

4.12. Event tickets not opened due to many events occurring at the same time

4.13. Use of confusing acronyms

4.14. Wrong priority for event ticket

4.15. OCC specialist does not understand event ticketing system

4.16. Event ticketing system fails; specialist not familiar with backup plan

5. Procedural Errors

5.1. Unclear backup plans

5.2. Procedure documents in use may not be the latest versions, or long overdue for updates

5.3. Non-standard procedures, varied from region to region

5.4. Specialist on call may not know specific procedures to solve a problem, which may indicate the wrong specialist was sent to the site

5.5. Fails to prioritize; resulting in more critical work being delayed

5.6. Fails to switch to backup system in a timely manner

5.7. Fails to attempt system reset in a timely manner

5.8. Loses situational awareness of status of technician in travel, or at site

6. Certification error

6.1. Failure to certify systems in a timely manner (allowing system to exceed its maximum certification interval)

6.2. Improper certification (certifying an uncertifiable system) i.e., certifying the system when a component facility is not certified

6.3. Loses situational awareness of status of leased services and the ongoing activities of the providers (leads to no follow-up)

6.4. Loses situational awareness on the status of NOTAM (Fails to assure cancellation NOTAM after a facility is returned to service)

6.5. Errors related to scheduled outages

6.6. Fails to follow-up on field specialist request for a scheduled outage. May cause an unscheduled outage due to specialist not being able to replace a failing component

6.7. Fails to inform technician that approval for a scheduled outage is withdrawn. Technician may assume is "ok" to remove facility from service.

6.8. Flight check coordination errors

6.9. Fails to advise field specialist of change in flight check schedule

6.10. Fails to inform AT of impending flight check. Results in significant impact to service provided by AT or canceling the scheduled flight check.

7. Remote Maintenance Subsystem (RMS) Errors

7.1. Unfamiliar with Remote Maintenance Monitoring (RMM) capabilities

7.2. Unable to update RMM parameters

8. Insufficient Training/Insufficient Experience Errors

    8.1. Inaccurate diagnosis of problem

    8.2. Poor troubleshooting methods

    8.3. Unfamiliar with interaction protocol with others

    8.4. Specialist does not hear alarm

    8.5. Not comfortable with assuming new AFCC functions

    8.6. OCC Specialist not familiar with OCC's boundaries/ domain

    8.7. Specialist not comfortable with MMS procedures

    8.8. Specialist not familiar with non-FAA organizations that could impact National Airspace System (NAS) infrastructure operations (e.g., Department of Defense (DOD) and air shows)

    8.9. Forgets to update event reports as needed (i.e., outages, accidents, incidents, etc.)

    8.10. Unfamiliar with reporting aircraft accident/ incident

    8.11. Unable to locate the Logical Unit Identification (LUID) screen in alarm/ alert

    8.12. Fails to recognize faults or degradation of services

    8.13. Is not situationally aware and makes errors in setting restoration priority

    8.14. Does not recognize need for preemptive action such as starting an engine generator prior to arrival of severe weather.

    8.15. Taking a preemptive action without knowing or realizing the current status. For example, trying to start the engine generator while an environmental specialist is working on the engine generator.

9. Errors due to lack of documentation

    9.1. May impact trend analysis (i.e., incomplete record of past failure may indicate erroneous trends)

    9.2. Scheduling work that has already been completed

10. Hazardous Materials Errors

    10.1. Failure to recognize hazardous materials (PCBs, battery acid, transformer oil)

11. Staffing Induced Errors

    11.1. Multiple failures in a geographic or specialty could require a range of knowledge and skills beyond that possessed by one specialist

    11.2. Heavy workload

    11.3. Manpower in times of crises

    11.4. Shift work errors

12. Lack of room to maneuver-bumps and trips

13. Labeling errors

Appendix B

POCC ERROR MITIGATION QUESTIONS

1. What do you see as major changes from the MCC working environment to the OCC environment that may cause human errors?

2. What do you anticipate to be the major causes of human errors in the OCC environment?

3. According to the AF Job Task Analysis (1992), nearly 50% of the Specialists tasks were communication tasks. A recent study indicated that poor communications was the major cause of human errors. Do you see this as a problem within the OCCs?

4. What are other potential causes of human error in AF?

5. Do you have any suggestions on how to reduce voice communications in the OCCs?

6. Would you like to see an Artificial Intelligence system added to the OCCs?

7. Is a record added to a database for incident tracking?

8. How accurate do you think the "status" information will be in the OCCs?