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Human Error Causes Outages in Airway Facilities

To prevent personnel-induced equipment outages, operations managers see opportunities to improve communication and coordination, address procedural problems and avoid issues caused by the introduction of new software or equipment.

FSF Editorial Staff

Opportunities have been identified to enable operations managers and maintenance specialists[1] in the U.S. National Airspace System (NAS) to prevent errors that affect aviation safety through service interruptions and equipment malfunctions based on a thorough review that focused on past errors.

A management system for NAS airway facilities consolidates management and maintenance of airway facilities into three regional operations control centers[2] and increases the use of remotely monitored, unstaffed airway facilities by the U.S. Federal Aviation Administration (FAA). The centers monitor and control airway facilities, assign personnel and resources, and coordinate airway facilities and air traffic information, an FAA report said.

"Human factors engineers researched human-error literature, analyzed human errors recorded in [airway facilities] databases, and conducted structured interviews with [NAS operations managers and NAS specialists representing airway facilities]," the report said. "Engineering research psychologists … conducted this study to identify potential causal factors of human errors, classify errors by type and investigate strategies to mitigate the occurrence of errors."

Major human errors in the past[3] involved communication and coordination, the introduction of new software or equipment, and procedural errors, the report said. Database analysis did not show fatigue as a causal factor, but airway facilities specialists told researchers during interviews that fatigue resulting from shift work "might indeed be related to some of the errors that occur."

Safety-related changes under the new management structure include reducing equipment-caused delays, reducing the number

and duration of equipment outages, and quicker implementation of new technologies. The context of the changes includes a 1999 FAA assessment that said, "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." The combination of management changes, increasing workload and technological changes can increase and/or compound human error, the report said.

In airway facilities maintenance, consequences of such errors comprise direct costs in damage to equipment and indirect costs of equipment outages and longer outage duration, the report said, citing a 1998 incident in which one human error led to a two-hour outage that caused 265 air traffic delays.

"The most frequent types of human error do not result in compromised safety, operational errors or outages," the report said. "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."

Severe errors, which are more evident than most errors, may be involved in accidents, violations of FAA standards or personnel-induced outages.

Relevant scientific literature shows that identifying "error-likely situations" (potential errors) is a first step toward minimizing or eliminating errors, the report said. Risk assessment of the effectiveness of current defenses (including confidential reporting systems) then can be conducted, and error-management methods can be implemented, including ongoing monitoring of potential errors and defenses.

Researchers analyzed data from airway facilities reports that contained cause codes representing all service interruptions from July 20, 1998, to July 20, 1999, to identify human errors (excluding errors induced by air traffic controllers and contractor-induced outages). They also compared delays that occurred during fiscal year 1999. This analysis was augmented by structured interviews, observations at field sites, previous error categorization by personnel of operations control centers, a previous inventory of equipment outages and data on job functions/tasks in airway facilities. The researchers derived 13 categories and 77 subcategories of outages induced by human error.

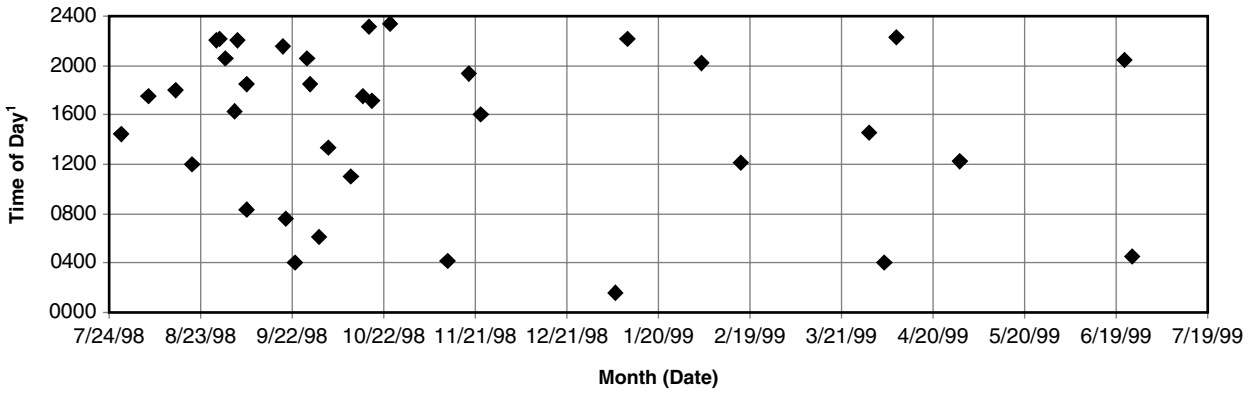
"Cause code 89 is the code for unscheduled outages or service interruptions in the 'other' category, which includes outages induced by airway facilities personnel," the report said. "Of the 50 cause-code-89 errors reported in the ad hoc reports during the [study] period, 35 of the incidents were attributed to airway facilities personnel. Researchers identified 13 additional personnel-induced outages that did not overlap with the ad hoc reports in the [delays report]. They analyzed these 48 errors and attributed them to nine major categories."

The analysis showed the following breakdown:

- "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;
- "Twelve percent of errors occurred in conjunction with new equipment or software installations or modifications;
- "Insufficient communication or coordination was blamed for 10 percent 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 [air traffic controllers];
- "Ten percent of errors were due to improperly [labeled equipment] or poorly labeled equipment or equipment that did not have a label but would benefit from one;
- "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;
- "Six percent of errors were due to incorrect data entry [keyboard-command errors]. It was not possible to determine whether the inadvertent keyboard commands were due to specialists accidentally hitting the wrong keys … or other reasons, such as the confusion of similar commands;
- "Four percent of the errors occurred when specialists forgot to return a switch to the correct position after maintenance;
- "Two percent of the errors were attributed to specialists using incorrect information such as drawings or schematics; [and,]
- "Thirty-three percent of the incident descriptions in the report did not contain sufficient information to properly categorize the data."

Plotting of incidents by month and time of day (Figure 1, page 3) showed that most errors occurred during the evening hours and that most occurred between 8 p.m. and midnight

Human Error in Maintenance of U.S. Airway Facilities
Incidents Plotted by Month and Time of Day, 1998–1999



[1]Local time

Source: U.S. Federal Aviation Administration

Figure 1

local time, with the next-largest number between 4 p.m. and 8 p.m., the report said.

"These data seem to imply a connection between time of day and errors," the report said. "However, these conclusions are premature based on the limited available data. A possible explanation [among many] is that managers are scheduling riskier work during times when the impact to air traffic operations may be minimized."

Researchers found that nearly all of the errors in the database were attributed to field technicians and that the errors by maintenance control center specialists were not documented.

"Airway facilities specialists from maintenance control centers indicated that [such] errors might be less likely to be directly linked to an outage. … Some of the errors that [these specialists] might make include calling a field technician who was not available or sending field technicians to the wrong site," the report said. Field interviews with airway facilities specialists helped to identify categories of errors by [these] specialists that were absent from the database. The following categories of these errors were identified:

- "Communication errors [were rated] as the principal current [source] and potential source of errors. … Communication problems may arise due to failures in communication among operations control center team members or between [these] team members and others (e.g., terminology differences between [the FAA Airway Facilities Division and the FAA Air Traffic Division]). A recent example of an outage caused by a communication error was when the terminal radar service was lost when transferring from engine-generator [power] to commercial power without coordinating with the FAA terminal radar approach control;

- "Errors due to incomplete or incorrect information [occurred]. 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. [Airway facilities specialists] also indicated that weather plays a critical factor in airway facilities decision making. However, observation and structured interviews revealed that specialists often do not have current weather information for their area;

- "Critical facility errors result from not being aware of the impact of events and resolution [of events] on other facilities. Airway facilities 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;

- "Shift work is not an issue for all maintenance control centers [because] many are only open during regular working hours. (However, operations control centers are intended to be open 24 hours a day, seven days a week.) Accurate data on when errors are occurring can give insight on the contribution [that] shift work may have to these errors; [and,]

- "Work in the maintenance control centers 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. … Specialists reported that during high-workload periods, it is easy for the specialist to [be] interrupted while performing an action and consequently [to] forget to complete the action."

The report said that the specialists interviewed also identified the following categories of errors as having the potential to increase under the new management system:

- "There is … the potential for increased human error [involving procedures that are not clear or procedures that are not followed] with the introduction of new procedures and business practices associated with the operations control centers. As one specialist said, 'In the maintenance control center, everyone is a generalist. In the operations control center, the need to communicate and collaborate between specialty positions is especially important and potentially could be problematic';

- "Remote-maintenance-monitoring interfaces for different facilities are not always consistent with one another or well integrated into the current system. Furthermore, some maintenance control center specialists were not familiar with using remote-maintenance monitoring to do remote certification. Interface design and integration should be examined for usability, and specialists should be trained on the use of remote maintenance monitoring; [and,]

- "The airway facilities workforce is aging, and new specialists are replacing those with years of experience. Many of the specialists [who] will work in the operations control centers may come from the field and may lack experience in a monitor-and-control environment. By consolidating operations, the operations control centers will risk losing area-specific knowledge that the specialists at the maintenance control centers have gained over the years."

FAA data revealed that the primary response to human errors was to counsel the person who committed the error, to install equipment guards where necessary and to create new procedures to prevent recurrence of the error, the report said. A requirement for more accurate error-tracking systems in FAA airway facilities also was identified; current systems were designed to track equipment performance — human error typically must be inferred, the report said.

"However, the purpose must be to document the errors, investigate them [with protection for the respondent] and come up with solutions, not to place blame," the report said. Error-reporting systems would have additional benefits, such as identifying opportunities for automation, weakness in procedures and problems in equipment design.

Several tools are available to reduce human error involving communication and coordination that affect the maintenance of airway facilities.

"Coordination points and channels of communication should be clearly defined and may need to be included on checklists or other mnemonic aids," the report said. "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. … Specialists should have clear instructions on how to install new systems without compromising existing systems." Checklists and similar user aids to follow procedures also may be warranted after further research.

In addition to the preceding types of human errors, others involved interaction between personnel in the FAA Airway Facilities Division and personnel in the FAA Air Traffic Division. These included failure to acknowledge information, misunderstandings, incorrect/incomplete/misleading information, lack of access to real-time data, interruptions caused by communicating over remote link rather than face-to-face, inability to locate correct contact information or directions to a site, absence of information about equipment-fault history, inability to verify when backup equipment was being used, and difficulty tracking the role of each facility under different operating conditions. Researchers found the following examples of human errors:

- Lack of responsibility for preparing an event ticket as required for the maintenance task (such as failure to update the event ticket or incorrect event ticket disposition). This involved delays caused by retrieving the wrong event ticket, incomplete event tickets, event-ticket procedures not standardized, use of confusing acronyms, wrong priority for the event ticket and unfamiliarity with the backup plan;

- Failure to use current standard procedures and backup plans, sometimes resulting in assignment of the wrong specialist to the site, the specialist delaying critical work because of prioritization error, the specialist failing to switch to a backup system or reset equipment in a timely manner, or specialists losing situational awareness;

- Allowing a system to exceed its maximum certification interval, improperly conducting a system certification, losing awareness of the status of leased services, failure to cancel a notice to airmen (NOTAM), failure to follow up on a field specialist's request for a scheduled outage (which may cause an unscheduled outage if a failing component cannot be replaced at the expected time), failure to inform a field technician that approval for a scheduled outage has been withdrawn, and errors in coordinating flight checks of airway facilities with air traffic control and flight-check personnel;

- Unfamiliarity with remote-maintenance subsystems and monitoring capabilities, and inability to update remote-maintenance-monitoring parameters;

- Errors involving insufficient training or experience, which lead to inaccurate diagnosis of the equipment, inadequate troubleshooting methods, unfamiliarity with required resources and expertise, failure to recognize/respond to an equipment alarm/alert, unfamiliarity with the organizational levels and remote-monitoring procedures, unfamiliarity with non-FAA organizations, failure to recognize faults or degradation of services, and failure to recognize a field requirement such as starting an engine-driven generator prior to the arrival of severe weather;

- Absence of documentation of work, which may cause faulty trend analysis and lead to rescheduling work that already has been completed;

- Failure to identify hazardous materials at the site;

- Inadequate staffing, including shift scheduling and personnel scheduling during heavy-workload situations and crises; and,

- Inadequate space for specialists to maneuver, which may cause bumping of equipment or cables and tripping.

Overall, managers of airway facilities should give special attention to designing clear and effective procedures and to ensuring that their specialists are adequately trained on these procedures, the report said.♦

[FSF editorial note: This article is based on "Human Error in Airway Facilities" by Vicki Ahlstrom and Donald G. Hartman, U.S. Department of Transportation, U.S. Federal Aviation Administration (FAA), Report no. DOT/FAA/CT–TN01/02ACT–530, January 2001. The study was conducted by the FAA Human Factors Division at the William J. Hughes Technical Center, Atlantic City, New Jersey, U.S. The report said that the researchers' principal objective was to prevent human errors that have been identified in the past from occurring under a new management system for airway facilities in the U.S. National Airspace System.]

Notes

1. The airway facilities specialists include maintenance control center specialists and field technicians.

2. In addition to the three regional operations control centers (which incorporate maintenance functions), the new U.S. Federal Aviation Administration (FAA) airways facility management system will include one national operations control center, 32 service operations centers and other work centers throughout the country.

3. In 2001, FAA's airways facility management system comprised one national maintenance control center and approximately 40 maintenance control centers. The maintenance control centers were responsible for scheduling, coordinating and tracking personnel and equipment resources. They also performed certification, maintenance and restoration of systems/services and equipment.

Further Reading From FSF Publications

McKenna, James T. "Maintenance Resource Management Programs Provide Tools for Reducing Human Error." *Flight Safety Digest* Volume 21 (October 2002).

FSF Editorial Staff. "Improved Understanding of Human Factors Could Reduce Foreign Object Damage." *Aviation Mechanics Bulletin* Volume 50 (July–August 2002).

FSF Editorial Staff. "Erroneous ILS Indications Pose Risk of Controlled Flight Into Terrain." *Flight Safety Digest* Volume 21 (July 2002).

FSF Editorial Staff. "Maintaining Visual Aids Helps to Prevent Runway Incursions." *Airport Operations* Volume 28 (May–June 2002).

FSF Editorial Staff. "Fatigue Evaluation Indicates Most Aviation Maintenance Personnel Obtain Insufficient Sleep." *Aviation Mechanics Bulletin* Volume 49 (November–December 2001).

Hobbs, Alan; Williamson, Ann. "Survey Assesses Safety Attitudes of Aviation Maintenance Personnel in Australia." *Aviation Mechanics Bulletin* Volume 48 (November–December 2000).

FSF Editorial Staff. "Knowledge of Hazardous Chemicals in Aviation Workplace Can Help Prevent Work-related Illness and Injury." *Aviation Mechanics Bulletin* Volume 45 (July–August 1997).

Adamski, Anthony J.; Stahl, Albert F. "Principles of Design and Display for Aviation Technical Messages." *Flight Safety Digest* Volume 16 (January 1997).

U.S. National Transportation Safety Board. "Special Safety Report: Air Traffic Control Equipment Outages." *Flight Safety Digest* Volume 15 (February 1996).

Rosenberg, Barry. "U.K. CAA Cites Inadequately Defined Inspection Procedures for Human Errors in Aircraft Inspection." *Aviation Mechanics Bulletin* Volume 43 (November–December 1995).

Wiener, Earl L. "Special Report: Intervention Strategies for the Management of Human Error." *Flight Safety Digest* Volume 14 (February 1995).

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