Human Factors in MAINTENANCE

Surveys reveal the importance of regulations mandating human factors programs.

BY WILLIAM B. JOHNSON AND CARLA HACKWORTH

D espite the existence of human factors programs in aviation maintenance since the late 1980s, such programs are not required throughout the world, and those that do exist are far from standardized. In 2006

and 2007, the U.S. Federal Aviation Administration (FAA) conducted two large-scale surveys that gave the international maintenance community and FAA aviation safety inspectors (ASIs) an opportunity to report progress and identify

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the human factors issues that need immediate attention. High response rates and frank answers to the surveys gave a clear view of the status and showed the direction future work should take.

During the 1980s, many flight organizations were enhancing safety by adopting cockpit resource management (CRM) programs. Flight crews were finding means to ensure and improve safety by focusing on teamwork, communication and developing operating procedures. The term evolved to become "crew" resource management and expanded to include a variety of human factors that affect performance and safety, such as fitness for duty, fatigue, nutrition and health, safety culture, and much more. There is no question that CRM has improved the safety of flight.

In 1988, the Aloha Boeing 737 fuselage-failure accident was the first of a number of significant events that focused attention on human factors in maintenance. That year, the U.S. Congress passed the Aviation Safety Act, which directed the FAA to conduct research on all aspects of human performance in aviation, including maintenance, launching the development of FAA's maintenance human factors research programs that continue today.

Continental Airlines in 1989 became the first to expand CRM and human factors principles to maintenance and engineering, introducing its Crew Coordination Concepts program. By the early 1990s, US Airways, with significant FAA research and development (R and D) participation, began its Maintenance Resource Management effort. Both programs continued for years, but without regulatory requirements to continue, they faded away when lean times arrived for the U.S. carriers.

By the mid-1990s, Transport Canada (TC), the U.K. Civil Aviation Authority and the FAA started an annual conference titled "Human Factors in Maintenance and Inspection." That conference provided excellent information exchange until 2002, when it took a hiatus until 2006. During that period, both TC and the Joint Aviation Authorities — now being replaced by the European Aviation Safety Agency (EASA) — enacted regulations requiring initial and continuing human factors

training for all maintenance personnel. At the same time, the FAA continued its human factors R and D, publishing extensive human factors guidance materials for U.S. domestic and international applications. The FAA also initiated human factors training for all of its nearly 1,800 ASIs. An expanded version of that training continues today. Yet, in spite of the extensive R and D, guidance material and internal employee training, the FAA has not issued a regulation requiring the industry to provide training for human factors in maintenance.

Regulatory Differences

Meanwhile, TC, EASA, the Civil Aviation Safety Authority of Australia and other regulatory agencies have adopted regulations for maintenance human factors programs. That situation prompted the authors to assess the status of human factors programs in maintenance organizations and airlines throughout the world. In addition, the FAA wanted to understand maintenance human factors in the United States as viewed by its ASI work force.

Both surveys, developed in cooperation with the EASA's European Human Factors Working Group, were Web-based, and respondents' answers were anonymous.[1] The industry questionnaire contained 78 items; the FAA survey had 45 questions. For the most part the surveys used five-point rating scales and provided open-ended opportunities for comments. The surveys discussed here are more fully described separately.[2, 3, 4]

The goals of the industry survey were to assess the current status of human factors programs, including:

- Training;
- Fatigue management;
- Leadership commitment;
- Error report systems;
- Use of technical documentation; and,
- Program cost justification.

And, most importantly, the survey was designed to assess the differences between mandatory and voluntary programs.

The international industry respondents had a lot to say. The invitation was sent to more than 600 valid e-mail addresses. Responses numbered 414, an unusually high 66 percent response rate, and included input from management, quality control, training and labor representatives in 54 countries. The highest percentage of respondents — 40 percent — worked within the United States. Some of the other countries included Canada, 9 percent; United Kingdom, 7 percent; and Australia, Norway and Singapore, all 3 percent.

The survey sample spanned the entire aircraft maintenance industry, with more than one-third from an airline maintenance department, 27 percent from repair stations, 9 percent in a general aviation/business operation, and 6 percent at a training facility or maintenance school. While specific respondent affiliation was secure and anonymous, it is estimated that approximately 200 organizations responded (Figure 1).

FAA-regulated maintenance operations were the most numerous, followed by those governed by EASA rules (Figure 2).

Regulations that require human factors programs make a difference, respondents said. To a question regarding the motivation for human factors programs, the two responses most frequently selected were flight safety and worker protection, followed by regulatory compliance and cost control.

While these responses reflect positively on the industry, results from this question likely were skewed by the high percentage of FAA-regulated respondents, who are not required to have a program. However, answers to further questions showed that those who had to comply with regulations indicated their programs were more robust, provided better training for instructors and trained higher percentages of staff.

But human factors programs go beyond regulations. The survey inquired about many aspects of a total human factors program, including topics such as use of error management systems, fatigue management and training, cost justification of human factors programs and technical documentation systems.

Some 55 percent of the respondents reported that error data were stored in a database, and less than half of all those responding said their database was reviewed in a proactive manner. In this day of increased attention to safety management systems (SMS), a data-driven process, that number is not high enough. The response indicates that there is plenty of opportunity for improvement and reinforces the idea that the collection of data, while challenging, is easier than data analysis. The SMS challenge is to discover what the data are telling us.

Fatigue is a safety issue in maintenance, according to 82 percent of the respondents. However, only 25 percent had a fatigue management system, and just 36 percent covered fatigue in the training program. This discontinuity between recognizing the fatigue threat and establishing barriers is alarming, and it was repeated in the inspector survey.

Less than 10 percent of respondents reported that an effort had been made to show a return on investment in human factors programs even though 51 percent said such information was important. Clearly, the industry must improve methods to assess the financial return on human factors programs if such programs are to flourish and expand beyond minimum regulatory requirements. The lack of justifications helps explain why the apparently successful voluntary programs from the early 1990s became victims of hard financial
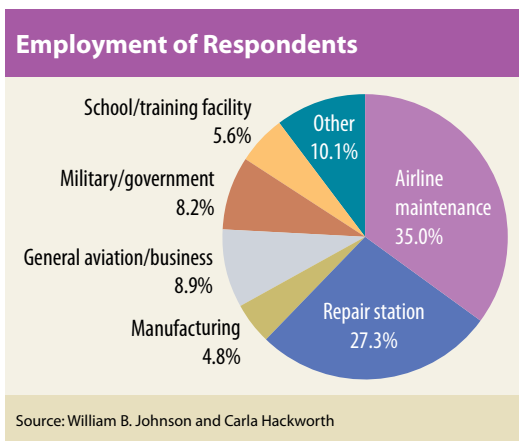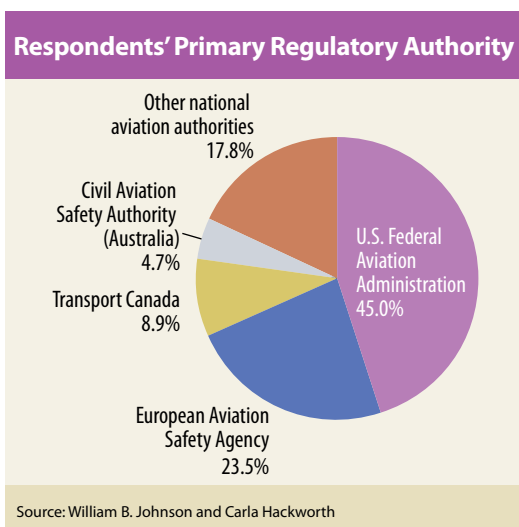
Employment of Respondents

School/training facility 5.6%

Other 10.1%

Military/government 8.2%

Airline maintenance 35.0%

General aviation/business 8.9%

Manufacturing 4.8%

Repair station 27.3%

Source: William B. Johnson and Carla Hackworth

Figure 1

Respondents' Primary Regulatory Authority

Other national aviation authorities 17.8%

Civil Aviation Safety Authority (Australia) 4.7%

Transport Canada 8.9%

U.S. Federal Aviation Administration 45.0%

European Aviation Safety Agency 23.5%

Source: William B. Johnson and Carla Hackworth

Figure 2

times. Those programs "felt" good, but did not take the time to prove their financial worth.

More than 70 percent of respondents' companies had a formal or informal policy to apply human factors considerations to the development or modification of documentation.

Proper use of technical documentation remains a very high priority for the industry. Failure to follow procedures is the no. 1 cause of most negative events, and human factors issues are often a root cause of documentation events. When people do not use documents correctly, event investigations must drill down to discover the reasons, not just assign blame. Effective use of error reporting systems is a very good way to raise human factors-related attention to technical documentation and procedures.

The industry survey indicates that the following are the best opportunities for improving how human factors are handled in maintenance:

- Use of event reporting data, creation of a fatigue management program;

- Increased use of data to provide cost justification of human factors programs; and,

- Greater attention to the human factors aspects during the development and use of technical documentation and procedures.

Inspectors and Human Factors

The second survey, completed in 2007, focused on the FAA inspector work force. The FAA survey had these goals:

- To gather opinions regarding the perceived level of human factors knowledge among the ASI work force;

- To assess the level of human factors support for ASIs;

- To obtain an inspector's view of human factors programs in the industry; and,

- To identify workplace challenges both for the aviation maintenance industry and the FAA.

The inspectors capitalized on the opportunity, and the survey obtained approximately 180 open-ended comments.

As with the industry survey, there was a high response rate. The voluntary participation by more than 800 ASIs meant that nearly 45 percent of FAA's inspectors participated.

The inspectors generally were evenly divided between the airlines and general aviation, with the airline group slightly larger (Figure 3). More than 80 percent of the respondents performed surveillance as part of their job and had maintenance experience in excess of 20 years. Some 44 percent of the inspectors reported that the companies they oversee comply with EASA rules with respect to human factors. Thus, the FAA ASIs are seeing a lot of human factors programs, but not because of FAA regulations.

A high percentage of FAA inspectors, 64 percent, said the human error investigations they see in the U.S. industry tend to be informal. In a separate item, 12 percent of the ASIs said their operators had implemented human factors practices to "a considerable extent" or "a great extent." The informality of the programs may be reasonable because good programs are not necessarily highly structured. Instead, they should be designed to fit the company culture and requirements derived from error reporting systems.

The 12 most common causes of human error in maintenance, named the "Dirty Dozen" by Canadian safety specialist Gordon Dupont, were presented for inspectors to rank the challenges (Figure 4, p. 39). The top three for maintenance were pressure, complacency and the use of norms — that is, the use of unwritten practices. The combination of these top-rated causes of error can contribute to the failure to use technical
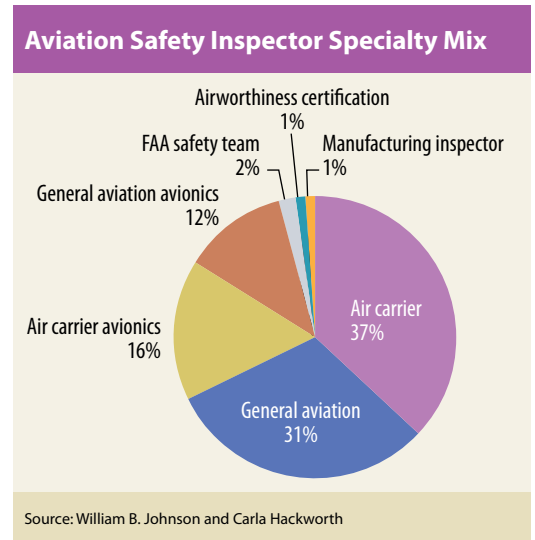
Aviation Safety Inspector Specialty Mix

- Airworthiness certification 1%
- FAA safety team 2%
- Manufacturing inspector 1%
- General aviation avionics 12%
- Air carrier avionics 16%
- Air carrier 37%
- General aviation 31%

Source: William B. Johnson and Carla Hackworth

Figure 3

Failure to follow procedures is the no. 1 cause of most negative events, and human factors issues are often a root cause of documentation events.

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Gordon Dupont's Dirty Dozen

The most common causes of human error:

- Lack of communication
- Lack of teamwork
- Norms
- Pressure
- Complacency
- Lack of knowledge

- Lack of awareness
- Lack of resources
- Distraction
- Assertiveness
- Fatigue
- Stress

Source: William B. Johnson

Figure 4

documentation, which surprisingly was rated only as the fifth on the inspectors' rating of challenges despite the fact that documentation issues are unarguably the leading contributor to maintenance error.

FAA inspectors rated the important attributes/programs for a quality maintenance organization and overwhelmingly identified a positive safety culture — 91 percent — and an SMS — 82 percent — as the most important (Figure 5). FAA management, especially from the Aviation Safety office (AVS), has been "walking the walk" with respect to safety culture and SMS, evidenced by the organization's recent ISO9000 certification and establishment of a new office dedicated to gathering, analyzing and sharing data.

Fatigue is a concern for the aviation industry.[5] Nearly 40 percent of ASIs responded that maintenance employee fatigue is a safety issue for the operators they oversee. Airline inspectors saw this as a greater issue — 43 percent — than did general aviation (GA) inspectors — 35 percent. Both categories of inspectors reported a need for regulations related to fatigue issues in maintenance, 91 percent for airline ASIs and 75 percent for GA inspectors. The FAA has ongoing research initiatives that are providing guidance and procedures to address fatigue in the maintenance workplace. This R and D involves a planned mix of approaches addressing issues including the science of fatigue and sleep, applications for nano-technology

sensors, real-time human performance modeling, advanced technology scheduling practices, economics of maintenance worker compensation practices and accident investigation analysis related to fatigue.

The FAA's three-day employee course, "Human Factors in Aviation Maintenance," is now required training; half of all airworthiness ASIs attended the previous two-day class. Two-thirds of the respondents indicated that they want biennial recurrent training in human factors; EASA requires biennial recurrent training for its certificate holders.

During 2006 and 2007, FAA released two operator's manuals for human factors, one for maintenance that received the FAA Administrator's Plain Language Award for 2006, and the other a report for airport operations.[6] ASIs

Ranking Importance of Maintenance Safety Programs

Note: Results from survey of FAA safety inspectors

Source: William B. Johnson and Carla Hackworth

Figure 5

indicated a limited familiarity with the maintenance operator's manual, suggesting that the FAA must not only publish guidance materials but also promote them both internally and externally.

Inspectors used the "Dirty Dozen" to rate their own job challenges, and selected distraction, lack of resources and pressure as their greatest challenges. There were many comments providing positive suggestions to improve inspectors working efficiency. Inspectors recognized the emerging requirement for additional oversight of domestic and international repair stations and said they knew that inspectors face a workload that is growing faster than the work force.

Inspectors said that there should be an FAA regulation for human factors programs, with 80 percent of airline inspectors and 72 percent of GA inspectors backing the idea. Their positions were reinforced by numerous comments that generally said that airline maintenance organizations are driven by regulations and will invest resources to follow the rules. When there are human factors regulations, there will be compliance by all. Until then, human factors programs will exist only where there are EASA certificates and/or enlightened U.S. maintenance organizations.

Combining Survey Data

The high rate of response to both voluntary surveys was evidence of a high interest in maintenance human factors. Respondents had positive attitudes and reported what they believed were the best opportunities for improvement. FAA inspectors were generally positive in their rankings and candid in their responses about maintenance human factors. Their comments demonstrated

an understanding of the impact of human factors programs in maintenance organizations. Many of the comments originated from the ASI's past employment in the airline maintenance industry.

There was general agreement between the two surveys that the no. 1 challenge is fatigue in maintenance. Throughout the world, the rules addressing fatigue are not strict. There are exceptions, usually due to national labor law. That leaves the responsibility of addressing fatigue challenges with companies, labor organizations and individuals.

A strict regulation regarding duty time may not be the best solution for everyone. The issue crosses a variety of domains, including but not limited to science, health, fitness for duty and safety, plus significant corporate and personal economic issues. One size does not fit all.

The industry must not wait for regulators to issue a mandate. Tools are available that organizations can use to assess the potential impact of their scheduling practices on fatigue and performance. Industry must step up to professional reviews of scheduling patterns, managing shifts and tracking duty time, plus beginning to recognize fatigue as a valid reason to miss or stop work.

Additional opportunities for improvement, depending on company and country, may include the following: increased use of error reporting system data; application of systems and data to cost-justify human factors programs; improved training for human factors trainers; improved systems for technical documentation; and more. The international movement toward a formal SMS environment is a step in the right direction. It is critical that SMS never

lose focus on the most important link in the safety chain, the human. ●

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Notes

1. Nearly 1,500 safety professionals worldwide contributed to these surveys. The research was a joint effort of the FAA Civil Aerospace Medical Institute (CAMI) at the Mike Monroney Aeronautical Institute, Oklahoma City, Oklahoma, U.S., and the Maintenance Division of the Flight Standards Service, Washington, D.C. Flight Standards participants were John J. Hiles and David Cann. CAMI team participants were Kali Holcomb, Joy Banks, Melanie Dennis and David Schroeder.

2. Hackworth, C.; Holcomb, K.; Dennis, M.; Goldman, S.; Bates, C.; Schroeder, D.; Johnson, W. (2007a). "Survey of Maintenance Human Factors Programs Across the World." *The International Journal of Applied Aviation Studies*, Volume 7, Number 2, 212–31.

3. Hackworth, C.; Holcomb, K.; Dennis, M.; Goldman, S.; Bates, C.; Schroeder, D.; Johnson, W. (2007b). *An International Survey of Maintenance Human Factors Programs* (Report No. 07/25). Oklahoma City, Oklahoma: FAA CAMI.

4. Hackworth, C.A.; Banks, J.O.; Holcomb, K.A.; Johnson, W.B.; Hiles, J.J. (2007c). *Aviation Safety Inspectors' (ASIs) Maintenance Human Factors Survey,* (Memorandum Internal FAA Report). Oklahoma City, Oklahoma: FAA CAMI.

5. U.S. National Transportation Safety Board (2006). *Most Wanted Transportation Safety Improvements, Federal Issues. Aviation: Reduce Accidents and Incidents Caused by Human Fatigue.* <www.ntsb.gov/recs/mostwanted/aviation_reduce_acc_inc_humanfatig.htm>.

6. Human factors manuals are available at <www.hfskyway.com>.