Human error has been documented as a primary contributor to more than 70 percent of commercial airplane hull-loss accidents. While typically associated with flight operations, human error has also recently become a major concern in maintenance practices and air traffic management. Boeing human factors professionals work with engineers, pilots, and mechanics to apply the latest knowledge about the interface between human performance and commercial airplanes to help operators improve safety and efficiency in their daily operations.
The term “human factors” has grown increasingly popular as the commercial aviation industry has realized that human error, rather than mechanical failure, underlies most aviation accidents and incidents. If interpreted narrowly, human factors is often considered synonymous with crew resource management (CRM) or maintenance resource management (MMR). However, it is much broader in scope, involving knowledge and skills for anticipating, understanding, and mitigating human error. Human factors involves gathering information about human abilities, limitations, and other characteristics and applying it to tools, machines, systems, tasks, jobs, and environments to produce safe, comfortable, and effective human use. In aviation, human factors is dedicated to understanding how humans can most effectively use technology while exercising good judgment. That understanding is then translated into design, training, policies, or procedures to help humans perform more safely and efficiently.

Despite rapid gains in technology, humans are ultimately responsible for ensuring the success and safety of the aviation industry. They must continue to be knowledgeable, flexible, and efficient while exercising good judgment. Meanwhile, the industry continues to make major investments in training, equipment, and systems that have long-term implications.

Because technology continues to evolve faster than the ability to predict how humans will interact with it, the industry can no longer depend as much on experience and intuition to guide decisions related to human performance. Consequently, Boeing flight decks incorporate intuitive, easy-to-use systems. These systems are designed to help humans perform to the best of their capability while compensating for their natural limitations.

Because improving human performance can help the industry reduce the commercial aviation accident rate, much of the industry’s focus is on designing human-airplane interfaces and developing procedures for both flight crews and maintenance technicians. Boeing also continues to examine human performance throughout the airplane to improve usability, maintainability, reliability, and comfort. In addition, human factors specialists participate in analyzing operational safety and developing methods and tools to help operators better manage human error. These responsibilities require the specialists to work closely with engineers, safety experts, test and training pilots, mechanics, and performance engineers to properly integrate human factors into the design of all Boeing airplanes. Their areas of responsibility include addressing human factors in:

1. Flight deck design.
2. Design for maintainability and in-service support.
3. Crew interaction capability.
4. Passenger cabin design.

Customer input. Boeing involves potential customers in defining top-level design requirements for new designs or major derivatives and in applying human factors principles. A good example is the high level of airline involvement in designing the 777.

From the beginning, operators’ flight crews and mechanics worked side by side with Boeing design teams on all airplane systems. Eleven of the initial operators also participated in dedicated flight deck design reviews early in the design process. An independent external team of senior human factors scientists also participated in a parallel set of reviews. In the final reviews, flight crews and other representatives from each operator spent time in the 777 engineering flight simulator to evaluate the design in a variety of normal and non-normal situations. These activities ensured that operator requirements were considered from the beginning, and validated that the implementation included a sound pilot-flight deck interface.

The focus is on design efforts that apply technology in the best way to satisfy validated requirements:

- Customer input.
- Appropriate degree of automation.
- Crew interaction capability.
DESIGN FOR MAINTAINABILITY AND IN-SERVICE SUPPORT

Over the past several years, airplane maintenance has benefited from an increased focus on how human factors can contribute to safety and operational efficiency. In maintenance, as in flight deck design, Boeing employs a variety of sources to address human factors issues, including:

- Chief mechanic participation.
- Computer-based maintainability design tools.
- Fault information team.
- Customer support processes.

Chief mechanic participation.

Modeling on the role of chief pilot, a chief mechanic was appointed to the 777 program and to all subsequent airplane programs (717, 737-600/-700/-800/-900, 757-300, and 767-400 Extended Range [ERJ]). As with the chief pilot, the mechanic acts as an advocate for operator or repair station counterparts. The appointment of a chief mechanic grew out of the recognition that the maintenance community contributes significantly to the success of airline operations in both safety and on-time performance. Drawing on the expertise of airline and production mechanics, reliability and maintainability engineers, and human factors specialists, the chief mechanic oversees the implementation of all maintenance-related features.

Computer-based maintainability design tools.

To improve this situation, Boeing has developed human factors tools to help understand why the errors occur and develop suggestions for systematic improvements.

ERROR MANAGEMENT

Failure to follow procedures is not uncommon in incidents and accidents related to both flight operations and maintenance procedures. However, the industry lacks insight into why such errors occur. To date, the industry has not had a systematic and consistent tool for investigating such incidents. To improve this situation, Boeing has developed human factors tools to help understand why the errors occur and develop suggestions for systematic improvements.
and structured manner so that effective remedies can be developed (see p. 33). Maintenance Error Decision Aid (MEDA). This tool began as an effort to collect more information about maintenance errors. It developed into a project to provide maintenance organizations with a standardized process for analyzing contributing factors to errors and developing possible corrective actions (see “Boeing Introduces MEDA” in Airliner magazine, April–June 1996, and “Human Factors Process for Reducing Maintenance Errors” in Aero no. 3, October 1998). MEDA is intended to help airlines shift from blaming maintenance personnel for making errors to systematically investigating and understanding contributing causes. As with PEAT, MEDA is based on the philosophy that errors result from a series of related factors. In maintenance practices, those factors typically include misleading or incorrect information, design issues, inadequate communication, and time pressure. Boeing maintenance human factors experts worked with industry maintenance personnel to develop the MEDA process. Once developed, the process was tested with eight operators under a contract with the U.S. Federal Aviation Administration.

Since the inception of MEDA in 1996, the Boeing maintenance human factors group has provided on-site implementation support to more than 100 organizations around the world. A variety of operators have witnessed substantial safety improvements, and some have also experienced significant economic benefits because of reduced maintenance errors.

Three other tools that assist in managing error are:
- Crew information requirements analysis.
- Training aids.
- Improved use of automation.

Crew information requirements analysis (CIRA). Boeing developed the CIRA process to better understand how flight crews use the data and cues they are given. It provides a way to analyze how crews acquire, interpret, and integrate data into information upon which to base their actions. CIRA helps Boeing understand how the crew arrived or failed to arrive at an understanding of events. Since it was developed in the mid-1990s, CIRA has been applied internally in safety analyses supporting airplane design, accident and incident analyses, and research.

Training aids. Boeing has applied its human factors expertise to help develop training aids to improve flight safety. An example is the company’s participation with the aviation industry on a takeoff safety training aid to address rejected takeoff runway accidents and incidents. Boeing proposed and led a training tool effort with participation from line pilots in the industry. The team designed and conducted scientifically based simulator studies to determine whether the proposed training aid would be effective in helping crews cope with this safety issue. Similarly, the controlled flight into terrain training aid resulted from a joint effort by flight crew training instructor pilots, human factors engineers, and aerodynamics engineers.

Improved use of automation. Both human factors scientists and flight crews have reported that flight crews can become confused about the state of advanced automation, such as the autopilot, autothrottle, and flight management computer. This condition is often referred to as decreased mode awareness. It is a fact not only in aviation but also in today’s computerized offices, where personal computers sometimes respond to a human input in an unexpected manner. The Boeing Human Factors organization is involved in a number of activities to further reduce or eliminate automation surprises and to ensure more complete mode awareness by flight crews. The primary approach is to better communicate the automated system principles, better understand flight crew use of automated systems, and systematically document skilled flight crew strategies for using automation. Boeing is conducting these activities in cooperation with scientists from the U.S. National Aeronautics and Space Administration (fig. 3). When complete, Boeing will use the results to improve future designs of the crewmember-automation interface and to make flight crew training more effective and efficient.

4 PASSENGER CABIN DESIGN

The passenger cabin represents a significant human factors challenge related to both passengers and cabin crews. Human factors principles usually associated with the flight deck are now being applied to examine human performance functions and ensure that cabin crews and passengers are able to do what they need or want to do. Some recent examples illustrate how the passenger cabin can benefit from human factors expertise applied during design. These include:
- Automatic overwing exit.
- Other cabin applications.

Automatic overwing exit. The 737-600/-700/-800/-900 is equipped with an improved version of the overwing emergency exit (fig. 4), which opens automatically when activated by a passenger or cabin or flight crew member. Human performance and ergonomics methods played important roles in both its design and testing. Computer analyses using human models ensured that both large and small people would be able to operate the exit door without injury. The handle was redesigned and tested to ensure that anyone could operate the door using either single or double handgrips. Then, approximately 200 people who were unfamiliar with the design and who had never operated an overwing exit participated in tests to verify that the average adult can operate the exit in an emergency. The exit tests revealed a significantly improved capability to evacuate the airplane. This major benefit was found to be unique to the 737 configuration. The human factors methodology applied during test design and data analysis contributed significantly to refining the door mechanism for optimal performance.

Other cabin applications. Working with payloads designers, human factors specialists also evaluate cabin crew and passenger reach capability, placard comprehension, emergency lighting adequacy, and other human performance issues. Because of the focus on human capabilities and limitations, the analyses and design recommendations are effective in reducing potential errors and in increasing usability and satisfaction with Boeing products.

More general issues of human usability have also been addressed. For instance, human factors specialists collaborated with engineers in various studies during 767-400ER program design. The reach and visibility of the passenger service units components were reviewed so cabin crews could use them more easily and effectively. The glare ratio on the sidewalls was analyzed and improved for increased passenger comfort. In addition, the cabin crew panel for controlling the in-flight entertainment system was modified for easier operation and maintainability.
In mid-1999 Boeing began distributing the Procedural Event Analysis Tool (PEAT) to its operators. The company is offering this safety tool to help operators understand the reasons underlying incidents caused by flight crew deviation from established procedures.

PEAT is a structured analytic tool (fig. 1) that operators can use to investigate incidents and develop measures to prevent similar events in the future. It is available to operators free of charge and is the result of a cooperative development effort among airlines, pilot union representatives, and Boeing human factors specialists.

PEAT originated from an extensive effort to identify the key underlying cognitive factors that contributed to procedural noncompliance in past accidents. In 1991 Boeing concluded a 10-year study that showed that flight crew deviation from established procedures contributed to nearly 50 percent of all hull-loss accidents. The aviation industry still lacks sufficient knowledge about the reasons for these deviations, however, and had no formal investigation tool to help identify them.

In addition to helping operators find these reasons, PEAT was designed to significantly change how incident investigations are conducted. When followed correctly, the PEAT process focuses on a cognitive approach (fig. 2) to understand how and why the event occurred, not who was responsible. Using PEAT successfully depends on acknowledging the philosophy that flight crews very rarely fail to intentionally comply with a procedure.

In addition, operators must adopt an investigative approach that fosters cooperation between the flight crew and the safety officer conducting the investigation.

PEAT contains more than 200 analysis elements that enable the safety officer to conduct an in-depth investigation, summarize the findings, and integrate them across various events. PEAT also enables operators to track their progress in addressing the issues revealed by the analyses.

Operators can realize several benefits by using PEAT:
- A structured, systematic approach to investigations.
- Consistent application and results.
- Visibility of incident trends and risk areas.
- Reduction or elimination of procedural-related events.
- Improved operational safety.
- Improved economic efficiencies.
- A means for communicating and sharing relevant information between organizations, both internal and external to the airline.
- Compatibility with existing industry safety tools.

Operators must acquire hands-on training to effectively adopt and apply the PEAT process and software. Requests for training should be addressed to Mike Moodi in Boeing Flight Technical Services (fax 206-662-7812). More information is available on the Boeing PEAT web site: