FEDERAL AVIATION ADMINISTRATION
FLIGHT DECK HUMAN FACTORS RESEARCH PROGRAM

Sheryl L. Chappell, Regina G. Bolinger, and Ashley C. Awwad
Federal Aviation Administration
Washington, DC

The next generation air transportation system (NextGen) is a comprehensive suite of state-of-the-art technologies and procedures that improves national airspace system (NAS) capacity and efficiency, while maintaining world-class safety. In order to realize these improvements, the roles and the systems of pilots and controllers are changing. Advanced technologies and new procedures make the information and the tasks more complex. The Federal Aviation Administration's (FAA) Flight Deck Human Factors Research Program examines flightcrew interaction with current and future technology and pilot performance of flight procedures. Human factors scientists across industry, government, and academia produce scientific and technical data-driven recommendations to support the FAA's development of regulatory standards, policies, and other guidance materials for aircraft manufacturers and operators' procedures, training, and equipage. A sample of the program's scope, methodology, findings, future needs, and challenges is described below.

In addition to providing the United States with air traffic control (ATC) services, the Federal Aviation Administration (FAA) is responsible for regulating U.S.-registered aircraft and their operation. The FAA recognizes the importance of human factors in both controlling air traffic and ensuring aircraft are built, maintained, and operated safely. In 1993, the FAA published the Human Factors Policy to establish the "policy and responsibilities for incorporating and coordinating human factors considerations in FAA programs, facilities, and activities to enhance aviation safety, capability, efficiency, and productivity" (FAA Order 9550.8). The order defines human factors as a "multidisciplinary effort to generate and compile information about human capabilities and limitations and apply that information to equipment, systems, facilities, procedures, jobs, environments, training, staffing, and personnel management for safe, comfortable, and effective human performance."

According to the FAA's definition, human factors research involves the scientific acquisition of information about human capabilities and limitations related to the following:

- Hardware
- Procedures
- Environments
- Errors
- Personnel management
- Software
- Jobs
- Training
- Situation awareness
- Decision support tools
- Facilities
- Organizations
- Staffing
- Workload
- Other performance implications in which the human is a component

The Human Factors Division in the Office of the Next Generation Air Transportation System (NextGen) has the responsibility of managing human factors aviation research for the agency. This paper provides a description of some of the research related to aircraft, pilots, and maintainers. The division also manages air traffic control human factors research, but that is not highlighted here. The Human Factors Flight Deck Research Program has the challenge to provide improved knowledge of the human-system interface and a reduction in accidents and incidents through enhanced aerospace vehicle, air traffic, and technical operations that adapt to, compensate for, and augment the performance of the human.

Human factors research provides the foundation for FAA guidelines, handbooks, orders, advisory circulars, technical standards orders, and regulations, which ensure the safety and efficiency of aircraft operations. This research also provides the aviation industry with information for use in designing and operating aircraft as well as training pilots and maintenance personnel. Sponsors from across the FAA determine research needs and the urgency. These are driven by operational safety trends and the timing of new aircraft and ATC system capabilities.

The Human Factors Division engages top human factors scientists in industry, government, and academia to conduct both short-term, sharply-focused and longer-term, comprehensive research. It is useful to think of the broad range of flight deck research—which currently exceeds 50 projects—as falling into two general categories: (1) the ability of the pilots and maintainers to perform their jobs safely, and (2) the design, operation, and maintenance of aircraft systems.

Pilots and Maintainers

To address the ability of pilots and maintainers to perform their tasks safely, the FAA is conducting studies on fatigue mitigation, pilot training and performance assessment, and maintenance risk-based decision making.

Fatigue Mitigation

Airlines are required to manage and mitigate pilot fatigue during day-to-day flight operations by developing and implementing fatigue management policies and procedures within their operations; providing fatigue awareness and education to improve alertness and reduce the potential for errors; and continuously assessing the performance of these policies and practices,

revising them as necessary. Air carriers can also develop a fatigue risk management system, allowing them to safely conduct specific flight operations not found in the prescriptive regulations. The carriers submit an alternative method of compliance supported by sleep and wake-time data and simple task performance data during a series of flight duty periods, including layover and post-trip recovery, to assure safety of flight. The air carriers monitor the effects of circadian rhythm changes, adequacy of layover rest, and returning flight schedules. Following the data collection exemption flights, the FAA evaluates the data and only authorizes those schedules exceeding regulation table limits that demonstrate that pilots are alert and well rested during those flight operations.

The Human Factors Division also manages research in fatigue management for maintenance personnel. The FAA provides training materials to individuals and flight organizations to educate them on the hazards of—and mitigations for—maintainer fatigue.

Air Carrier Pilot Training and Evaluation

FAA air carrier policy makers, inspectors, and airline training departments constantly evaluate the performance of pilots and ask researchers how to make training more targeted for areas in need of improvement. Some areas currently under study include the following:

- Manual and cognitive skill degradation with increasing automation
- Crew resource management best training and evaluation practices
- Flight path monitoring
- Response to unexpected events, and
- Training on the increased complexity of instrument procedures and flight deck system automation.

The FAA uses data from these research programs to provide updates to advisory circulars and inspectors' handbooks, and the airlines use the data to improve their training curricula.

Maintenance Risk-Based Decision Making

As the industry and the FAA mature their risk-based decision-making capability, they measure human performance and take into account the assessment of risk. Safety management systems at the FAA as well as flight operators collect data from aircraft and air traffic operations. These collected data provide a rich source of human performance data.

One area this science is increasingly mature in is the maintenance of aircraft. FAA-funded human factors research products include the following:

- Maintenance-line operations safety assessment tools, a method to collect data during normal operations from those doing the work
- Fatigue risk management techniques, and
- Design principles for technical documentation.

These products are currently undergoing field-testing, the results of which will be used to underpin implementation guidance for FAA inspectors and maintenance operators.

Design and Operation of Aircraft

Research, performed under the management of the Flight Deck Human Factors Research Program on the design and safe operation of aircraft systems, covers most types of aircraft and flight operations, including unmanned aircraft systems (UAS), single-engine private pilot flying, rotorcraft operations, and air carrier operations. Studies include the following:

- Ability of pilots to taxi in poor visibility using enhanced vision displays
- Design of unmanned aircraft system control stations to provide flight information to the pilot on the ground
- Pilot's management of the aircraft's flight path
- Use of digital communications between pilots and controllers, and
- Information needed for time-based navigation.

The tools researchers use to investigate human performance can range from a tablet computer to a full-mission simulator with ATC and other traffic. Experimental scenarios are key to providing the proper level of context and workload. Dependent measures include:

- Response time
- Response accuracy
- Number of control inputs
- Flight control movement
- Course, altitude, and speed deviations, and
- Number and length of communications.

Other measures include subjective workload, preference ratings, and the discriminability of symbols and flight parameters.

As flight deck systems and procedures evolve, the FAA must address fundamental human factors issues. The FAA recognizes that the increased complexity of both the systems and the procedures introduces brittleness. Pilots are confronted with elaborate failure modes and a vast array of possible alerts. Not only how, but also where, to convey this information is an area of current study. To reduce the impact of system and procedure complexity, the FAA is also sponsoring research on the efficacy of displaying aggregated flight parameters, such as the aircraft's energy state.

New Flight Deck Systems

A Federal regulation (14 CFR 25.1302) requires new systems for transport category aircraft to be "designed so that qualified flightcrew members trained in their use can safely perform all of the tasks associated with the systems' and equipment's intended functions." The regulation requires controls and information to be clear and unambiguous and to enable the flightcrew to manage errors. FAA human factors research evaluates flightcrew use of new technologies for both displays and controls on the flight deck.

The addition of electronic flight bags, which provide updated charts, manuals, weather, and safety information to the flight deck, brings standard user interface human factors issues to be studied, e.g., managing multiple applications and verifying the integrity of the data. The shift in communications from verbal to digital is another area of study, as the technology becomes

more available and advantageous. New international standards are being formed with the knowledge resulting from the FAA's datalink communications research program.

New vision systems that are available for use by the pilot, and which are the subject of FAA human factors research, include advanced vision systems permitting low-visibility taxi and takeoff operations. The FAA is also studying enhanced flight vision systems that allow landing at airports with reduced airport infrastructure. Other areas of research focus on determining minimum requirements with synthetic vision and combined vision systems.

Rotorcraft in near-to-ground operations have a significant number of incidents that involve striking obstructions or obstacles. Research is ongoing on display technologies to provide additional awareness of the presence of obstacles, especially head-mounted displays, which are a logical extension of natural-vision-referenced flight guidance. This research will provide guidance for both the certification and the operational approval for these new devices and will help to identify potential hazards associated with head-mounted systems. The results could be applied immediately to generate an advisory circular, with updates to relevant regulations to follow later.

Not only are visual flight deck displays being studied, other sensory modes are also explored. Presenting information aurally and tactually reduces the load on the visual information stream and the FAA is researching how to use these modes effectively on the noisy, vibrating flight deck. The FAA is also researching controls using other sensory modes. The speed and accuracy of touch, gaze, and voice interactions are being evaluated for control of flight deck systems.

New Flight Deck Procedures

The FAA's NextGen implementation is transforming the NAS in order to advance growth and increase safety while also reducing aviation's environmental impact. New ATC and flight deck procedures are enabling this transformation. These new procedures shift certain decision-making abilities from the controller to the pilot. Measuring the pilots' performance on the new procedures is an important part of the work managed by the Human Factors Division.

A NextGen capability, interval management time-based sequencing and spacing, will improve schedule predictability and system performance by maximizing throughput to use available system capacity and by reducing vectoring and holding, thereby improving fuel

efficiency. A current study of this capability evaluates both controller and pilot performance. This research will identify the minimum information controllers and pilots need and will recommend procedures for successful implementation.

Unmanned Aircraft Systems

The Human Factors Division manages several research projects looking at the human performance of UAS pilots and of the air traffic controllers who are interacting with these new systems. Research is underway to determine what current flight deck standards apply to the design of the UAS controls station and how to substitute the information a pilot senses when in the aircraft. For example, the pilot is unable to physically see, and therefore avoid, other aircraft. Sensor systems providing data on the relative position of other aircraft as well as displays with alerting are necessary to provide this information in a meaningful way for pilots to remain well clear of other aircraft. Human factors research data on pilots' use of displays and alerting feed directly into industry standards.

When the datalink between the control station and the unmanned aircraft is unavailable, the aircraft will revert to a lost-link flight path. The air traffic controller responsible for separation of that aircraft with other traffic must know (1) that the loss of control has occurred, and (2) where the aircraft is going to go and when. Currently, most UAS operations take place in military airspace. This will not be true in the near future. Information and procedures are necessary for both the controller and the pilot to accommodate safe integration with the NAS. This requires a study of air traffic controller and UAS pilot performance using a high-fidelity simulation and realistic scenarios. Data collected from this research will result in modifications to controllers' displays and inform new procedures for controllers and pilots.

Summary

The Flight Deck Human Factors Research Program examines both flightcrew interaction with current and future technology and pilot performance of flight procedures. Research data are used to change or develop new avionics and air traffic procedures through regulations and guidance materials. FAA aircraft certification officials apply the findings of human factors research to the approval of aircraft systems. Other FAA personnel, such as air carrier principal operations inspectors and maintenance operations inspectors, incorporate research findings into their airline oversight. The airlines use these research findings to improve their pilot and maintainer procedures and training. Finally, aircraft manufacturers use data from the Flight Deck Human Factors Research Program to improve the functions as well as the displays and controls of their flight deck equipment. As FAA's NextGen technologies continue to evolve and enter into service in the NAS, flight deck human factors research will continue to play a vital role in increasing safety and improving the movement of aircraft through the National Airspace.