

DEVELOPING AVIATION TECHNOLOGIES FOR THE FUTURE

FEDERAL AVIATION ADMINISTRATION

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The U.S. aviation system is under heavy pressure to keep pace with rising traffic demand, the need for safety and security improvements, requirements for more flexible and efficient air-traffic management operations, and the desire to further mitigate the environmental effects of aircraft operations. To meet these challenges, the Federal Aviation Administration operates a comprehensive research and development program through which it has made many valuable investments in technological innovation. These investments have contributed significantly to the safety, efficiency, and cost-effectiveness of the U.S. aviation system.

NEW AIR-TRAFFIC CONTROL TECHNOLOGIES

Since the 1940s one of the most difficult jobs for the Federal Aviation Administration and its predecessor, the Civil Aeronautics Administration, has been to modernize the air-traffic control system and improve safety. The challenge has been to phase in new technologies without disrupting the essential service provided by a sophisticated and complex aviation system. Many of FAA's successes in increasing the system's safety and efficiency have come through the research and development program.

Collision Avoidance

Advances in aviation safety are often triggered by high-profile accidents. One such accident occurred in 1974 near Dulles International Airport in Chantilly, Virginia. A TWA 727 aircraft making a normal approach slammed into Round Hill about 56 kilometers (35 miles) northwest of Washington, killing all 92 people aboard. That accident was traced to several causes, including the absence of a

cockpit warning system to alert the crew that the plane was dangerously close to the hill. This type of accident, termed controlled flight into terrain, previously occurred an average of 1.5 times a year in the United States and continues to be the leading cause of airplane accidents worldwide. As a direct result of the Dulles crash, FAA helped to develop a ground-proximity warning system, which sounds an alarm whenever a plane flies too near the ground. Because the agency requires large commercial aircraft to be equipped with the system, no more accidents like the Dulles crash have been experienced by major U.S. carriers. FAA expects the next generation of ground-proximity warning systems to be even more effective because of the use of greatly improved terrain data bases.

Satellite-Based Systems

Much of current navigation research and development efforts of the Federal Aviation Administration are aimed at the application of satellite-based communications, navigation, and surveillance to civil aviation. Through agency research and development activities, techniques have been devised and refined to increase the accuracy, integrity, and availability of the global positioning system, which is now used as a primary tool for navigation in oceanic airspace. With the system, pilots can determine their position over vast stretches of ocean to within 100 meters (328 feet). The global positioning system also is being used as a supplemental system for nonprecision approach guidance. Approximately 90 percent of U.S. airports with instrument-flight rules now use the system on some approaches. FAA is also rapidly implementing the system for precision approaches. Further research will focus on establishment of the system as a primary tool for nonprecision approaches

by 1998 and for Category I precision approaches by 2002.

In 1995 the International Civil Aviation Organization and its 185 member nations endorsed the use of satellite navigation as an early component of the universal air-traffic management system envisioned for the 21st century. Fourteen countries already have approved the global positioning system as a supplemental tool for navigation in their airspace. To advance acceptance of the system throughout the world, the United States has promised to make it continuously available, without charge, for the foreseeable future.

The global positioning system can perform in all weather conditions and eliminate the need for many current ground-based navigation systems, which are expensive to operate and maintain. Along with other advanced technologies, the global positioning system is playing a major role in "free flight," a new government-industry initiative that will gradually allow pilots to choose their own routes and file the most efficient and economical flight plans. Using free-flight technologies, pilots operating under instrument-flight rules will be able to select their aircraft's course, speed, and altitude in real time. Free flight will also increase flight-planning flexibility. When fully implemented, free-flight technologies could reduce the duration of some trips by as much as 20 percent and save U.S. carriers as much as \$5 billion a year.

Free flight will radically change the way the air-traffic control system works by increasing collaboration between pilots and traffic-flow management specialists. Through greater sharing of real-time information, users of free-flight technologies will be more involved in traffic-flow management.

As the Federal Aviation Administration shifts from a totally ground-based air-traffic control system to one in which the pilots are involved in the decision-making process, research and development activities will increasingly concentrate on the interface between pilots and controllers. The agency will conduct human-in-the-loop simulations to assess human performance (for example, problem recognition and resolution skills and human error, workload, response times, situation awareness, and ability to adapt to changing circumstances) as a function of variations in the free-flight environment. The results of this research will help to validate or invalidate proposed changes in controller separation rules and pilot maneuver limits.

As with the global positioning system, FAA's experiments with digital data link also have been highly successful. Data-link technology allows the

electronic transmission of flight and weather information from the ground to the cockpit, further extending the revolutionary capabilities of the information superhighway to the world of aviation. In conjunction with the global positioning system, data-link technology is reducing operating restrictions in remote oceanic areas, where reliable communications have not been available.

Until recently, a pilot flying over the ocean and out of range of ground-based radar had to make hourly position reports over high-frequency radio. The pilot's voice messages were converted manually into digital data and transmitted by teletype to air-traffic controllers. Having no direct contact with the pilots and no radar picture of the airspace, controllers tracked oceanic flights by using flight plans containing an aircraft's route, altitude, and position on strips of paper.

To maintain safety, aircraft crossing the Atlantic and Pacific oceans used a few major, fixed routes and kept a distance from one another of 161 kilometers (100 miles) or more. Because of the time gap between position reports, the unreliability of radio communications, and the potential for error, pilots were required to file a flight plan and stick to it, often having to remain at fuel-inefficient altitudes. The system could not easily accommodate a pilot's taking advantage of existing winds, limiting the efficiency of the system and raising costs for airlines.

The development of a new satellite-based communication, navigation, and surveillance system has made possible direct pilot-to-controller data communications over oceans. The first operational use of satellite data link for air-traffic control began in 1995. Known as oceanic data link, the new system provides direct communications with aircraft equipped with a computer-based communications technology called the future air navigation system (FANS-1). The system, which is endorsed by the International Civil Aviation Organization, consists of global-positioning-system navigation equipment and a voice and data communications package. Through a computer display, a controller can link on to FANS-1 aircraft and exchange messages over a satellite network. Oceanic data-link services should begin in Atlantic Ocean airspace by late 1997. This service will allow pilots to fly more flexible routes, reduce the airspace reserved for each aircraft, save time and money for airlines, and create a more efficient oceanic-airspace operating environment.

Oceanic data link and the future air navigation system are products of almost 2 years of unprecedented cooperative development and deployment by civil aviation authorities, aircraft component

manufacturers, airlines, and communications service providers. The United States developed this new air-traffic control system in cooperation with Australia, New Zealand, France, and Fiji and with United Airlines, Air New Zealand, Qantas, Honeywell, and the Boeing Company. The telecommunications service providers, Aeronautical Radio, Inc., and the Société Internationale de Telecommunications Aeronautiques, also played an integral role in fielding this new data-link technology.

The FANS-1 data-link service will be available throughout South Pacific airspace this year. Within the next 2 years, a similar service will be available throughout the Pacific Rim in Asia. Implementation of the service throughout Asia and in Indian Ocean airspace is being discussed.

AIRCRAFT AND AIRPORT SAFETY

Safety is the Federal Aviation Administration's first priority. The agency is developing technologies that will improve the safety of aircraft and airports.

Fire Safety

The agency has steadily improved fire-safety design standards for commercial airlines. These standards minimize or eliminate fire-related injuries and increase survival rates for aircraft occupants during postcrash fires. Working with industry and academia, FAA has conducted an aggressive research program to improve cabin safety, increasing the chance that passengers will survive fire and smoke in the aftermath of a crash. As a result of this program, seats have been redesigned to withstand an impact of 16 g's and cabins are equipped with fire extinguishers and smoke detectors, heat-resistant

slides, emergency floor lighting, and an independent power source for public address systems. Fuel tanks have been strengthened to reduce their risk of rupture on impact, and cargo and baggage compartments have been reinforced with flame-resistant materials to prevent fires from burning through walls into the passenger cabin.

Fire research also resulted in the agency's regulation of seat-cushion flammability in 1984. Testing proved that the addition of a lightweight fire-blocking material to urethane-foam seat cushions would reduce the flammability of seats, preventing certain types of in-flight fires and providing an additional 40 to 60 seconds for passengers to escape during a severe fuel-fed postcrash fire. During a 3-year period, the airline industry retrofitted more than 650,000 aircraft seats with fire-blocking layers. In the first accident involving a fire in an aircraft with fire-blocked seats, it was estimated that 37 lives were saved because seats contained the protective layers. All commercial aircraft worldwide adhere to this regulation.

In a project with the British Civil Aviation Authority and in conjunction with its industry and university partners, FAA is increasing the burn-through resistance of fuselages. Recent tests demonstrated that a new thermal-acoustical insulation, a heat-stabilized polyacrylonitrile, may help save lives by more than doubling the time it takes a fire to burn through an aircraft's fuselage. In tests conducted at the agency's full-scale fuselage burn-through test facility, researchers confirmed that jet-fuel fires take as little as 2 minutes to penetrate a fuselage's aluminum skin and fiberglass insulation. In contrast, the new insulation either does not burn or takes 7 minutes to burn through this material when subjected to fuel fires of 871 to 982 degrees Celsius (1,600 to 1,800 degrees Fahrenheit).

Soft-Ground Arresting System

Another recent agency research product is a new technology to better protect passengers and aircraft in the event that aircraft overshoot the runway. The impetus for the development of this soft-ground arrestor system came in 1984 when a DC-10 aircraft could not stop within the confines of a runway at New York's John F. Kennedy International Airport and subsequently slid into Thurston Basin. Although no serious personal injuries occurred, the incident resulted in \$30 million in damages and prompted the National Transportation Safety Board to issue a safety recommendation to the Federal Aviation Administration to ascertain whether a soft-ground arrestor system was feasible and practical.

Boeing 727-100 aircraft is used to test soft-ground arrestor at Federal Aviation Administration's William J. Hughes Technical Center.



In 1994 FAA entered into a cooperative research and development agreement with Engineered Systems Company to develop a soft-ground arrestor. Testing of a low-density concrete revealed that soft-ground arrestors increase safety at airports with limited overrun areas. Subsequent tests led the Port Authority of New York and New Jersey to authorize funding of \$4.5 million for the installation of up to five arrestor beds at its airports. Using studies of these beds, the agency is preparing soft-ground arrestor standards for airports across the nation.

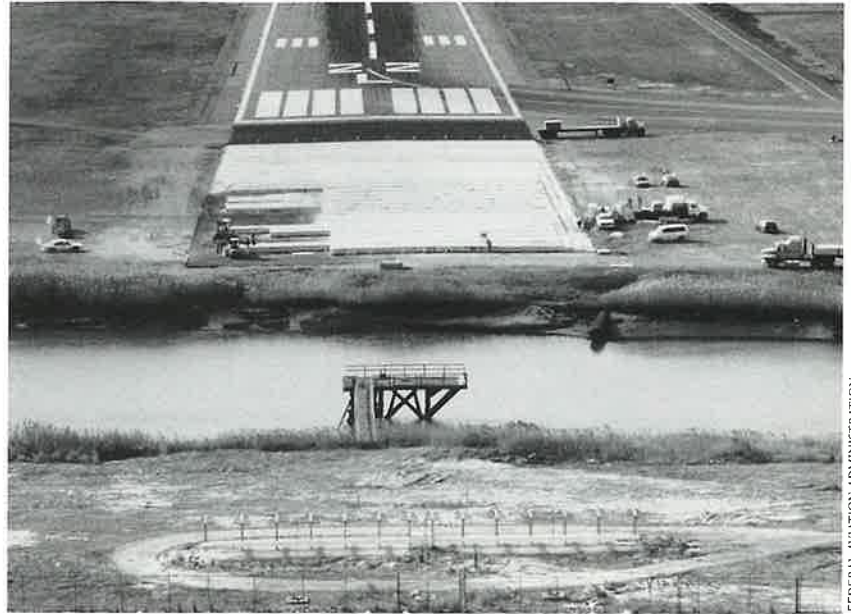
HUMAN PERFORMANCE

The Federal Aviation Administration has placed special emphasis on the elimination of the human factor as a contributor to aviation accidents and incidents. To achieve its human-factors goal, the agency, in collaboration with the National Aeronautics and Space Administration and the U.S. Department of Defense, is researching the interface between human performance and aviation technologies and using findings to overcome deficiencies in human performance.

To help minimize human error in the control and management of the air-traffic system, FAA recently began testing a new technology to convert aircraft flight-recorded digital data into safety and human-factors information. The automated performance-measuring system, which analyzes, processes, and manages digital flight-recorded data, will make aircraft's flight-performance data accessible and useable. Currently, the agency is evaluating the system's capability to extrapolate and analyze a continuous stream of aircraft data and translate it into information that will aid in the detection and correction of safety problems before accidents occur.

Last year the agency and the airline industry agreed to develop a process to collect, analyze, and disseminate safety data through the use of flight-operations quality-assurance programs. In cooperation with industry, the agency sponsored a demonstration project to develop hands-on experience with current off-the-shelf technology to analyze and process in-flight data. The demonstration revealed that such data are difficult to use without the proper hardware and software. Using the automated performance-measuring system, the agency is developing methods and tools to make flight data useful to the agency, air carriers, and pilots.

When fully operational, the performance-measuring system could help FAA and air carriers improve the safety and efficiency of flight operations and aircraft maintenance. The system could be used by



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Soft-ground arrestor bed is being installed at runway 4R overrun of John F. Kennedy International Airport.

the agency to evaluate the overall safety and efficacy of operational procedures in the national airspace and by carriers to identify operational problems specific to the airports and aircraft they use. Carriers also can use information from the performance-measuring system to shape and evaluate operational procedures and training. Air crews could use computer animation of flight data, showing both optimal and suboptimal performance, to review their own operations and those of others. Data also could be used to evaluate minimum distances between aircraft in flight, to develop improved measures of practical traffic capacity, and to monitor the consequences of new traffic-control concepts such as free flight.

AVIATION SECURITY

Preventing fatalities, injuries, property loss, and air-traffic disruptions resulting from intentional criminal acts is the focus of other agency research, development, testing, and evaluation efforts. FAA's goal is to develop technologies that will increase security without excessive costs or inconvenience to the air-transport industry or passengers.

The agency is working with industry to design fast and effective computer-assisted security systems. Building on technology first used in the medical field, industry is adapting computer tomographic-imaging technology, often referred to as the CAT scan, to distinguish explosives from the many items travelers pack in their luggage.

In 1993 the agency published certification standards for an explosive-detection device, and in 1994



CTX 5000, developed with FAA support, uses transmission X-ray data to acquire an overall map of objects in luggage.

It certified the first explosive-detection system, the CTX 5000, which met the criteria for checked-baggage inspection. Developed with FAA support, the automated system uses transmission X-ray data to acquire an overall map of objects in the luggage and strategic computer tomography to identify objects that may be explosives. When a potential threat is detected, the operator is alerted. He or she then uses the instrument's threat-resolution features to assess whether the threat is real. In January the first CTX-5000 machines were installed at John F. Kennedy Airport in New York and O'Hare in Chicago.

The agency is continuing to explore other approaches to detect explosives, including integrating different technologies. One such approach is to combine two types of detectors, one to find explosives and another to find detonators. Another approach is to use passenger profiling to identify those travelers who do not represent a great threat and the CTX 5000 to examine the baggage of the other passengers. Although no combinations of technologies have been submitted for certification under the agency's rigid standards for explosive-detection systems, some already are in use in European airports.

FUTURE CHALLENGES

The rapid growth of air travel projected for the next decade will be a severe test for the Federal Aviation Administration and its research and development program. The anticipated traffic volume could overwhelm the agency's capacity to efficiently manage airspace or provide the level of service expected by the flying public. The impending conflict between expanding responsibilities and shrinking resources can be resolved only by the

introduction of increasingly sophisticated information systems. Moreover, continued U.S. leadership in the world aviation community will be based largely on FAA's ability to integrate these systems into air-traffic control systems and into the cockpit. Research efforts have begun to make such integration possible.

The Federal Aviation Administration is being transformed into an entity resembling a company belonging to the knowledge industry. In the future the agency will essentially run on software. This is a radically different conception of how the agency not only will function, but must function. It is a totally new paradigm, dictated by the realities the agency now faces.

Great strides in automation and information technologies have brought greater attention to human factors issues. Because the interaction between pilots and computers is turning out to be more complicated than anyone could have anticipated, a clearer understanding of the human element in aviation is essential to future gains in safety. Automation has introduced so many new, unexplored variables that the study of the interaction between humans and computers is becoming a highly specialized subfield within human factors. If pilots do not understand the logic behind software, they may be baffled by the performance of the aircraft. Therefore FAA engineers are now looking into the question of design and automated flight systems.

Another likely consequence of this convergence in technologies is that aviation will be among the first industries with a globally integrated infrastructure. It is difficult to think of anything the agency has undertaken that rivals the program to tie together satellites, digital data links, and automated decision support to create an integrated system of air-traffic management. The ultimate objective is a seamless system that spans the globe, a goal that will only be reached through an intensive research and development effort.

Largely because of its research and engineering efforts, the Federal Aviation Administration has developed a national aviation system that is universally recognized as the safest and most technologically advanced in the world. The agency's research organizations have provided a solid foundation for these improvements in aviation, an evolutionary process from the first rotating light beacons to satellite-based communications, navigation, and surveillance systems. A strong commitment to research, engineering, and development will be even more vital in the years ahead as the agency continues to develop new aviation technologies and systems in support of a safe, secure, and modern global aviation system.