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Report to the Chairman, Subcommittee on Aviation, Committee on Public Works and Transportation, House of Representatives

September 1993

AIRCRAFT CERTIFICATION

New FAA Approach Needed to Meet Challenges of Advanced Technology

GAO/RCED-93-155

GAO

United States
General Accounting Office
Washington, D.C. 20548

Resources, Community, and
Economic Development Division

B-253122

September 16, 1993

The Honorable James L. Oberstar
Chairman, Subcommittee on Aviation
Committee on Public Works
and Transportation
House of Representatives

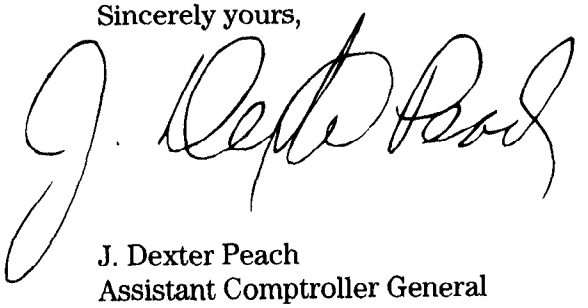
Dear Mr. Chairman:

This report, prepared at your request, examines the Federal Aviation Administration's (FAA) process for certifying that the designs of transport aircraft meet safety standards. Over the last decade, FAA has not ensured that its staff are effectively involved in a certification process that delegates the vast majority of responsibilities to aircraft manufacturers. In addition, FAA staff have not received the technical assistance or training needed to ensure their competence in evaluating new aircraft technologies. We are therefore making recommendations aimed at ensuring that FAA staff are (1) effectively involved in the certification process and (2) competent in assessing the latest technologies.

As arranged with your office, unless you publicly announce its contents earlier, we plan no further distribution of this report until 30 days after the date of the letter. We will then send copies to the Secretary of Transportation; the Administrator, FAA; the Director, Office of Management and Budget; and other interested parties. We will also make copies available to others upon request.

This work was performed under the direction of Kenneth M. Mead, Director, Transportation Issues, who can be reached at (202) 512-2834. Other major contributors are listed in appendix IV.

Sincerely yours,



J. Dexter Peach
Assistant Comptroller General

Executive Summary

Purpose

The Federal Aviation Administration (FAA), which is responsible for certifying that new aircraft designs and systems meet safety standards, is faced with the daunting task of keeping abreast of increasingly complex technologies. Douglas Aircraft Company's MD-11 aircraft, for example, relies on sophisticated software systems to continuously monitor and adjust the hydraulic, electrical, and fuel systems without any action by the crew. Stating that it is crucial for FAA to understand new technologies to certify the safety of commercial aircraft, the Chairman, Subcommittee on Aviation, House Committee on Public Works and Transportation, asked GAO to determine if FAA staff are (1) effectively involved in the certification process and (2) provided the assistance and training needed to be competent in these technologies.

Background

Before introducing a new type of aircraft into commercial service, a manufacturer must obtain FAA's certification that the aircraft meets safety standards. Over what is typically a 5-year process, the manufacturer must supply FAA with detailed analyses as well as produce a prototype of the aircraft. The Federal Aviation Act allows FAA to delegate activities, as the agency deems necessary, to approved employees of aircraft manufacturers. Although paid by manufacturers, these designees act as surrogates for FAA in examining aircraft designs. FAA is responsible for overseeing the designees' activities and determining whether the designs meet FAA's requirements. A 1980 review by the National Academy of Sciences found that this delegation system was sound but warned that FAA was falling behind the industry in competence. The Academy recommended that FAA define a structured role for itself in the certification process and hire 20 to 30 experts to assist staff. FAA concurred with the findings, noting that it was developing a program employing experts and was committed to improving its training program.

Results in Brief

FAA has not ensured that its staff are effectively involved in the certification process. Despite the National Academy of Sciences' recommendation in 1980 that FAA develop a more structured role in the process, the agency has increasingly delegated duties to manufacturers without defining such a role. FAA now delegates up to 95 percent of the certification activities to manufacturers without defining (1) critical activities in which FAA staff should be involved, (2) guidance on the necessary level and quality of the oversight of designees, and (3) standards to evaluate staff members' performance. As a result, FAA staff no longer conduct all of such critical activities as the approval of test plans and

analyses of hypothetical failures of systems. Because FAA has increased delegation over the last 13 years, its ability to effectively oversee or add value to the certification process as well as understand new technologies has been questioned by internal reviews and FAA and industry officials.

FAA has also not provided its staff the assistance and training needed to ensure competence in new technologies. While many FAA and manufacturing officials GAO interviewed stated that FAA's hiring of experts to assist staff is an excellent concept, FAA never fully implemented the program. FAA identified a need for 23 experts but has staffed only 8 positions. In addition, FAA has not identified critical points in the certification process that require experts' involvement. As a result, the experts are sometimes not sought for advice and are often involved in the process too late for them to be most effective. Also, FAA's training has not kept pace with technological advancements. GAO found, for example, that between fiscal years 1990 and 1992, only 1 of the 12 FAA engineers responsible for approving aircraft software attended a software-related training course. FAA officials acknowledged that inadequate training over the last decade has limited the certification staff's ability to understand such areas of dramatic technological advancement. As a result, FAA is developing a new training program. However, the program may not have the structure necessary to improve the staff's competence. The program does not, for example, establish specific training requirements for staff in their areas of responsibility.

Principal Findings

FAA Has Increased Delegation Without Ensuring an Effective Role for Staff

Since 1980, FAA has delegated most certification activities to designated manufacturing employees without defining or measuring an effective role for its own staff. Between 1980 and 1992, the number of designees rose from 299 to 1,287 (330 percent), while the number of FAA engineers and test pilots increased from 89 to 117 (31 percent). FAA has increasingly relied on designees because of a dramatic growth in its work load caused by more complex aircraft systems and an increase in such higher-priority duties as issuing directives to ensure the safety of already certified aircraft. FAA estimated, for example, that it delegated approximately 95 percent of the certification activities for the Boeing 747-400 aircraft. An FAA review in 1989 concluded that the amount of work delegated to designees had reached the maximum for properly managing the

certification process and that further delegation would reduce FAA's ability to understand new technologies. Another internal review found that staff were not sufficiently familiar with the Boeing 747-400's flight management system to define requirements for testing it or verifying regulatory compliance. Both FAA's and Boeing's Certification Directors acknowledged that FAA's approach is too ad hoc and unmeasured to ensure a minimum effective level of involvement by FAA.

The National Academy of Sciences raised similar concerns in 1980. However, FAA has yet to identify critical activities in which staff should be involved, set standards governing the level and quality of the oversight of designees, or develop measures through which staff members' performance can be evaluated. For example, FAA has not established the extent to which it needs to be involved in the development and approval of test plans for key aircraft systems. The Academy concluded that the delegation system was sound, in part because FAA retained the approval of test plans. GAO found, however, that FAA has delegated the approval of as many as 95 percent of test plans to designees. FAA's Aircraft Certification Service Director has acknowledged the need to better define and measure an effective role for FAA staff in the certification process and stated that the agency will initiate an effort to define such a role. Until FAA completes this effort, questions will remain about the value that the agency's employees add to the process.

Staff's Competence Limited by Lack of Assistance and Training

FAA has not provided the technical assistance needed to ensure the staff's competence in evaluating the latest technologies. FAA did not fully implement a program in which experts assist staff during the certification process. In 1979, FAA identified a need for over 20 experts in such areas as advanced avionics but authorized only 11 positions and staffed only 8. FAA officials stated that the agency could not attract qualified people but acknowledged that (1) FAA has not formally examined the need for additional experts since 1979 and (2) recent layoffs by manufacturers may have increased the pool of qualified individuals. Furthermore, because FAA has not identified key points in the process requiring the involvement of experts, their knowledge is not optimally used. For example, two experts were not involved in crucial early junctures in the certification of the Boeing 777. After discovering that Boeing was employing new designs, the two raised concerns about test requirements. Because of these concerns, Boeing modified its test procedures in one case and is currently reviewing them in the other.

In 1991, a contractor hired by FAA found that the agency does not have adequate training for its certification staff in such areas as composite materials and software systems. GAO found that this lack of training has occurred despite a 1987 internal study that recommended FAA establish annual training requirements. Citing the increasing inexperience of FAA staff—over half of the engineers with primary responsibility in the certification of the Boeing 777 have never participated in a major certification project—FAA is developing a new training program. While supporting this effort, GAO is concerned because it does not establish specific training requirements or identify technical training available from universities, private industry, and other government agencies.

Recommendations

GAO recommends that the Secretary of Transportation direct the Administrator, FAA, to define a minimum effective role for the agency in the certification process by identifying critical activities requiring FAA's involvement or oversight, establishing guidance on the necessary level and quality of the oversight of designees, and developing measures through which staff members' effectiveness can be evaluated. GAO also recommends that the FAA Administrator formally examine the need to hire experts in areas of technological advancement, require experts' involvement early in the certification process and at other key junctures, establish specific training requirements, and identify training in new technologies that is available at universities, industry, and other government agencies.

Agency Comments

Although the Department of Transportation (DOT) takes the position that FAA staff and experts are effectively involved in the certification process, it concurred in part with GAO's recommendations. DOT did not fully concur with the recommendations because it felt that they would impose rigid requirements dictating the sequence and participants at each juncture of the process. GAO's recommendations are not designed to impose rigid requirements, but rather to enhance the technical competence of FAA staff and ensure that they add more to the certification process. GAO found that FAA needs to establish basic guidance that describes the critical activities requiring staff members' involvement, establishes measures to evaluate staff members' performance, and defines when experts should be consulted. The lack of such guidance—combined with inadequate training—has brought into question the value added by FAA's activities. An advisory group of individuals with distinguished aviation backgrounds agreed with GAO's conclusion.

DOT also stated that the delegation system has been effective. GAO agrees. The current process results in safe designs largely because of the efforts and expertise of the designees. What is less clear, however, is the extent to which the contributions of FAA staff materially add to this level of safety. Finally, DOT maintained that annual training requirements would be too "rigid." GAO acknowledges DOT's concern and has deleted its reference to annual requirements in recommending that staff receive the training needed to fulfill their certification mission.

Contents

Abbreviations

ACO	Aircraft Certification Office
DER	designated engineering representative
DOT	Department of Transportation
FAA	Federal Aviation Administration
GAO	General Accounting Office
MIT	Massachusetts Institute of Technology
NASA	National Aeronautics and Space Administration
NRS	national resource specialist
NTSB	National Transportation Safety Board

Introduction

The Federal Aviation Administration (FAA) is responsible for certifying that aircraft produced in the United States or imported by U.S. companies and individuals meet minimum safety standards. In carrying out this mandate, FAA has established detailed requirements governing the certification of the designs and systems of commercial transport airplanes.[1] FAA certifies new designs and systems as meeting these requirements over an aircraft development process that typically lasts 5 years. Although FAA is responsible for verifying regulatory compliance, the Federal Aviation Act allows the agency to delegate tests and analyses, as necessary, to designated employees of aircraft manufacturers. In 1980, a committee established by the Department of Transportation (DOT) found that FAA's delegation system was sound but warned that FAA's technical competence was falling far behind the industry's. Since the early 1980s, the complexity of aircraft designs and systems has increased dramatically, further challenging FAA's ability to keep abreast of the new technologies.

FAA's Aircraft Certification Process

The Federal Aviation Act of 1958 requires FAA to promote the highest degree of aviation safety. The act mandates that FAA certify aircraft registered in the United States as meeting minimum safety standards before the aircraft can be operated. FAA carries out this mandate by approving particular designs and quality control methods employed during production and by verifying that aircraft conform to certified designs and production processes.

Before introducing a new type of aircraft into commercial service, a manufacturer must first obtain from FAA a certificate signifying that the basic design and systems meet minimum safety standards. When applying for this certificate, the manufacturer must supply FAA with detailed plans, drawings, test reports, and analyses demonstrating the aircraft's compliance with FAA's design requirements. During the course of this 5-year certification process, the manufacturer also must produce a prototype of the new aircraft and conduct both ground and flight tests. FAA engineers and test pilots are responsible for reviewing the data submitted by the manufacturer and conducting the tests and analyses necessary to determine if the new design complies with FAA's safety standards. If FAA determines that the proposed design meets those standards, it signifies its approval by issuing a certificate.

[1]FAA's regulations governing the certification of transport airplane designs are contained in title 14, part 25, of the Code of Federal Regulations. Generally, transport category airplanes are those weighing over 12,500 pounds and having 10 or more seats.

Recognizing that with limited resources, FAA could not fulfil this mission alone, the Federal Aviation Act authorizes the agency to delegate certification activities, as necessary, to designated, FAA-approved employees of manufacturers. Although paid by the manufacturers, these designated engineering representatives (DER) act as surrogates of FAA in analyzing, testing, and examining aircraft designs and systems. FAA staff are responsible for overseeing DERs' activities and making the final determination as to whether a design meets FAA's safety requirements. For aircraft imported into the United States, FAA relies on foreign authorities to conduct many of the necessary certification activities but is responsible for certifying that the aircraft meet its requirements.

Aircraft Certification Service's Structure and Resources

FAA manages its certification activities through its Aircraft Certification Service, in Washington, D.C. The Service is composed of four directorates that certify the airworthiness of transport airplanes, small airplanes, engines, and rotorcraft. The four directorates are the Transport Airplane Directorate, in Renton, Washington; the Small Airplane Directorate, in Kansas City, Missouri; the Engine and Propeller Directorate, in Burlington, Massachusetts; and the Rotorcraft Directorate, in Fort Worth, Texas. As of January 1993, the Aircraft Certification Service had 848 staff and a $67 million budget.

The Aircraft Certification Service's Transport Airplane Directorate is responsible for overseeing the certification of new aircraft as well as issuing standards governing the continued airworthiness of the existing fleet. To accomplish these missions, the directorate develops and enforces regulatory standards for new designs and issues airworthiness directives to correct safety problems of aircraft already in commercial service. As of January 1993, the Transport Airplane Directorate had a staff of 288. The engineers and test pilots with the responsibility for certification are located in two Aircraft Certification Offices (ACO)—the Los Angeles ACO, in Long Beach, California, and the Seattle ACO, in Renton, Washington.

As of March 1993, 118 engineers and test pilots were assigned to the Los Angeles and Seattle ACOs. These staff are divided into four disciplines: airframes, systems and equipment, power plants, and flight testing. These staff are responsible for overseeing the work of DERs at the Boeing Company and Douglas Aircraft Company and certifying that these companies' designs and systems for transport aircraft meet FAA's safety standards. In addition, the ACO staff assist in the certification of aircraft designed by the other three producers of transport airplanes—Airbus

Industrie, British Aerospace, and Fokker Aircraft B.V.—and imported into the United States.

In 1979, FAA established the National Resource Specialist (NRS) Program to assist during the certification process and improve the agency's technical competence. Under this program, technical experts serve as advisers to the four directorates and their staff by providing technical guidance and advice during the certification process. These advisers provide expertise in the areas of advanced avionics and electrical systems, computer software, flight loads, flight management, advanced composite materials, crash dynamics, metallurgy, and nondestructive evaluation.

1980 Blue-Ribbon Review of FAA's Certification Program

After maintenance and design problems with a McDonnell Douglas DC-10 aircraft were found to have contributed to an accident resulting in 273 fatalities, in 1979 the Secretary of Transportation established a "blue-ribbon" committee to assess the adequacy of FAA's certification program. Under the direction of the National Academy of Sciences, the committee reported in 1980 that FAA's system of delegation to DERs was sound, in part because FAA reserved most of the critical activities, such as approving all test proposals, for its own staff.[2] The report warned, however, that FAA's technical competence was falling far behind the DERs' to the point that the agency's oversight was becoming superficial. The Academy called on FAA to establish a "higher esprit de corps" by hiring, retaining, and training highly competent engineers.

Stating that FAA needed to improve the technical competence of its staff to adequately assess manufacturers' work in designing new aircraft, the Academy recommended that FAA establish a centralized engineering organization led by a cadre of 20 to 30 senior experts. These specialists would be responsible for making key decisions affecting a certification project and assisting FAA engineers in understanding the more complex technologies during that project. In addition, the Academy recommended that FAA develop a more systematic approach toward certification by identifying critical periods in the process and examining samples of data and test results to provide more thorough technical reviews in determining regulatory compliance.

In its response to the report, FAA concurred with the Academy's conclusions and noted that its technical competence had to be improved if

[2]Improving Aircraft Safety: FAA Certification of Commercial Passenger Aircraft, National Academy of Sciences, National Research Council, Committee on FAA Airworthiness Certification Procedures (June 1980).

it was, in the face of rapidly developing technology, to effectively carry out its mission of certifying aircraft. FAA outlined several initiatives designed to improve the technical competence of its staff. First, the agency would centralize the responsibility for certifying transport aircraft, a step that resulted in the creation of the Transport Airplane Directorate, in Renton, Washington. Second, FAA would continue to implement its planned NRS Program and hire over 20 experts to increase its staff's competence through frequent visits, project reviews, consultation, and seminars. Finally, FAA committed to improving the technical training provided FAA engineers and test pilots.

Sophisticated Technologies Deployed on Current Aircraft

Since the early 1980s, technological advances have generated increasingly complex designs and systems for commercial aircraft. For example, advances have occurred in the use of software-based systems to monitor and control functions traditionally performed by cockpit crews and in the use of composite structural materials to increase performance. In many cases, the software-based systems have virtually replaced the hydraulic and mechanical systems used on earlier generations of aircraft, as the following examples show:

- Pilots of Boeing's 747-400 aircraft—certified in 1989—depend on an automated system—rather than themselves—to land the aircraft during severe weather.
- Pilots of Douglas' MD-11 aircraft—certified in 1990—depend on complex software systems to continuously monitor and adjust the hydraulic, electrical, and fuel systems without action by the crew, thereby reducing the number of cockpit personnel needed from three to two. Unlike its predecessor—the DC-10 aircraft, certified in 1971, which has almost no software—the MD-11 utilizes complex software to control many critical functions previously handled by a flight engineer.
- Pilots of the new Boeing 777 aircraft—to be certified in May 1995—will no longer mechanically control the aircraft's rudders and wings. Instead, they will depend on software systems to operate these critical components.

In addition, foreign aircraft producers such as Airbus Industrie are deploying cutting-edge technology in their aircraft. For example, Airbus's A320 aircraft—certified in 1988—employs "glass cockpit" technology, in which many mechanical gauges are replaced by computer systems capable of analyzing flight information and displaying the results on video screens in the cockpit. According to FAA officials, Airbus's A340 aircraft—certified by FAA in May 1993—further revolutionizes this technology by enhancing

the computer system's analytical capability and employs the most advanced composite materials ever developed.

According to National Aeronautics and Space Administration (NASA), National Research Council, FAA, and industry officials, further dramatic technological changes will be incorporated in the next generation of commercial aircraft.[3] Douglas officials estimate, for example, that the next aircraft the company will develop—the MD-12—will double the amount of software currently employed in the MD-11. By 2005, according to NASA officials, pilots of a high-speed civil transport aircraft will likely navigate using sensors and satellite systems, while traveling at 3 times the speed of current aircraft. Instead of looking out the cockpit window, pilots will view a video screen that will display an enhanced image of the outside generated by these systems.

Objectives, Scope, and Methodology

At the request of the Chairman, Subcommittee on Aviation, House Committee on Public Works and Transportation, we examined FAA's certification process and ability to meet the challenges posed by new technology. Specifically, we determined if FAA ensures that its staff are (1) effectively involved in the certification process and (2) provided the technical assistance and training needed to be competent in evaluating the new and complex aircraft technologies.[4] As agreed with the Chairman's office, we limited the scope of our review to FAA's certification of designs and systems for transport category airplanes. We did not review FAA's certification program for smaller aircraft or rotorcraft.

We performed our work primarily at FAA's Aircraft Certification Service, in Washington, D.C.; Transport Airplane Directorate, in Renton, Washington; Seattle ACO, in Renton, Washington; and Los Angeles ACO, in Long Beach, California. We reviewed relevant legislation and FAA's regulations and policies governing certification. In addition, we interviewed officials from the Boeing Commercial Airplane Group, in Seattle, Washington, and Douglas Aircraft Company, in Long Beach, California. As part of our review of FAA's certification of aircraft software systems, we also interviewed officials from FAA's Engine Certification Office, in Burlington, Massachusetts, and a representative of Pratt and Whitney Company, in East Hartford, Connecticut.

[3]See Aeronautical Technologies for the 21st Century, National Research Council (1992).

[4]This report is our second for the Chairman on FAA's certification activities. See Aircraft Certification: Limited Progress on Developing International Design Standards (GAO/RCED-92-179, Aug. 20, 1992).

To provide a frame of reference for our work, we reviewed the National Academy of Sciences' 1980 evaluation of FAA's certification program, workpapers that supported the report, and FAA's official response to the study. To analyze FAA's response to the committee's recommendations designed to improve the agency's technical competence, we interviewed FAA headquarters officials, as well as past members of the committee, who are still active in the aviation community.

To determine if FAA ensures that its staff are effectively involved in the certification process, we reviewed FAA's and manufacturers' documents and data on recent projects. We also interviewed FAA and manufacturing officials to obtain their views on the agency's involvement in the process. We reviewed studies that evaluated FAA's role in the process and discussed the results of the studies with FAA headquarters, directorate, and ACO officials. To document trends in the level of FAA's involvement in and oversight of the certification process since 1980, we analyzed FAA's and manufacturers' data on the number of DERs and FAA engineers and interviewed manufacturing officials, DERs, FAA engineers, certification project managers, and ACO managers.

To determine if FAA provides its engineers the technical assistance and training needed to be competent in evaluating the latest technologies, we reviewed FAA's use of in-house experts under the NRS Program and the agency's ability to hire, train, and retain certification engineers. We reviewed the FAA order governing the NRS Program and interviewed all of the experts in the program to determine its effectiveness and the extent of their involvement in recent certification projects. We also discussed with staff of the Seattle and Los Angeles ACOs the extent to which they involve the experts in the certification process and interviewed FAA headquarters and directorate officials on their implementation of the NRS Program. To evaluate FAA's training program for certification staff, we reviewed relevant studies by the agency and an agency-hired contractor and examined the agency's response to the recommendations made. We also analyzed each ACO certification engineer's training records through 1992. In addition, we interviewed FAA headquarters officials to document current initiatives to upgrade the training program for certification staff. Finally, we reviewed reports by the Office of Technology Assessment and by Aerospace Industries Association of America concerning the need for a technically competent certification staff.[5]

[5]Safe Skies for Tomorrow: Aviation Safety in a Competitive Environment, Office of Technology Assessment (July 1988); and Aerospace Industries Association of America, Inc., Maintaining a Strong Federal Aviation Administration: The FAA's Important Role in Aircraft Safety and the Development of U.S. Civil Aeronautics (Sept. 1989).

Because of the significant technological advancements in aircraft software over the last decade, we were particularly interested in FAA's certification process for it. We documented the degree to which FAA has been involved in certifying software-based systems on past projects primarily by obtaining FAA and manufacturing officials' views on the agency's involvement in the process. Our analysis of FAA's and manufacturers' data concerning the certification of software was limited because of a lack of documentation at the agency and a reluctance by manufacturers to provide these data because of their proprietary nature. We also interviewed FAA software engineers about the quality of the training available to them. The engineers we interviewed were asked identical questions about the type and amount of software-related training they had received, its adequacy, and the type of training they needed. We also compared their requests for training with the approved training. Finally, we reviewed FAA's training catalog to determine the availability of training pertinent to certifying software-based systems.

To provide external and technical perspectives on the range of issues examined, we obtained the views of five individuals with distinguished aviation backgrounds. Between January and June 1993, we met with this group four times and obtained a wide range of technical viewpoints on FAA's aircraft certification process. (App. I summarizes the comments made by group members.) The group included a former FAA Administrator and the previous Chairman of FAA's Aviation Rulemaking Advisory Committee. Three members served on the National Academy of Sciences' 1980 blue-ribbon committee. The five participants were (1) Dr. James W. Mar, Professor Emeritus, Aerospace Education, Massachusetts Institute of Technology; (2) Mr. Jonathan Howe, Counsel, Zuckert, Scoutt & Rasenberger; (3) Dr. John L. McLucas, Aerospace Consultant; (4) Mr. Donald W. Madole, Senior Partner, Speiser, Krause, Madole & Lear; and (5) Mr. James J. Foody, President, J.J. Foody & Associates, Inc. (App. II provides biographical information on each group member.)

We obtained written comments from DOT on a draft of this report and incorporated them where appropriate. The full text of DOT's comments and our responses to them appear in appendix III. We also provided domestic manufacturing representatives with appropriate sections of a draft of this report and incorporated their changes where appropriate. We conducted our work between March 1992 and June 1993 in accordance with generally accepted government auditing standards.

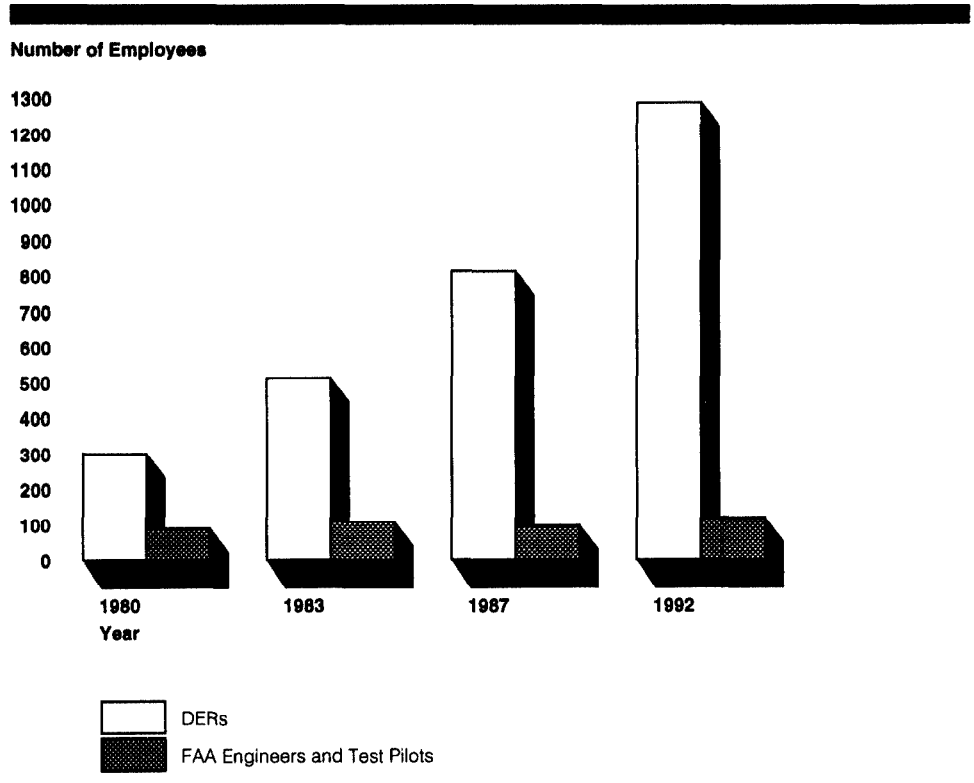
FAA Lacks Defined Role in Certification Process

In response to a dramatically escalating work load, FAA has delegated certification duties without defining a clear role for its staff to ensure that they are effectively involved in the certification process. As a result, FAA's involvement in the process has diminished to the point that the agency's ability to understand and certify new technologies is threatened. In addition, FAA's diminishing, undefined role has weakened safeguards identified in 1980 by the National Academy of Sciences as critical to a successful delegation system. Although FAA developed general guidance defining its directorate structure, the agency has not established guidance to ensure its effective involvement in the process nor standards to measure staff members' performance. Internal reviews as well as some FAA and industry officials have questioned FAA's ability to effectively oversee the process or understand new technologies because the agency has delegated most activities without defining or measuring a minimum effective role for its staff. Largely because of the manufacturers' expertise and commitment to safety, however, FAA's current approach and diminishing involvement apparently have not compromised the safety of aircraft designs and systems.

FAA's Role in Certification Process Has Diminished

As a result of the increasing complexity of aircraft designs and systems and the consequent increase in the work load for FAA, the agency has shifted most certification responsibilities to DERs since 1980. FAA officials explained that the increasing work load has resulted in more delegation, to the point that between 90 to 95 percent of all activities are now delegated to Boeing's and Douglas' DERs. For example, an internal study found that FAA delegated 95 percent of the certification activities for the Boeing 747-400. As figure 2.1 shows, FAA's use of DERs has grown dramatically. The number of DERs that Seattle and Los Angeles ACO engineers and test pilots must oversee rose from 299 to 1,287, or 330 percent, between 1980 and 1992. At the same time, the number of FAA engineers and test pilots responsible for certifying the designs and systems of transport airplanes rose from 89 to 117, or 31 percent. Therefore, the ratio of DERs to FAA staff, which was about 3 to 1 in March 1980, increased to 11 to 1 by 1992.

Figure 2.1: Comparison of the Number of DERs With the Number of FAA Engineers and Test Pilots at the Los Angeles and Seattle ACOs, 1980 Through 1992



Note: Figures for 1980 are from March 1980. All other data are as of the end of the fiscal year.

Source: GAO's analysis of data from FAA and the National Academy Sciences.

Today's certification projects require FAA to review, evaluate, and approve a great deal more compliance documents, detailing analyses and tests of more complex systems, than past projects required. For example, when the DC-10 aircraft was certified in 1971, FAA was required to review and approve about 1,400 compliance documents, but when the more advanced MD-11 was certified in 1990, the number of compliance documents requiring review had more than doubled to 3,069. Similarly, Boeing officials estimated that the number of compliance documents developed for the current certification of the 777-200 aircraft will be double the number for the certification of the 747-400 aircraft in 1989. Since the beginning of the jet aviation age in the late 1950s, the overall work load involved in certifying a new aircraft has increased by as much as five-fold, these officials estimated.

FAA staff responsible for certification have also seen their work load increase in their two other areas of responsibility, which FAA defines as having higher priority. These staff, besides certifying aircraft, must (1) continuously monitor already certified aircraft and issue airworthiness directives to ensure continued safety and (2) assist in developing new regulations and policies. Increased demands in these other areas, particularly continued operational safety, limit the amount of time staff can spend on lower-priority work involving certification. FAA's Seattle ACO, for example, issued 125 airworthiness directives in 1990, an increase of 421 percent from the 24 issued in 1981. An engineer assigned to the certification of the Boeing 777 told us that he had to delay his review of certification data because work on airworthiness directives took 80 to 90 percent of his time.

Because of this rise in work load, FAA's dependence on DERs has also increased. The increase has been particularly dramatic, however, in those disciplines responsible for certifying new, highly advanced aircraft software and computer systems. For example, in the Los Angeles ACO's Electronic Flight Control Section, the ratio of DERs to FAA engineers was 7 to 1 in 1981, but by 1989, the ratio had increased to 30 to 1. And for the MD-11's software systems, FAA delegated between 90 and 95 percent of the certification activities to Douglas, an agency official estimated.

FAA's Diminishing Role May Threaten the Agency's Technical Competence

FAA's involvement in the process is the primary method by which the agency's engineers develop the knowledge and skills needed to understand and certify new technologies. According to certification staff, internal studies, and manufacturing officials, FAA's increasing delegation may result in staff members' not understanding those technologies. For example, a 1989 internal review concluded that (1) the amount of work delegated to DERs had reached the maximum for properly managing the certification process and (2) further delegation would reduce FAA's ability to effectively understand and monitor the highly complex technical work being done by DERs.[1] We found, however, that the amount of delegation has increased since 1989. For example, the number of DERs involved in certifying transport aircraft has increased over the last 3-1/2 years by an average of 90 per year, with an increase of only about 3 FAA certification staff per year.

[1]Aircraft Certification Service Program Evaluation of the Transport Airplane Certification Directorate Designated Engineering Representative Program, FAA, Aircraft Certification Service (May 1989).

Several FAA headquarters and ACO officials we interviewed stated that increased delegation was a matter for concern because the agency could lose competence in understanding the systems it is responsible for certifying. Problems encountered during the certification of the Boeing 747-400 aircraft in the late 1980s illustrate these concerns. An internal study by the Transport Airplane Directorate found that FAA engineers delegated to DERs the approval of the entire flight management system, which operates the navigational system and monitors the performance of other systems, because the FAA staff "were not sufficiently familiar with the system to provide meaningful inputs to the testing requirements or to verify compliance with the regulatory standards." As a result, FAA allowed Boeing to conduct the certification activities without the FAA staff members' understanding the system. Similarly, because FAA engineers had minimal knowledge of 10 other systems, including the aircraft's braking system, the agency delegated to DERs key analyses of those systems—analyses that on previous certification projects FAA had reserved for its own staff.

In general, officials of FAA, the National Transportation Safety Board (NTSB), and manufacturers told us that FAA needs to improve its understanding of new technologies to adequately verify their regulatory compliance, including technologies developed by foreign manufacturers. These officials pointed out that FAA cannot depend on DERs when certifying foreign systems for use in the United States. For example, FAA must determine—without the assistance of Boeing's or Douglas' DERs—whether the new uses of composite materials in the Airbus A340 meet safety standards.

Emphasizing the need for a competent FAA certification staff, reports by DOT, the Office of Technology Assessment, and the Aerospace Industries Association have also raised questions about FAA's ability to understand new technologies. For example, a 1987 study by DOT of FAA's certification program emphasized the need for a staff competent in new technologies, explaining that remaining competent was vital so that the agency could effectively promote safety and verify that new aircraft meet safety standards. DOT reported, however, that FAA was having difficulty in maintaining its competence. The earlier cited 1988 study by the Office of Technology Assessment reported that senior FAA officials recognized that the certification program was unable to keep up with technical developments because of a shortage of expertise. The report emphasized that in the long term, FAA needed greater expertise to effectively oversee the certification of new technologies. Finally, the Aerospace Industries

Association stated in 1989 that a more competent FAA certification staff was essential. The report said,

It is in the interest of manufacturers and their airline customers—and of the flying public whose first concern is safe, affordable and efficient air transport—that the FAA remain the preeminent technical agency for civil aviation. . . . Engineers and others need to become better informed about industry technology developments, changes in engineering practice and design aids.

FAA's Increasing Reliance on Manufacturers' Designees Has Weakened Safeguards

In 1980, the National Academy of Sciences concluded that FAA's use of DERs was sound, despite the potential conflict of interest, because safeguards existed. Because of its increasing work load and growing dependence on DERs over the last decade, however, FAA no longer conducts many of the key tests and analyses that the Academy emphasized FAA be responsible for to safeguard against this conflict of interest and ensure the integrity of the certification process. And as this delegating has increased, FAA's supervision of DERs has declined. Although FAA no longer has the resources to conduct all of the tests and analyses identified in 1980, given the dramatic growth in its work load, it has not defined which tests and analyses its staff should be involved in to ensure an effective role. In addition, FAA has not developed standards to measure the effectiveness of its current role.

National Academy of Sciences Approved of DER System Provided Safeguards Remained

The Academy concluded that the use of DERs by FAA to supplement its own staff was indispensable. As explained earlier, at the time of the study, the ratio of DERs to FAA engineers and test pilots responsible for certifying transport aircraft was 3 to 1. Approximately 89 FAA staff had to oversee 299 DERs. The study found that the system worked successfully, despite the potential for a conflict of interest between DERs' roles as surrogates for FAA and as employees of the manufacturers, because four safeguards were in place. The safeguards were (1) the manufacturers' self-interest in building safe and therefore marketable aircraft, which in turn led manufacturers to appoint DERs who were senior and experienced engineers; (2) the integrity and professionalism of DERs; (3) FAA's supervision of the work performed by DERs; and (4) FAA's insistence that certain critical decisions be made by the agency's engineers. The decisions that FAA reserved for its own staff included the approval of all plans for testing and analyses of hypothetical failures:

- Test plans. These plans describe the manner in which the manufacturer intends to demonstrate that an aircraft's design or a particular system complies with regulatory standards. FAA's involvement in approving the plans allowed the agency to influence the scope and rigor of the testing and ultimately determine whether the tests would adequately demonstrate compliance.
- Failure analyses. In these analyses, each aspect of the design, structure, systems, or components of an aircraft is assumed to malfunction or fail. An analysis could consider, for example, what happens when an aircraft's hydraulic system malfunctions or fails. FAA's involvement in these analyses allowed the agency to examine firsthand the assurance that the aircraft would continue to operate safely in the event of a malfunction or failure.

Increasing Delegation and Less Supervision Have Weakened Safeguards

The increasing dependence on DERs has weakened the safeguards that the Academy found in place in 1980. FAA is now delegating to DERs critical decisions it once reserved for itself. The delegation of critical activities is evident in the approval of test plans and failure analyses. In addition, FAA's ability to effectively supervise DERs is threatened.

Although FAA approved all test plans in 1980, the agency's delegation of this task to DERs has now become a common practice. Four of the six engineers and supervisors we interviewed, who represent the three technical branches that review test plans at the Seattle and Los Angeles ACOs, said that DERs now approve test plans. Though in estimating the percentage of test plans approved by DERs, these staff varied greatly. One engineer stated that DERs conduct the approval of 5 percent of the test plans under his branch's jurisdiction, while another estimated that for his branch, the level of delegation has reached 95 percent. According to officials in the branch responsible for certifying most of the advanced computer systems, the figure has reached between 75 and 95 percent.

When the approval of test plans is delegated to DERs, the scope of FAA's involvement diminishes. In such situations, the documents FAA approves do not provide details on how a test will be conducted or what criteria will be used to determine when a test is successful. In contrast, in situations in which FAA is responsible for reviewing and approving test plans, it has an opportunity to have input on how a design, component, or system will be demonstrated as safe.

Similarly, FAA is now delegating the approval of failure analyses to DERs. As discussed above, the Seattle ACO delegated to DERs the approval of the

failure analyses of 10 major systems on the Boeing 747-400. Our interviews with supervisors and engineers also showed that such delegation was occurring, though not to the extent for the approval of test plans. Of the four engineers and supervisors we interviewed who are responsible for failure analyses, two told us that DERs approval of failure analyses and the level of delegation ranged from 30 to 80 percent.

In addition, the rapid increase in the number of DERs and in the number of duties delegated to them has reduced the amount of supervision FAA can provide and may have reduced the quality of that supervision. At both the Seattle and Los Angeles ACOs, supervisors responsible for certifying most of the computer-based aircraft systems, for example, said they are concerned that the engineers do not have sufficient time to review DERs' submissions. Although FAA's 1989 review found that the supervision and monitoring of DERs was generally adequate, it noted that the disciplines responsible for most failure analyses and the certification of computer-based systems had "uncomfortably high" ratios of DERs to FAA engineers. In this review, FAA concluded that with its present staffing level, it could not effectively manage any increase in the number of DERs. Following the review, FAA surveyed DERs to obtain their views on the level and quality of the agency's oversight and supervision. Some DERs within the Transport Airplane Directorate expressed dissatisfaction with the number of contacts with FAA staff, as more than 33 percent responded that they wanted more visits by FAA personnel. But despite this review and the follow-up survey, FAA staff members' burden in supervising more DERs grew.

FAA Has Not Adequately Defined or Measured Its Role in the Certification Process

Despite the warnings expressed in the Academy's review in 1980 and the internal review in 1989, FAA has not changed its approach toward certification. Although both studies highlighted the potential negative effects that increased delegation could have on FAA's technical competence and the oversight of DERs, FAA has not defined its role in the process or established a system to measure the effectiveness of its staff members' involvement. Without a clearly defined level of involvement or a system to track the amount and type of monitoring being done, FAA cannot determine whether its staff are effectively (1) involved in the process or (2) overseeing DERs' activities.

The Academy warned that FAA's oversight of the process was becoming superficial and lacked technical quality. To reverse these trends, the Academy concluded, FAA needed to revise its approach by identifying

critical periods in the process and examining a small sample of data. The Academy recommended a systematic review based on sampling because it would "assure compliance with the full intent of safety regulations as well as their specific details" and result in a review of higher technical quality. FAA's 1989 internal review identified a similar need for a better defined role in the process. The study, which found that FAA's reliance on DERs had reached uncomfortable levels in some areas and threatened FAA's ability to understand new technologies, recommended that FAA establish uniform "monitoring requirements" for overseeing DERs. Another internal review warned that allowing DERs to make findings of compliance with safety standards without FAA's knowledge of what is being approved threatens the system's integrity.

Despite these recommendations and warnings, FAA has not changed its approach in the last 13 years. Although FAA has issued general guidance that defines its directorate structure, its ACOs continue to use a standard established in 1967 that requires its staff to review 5 percent of experienced DERs' work and 33 to 50 percent of new DERs' work, without specifying the areas that should be reviewed and the type of review to be performed in each area. According to FAA headquarters and manufacturing officials, this standard is meaningless because FAA does not measure whether it is being met and because it, along with not specifying what should be reviewed, does not specify the level and quality of reviews. Instead of identifying critical activities in which staff should be involved, establishing guidance on the expected level and quality of the oversight of DERs, and adopting standards to evaluate staff members' performance, FAA continues to employ general guidance that allows each engineer to determine his or her own level of involvement and supervision of DERs. As a result, FAA does not know if its staff are effectively involved in or effectively overseeing such critical activities as the approval of test plans.

NTSB, Boeing, and Douglas officials stated that FAA has an important role to play in the certification process. These officials emphasized that FAA needs to better define its role to ensure a minimum level of involvement that includes (1) establishing early on and up-front the requirements concerning the design, analyses, and testing; (2) identifying how the manufacturer plans to demonstrate compliance with safety requirements; (3) sampling detailed analyses and test results when the manufacturer demonstrates compliance; and (4) reserving for its staff such major decisions as the approval of key test plans. Boeing's Certification Director and a senior NTSB accident investigator noted that FAA's current approach

is too ad hoc and unsystematic to ensure that FAA staff have a minimum effective level of involvement and understand new technologies.

FAA's Director and Deputy Director, Aircraft Certification Service, acknowledged these deficiencies and noted that FAA needs to better define and measure its role to ensure that it adds value to the certification process. The Director indicated that he will soon initiate an in-house effort to examine and better define a minimum effective role for FAA. The Director also stated that he has asked FAA's Aviation Rulemaking Advisory Committee to examine new approaches to certification, including a system in which FAA would approve manufacturers to carry out the entire certification process. He stated that under such a system, FAA would spot-check the manufacturers' design processes and then certify the final product.

Although we did not find any evidence that the current certification system's integrity has been compromised, a recent accident raises concern about FAA's diminished, undefined involvement. In May 1991, a Lauda Air Boeing 767 crashed in Thailand after an engine thrust reverser accidently activated in flight. Two hundred and twenty-three people were killed. During the certification of the Boeing 767 in 1982, FAA, in approving the thrust reverser as safe, had required Boeing to, among other things, address the effects of an in-flight deployment. However, the agency relied on Boeing's DERs to approve the failure analysis of the device. The documentation Boeing submitted to obtain certification was simply a statement that an in-flight deployment had been considered and that the aircraft would operate safely. During the certification process, FAA did not review the actual analysis or the assumptions made; rather, it asked Boeing's DERs to recommend the approval of the failure analysis. Upon this recommendation, FAA approved the analysis. NTSB's chief representative in the Thai government's investigation of the May 1991 accident stated that FAA added little value to the process in this instance.

Performance by Manufacturers Has Kept the Number of Design-Related Safety Problems Low

Compared to other causes of aircraft accidents, design problems have accounted for relatively few accidents over the last decade. Between 1982 and 1991, 163 "hull loss" accidents occurred; for 120 of these, causes have been officially identified.[2] Of these 120 accidents, 15, or 12.5 percent, were caused by a failure of the aircraft's design or systems.

[2]"Hull loss" accidents, commonly cited in discussions about aviation safety, are those in which the aircraft is damaged beyond repair. Boeing Commercial Airplane Group, Statistical Summary of Commercial Jet Aircraft Accidents, Worldwide Operations, 1959-1991 (June 1992).

By comparison, 86 hull loss accidents, or 71.7 percent, were caused by errors made by the flight crew. Moreover, at the time of our review, several of the "new generation" aircraft designed and manufactured domestically in the 1980s—the Boeing 757, Boeing 747-400, and Douglas MD-11—had not had a hull loss accident.

Officials of FAA, NTSB, and manufacturers stated that this safety record is due in large part to manufacturers' expertise and high commitment to build safe aircraft. These officials noted that it is in the manufacturers' interest to design aircraft that are as safe as possible because accidents linked to design problems can cause airlines not to purchase the types of aircraft believed to be unsafe. Nevertheless, these officials emphasized that FAA has a key role to perform in overseeing manufacturers' efforts to ensure that checks of an aircraft's design and systems are as thorough as possible. To fulfill this role, according to these officials, FAA must understand new, advanced systems before certifying the airworthiness of commercial aircraft.

Conclusions

Balancing the combined effects of an increasing work load, increasingly complex technologies, and limited resources creates a formidable and continuing challenge for FAA. Although delegating duties to DERs is a feasible and responsible mechanism to address this challenge, this approach can weaken FAA's role in the certification process if not adopted correctly. FAA's delegation of certification duties without establishing specific guidance for its staff displays the weaknesses of this approach. FAA has delegated key activities without defining a minimum role for itself in the process, specifically, without defining critical activities that staff should be involved in, the necessary level and quality of the oversight of DERs, and standards to evaluate staff members' effectiveness. As a result, FAA has little assurance that its staff are effectively involved in or add value to the process. We recognize that the demands on FAA's resources and that the complexity and size of certification projects make it unreasonable to expect FAA engineers to review all certification data. However, FAA must balance the demands on its resources with its responsibility to promote safety and play an effective role in the certification process. This balance requires FAA to strategically plan its involvement at key points in the process to maximize its staff members' impact, develop an approach that ensures DERs are properly supervised, and develop meaningful measures of staff members' effectiveness.

FAA's diminishing, undefined role in the certification process threatens FAA staff members' competence in new technologies. Without an

understanding of new technologies, FAA staff will not be able to fulfill their mission of promoting safety because they will not be able to adequately verify that new aircraft meet safety standards. In some instances, this has already occurred. By not addressing concerns raised 13 years ago and by retaining its current approach, FAA has increasingly brought into question the value added by its certification activities and jeopardized staff members' ability to understand new technologies.

Recommendation

To ensure that FAA staff are effectively involved in the certification process and competent in new and complex technologies, we recommend that the Secretary of Transportation direct the Administrator, FAA, to define a minimum effective role for FAA in the certification process by identifying critical activities requiring the agency's involvement or oversight, establishing guidance on the necessary level and quality of the oversight of DERs, and developing measures through which staff members' performance and effectiveness can be evaluated.

Agency Comments and Our Evaluation

In commenting on a draft of this report, DOT stated that FAA staff are effectively involved in the certification process. We found, however, that FAA's diminishing, undefined role in the process has brought into question the value added by the agency's activities and jeopardized staff members' ability to understand new technologies. For example, FAA engineers delegated to Boeing the approval of the 747-400's highly advanced flight management system because they did not understand the system. FAA's internal studies and our interviews with FAA staff and manufacturing representatives support our findings. FAA's 1989 study, for instance, concluded that the amount of work delegated to DERs had reached the maximum for properly managing the certification process and that further delegation would reduce FAA's ability to understand the highly complex work being conducted by DERs. Since 1989, however, the amount of delegation has continued to increase.

To ensure that FAA staff add value to the certification process, we recommend that FAA identify critical activities requiring the agency's involvement or oversight and establish measures through which staff members' performance and effectiveness can be evaluated. Although agreeing that FAA needed to continually ensure the effective involvement of staff, DOT did not fully concur with our recommendation, saying it would establish "rigid requirements dictating the sequence and participants at each juncture of the certification process." However, our recommendation

does not call for such requirements. Instead, we found that a need exists for basic guidance that describes the critical activities requiring FAA's involvement. We believe that such guidance must be more specific than the general guidance currently governing FAA's role in the process. However, we do not believe that such guidance needs to dictate the sequence and participants at each juncture of the certification process. Rather, the guidance should be specific enough to (1) ensure FAA involvement in key activities in the process and (2) allow for the development of measures through which staff members' performance and effectiveness can be evaluated.

DOT disagreed with our conclusion that FAA has not adequately responded to the Academy's recommendation in 1980 that FAA develop a more structured role in the certification process. DOT stated that FAA developed the directorate system to enhance the structure and standardization of the process. In the draft of this report provided DOT, we noted that FAA established the directorate system in response to the Academy's findings. However, our concern is not about FAA's overall directorate structure, but rather the direction and guidance FAA provides its certification engineers. Despite the creation of the directorates in 1982, FAA still relies on general guidance established in 1967. It is this same lack of specific guidance that the Academy criticized in 1980. According to the three committee members we interviewed, FAA's establishment of the directorate system was a good first step in responding to the Academy's criticism. However, they emphasized that their primary concern was the lack of systematic, defined involvement by FAA engineers during the certification process—a concern, they noted, that FAA has not yet adequately addressed.

DOT also maintained that our conclusion that FAA has delegated its certification duties with little meaningful guidance to its staff resulted from an incomplete understanding of the process. We believe that our review provided us with an accurate understanding of the certification process. We conducted extensive interviews with numerous FAA officials, ACO engineers, and manufacturing representatives, as well as each expert in the NRS Program. We also reviewed FAA's internal studies—many of which reached conclusions similar to ours. Recognizing the technical nature of this area, we also assembled a group of individuals with distinguished aviation backgrounds to provide external, technical perspectives on the issues examined in our review. The group included a former FAA Administrator and the previous Chairman of FAA's Aviation Rulemaking Advisory Committee. Three group members served on the National Academy of Sciences' 1980 committee.

Finally, DOT stated that the DER system has been efficient and effective. We agree. Currently, the certification system results in safe aircraft designs largely because of the efforts and expertise of the manufacturers' DERs. What is less clear, however, is the extent to which the contributions of FAA staff materially add to this level of safety. Thus, our concern is not over the role DERs play, because they are the key to the entire process. Rather, we believe that FAA's current approach and general guidance has greatly limited the value that FAA engineers add to that process. It is precisely to improve FAA's role—not that of the DERs—that we are recommending that FAA identify critical activities requiring the agency's involvement or oversight, establish guidance on the necessary level and quality of the oversight of DERs, and develop measures through which staff members' performance and effectiveness can be evaluated.

Program Providing Technical Assistance to FAA Staff Is Not Fully Implemented

One approach FAA has taken for building the technical competence of its staff has been to develop a program of in-house experts in such subjects as crash dynamics, composite materials, and advanced avionics. The program was specifically established to ensure continued technical competence in aircraft certification programs. However, the program is much smaller than originally envisioned, with only 11 positions authorized (though FAA had identified a need for 23) and only 8 of the 11 actually filled. FAA also has not developed a mechanism for ensuring that these experts are involved at appropriate points in the certification process. As a result, the experts are sometimes not sought for advice or are often involved too late for them to be most effective.

Program Designed to Meet Deficiencies in Technical Competence Only Partially Staffed

Acknowledging that its staff was falling behind industry in technical competence, FAA established a program in 1979 to increase staff members' knowledge of state-of-the-art technologies. Under the National Resource Specialist (NRS) Program, FAA identified a need for expertise in 23 areas, including crash dynamics, fuel and landing gear systems, advanced materials, advanced avionics, and the effects of such environmental factors as ice. Experts in the program were to be responsible for maintaining the highest level of technical expertise in their particular specialty and acting as advisers to staff during the certification process. In 1980, the National Academy of Sciences praised FAA's decision to develop the NRS Program because the Academy had found that the technical competence of FAA staff was falling far short of the level present in industry. The Academy concluded that FAA needed a centralized engineering organization staffed by a cadre of 20 to 30 senior experts to provide, among other things, technical assistance on key decisions during the certification process and noted that the NRS Program was a step in the right direction.

But FAA never fully implemented the program. Of the 23 positions FAA identified as critical, only 11 were authorized. According to the manager of the NRS Program, FAA intended to authorize all of the positions but did not do so because it could not attract qualified individuals to fill all of them. The manager said early attempts to recruit experts showed that in a number of specialties, those with suitable expertise were interested only in having consulting contracts, not full-time FAA positions. In addition, FAA has staffed only 8 of the 11 authorized positions. Again, the NRS Program manager cited an inability to attract qualified experts to fill the three vacant positions. Listed below are the positions that are filled, that are vacant, and that were never established.

Positions Filled, Vacant, and Never Established in FAA's Program Providing In-House Expertise, as of April 1993

Areas in Which Positions Were Authorized and Filled	Advanced avionics/electrical Advanced composite materials Aircraft computer software Crash dynamics Flight loads/aeroelasticity (fixed-wing aircraft) Flight management Fracture mechanics/metallurgy Nondestructive evaluation
Areas in Which Positions Were Authorized but Are Vacant	Engine propulsion system dynamics (vacant since 1987) Flight environment (icing) (vacant since 1987) Quality assurance/technology (never staffed)
Areas in Which Positions Were Never Authorized	Aircraft systems safety analysis Flight loads/aeroelasticity (rotorcraft) Fuel systems Hydromechanical systems Landing gear systems Maintenance (air transportation systems) Noise certification Nondestructive testing Performance (fixed-wing aircraft) Performance (rotorcraft) Propeller design Rotorcraft drive systems

According to certification staff and experts in the NRS Program, FAA's not fully staffing the program has caused staff to fall farther behind in some areas of expertise. For example, according to certification staff, FAA has no one who is maintaining state-of-the-art expertise in the effects of ice on new airplane designs, as the relevant position in the program has been

vacant since 1987.[1] The effects ice has on different aircraft designs vary greatly, making it imperative that FAA have an expert in this area, according to the acting manager of the Propulsion Branch at the Los Angeles ACO. Because the position has not been filled and engineers with some expertise in this area are retiring, the new staff are falling farther behind in understanding the principles and effects of ice, he stated.

In commenting on a draft of this report, FAA's Aircraft Certification Service Director stated that FAA staff were not falling behind in understanding the principles and effects of ice. He noted that FAA has recently issued regulations governing airlines' ground operations during icing conditions. As a result, we confirmed with the acting manager of the Propulsion Branch at the Los Angeles ACO the accuracy of the point made in the draft report. Although acknowledging that new regulations governing airline operations had been issued by FAA headquarters, he reiterated that new certification staff are falling farther behind in understanding the principles and effects of ice on aircraft designs because FAA has not hired an NRS on icing to assist staff in understanding those principles and effects.

In addition, some NRSs are stretched increasingly thin in part because they must (1) perform duties originally intended for another NRS position that was never authorized and (2) develop expertise to cover additional areas because of technological advancements. For example, according to the NRS for advanced avionics, he must also cover aircraft systems safety analysis—a subject envisioned to warrant its own expert, but such a position was never authorized. According to certification supervisors, this NRS is stretched too thin to adequately perform his duties.

According to the manager of the NRS Program, the management of FAA's Aircraft Certification Service informally discussed the need for additional NRSs 3 years ago and decided no new positions were needed—especially since the agency could not attract qualified experts for the three vacant positions. He acknowledged, however, that (1) FAA has not formally evaluated the need for additional experts since 1979 in the areas originally identified or in other areas in which technology has advanced in the last decade and (2) recent layoffs by manufacturers and airlines may have increased the pool of qualified individuals. All three members of the National Academy of Sciences' 1980 committee whom we interviewed stated that they believe the NRS Program does not adequately respond to the Academy's recommendation that FAA establish a cadre of 20 to 30

[1]We reported earlier on FAA's efforts to develop regulations governing airlines' ground operations during icing conditions. See Aviation Safety: New Regulations for Deicing Could Be Strengthened (GAO/RCED-93-52, Nov. 18, 1992).

experts, largely because the program has been understaffed. These three individuals stressed that there are too few NRSs and that the eight currently with the program may be stretched too thin to adequately assist FAA staff in understanding new technologies. The three stated that FAA should consider hiring more experts because the limited additional resources needed for such positions would be justified by the agency's increased competence in critical areas. Because it has not formally examined since 1979 the need for hiring NRSs, FAA does not know if its current program is adequately staffed and cannot respond to criticism that the program does not adequately address the Academy's concerns raised 13 years ago.

Lack of Requirements for Experts' Involvement During Process Limits Program's Effectiveness

A lack of direction from management has also limited the NRS Program's potential. FAA's guidance is silent on when and to what extent NRSs should be involved in the certification process. The experts are not required to involve themselves in the process, nor are certification staff required to use them, even though the experts are full-time FAA employees. Decisions about involvement are left to the discretion of the staff and experts involved. As a result, the experts are sometimes not sought for advice or are often involved in the process too late for them to be most effective.

Under FAA's policy, no requirement exists to involve NRSs during key junctures in the certification process. FAA Order 8000.45C, which provides the basic guidance for the NRS Program, lists experts' responsibilities but leaves with individual experts the decision of how to set priorities and meet these responsibilities. The manager of the NRS Program explained to us that he leaves up to each expert the decisions about what priorities to establish and when and how to become involved in certification activities. Similarly, FAA's procedures contain no requirements for NRSs to review or approve critical systems about which they have relevant expertise. The FAA certification staff we interviewed stated that they used their professional judgment as to when to request experts' involvement.

Our review of recent certification activities shows that several NRSs were not involved during key junctures of certification projects, while others were extensively involved. Several NRSs stated that they were not routinely asked to participate in key certification activities and, from their perspective, were not being effectively involved. Two cases, both involving certification activities for the Boeing 777, serve as examples. First, the NRS for advanced composite materials told us that on his own initiative he followed up on the certification staff's analysis of relevant testing. In doing so, he raised several concerns about how Boeing was going to

demonstrate compliance with safety standards. He stated that for one part of the aircraft, Boeing proposed—and the certification staff initially approved—using a test procedure used for an earlier aircraft, the 767, even though the designs of the two aircraft are substantially different. The NRS concluded that the differences between the two aircraft made relying on this test highly questionable. According to the expert, Boeing acknowledged his concerns and agreed to modify its test procedure.

Second, the NRS for fracture mechanics told us that he intervened in the process when he learned from an industry source that Boeing's proposed design for the 777 excluded "crack stoppers"—devices installed on the fuselage skin to prevent cracks from growing to unsafe sizes. Upon reviewing Boeing's proposals, he raised concerns about the tests proposed to show that such an approach complies with safety standards. As a result of his actions, he said Boeing is reviewing its test procedure in this area. The certification engineer explained that she did not request the expert's involvement because she believed no problems existed and no guidance defines when experts should be consulted.

In the case of two other NRSs, however, the demand for their expertise was so extensive that they and other FAA officials were exploring ways to reduce it. The NRS for aircraft software, for example, stated that he has been very involved in recent certification projects and that his continuous involvement is essential because FAA does not have a sufficient number of qualified software engineers. He stated that his heavy involvement has precluded his performing such other key functions as providing training seminars in new technologies for certification staff.

Lack of Early Involvement Also Limits Experts' Effectiveness

The timing of the involvement of NRSs is of particular importance in making effective use of their expertise. All of the experts stated that if their involvement is to be effective, it needs to come early, when FAA is reviewing an aircraft's design, descriptions of systems, and the manufacturer's proposed means for demonstrating compliance with safety standards. On the basis of this early involvement, they said, they can identify whether any future involvement is needed.

According to several NRSs, their involvement often has been requested too late by staff, making it difficult to resolve their concerns. Several stated that by the time they are involved, the certification staff and the manufacturers have already reached agreement on many matters. We found that this lack of early involvement has created problems for

manufacturers and limited the consideration given to an NRS's concerns. According to Boeing certification officials, for example, the lack of early involvement sometimes leads to inconsistency in FAA's direction to the manufacturer and lost time and money for the company. They stated that if the NRS is not involved in FAA's initial review of a design and the proposals for showing compliance with requirements, any concerns the NRS may have may not be raised until the manufacturer already has its design, analyses, and test plans well in place. Modifying them at this time can result in delays and higher costs. For cost-effectiveness, the Boeing certification officials said, FAA's certification staff and the NRS should be involved at the same time. In addition, Boeing officials emphasized that the NRS function of bringing FAA staff "up to speed" on key new technologies is not being fully carried out because of the lack of early involvement of the NRSs.

In FAA's review of the Airbus A330 and A340 aircraft, participation by the NRS for composite materials apparently came too late to address his concerns. According to the NRS, FAA staff said they considered the composite technology being used on these aircraft to be "old technology" and therefore did not need his involvement. When he pressed to be involved and eventually examined the plans, he found that Airbus's use of composites was at the highest stage of technological advancement. He stated that his review of the plans and Airbus's testing came too late, however, for the company to take his concerns into account in setting up its compliance testing. According to the manager of the NRS Program, this was not an isolated example; NRSs have had particular difficulty getting involved in FAA certification projects for European aircraft. He stated that FAA's management has discussed this problem with the NRSs, ACO managers, and FAA's European staff to increase the experts' involvement.

Different Causes Cited for Lack of Effective, Timely Involvement of Experts

While acknowledging that the experts are sometimes not involved early enough to be used effectively, NRSs, FAA officials, and certification staff differed on the reasons for this. NRSs and FAA officials indicated that some of the reasons for the lack of timely involvement may have to do with staff members' reluctance to use NRSs. NRSs and FAA officials cited three perceptions:

- A lack of commitment by the Transport Airplane Directorate's management to using NRSs. In April 1991, the directorate issued a memorandum reaffirming support for the NRS Program and stressing the importance of utilizing the experts; however, according to several NRSs, it

was common knowledge that the directorate's manager in place at the time did not want the certification staff to make use of NRSs' assistance. FAA headquarters officials acknowledged that the directorate's former manager, apparently feeling that his staff did not need assistance, resisted using the experts. The headquarters officials noted, however, that the new manager—in place since mid-1992—is committed to changing this unwritten policy. The Assistant Manager, Transport Airplane Directorate, told us that he was not aware of any past attempt to exclude NRSs, but he acknowledged that the directorate needed to do a better job of involving them early in the certification process.

- A reluctance on the part of certification staff to use someone with greater expertise than their own. Several NRSs stated that they encountered situations in which the least knowledgeable staff were the least likely to involve them. By contrast, they said, those staff with greater levels of expertise were more likely to seek NRSs' input.
- A lack of recognition by certification staff of technological advances in new aircraft designs. Several NRSs said certification staff may believe they understand a new application of technologies on new aircraft designs—and therefore do not call on the assistance of an NRS—when in fact they do not understand the new application. Such an instance occurred when certification staff decided that the use of composites on the Airbus A330 and A340 was old technology when this was not the case.

Despite an apparent reluctance by staff to use NRSs, FAA headquarters and directorate officials indicated that they did not favor establishing priorities for NRSs or identifying key points in the process requiring NRSs' involvement. FAA's Aircraft Engineering Division Manager, who is responsible for managing the NRS Program, and the Assistant Manager of the Transport Airplane Directorate, who is responsible for managing the certification staff, both said that they are aware of instances in which NRSs have not been involved early enough to be used effectively, as well as instances in which NRSs have not been available to assist certification staff because of scheduling conflicts. Both officials do not believe a requirement is needed to ensure that NRSs are effectively involved. Rather, the officials stated, FAA's management needs to make clear to certification staff that NRSs' involvement during critical junctures of the process is necessary and that early involvement is most effective.

The certification staff we interviewed stated that in the cases in which NRSs were not involved in a timely manner, the cause was the experts' not being available to assist them when needed. Stating that they were not reluctant to use NRSs—as FAA officials and NRSs asserted—certification

staff noted that they could not always obtain expert assistance when it was requested on short notice. Staff attributed this problem, in part, to the lack of specific priorities for NRSS. Under FAA's guidance, NRSS' involvement in international conferences, for example, has the same importance as involvement in key junctures of certification projects. NRSS acknowledged that assisting certification staff on short notice is difficult because they are also interacting with industry, researchers, and the international community. As a result, NRSS' schedules are developed months in advance and are difficult to change.

Conclusions

The rapid technological advances being made in the aerospace industry make it essential for FAA staff to deal effectively with their counterparts in industry. Although FAA recognized the need for a strong technical staff and established the NRS Program to provide a cadre of technical specialists in different disciplines, FAA never fully implemented the program because the agency could not attract qualified experts. In this era of layoffs by aircraft manufacturers and airlines, such a constraint may no longer exist. Because staff are falling farther behind in key technical areas and some NRSS are being stretched increasingly thin covering several areas of expertise, we believe that FAA needs to formally examine the need for hiring NRSS in areas of technological advancement.

Because of the continuing rapid advances being made in the aerospace industry that increasingly challenge FAA certification staff members' ability to stay current with new technologies, we also believe that FAA needs to reestablish the premise that the NRS Program exists to inject expertise into the certification process. FAA's current unstructured approach sometimes results in FAA's expertise not being effectively applied at appropriate steps in the certification process. With little guidance, certification staff are left on their own to determine when they will involve NRSS. If a formal requirement existed making NRSS' involvement mandatory early in the certification process, such as during the establishment of key test requirements and procedures, it would ensure that FAA's most competent specialists are involved (1) in these key junctures of the certification process, (2) before agreements are made between FAA's certification staff and the manufacturer so that the NRSS' concerns do not impose a financial burden on the manufacturer or possibly delay the certification project, (3) early in foreign manufacturers' certification projects that involve highly advanced technologies different from those developed by domestic manufacturers, and (4) when the certification staff need them.

Recommendations

We recommend that the Secretary of Transportation direct the Administrator, FAA, to (1) formally examine the need to hire NRSs in areas of technological advancement over the last 14 years and (2) require NRSs' involvement early in the certification process and at other key junctures.

Agency Comments and Our Evaluation

In responding to a draft of this report, DOT stated that FAA does not need to formally examine the need to hire experts in areas of technological advancement over the last 14 years because FAA periodically assesses the NRS Program. DOT noted that these assessments have "served effectively." As our report details, however, NRSs and FAA staff provided us examples in which FAA staff have fallen farther behind in some areas of expertise because the agency has not fully staffed the program. In addition, three members of the National Academy of Sciences' 1980 committee stated that the NRS Program has been an inadequate response to the Academy's call for greater competence by FAA in the certification process, in part because it has been understaffed. In its response, DOT acknowledged that some NRSs are "in high demand and overworked." For these reasons, we are calling for the first formal assessment of the program since its inception 14 years ago.

DOT stated, however, that a formal examination of the NRS Program's staffing level would add unnecessary costs. In light of FAA's diminishing role in the certification process and staff members' difficulty in staying current with the latest technologies, we believe that such a staffing study is justified. It would provide both the Congress and the public greater assurance that FAA is targeting its limited resources to (1) improve staff members' competence in the areas of the latest technological advancement and (2) enhance the value NRSs and staff add to the certification process.

In addition, DOT—though agreeing that NRSs should be involved at appropriate junctures in the certification process—did not fully concur with our recommendation that FAA require NRSs' early involvement in the process and at other key junctures. DOT stated that we are recommending rigid requirements specifying the timing and type of NRSs' involvement, which will unnecessarily delay certifications. We are not recommending that FAA specify the type and timing of NRSs' involvement in every certification project. Rather, FAA should define general requirements that would ensure involvement by NRSs in key certification projects early enough to have their concerns resolved and assist in bringing staff up to speed on new technologies. For example, FAA could specify key

certification projects as those involving new designs by Boeing or Airbus. In addition, FAA could identify smaller, less complex projects as not requiring NRSs' involvement. Currently, no requirements govern NRS involvement in the certification process. We believe that the lack of any requirements has limited the value that NRSs add to the process, and we believe that FAA can rectify this deficiency without establishing rigid requirements.

FAA's Training Is Not Improving the Technical Competence of an Inexperienced Staff

Since 1980, FAA has known about—and tried to address—its certification staff's lack of training and experience in the latest technologies. But the agency's efforts have not been successful. As a result, FAA has not improved the technical competence of its staff as it committed in 1980 to do. We found that most courses taken by certification staff deal with such nontechnical subjects as supervision and writing or with subjects that are outside their certification responsibilities. The lack of training in technical subjects is accompanied by the declining experience of the certification staff on the whole. In response, FAA is developing a new training program specifically emphasizing critical technical areas and expects to implement new courses over the next several years. We are concerned, however, that this effort may not succeed because it does not establish specific training requirements and does not identify training available outside FAA.

Training Deficiencies Identified Several Times Since 1980

Over more than the past decade, FAA and others have examined the training program for certification staff. Each evaluation has disclosed substantial—and essentially the same—weaknesses.

1980 Review by the National Academy of Sciences Found FAA Falling Behind Industry

The National Academy of Sciences' review, already discussed in other contexts in chapters 2 and 3, found that FAA's engineering staff were considerably less competent than the engineers in the industry FAA regulates. The review concluded that the agency would need to regain a higher level of competence to certify aircraft and to command the respect of the aviation community. FAA's Administrator concurred with the Academy's conclusions and said that the agency would take actions to ensure that staff were up to date with scientific and technical advancements. FAA's Aircraft Certification Service Director responded by saying that the agency needed to look at upgrading its technical training programs. He emphasized that FAA needed to ensure that the technical work force was trained in specialized disciplines to minimize the reliance on manufacturers for education in the latest technologies.

But according to FAA officials, little was done to respond to the Academy's study. The officials said that budgetary constraints prevented an adequate level of participation by staff in important technical training.

FAA's 1987 Study Found Training Inadequate

In 1987, FAA released a study on "Project Smart," which examined the entire certification program, including training. Like the Academy's 1980 study, FAA's study found that the certification work force was not keeping

current with technological changes. Many staff interviewed for the study said that inadequate training was leaving them 3 to 5 years behind the developments in industry. Industry representatives voiced similar concerns, with some saying that FAA's lagging expertise delayed the introduction of advances in aircraft design and manufacturing that would enhance performance and increase efficiency.

The study recommended that FAA develop and implement a more formal, structured program with specific annual training requirements. This program was to include a system for identifying, developing, and evaluating training opportunities both inside and outside FAA and sufficient travel funds to allow FAA personnel to attend the training. FAA was able to do little to respond to these recommendations, according to agency officials. As with the aftermath of the National Academy of Sciences' study, budgetary constraints again prevented progress, the officials said.

Contractor's 1991 Report Again Found Training Inadequate

In the face of little progress in improving training, FAA hired a contractor in 1990 to survey the certification work force and document the needs in this area. In February 1991, the contractor reported that all levels of the certification organization were dissatisfied with the state of technical training.[1] Among the report's findings and conclusions were the following:

- Certification staff had no comprehensive, up-to-date program that (1) described the training courses needed; (2) related these courses to job performance; (3) established the sequence in which the courses should be taken; and (4) ensured that the courses were available.
- FAA's own training program, operated by the FAA Academy, fell short of meeting the certification staff's needs.[2] Some of the training courses were not up to date, and attempts to develop new courses or seminars in specialized state-of-the-art areas had failed. Only one course related to certification had been developed since 1982. As a result, certification staff managers felt forced to choose from a limited array of courses that did not match their needs.
- Because FAA's own training fell short of meeting the certification staff's needs, managers were relying on outside training arranged by the FAA regions. However, this training was often not well planned, and funding

[1]Human Technology, Inc., Description of the Current Training System Within the Aircraft Certification Service (Feb. 1991).

[2]We reported earlier that the FAA Academy was having difficulty providing sufficient training to other FAA units. See Aviation Training: FAA Aviation Safety Inspectors Are Not Receiving Needed Training (GAO/RCED-89-168, Sept. 14, 1989).

was difficult to obtain because the certification staff had to compete with other FAA units for limited funds. This "out-of-agency training," as it was called, was further complicated by the degree of specialization in the certification staff. During the past 5 years, almost all of FAA's attempts to initiate new national out-of-agency training had not resulted in actual courses because of an insufficient number of interested individuals in those specialized areas.

The contractor's survey identified a need for training in over 100 different subject areas, ranging from such technical subjects as composite materials and software systems to such nontechnical subjects as resolving conflicts and managing stress. In commenting on a draft of this report, FAA's Aircraft Certification Service Director said that these efforts must be viewed together. He acknowledged that FAA paid little attention to training between 1980 and 1985. He noted that in 1985, FAA admitted that certification training was "a mess" and started Project Smart to analyze tasks and the training needed to accomplish those tasks. Finally, in 1990 FAA contracted for the more detailed analysis that culminated in the current training initiative.

Training Still Inadequate to Ensure Staff's Competence

Our review of training records and interviews with certification staff showed that the training program still does not provide a framework for ensuring staff members' competence in their specific area of responsibility. Most of the training the staff have received has been outside their areas of responsibility in the certification process, and the availability of technical courses in their specialties continues to be limited.

Most Training Is Nontechnical or Not Related to Specialties Within Certification Process

Our review of the training records of certification engineers in FAA's Seattle and Los Angeles ACOs for a 3-year period (1990-1992) showed that 73 percent of the training courses taken fell into two categories. First, FAA staff received nontechnical training, in supervisory skills or word processing, for instance. Second, FAA staff received technical training for job responsibilities other than certification, such as courses in investigating aircraft accidents and controlling corrosion on aging aircraft.

For example, our review of the training records for the eight engineers and one test pilot on the team for certifying the Boeing 777 found that of the 31 courses taken for a 3-year period (1990-1992), 9 (29 percent) were technical courses directly supporting certification activities. Of the remaining 22 courses, 7 were either managerial or orientational; 9 were

technical but in areas not related to certification responsibilities; and 6 covered the automation of office work, for instance, word processing. Similarly, our review of the training records for 90 certification engineers, showed that 43 percent received no technical training that directly supported certification. For example, one engineer who began work on certification projects in September 1990 had taken three personal computer courses, a human relations course, a leadership development course, and an equal employment opportunity course. Another engineer had taken four courses on personal computer programming, a course on total quality management, and a course on the "human factors" involved in certification, but had received no training in his technical area during this period. According to the manager and assistant manager of the Seattle ACO, nontechnical courses are becoming more important so that FAA can effectively manage and oversee DERs' work.

We do not question whether such courses have merit. However, they are not likely to meet the need identified as the most critical by certification managers, which is technical competence in fields directly related to certification. In addition, most of the courses appear to have only a marginal impact on FAA's ability to oversee DERs, and FAA does not have a course specifically aimed at improving the oversight of DERs.

Availability of Technical Training Is Limited

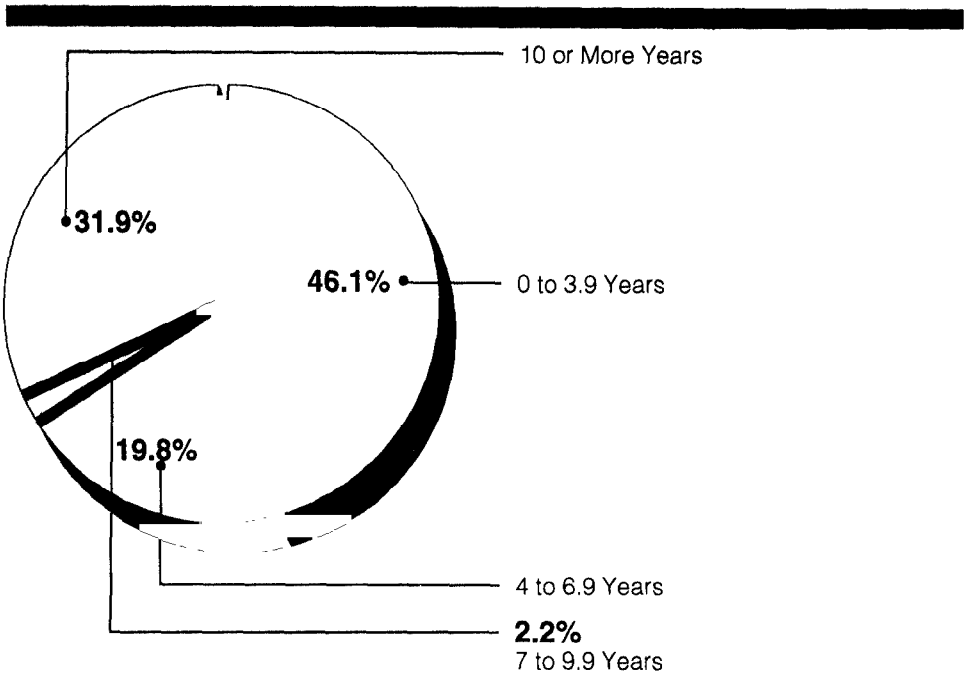
The amount of technical training available to staff to improve their competence remains extremely limited. For example, FAA has provided little training in the sophisticated computer systems being developed for current aircraft. In our review of FAA's software-related training curriculum, we found that the agency offers no training courses in certifying software. We also found that between fiscal years 1990 and 1992, only 1 of the 12 engineers responsible for approving aircraft software in the Los Angeles and Seattle ACOs attended a software-related training course. The NRSs for software and avionics as well as ACO engineering supervisors and software engineers we interviewed criticized FAA's training, stating that the agency has no courses designed specifically for ACO engineers responsible for approving airborne software-based systems and that the software-related training that is available fails to meet their needs. In part because of this lack of training, a disparity exists between the qualifications of FAA engineers responsible for approving airborne software systems and DERs specializing in software. Only 2 of the 12 FAA transport engineers responsible for certifying aircraft software, for example, meet the minimum qualifications the agency requires of DERs.

Certification officials acknowledged that the FAA Academy has a limited ability to react quickly with the kinds of advanced, state-of-the-art training needed to bring staff members up to date on the most current technology. Because of the lack of adequate internal training, certification staff must therefore locate non-FAA sources, such as universities, manufacturers, and private organizations within the aerospace industry, to obtain technical training related to their disciplines within the certification process, according to the contractor's study. Although certification officials cited this training as the best available, they said that funding limitations greatly restrict the number of courses that can be taken. Some FAA software engineers we interviewed, for example, noted that their requests for externally sponsored software-related training are generally not approved. Moreover, the NRS for software stated that in 1992, he identified two courses sponsored by contractors that FAA engineers should attend; however, funding was not available for engineers to enroll in either course. At the Transport Airplane Directorate, the funding for such out-of-agency technical training had declined from $89,200 in fiscal year 1991 to $77,000 in fiscal year 1992. In fiscal year 1993, the Seattle and Los Angeles ACOs have projected their needs for outside training to cost $115,000 but expect to receive $63,400.

High Turnover of Staff Complicates FAA's Efforts to Ensure Technical Competence

The effect of limited technical training is compounded by the fact that once staff gain some degree of experience in certification, many tend to leave for other jobs. At the Seattle and Los Angeles ACOs, the average number of years of experience for all nonsupervisory certification engineers in April 1993 was about 8, and 46 percent had fewer than 4 years of experience (see fig. 4.1). Of the eight engineers with primary responsibility on the certification of the Boeing 777, for instance, six have fewer than 5 years of experience and have not been through a major certification project before according to the engineers. By contrast, according to FAA's Aircraft Engineering Division Manager, in industry the average number of years of experience is about 20.

Figure 4.1: Years of Experience of FAA Nonsupervisory Certification Engineers at the Seattle and Los Angeles ACOs, as of April 1993



Source: GAO's analysis of data from FAA.

FAA officials told us that in such areas as software certification, they are concerned that staff do not have sufficient experience to do the job adequately. For instance, in 1987, 58 percent of the Seattle ACO's engineers in the Systems and Equipment Branch—largely responsible for software certification—had at least 6 years of experience in certification. However, as of April 30, 1993, the number of staff with 6 years' experience or more had decreased to about 17 percent. In 1992, the NRS for computer software raised concerns about whether the remaining staff had the technical competence to carry out their certification responsibilities. The NRS still has similar concerns, as do several engineering supervisors at the ACOs. They stated that in the ACOs, the level of expertise concerning software needs to be improved to meet the existing and expected work loads.

The results of a survey issued in 1991 by FAA raised similar concerns, voiced this time by DERs. Twenty-five percent of the DERs who responded said they were dissatisfied with FAA staff members' knowledge in interpreting rules and regulations, and 15 percent said they were

dissatisfied with FAA staff members' knowledge of how to show compliance with the agency's rules and regulations. FAA's Aircraft Certification Service Director expressed concern about these results because 18 percent of the DERs wrote that they questioned the technical competence of the person responsible for overseeing them.

FAA officials stated that a high turnover among staff has severely limited their ability to ensure competence. These officials attributed much of the turnover to a lack of a technical career path within the certification unit. Certification staff seeking a promotion must move to supervisory or managerial positions outside the unit. Our review of personnel actions showed that such moves were taking place. Between October 1982 and November 1992, 99 engineers and test pilots had worked for and left the Seattle and Los Angeles ACOs.[3] Of these 99, 46 engineers and test pilots, or 46 percent, transferred to other FAA units (35 of them via promotions to supervisory or managerial positions). According to both ACO managers, technically inclined people who choose not to pursue supervisory or managerial positions must look outside FAA for advancement. During the same period, 53 of the 99 staff, or 54 percent, left FAA altogether (33 for retirement and 20 for other jobs).

Acknowledging Past Problems, FAA Has Committed to New Initiatives

Recognizing past difficulties in training and retaining competent staff, FAA has initiated two efforts to improve staff members' competence. First, it has begun to develop a technical training program. Second, FAA plans to implement a technical career path for certification engineers. Although both efforts hold potential for improving competence, the limited nature of the current plans for training and the failure of similar commitments made in 1980 raise questions about the eventual success of these efforts.

FAA's Initiatives to Improve Certification Training

FAA officials acknowledged that inadequate training has limited the certification staff's ability to understand areas of dramatic technological advancement. The Aircraft Certification Service Director also acknowledged that inadequate training since 1980 has resulted in a dependence on manufacturers to provide on-the-job training in such technologies—a situation that may prevent effective oversight of manufacturers. As a result, FAA is developing a new training program. Recognizing the urgent need for this effort, FAA plans to increase the Aircraft Certification Service's training budget from $3.3 million to $4.4

[3]In 1982, the Seattle and Los Angeles ACOs employed approximately 90 engineers and test pilots in the airframe, systems and equipment, propulsion, and flight test branches; as of March 1993, they employed 116.

million, or 33 percent, between fiscal years 1993 and 1994. According to the Aircraft Certification Service Director, the training initiative is the most important effort to improve staff members' competence. He stated that a strategic plan for certification training, which will describe the current initiative, will be issued by December 1993. According to FAA officials, the kinds of activities under way include the following:

- FAA established a Technical Training Steering Committee in February 1992 to identify training needs and review and recommend the design, development, and implementation of new courses on certification. The committee is scheduled to meet once every 6 months.
- FAA is developing training profiles for certification staff for each of six technical disciplines.[4] The profiles are designed to outline training for each discipline. According to FAA officials, some courses will be mandatory, but most will not.
- FAA is designing six new technical training courses and revising six existing ones. FAA has set aside $230,000 for conducting the first of the new training courses, Aviation Safety Engineer Evaluating Program, in fiscal year 1993.

FAA officials said that they plan to determine FAA's specific technical needs and train a sufficient number of staff in those areas to meet the identified needs. To accomplish this, FAA expects to develop a series of core courses in each discipline and other technical courses as needs are identified. But FAA's current plan, although a step in the right direction, may not have the structure or scope necessary to improve identified deficiencies in staff members' competence, which were caused in part by the inadequate training over the last decade. Specifically, the program does not (1) establish specific training requirements—as recommended by the agency's Project Smart in 1987—to systematically ensure that staff receive a minimum level of training each year in their areas of responsibility and (2) identify in each discipline the training in new technologies available from universities, private industry, and other government agencies such as NASA.

Initiatives for a Technical Career Path

FAA has also initiated efforts to retain competent engineers by attempting to create a technical career path. FAA officials stated that they continue to be concerned about the turnover of certification staff and noted that a technical career path is needed. In 1992, FAA began a review of the

[4]Avionics and electrical systems, structures, mechanical and environmental systems, engine certification, propulsion, and flight tests.

classification standard for nonsupervisory engineers, with the intent of recommending to the Office of Personnel Management the creation of a formal technical career path between the GS-13 engineer positions and the GS-15 NRS positions. According to FAA officials, the Office of Personnel Management is studying the proposed GS-14 "senior engineering series" while FAA completes its review. According to the FAA official responsible for this project, the agency expects to receive the Office of Personnel Management's approval for a technical career path and have such a path in place by October 1994. FAA officials stated that the new position should stem the high rate of turnover that has occurred. FAA's Aircraft Certification Service Director emphasized that the creation of the GS-14 senior engineer positions—combined with the training initiatives—will significantly improve the staff's competence over the next several years.

Conclusions

The aviation industry has witnessed rapid changes in aircraft technology. The future will bring more changes, such as the further development and use of electronic systems for sensing the environment and controlling the aircraft and more advanced uses of composite materials in aircraft structures. Certifying such advanced technologies and ensuring safety will present significant challenges to FAA. FAA engineers and test pilots must be up to date to carry out their certification and regulatory tasks. But FAA currently does not offer the training needed to provide such technical competence.

In 1980, the National Academy of Sciences found that certification staff were less competent than the engineers in the industry they regulated. As a result, FAA promised to upgrade its technical competence. But 13 years later, FAA staff members are not receiving the training they need to effectively perform their jobs. Again, as in 1980, FAA says it is embarking on an ambitious initiative to upgrade and modernize its training program. But the current program may not have the structure or breadth necessary to significantly improve staff members' competence. With nearly half of its certification staff having less than 4 years' experience, FAA needs a vastly improved training program more than ever. We support FAA's current initiative to improve training but believe that having staff meet specific training requirements would help ensure that staff receive adequate training in their areas of responsibility to effectively fulfill their mission of certifying aircraft. We also believe that FAA must assist staff in identifying the training available at universities, private industry, and other government agencies. If such specificity and breadth are not included, we believe that this initiative may fail, as a similar effort in 1980 did.

Recommendations

To ensure that FAA staff receive the technical training needed, we recommend that the Secretary of Transportation direct the Administrator, FAA, to establish specific training requirements for each certification discipline, ensure that each staff member meets those requirements, and keep the training as current as possible by identifying the training in new technologies that is available at universities, private industry, and other government agencies.

Agency Comments and Our Evaluation

In commenting on our report, DOT stated that FAA has efforts under way to ensure that its certification work force is adequately trained. DOT also noted that FAA is systematically identifying a training profile for each engineering discipline and that FAA will allocate its limited training resources by identifying and meeting (1) individual staff members' needs in relation to these profiles and (2) the organization's needs to possess various skills. Referring to this as a "true need concept," DOT maintained that training will be predicated on individual and organizational needs and on the work to be done, rather than on an arbitrary number of courses or annual requirement.

We fully support FAA's initiative to improve certification training. However, FAA made a similar commitment to the Academy 13 years ago. Despite this commitment, a 1987 internal study and 1991 contracted study found that certification training was inadequate. We also found a lack of adequate certification training. For example, 11 of 12 FAA software engineers did not receive software-related training during fiscal years 1990, 1991, and 1992. According to FAA officials, such a lack of technical training limits the value FAA engineers can add to the certification process and makes the engineers more dependent on the manufacturers to provide on-the-job training. Such a dependence, according to these officials, may prevent effective oversight of the manufacturers. We believe that inadequate training has led to such situations as the FAA staff's delegating the certification activities for Boeing's highly advanced flight management system for the 747-400 because—as FAA's 1989 review found—staff "were not sufficiently familiar with the system to provide meaningful inputs to the testing requirements or to verify compliance with the regulatory standards."

To help ensure that FAA follows through on the current initiative, in our draft report we recommended that FAA establish annual requirements for each discipline. DOT maintained, however, that annual training requirements would be "rigid" and conflict with its "true need" approach. We acknowledge that annual requirements for all staff may be too rigid.

However, we believe that FAA must establish specific requirements to ensure that staff receive the technical training needed to fulfill their certification mission. FAA's 1987 study made a similar recommendation. Specific requirements would ensure that some staff are not overlooked as FAA identifies its true needs. In light of the high turnover within the certification work force, FAA's current approach leaves the agency vulnerable: Staff who receive training addressing true needs could leave the agency, and other staff will not have received any training.

As a result of DOT's comments, we have revised our recommendation. We have deleted our reference to annual requirements and now recommend that FAA (1) establish specific training requirements for each discipline, (2) ensure that each staff member meets those requirements, and (3) keep the training provided as current as possible by identifying the training in new technologies that is available at universities, private industry, and other government agencies. By taking these actions, FAA can ensure that staff receive the training needed to meet the challenges of advanced technology and fulfill their certification function.

Views Expressed by the Advisory Group We Convened

To provide external and technical perspectives on the range of issues involved, we obtained the views of a diverse group of distinguished individuals in the field of aviation. (App. II provides biographical information on each member.) We chose three of the five members—Dr. James Mar, Dr. John McLucas, and Mr. Don Madole—in part because they served on the National Academy of Sciences' 1980 Committee on FAA Airworthiness Certification Procedures and are still active in the aviation community. We chose another member—Mr. Jonathan Howe—in part because of his 23 years of service at the Federal Aviation Administration (FAA), which included overseeing all legal and regulatory aspects of the agency's certification program for Boeing's 747, 757, and 767 aircraft. Finally, we chose Mr. James Foody in part because of his 40 years of experience in the aircraft manufacturing industry, specializing in airborne computer systems. Between January and June 1993, we held four meetings with this group. Below is a summary of their views.

FAA's Diminishing, Undefined Role in Certification

Advisory group members generally agreed that FAA's diminishing role was a cause for concern because of its potential impact on the agency's technical competence. Members of the group noted that such a diminishing role did not raise immediate concerns about safety because of manufacturers' expertise as well as commitment and need to design safe aircraft. However, the group members generally stated that (1) by not defining a clear role for its certification staff, FAA had little assurance that its staff are effectively involved in and overseeing the process so that they understand new and critical technologies and (2) without an understanding of such technologies, FAA will be unable to fulfill its mission of promoting safety through an independent, effective check of manufacturers' activities.

Most group members expressed a much more critical assessment of FAA's current role in certification than presented in this report. They held that the cause of FAA's increasing delegation of certification duties was a fundamental lack of technical competence. Three members maintained that FAA does not adequately understand most systems currently being developed by manufacturers and as a result has delegated most of its certification duties. They stated, for example, that FAA's total delegation of the review of the 747-400's flight management system to Boeing's designees was caused by a fundamental lack of competence in evaluating such complex systems. Believing that such an assertion was too strong, another member said that certification staff have technical competence in such "old" technologies as aircraft structures but have been unable to

adequately keep up with such "new" technologies as advanced airborne software. Finally, one member held that such premises were extremely difficult to prove or measure and that one could only definitively state that an ill-defined, diminishing role probably has a negative impact on FAA's competence if adequate technical assistance and training are not provided.

Little consensus was reached among the group members, however, on the actions FAA should take to ensure its effective involvement in and oversight of the process. Although agreeing that (1) the current process was generally resulting in safe aircraft, (2) FAA needs to better define its role and measure its effectiveness in the certification process, and (3) greater involvement—and thus increased resources—would be difficult to justify given the scarcity of federal resources and the current safety record, group members reached little agreement on specific actions FAA should take. One member argued that FAA, using the existing level of resources, should replace its directorate structure with a central engineering organization to create a "critical mass" of talent responsible for overseeing all certification activities for transport airplanes, engines, small airplanes, and rotorcraft. Another member suggested that FAA consider replacing the current system relying on manufacturers' designees with a system delegating all activities to manufacturers that have FAA-approved design processes and then strategically auditing or spot-checking those processes, with a focus on new and critical technologies.

FAA's National Resource Specialist Program

Each member of the group agreed that it is critical for FAA staff to understand new and different aircraft technologies to effectively fulfill the legislative mandate of promoting safety and verifying that aircraft meet minimum safety standards. Each member stated that FAA's hiring of experts to assist certification staff was an excellent investment of federal resources to ensure competence. The three former participants in the Academy's 1980 study explained that (1) they had recommended that FAA hire a cadre of 20 to 30 experts to assist staff during critical points in the certification process and (2) FAA told the Academy that the National Resource Specialist (NRS) Program would fulfill this objective. These group members stated, however, that the NRS Program does not adequately respond to the Academy's recommendation because it has been understaffed and ineffectively managed. One member noted, for example, that he personally knows two NRSs whose involvement during critical

junctures often had not been requested by staff because of a lack of clear guidance on when NRSs should be consulted.[1]

Consensus was reached among the group members concerning the actions FAA should take to improve the NRS Program. Advisory group members stated that FAA should reexamine its need for experts in areas of technological advancement. They also noted that FAA should consider hiring additional experts in areas already staffed by an NRS if the agency finds that the NRS is stretched too thin, given the technological advancements that have occurred. The group members also agreed that the limited additional resources needed to establish and fill these positions would be justified by the increases in FAA's technical competence in critical areas. Several in the group emphasized that FAA needed to establish clear priorities for NRSs, while others stated that it may be prudent to allow these experts to establish their own priorities.

FAA's Training Program for Certification Staff

Members of the group expressed different views on FAA's training program for certification staff. Several stated that FAA should be commended for its current initiatives. Others expressed skepticism, stating that the resources needed for FAA to produce an adequate training program in new technologies would be massive. These members suggested that these resources would be better spent on hiring a limited number of additional NRSs. These members noted that FAA probably would have to go outside the agency to obtain the training needed to be competent in evaluating the latest aircraft technology.

One member of the group stated that FAA should consider two alternatives to make staff competent. The first alternative would include intense 6-month training sessions developed and taught by such non-FAA sources as universities, the National Aeronautics and Space Administration (NASA), manufacturers, and private organizations within the aerospace industry. The second alternative would have staff work for manufacturers for a specified period of time, such as 2 years. He also said that because FAA staff lack technical competence, short 1- to 3-day workshops or 1-week training courses by the agency will not provide the understanding or knowledge certification staff need.

Finally, another member stated that FAA's technical training program for certification staff is insufficiently funded. He stated that FAA's top management needs to understand that although the certification staff is

[1]Our discussions with these two NRSs confirmed the group member's statements.

relatively small in comparison to other groups of FAA employees—for instance, controllers—technical training for certification staff is important if they are to perform their responsibilities. He stated that FAA needs a technical training program specifically established for certification staff that includes specific annual training requirements for staff in their areas of responsibility. He observed that FAA currently spends too much money on training in human resource management which, though "nice to have," comes at the expense of training people to perform the agency's certification mission.

Other Issues Discussed but Not Covered in This Report

Members of the group also provided their views on several other topics related to aircraft certification. For example, one member stated that FAA's declining competence could lead to the development of inadequate regulations. Another member expressed concern about FAA's ability to understand manufacturers' new uses of computers to analyze and store intricate information critical to the certification process. Finally, two members suggested that the certification process for commuter aircraft may have problems similar to those of the process for transport aircraft.

Biographical Information on Advisory Group Members

Dr. James W. Mar is currently the Chairman of the Technical Oversight Group for Aging Aircraft, which reports directly to FAA's Associate Administrator for Certification and Regulation. Dr. Mar retired in 1990 from his position as Hunsaker Professor of Aerospace Education at the Massachusetts Institute of Technology (MIT). He became a member of the faculty in 1950 and was head of the Department of Aeronautics and Astronautics from 1981 to 1983. Before joining MIT, Dr. Mar served as head of the section of Curtis-Wright Corporation specializing in structural testing. From 1970 to 1972, Dr. Mar served as Chief Scientist of the Air Force, for which he was awarded the Decoration for Exceptional Civilian Service. He has served on several committees of the National Academy of Sciences, including, in 1980, the Committee on FAA Airworthiness Certification Procedures and, in 1991, the Committee for the Study of Air Passenger Service and Safety Since Deregulation. He is also an honorary fellow in the American Institute of Aeronautics and Astronautics and a member of the National Academy of Engineering.

Mr. Jonathan Howe is currently a partner in the law firm of Zuckert, Scoutt & Rasenberger. Mr. Howe serves on numerous advisory committees regarding aviation, including the Federal Research Engineering and Development Advisory Committee, Congressional Committee on Passenger Facility Charges, and Office of Technology Assessment's Advisory Council. He is also the Chairman of the Federal Research Engineering and Development Advisory Committee's Subcommittee on Aircraft Noise. Between 1991 and 1992, Mr. Howe was the Chairman of FAA's Aviation Rulemaking Advisory Committee. From 1986 to 1991, he was the President and Chief Executive Officer of the National Business Aircraft Association. Prior to this, Mr. Howe worked for FAA for 23 years, holding senior positions that included FAA's highest-ranking career attorney, Administrator of the Southern Region, and Deputy Regional Administrator for the Northwest Mountain Region. During this period, he oversaw all legal and regulatory aspects of FAA's certification program for Boeing's 747, 757, and 767 aircraft. In 1980, Mr. Howe received the Presidential Meritorious Service Award; in 1991, he received FAA's highest civilian award—the FAA Award for Extraordinary Service.

Dr. John L. McLucas is currently an aerospace consultant and a member of the FAA Administrator's Advisory Committee and the Comptroller General's Advisory Committee. Between 1988 and 1991, Dr. McLucas was the Chairman of the National Aeronautics and Space Administration Advisory Council. He served as the FAA Administrator between 1975 and 1977 and Secretary of the Air Force between 1973 and 1975. Prior to 1973,

he held many government and corporate positions, including Undersecretary of the Air Force, Assistant Secretary General of the North Atlantic Treaty Organization for Science, and President of Comsat World Systems, Inc. He also served as a member of the National Academy of Sciences' 1980 Committee on FAA Airworthiness Certification Procedures. He is an honorary fellow in the American Institute of Aeronautics and Astronautics and a member of the National Academy of Engineering.

Mr. Donald W. Madole is currently with the Washington, D.C., law firm of Speiser, Krause, Madole & Lear, which is active in aviation tort litigation. Mr. Madole was counsel for the plaintiffs in the trial arising from the 1989 accident at Sioux City, Iowa, involving United Airlines' Flight 232. He was the cochairman of the Plaintiffs' Trial Committee for the 1983 accident involving Korean Airlines' Flight 007 and lead counsel for the plaintiffs in the trial resulting from the 1982 crash of an Air Florida plane. Mr. Madole served on the National Academy of Sciences' 1980 Committee on FAA Airworthiness Certification Procedures. Prior to 1980, he served in several positions related to aviation, including trial attorney for FAA and a U.S. Delegate to the International Civil Aviation Organization. In 1966, he received the William A. Jump Memorial Foundation Award from the Civil Aeronautics Board for exemplary achievement in public administration. Mr. Madole was also a pilot for the U.S. Navy. He is now a fellow of the International Academy of Trial Lawyers and a member of the American Law Institute.

Mr. James J. Foody is currently the President of J.J. Foody & Associates, an aviation consulting firm in Washington, D.C. Between 1978 and 1984, Mr. Foody was Vice President for Product Development at Fairchild Industries, Inc. Between 1962 and 1978, he held various positions at the Boeing Company, including Assistant to Vice President for Research and Development; Director, Military Aircraft Product Development; Program Manager for the YC-14 military cargo aircraft; and Development Program Manager for the 747 aircraft. Between 1948 and 1962, Mr. Foody held various positions at Short Brothers & Harland, in Belfast, Northern Ireland. Most notably, he was the head of the Electrodynamics Department, responsible for the development of several airborne analogue and digital computer systems. Mr. Foody received a master's degree in aircraft design in 1950 from Cambridge University, in England.

Comments From the Department of Transportation

Note: GAO comments supplementing those in the report text appear at the end of this appendix.

U.S. Department of Transportation

Assistant Secretary for Administration

400 Seventh St., S.W.
Washington, D.C. 20590

July 16, 1993

Mr. Kenneth Mead
Director, Transportation Issues
U.S. General Accounting Office
441 G Street, NW
Washington, D.C. 20548

Dear Mr. Mead:

Enclosed are two copies of the Department of Transportation's comments concerning the U.S. General Accounting Office draft report entitled, "Aircraft Certification: New FAA Approach Needed to Meet Challenges of Advanced Technology," RCED-93-155.

Thank you for the opportunity to review this report. If you have any questions concerning our reply, please contact Martin Gertel on 366-5145.

Sincerely,

for Jon H. Seymour

Enclosures

DEPARTMENT OF TRANSPORTATION (DOT) REPLY

TO

GENERAL ACCOUNTING OFFICE (GAO) DRAFT REPORT

ON

AIRCRAFT CERTIFICATION:

"New FAA Approach Needed to Meet Challenges

of Advanced Technology"

RCED-93-155

SUMMARY OF GAO FINDINGS AND RECOMMENDATIONS

The GAO draft report maintains that the Federal Aviation Administration's (FAA) process for aircraft certification is not sufficiently structured to ensure effective FAA involvement. The draft report questions the significance of FAA's role in the certification process in light of: increased numbers of manufacturers' employees acting on behalf of the FAA as Designated Engineering Representatives (DER); increased delegation of approval authority to DERs for certain aspects of the certification process; and the availability of in-house technical training and expertise.

The GAO recommended that the Secretary direct the FAA Administrator to:

(1) Define a minimum effective role for FAA in the certification process by (a) identifying critical activities requiring the agency's involvement or oversight, (b) establishing guidance on the necessary level and quality of designated engineering representative oversight, and (c) developing measures through which staff members' performance and effectiveness can be evaluated.

(2) Formally examine the need to hire national resource specialists (NRS) in areas of technological advancement that have occurred over the last 14 years.

(3) Require early NRS involvement in the certification process and at other key junctures.

(4) Establish annual training requirements for each certification discipline and identify the training in new technologies available at universities, private industry, and other Government agencies.

SUMMARY OF THE DEPARTMENT OF TRANSPORTATION POSITION

See comment 1.

The Department maintains that FAA's role in aircraft certification is well structured and functions effectively. The FAA

substantially refined the Aircraft Certification Program in response to the 1980 National Academy of Sciences (NAS) report recommendations. In particular, FAA strengthened and centralized its management structure for the aircraft certification process, enhanced the FAA orders that guide the program, and implemented the NRS Program. The FAA's Aircraft Certification Service continuously monitors program effectiveness and presently has initiatives underway to improve program guidance, training, and staffing further.

See comment 2.

See comment 3.

While the Department and GAO share the goal of ensuring that FAA provides the most efficient and effective aircraft certification process in the world, the Department differs with several of the methods that the GAO draft report proposes to achieve this goal. In particular, we differ with the draft report's proposal to create rigid structures governing NRS involvement in certification projects and the provision of training to FAA's certification engineers. We maintain that the most effective means for achieving these goals is through the application of appropriate judgment through sound management practices and not by establishing rigid requirements without regard for the dynamics of the certification system or the true needs of the organization. While both methods may accomplish the objective, we maintain that the FAA's methodology will achieve the objective most efficiently and effectively and at lower cost to the taxpayers.

DETAILS OF THE DEPARTMENT OF TRANSPORTATION POSITION

The FAA Has Maintained Effective Control of the Certification Process

See comment 4.

The FAA has continuously maintained effective management control over the most critical aircraft certification decisions and approvals. Critical elements of the certification process are managed by FAA personnel to ensure appropriate control over the certification process. These include establishing the certification basis; establishing any special conditions, such as standards for any novel or unique features not addressed in the Federal Aviation Regulations (FAR); approving any equivalent level of safety findings; and approving manufacturer compliance plans and methods. In approving the manufacturer compliance plans, the FAA is able to plan strategically its involvement at key points in the process to maximize its staff members' impact while ensuring that appropriate duties are delegated to the DERs. In order to ensure that delegation of activities to DERs is accomplished appropriately, a number of checks and balances are built into existing FAA guidance. Appendix 1 and 2 of FAA Order 8110.37 and other formal FAA policies and procedures enumerate specific detailed requirements for the process and limitations applied to DERs. Together these actions ensure that the certification process is properly conducted in a manner which provides an appropriate role for all participants in the process with overall management control by the FAA.

The GAO draft report implies that since the 1980 report by the NAS, FAA delegated its critical approvals by allowing DERs to approve some test plans and failure analyses. As a result, the draft report concludes increased dependence on DERs has weakened the safeguards the Academy found in place in 1980. However, the functions identified by the GAO draft report do not fall within the parameter of critical approvals. In addition, the DER Handbook, FAA Order 8110.37, issued prior to the NAS report in 1979, listed delegated functions including approving failure analysis, individual test plans, and reliability analysis. Therefore, the draft report's criticism of these practices, which were in place prior to the NAS report, needs to be moderated.

FAA's Certification Management Structure was Strengthened in Response to NAS Recommendations

See comment 4.

Important FAA organizational changes since the NAS report have enhanced the structure and standardization of the type certification process. Prior to the NAS report, type certification responsibility was splintered among 10 regions and headquarters. Since that time, the FAA created four certification directorates to focus certification authority centrally. FAA Order 8000.51, Aircraft Certification Directorate, dated February 1, 1982, established the Aircraft Certification Directorates to perform technical policy management and project management for aircraft certification programs. These directorates were established to: provide consistent application of the airworthiness standards; establish single point type certificate accountability for specific product categories, such as transport and small airplanes, aircraft engines, and rotorcraft; and concentrate expertise accountable for technical and policy decisions. The directorates are responsible for (1) issuing all rules related to its area, (2) ensuring that rules are consistently applied in a standardized manner, and (3) applying the rules in new ways. Recently, FAA further centralized its management so that all four directorates and the headquarters divisions within the Aircraft Certification Service report to the same person. This has further standardized the four directorates.

See comment 4.

The policy staff within each directorate plays a key role in developing and standardizing regulations and policy, ensuring capabilities for dealing with new technologies, and monitoring specialist participation in certification projects. As new technologies evolve, the policy staff is instrumental in developing special conditions and, if necessary, issuing regulations and policy. The policy staff monitors certification projects and endeavors to ensure that specialists participate as necessary to help define a proper basis for the type certificate and work with the Aircraft Certification Office (ACO) performing the design evaluation to apply the airworthiness rules and procedures adequately and uniformly. In addition, policy staff personnel may participate in compliance determinations at their discretion.

See comment 5.

FAA's Aircraft Certification Process Is Highly Structured

The FAA has a highly structured approach to the certification process that is governed by requirements established in FAA orders. While the process may appear "ad hoc" to the uninitiated, type certifying a commercial aircraft is a highly complex technical undertaking which does not lend itself to a step-by-step cookie cutter approach. It requires the application of technical skills in a context with sufficient flexibility to contend with innovation and new ideas. At the beginning of each certification project, the FAA and the applicant have several meetings during which the FAA and the applicant's roles, including any designees, are specifically defined within the context of the requirements governing the certification process.

The type and extent of FAA involvement depends on the project, the technologies involved, and the qualification of the applicant and its designees. Since each project is unique, it would be inefficient and counterproductive to force artificially any specific, minimum level of FAA involvement for each and every project. Under the existing system there is a defined role for each participant in the certification process and the checks and balances built into the FAA orders and managed by the directorate system allow for effective oversight of the process.

The GAO draft report could benefit from explicitly recognizing the extensive guidance governing the aircraft type certification process, describing the checks and balances now in place, and explaining how FAA is working to refine the process. The guidance includes:

FAA Order 8100.5 - Aircraft Certification Directorate Procedures;

FAA Order 8110.4 - Type Certification Handbook;

FAA Order 8000.45 - Aircraft Certification National Resource Specialists; and

FAA Order 8110.37 - Designated Engineering Representative Guidance Handbook.

See comment 5.

These orders contain guidance that governs every aspect of the type certification program. Each order was issued or revised since the NAS report, or is presently being revised. While the draft report concluded that "FAA's ad hoc delegation of certification duties displays the weaknesses of this approach," we maintain that such statements result from an incomplete understanding of the process and its implementation. The delegation of certification duties is specifically provided for in the DER order. As extensive as this guidance presently is, the FAA is revising the order to ensure that it continues to

guide this complex and dynamic process effectively. The revised guidance will be even more comprehensive and will add a new section on DER qualification requirements.

The DER Program Functions Effectively

See comment 6.

The DER system has evolved over the last 42 years into an efficient and effective system which minimizes the burdens on taxpayers, directs system costs primarily to its users, and results in commercial aircraft of unrivaled safety. Based on accumulated experience over this period, we have concluded that the quality of data approvals processed by designees is at least the equal of data reviewed and approved by FAA certification engineers. Although the draft report identifies one accident in which one National Transportation Safety Board investigator criticized the level of FAA involvement in a certification process, we do not agree that the certification process was a substantial contributor to the accident. Even if the certification process was implicated, we do not agree that one event is sufficient to indict the integrity of the entire process.

To ensure that the FAA's aircraft certification program remains strong and effective, the FAA has been further refining its implementation of the DER program and applying management oversight. As previously described, the DER order has been revised and improved. Program implementation has been modified by increasing emphasis on new technologies and increasing the number of highly specialized DERs. Although new technologies have recently emerged, the vast majority of the increasing certification activity involves existing technologies. To

See comment 7.

ensure that adequate time and attention is given to the new technologies, FAA is delegating more of the routine administrative certification functions related to existing technologies. As a result, FAA can concentrate its resources so that its certification engineers are more in control of the overall certification process, including critical areas and new technologies. More DERs are being appointed because technology has become so specialized that each DER has a narrower field of

See comment 8.

applicability than before. Contrary to one of the GAO draft report findings, the increased number of DERs does not always increase FAA's oversight workload since the total amount of work by each DER has been reduced.

See comment 9.

To ensure that the program is operating effectively and efficiently FAA's management has consistently applied the total quality principles of continuous evaluation and improvement. In 1991, FAA conducted an extensive evaluation of the DER program which found that the system was functioning effectively and identified opportunities to refine and improve the program. In addition, we recently tasked an Aviation Rulemaking Advisory Committee to review the system of delegations and identify potential refinements.

The increasing use of designees is a worldwide trend with some foreign programs patterned after FAA's system. For example, nearly all findings for the United Kingdom's Civil Aviation Authority are made by organizations approved to act on its behalf. Similarly, the French aviation authority contracts out all of its manufacturing quality control responsibilities and much of its engineering resources. Transport Canada is also developing an engineering delegation system patterned on our DER system.

National Resource Specialist Program Requires Flexibility

See comment 2.

The NRS program has provided valuable expertise which has been effectively integrated into the certification process and the directorate system. As recognized in the GAO draft report, FAA previously took action to ensure that NRS staff was appropriately utilized. While FAA's Aircraft Certification Service is continuing to oversee NRS involvement in certification projects and make refinements as appropriate, we disagree with the GAO draft report on the need to specify the timing and type of NRS involvement rigidly.

Rigid requirements for specific approvals could create costly and counterproductive bottlenecks in certification projects. As the draft report recognizes, NRSs are in high demand and are overworked. Therefore, it is important that NRSs reserve their involvement as technical consultants to new and novel technology applications and areas where the ACO may not have the proper expertise. As a result, NRS involvement in the certification process varies from project to project and depends on the need of the particular ACO. In addition to their role as technical consultants on certification projects, NRSs are actively involved in developing policy or technical standards related to their areas of expertise. Several NRSs are working with teams of specialists from the directorates on projects involving new technology to provide on-the-job training. One such team is the Software Action Team (SWAT). This team has been very successful in developing the latest software guidance which the team members have taken back to field offices for implementation. The NRSs are also involved in developing qualification requirements for DERs and participating in the review and selection of DER applicants.

Flexibility is also needed to provide the ability to attract and retain competent engineers with specialized technical skills. Toward this end, in 1991 the FAA initiated efforts to create a viable technical career path for GS-13 journey-level engineers to progress through the GS-14 and, ultimately, to the GS-15 NRS positions. The Office of Personnel Management has completed its rewrite of the aerospace engineering classification standard which makes possible a properly formulated classification guide to establish the GS-14 link. This non-supervisory technical career path could help stem the high turnover rate that has

occurred over the last decade. In addition, the creation of GS-14 senior engineer positions, combined with the training initiatives described below, will significantly enhance the staff's competence over the next several years.

FAA Has Certification Training Initiatives Underway

See comment 3.

The FAA has efforts underway to ensure that its certification work force and DERs are afforded appropriate, high-quality training. The FAA systematically identified the training areas required for new certification engineers, experienced engineers, project managers, and regulatory specialists. These training subject areas are documented in training profiles for each engineering discipline, including structures, mechanical and environmental systems, propulsion installation, engine certification, and flight test. In addition, the FAA considers skill needs and their availability within available staff resources when allocating training. In this way training is predicated on individual and organizational need and not on an arbitrary number or annual requirement.

By considering individual needs and how they fit into our pool of available resources, FAA can carefully manage its limited training resources and apply them where they will be most useful. Certification engineers need to be knowledgeable in: (1) fundamental engineering principles; (2) FAR and FAA certification philosophy; (3) design concepts and how they relate to regulatory compliance; (4) evaluating major data submittals; and (5) managing designees. The training program must provide these basic skills to all of our engineers. The need for other highly technical skills required to perform specific certification functions will vary depending on project and customer demands. These specialized technical skills must be available in the work force as a whole, but are not necessary for every engineer. This is a concept we call true need. It matches the skill needs of each office to the customer base it must serve and then matches those needs with the skills possessed by the available work force.

In addition to formal training, the Aircraft Certification Service provides two or three workshops each year on specific technologies to provide specialists with briefings and a discussion forum on the latest state-of-the-art technologies. The workshops have a very high participation by NRSs and industry representatives. One such workshop is scheduled for July on computer software.

Since the 1980's, the FAA has also significantly expanded its efforts to keep DERs current in FAA's policy and procedures. We have recently developed a DER training course for this purpose. There is a quarterly designee newsletter sent out by each directorate to all designees they manage. This newsletter discusses national and directorate policy changes. We have also

instituted local DER conferences throughout the directorates to educate large and small groups of designees on policy and procedures changes.

RESPONSE TO GAO RECOMMENDATIONS

Recommendation: Define a minimum effective role for FAA in the certification process by (a) identifying critical activities requiring the agency's involvement or oversight, (b) establishing guidance on the necessary level and quality of designated engineering representative oversight, and (c) developing measures through which staff members' performance and effectiveness can be evaluated.

Response: Concur-in-part. The roles, guidance, and measurement definitions called for in this recommendation have all been established in FAA orders and requirements that currently exist, although some of these orders are being revised to be more comprehensive. However, as described in the above sections, we do not agree with the GAO draft report's proposed methodology of creating rigid requirements dictating the sequence and participants at each juncture of the certification process. Such rigidity could create expensive bottlenecks which ultimately hinder productivity and create inefficiencies. Rather, we prefer to continue to refine our framework for actions and depend on sound management practices to ensure appropriate and effective involvement in and oversight of the aircraft certification process. Although the process that presently exists is sound, the FAA is continually assessing its certification work functions, how they are accomplished, and how they could be revised to perform the FAA safety mission more effectively.

See comment 1.

Recommendation: Formally examine the need to hire national resource specialists (NRS) in areas of technological advancement that have occurred over the last 14 years.

Response: Concur-in-part. The FAA's Aircraft Certification Service through the Aircraft Certification Management Team (ACMT) periodically assesses NRS staffing levels and needs. This process, which involves top level FAA involvement as well as program management, has served effectively. Conducting a formal examination of the NRS staffing and needs would only add unnecessary costs. The FAA will continue to review the NRS program staffing and specialties to ensure that we do everything possible to match available resources with contemporary work requirements.

See comment 10.

Recommendation: Require early NRS involvement in the certification process and at other key junctures.

Response: Concur-in-part. We agree that NRSs should be involved in certification projects at appropriate junctures for them to achieve maximum productive input. The FAA has made substantial progress working toward that goal since the inception of the NRS

See comment 2.

program. While implementation may not have been optimal in every instance, the Aircraft Certification Service is continuing to monitor the program and make refinements as necessary. However, we do not agree that creating rigid requirements specifying the timing and type of participation will efficiently achieve the intended objectives. Creating specific rigid requirements for NRSs could create costly and counterproductive bottlenecks in certification projects, unnecessarily delay certifications, and increase costs without producing a discernable benefit to the customer or the flying public.

Recommendation: Establish annual training requirements for each certification discipline and identify the training in new technologies available at universities, private industry, and other Government agencies.

Response: Concur-in-part. While the FAA is endeavoring to provide necessary and appropriate training for its certification work force as described above, we cannot agree with establishing rigid annual training requirements. The FAA has identified training profiles based on an individual's certification role and the expertise available within the work force. In this way training is predicated on individual and organizational need and not on an arbitrary number or annual requirement. By considering individual needs and how they fit into the pool of available resources, FAA can carefully manage its limited training resources and apply them where they will be most useful. In addition, the FAA intends to continue its aggressive program to develop more certification training courses and is committed to making them available to all employees that have been identified as requiring them under the true need concept.

See comment 3.

The following are GAO's comments on the Department of Transportation's letter of July 16, 1993.

GAO's Comments

1. In response to our conclusion that FAA has little assurance that its staff are effectively involved in the certification process, DOT states that FAA staff are effectively involved. We found, however, that the diminishing, undefined role FAA has in the certification process has brought into question the value added by its activities and jeopardized its staff members' ability to understand new technologies. For example, FAA engineers delegated to Boeing the approval of the highly advanced flight management system for the 747-400 because they did not understand the system. FAA internal studies and our interviews with FAA staff and manufacturing representatives support our findings. An internal study in 1989, for instance, concluded that the amount of work delegated to designees had reached the maximum for properly managing the certification process and further delegation would reduce FAA's ability to understand the highly complex work being conducted by designees. Since 1989, however, the amount of delegation has increased.

To ensure that FAA staff add value to the certification process, we recommend that FAA identify critical activities requiring the agency's involvement or oversight and establish measures through which staff members' performance and effectiveness can be evaluated. Although agreeing that FAA needed to continually ensure the effective involvement of staff, DOT did not fully concur with our recommendation, saying it would establish "rigid requirements dictating the sequence and participants at each juncture of the certification process." However, our recommendation does not call for such requirements. Instead, we found that a need exists for basic guidance that describes the critical activities requiring FAA's involvement. We believe that such guidance must be more specific than the general guidance currently governing FAA's role in the process. However, we do not believe that such guidance needs to dictate the sequence and participants at each juncture of the certification process. Rather, the guidance should be specific enough to (1) ensure FAA's involvement in key activities in the process and (2) allow for the development of measures through which staff members' performance and effectiveness can be evaluated.

2. DOT—though agreeing that NRSs should be involved at appropriate junctures in the certification process—did not fully concur with our recommendation that FAA require NRSs' early involvement in the process

and at other key junctures. DOT states that we are recommending rigid requirements specifying the timing and type of NRSS' involvement, which will unnecessarily delay certifications. We are not recommending that FAA specify the type and timing of NRSS' involvement in every certification project. Rather, FAA should define general requirements that would ensure involvement by NRSS in key certification projects early enough to have their concerns resolved and assist in bringing staff up to speed on new technologies. For example, FAA could specify key certification projects as those involving new designs by Boeing or Airbus, requiring more involvement than much smaller, less complex projects. Currently, no requirements govern NRSS' involvement in the certification process. We believe that the lack of any requirements has limited the value that NRSS add to the process. We also believe that FAA can rectify this deficiency without establishing rigid requirements.

3. DOT states that FAA has efforts under way to ensure that its certification work force is adequately trained. DOT notes that FAA is systematically identifying a training profile for each engineering discipline and that FAA will allocate its limited training resources by identifying and meeting individual staff members' needs in relation to these profiles. Referring to this as a "true need concept," DOT maintains that training will be predicated on individual and organizational needs and the work load, rather than on an arbitrary number of courses or annual requirement.

We fully support FAA's initiative to improve certification training. However, FAA made a similar commitment to the Academy 13 years ago. Despite this commitment, a 1987 internal study and 1991 contracted study found that certification training was inadequate. We also found a lack of adequate certification training. For example, 11 of 12 FAA software engineers did not receive software-related training during fiscal years 1990, 1991, and 1992. According to FAA officials, such a lack of technical training limits the value FAA engineers can add to the certification process and makes the engineers more dependent on the manufacturers to provide on-the-job training. Such a dependence, according to these officials, may prevent effective oversight of the manufacturers. We believe that inadequate training has led to such situations as the FAA staff's delegating the certification activities for Boeing's highly advanced flight management system for the 747-400 because—as FAA's 1989 review found—staff "were not sufficiently familiar with the system to provide meaningful inputs to the testing requirements or to verify compliance with the regulatory standards."

To help ensure that FAA follows through on the current initiative, in our draft report we recommended that FAA establish annual requirements for each discipline. DOT maintains, however, that annual training requirements would be "rigid" and conflict with its "true need" approach. We acknowledge that annual requirements for all staff may be too rigid. However, we believe that FAA must establish specific requirements to ensure that staff receive the technical training needed to fulfill their certification mission. FAA's 1987 study made a similar recommendation. Specific requirements would ensure that some staff are not overlooked as FAA identifies its true needs. In light of the high turnover within the certification work force, FAA's current approach leaves the agency vulnerable: Staff who receive training could leave the agency, and other staff will not have received any training.

As a result of DOT's comments, we have revised our recommendation. We have deleted our reference to annual requirements and now recommend that FAA (1) establish specific training requirements for each discipline, (2) ensure that each staff member meets those requirements, and (3) keep the training provided as current as possible by identifying the training in new technology available at universities, private industry, and other government agencies. By taking these actions, FAA can ensure that staff receive the training needed to meet the challenges of advanced technology and fulfill their certification function.

4. In disagreeing with our conclusion that FAA has not adequately responded to the Academy's recommendation in 1980 that FAA develop a more structured role in the certification process, DOT states that FAA developed the directorate system to enhance the structure and standardization of the process. In the draft of this report provided DOT, we noted that FAA established the directorate system in response to the Academy's findings. However, our concern is not about FAA's overall directorate structure, but rather the direction and guidance FAA provides its certification engineers. Despite the creation of the directorates in 1982, FAA still relies on general guidance established in 1967. It is this same lack of specific guidance that the Academy criticized in 1980. According to the three committee members we interviewed, FAA's establishment of the directorate system was a first step in responding to the Academy's criticism. However, they emphasized that their primary concern was the lack of systematic, defined involvement by FAA engineers during the certification process—a concern, they noted, that FAA has not adequately addressed.

DOT states, however, that FAA orders define a well-structured role for FAA staff in the certification process. During our review, we examined FAA orders relating to the certification process, including those cited by DOT, and discussed the certification process with FAA staff. We note that the two primary orders governing the certification process—Order 8110.4 (Type Certification Handbook) and Order 8110.37 (DER Guidance Handbook)—existed when the Academy conducted its 1980 review and recommended a better defined approach by FAA. We also found these orders to be too general to ensure staff members' effective involvement in the certification process. For example, they require that staff review 5 percent of experienced designees' work and 33 to 50 percent of new designees' work, without specifying the areas that should be reviewed and the type of review to be performed in each area. Moreover, FAA and manufacturing officials stated that this standard is meaningless because FAA does not measure whether it is being met and because the standard, along with not specifying what should be reviewed, does not specify the level and quality of reviews.

In addition, DOT's contention that the FAA orders provide extensive guidance on the certification process appears to contradict the findings of FAA's own internal studies and comments by FAA officials. For example, FAA's 1989 internal review, which found that FAA's reliance on designees had reached uncomfortable levels in some areas and threatened FAA's ability to understand new technologies, recommended that FAA establish specific "monitoring requirements" for overseeing designees. Similarly, one document from an FAA region stated:

National guidelines and policies are provided by Order 8110.4. This information, however, is very broad and general; therefore, a need exists to define field office procedures and practices on major projects in more detail to ensure that all parties hold a common understanding on how the offices will work toward accomplishment of type certification.

Although we recognize that the FAA orders governing the certification process are currently being revised, an FAA official responsible for revising the DER Handbook told us that the revisions were not substantive and involved updating the orders for changes in the agency's organizational structure and terminology used in the aircraft design process. Finally, on two occasions, FAA's Aircraft Certification Service Director and Deputy Director told us that FAA needed to better define and measure an effective role for FAA staff in the certification process and stated that the agency was planning to initiate an effort to define such a role.

5. DOT states that our conclusion that FAA has delegated its certification duties with little meaningful guidance to its staff results from an incomplete understanding of the process. We believe that our review provided us with an accurate understanding of the certification process. We conducted extensive interviews with FAA officials, ACO engineers, and manufacturing representatives, as well as each NRS. We also reviewed FAA internal studies—many of which reached conclusions similar to ours.

Recognizing the technical nature of this area, we also assembled a group of individuals with distinguished aviation backgrounds to provide external, technical perspectives on the issues examined in our review. Among the group's members were Mr. Jonathan Howe and Dr. James Mar, who are well versed in FAA's certification process. Mr. Howe is the former chairman of FAA's Aviation Rulemaking Advisory Committee and had 23 years of service at FAA, including overseeing all legal and regulatory aspects of the agency's certification program for Boeing's 747, 757, and 767 aircraft. Dr. Mar is currently the Chairman of the Technical Oversight Group for Aging Aircraft, which reports directly to FAA's Associate Administrator for Certification and Regulation. Also, Dr. Mar and two other members of our group served on the National Academy of Sciences' committee in 1980.

6. DOT states that the DER system has been efficient and effective. We agree. Currently, the certification system results in safe aircraft designs largely because of the efforts and expertise of the manufacturers' designees. What is less clear, however, is whether the contributions of FAA staff materially add to this level of safety. Thus, our concern is not over the role the designees play, because they are the key to the entire process. Rather, we believe that FAA's approach and general guidance has greatly limited the value that FAA engineers add to that process. It is precisely to improve FAA's role—not that of the designees—that we are recommending that FAA identify critical activities requiring the agency's involvement or oversight, establish guidance on the necessary level and quality of the oversight of DERs, and develop measures through which staff members' performance and effectiveness can be evaluated.

7. DOT states that FAA is delegating to manufacturers more of the routine functions related to certifying existing technology so that its engineers can focus on critical areas and new technologies and control the process. We found that FAA now delegates as much as 95 percent of all certification activities to manufacturers. We also found that such delegation has occurred with little meaningful guidance to FAA staff, thus limiting their ability to add value to the process. For example, FAA delegated the

certification activities for the Boeing 747-400's flight management system, in part because staff could not provide meaningful opinions about the test requirements. In addition, DOT's assertion that FAA staff are able to control the process contradicts FAA's own 1989 internal review, which concluded that the amount of work delegated to DERs had reached the maximum for properly managing the process. We found that the level of delegation has continued to increase since that review as the number of DERs has increased over the last 3-1/2 years by an average of 90 per year, with only a minimal increase in FAA's certification resources.

8. DOT notes that in some cases, FAA's oversight work load does not increase because the total amount of work by each DER has been reduced as this work has become increasingly specialized. FAA's studies found, however, that the growing number of DERs has increased FAA's oversight workload over the last decade. For example, FAA's internal review in 1989 concluded that the disciplines responsible for such critical areas as the certification of computer-based systems had "uncomfortably high" ratios of DERs to FAA engineers.

9. DOT states that FAA conducted an extensive evaluation of the DER program in 1991 and found that the system was functioning effectively. In addition, DOT mentions that FAA recently tasked the Aviation Rulemaking Advisory Committee with reviewing the delegation system and identifying potential refinements. We agree that the delegation system has been effective and support FAA's efforts to improve it. However, we reiterate that we are not questioning the integrity or effectiveness of the delegation system but rather the value added by FAA's role in the process.

10. DOT states that FAA does not need to formally examine the need to hire experts in areas of technological advancement over the last 14 years because FAA periodically assesses the NRS Program. DOT notes that these assessments have "served effectively." As our report details, however, NRSs and FAA staff provided us examples in which FAA staff have fallen farther behind in some areas of expertise because the agency has not fully staffed the program. In addition, three members of the National Academy of Sciences' 1980 committee stated that the NRS Program has been an inadequate response to the Academy's call for greater competence by FAA in the certification process, in part because the program has been understaffed. In its response, DOT acknowledges that some NRSs are "in high demand and overworked." For these reasons, we are calling for the first formal assessment of the program since its inception 14 years ago.

DOT states that a formal examination of the NRS Program's staffing level would add unnecessary costs. We do not believe that a staffing study of a program that DOT states is being continuously monitored would be costly. In light of FAA's diminishing role in the certification process and staff members' difficulty in staying current with the latest technologies, we believe that such a staffing study would be a prudent public investment. It would provide both the Congress and the public greater assurance that FAA is targeting its limited resources to (1) improve staff members' competence in the areas of the latest technological advancement and (2) enhance the value NRSs and staff add to the certification process.

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