Institutional and Management Issues for Civil Aviation Research and Technology

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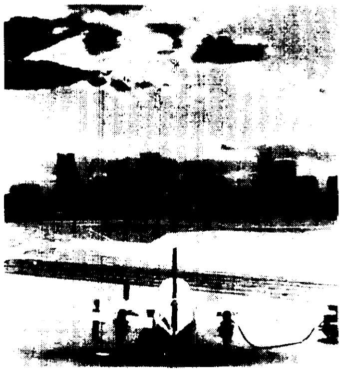
The federal government is involved in most aspects of a typical aircraft flight in the United States. The aircraft design, its flight and maintenance crew, and the public airport it operates out of must all be certified by the Federal Aviation Administration (FAA), under the U.S. Department of Transportation (DOT). On the infrastructure side, most of the pavement, lights, and navigation devices at the airport are financed with federal funds, and air traffic control (ATC) and airspace systems through which the aircraft flies are owned and operated by FAA.

The tremendous size of the air transportation system and its importance to the U.S. economy, the federal responsibility for ATC, and the lack of commercial market or profit potential for certain safety, environmental, and air traffic management research have propelled the federal government into the role of major provider of aviation research and development (R&D). Within the United States, only the federal government has the resources to support large-scale, applied R&D programs for aviation safety and infrastructure. This chapter describes the present organizational framework for aviation R&D and discusses management and technology issues of concern to Congress.



ORGANIZATIONAL FRAMEWORK

Federal involvement in aviation began shortly after the inception of powered flight. At the end of World War I, Congress created the National Advisory Committee for Aeronautics (NACA) as an advisory group for aviation research, thus intertwining the federal government's interest in aviation for military and civil purposes from early on.

Many organizations hold prominent roles in U.S. civil aviation, especially in the areas of policy, regulation, and research and technology. This section looks at the roles of FAA, the National Aeronautics and Space Administration (NASA), and other organizations in providing the technical underpinnings for civil aviation.

Federal Aviation Administration

FAA promotes safety and fosters air commerce in three key areas—safety regulation, infrastructure development, and ATC system operation—and in the research and technology development to support them. FAA's regulatory authority covers virtually every aspect of aviation, from airports and airways to aircraft and the people who work in and around them. The agency is responsible for the nation's ATC system, a complex amalgam of people and equipment that must run 24 hours a day, every day of the year, in numerous locations across the United States and its territories.

Aviation R&D important to FAA is primarily mission-oriented; its key purpose is problem solving rather than other policy purposes such as technical leadership, competitiveness, educating scientists, or national security. Much of the fundamental research and core technology development for aviation is conducted outside of FAA.

FAA's legislative mandate for R&D is found in sections 312 and 316 of the Federal Aviation Act of 1958.[1] The act directs the Administrator to make long-range plans for developing airspace and landing areas, airways, radar installations, and other systems. It empowers the Administrator to develop improvements for aircraft and engines; to develop systems, procedures, and facilities for safe and efficient navigation and ATC; and to protect against terrorism. Although the language is broad, it supports R&D related to ATC.[2]

The Federal Aviation Agency was created in 1958

FEDERAL AVIATION ADMINISTRATION

Congress passed the Aviation Safety Research Act of 1988[3]“. . . to add additional topics (structures, fire safety, human factors, and ATC computer simulation) to those on which FAA performs research. ”[4] Under the 1988 act, FAA must each year prepare an Aviation Research Plan. The act further required the FAA Civil Aeromedical Institute (CAMI) to conduct medical research, established an FAA Research Advisory Committee, and increased authorized funds.

The 1988 act also supported an expanded research program by directing FAA to create more “visibility and structure“ in its research. Another aim of the legislation was for FAA to develop expertise in each of the new research areas and to have a closer working relationship between FAA R&D staff and the portions of the agency that implement the results, Congress designated 15 percent of the FAA research, engineering, and development budget for long-term research and also

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[1] Public Law *85-726,* Aug. *23, 1958.*

[2] U.S. Congress, House of Representatives, *Aviation Safety Research Act of 1988, To Accompany H.R. 4686,* H. Rpt. 100-894 (Washington. DC: U.S. Government Printing Office, 1988), pp. 5-6.

[3] Public Law *100-591,* Nov. 3, 1988.

[4] House of Representatives, op. cit., fOotnote 2, p. 5.

emphasized closer coordination with NASA's research program.[5]

Some of FAA's R&D is conducted in-house, primarily at the Technical Center in New Jersey and at CAMI in Oklahoma City. (Organizations within FAA that fund or conduct scientific or technological R&D are highlighted in figure 2- 1.) FAA also does cooperative research with NASA, the Department of Defense (DOD), the Department of Commerce, and other federal agencies.

National Aeronautics and Space Administration

Although it is sometimes difficult to draw a precise line between NASA activities that support military aviation and those supporting the civil side, commercial aircraft manufacturing is one of the few industries for which the U.S. government routinely funds R&D. The traditional rationale for this support is that it compensates for the tendency of the manufacturers to do less than the "socially optimal" levels of research.[6] NASA is the key agency conducting aeronautical research, and has the third largest federal research budget, although most of that is for space-related activities. NASA aeronautical research and technology activities support both military and civil aviation.

Following a June 1993 reorganization, NASA has two offices as its focal points for aviation: the Office of Advanced Concepts and Technologies and the Office of Aeronautics. NASA's aeronautics research is almost all basic and applied. Although the Associate Administrator makes most decisions about the direction of the research, the process is relatively open. with ample opportunity for those outside NASA to comment.

In the early 1990s, NASA's aeronautics program had six key areas:

- subsonic transport, for technology directed toward U.S. commercial transport aircraft:
- high-speed transportation, to resolve critical environmental issues and lay the foundation for economical, supersonic air transportation:
- high-performance aircraft, oriented toward military applications;
- hypersonic and trans-atmospheric flight research;
- critical disciplines, with emphasis on basic sciences: and
- critical national facilities, to modernize and refurbish the NASA wind tunnels and other research facilities.[7]

The NASA laboratories use about 50 percent of the aeronautics R&D funds, another 30 percent *goes to contracts* with industry, and the remainder is designated for university research.[8] Each NASA lab maintains unique facilities and areas of staff expertise. The Ames Research Center, at Moffett Field. California, has special capabilities in computational fluid dynamics and computer applications, along with facilities for aerodynamic testing and flight simulations. NASA is recognized as a world leader in human factors research, and Ames is the key research center in this effort. NASA Ames also conducts research in areas such as ATC, flight dynamics, and guidance and digital controls.

Among the other NASA centers, the Dryden Flight Research Facility at Edwards Air Force Base, California, focuses on aeronautical research and flight testing. while the Lewis Research Cen-

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[5] Ibid,. pp. 15. 18

[6] In the case of aircraft manufacturers, the amount of money required to support some of the necessary research is so great that it is highly unlikely that an individual manufacturer would ever capture a return on its investment. U.S. Congress, Office of Technology Assessment, *Competing Economies America, Europe, and the Pacific Rim*, OTA-ITE-498 (Washington, DC. U.S. Government Printing Office. October 1991), p. 344.

[7] National Aeronautics and Space Administration, *Aeronautics and Space Report of the President: Fiscal Year 1991 Activities* (Washington, DC: 1992), p. 47.

[8] U.S. Congress, Office of Technology Assessment, *Federally Funded Research: Decisions for a Decade*, OTA-SET-490 (Washington, DC: U.S. Government Printing Office, May 1991), pp. 126-127.

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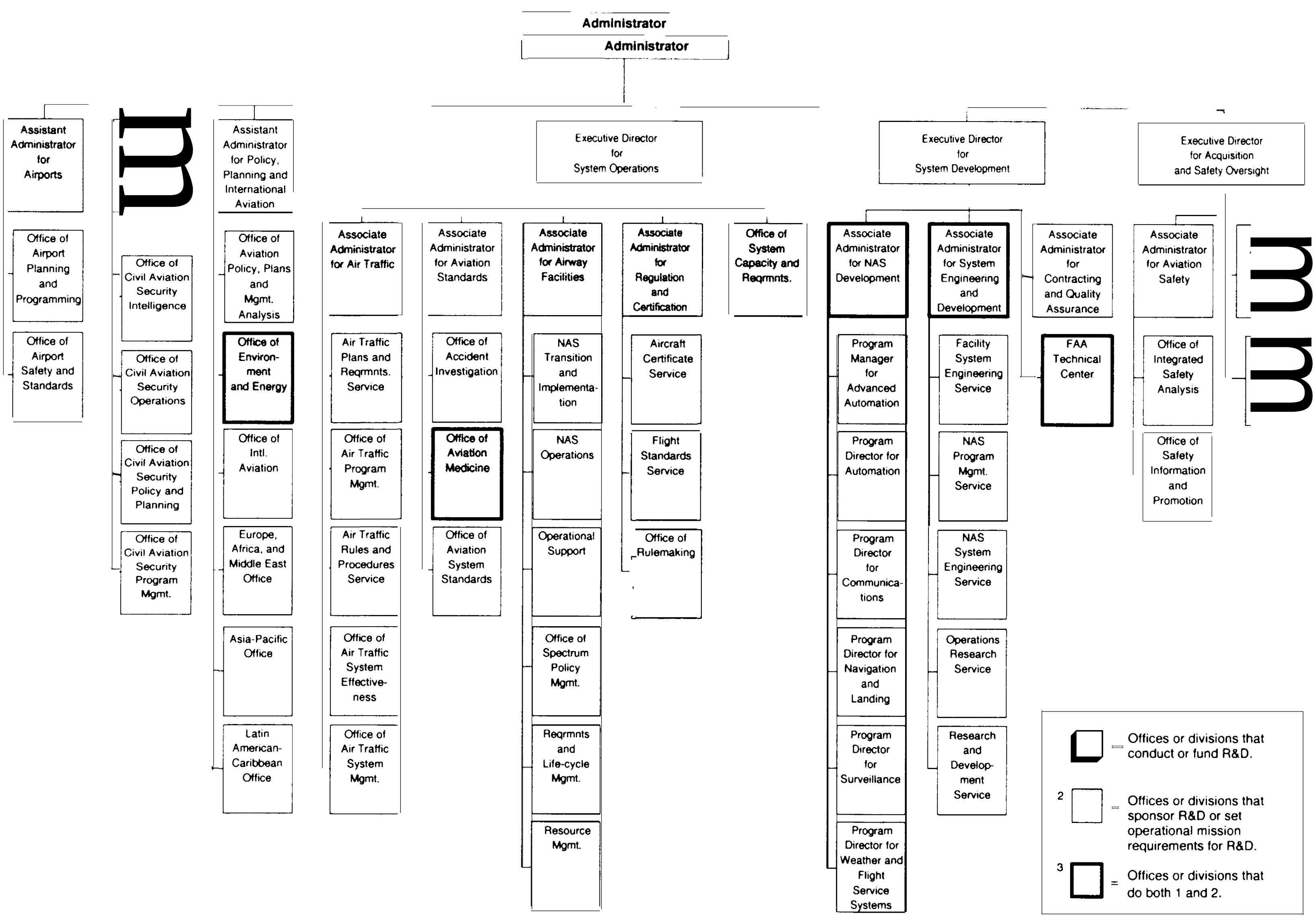
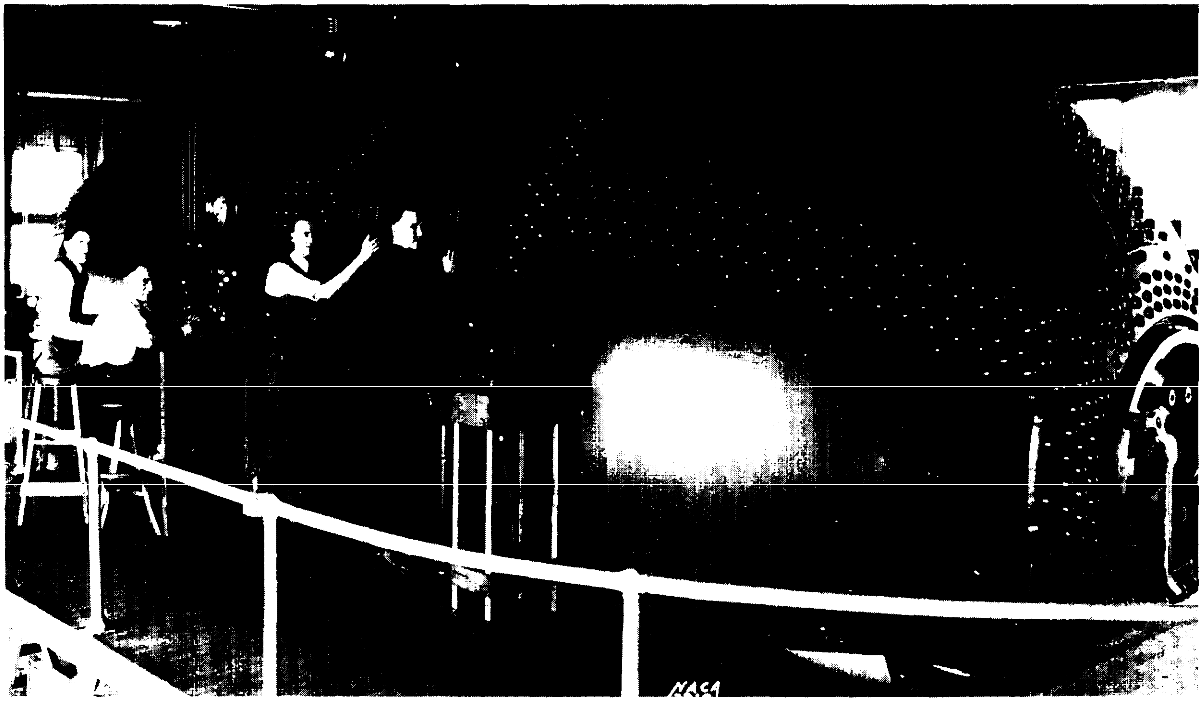


NOTE: Due to space limitations, FAA regional offices and administrative support sections have been omitted from ~s figure.

SOURCE: Office of Technology Assessment, 1994, based on Federal Aviation Administration information.



NATIONAL AERONAUTICS AND SPACE ADMINISTRATION

The National Advisory Committee for Aeronautics conducted aeronautics research for civil and military applications, as NASA does now

ter in Cleveland is a center for propulsion research. Finally, Langley Research Center, in Hampton, Virginia, has expertise in areas such as fundamental aerodynamics and fluid mechanics. computer science, unsteady aerodynamics, human factors, and aeroelasticity. Additional work at this NASA lab involves structures and material, flight control, windshear technologies, noise reduction, and simulations of advanced systems.

NASA labs conduct R&D of importance to FAA. Ames and Langley have worked with FAA on cockpit resource management, fatigue, information transfer. and ATC human-factors studies. Ames is the lead research facility for development of the Center-TRACON Automation System (CTAS, part of FAA's Terminal ATC Automation-or TATCA—system), which projects where aircraft are likely to go on final approach and creates an arrival plan for the controllers. Langley is the center for development of airborne windshear technology, which provides early warnings of hazardous windshear that may cross an aircraft's flight path.

State Authorities and Airport Operators

New air navigation technologies. environmental policies, and intermodal demands affect more than FAA research and technology decisions. Private companies, states, airport authorities, and other nonfederal organizations are now planning and installing air navigation and communication systems that could supplement, enhance, or replace existing or proposed federal ATC infrastructure (see box 2-1 for one example). Additionally, some airports are investigating and implementing technologies to address environmental and other challenges without FAA guidance or support.[9]

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[9] OTA survey of airport operators and state aviation authorities, conducted by Jeanne Olivier, Port Authority of New York and New Jersey, on detail to OTA, January-April 1993.

BOX 2-1: Virginia's Initiative for Pilot Weather Information Technology

In the absence of timely federal support, states themselves often fund and oversee aviation research and development projects. In 1993, Virginia funded an engineering effort to take advantage of new technology to improve weather service for general aviation and business pilots using Virginia airports While applying a new technology, the Virginia effort also relies heavily on the existing aviation weather communication Infrastructure.

Weather is a critical factor in flight operations. Of both air carrier and general aviation accidents between 1983 and 1987, 25 percent were due, at least in part, to weather conditions.[1] The Federal Aviation Administration provides weather briefings to pilots through its Flight Service Stations and its computerized Direct User Access Terminal Service as part of the National Airspace Data Interchange Network (NADIN) This information, Including wind speed and direction, precipitation, barometric pressure, and cloud height, comes from manned weather stations and Automated Weather Observation Systems (AWOS) located at airports across the country. It is accessible on the ground for preflight planning as well as en route for in-flight adjustments to flight plans,

Pilots find it particularly useful to have advance information on the weather conditions at the specific airport where they will be taking off or landing so that they may make adjustments to avoid hazardous weather patterns. For this reason, in addition to the weather stations at major commercial airports, FAA has installed automated weather observation stations at 170 air taxi and commuter airports and at general aviation airports that are considered important to the national air system. (FAA is in the process of installing 30 additional sites) Still, many small airports do not have onsite weather observation systems Pilots using these airports must rely on weather reports from neighboring airports or other observation stations for their flight judgments Due to the variability of weather, this reformation is less reliable than onsite reports To improve the weather service for their customers, some sponsors of small airports have independently installed AWOS at their airports after FAA declined to do so Ninety percent of the cost of Independent AWOS may come from Airport Improvement Program grants, for those airports that qualify FAA maintains only AWOS that it installs; the airport sponsor must maintain those systems that it installs Independently

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[1] National Transportation Safety Board, "Annual Review of Aircraft Accident Data U S Air Carrier Operations, Calendar Year 1988,"Apr 8, 1991, p 31 and National Transportation Safety Board, "Annual Review of Aircraft Accident Data U S General Aviation, Calendar Year 1988, " Mar 27, 1991, p 20

Airport operators note that federal aviation R&D focuses more on aircraft, ATC technology, and large airports, thus neglecting the interests of smaller airports. For example, noise reduction and capacity expansion research primarily benefits large airports, not general aviation airports, for which these issues are rarely problems. Large and small airports stand together in their position that there are not enough funds applied to airport research, but some state and local agencies have sought their own answers to pressing research and technology issues.

States generally do not have much money for research, although a number do fund and oversee testing and evaluation. For example, California funds several aviation research projects at the Air Transportation Research Center of the Institute of Transportation Studies (part of University of California, Berkeley). These include airport landside analysis for off-airport terminals, and the ap-

BOX 2-1: Virginia's Initiative for Pilot Weather Information Technology (Cont'd.)

Until Virginia's recent initiative few nonfederal AWOS have been linked to FAA's NADIN system due to financial and technological barriers[2] A pilot could get the information only by contacting the airport directly by phone or through a very-high-frequency radio broadcast accessible only in close proximity to the airport This access constraint limited the use of the data to local departure and landing approach aids and excluded pilots' use en route to these airports Those federal AWOS installations linked to NADIN are connected by telecommunication land lines at a monthly cost to FAA of $800 per AWOS[3] This high cost deterred FAA from assuming the expense for linkage of Independent AWOS to NADIN and similarly discouraged state aviation authorities from financing the connection

Working with a private contractor, the Virginia Department of Aviation has supported the development of a satellite-based linkage of AWOS to FAA's NADIN system, which obviates the need for expensive land line connections Virginia's contractor will use efficient communication bands of satellite technology to transmit weather data from 23 AWOS in Virginia to a collection point in Minnesota From this point the Information will be entered into NADIN for dissemination to FAA Flight Service Stations and the Direct User Access Terminal Service, FAA 604 service (venue for private vendors), and the National Weather Service Pilots nationwide will have access to weather Information for many of Virginia's general aviation airports and will be able to radio a flight service station en route to find out the weather at the airport where they will be landing, or any number of airports along their flight path The five-year cost for this system, including equipment, maintenance, and operation, is expected to be about $400,000 Officials of the Virginia Department of Aviation project that this will be one-third the cost of providing the same Information via land telephone lines

FAA is now looking into the Innovative work of Virginia in satellite linkage of AWOS and NADIN because of the dramatic operational cost advantages for its own AWOS data dissemination Other state aviation authorities have also expressed interest in providing this service

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[2] The stale of Minnesota provides land line linkage of some AWOS in that state to NADIN Due to the favorable cost of the satellite linkage demonstrated by Virginia Minnesota will soon convert these land line connections to satellite linkage

[3] Ken Krous Federal Aviation Administration personal communication Apr 7 1993

plication of artificial intelligence to airport ground transportation systems.[10] occasionally, locally funded or state-funded projects[11] address a problem that the local agency has had trouble drawing to FAA's attention; they may also aim to counter FAA standards that do not consider the unique physical constraints of certain airports.

For example, LaGuardia (New York) Airport's two runways each have one end that extends over water, and the other end of one runway terminates at a dike adjacent to Flushing Bay. Faced with an FAA requirement to extend the emergency overrun areas of runways to a length of 1,000 feet—and resistance from nearby communities to do

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[10] Ibid.

[11] What monies airports have for R&D usually come from state or airport revenues, not federal funds. (See box 2-1 again.)

this[12]*—the Port Authority of New York and New Jersey conducted independent research on passive in-ground arrestors that could safely stop an aircraft in a relatively short distance during an emergency.[13] If the in-ground arrestors are validated and become available, the Port Authority would likely put the arrestors at all four runway ends; the installation and maintenance would be much less costly than further extending overrun areas.[14]

Some states have universities with transportation research centers that conduct aviation research. These centers receive both state and federal funding and provide a useful supplement to the states' resources. An FAA initiative for pooling research resources with state agencies may become another way to expand available resources and to focus on projects important to state authorities.

For example, the "Minnesota Partnership" is an FAA experiment in cooperation on 10 research projects. Among these projects is an FAA study of pavement under cold region conditions using a Minnesota Department of Transportation test facility consisting of a 3-mile strip of instrumented pavement. However, there are usually administrative impediments to FAA's contracting out work to states. Principal among these impediments is the rigid federal procurement system for contract services.[15]

Airport operators often claim to have unmet research needs, but few can specify what these are. However, state aviation officials, industry analysts, and FAA managers concerned with airports maintain that this inability to articulate specifics does not belie the need; what may be necessary first is a mechanism for identifying research requirements. At issue, too, is the fact that airport managers claim to be restricted in their ability to share research conducted by consultants, even though the results might prove useful to other airports, obviating additional expense. States and airport authorities seldom share information about work that might benefit others. Of the several states conducting pavement research, for example, most are unaware of the projects of their counterparts.[16]

Public-Private Partnerships

The potentially increasing role of commercial communications in the air traffic system infrastructure makes public-private partnerships an attractive option for speeding technology development and implementation. Federal law permits and encourages agency participation in cooperative R&D agreements.[17] FAA has recently teamed with private industry to develop and test some commercial technologies for ATC functions. Examples include ATC pre-departure clearance delivery via the commercial ARINC Communications and Reporting System (ACARS) datalink and automatic dependent surveillance of oceanic flights by United Airlines through INMARSAT communciation links. Participants at an Office of Technology Assessment (OTA) workshop observed that such partnerships are most successful when the major customer for the technology is the

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[12] The Port Authority required approval from several city and state agencies in New York, along with FAA and the Army Corps of Engineers, to make changes to the runways. Perceiving that any extension of the landing and takeoff surfaces would lead to the use of larger planes and higher levels of activity at the airport, many communities actively opposed increasing the length of the overrun area. Steven Smolenski, Manager, Airport Facilities Division, LaGuardia Airport, Port Authority of New York and New Jersey, personal communication, July 20, 1994.

[13] The testing program evolved into a cooperative effort with FAA to further study foam-based arrestors at the FAA Technical Center.

[14] Smolenski, op. cit., footnote 12.

[15] Patricia Haynes, Federal Aviation Administration, persona] communication, Mar. 16, 1993.

[16] OTA survey of airport operators and state aviation authorities, op. cit., footnote 9.

[17] From 1980 t. 1989, Congress passed several major laws that directed federal agencies and the labs 10 transfer technologies to State and local governments and the private sector. See Office of Technology Assessment, *Defense Conversion: Redirecting R&D, OTA*- ITE-552 (Washington, DC: U.S. Government Printing Office, May 1993), p. 86.

private sector, not the federal government (and where both need the technology at the same time).[18]

In 1992, FAA announced support for a cost-shared, public-private partnership with the airline community. Its objective was to enable FAA to enter into a cooperative agreement with an industry consortium to develop, test, and build the first Aeronautical Telecommunications Network (ATN)[19] components, taking advantage of "good commercial contracting practices."[20] FAA's contributions would include contract resources, test facilities and aircraft, expedited avionics certification, and accelerated procedures and standards development.

By the summer of 1993, nine airlines had formally indicated their willingness to conduct the work and had tentatively elected to have the consortium assume a full corporate identity.[21] The Mitre Corporation will likely continue to have a significant role in supporting the efforts of the ATN Consortium;[22] DOD intends to participate in the project.[23] Remaining issues include speeding the certification of commercial off-the-shelf software and operational system software.

One development that has boosted government-industry cooperation is the increased use of cooperative research and development agreements (CRADAs). Designed to promote technology transfer, they allow federal labs and private companies to share R&D projects; the Clinton Administration would like to see the national labs devote up to 20 percent of their budgets to these partnerships. While facing resistance from some government scientists who, up until now, have considered commercialization of technology a low priority, managers at the national labs realize that the labs' very existence may depend on how useful they can be to the private sector. The Air Force has therefore participated in CRADAs that could ultimately benefit commercial aviation.

Like DOD, FAA is using CRADAs as a means to work more closely with industry. As of July 1993, FAA had 50 CRADAs in place, although with eight completed and 31 still in the administrative process, only 11 could be considered active. Almost one-half (22) of the total were in the area of aircraft and airport safety; security and air traffic control split another 20 CRADAs between them.[24]

International Civil Aviation Organization

The International Civil Aviation Organization (ICAO), founded in 1944 and now part of the United Nations, had 182 signatory nations as of November 1993. These nations have agreed to adopt minimum standards regarding aircraft, ATC, pilot qualifications, and other areas of civil

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[18] Remarks at OTA workshop, February 1993

[19] In 1990 the Mitre Corporation began a voluntary government-industry program known as the Aeronautical Telecommunications Network (ATN) Project, to build an initial version of ATN components. ATN is intended to support user-transparent data transfer between aircraft and ground systems using any combination of datalink media. Also participating in the ATN Project were FAA, vendors (IBM, Honeywell, Rockwell-Collins, and Teledyne), and air-ground communication network service providers, including ARINC, the Communications Satellite Corporation (COMSAT), and the International Society of Aeronautical Telecommunications (SITA). Due primarily to resource constraints, the project is no longer active and will be subsumed by the ATN Consortium. See Lillian Z. Ryals, The Mitre Corporation "Development and Implementation of the Aeronautical Telecommunication Network (ATN), briefing for OTA, Mar. 13, 1992.

[20] John Fearnsides, General Manager and Senior Vice President, The Mitre Corporation, personal communication, Apr. 21, 1994.

[21] Hal Ludwig, FAA Liaison to the ATN Consortium, personal Communication, Aug. 5, 1993.

[22] Ibid.

[23] Frank Colson, Executive Director, DOD Policy Board on Federal Aviation, personal communication, June 29, 1994.

[24] U.S. Department of Transportation, Federal Aviation Administration, *Report to Congress: Survey of Research, Engineering, and Development Research Facilities* (Washington, DC: July 1993), p. B-1.

aviation. The standards provide member nations with a baseline level of safety in international aviation operations.[25]

ICAO's authority on such topics as communication and navigation standards and air travel over the high seas is essentially absolute. For their respective territories, implementation is up to individual countries, which reserve the right to differ from ICAO standards. While the United States generally has no difficulty with compliance, other nations sometimes do.

ICAO has certain limitations. It lacks inspection capability and conducts no enforcement activities. Its standards tend to be the lowest common denominator, the result of many members trying to reach consensus. Although there has been some success, such as the significant progress made in determining the direction of air navigation development, ICAO can be slow to act. For example, despite pressure from industry groups eager to use the Global Positioning System (GPS) of satellite navigation, ICAO is powerless to establish an agency to oversee implementation of satellite communications, navigation, and surveillance systems.[26]

ICAO's ineffectiveness can have adverse effects on U.S. interests. For example, ICAO has worked since 1981 to establish guidelines for the use of the Traffic Alert and Collision Avoidance System (TCAS). So little progress has been made, however, that the panel chairman compared himself to "a rat on a treadmill," and speculated whether some ICAO members used the organization as a shield to avoid making decisions.[27] Meanwhile, the three companies that manufacture TCAS equipment—all of them American—wait for the impasse on this $350-mi lion market to break.[28] However, one expert believes that ICAO's ineffectiveness stems from poor leadership by the United States in ICAO forums.[29]

Although FAA, through the Department of Transportation, attends ICAO meetings, all official U.S. positions are cleared through the Interagency Group on International Aviation (IGIA), which includes the U.S. Departments of Transportation, Commerce, Defense, Labor, and State, as well as NASA, the National Transportation Safety Board (NTSB), and the Federal Communications Commission (FCC). IGIA must also be informed when FAA negotiates or amends bilateral airworthiness agreements .30

Bilateral airworthiness agreements exist in part because FAA does not regard all ICAO airworthiness standards to be adequate and therefore holds some imports of aeronautical products to higher standards. U.S. bilateral agreements predate ICAO; the first was negotiated with Canada in 1929. The United States and selected countries negotiate these agreements, which may facilitate export of aviation items or may obligate the parties to treat each other's civil aeronautical products as equally airworthy, provided they have been certified through acceptable methods by the home country's aviation authorities.[3]1 (Table 2-1 lists the countries with which the United States had bilateral airworthiness agreements in place in 1993.)

European Aviation Organizations

Despite the growing influence of the European Union (EU) and the European Free Trade Association (EFTA), European aviation organizations remain primarily advisory. But as European unity

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[25] George A. Berman, *Regulatory Cooperation With Counterpart Agencies Abroad: The FAA's Aircraft Certification Experience* (Washington, DC: Administrative Conference of the United States, 1992), p. 82.

[26] "IATA Fails To Persuade ICAO To Set Up Special Agency for GPS," *Aviation Daily*, vol. 312, No. 64, June 30, 1993, p. 503.

[27] Lisa Burgess, "TCAS Rules: The Devil Is in the Details," *Commercial Aviation News, vol. 1, No. 33,* Sept. 13, 1993, p. 4.

[28] Ibid.

[29] Robert Simpson, Massachusetts Institute of Technology, personal communication, June 23, 1994.

[30] Berman, op. cit., footnote 25, pp. 119-120.

[31] Ibid., pp. 87-88.

TABLE 2-1: Countries With Which the United States Has Bilateral Airworthiness Agreements

Joint Aviation Authority member countries	Non-Joint Aviation Authority countries
Austria	Argentina
Belgium	Austria
Denmark	Brazil
Finland	Canada
France	China
Germany	Czech Republic
Italy	Indonesia
Netherlands	Israel
Norway	Japan
Spain	New Zealand
Sweden	Poland
Switzerland	Romania
United Kingdom	Singapore
	Slovakia
	South Africa

SOURCE Federal Aviation Administration 1993

moves from concept to reality, a number of aviation organizations have taken on more prominent roles. (For membership of these groups and those discussed below, see figure 2-2,) The EU, for example, has a number of programs underway to determine specifications for common ATC equipment and facilities.

The Joint Airworthiness Authorities (JAA), established in 1970, is not a formal political body, although it could become the basis for a pan-European civil aviation authority. While largely driven by the demands of the EU and, to a lesser extent, EFTA, the organization does attempt to set common aviation standards for European nations. Like ICAO, however. JAA has no enforcement authority. J AA member nations jointly certificate air-craft. but the ICAO treaty and national laws require that national authorities remain responsible for actual certification in their own countries.[32]

One of the stated goals of JAA is to have Joint Airworthiness Regulations (JARs) that are similar to the FAA's Federal Aviation Regulations, although sometimes this involves JAA trying to persuade FAA to change. JAA and FAA hold joint policy meetings on a regular basis and working group sessions as needed.[33] JARs developed thus far cover certification of aircraft design and production; pending JARs will deal with maintenance, repair, and overhaul activities.

The European Civil Aviation Conference (ECAC), which has 31 member countries, was founded in 1955 to review the development of European air policies and promote coordination. Like the other international organizations, ECAC is a consultative body; political power rests with transport ministers of member nations. ECAC's ability to speak through the Ministers of Transport gives it some of the effectiveness that other groups seem to lack. It now also represents nations beyond Western Europe.

Eurocontrol, an air traffic management organization founded in 1960, aims to provide air traffic services for 15 European nations (see figure 2-2 again). Eurocontrol faces the massive task of harmonizing and integrating 31 different European ATC systems, most of which are incompatible with each other. This task is complicated by sovereignty issues.

With ECAC member nations likely to spend more than $3 billion on new ATC equipment by the end of the century, it is possible that some new systems could meet Eurocontrol specifications, or at least help speed the integration process. For Eurocontrol, this would be a strong and long overdue step. However, Eurocontrol's objectives cannot be met until there is continuous radar coverage across Europe.[34] There are areas of Europe where aircraft separations from 5 to 20 nautical miles are currently applied due to varying radar coverage.

Eurocontrol undertook a study of the ATC systems of the 23 nations that were ECAC members

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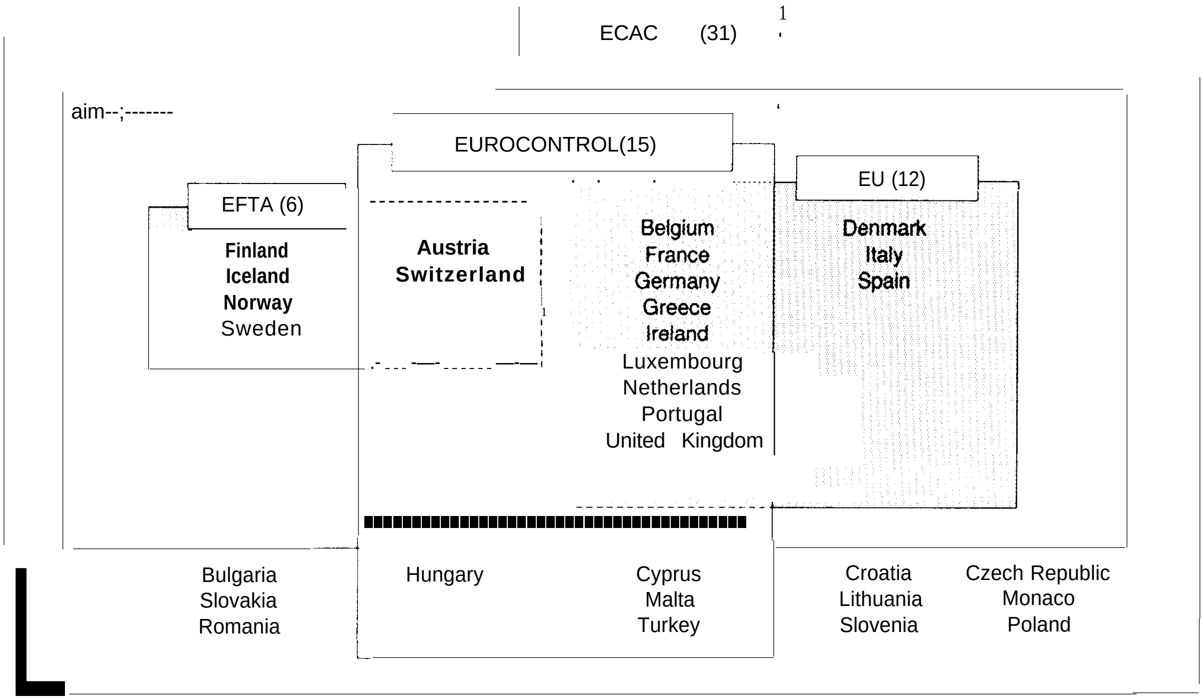
[32] Ibid., pp. 100102. In October 1993, FAA and JAA conducted the first simultaneous U.S. and European certification of a jet transport, the Airbus A330. "News Breaks," *Aviation Week & Space Technology*, vol. 139, No. 17, Oct. 25, 1993. p.17.

[33] Berman, op. cit., footnote 25, p. I 07.

[34] Chris Yates, "Eurocontrol Comes of Age," *June's Airport Review*, vol. *4, No. 3,* April 1992, p. 42.

FIGURE 2-2: Membership of Selected European Organizations With Responsibility for Aviation



KEY ECAC = European Civil Aviation Conference JAA = Joint Aviation Authorities; EU = European Union, EFTA= European Free Trade Association, EUROCONTROL = European Organization for the Safety of Air Navigation

SOURCE Federal Aviation Administration and *Interavia Aerospace World, 1993*

in 1988, as part of the European Air Traffic Control Harmonisation and Integration Programme (EATCHIP). The goal of EATCHIP is to make the different national systems work together so well as to be virtually transparent to pilots.[35] Its focus is primarily on en route airspace. The United States and Canada have observer status for EATCHIP and the Airport./Air Traffic Systems Interface. Another Eurocontrol project, the ATC Radar Tracker and Server program, has the goal of harmonizing data from multiple radar systems.

INTERAGENCY COORDINATION ON AVIATION R&D

The budget deficit and defense conversion are among the factors that have led to increased congressional interest in cooperation among federal agencies conducting aviation R&D. The primary advantages of interagency R&D programs include economies of scale, elimination of redundant efforts, and more rapid technology development and deployment. Such programs should reflect one or more of these benefits, as cooperation con-

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[35] Brooks Tigner, "Two Plans, One Goal: Align Europe's ATC," *Commercial Aviation News*, July 12-18, 1993, p. 10.

ducted for its own sake is seldom enough to justify the time and resources involved. And some agencies can benefit from access to the expertise of the in-house staff of other federal entities and also to the private sector research firms that work with those entities.[36]

Congressional actions affect the interests of cooperative research. When Congress passed the Aviation Safety Act of 1988 and the Catastrophic Failure Prevention Research Program,[37] both recognized that FAA's level of in-house expertise might be less than optimal, and so encouraged work with NASA, DOD, and other sources by providing enabling authority. By contrast, when Congress directs money for specific projects to specific institutions, problems may result from the recipient's lack of understanding of aviation needs. For example, one Federally Funded Research and Development Corporation (FFRDC) directed to address aviation security problems applied nuclear plant security systems without fully accounting for the dynamic needs of airports.[38]

Interagency Coordination at FAA Today

Coordination among federal agencies occurs at two levels: the agency program level and the researcher level. Agency advisory committees often promote agency-level coordination; coordination at the researcher level occurs through meetings and other activities.[39] And, as one FAA manager pointed out, when scientists learn of a project in their area, they often contact the funding source on their own. As he put it: "Resources draw others to the doorstep. others who want a piece of the funding and the action and who try to get involved."[40] The number of FAA interagency agreements for R&D grew rapidly in the late 1980s (see figure 2-3).

In 1991, the FAA Research. Engineering, and Development (RE&D) Committee advised that innovative and cooperative research be emphasized throughout the entire FAA RE&D Plan. A 1992 General Accounting Office report also recommended cooperative programs, with special emphasis on NASA and DOD in-house capabilities as a cost-effective alternative to private contractors and FFRDCs.[41]

Some of FAA's long-term research needs, such as human factors. are common to many other federal agencies. FAA conducts little basic or fundamental scientific research; its efforts are mostly systems development and engineering. However, there are substantial federal research efforts under way in areas important to aviation operations. For example, defense programs have been the source of many fundamental technologies for civil aviation—radar, computers, datalink, and satellite-based navigation, to name a few. Moreover, for aviation environmental and security issues, FAA must depend on other agencies research and data to characterize and assess risks.

Two examples of cooperative R&D efforts for aviation are aging aircraft and weather research. In the National Aging Aircraft Research Program, FAA's long-term goal of developing a corrosion-control management plan for aircraft is being met with the help of other government agencies, industry, and academia. One organization involved in this program is the Center for Aviation Systems Reliability, a consortium of institutions based at Iowa State University, which is charged with studying several aspects of corrosion control and re-

[36] Gellman Research Associates, "Cooperation and Coordination in Federal Aviation Research," OTA contractor report. Dec. 30, 1992, pp. 1-2.

[37] Public Law 101-508, section 9208, Nov. 5, 1990.

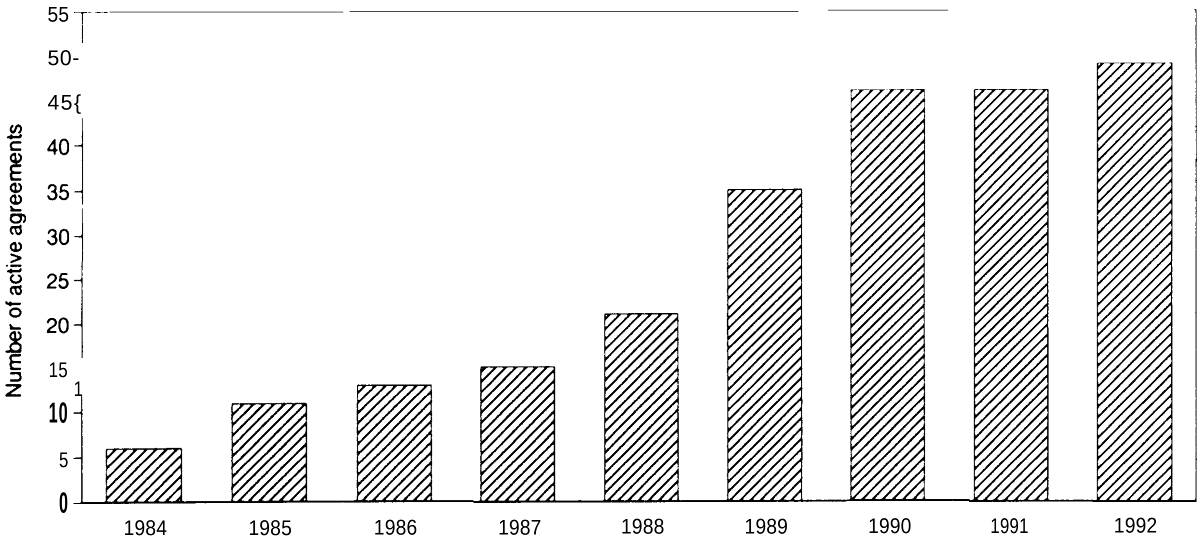
[38] Gellman Research Associates, op. cit., footnote 36. pp. 30-31.

[39] Office of Technology Assessment, op. cit., footnote 8, p. 117.

[40] Ken Byram, Research and Development Service, Federal Aviation Administration, personal communication, Apr. 9, 1992.

[41] However, both NASA and DOD rely heavily on contracts for R&D. Gellman Research Associates, op. cit., footnote 36, pp. 5-6.

FIGURE 2-3: Active FAA R&D Interagency Agreements, 1984-92



SOURCE Off Ice of Technology Assessment, 1994, based on Federal Aviation Administration data

lated human factors for maintenance and inspection. Another aging aircraft consortium is centered at DOE's Sandia National Laboratory; participants include the DOD's Naval Air Warfare Center, Air Force Flight Dynamics Laboratory and Wright Laboratory, NASA, the United Kingdom and Netherlands Civil Aviation Authorities, and various industry groups.[42]

Similarly, weather research involves multiple agencies. While the Terminal Doppler Weather Radar project is a well-run cooperative program, communication in the Automated Weather Observing System program has been spotty at best.[43] The differing needs of the participants in weather research may result in a fuzzy focus and difficulty in establishing common ground. Sometimes, too, the large number of participants-up to 13 in some cases—makes coordination an issue in itself.

FAA and NASA

Among its R&D relationships with other federal agencies, FAA's ties are strongest to NASA. Although NASA and FAA have worked together since their inception in 1958, it was not until 1990 that FAA and NASA Administrators took personal and administrative actions to bolster the ties between the two agencies. The agencies now coordinate aviation research programs and planning through a joint committee, and have established six Memoranda of Understanding (MOU) in areas of mutual interest—ATC-cockpit integration, human factors, severe weather, airworthiness, environmental issues, and "program support."[44]

FAA has field offices at NASA's Ames and Langley Research Centers to monitor joint programs and to provide FAA with a close look at NASA's aeronautics work. This cooperation al-

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[42] 1 bid., pp. 15-19.

[43] 1 bid., pp. 23-24.

[44] U S Department of Transportation, Federal Aviation Administration, *The Federal Aviation Administration Plan for Research, Engineering and Development—1994: Final Draft* (Washington, DC: September 1993), p. A-3.

lows a thorough understanding of mutual interests, reduces duplication of effort, and helps conserve scarce resources.[45] Typically, FAA identifies its needs and NASA determines the feasibility of providing the necessary support. Field office projects have dealt with such areas as simulation capabilities, human factors, windshear, microwave landing systems, and GPS.[46]

FAA and NASA also have a Joint University Program for air transportation research, in which university research supports national airspace system activities. FAA and NASA Langley Research Center sponsor annual grants to the Massachusetts Institute of Technology, Ohio State University, and Princeton University to work on topics suggested by the two agencies and related to their long-term needs.[47]

Joint FAA/NASA research and development activities typically occur under MOUs, Memoranda of Agreement (MOA), and Interagency Agreements for the Transfer of Funds (IAA/TOF). An MOU defines a broad area of interest between two or more federal agencies. These are usually arranged at high levels, with approval of both Administrators. NASA supplies most of the research personnel and facility support and contributes about $40 million beyond what is explicitly counted in interagency fund transfers.[48] Within MOUs, MOAs specify actual R&D activities to be undertaken and the resources to be committed by both agencies. MOAs are in effect for five years[49] and can be planned at lower managerial levels within the two agencies. Finally, the IAA/TOF is the budget transfer to NASA; it functions like a contract.[50]

Some tension exists between FAA and NASA regarding the financing of cooperative programs. FAA's contributions are explicit, for they require a transfer of funds. NASA, however, provides facilities and other institutional capabilities that are not delineated by a specified dollar amount. As a result of this technically unacknowledged contribution, NASA might be somewhat less enthusiastic than desired in pursuing cooperative ventures with FAA. More accurate accounting procedures that consider NASA's true costs might encourage NASA to pursue additional cooperative ventures.[51]

A potential handicap for FAA/NASA joint research is budget review. Different divisions of the Office of Management and Budget review the FAA and NASA budgets, leading to possible difficulties in pushing through joint projects. Similarly, separate congressional committees approve funding for FAA and NASA. This, too, can impede joint research. Similar situations exist for joint aviation research with DOD.

FAA and Defense Laboratories

FAA has made efforts to involve the national laboratories in aviation R&D programs within their areas of expertise. Many of these facilities, especially the Air Force labs, have capabilities of direct relevance to FAA. For example, the effect of high-intensity radiation on aircraft electronics is a certification issue for FAA, and is an area where DOD has expertise and research and test capabilities. R&D conducted for DOD's diverse aircraft inventory, such as the use of composite materials for aircraft primary structures, has applications in

[45] Ibid.

[46] Gellman Research Associates, op. cit., footnote 36, p. 28.

[47] Federal Aviation Administration, Op. cit., footnote 44, p. A-2.

[48] Gellman Research Associates, op. cit., footnote 36, p. 30.

[49] Extensions are possible.

[50] Gellman Research Associates, op. cit., footnote 36, p. 25.

[51] Ibid., p. 29.

civil aviation. Although some basic technologies can be applied in both civilian and military projects, most high-performance systems produced to meet military needs are not relevant to civilian aviation.

Military R&D has had a positive effect on the U.S. commercial aviation industry. There have been a few cases of entire systems developed for the military becoming integral to commercial application, reducing R&D costs. Military development programs often assume the risks of proving advanced technologies, and this has helped the U.S. commercial aircraft industry to achieve its current prominence. However, the increasing divergence in the interests of military and civil aviation applications means that such advantages will occur less frequently.[52] Meanwhile, civilian applications of new technologies are of growing importance to the military, because some commercial products can be five or more years ahead of military development.[53] The current DOD industrial base policy calls for more DOD reliance on the civil sector, especially in areas of rapidly changing technology and a large civilian demand base, such as avionics and communications.[54]

FAA has had long-term cooperative programs with two DOD laboratories under the Army Corps of Engineers: the Cold Regions Research and Engineering Laboratory (CRREL) in Hanover, New Hampshire; and the Construction Engineering Research Laboratory (CERL) in Urbana, Illinois. CRREL, as its name indicates, concentrates on the cold weather-related problems such as stresses on pavement and metals, as well as ice-related problems. CERL emphasizes environmentally benign construction quality and energy efficiency. Included among its programs are projects on nondestructive testing, corrosion prevention, materials, and information systems.[55]

Unlike NASA, the DOE and DOD national labs thus far do not have funds of their own to put toward FAA research projects.[56] While NASA can provide additional facilities and staff to an FAA project, the DOD and DOE labs can contribute only what FAA is willing to pay for. From the perspective of FAA and airspace users, limited FAA research dollars for cooperative programs might be stretched the most through joint efforts with NASA.[57] However, a broad, multiagency view should not be ignored. The DOD/Air Force facilities have extensive backgrounds in military aviation R&D. Whether this can be applied effectively to civil aviation R&D is open to question, but it bears investigation. FAA had agreements with 36 government labs (including NASA's) as of July 1993. The total dollar commitment exceeded $56 million, the largest single agreement being over $16 million with DOD's Lincoln Labs for ATC research (see table 2-2).

Barriers to Coordination

Although OTA has found that many cooperative activities are taking place, there are some funding and bureaucratic constraints that may prevent successful coordination. These constraints include administrative requirements and conflicting agency roles and responsibilities, as well as the

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[52] Office of Technology Assessment, op. cit., footnote 6, p. 345.

[53] U.S. Congress, Office of Technology Assessment, *The Defense Technology Base: Introduction and Overview—A Special Report,* OTA-ISC-374 (Washington, DC: U.S. Government Printing Office, March 1988), p. 42.

[54] Colson, op. cit., footnote 23.

[55] U.S. Congress, Office of Technology Assessment, *Delivering the Goods: Public Works Technologies, Management, and Financing,* OTA-SET-477 (Washington, DC: U.S. Government Printing Office, April 1991), p. 215.

[56] This could change as the roles and operating modes of the national labs will likely adapt to accommodate the R&D needs Of America post-Cold War. Office of Technology Assessment, op. cit., footnote 17, p. 39.

[57] Gellman Research Associates, op. cit., footnote 36, p. 26. There is also the difficult-to-quantify benefit of NASA's greater experience with FAA R&D projects.

TABLE 2-2: Federal Aviation Administration Research Agreements With Other Federal Facilities

FAA research area	Number of federal facilities with FAA agreements DOD	NASA	DOE	Other[a]	Total by research area
Aviation security	7	0	3	1	11
Aircraft safety	8	2	2	0	12
Air traffic control	2	2	1	5	10
Airports	3	0	0	0	3
Total by facility	20	4	6	6	36
FAA funding commitment ($ millions)	$250	$74	$84	$156	$563

[a] Primarily weather research

NOTE Dollar totals may be different than sums due to rounding

KEY DOD - Department of Defense DOE = Department of Energy NASA = National Aeronautics and Space Administration

SOURCE Off Ice of Technology Assessment 1994 based on Federal Aviation Administration Report to Congress (pursuant to Public Law 102-388) July 1993 p 3 and app C

budget approval process and funding issues discussed earlier.

During the course of this study, OTA heard from many members of the aviation community familiar with civilian aviation R&D who generally gave NASA high marks for interagency communication, including its various efforts with FAA. Some have noted, however. that while the FAA/NASA Coordinating Committee and other mechanisms might be the right methods for ensuring interagency coordination, they are not working as well as they should.

One former government manager felt that while coordination was good at the staff level, it was generally inadequate for policy and planning. He blamed this on what he saw as a fundamental incompatibility between FAA and NASA: NASA prefers to look at the development of new aeronautical technologies, while FAA gives more attention to the actual implementation of systems using new or existing technologies.

Better interagency coordination and cooperation for aviation R&D is more than a NASA/FAA issue. While DOD helped FAA and NASA develop the National Plan for Aviation Human Factors, and FAA and NASA human factors programs are coordinated and linked to the National Plan, there is no formal agreement between FAA and DOD. However, closer involvement by DOD could be beneficial to civil aviation. FAA has established cooperative agreements with DOD laboratories. For example, Wright Laboratory is performing aircraft-hardening R&D in support of FAA's security program.

Furthermore, current FAA cooperative agreements do not adequately allow for basic research and independent R&D. A small pool of unallocated funds might help foster creativity and innovation within broader R&D objectives, although such funds are the most vulnerable to budget cuts.[58] An attempt to address this need is found in FAA's Innovation Development and Engineering Applications program, which ".. . will provide the FAA with a formal structure to ensure that novel ideas for innovative RE&D projects .,. will be evaluated and, if feasible, sponsored. "[59]

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[58] Ibid., p. 31.

[59] Federal Aviation Administration, op. cit., footnote 44, p. A-7

Another issue is related to the overlap between some agency roles and responsibilities. For example, the Environmental Protection Agency (EPA) and FAA have shared responsibility for establishing aircraft noise standards, although aircraft noise is currently under FAA's domain.[60] But EPA has sole authority over other environmental issues that increasingly affect aviation and the air transportation industry, and explicit guidance for cooperation between the two agencies on these issues has not been provided.

The current basis for regulating upper atmospheric (i.e., stratospheric) pollution by aircraft is in international treaty, and EPA has authority to regulate materials and activities that contribute to the depletion of the ozone layer.[61] These include halons, used extensively in aviation for fire suppression. In addition, EPA sets standards for polluted stormwater runoff, engine emissions, and other sources of ground-level environmental problems. FAA, on the other hand, is charged with developing guidance for airport operators for facilities design and maintenance practices, imposing engine certification and aircraft equipment requirements, and regulating aircraft operations. This division of regulatory responsibility leaves open the possibility of ambiguity and even conflict over aviation environmental issues. Furthermore, neither agency conducts much related research. NASA conducts the lion's share of aviation environmental R&D, although the majority of this is focused on global atmospheric questions.

Finally, there is the possibility of competition between NASA and the national labs for FAA R&D funds. This may become acute as the national labs strive to demonstrate their versatility by moving beyond defense projects.[62]

TECHNOLOGY DEVELOPMENT AND IMPLEMENTATION FOR ATC

The following section focuses on ATC system development difficulties, an area where institutional and management issues are crucial. (ATC technologies are addressed in more detail in chapter 4.)

FAA-managed ATC projects often move slowly—to go from concept to operation can take 15 years or longer. As a result, Congress hears perennial calls to boost FAA R&D spending and make the agency more independent of federal personnel and procurement rules. Most recently, the Clinton Administration's "National Performance Review" and "Air Traffic Control Corporation Study," as well as the National Commission To Ensure a Strong and Competitive Airline Industry (known as the Airline Commission) have pro-

FEDERAL AVIATION ADMINISTRATION

For ATC, operational procedures and technologies have always been closely linked

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[60] FAA's statutory authority on noise issues is discussed in chapter 3.

[61] See section 604 of the Clean Air Act Amendments of 1990, Public Law No. *101-549.*

[62] Gellman Research *Associates,* op. cit., footnote 36, p. 32.

posed reorganizing FAA in order to improve ATC operations, finances, and modernization efforts.[63]

The combination of extreme safety requirements, continuous operations, large scale, and complexity make the ATC system unlike any other technological system (see box 2-2 and chapter 4, box 4-3). ATC technology is not just equipment, but operating standards and procedures—the rules of the game, so to speak. And both parts of the system must be developed in concert. More so than in other fields, it is necessary to know clearly what the equipment is supposed to do before building it. However, that is not what has been done.

While more technology R&D and easier procurement could help, major improvements will require fundamental changes in the system development process at FAA. Operational and procedural issues for ATC, not basic technologies, most often have been the critical hurdles to timely system implementation. ATC technologies frequently reach an advanced stage of development before those who are to install or use them discover that what was developed is not what was needed.

Better systems engineering could help, and FAA has strengthened its systems engineering capabilities in recent years. **However, aviation systems engineering must be more than making technologies work together.** It must get people, organizations, procedures, and technologies to work together. Unless this happens, improvements to safety. efficiency, and airspace capacity will continue to be prolonged.

I Problems in System Development and Acquisition

Examples of FAA's slow implementation of aviation technology abound and are often mentioned in analyses of U.S. civil aviation. Most prominent is the National Airspace System plan, a multibillion dollar program to update FAA's ATC technology, whose elements have drastically fallen behind schedule. Similar situations prevail for software, weather, and radar systems, and other products that FAA must acquire and activate. Frustration with the habitual delays extends to all corners; even the most enthusiastic air traffic controller interviewed for this report lamented that for once he would like to use equipment that was state-of-the-art instead of two or three generations behind.

At the core of this problem is that FAA has set technical requirements for systems without adequately studying and developing operational procedures the systems are to support. In many cases. operational problems have remained undetected until after a prototype ATC system has been completed and procurement is imminent or under way. For example, FAA committed to the development and production of the Advanced Automation System (AAS) before fundamental operational issues

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[63] National Performance Review, *From Red Tape to Results: Creating a Government That Works Better & Costs Less* (Washington, DC: Office of the Vice President, September 1993); U.S. Department of Transportation, *Air Traffic Control Corporation Study: Report of the Executive Oversight Committee to the Secretary of Transportation* (Washington. DC, May 1994); and National Commission To Ensure a Strong Competitive Airline Industry, *Change, Challenge, and Competition: A Report to the President and Congress* (Washington, DC: U.S. Government Printing Office, August 1993).

The Airline Commission recommendations are unclear as to the ultimate status of FAA. The Airline Commission calls for FAA to be established as an independent government corporation (on page 8) but also recommends that only ATC and related functions be placed in the corporation (page 9). According to the commission chairman, this inconsistent language stemmed from the inability of the commission to reach consensus. See also H. Jasper, "What Could Be Better Than an Air Traffic Control Corporation?" *ATC, Incorporated: The Corporatization of Air Traffic Control*, Les Blattner et al. (eds.) (New York, NY: McGraw Hill, June 1994).

BOX 2-2: U.S. Air Traffic Control System Overview

The federally operated ATC system, established principally for flight safety and efficiency, coordinates and directs all flights to and from U.S. airports, and comprises one of the most complex transportation systems in the world.[1] The routes and airspace that link airports are defined electronically and procedurally, not by physical structures, Assisted by ground- and cockpit-based navigation systems, pilots fly along paths prescribed by air traffic rules and instructions While modern electronics make such a complex system possible, its ultimate success depends primarily on human capabilities—monitoring, decisionmaking, and communicating

For air traffic control (ATC) purposes, the airspace above the United States and its territories is partitioned according to airport locations and the amount of traffic into three broad categories terminal, en route, and oceanic airspace Terminal airspace surrounds airports and is characterized by aircraft changing speed, direction, and altitude as they maneuver after taking off or before landing The airways connecting airports make up the en route airspace, while oceanic airspace begins over International waters, with much of it lying beyond sight of land

The ATC system provides three basic services navigation aid, flight planning and advisory information, and traffic control Ground-based, line-of-sight radio navigation facilities define airways and approach paths to airports Satellite-based radio navigation will likely become the primary air navigation system in the next decade or so.

FAA, in conjunction with the National Oceanic and Atmospheric Administration, provides weather and other flight planning and advisory information to pilots, and publishes aeronautical charts and related documents Timely and accurate weather information is critical to all aspects of flight planning and operations, including whether the flight must be conducted under instrument flight rules (IFR) or visual flight rules (VFR) The IFR/VFR distinction governs the structure of the airspace and the corresponding pilot qualifications and the aircraft equipment required to operate in it.

The key aspect of traffic control is separation assurance, where ground controllers use surveillance radars to track aircraft and to detect and resolve conflicts. Controllers in the field and at the FM's System Command Center* also use flight plans, weather data, and airport and facility status reformation to anticipate potential flight conflicts Takeoffs are metered and flights are rerouted to avoid hazardous situations and to reduce congestion and delay.

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[1] Information in this box is drawn from U S Congress, Off Ice of Technology Assessment, *Delivering the Goods Public Works Technologies, Management and Finance*, *OTA-SET-477* (Washington, DC U S Government Printing Office, April 1991), p 118 and U S Congress, Off Ice of Technology Assessment, *Airport and Air Traffic Control System*, OTA-STI-175 (Washington, DC U S Government Printing Office, January 1982), pp 28-68

[2] Formerly called the Central Flow Control Facility

were resolved, including how controllers would use the new equipment and how present ATC facilities would be consolidated.[64] Underestimating the technical complexity of the systems has led to promises of overly optimistic delivery dates.[65] Ineffective management procedures and a rigid procurement process also contribute to these delays.[66]

Failure of FAA System Operations and System Development Directorates (see figure 2-1 again for FAA organizational chart) to emphasize and clearly establish operational requirements has resulted in some FAA R&D programs being driven by "technology push" rather than "operational needs." For ATC, the primary objective of new technologies is to allow a significant improvement in both the cost of providing air traffic services and the efficiency of aircraft operations.[67] A suggested iterative process for the engineering of ATC systems entails (see also figure 2-4):

- creating a set of operational concepts, based on using new technologies for communications, navigation, and surveillance (CNS), that allow the subsequent creation of detailed, safe, and efficient operational procedures acceptable to pilots, controllers, and other airspace users and operators; and
- using the defined procedures to generate both operational specifications for new air traffic management procedures and the technical specifications for supporting CNS equipment.[68]

Some Examples

The usual practice has been for FAA to develop technical specifications and proceed directly into a development contract for prototype systems. System needs and required modifications become apparent as procurement becomes imminent and years of development activities have taken place.[69] Examples of where this approach was used include FAA's Wake Vortex Advisory System (WVAS), Microwave Landing System (MLS), and Precision Runway Monitor programs.

The WVAS program was under development for several years before controllers and pilots began to ask pointed questions about how the system was expected to operate. WVAS was to advise controllers whenever local meteorological conditions were such that an aircraft's trailing vortices would persist and pose a hazard to a following aircraft on final approach. Tested in 1979 and 1980 at Chicago's O'Hare International Airport, the project was deemed ". . . a technical success but an operational failure."[70] It became clear that vortex monitoring needed greater coverage, and that a complementary system for local area meteorological measurements and forecasting was needed. In this instance, the operational requirements

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[64] At an estimated cost of $5,9 billion, AAS was intended to be the heart of FAA's ATC modernization effort. It was designed to replace the existing computer systems, including workstations. used by controllers at FAA facilities, and to increase controllers productivity through new software functions. AAS has had major cost and schedule problems since its start in 1988. See U.S. Congress, General Accounting Office, "Advanced Automation System: Implications of Problems and Recent Changes," GAO/T-RCED-94-188, unpublished document. Apr. 13, 1994; and U.S. Congress, General Accounting Office, *Air Traffic Control: Status of FAA's Modernization Program, GAO'* RCED-94-167FS *(Washington,* DC: Apr. 15, 1994). In June 1994, FAA was in the process of modifying, including canceling some parts, of AAS.

[65] National Research Council, Transportation Research Board, *Winds of Change: Domestic Air Transport Since Deregulation* (Washington, DC: 1991), pp. 257-258.

[66] James L. Crook, Vice President for Operations, Air Traffic Control Association, Inc., personal communication, June 30, 1994.

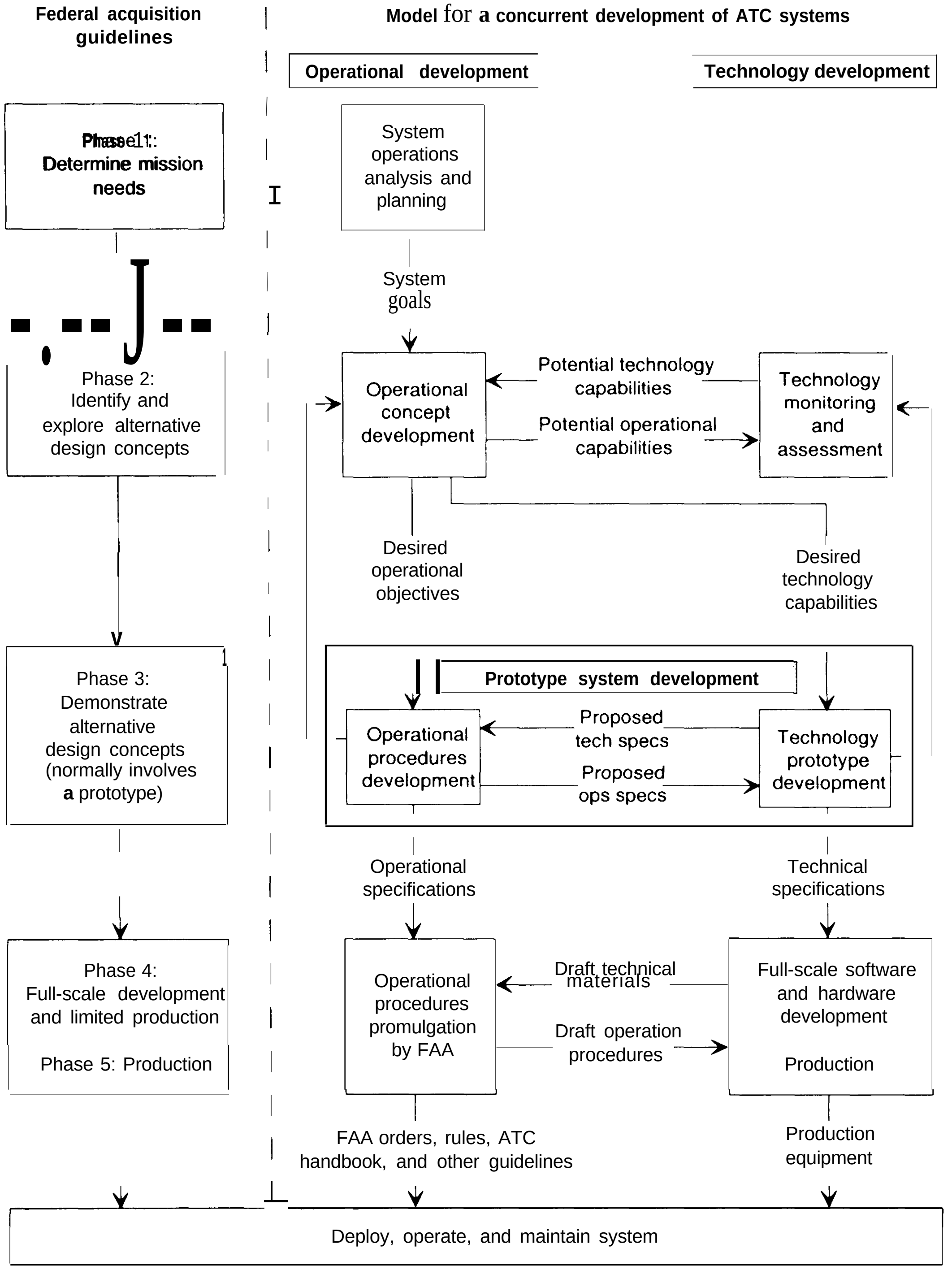
[67] Robert W. Simpson, "Using ATC Operational Requirements To Guide FAA R&D and procurement Activities," OTA contractor report, June 1993, p. 2.

[68] Ibid.

[69] Ibid., p. 3.

[70] Robert Machol, FAA Chief Scientist, personal communication, Aug. 30, 1993

FIGURE 2-4: Federal Acquisition Guidelines Compared With a Model for Concurrent Development of ATC Systems



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[a] From Office of Management and Budget Circular A-109

SOURCE Office of Technology Assessment, 1994 were not studied, so technical requirements were inadequate.[71] Related R&D started again in the late 1980s, and by 1993 NASA had become the lead agency of a much larger effort designated Wake Vortex Systems Research, which is part of the NASA Terminal Area Productivity Program.

Operational procedures and specifications should be regularly revisited over the life of a program as the environment changes. In the 1960s, deficiencies in the existing instrument landing system (ILS) and the U.S. airlines' goal of all-weather automatic landings prompted the development of MLS; the airlines renounced the goal in the 1970s as not economically feasible. No studies of the continuing need for MLS were launched. Similarly, ILS has since been upgraded but no new operational need studies for MLS were initiated until the early 1990s.

By 2008, FAA had planned to acquire 1,280 MLS units at an estimated cost of $2.6 billion.[72] FAA canceled the MLS program in favor of using GPS-based systems to meet some (and possibly all) future instrument approach needs.[73] Curved final approaches using MLS (or GPS) have been promoted as a means of providing better approach and landing capacity at major airports in instrument flight rules conditions. To date, no detailed study of the operational procedures required for certificating curved approaches has been made.[74] The issues of obstacle clearance, missed approach paths, safe approach speeds, maximum bank angles, and maximum allowable windspeeds have yet to be considered for curved approaches.

The Precision Runway Monitor program is another example of an inverted development process. FAA did not begin conducting dynamic simulations involving real pilots and controllers until the two prototype technology development projects were completed. The results of these simulations have raised serious questions about test and evaluation criteria for PRM, and whether emergency procedures are adequate for all airports that could use the system.[75]

The agency's own RE&D Advisory Committee pointed out some of these problems in 1991:

> The nature of system enhancements and the advent of new technology now make it possible to manage FAA research and development as a process of innovation, which stresses prudent overlap in concept formulation, development and implementation, rather than a purely sequential process that begins with invention and postpones subsequent programmatic decisions until total demonstration of each facet of the concept and technology. . . . [A]n important part of developing new technologies is concurrently developing certification standards, protocols, operating procedures and the like. These processes are critical in bringing new technologies on line.[76]

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[71] Simpson, op. cit., footnote 67, p. 3.

[72] U. S. Congress, General Accounting Office, *Air Traffic Control: Status of FAA's Modernization Program,* GAO/RCED-93-121FS (Washington, DC: April 1993), p. 45.

[73] "FAA Cancels MLS in Favor of GPS," *Aviation Week & Space Technology,* June 13, 1994, p. 33; and "Europe Still Plans To Implement MLS," *Aviation Daily,* June 14, 1994, p. 419.

[74] Simpson, op. cit., footnote 67, pp. 3-4.

[75] The key issue is when an aircraft approaching one of the parallel runways deviates off-course (or "'blunders") toward the approach path of the other runway. In this situation, the "nonblundering" aircraft would have to be redirected laterally away from the conflicting aircraft, but some airports do not have sufficient obstacle clearances to the sides of approach paths to permit this maneuver. Typical "missed approach" procedures for single or widely spaced runways usually require an aircraft to immediately begin a climb. However, this is not possible in this "'blunder scenario," since it could be unclear which aircraft is above the other (aircraft altimeter measurement errors could be larger than the actual altitude difference between the two aircraft).

[76] FAA Research, Engineering and Development Advisory Committee, R&D Plan Review Panel, *Review of the FAA Research, Engineering and Development Program* (Washington, DC: November 1991), pp. 32-33.

I Current Federal Policy for System Development and Acquisition

Critics point to a slow, cumbersome FAA procurement process as the cause of slippage and cost escalation of ATC milestones. While some institutional reforms may help improve the ATC system, few specifics have been given on how a new ATC entity, such as a U.S. Air Traffic Services Corporation. or changes in procurement rules would resolve ATC operational planning and development problems discussed above or otherwise significantly speed up the acquisition of complex, safety-critical systems.

The U.S. General Accounting Office has studied this issue and concluded that for FAA, government procurement policies and regulations are not the key snag. The central problem for the past decade, according to GAO, is that FAA did not follow federal acquisition guidelines for project development—specifically, OMB Circular A- 109 for planning and management oversight (see figure *2-4,* again), and OMB Circular A- 11 for budget oversight.

OTA spoke with companies handling FAA contracts for new ATC systems, and common among these manufacturers was frustration with the agency for constantly changing criteria, adding “bells and whistles” (or, more accurately and most often, software) that were never mentioned at the time of contract bidding.

The Federal Acquisition/ OMB Circular A 109 Process

In 1986, in testimony before Congress, GAO stated that it”. ., would expect a major system acquisition program with significant technical, operational, and economic risks to require strict adherence to the phasing and extended competition principles fundamental to Office of Management and Budget Circular A- 109.”[77] Unlike the four-phase process called out in A- 109, FAA’s existing procurement strategy incorporated only one decision point before committing to a combined development, test, and production phase. Neither FAA nor the contractors planned to validate the contractors’ models of the Advanced Automation System to ensure the proposed systems performed as required before the production commitment was made.

None of the 11 major system projects contained within AAS was subjected to the sequential A- 109 process; instead, FAA submitted all for DOT’s acquisition approval at either of the final two phases of the process called out in A-109, that is, full-scale development and full production (see figure *2-4,* again).[78] Between 1983 and 1991, the average delay for first-site implementation of these projects grew to five years.[79] Modernization costs continue to escalate.

FAA did not follow the A-109 process for other major programs. In February 1983, FAA submitted the MLS program for production approval, bypassing the first three key decision points in A- 109.[80] As with other FAA projects that circumvented the Office of Management and Budget (OMB) process, the MLS project met schedule delays and cost overruns.[81] Even though the $353-million Terminal Doppler Weather Radar program was ahead of schedule, FAA committed to production before operationally testing the deliverable design. The prototype software that had been tested was not the same—nor was the com-

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[77] Carl R. Palmer, Associate Director, Information Management and Technology Division, U.S. General Accounting Office, testimony at hearings before the House Committee on Appropriations. Subcommittee on Transportation, Aviation, and Material\, Apr. 16, 1986, p. 7.

[78] U.S. Congress, General Accounting Office, *Aviation Acquisition: Improved Process Needs To Be Followed,* GAO RCED-87-8 (Washington, DC: U.S. Government Printing Office, March 1987), p. 20.

[79] U S. Congress, General Accounting Office, *Air Traffic Control: Status of FAA's Modernization Program,* GAO 'RCED-92-136BR (Washington, DC: U.S. Government Printing Office, April 1992), pp. 26-27.

[80] General Accounting Office. op. cit., footnote 78, p. 26.

[81] These problems were with the program for Category 1 systems. The development programs for more precise Category 2 and 3 systems were on schedule when terminated in favor of GPS. Crook, op. cit., footnote 66.

puter system—as what would ultimately go into the field.[82]

But there have been positive changes at FAA. An FAA directive issued in March 1993[83] revises FAA procurement guidelines to require mission need statements and key decision points, closely following the A-109 process.[84] Moreover, FAA cites more adherence to the A-109 process in the early 1990s, even before this guidance was issued. Today, mission needs are reviewed by its acquisition review committee before the first decision point. FAA's Office of Acquisition Policy and Oversight staff provide guidance to programs developing mission need statements, and have "inserted some discipline into the process" of approving program justifications.[85]

FAA already has seen success with the approach. For example, acquisition of a new voice switch for control towers "hit all the key decision points" and met both schedule and budget goals.[86] However, FAA's latest acquisition policy still does not emphasize operational procedure development. Furthermore, FAA has yet to fully make the cultural transition to a more demanding acquisition policy. The requirement for more quantitative justification for new programs and an exacting compliance atmosphere have generated some controversy; some program offices have not warmed to the stricter process .87

The Budget Process

OMB Circular A- 11 provides guidelines for federal agencies in preparing annual budgets. For R&D, A-1 1 calls for the following budget categories: basic research, applied research, and development. For major system development and acquisition, the budget criteria in A-11 parallel the acquisition phases in A-109. As GAO put it in a recent report, "[h]owever, FAA has repeatedly ignored these criteria by budgeting development activities in its F&E account."[88] DOD organizes its R&D closer to OMB criteria than FAA. For example, DOD R&D categories 6.1 (basic research) through 6.5 (management and support) roughly correspond to A-109 milestones.[89]

Development work done under two budget accounts

FAA's budget criteria require facilities and equipment (F&E) funding for programs beginning at full-scale development, then limited and full production. Projects that require R&D are first budgeted in the RE&D appropriation account. According to GAO, however, some RE&D projects, such as Terminal Air Traffic Control Automation, receive both RE&D and F&E funds.[90] FAA routinely budgets substantial amounts of R&D work into its F&E account. For example, much of FAA support for weather R&D comes out of F&E

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[82] U.S. *Congress, Genera]* Accounting Office, *Aviation Acquisition: Further Changes Needed in FAA's Management and Budgeting Practices,* GAO/RCED-91*-159* (Washington, DC: July 1991), p. 6.

[83] U.S. Department of Transportation, Federal Aviation Administation, "Acquisition Policy Handbook," Order 1810. I F, Mar. 19, 1993.

84 David Morrissey, Director, FAA Office of Acquisition Policy and Oversight, persona] communication, May 17, 1993.

[85] David Morrissey, Director, FAA office of Acquisition Policy and Oversight, personal *Communication,* Apr. 15, 1994.

[86] Ibid.

[87] Ibid.

[88] General Accounting Office, op. cit., footnote 82, p. 2.

[89] 1 bid., p. 26.

[90] U.S. Congress, General Accounting Office, "FAA Reauthorization: Opportunity Exists To Address Safety, Capacity, and Efficiency Issue," GAO/T-RCED-93-75, Sept. 28, 1993.

funds. In a recent Office of Science and Technology Policy overview of U.S. weather research programs,[91] all weather-related R&D funding by FAA came from the F&E account.[92]

Including development and engineering tasks under F&E contracts accounts for the impression of delay in procurement, if the F&E account is viewed primarily for production. The reason for this budgeting oddity has to do with authorization levels for the RE&D account; if the development work in F&E were moved under RE&D, the latter account would exceed its authorization.[93]

This budget confusion has led some in the aviation community to conclude that FAA under-invests in technology R&D, and that this is a key source of ATC system modernization problems. It is true that the fraction of FAA's total budget designated as RE&D is small, especially when compared with R&D investments at other federal agencies and high-tech industries (see figure **2-5).** However, FAA funds about five times as much air traffic control R&D in its F&E account than in its RE&D program. Consequently, FAA R&D for air traffic control, including the R&D spending outside of the RE&D account, was 10.5 percent of FAA's total annual budget for ATC in 1993 (see table 2-3). This level of R&D investment compares favorably with figures for high-tech industries such as telecommunications and computer software. Insufficient funding for research and technology development is not a major source of FAA's ATC modernization difficulties.

Limitations of current procurement rules

Although the implementation delays caused by the federal procurement rules should not be overemphasized, they do slow the purchase of what should be readily available equipment. These laws ". . . place heavy reliance on competition. They give losing bidders multiple opportunities to protest, thereby delaying decisions for long periods."[94] This often prevents FAA from simply returning to a proven supplier, requiring instead a virtual repetition of the process for the initial procurement. "Procurement officers' emphasis on awarding a contract to the lowest bidder, despite significant quality advantages with other bidders, is one example of how procurement and program objectives often clash."[95]

Others have expressed similar views, that the competitive procurement system causes delays and added expense, although the resulting time lag seems to be roughly one year at most.[96] "An FAA study identified 250 government documents that levied requirements on acquisition officials, 140 of which were FAA generated . . . and included 4,500 citations that were identified as 'required activities. FAA has reduced these to 1,400 action steps."[97]

Purchase of off-the-shelf equipment, such as personal computers and radar display screens, would be most affected by any move to exempt FAA from federal procurement rules. By contrast, procurement of the large ATC systems unique to FAA is likely to be affected much less by such an

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[91] Office of Science and Technology Policy, Federal Coordinating Council for Sciences, Engineering, and Technology, Committee on Earth and Environmental Sciences, Subcommittee on Atmospheric Research, "Predicting Our Weather: A Strategic Plan for the U.S. Weather Research Program," July 1992.

[92] Ibid., p. 33. The $18.4 million listed under DOT for fiscal year 1991 is all from FAA's F&E budget. Greg Geisler, Office of Budget, Federal Aviation Administration, personal communication, June 22, 1994.

[93] General Accounting Office, op. cit., footnote 82, p. 8.

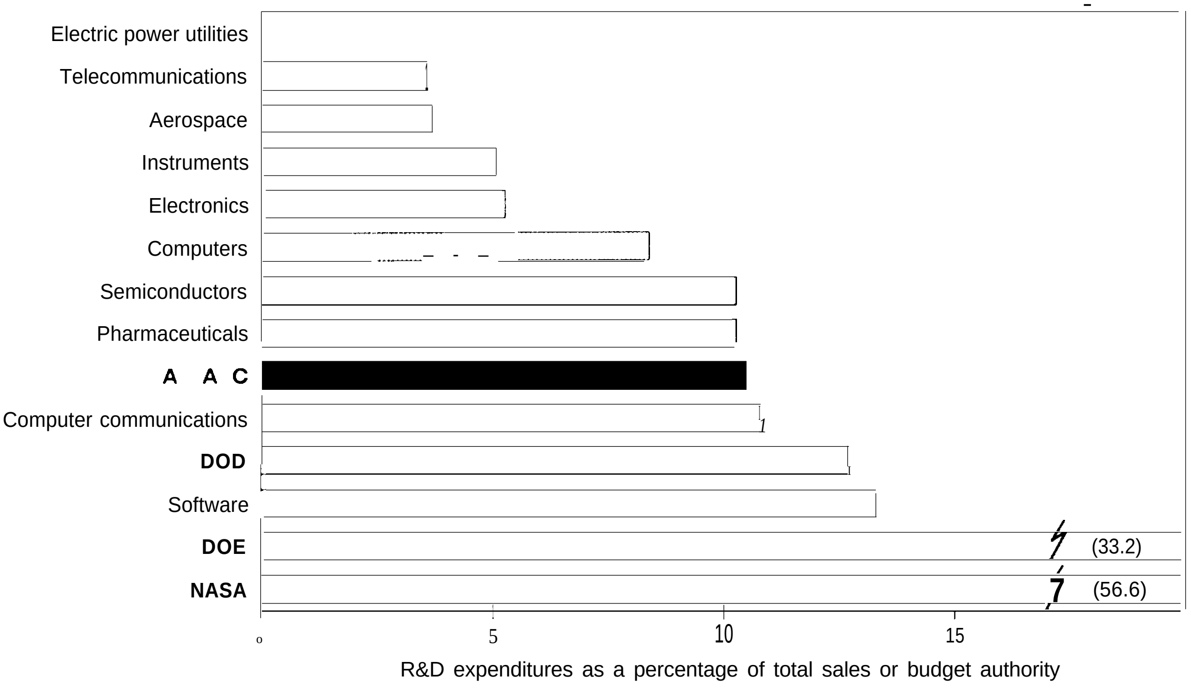
[94] National Research Council Transportation Research Board, *Winds of Change: Domestic Air Transport Since Deregulation* (Washington, DC: 1991), p. 329.

[95] Ibid., p. 330.

[96] John Turner, FAA Associate Administrator for National Airspace System Development, personal communication, Oct. 21. 1992; and Crook, op. cit., footnote 66.

[97] The National Commission To Ensure a Strong Competitive Airline Industry, op. cit., footnote 63, p.10.

FIGURE 2-5: Research and Development Spending: Comparison of Selected Industries and Federal Agencies



[a] See table 2 3 for ATC R&D budget data

NOTES Values for individual federal agencies are for fiscal year 1993, values for Industries are for 1990

KEY FAA ATC Federal Aviation Administration air traffic control-related R&D spending as a percent of total FAA spending on ATC DOD Department of Defense DOE = Department of Energy, NASA = National Aeronautics and Space Administration

SOURCE Off Ice of Technology Assessment, 1994 based on Aerospace Industries Association; "R&D Statistics," *Business Week/ Quality* 1991, p 214 Department of Energy Energy Information Administration, *Financial Statistics of Major Investor-owned Utilities 1991* Office of Management and Budget

exemption, although relief from the multiple reviews and challenges by losing bidders would have some impact. According to the Transportation Research Board:

> ... no matter how much better the FAA plans its procurements, there are statutory impediments prescribing policies and practices, which give rise to many of the difficulties. Prominent among these are insistence on advertising and competition, even if only one or a few bidders are qualified: emphasis on choosing the lowest bidder when others may offer superior quality and value; prohibitions on working with contractors during the specification of follow-on procurements; and complex, time-consuming procedural requirements, including those affording allegedly aggrieved, unsuccessful bidders the right to multiple and protracted appeals.[98]

The Federal Acquisition Streamlining Act of 1994 would make it easier for federal agencies to purchase off-the-shelf products and technologies.

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[98] Transportation Research Board, op. cit., footnote 94, pp. 336-337.

TABLE 2-3: Federal Spending on Civil ATC Research, Development, and Engineering

Accounts and calculations	FY 1993 actual ($ millions)	FY 1994 request ($ millions)
FAA:		
RE&D account		
(1) ATC portion	$ 988	$ 1126
F&E account		
(2) EDT&E	555.2	5492
(3) DT&E	160	106
(4) Non-ATC procurement	596	1272
(5) Total	2,4650	2,524.0
Operations account		
(6) ATC programs	3,480.9	3,522.9
(7) Overhead (ATC portion)[a]	4236	4157
(8) **Total ATC-related R&D spending= (l)+(2)+(3)**	**6700**	**6724**
(9) **Total FAA spending on ATC = (l)+(5)-(4)+(6)+(7)**	**6,4087**	**6,4480**
FAA ATC-related R&D spending as a percentage of total FAA spending on ATC = (8)/(9)	10.5%	10.4%
NASA:		
ATC portion of aeronautics R&D	319	50.6
Total ***NASA and FAA ATC-related R&D spending:***	***701.9***	***723.0***

[a] Office of Technology Assessment estimate Overhead spending was prorated according to the ratio of ATC programs to non-ATC programs in the operations account

KEY DT&E = development test, and evaluation, EDT&E = engineering, development, test, and evaluation; F&E = facilities and equipment; RE&D = research, engineering, and development

SOURCES Office of Technology Assessment, 1994, based on Budget of the United States Government, Fiscal Year 1994, Federal Aviation Administration budget documents, National Aeronautics and Space Administration

While this legislation is aimed largely at DOD, if enacted it will apply to other federal agencies, including FAA.[99]

I The System Development Process at FAA

In many cases, complying with A-109 (or FAA's own acquisition policy, which expands on A- 109) could have helped FAA identify, and possibly resolve, operational and procedural problems before committing to expensive technology development. However, while OMB guidelines provide a foundation for proper system development oversight, they cannot alone ensure fast and successful ATC system development and implementation. What is also needed is a change in ATC system development philosophy that places a much stronger emphasis on operational concept and procedure development.

Previous studies have concluded that stable leadership is needed at FAA to improve the system development and acquisition process.[100] The

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[99] The legislation was in the conference committee as this report went to publication.

[100] Some examples include *Aviation* Safety Commission, *Volume 1: Final Report and Recommendations* (Washington, DC: April 1988); U.S. Congress, Office of Technology Assessment, *Safe Skies for Tomorrow: Aviation Safety in a Competitive Environment, OTA-SET-38 I* (Washington, DC: U.S. Government Printing Office, July 1988); and Transportation Research Board, op. cit., footnote 66.

average tenure of FAA Administrators (around two and one-half years during the past two decades) is far shorter than the development cycle of most ATC systems. And presently, no one below the Administrator has the authority to effectively bridge the operational and technological divisions of FAA. This means that ATC system development programs have had neither the mandate nor the leadership to ensure that operational and technological goals are continually coordinated and validated.

Technology development is the dominant culture in FAA system development programs. Technological improvements, rather than operational advances, become the focus of many projects. Furthermore, FAA technology development projects sometimes take on a life of their own. For example, the primary justification for MLS was changed or superseded by other technologies [101] at least three times in the project's history—yet the project stayed alive for three decades. Scrutiny by operational experts can threaten such projects and is rarely sought by technologists until absolutely necessary. Controllers and pilots are the ultimate users of the system and want to prevent new safety flaws from being introduced—implementation delays do not hurt that goal. Whether pilots and controllers are consulted early or late, their assessments have major impacts on new systems (see box 2-3 for one example).

Good acquisition policies alone are no panacea for FAA. One reason is that ATC system development issues are as much cultural as they are managerial. Air traffic controllers, equipment technicians, pilots, engineers, administrators, and managers are vital to ATC system development and operation. Each group has strengths and shortcomings, and communication across these cultural gaps can be difficult-inadequate coordination between the operational sections and the technology developers is a longstanding problem at FAA.[102] One former Administrator believes that the most critical challenge is to get the "Air Traffic. Flight Standards. and R&D parts of FAA to work as a team. It has never happened." [103]

Moreover, these cultural differences may send conflicting messages to policymakers: each group may have a different priority or perspective on ATC problems. Safety and efficiency are the primary purposes for ATC, but rarely is there agreement on what levels of safety and efficiency are acceptable or how they can be measured. However, current U.S. ATC is remarkably safe as measured by accident risk, and no safety crisis exists. Unresolved concerns about new risks slow the ATC development process. The tradeoff is that once the new ATC system safety concerns are satisfactorily addressed, the actual safety increase realized will likely be too small to measure, but the increase in efficiency could be substantial—worth billions of dollars per year.[104] Consequently, it is important to tackle safety concerns as early and openly as possible to minimize the costs of delayed operating efficiency benefits.

The View From Inside

OTA talked to mid- and low-level FAA managers about the agency culture for research and system

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[101] New capabilities that could serve some MLS missions include better ILS performance, potential for curved approaches using onboard flight management systems, and highly accurate satellite navigation.

[102] The problem has not been confined to the ATC arena. In the late 1980s, coordination was weak between FAA's aviation security regulation section and the agency's security R&D branch at the Technical Center. For more information, see U.S. Congress, Office of Technology Assessment, *Technology Against Terrorism: Structuring Security*, OTA-ISC-511 (Washington, DC: U.S. Government Printing Office, January 1992).

[103] John McLucas, personal communication, June 29, 1994.

[104] For example, world airlines could potentially save as much as $5 billion a year in fuel and delay costs by using satellite navigation according to Assad Kotaite, ICAO Council President. Lisa Burgess, "ICAO Urged To Help Nations Implement FANS," *Commercial Aviation News*, July 12-18, 1993, p. 8.

BOX 2-3: Difficulties With Intra-Agency Teams—Case Study on the Multiple Parallel Approach Program

In 1988, the Federal Aviation Administration's Air Traffic Service asked the Research and Development Service to help determine if multiple simultaneous parallel instrument approaches (to three- and four-runway configurations, referred to as triples and quads) were feasible using existing radar and monitoring equipment, Managers from the air traffic division created the Multiple Parallel Approach Program (MPAP) to conduct these studies, and formed a Technical Working Group (TWG) from representatives of interested FAA offices to design and evaluate the necessary simulations.

During its first few years, members described TWG as a successful group in which all participants understood and addressed not only their own needs, but those of the other members as well. [1] In the opinion of one participant, the mutual understanding was so strong that the team came to consensus about 99 percent of the time,[2] According to another TWG member, " [a]t FAA, much of what works occurs when the key players enter early and are included for the duration of the process, "

TWG met several times to develop test criteria before beginning simulations. Among the criteria agreed on in July 1989 were aircraft airspeeds of 150 to 180 nautical miles per hour and flight path "blunders'" of up to 30 degrees as the deviation the controllers and pilots in the test must successfully overcome.[3]

Competing Technologies

Evaluations began in 1990 with human-in-the-loop simulations of the radar and display indicators[4] currently in use at U.S. airports. This equipment passed tests of triples spaced at 5,000 feet apart. But with a 4,300-foot separation,[5] this combination failed the test, largely because of the poor resolution provided by the displays,[6]

TWG then brought in the Final Monitor Aid (FMA), a 20- by 20-inch, high-resolution color display with new features. The FMA had been developed as part of the Precision Runway Monitor (PRM) radar system but was separable, which allowed TWG to pair it with the Mode-S monopulse radar system.[7] The Mode-S/FMA combination passed the tests of triples at 4,300 feet, With the faster PRM radar, the FMA would likely perform even better.[8] FM documents from 1990 through mid-1 992, along with Off Ice of Technology Assessment interviews, indicated across-the-board acceptance-even enthusiasm—for the FMA,

The Turning Point

In summer 1992, a controversy began brewing concerning runway separations at the Denver International Airport (DIA), then under construction. FM had assured Denver officials that the airport would have independent triple Instrument flight rules capability on opening day, [9] and at first glance, the

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[1] Interviews with various FAA personnel

[2] Interview with manager in the Off Ice of System Capacity

[3] A "blunder" is when an aircraft established on its final approach path to a runway deviates frOm its intended course

[4] These are the ASR-9 radar and the ARTS IIIA/Data Entry and Display Subsystem (DEDS)

[5] Independent instrument flight rules approaches to dual parallel runways separated by at least 4,300 feet have been authorized without incident since 1974 The closest spacing in actual operation is at Atlanta Hartsfield International Airport, where the runway centerlines are separated by a little over 4,400 feet Notably, however, before setting this standard, FAA had not run simulations for parallel runways closer than 5,000 feet

[6] FAA Contract Report, Comparison of Controller Performance Using the Final Monitor Aid and the ARTS/DEDS Display Systems, " Air Traffic Control Simulation Contract No DTFA03-89-C-OO023, Sept 29, 1992, pp I-6--4-8

[7] The Mode-S system has the same one milliradian radar accuracy at PRM, but a slower update rate (4 8 seconds for Mode-S; 1 0 seconds for PRM)

[8] The PRM radar was only tested for 3,000- and 3,400-foot runway separations in the MPAP simulations However, controllers Indicated that the faster update rate significantly improved their performance CTA, Inc , "Test Report, Phases V b 1 & V b 2,Evaluation of Dual and Triple Simultaneous Parallel ILS Approaches Spaced 3,000 Feet Apart Using the Precision Runway Monitor System With a Simulated 10 Second Radar Update Rate, " Engineeing Research Psychology Services Contract No DTFA03-89-C-OO023, CDRL Item 002, June 16, 1992, p x

[9] City and County of Denver, ' FAA Affirms Triple Simultaneous Landings at DIA, " press release, Feb 26, 1993

BOX 2-3: Difficulties With Intra-Agency Teams—Case Study on the Multiple Parallel Approach Program (Cont'd.)

test results discussed above supported this claim The first three DIA parallel runways built are separated by 5,280 feet and 7,600 feet—greater than the 5,000 feet previously tested However, FAA had not adequately considered the effects of thinner air at higher altitudes in its tests on triples—without changing other aerodynamic parameters, an aircraft files faster as the air becomes thinner Consequently, for the same level of safety, parallel runways would need to be farther apart at Denver elevations than at sea level sites because of greater aircraft speeds,

Several members of TWG recommended testing to see if there might be a problem with DIA's runway configuration, and if so, whether there might be a technology solution. Despite strong sentiment by some FAA offices against running new simulations, TWG received senior management approval and conducted tests of high-alhtude runway configurations

The first simulation scenario strongly resembled DIA, though it was not explicitly designated Conducted in September 1992 and using previous test criteria, current radar and displays (ASR-9/DEDS combination) proved Inadequate in these simulations It was at this point that TWG became fractious, and research objectivity fell by the wayside Personnel from Air Traffic Service and FAA's Northwest Mountain Region (NWM) protested that the test criteria, which they had accepted in previous simulations, were the reason for the equipment's failure to pass the tests They Insisted that blunders did not happen and that the aircraft approach speeds were too high Project participants from FAA's regulatory and standards divisions and the Air Line Pilots Association held that the agreed-on criteria were necessary to the tests. Also, the original project manager from the Off Ice of System Capacity was replaced by someone from the Research and Development Service

At a TWG meeting a month later, the new project manager announced that these simulation data would not be used in the TWG analyses Instead, new simulations would be conducted, called the DIA simulations, which would replace the current controller displays with an upgrade, the Full Dlgital Automated Radar Terminal System Display System (FDADS) At the Insistence of NWM, and over the protests of others, TWG recommended that the simulation airspeeds be changed [10] The meeting minutes show that in the future only the TWG chairperson, not Individual members, would speak for the team when discussing the simulations[11]

The DIA simulations took place in November 1992 Even though the upgraded displays were supposed to provide better Information, the results of the first two days of testing appeared similar to those of the previous simulations. After much discussion. the FMA displays were used for the remainder of the simulation and were successful When the working group met again in January 1993, the MPAP manager stated that the data from the September 1992 simulations would remain archived and that there would be no mention of the aborted test of the upgraded display (FDADS) in the DIA report [12] However, all data were published in that report

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[10] These airspeeds are different than those used in any simulation we have observed thus far The twm-engine piston aircraft normally fly at 120 knots, the turboprop at 150 knots, and the turbojets at 180 knots until the final approach fix Raising the speed of piston and turboprop aircraft and lowering the speeds of turbojets to the point where both types of aircraft are operating outside of their normal flight envelopes is not a realistic solution to reducing the potential blunder situations Air Line Pilots Association, letter to the Federal Aviation Administration, Dec 17, 1992

[11] Multiple Parallel Approach Program (MPAP) Technical Work Group (TWG) Meeting Minutes, ' Washington, DC Oct 6-8 1992

[12] There was no consensus among TWG members on these decisions Further ' [t]his directive is apparently coming from a higher authority than the program manager No FAA person will name that authority ' National Air Traffic Controllers Association Internal memorandum Mar 22 1993

BOX 2-3: Difficulties With Intra-Agency Teams—Case Study on the Multiple Parallel Approach Program (Cont'd.)

Based on measurement of controller performance, the FMA performed 13,5 times better than FDADS, [13] and it appears to be no more costly.[14] Yet some factions within the Federal Aviation Administration tried hard to make FDADS pass, although it is unclear why. However, FAA ultimately decided that FMAs will be used at DIA.

Conclusions

Fundamental data from the field are essential Everyone agrees that testing against blunders can be helpful in developing and validating new air traffic system technologies and procedures. As stated by FAA's Chief Scientist "[i]f the system is shown to be safe even with extreme assumptions such as the 30-degree blunder, then the most reluctant doubters are easily convinced. But when such a model shows the system to be unsafe, we have learned nothing, and should not assume that it is really unsafe.'" [15]

At issue, then, is how often blunders actually happen and what criteria should be used in certifying new systems for actual operation. Although the 30-degree blunder criterion has been used by FAA since 1974, it was not until the status quo was challenged that individuals at FAA began to state that blunders are so rare that they should not be part of the tests. However, FAA has lacked the empirical data to support changing this criterion.

According to Flight Standards, "[t]he remaining issue is what should we be protecting against? .,, Deviations are rare events, but when one does occur, does the FAA have the capability to detect/recognize the deviation, alert the controller, and have the controller resolve the conflict?"[16] Over the years, FAA has Invested a great deal of resources and research into the development of PRM, FMA, new controller positions, and new safety procedures for simultaneous parallel approaches. All these efforts have been for the purpose of detecting and resolving the unlikely event of an aircraft deviating off the approach path, But better system data are needed. As the Director of Flight Standards stated, "[t]o date, no formal FAA data collection effort has been in place to capture the events of aircraft deviations and the degree of deviations systemwide.[17]

Intra-agency teams are valuable, but are difficult to manage under the current FAA organizational structure. There is an Inherent tension between system evaluation and implementation. Yet, many of the same groups—pilots, controllers, technologists—must have effective roles from start to finish in both the evaluation process and in system development and implementation, Close coordination among these groups is needed to establish the underlying operational objectives, criteria, and procedures essential to make both the evaluation and implementation processes more timely and effective. It is Important to note that top managers from FAA's different organizations participated in the MPAP discussions, the crosscutting team approach of TWG was quite successful at identifying potential problems early and figuring out ways to evaluate them.

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[13] "[T]he acceptable rate for the FMA is about 135 times larger than the acceptable rate for the FDADS, thus indicating that the use of the FMA will result in an operation with far less risk than the FDADS " Federal Aviation Administration, "FDADS Simulation at Denver, " draft Internal memorandum, n d

[14] Federal Aviation Administration Mission Needs Statement, "High-Resolution Display Requirements for Final Monitor Aid, MNS Number 225, section 11 (d), Feb 9, 1994

[15] Robert Machol, FAA Chief Scientist, internal memorandum, Jan 4, 1993

[16] Thomas C Accardi, Director, Flight Standards Sef'vice, FAA Internal memorandum, Apr 7, 1993

[17] Ibid

BOX 2-3: Difficulties With Intra-Agency Teams—Case Study on the Multiple Parallel Approach Program (Cont'd.)

However, such crosscutting teams face a dilemma Involving the power of each member A strong voice for each is essential, but too much Influence on the decision process leads to problems, According to the National Air Traffic Controllers Association and others, in the past FAA has had working groups do retests, with the aim of validating favored technologies or procedures.[18] One option to address this problem is that when a team is created, the boundaries of authority and the levels of required management review must be clearly identified, This did not happen for TWG. Another option is to place evaluation teams such as TWG under the authority of a high-level, Independent arbiter who understands operational development issues as well as technology concerns Currently, FAA has the organizational structure to Independently evaluate major system acquisitions, but not the operational procedures and criteria the systems are to support.

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[18] Representatives of National Air Traffic Controllers Association, personal communication, Aug 11.1993

development.[105] While much positive was discovered, also unearthed were signs of a few pitched battles within the Systems Operations Directorate.[106] These conflicts placed the Air Traffic and System Capacity divisions on one side, and the Regulation and Certification division on the other. And the regulatory division did not always win. Some Air Traffic personnel have been quoted as saying that their job was not to improve safety but to increase capacity—as though the two were mutually exclusive.[107]

During its investigations, OTA found that FAA's upper management was attempting to change the culture of the agency by creating a research orientation and encouraging employees to think long term. The managers interviewed were aware of this effort and applauded it, though not all predicted success. Many felt FAA had a number of significant internal problems to address in order to reach its goal of well-coordinated research, technology development, and implementation. They emphasized the disparate relationships the offices within the System Operations Directorate have with those in the System Development Directorate.

FAA now emphasizes continual review of R&D projects by managers from the System Operations Directorate, which in turn requires good relationships between the Directorates and their respective divisions and offices. With all the talk of improved communications, however, the System Engineering and Development division (called the "R&D division" below) still seems to have a different relationship with each System Operations division. This may be only logical in light of the diverse natures of these divisions, it may be a function of an agency in transition, or it may be a remnant from the past. It is here that differences in agency culture remain an unresolved issue.

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[105] OTA staff spoke t. more than 30 low- and mid-level managers in order to get the perspective of those charged with actual implementation of upper management's plans.

[106] In this report, sections of FAA managed by Executive Directors are referred to as *directorates* and those managed by Associate Administrators or Assistant Administrators as *divisions*. *These* terms are not used by or have different meanings within FAA.

[107] The case history concerning parallel runways at Denver, presented in box 2-3, also involved animosity among participants. Those wanting to keep the more stringent test criteria claimed to be doing so in the name of safety, while those seeking new criteria cited the need for increased capacity and tended to come from ATC-related divisions of FAA.

One often-cited problem from the recent past was lack of communication between R&D personnel and the operating divisions, resulting in unwanted or unusable R&D. Therefore, when seeking solutions to this problem, FAA management first turned to improving relationships between R&D and the operating divisions. In some cases, "improving relationships" meant increasing the flow of current communications; in other cases, the managers involved started virtually from scratch.

More than one operating division manager has accused the R&D division of politicizing its priority-setting process to favor some operating divisions at the expense of others. Conversely, other division managers believe they have an advantage in their rapport with key individuals in the R&D division, but they also worry about what would happen to their projects if these persons were to leave. Maintaining continuity over long-term projects is a common concern.

Some parts of the System Operations Directorate, such as the Flight Standards Service, have specific branches to deal with the R&D division. Not every operating group at FAA is large enough to afford such units; indeed, the technical programs section within Flight Standards has more branches than some entire offices or services elsewhere in the agency. Furthermore, where some offices within the System Operation Directorate have a history of cooperation with the R&D division, others have a background of far less cordial relationships.

Within the offices under the Assistant Administrator for Airports (which is separate from the Directorates mentioned above), there have been discussions of a periodic review of R&D projects. There remains some concern within this group that the improved relationships with the R&D division are based on having "nice guys in charge;" they would like to see any new procedures fornalized so that success in accomplishing their R&D goals is less dependent on having a good rapport with a particular individual. A Flight Standards manager maintained that R&D programs go most smoothly when the R&D program manager seeks the help and input of the operating divisions, and the operating divisions have and take advantage of opportunities to outline their needs. The air traffic division uses quality action teams [108] to review the processes used to determine R&D (and other) projects, thus ensuring that Air Traffic's policies and technology needs are taken into account in the R&D decisionmaking process.

Another office that depends on the R&D division, the Office of Environment and Energy (under the Associate Administrator for Policy, Planning, and International Aviation), also has had improved cooperation with the R&D division. They have seen a major change in how the R&D division involves Environment and Energy people in the process. Although the planning and coordination process for R&D takes longer, Environment and Energy has found that it works better. They submit proposals and justifications for the following five years, which are then reviewed at several levels. The office is pleased with this procedure. According to one manager: "[t]he decisionmaking process is now on the table instead of in the back room."

Many FAA R&D projects involve or interest more than one operating office or division. For such projects, good communications require that multiple groups cooperate with one another. While the accusation has been made in the past that the different divisions had tunnel vision, not seeing past their own concerns, there is increased emphasis on ensuring that each relevant division be represented in the R&D decisionmaking process.

One R&D division manager likes to see the operating divisions making a strong commitment to

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[108] These are part of total quality management (TQM) implementation. TQM is a concept that encourages team-building, increased communication, employee input, and continuing review as away of meeting a defined mission. A number of companies and government agencies now rely on TQM.

their projects. His feeling is that this has not always been the case. but that participation has improved and is now more active. He recalled that in the past, operations managers were sometimes passive and behaved "like judges of something other people were doing," rather than as integral members of a system development team. He prefers the increased number of R&D projects he is seeing in which the operations representatives "are more like team players. "

Positive Steps

In many ways. FAA is in transition. FAA has recognized some of the operational development problems discussed earlier and is making efforts to resolve them. Almost all agency operating units report improved relations with FAA's R&D division, and the general feeling is that technology R&D is more targeted than in the past to the needs of the operating units.

As mentioned above, acquiring user input is an essential step in identifying operational requirements. For the development of the new 777 aircraft, Boeing has used this approach and met with success. Likewise, FAA increasingly welcomes industry into its fold. In 1991. FAA established operational implementation teams for satellite navigation and for satellite communications and surveillance. The teams have worked closely with representatives of the various FAA organizations, as well as with other parts of the aviation community. to improve the process for developing performance standards and requirements.[109]

The Satellite Operational Implementation Team (SOIT) was established to help speed the introduction of satellite navigation functions into the U.S. air traffic system. Sponsored by FAA's Flight Standards Service. SOIT serves as the single focal point for the review and approval of all operational implementation requirements: the team includes representatives of all the functional entities involved in implementing satellite technology. Industry. academia, and other advisory groups are also involved in certain SOIT activities, at the invitation of FAA. But by law, FAA must exclude industry from those sessions that involve rulemaking.[110] However, some industry representatives consider these prohibitions to be excessive—industry is now excluded from all meetings of the navigation portion of SOIT.[111]

SOIT provides guidance and direction to program offices responsible for research, development, operation, and acquisition of satellite navigation technologies. For example, SOIT consulted with the R&D division to develop the mission needs statement for GPS (i.e., for the first key decision point in the A 109 process) prior to the program's budgeting. In addition, SOIT is authorized to task member organizations to support agreed-on activities.[112] In 1993, FAA separately chartered a Communications/Surveillance Operational Implementation Team (C/SOIT) from a working group formerly based within SOIT. C/SOIT is focusing on the early operational implementation of satellite communications, surface movement surveillance systems, and datalink technologies.

CONCLUSIONS

Aviation research and technology development are performed by various public and private institutions in the United States and across the globe. The U.S. federal government is the major provider of R&D for aviation safety, security, environmental protection. and the airspace system. Such research is vital to FAA's regulatory and operating missions, and FAA is both a customer and supplier of R&D products in these areas.

FAA depends on other agencies for most basic research such as human factors and environmental science. To the extent that such research is

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[109] Jim Crowling, Chairman, FAA Satellite Operational Implementation Team, personal communication, June 14, 1993.

[110] Jim Crowling, Chairman, FAA Satellite Operational Implementation Team, personal communication, July 13, 1994.

[111] Edwin Thomas, United Air Lines, personal communication, July 14, 1994.

[112] From the Satellite Operational Implementation Team charter, June 7, 1993.

BOX 2-4: Possible Steps for More Effective ATC System Development

- **Involve suitably experienced operational personnel in the planning and prototype development process. Effective system development requires a balance of operational and technical views, and neither should dominate,** The planning, analyses, and experience of operating organizations, at the Federal Aviation Administration and across the aviation community, are critical to properly matching technological options to safety and operational initiatives "Too little, too late" has usually described the Involvement of operational experts in air traffic control (ATC) development
- Conduct operational **analyses and develop operational procedures for new system concepts early enough to affect the technology development process. Proposed operational procedures must be developed in sufficient detail that controllers, pilots, and other groups can understand and draw conclusions on the safety and operational implications Moreover, the operational and technical components of each ATC system must be developed concurrently, and must include frequent feedback from the aviation community (see figure 2-4),**
- **Use dynamic ATC simulations as "operational development" as well as "technology development" tools. Dynamic ATC simulation resources, capable of including real controllers and pilots, are essential to rapidly develop and test new ATC system concepts and procedures Operational** issues such as human-machine Interface and airspace configurations can be studied before the technology is fully mature Proposed operational procedures and technological concepts can be criticized constructively with dynamic simulations, provided that both operational and technical experts are closely involved in the process When used in the past, dynamic simulations have focused primarily on validating and fine-tuning technological concepts

SOURCE Off Ice of Technology Assessment, 1994

conducted within federal programs, coordination and cooperation for aviation R&D among federal agencies have improved in recent years, although it could be stronger still.

For its part, FAA's foremost responsibility for interagency research and technology is to identify the long-term operational needs and objectives for the aviation system. **It is especially important for FAA to confer with federal agencies conducting research to ensure that the specific needs of civil aviation, especially as they relate to U.S. policy in international standards-setting, are addressed within other research programs. FAA** can contribute the most to aviation R&D by providing an important operational perspective—whether or not it conducts or funds the R&D. FAA is in a strong position to be the catalyst and clearinghouse for technological advances vital to aviation progress; the agency alone has the breadth of expertise and connections across the aviation community to provide this service.

Although FAA has relatively little to offer as a supplier of scientific R&D in interagency programs, certain technological systems developed and engineered in FAA programs, such as those for explosives detection or air traffic control, are useful to other agencies. For example, DOD plans to install the same air traffic equipment as FAA in its domestic control facilities. Additionally, FAA research facilities for aviation securit y, fire safety, and ATC simulation are national resources that could be useful to other agencies. While some interagency research projects are under way at the FAA Technical Center, FAA research programs and facilities have offered few research opportunities for NASA, DOD, and other researchers.

However, it is the system development programs at FAA that need the most improvement. ATC system development and implementation are chronically delayed, in large part due to shortcomings in analyzing and establishing operational requirements, Reform is most needed in ATC system development management rather than procurement rules. **If longstanding ATC modernization problems** are to be resolved, research and development of operational requirements and procedures must be strengthened and made into an integral part of FAA's ATC system development process. Box 2-4 presents three critical steps that could be part of an improved ATC system development process,

FAA does incorporate operational expertise into parts of its ATC technology development efforts, but it is unlikely that, on its own, FAA can take all the steps necessary to resolve internal management and cultural impediments to improving the ATC system development process. In the course of its research, however, OTA heard little confidence expressed in FAA's ability to plan for and introduce new ATC systems effectively without some change in institutional structures and incentives. FAA has claimed, and then failed. to have overcome system development and acquisition hurdles a number of times during the past decade. As long as technology development remains the dominant culture in FAA system development programs, however, implementation problems will persist.