

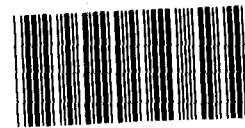
GAO

Fact Sheet for the Chairman,
Subcommittee on Transportation and
Related Agencies, Committee on
Appropriations, U.S. Senate

September 1991

AIR TRAFFIC CONTROL

FAA's Transition of Communications System to Digital Technology



145130

RELEASED

**RESTRICTED—Not to be released outside the
General Accounting Office unless specifically
approved by the Office of Congressional
Relations.**

Information Management and
Technology Division

B-245487

September 26, 1991

The Honorable Frank R. Lautenberg
Chairman, Subcommittee on Transportation
and Related Agencies
Committee on Appropriations
United States Senate

Dear Mr. Chairman:

In response to your request, we reviewed the status of the Federal Aviation Administration's (FAA) planning for the transition of the Radio Communications Link (RCL) system from analog to digital technology.¹ RCL is an integrated voice and radar data transmission system that is the largest of three components in FAA's program to replace and expand the existing Radar Microwave Link communication system.² RCL, when completed, will serve as the backbone for FAA's communications network.

FAA is now in the seventh year of an 8-year contract with American Telephone and Telegraph (AT&T) Technology Systems, estimated to cost \$296 million, to implement this analog-based system. Appendix I provides details of our objective, scope, and methodology.

Results in Brief

FAA recognizes that it should eventually change its communications network to a predominantly digital architecture because of the obsolescence of analog technology. In August 1991, FAA began installing equipment on the RCL system to enable the transmission of digital data over digital communications lines, while maintaining the current analog-based RCL system. To plan for the transition of its communications network to digital technology, FAA initiated two contractor studies to (1) design a future all-digital architecture for FAA's communications systems, and (2) determine when to fully convert the agency's interfacility communications system, including RCL, to digital technology.

Background

The RCL system is intended to provide transmission capabilities to allow long-distance communications between air traffic control facilities. It is

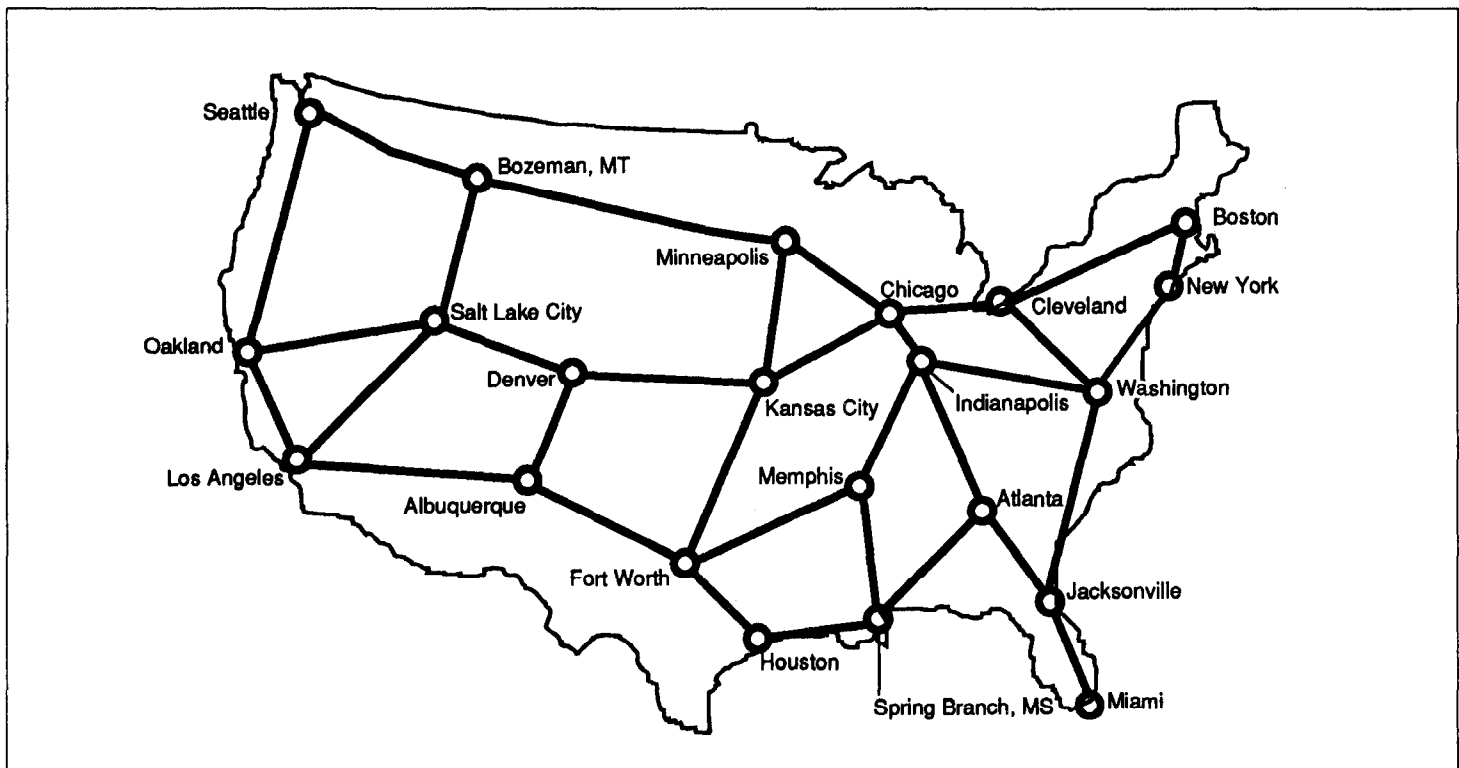
¹Data are transmitted over a communications channel in either of two forms: analog or digital. When analog transmission is used, the electrical signals that constitute a message exhibit a continuous wave form. During digital transmission, data are transmitted as discrete electrical pulses.

²The other two components are the Low Density RCL and the Routing and Circuit Restoral. Contracts have not been made final on these two components.

the largest of three projects within FAA's Radar Microwave Link Replacement and Expansion Program, a \$315-million program to update and replace the existing Radar Microwave Link system with a transmission system intended to increase the reliability, message quality, and availability of voice and data communications.

In May 1985, FAA awarded a contract to AT&T to design, test, and implement the RCL system. RCL is intended to handle voice, data, and broadband radar data traffic, and is to include redundant and alternate routing capability.³ The RCL system is designed to ultimately accommodate 960 voice channels and form the backbone of FAA's communications network. Figure 1 shows the RCL backbone system connecting FAA's 20 air route traffic control centers in the continental United States and two switching facilities at Bozeman, Montana, and Spring Branch, Mississippi, that will support data rerouting capability.

Figure 1: RCL Backbone System



³A broadband network may incorporate multiple operations in different channels so many users on a network have access to different applications on the network.

The RCL backbone system contains 818 sites (all being upgraded), consisting of the 22 sites shown in figure 1 and 796 radar and repeater⁴ sites located between these major 22 sites. As of September 1991, FAA had performed acceptance testing at 690 of the 818 sites in the RCL system. FAA expects to complete the implementation of basic service by December 1991, which will accommodate 180 voice channels. The RCL system is designed to be able to accommodate 960 voice channels, as needed.

Concerns Raised About the Analog System

FAA originally chose analog technology for the development of the RCL system in 1985 because it believed digital technology for networks was unproven. Moreover, at that time FAA felt that the requirement for broadband radar data transmission from long-range radar sites to air traffic control centers could be satisfied more easily using analog rather than digital technology.

Since the mid-1980s, digital technology has advanced while analog technology has become obsolete, and cost differences between the two technologies for long-distance communications have narrowed, making digital technology more attractive from a cost viewpoint. In fact, in a draft report on FAA telecommunications, Martin Marietta Corporation—one of the contractors studying FAA's transition to digital technology—stated that the RCL system was the last large-scale analog microwave system purchased in the United States. Because digital transmission is now preferred, major telecommunications companies, such as AT&T, have converted or are converting their networks to digital, and manufacturers of telecommunications equipment are also favoring the production of digital over analog equipment. Appendix II provides a technical comparison of analog and digital technologies.

Past Studies Favored Digital Technology

Because analog systems were becoming technologically obsolete and the advantages of digital technology were being realized, several studies performed for FAA in 1988 and 1989 favored digital technology over analog, and recommended the conversion of the analog RCL system that was being installed to digital technology. These studies concluded that digital technology would be needed to meet FAA's future air traffic control requirements, while offering performance improvements with reduced operating costs. However, rather than convert immediately, FAA decided in 1989 to continue with the installation of the analog RCL

⁴Repeaters boost the energy in the signal to transmit over longer distances.

system. According to agency officials, this decision was made because FAA (1) wanted to realize a return on the substantial investment already made in analog technology, (2) believed the analog RCL system would provide enough capacity to meet the communications work load through the end of the century, and (3) wanted to study further when to convert to digital technology.

During this time, congressional interest in FAA's progress in planning for a future digital communications system was evidenced by the conference report on the Department of Transportation's fiscal year 1990 appropriations. It directed FAA "to continue with its planning to transition to a digital radio communications system consistent with sound operational and economic practices and established long-term requirements."

FAA Deploying Limited Digital Enhancements While Studying Complete Transition

FAA has begun installing digital transmission capability to the present analog RCL system. In May 1990, AT&T proposed the installation of digital capability to the analog RCL backbone system as part of an alternative to replace multiplexers.⁵ Following testing that supported the feasibility of this alternative, FAA accepted the proposal.

This alternative is to augment each of the 33 links connecting the 22 facilities (see fig. 1) in the RCL backbone with up to five T1 lines⁶ for transmitting digital data. Hardware for this augmentation includes new multiplexers, modems for digital to analog conversion, and digital channel banks.⁷ In the event of failure, either in the hardware or in any one of the T1 lines, other T1 lines can be used for backup purposes. According to FAA and contractor officials, besides adding partial digital communications capabilities to the existing analog RCL backbone, this enhancement introducing digital transmission capabilities could facilitate the transition to a future digital architecture. FAA began installing this equipment on the present RCL system in August 1991. It is scheduled for complete installation in June 1992.

⁵A multiplexer is a device that permits two or more data sources to share a common transmission medium.

⁶T1 lines are digital communications links that can handle up to 48 voice channels. The overall transmission rate for T1 lines is 1.544 Mbps (million bits per second).

⁷Channel banks provide the links between the voice channels and T-1 lines.

FAA Studying Transition of Communications Network to Digital Technology

FAA recognizes that it must eventually change its communications network to predominantly digital technology. According to the agency's October 1990 Telecommunications Strategic Plan, "the FAA should transition to a predominantly digital telecommunications network with standard interfaces and integrated voice and data." To assist in the planning for this transition, FAA initiated two contractor studies to (1) design a future digital communications architecture, and (2) determine when to fully change the agency's interfacility communications system, which includes the RCL system, to digital technology.

The first study, being conducted by Mitre Corporation, is assessing the technical impact of introducing digital technology, evaluating current and future digital technologies and standards, and determining the transitional strategy from the existing to the future digital communications network. Alternative digital architectures, such as fiber optics, satellite links, and an integrated services digital network, are being considered and analyzed to meet FAA's future communications requirements. Mitre Corporation officials plan to recommend a specific communications architecture to FAA by the end of 1991. A final report with detailed analysis, evaluation, and design is expected to be completed by December 1992.

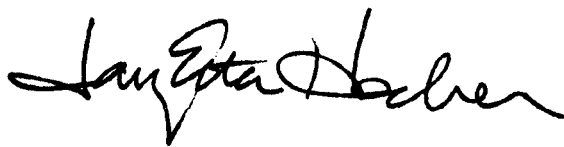
The second study, being done by Martin Marietta Corporation, is part of a comprehensive review of all communications projects involving FAA's telecommunications network to determine FAA's ability to meet the future availability, capacity, and timeliness requirements of the air traffic control system. Martin Marietta Corporation has provided FAA with a draft report on the results of this study. The draft report states that FAA needs to determine what it will do beyond RCL's useful life, including whether FAA should own or lease the next generation backbone system. Assuming that RCL can be used until the year 2004, the draft report concludes that there is a need to start planning now for a transition to a new digital system at the start of the 21st century. FAA's final response to this draft report is expected next month.

Although we did not obtain written comments on a draft of this report, we discussed the results of our work with FAA, Mitre Corporation, and Martin Marietta Corporation officials, and have reflected their views in the report where appropriate. We plan no further distribution of this report until 30 days from the date of this letter. We will then send copies to the Secretary of Transportation; the Administrator, FAA; the Director, Office of Management and Budget; interested congressional committees;

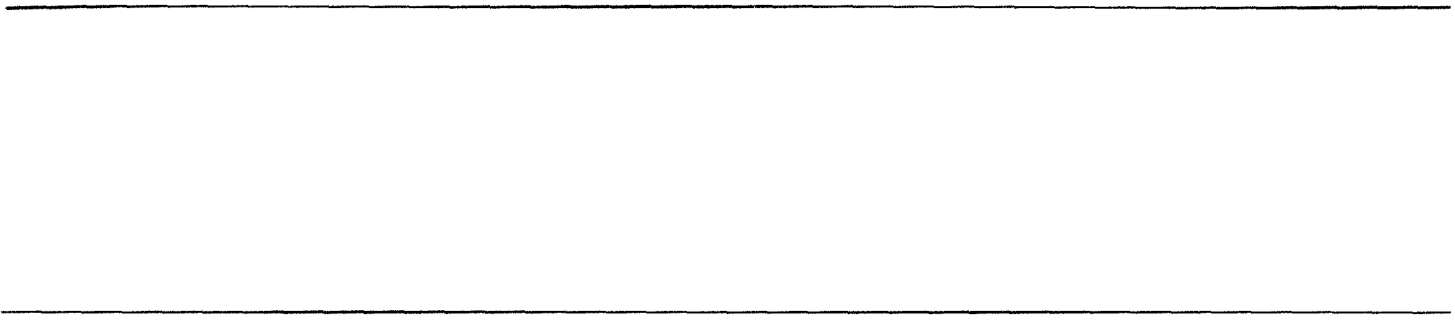
and other interested parties. Copies will also be made available to others upon request.

Should you have any questions concerning this report, please contact me at (202) 275-9675. Major contributors to this report are listed in appendix III.

Sincerely yours,



JayEtta Z. Hecker
Director, Resources, Community,
and Economic Development
Information Systems



Contents

Letter		1
Appendix I Objective, Scope, and Methodology		10
Appendix II Comparison of Analog and Digital Technologies	Analog and Digital Data Analog and Digital Signals Analog and Digital Transmission	11 11 12
Appendix III Major Contributors to This Report		14
Figures	Figure 1: RCL Backbone System Figure II.1: Relationship Between Analog and Digital Data and Signals	2 12

Abbreviations

AT&T	American Telephone and Telegraph
FAA	Federal Aviation Administration
GAO	General Accounting Office
IMTEC	Information Management and Technology Division
RCL	Radio Communications Link

Objective, Scope, and Methodology

In response to the request of the Chairman, Subcommittee on Transportation and Related Agencies, Senate Committee on Appropriations, our objective was to identify the status of FAA's planning for the transition of the RCL system from analog to digital technology.

To accomplish this objective, we met with FAA headquarters officials and Mitre Corporation and Martin Marietta Corporation contractor personnel to discuss FAA's plans for the transition of the RCL system to digital technology. We also analyzed various FAA and contractor documents related to these transitional plans, including plans and schedules for installing limited digital capability to the present system, past conversion studies, and two ongoing studies being conducted by Mitre Corporation and Martin Marietta Corporation.

We conducted our work from June to September 1991 at FAA headquarters in Washington, D.C. Although we did not obtain written comments on a draft of this report, we discussed the results of our work with FAA officials and contractor personnel and have incorporated their comments where appropriate. Our review was conducted in accordance with generally accepted government auditing standards.

Comparison of Analog and Digital Technologies

The terms analog and digital are used frequently in data communications in three contexts: data, signals, and transmission. Data is the representation of facts or ideas in a formalized manner that conveys meaning. Signals are electromagnetic encoding of data for transmitting information. Transmission is the communication of data by the propagation and processing of signals.

Analog and Digital Data

Analog data are continuously variable, are functions of time, and occupy a limited frequency range. Examples are audio, video, and data collected by sensors, such as temperature and pressure.

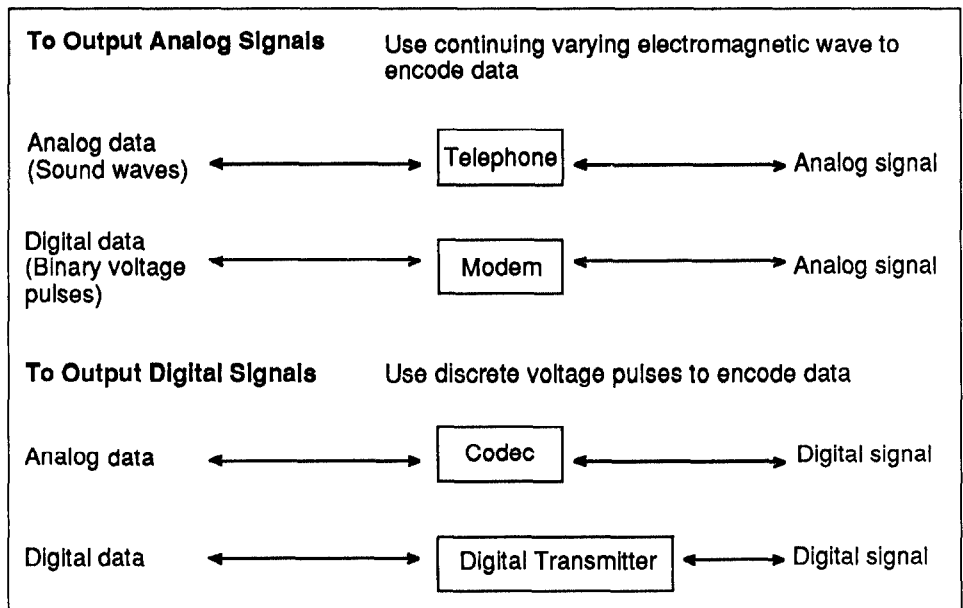
Digital data take on discrete values, consisting of binary digits; that is, ones and zeros. Numbers and characters are represented as strings of binary digits.

Analog and Digital Signals

In a communications system, data travel from one point to another by means of electromagnetic signals. An analog signal is a continuously varying electromagnetic wave. A digital signal is a sequence of discrete, discontinuous voltage pulses. For example, a constant positive voltage level may represent binary 1 and a constant negative voltage level may represent binary 0. The following figure illustrates the relationship between data and signals.¹

¹This figure and much of the information in this appendix was obtained from William Stallings' Data and Computer Communications, second edition, (New York: Macmillan Publishing Company, 1988).

Figure II.1: Relationship Between Analog and Digital Data and Signals



As the figure shows, telephones and modems (modulator/demodulator)² generate analog signals from analog or digital data. In the case in which digital data are input to a modem, the analog signal that is output is obtained by converting the binary voltage pulses to a continuous variation of voltage. This analog signal is then encoded onto a carrier frequency, such as for telephone lines.

Similarly, analog data can be represented by digital signals. A codec (coder-decoder)³ for analog (voice) data and a digital transmitter for digital data generate discrete voltages (digital signals) from analog or digital data. A codec takes an analog signal (encoded analog data) and approximates the signal by a stream of binary digits, which are used to regenerate the analog data at the receiving end.

Analog and Digital Transmission

Analog transmission sends analog signals irrespective of their content. The analog signals may be either encoded analog (voice) data or digital data (binary data that pass through a modem). Because analog signals become weaker (attenuate) with increasing distance of transmission,

²A modem transforms a digital bit stream into an analog signal (modulator), and vice versa (demodulator).

³A codec transforms analog data into a digital bit stream (coder), and digital signals into analog data (decoder).

analog transmission systems use amplifiers to boost the signal at points along the transmission. Unfortunately, amplifiers also boost the noise components of the signal, which distort the signal at the destination.

In contrast, digital transmission is concerned with the content of the signal. As with analog transmission systems, attenuation does endanger the integrity of the signal after short distances. However, in digital transmission systems, instead of amplifiers, repeaters are used to boost the signal. Repeaters receive the digital signal, recover the pattern of 1's and 0's (binary digits), and retransmit the signal without boosting the noise component of the signal. The same technique may be used with an analog signal that is carrying digital data. The repeaters recover the digital data from the analog signal and generate a new, clean analog signal, without accumulating the noise.

Digital transmission technology is favored over analog technology in the telecommunications industry. Reasons cited include:

- The advent of large-scale integration technology has led to a continuous drop in the cost of digital circuitry. A comparable drop has not occurred with analog hardware.
- Data integrity is better protected using repeaters rather than amplifiers. It is, therefore, possible to transmit data longer distances over lesser quality lines by digital means.
- It has become economical to purchase very high bandwidth transmission links (fiber optic and satellite links, for example.) The time-division multiplexing associated with digital technology is cheaper than the older, frequency-division multiplexing used in analog systems.
- Security and privacy using encryption techniques can be readily applied to digital data and signals that have been digitized.

Major Contributors to This Report

Information
Management and
Technology Division,
Washington, D.C.

Joel Willemsen, Assistant Director
Prithviraj Mukherji, Senior Technical Adviser
William G. Barrick, Evaluator-in-Charge
Charles S. Stanley, Staff Evaluator

Ordering Information

The first five copies of each GAO report are free. Additional copies are \$2 each. Orders should be sent to the following address, accompanied by a check or money order made out to the Superintendent of Documents, when necessary. Orders for 100 or more copies to be mailed to a single address are discounted 25 percent.

**U.S. General Accounting Office
P.O. Box 6015
Gaithersburg, MD 20877**

Orders may also be placed by calling (202) 275-6241.

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

**Official Business
Penalty for Private Use \$300**

**First-Class Mail
Postage & Fees Paid
GAO
Permit No. G100**
